

Aurbacher, Joachim (Ed.) et al.

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INNOVATIVE KONZEPTE FÜR EINE ZUKUNFTSFÄHIGE AGRAR- UND ERNÄHRUNGSWIRTSCHAFT

Mit Beiträgen von

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Im Auftrag der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V. herausgegeben von Prof. Dr. Joachim Aurbacher, Prof. Dr. Dietmar Bräunig, Prof. Dr. habil. Jon Hanf, Prof. Dr. Christian Herzig, Prof. Dr. Martin Petrick, Prof. Dr. Ramona Teuber

**64. Jahrestagung der
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vom 25. bis 27. September 2024**

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Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V.

VORWORT

Auf dem Weg zu nachhaltigeren Wirtschaftsformen im Agrar- und Ernährungssektor spielen Innovationen eine bedeutende Rolle. Zur Begegnung von Herausforderungen im Umwelt- und Ressourcenschutz sowie dem Erhalt von Biodiversität sind tragfähige Konzepte gefragt, die in Zeiten von Klimawandel und anderen menschengemachten Krisen ein resilientes Agrar- und Ernährungssystem helfen aufzubauen. Die 64. Jahrestagung der GEWISOLA bot daher Raum zur Auseinandersetzung mit Forschungsarbeiten, die sich der Entwicklung und Erprobung innovativer Technologien, Produkte und Prozesse im Agrar- und Ernährungssektor widmen, neue Betriebs- und Geschäftsmodelle untersuchen und die Gestaltung und Transformation von Wertschöpfungsketten und -räumen aus der Perspektive verschiedener Akteur*innen betrachten.

Die Tagung fand vom 25. bis 27. September 2025 an der Justus-Liebig-Universität Gießen statt und trug den Titel „Innovative Konzepte für eine zukunftsfähige Agrar- und Ernährungswirtschaft“. Sie wurde gemeinsam vom Fachbereich 09 Agrarwissenschaften, Ökotrophologie und Umweltmanagement der JLU Gießen, dem Zentrum für Nachhaltige Ernährungssysteme (ZNE) der JLU Gießen und dem Institut für Wein- und Getränkewirtschaft der Hochschule Geisenheim University durchgeführt.

Innovationen wurden im Kontext der Jahrestagung breit verstanden: Sie können auf allen Ebenen des Ernährungssystems stattfinden und technologische mit sozialen und kulturellen Neuerungen verbinden. Der Aufruf für einzureichende Beiträge umfasste auch Arbeiten, die sich mit Fragen der Verbreitung und Diffusion von Innovationen im Agrar- und Ernährungssektor befassen und z.B. die diesbezügliche Rolle von Nischeninnovationen, Wissenstransfer und Beratung adressieren. Darüber hinaus wurden Beiträge herzlich willkommen geheißen, die innovative Konzepte aus zwei weiteren Blickwinkeln betrachten. Erstens stellt sich die GEWISOLA als wissenschaftliche Gesellschaft die Frage, wie Bildungsarrangements neu gedacht und gestaltet werden müssen, um in Zeiten des ständigen Wandels und soziotechnischer Veränderungsprozesse Lehr- und Lernstrategien sowie Kompetenzförderung wirkungsvoll zu gestalten. Hierzu zählen auch vielfältige außeruniversitäre Bildungskonzepte, -programme und neue Qualifikationsansätze. Zweitens werden zur Entwicklung und Untersuchung von soziotechnischen Innovationsprozessen auch neue und kreative Wege der Wissenserzeugung benötigt. Daher wurden auch Beiträge in das Programm eingebunden, die sich mit innovativen Forschungsmethoden und -designs auseinandersetzen, um z.B. systemare und kooperative Fragestellungen zukünftiger Agrar- und Ernährungssysteme zu untersuchen.

Das Spektrum an theoretisch-konzeptionellen und empirischen Beiträgen widmete sich somit vier Bereichen:

1. Entwicklung, Untersuchung und Erprobung innovativer Konzepte für die Agrar- und Ernährungswirtschaft
2. Verbreitung von Innovationen in der Agrar- und Ernährungswirtschaft
3. Innovative Kompetenzvermittlung und Bildungskonzepte für eine zukunftsfähige Agrar- und Ernährungswirtschaft
4. Innovative Forschungsmethoden für eine zukunftsfähige Agrar- und Ernährungswirtschaft

Am Vormittag des ersten Tagungstages fanden 3 Präkonferenzworkshops statt:

- Innovative Konsensfindungsverfahren in der Agrar- und Ernährungspolitik (Leitung: Prof. Dr. Ramona Teuber)

- Wissenstransfer zur Förderung von Innovationen durch Kommunikation und Beratung (Leitung: Prof. Dr. Jasmin Godemann)
- Post-Soviet countries as laboratories for land use change analysis (Leitung: Prof. Dr. Martin Petrick)

Die Tagung wurde von der Vorsitzenden der GEWISOLA, Frau Prof. Dr. Monika Hartmann, sowie Grußworten der lokalen Organisator*innen – Prof. Dr. Karsten Krüger, Vizepräsident der JLU Gießen; Prof. Dr. Christian Herzig, Zentrum für Nachhaltige Ernährungssysteme; Prof. Dr. Martin Petrick, lokales Organisationskomitee – eröffnet.

In der ersten Plenarveranstaltung wurde mit zwei Keynotes von Prof. Dr. Frank Ewert vom Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) und Prof. Jennifer Clapp von der University of Waterloo aus Kanada inhaltlich in die Tagung eingeführt. Unter dem Titel „Innovative concepts for the transformation of agricultural systems“ betonte Herr Prof. Ewert die Dringlichkeit transformativer Veränderungen und Innovationen vor dem Hintergrund der diversen Herausforderungen wie Klimawandel und Biodiversitätsverlust, denen sich die Landwirtschaft gegenüber sieht. Für die Erreichung von Nachhaltigkeits- und Resilienzziele sei eine umfassende Systemperspektive entscheidend, um Landwirtschaft als Teil der größeren Agrar- und Ernährungssysteme zu begreifen und transdisziplinäre Forschung sowie die Einbeziehung von Akteur*innen zu fördern. Als vielversprechendes Konzept zur Unterstützung dieser Transformation in Agrarlandschaften wurde das Living-Lab-Format vorgestellt und neuer Forschungsbedarf zur Unterstützung der Transformation von Agrar- und Ernährungssystemen formuliert, unter Berücksichtigung von Systemdiversifizierung und Agroökologie. In dem sich anschließenden Vortrag zu „Corporate power and the struggle for sustainable food systems innovation“ widmete sich Frau Prof. Clapp der langjährigen Debatte, ob große und konzentrierte Unternehmen disruptive Innovationen hervorbringen müssen. Sie erörterte die Frage in Hinblick auf die Unternehmenskonzentration in der Agrarindustrie und legte dar, dass große, marktbeherrschende Unternehmen in diesem Sektor dazu tendieren, ihre Investitionen und F&E-Ausgaben auf defensive Innovationen zu konzentrieren, um ihre dominante Stellung zu behaupten und Eintrittsbarrieren zu schaffen, anstatt bahnbrechende Innovationen zu entwickeln. Entsprechend habe diese Dynamik wichtige Auswirkungen auf ökologische und soziale Ziele und erfordere die Betrachtung möglicher politischer Lösungsansätze.

Die zweite Plenarveranstaltung trug den Titel „Academic publishing in transition - current challenges and future pathways“. Prof. Dr. Arne Henningsen, University of Copenhagen, Dänemark, trug zu Veröffentlichungen in agrarökonomischen Zeitschriften unter besonderer Betrachtung der Reproduzierbarkeit und offene Wissenschaft vor. Danach gab Frau Prof. Dr. Silke Hüttel, Universität Göttingen, Einblicke in das agrarökonomische Publizieren aus der Perspektive einer Zeitschriften-Editorin. In der dritten Keynote berichtete Frau Prof. Dr. Ramona Teuber, JLU Gießen, über die Ergebnisse des neuen GEWISOLA Zeitschriftenrankings und zeigte auf, wo Agrar- und Ernährungsökonom*innen heute veröffentlichen und wie sie die Qualität dieser Fachzeitschriften bewerten.

Die dritte Plenarveranstaltung widmete sich der Insektenbiotechnologie (gelbe Gentechnik). Herr Prof. Dr. Andreas Vilcinskas, Professor am Institut für Insektenbiotechnologie der JLU Gießen und Leiter des Fraunhofer-Instituts für Molekularbiologie und Angewandte Oekologie (IME) hielt eine Keynote zum Thema „Insect farming for a Circular Bio-Economy in Controlled Environmental Agriculture“. Dem Vortrag schloss sich eine Verkostung von Insektensnacks und Wein der Hochschule Geisenheim an.

Während der Tagung wurden 36 Paper-Beiträge in thematischen Sessions vorgestellt und über 40 Poster in Kurzvorträgen präsentiert. Des Weiteren fanden vier selbstorganisierte Arbeitsgruppen zu den Themen „Food System Analysis and Nutrition Security - International Challenges“ (Prof. Dr. Gudrun Keding), „Monitoring und Evaluierung des AKIS: Anforderungen aus Wissenschaft und Praxis“ (Prof. Dr. Andrea Knierim), „International Trade and Sustainable

Food Systems: A Session in Honor of Stefan Tangermann“ (Prof. Dr. Harald Grethe) und „Is agricultural economics in need of decolonisation? Arguments, challenges and experiences“ (Dr. Stephanie Domtpail) statt. Der vorliegende Tagungsband gibt einen Einblick in die vielfältigen Inhalte der Tagungsbeiträge.

Die Organisatoren und Organisatorinnen der Tagung danken dem Bundesministerium für Ernährung und Landwirtschaft, der Vereinigten Hagelversicherung VVaG, der Gießener Hochschulgesellschaft und dem Förderkreis Agrarwissenschaften, Ökotrophologie und Umweltmanagement Gießen e.V. für die finanzielle Unterstützung der Tagung.

Außerdem danken wir Usha Beher, Prof. Dr. Dietmar Bräunig, Prof. Dr. Jasmin Godemann, Dr. Anett Illing, Dr. Susanne Kühner und Dr. Irina Solovieva für die Unterstützung bei der organisatorischen Vorbereitung der Tagung. Für die Betreuung der IT und Unterstützung während der Konferenz danken wir den zahlreichen Helfer*innen: Ife Abulude, Lucy Adundo, Titi-tilayo Akinwehinmi, Eduard Bukin, Kristina Gruber, Lara Heinen, Lara Herrlich, Irina Hopp, Rovshen Ishangulyyev, Maike Kötzsche, Sonja Kricheldorf, Laura Löllmann, Lara Pellen, Naser Atu Qasim, Christin von Schoenfeldt, Jessica Schroepf, Denis Soldera, Petra Spamer-Trapp, Svea Spieker, Benjamin Staudenmaier, Alexandra Stuhlmann, Sören Thalmann, Corinna Ullrich, und Marek Viehstädt. Sandra Drebes und Rahel Surmann danken wir für die Unterstützung bei der Erstellung des Tagungsbandes, sowie den fast 90 Gutachter*innen und über 200 Tagungsteilnehmenden, die zu einem spannenden Austausch und den vielen interessanten Begegnungen während der 64. GEWISOLA-Tagung beigetragen haben.

Gießen, im Mai 2025

Die Mitglieder des Programmkomitees der GEWISOLA-Jahrestagung 2024: Prof. Dr. Joachim Aurbacher, Prof. Dr. Dietmar Bräunig, Prof. Dr. habil. Jon Hanf, Prof. Dr. Christian Herzig, Prof. Dr. Martin Petrick, Prof. Dr. Ramona Teuber

INHALTSVERZEICHNIS

VORWORT	I
RISK AND CRISES	1
The effect of Covid-19 on trade survival of Norwegian seafood products; application of the firm-level data with Kaplan-Meier estimator	3
<i>Tinoush Jamali Jaghdani, Elisabeth Maria Fugger, Thomas Glauben</i>	
AGRICULTURAL PRODUCTION	17
Irrigation expansion in Africa – a comparative economy-wide study on Benin and Kenya	19
<i>Jonas Lens Luckmann, Zuhail Elnour, Agossoussi Thierry Kinkpe, Codjo Serge Aballo, Stephen Mailu</i>	
The effects of digital yield monitoring on greenhouse gas emissions in the United States	33
<i>Thomas Kopp, Robert Finger, Robert Huber, Markus Nabernegg, Richard J. Sexton</i>	
SUSTAINABLE DEVELOPMENT OF PEATLAND	45
Opportunity costs of rewetting agriculturally used organic soils in Germany.....	47
<i>Niklas Domke, Alexander Gocht, Harald Grethe</i>	
Nature sanctuary, agricultural production site or opportunities from innovative land use? How political actors frame the future use of German peatlands	63
<i>Cora Petrick, Wiebke Nowak, Harald Grethe</i>	
Hemmnisse, Lösungsansätze und Finanzbedarf für die Förderung von Paludikultur	75
<i>Anke Nordt, Achim Schäfer, Sabine Wichmann</i>	
CAP SUPPORT	85
Planning the evaluation of CAP Strategic Plans 2023-2027. Examples from Austria and Germany	87
<i>Andrea Pufahl, Franz Sinabell</i>	
MARKETS	101
The impact of product differentiation on exports of agricultural and food products: Evidence from Georgia	103
<i>Ketevan Melkadze, Helena Engemann, Yaghoob Jafari</i>	
Preference shift and trade policies as boosters of poultry processing development in Benin?	115
<i>Agossoussi Thierry Kinkpe, Harald Grethe, Jonas Luckmann</i>	

NACHHALTIGE AGRARPRODUKTION	129
Welchen Einfluss hat der Schulunterricht auf das Wissen von Jugendlichen über Landwirtschaft? Eine empirische Untersuchung in einem bayerischen Landkreis	131
<i>Nikolas Bublik, Franziska Mittag, Sebastian Hess</i>	
Was kostet Streifenanbau? Erste Ergebnisse am Beispiel von Winterweizen	143
<i>Sören Thalmann, Joachim Aurbacher</i>	
Der Einsatz von Drohnen und Vergleich mit anderen Fernerkundungsmethoden im Pflanzenbau	153
<i>Clemens Fuchs, Paul Gütschow</i>	
FOOD WASTE	165
The effect of food prices on fruit and vegetable - Food waste in private households	167
<i>Vicky Heijnk, Sebastian Hess</i>	
Reducing food waste: Consumer preferences for beef color and unwillingness to buy	183
<i>Annika Johanna Thies, Brianne Andrea Altmann, Amanda Countryman, Colton Smith, Maggie Holloway, Mahesh N. Nair</i>	
VULNERABILITÄT UND RISIKEN	193
Vulnerabilität der deutschen Nutztierhaltung im Falle einer Energiemangellage ...	195
<i>Sebastian Kleingraeber, Josef Efken</i>	
Erzeugergemeinschaften in der Weinbranche im Spannungsfeld der Teilablieferrung.....	207
<i>Hannah Katharina Thissen, Frederik Nikolai Schulz, Jon H. Hanf</i>	
How sustainable is premium subsidization for index insurance? – A quantitative impact analysis along a global program database	219
<i>Lena Kuhn, Ihtiyor Bobojonov</i>	
AGRICULTURAL FACTOR MARKETS	237
Alternatives to diesel in agriculture? Farmers' perceptions of alternative fuel tractors in German agriculture.....	239
<i>Marius Michels, Vanessa Bonke, Hendrik Wever, Oliver Mußhoff</i>	
Crop straw pellets as innovative and sustainable substrate alternative for German biogas plants – a scenario-based profitability assessment	253
<i>Sören Mohrmann, Verena Otter</i>	
CONSUMER BEHAVIOUR	267
Navigating cannabis and wine: complementary or substitute recreational choices	269
<i>Sophie Ghvanidze, Milan Ščasný, Miranda Svanidze, Jon Hanf</i>	
Societal change in nutrition – wishful thinking or reality?	281
<i>Jörg Luy, Ivica Faletar, Martin Banse, Marie von Meyer-Höfer</i>	

Bridging Gaps: Linking Sectoral Models and Individual Dietary Behavior.....	291
<i>Ferike Thom, Alexander Gocht</i>	
RESIDUE USAGE AND CIRCULAR ECONOMY.....	305
Circular economy in der Agrar- und Ernährungswirtschaft? Eine vergleichende Analyse von drei kreislaufbasierten Innovationen in Deutschland.....	307
<i>Victoria Dietze, Peter Feindt, Heike Hess, Volkmar Keuter, Georg Mildenberger, Sandra Schwindenhammer</i>	
POSTER SESSION 1: INTERNATIONAL AGRICULTURE AND FOOD MARKETS	329
Exploring the interplay of attitudes towards novel food technologies and animal ethics orientation on consumer acceptance of cultured meat: insights from a Croatian study	331
<i>Ivica Faletar, Marija Cerjak</i>	
Geopolitical tensions and food security - policy narrative in the EU and UK.....	335
<i>Kristina Mensah</i>	
Moving away from illicit crops for promoting sustainable agriculture: unveiling the drivers of decision to cultivate and the intensity of poppy cultivation among farmers narcotics-opium in Afghanistan	339
<i>Mojtaba Nikzad, Eva Gerharz</i>	
Economy-Wide Impacts of Climate Induced Crop Yield Changes In Kenya: Exploring the Implementation of Productivity Shocks in CGE Modeling.....	349
<i>Peter Mwangi, Zuhail Elnour, Harald Grethe</i>	
Analyzing wheat production cost structure in Iran: implications for innovations sustainable optimization in agri-food systems	353
<i>Mojtaba Nikzad, Eva Gerharz</i>	
Implications of increasing schooling enrolment in developing countries: An economy-wide analysis	357
<i>Zuhail Elnour, Khalid Siddig, Harald Grethe</i>	
POSTER SESSION 2: SUSTAINABILITY AND AGRICULTURAL PRODUCTION	361
Assessing economic and distributional impacts of restoring degraded rangelands in Jordan	363
<i>Sawsan Abdul-Jalil</i>	
Identifying the fundamental elements for setting up a business model for ecosystem services valorisation in mountain regions.	365
<i>Stefan Kirchweiger, Hannah Politor, Katharina Kinglmayr, Lena Schaller</i>	
Nutrient management practices contribution to a social ecological transformation towards circularity in the agricultural production	369
<i>Friederike S. Selensky, Andrea Knierim</i>	
Fallow Land in the EU – How are Agricultural Revenues and Markets affected? ..	373
<i>Verena Laquai, Max Zirngibl, Marlen Haß</i>	

POSTER SESSION 3: MARKETING, ENTREPRENEURSHIP AND RENEWABLE

RESOURCES..... 377

Attached to se(a)e? Consumer preferences for North Sea brown shrimp: the effect of touristic experience on food choice 379

Brianne Andrea Altmann, Thiemo Wolgast, Charlotte Bühner, Antje Risius

Rediscovering Entrepreneurship in Cooperatives: Implications for Organization and Management in the Context of the German Wine Industry 383

Frederik Nikolai Schulz, Jon H. Hanf

Eine Weinregion als Marke: Nutzung des Markensteuerrades zum Vergleich von Markenidentität und Markenimage der Weinregion Südtirol 387

Katharina Mybes, Lea Pircher, Jon H. Hanf

Wer besucht eine Eventmarketing Veranstaltung für regionale Äpfel und warum? 391

Rebecca Hansen, Michael Gscheidle, Sebastian Hess

Stakeholder inclusion in the governance of innovation: the case of biomethane production in Germany..... 395

Hyunjin Park

Portfolioeffekt bei Investitionen in Biogasanlagen: wieviel Risiko lässt sich diversifizieren? 399

Isatu Waag

POSTER SESSION 4: VERBRAUCHERVERHALTEN, SOZIOÖKONOMIE UND

WISSENSTRANSFER..... 403

Strukturen urbaner agrar- und ernährungswirtschaftlicher Cluster im regionalen Vergleich – untersucht anhand der Beispiele Berlin, Frankfurt am Main, Hamburg, Köln und München 405

Johannes Harsche

Von Vision zu Aktion: Eine Roadmap zu mehr Nachhaltigkeit in der Vollverpflegung..... 409

Julia Heinz, Katharina Eck, Melanie Speck

Express-Lieferung vs. Click & Collect: Ein Preis- und Sortimentsvergleich für Lebensmittel bei Flink und Rewe..... 413

Johann Scharnhop, Jens-Peter Loy

Gleichstellung am Arbeitsmarkt? Die Perspektive familienfremder ständig angestellter Frauen und weiblicher Auszubildender in der Landwirtschaft 417

Christine Niens

Generation Z in der Landwirtschaft: Herausforderung oder Chance? 421

Lena Marie Meyer, Bernd Hübers, Nana Zubek

Grüne Gentechnik in deutschen Agrar- und Massenmedien als Teilbereich medialer Wissenschaftskommunikation 425

Christine Rother, Nana Zubek

Stellenwert der Subsistenzlandwirtschaft in Krisenzeiten. Empirische Belege aus der Ukraine im Kriegszustand.....	429
<i>Iryna Tröster, Michael Friedrich Tröster, Iryna Yakymchuk, Svitlana Samofalova, Tatiana Tyshkovets, Olha Orel, Nataliia Smyslova, Uliana Dudka, Iryna Shapoval</i>	
POSTER SESSION 5: NACHHALTIGKEITSTRANSFORMATIONEN	433
Wer sollte die Rechnung zahlen? Die Sicht deutscher Landwirte auf die Bereitstellung öffentlicher Güter der Landwirtschaft.....	435
<i>Nils Langanke, Marlene Noack, Michael Grunenberg, Uwe Latacz-Lohmann</i>	
Bauliche Umsetzung von Photovoltaik Freiflächenanlagen auf wiedervernässten Moorstandorten	439
<i>Enna Marleen Wetjen, Uwe Latacz-Lohmann</i>	
Dauergrünlandumwandlung und Klimaschutz: Eine Analyse für mineralische Grünlandstandorte in Nordwestdeutschland	443
<i>Jan-Hendrik Buhk, Torben Tiedemann, Uwe Latacz-Lohmann</i>	
Wirtschaftlichkeit von Nitrifikationsinhibitoren im Winterweizen	447
<i>Tobias Jorissen, Felix Sebastian Ohmann, Guido Recke, Hans-Werner Olfs</i>	
Luzerne als Kraftfuttermittelalternative in Brandenburger Milchviehbetrieben.....	449
<i>Anatol Thös, Johannes Schuler, Peter Zander, Klaus Gutser</i>	
Einschätzung möglicher Maßnahmen zur Optimierung des Wissenstransfers im Milchviehbereich aus ExpertInnensicht	453
<i>Jasmin Godemann, Tamara Simonis</i>	
ANHANG	457
Autorenverzeichnis.....	459
Gutachterverzeichnis	461
Jahrestagungen der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V. (Stand: April 2025).....	463
Anschriften der Mitglieder des Vorstandes und der Geschäftsstelle der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V. (Wahlperiode 01.01.2023 bis 31.12.2025)	469
Ehrenmitglieder der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V. (Stand: April 2025).....	471

RISK AND CRISES

THE EFFECT OF COVID-19 ON TRADE SURVIVAL OF NORWEGIAN SEAFOOD PRODUCTS; APPLICATION OF THE FIRM-LEVEL DATA WITH KAPLAN-MEIER ESTIMATOR

Tinoush Jamali Jaghdani^{*+}, Elisabeth Maria Fugger^{**}, Thomas Glauben^{*}

Summary

The COVID-19 pandemic which was started in 2020 was one of the major disruptions in the seafood industry that challenged many actors along the whole supply chain in both marine capture and aquaculture globally. As international trade is key to this supply chain, the trade disruption could be disastrous to many actors. Nevertheless, the seafood trade from Norway which is the second major exporter of seafood products did not suffer dramatically and presented a high level of resilience. This has attracted the attention of scholars to study the reasons for this resilience in the Norwegian seafood industry. Available studies show, that until 2018, the average trade duration between Norwegian seafood exporters and their international trading partners was relatively short-lived for cod and salmon. We study the change in the persistence of trade relations at the firm level due to the COVID-19 pandemic. Two data structures are considered. In the first approach, the whole export and import are aggregated at the level of year-exporting firm-importing firm. In the second approach, the same aggregation is conducted for the six most important seafood commodity groups at the year-exporter firm-importer firm level (the number of trade spells is more than 6000 in each group). The six commodity groups are salmon whole (fresh/chilled & frozen), salmon fillet (fresh/chilled & frozen), cod whole (fresh/chilled) and mackerel whole (frozen). The original dataset consists of 3179300 export declarations for the years 2004-2021. The aggregated dataset (firm-to-firm, annual, all commodity groups) which is used in the analyses consists of 117369 trade spells. We have applied a non-parametric Kaplan-Meier model, estimating the differences in survival rate for the time intervals 2004-2017, 2018, 2019 and 2020 (trade spells which are stopped or survived in this four-time cluster). Furthermore, the differences in survival rates of the four clusters are tested for significance by applying the log-rank test. The estimated survival rates show a significant difference in trade persistence between the 2004-2017, 2018, 2019 and 2020 clusters both for the total seafood and the commodity groups. However, this difference is not large enough in its magnitude to conclude there is a change in duration pattern.

Keywords

Seafood trade duration, Norway, firm-level transaction data, Kaplan-Meier estimator

1 Introduction

The COVID-19 pandemic is considered as one of the most challenging disruptions in the international food system that affected all trade-dependent food industries including fisheries and aquaculture. The entire fisheries and aquaculture value chain was severely disrupted as a result of the lockdown (FAO, 2022) and international trade plays an important role for the actors in the seafood market (ANDERSON et al., 2018). The total seafood consumption (marine capture and aquaculture) per capita has approximately doubled over the last half a century. Being the main source of supply for this expanded demand, aquaculture production has approximately

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tripled in the last 25 years (NAYLOR et al., 2023). Furthermore, seafood is gaining importance for ensuring food and nutritional security (COJOCARU et al., 2022; NAYLOR et al., 2023). Rising incomes, urbanisation, improvements in post-harvest practices and changes in dietary trends are projected to increase seafood consumption (FAO, 2022). The global production of aquatic animals was estimated at 178 million tonnes in 2020, a slight decrease from the all-time record of 179 million tonnes in 2018 (FAO, 2022). According to the FAO (2020), in 2018, 67 million tonnes of fish (live weight equivalent) were traded internationally, which accounts for almost 38% of all fish caught or farmed worldwide. The trade data shows that 221 states and territories reported some fish trading activity globally. The total export value of fish products in 2018 reached 164 billion United States dollars (USD), which was approximately 11% of the value of agricultural product exports (excluding forest products). Three separate but interconnected sectors contribute to the global seafood supply, which are commercial capture or wild-caught fisheries, recreational or subsistence fisheries and aquaculture (COJOCARU et al., 2022). Norway is the second top exporter of seafood internationally and has an important share in aquaculture as the world's largest producer and exporter of farmed Atlantic salmon (FAO, 2022). Norway and Chile are two members of the OECD and are categorized as high-income countries among top 5 exporters of aquatic products in 2020 (FAO, 2022).

The COVID-19 pandemic has created challenges and opportunities globally for seafood systems with heterogeneity in impacts among industrial and small-scale sectors, production methods, geographies, value chains and by gender (LOVE et al., 2023). Nevertheless, the Norwegian seafood trade does not show a drastic change at the country level and product level as a result of disruptions caused by the pandemic (ASCHE et al., 2022). By focusing at the firm-level trade pattern of four different salmon products, STRAUME et al. (2022) found insignificant changes at the aggregate level of the trade volume and minor changes at the firm-level trade volume due to the pandemic. They concluded that the salmon supply chain is resilient. They argue that the Norwegian exporters could offset the losses by finding alternative markets. The question that arises here is whether the trade duration was also stable similar to trade volume in this period. Available studies show that trade relations in the Norwegian seafood industry are short-lived, at least for salmon and cod (STRAUME, 2017; ASCHE et al., 2018; JAGHDANI et al., 2024).

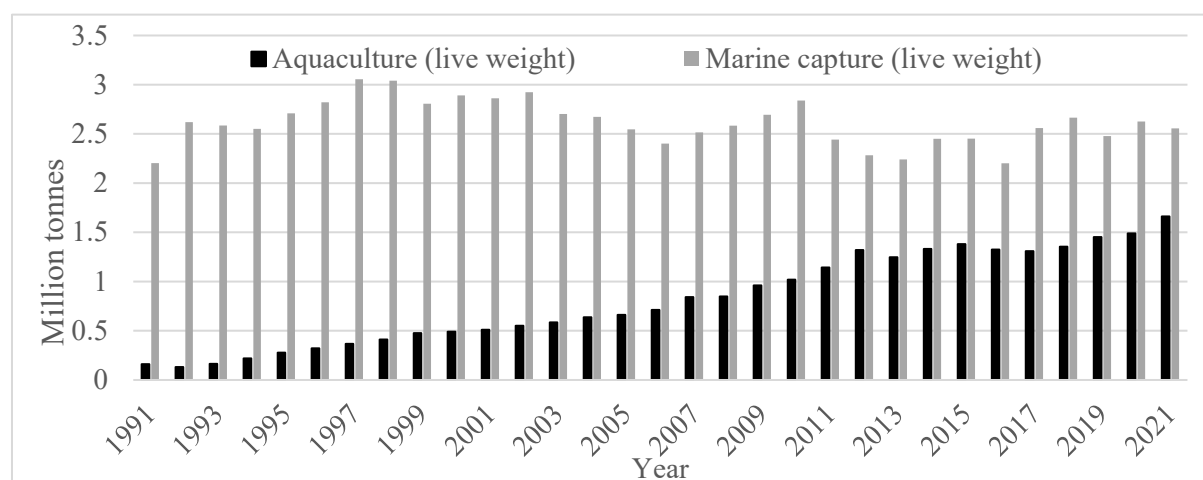
Trade duration is an emerging area for studying trade stability and according to STRAUME (2017), given the general literature on the subject, the development of stable trade relations is an important success criterion for exporters of aquaculture products. Trade stability or the survival of a trade relation between an exporter and importer is a necessary requirement for deepening trade and export growth that at least covers the cost of establishing a trade link (BESEDEŠ and PRUSA, 2011). Trade duration analysis is an approach for exploring the length of trade relationships without interruptions and factors affecting the length of those relationships. Longer trade between partners is a sign of higher vertical coordination and lower transaction costs (KETOKIVI and MAHONEY, 2020). Observing the available trade relations shows that a large share of trade relations are short-lived and, if a trade relationship survives in an export market over a period of time, the possibility of trade failure decreases tremendously (STRAUME, 2017). There is no clear theoretical framework available for direct analyses of the duration of trade relationships (FUGAZZA and MOLINA, 2016; ENGEMANN et al., 2022). However, the heterogeneous firm trade model (HFTM), introduced by MELITZ (2003), can be used to explain trade duration partially. In this theory, firm differences in productivity and fixed entry costs for each export market are key for explaining trade stability. Trade duration models allow us to consider time as an element in the trade relationship and study the disruption or interruption of trade. In spite of all arguments on the importance of trade stability, the short-lived trade relation has been acknowledged in some trade duration studies (e.g. Gullstrand & Persson, 2015; Zongo et al., 2022). Other scholars argue that the stability of trade flow is of higher importance for food items and especially perishable foods (PETERSON et al., 2018).

Based on the increase in uncertainty through the pandemic for the actors on the market combined with the resilience of Norwegian seafood export to it, one interesting research question is whether seafood actors have engaged in more stable trade relations as a reaction to the shock. The duration of seafood products export, which is mainly traded fresh or chilled from Norway, is the issue that is explored in this paper including the COVID-19 pandemic period. Utilising firm-to-firm trade data provides an opportunity to employ micro-firm level data on both the exporter and importer sides. In this study, we apply the survival approach by employing the Kaplan–Meier estimator to analyse the trade duration pattern. For this analysis, we have used firm-to-firm level transaction data on all seafood products (marine capture or aquaculture) between exporting and importing firms for the 2004–2021 period. Primarily, we have estimated the survival rate on the aggregated total seafood market of the trade relation at the firm level. Additionally, by considering the heterogeneous aspects of products (e.g., type of the products (whole / fillet), type of the preservation (fresh or chilled/frozen), species (salmon / cod / mackerel / ...)), we have estimated the survival rate of the trade relation for some specific product groups. We have tested the differences in the survival rate for the aggregated dataset for the three cluster of periods namely 2004–2017, 2018, 2019 and 2020 to see if there is a drastic change on trade survival strategy. The results show that the change in stability of trade relations between the different trade periods is significant, but not at higher magnitudes considering the COVID-19 pandemic. We concluded that the resiliency of the Norwegian seafood industry is not due to the changes in trade duration patterns. This paper continues by presenting an overview of the Norwegian seafood industry. The methodology and data are presented in the subsequent sections followed by the results and conclusion.

2 The seafood industry and export in Norway

In addition, to having high level of revenue from exporting of fossil energies and marine industries, seafood export plays an important role for providing revenue and employment along the long coast of Norway. For instance, in 2017, the seafood export of Norway reached to 94.5 billion Norwegian Krone (NOK), accounted for 7.9% of national export revenue as petroleum accounted for 38.5% in that year (JOHANSEN et al., 2019). Additionally, the value creation in the total value chain has a ripple effect in the rest of the economy and it is expected that the sector will grow further in the future which is mainly due to the expansion of aquaculture (JOHANSEN et al., 2019). The Norwegian seafood value chain consists of fisheries, aquaculture, fish processing (both marine capture and aquaculture) and wholesale trade (Johansen et al., 2019). Figure 1 shows the development of both marine capture and aquaculture since 1991.

Figure 1: Norway’s marine capture and aquaculture production (1991–2021)

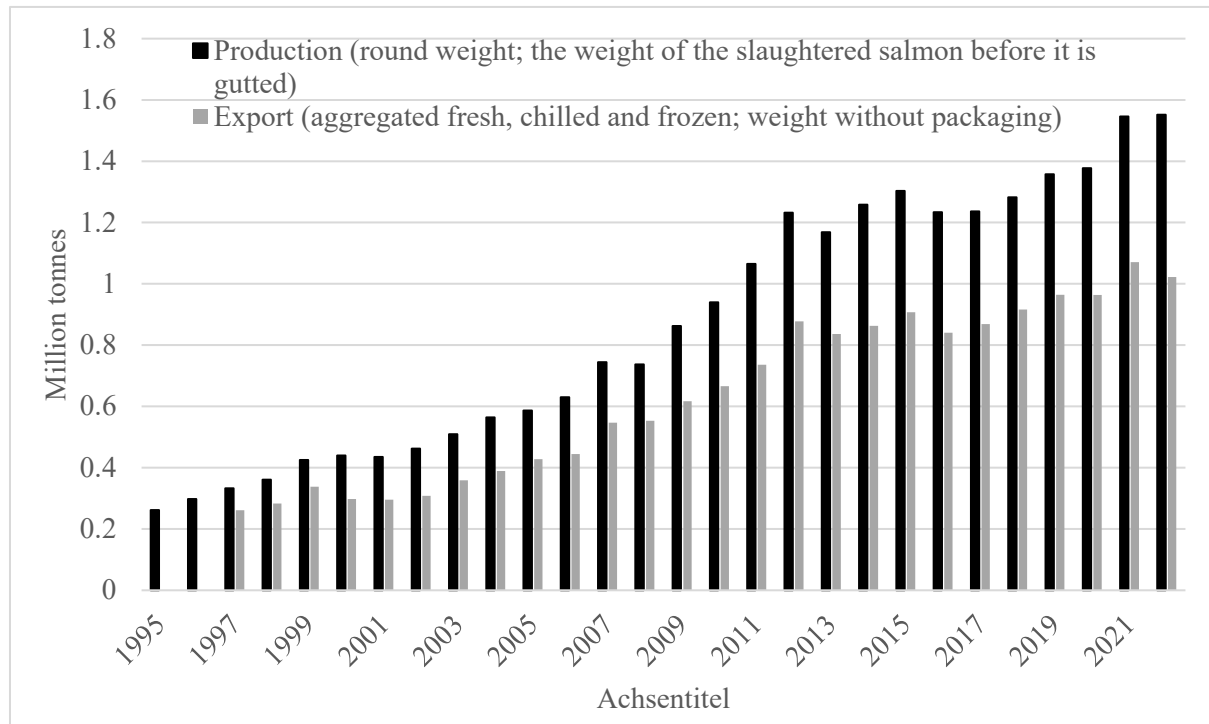


Source: FAO Fisheries and Aquaculture Statistics¹

¹ FAO Fisheries and Aquaculture Statistics: https://www.fao.org/fishery/en/collection/global_production?lang=en

As we can see, the role of marine capture is stable or even slightly reducing while aquaculture production is growing. The Norwegian seafood sector has three components that are whitefish sector, the pelagic sector and aquaculture. This accounts for 92% of the sector. The rest is accounted for crabs, mussels and algae (STRAUME et al., 2024). Considering the size of Marine capture in 2020, Norway is in the top ten countries globally and by considering mariculture (not inland aquaculture), Norway is one of the major aquaculture producers and second exporter (of all seafoods) in the world. European Union is by far the most important market for Norwegian seafood export (FAO, 2022). Compared to fishery, aquaculture is a young sector in Norway which is growing and Atlantic salmon production accounts for 94% of this subsector (STRAUME et al., 2024). The main part of salmon production is for export (see Figure 2).

Figure 2: Norway's salmon production and exports



Source: SSB², Directorate of Fisheries (Fiskeridirektoratet), USDA-FAS (1999-2001)

STRAUME et al. (2024) mentioned that aquaculture and fisheries are usually considered as two separate sectors. However, larger firms do normally cover both, aquaculture and fishery products. In their analysis for the period 2016-2020, they have recognized 437 exporting firms, 172 importing countries and 11024 importing firms. Fresh-farmed salmon, fresh fillet salmon and frozen fillet salmon are three major seafood products that are exported to more than 100 countries. They have found that the behaviour of exporting firms is very heterogeneous on the export of type of products and many large firms are multi-product exporters. They found also that COVID-19 did not cause a big challenge to this industry which encourages our study to test if the change in trade duration is one of the resilience strategies in this industry.

3 Methodology and Data

3.1 Methodology

In this research, we have applied survival analysis by a non-parametric *Kaplan-Meier survival estimator* to understand trade persistence of Norwegian seafood trade. Survival analysis refers to the study of survival time and the factors that affect this survival time. Type of studies with survival outcomes include clinical trials, prospective and retrospective observational studies

² SSB refers to *Statistisk sentralbyrå* (in Norwegian) or *Norwegian Statistics Bureau*.

and animal experiments that have time to event as the subject of study (MOORE, 2016). There are a wide variety of survival/hazard functions. Statistical presentation of the survival model from HARRELL (2015), MOORE (2016) and BROSTRÖM (2022) are used in this part. Kaplan-Meier survival estimator is hypothesised on the continuous-time structure. If the discrete-time concept is considered, the survival rate can be estimated by employing the discrete-time hazard model (e.g. TUTZ and SCHMID, 2016; JAGHDANI et al., 2025). In this research, we focus on the time of the trade survival and the role of the pandemic, as the only explanatory variable. Other explanatory variables affecting the survival rate will be subject to future research work.

As mentioned before, the object of interest in this study is a measure of survival of exports of seafood products exported by firm X from Norway to firm M in the importing country Z . We use T_i as a non-negative random variable representing the failure time (or the time until trade cutting occurs) after period t of an individual i th trade relationship (or i th spell of trade) from the homogeneous population. A spell of trade is defined as the period with uninterrupted trade of a specific product between an importer and an exporter. Instead of defining the statistical model for the response T in terms of the expected failure time, it is advantageous to define the survival function, $S(t)$:

$$(1) \quad S(t) = \text{Prob}\{T_i > t\} = 1 - F(t)$$

where $F(t)$ is the cumulative distribution function. If the event is seafood trade failure, $S(t)$ is the probability that seafood trade failure occurs after period t , that is, the probability that the subject of trade relation will survive at least until time t . $S(t)$ is a non-negative right-continuous function of t with $S(0)=1$ meaning all subjects survive at least to time zero. The survival function must be non-increasing as t increases.

Kaplan-Meier survival estimator: the Kaplan-Meier estimator in equation (2) is a non-parametric estimate of a survival function $S(t)$ as defined in equation (1):

$$(2) \quad \widehat{S(T_m)}^k = \prod_{t=1}^m \frac{n_t^k - d_t^k}{n_t^k}$$

where n_t^k is the number of objects (trade relations or trade spells in this case) at risk at time t in sample k , d_t^k is the number of failures of trade at time t in sample k . In equation (2), $t = 1, 2, \dots, m$ where m is the longest spell length that we have in the sample. $\widehat{S(T_m)}^k$ estimator is a standard robust measure in survival analysis for sample k . However, it does not say anything about the relation between the survival rate and its potential covariates.

Log-rank test: the log-rank test is the most common method for comparing the overall survival experience between two groups. The log-rank test is a k -sample test of equality of survival functions ($S(t)$). It is a powerful test against proportional hazard alternatives but may be very weak otherwise (BROSTRÖM, 2022). The object of analysis in this test is $S^k(.)$ without considering the t . Therefore, the null hypothesis can be tested as

$$H_0: S^{k=1}(.) = S^{k=2}(.)$$

where the dot means the whole range of the survival time on the survival function $S^k(.)$. By considering the d_t^k as number of failures of trade at time t in sample k in equation (2), the empirical test statistic can be estimated for two samples $k=1$ and $k=2$ as (JOHNSON, 2018; BROSTRÖM, 2022):

$$E(d_t^{k=1}) = (d_t^{k=1} + d_t^{k=2}) \frac{(n_t^{k=1})}{n_t}$$

$$(3) \quad VAR(d_t^{k=1}) = (d_t^{k=1} + d_t^{k=2})[(n_t^{k=1} - d_t^{k=1}) + (n_t^{k=2} - d_t^{k=2})] \frac{(n_t^{k=1})(n_t^{k=2})}{n_t}$$

$$Z = \frac{\sum_{t=1}^m (d_t^{k=1} - E(d_t^{k=1}))}{\sqrt{\sum_{t=1}^m VAR(d_t^{k=1})}}$$

where n_t is the total number of objects in $k=1$ and $k=2$, $E(d_t^{k=1})$ is expected number of failures of trade at time t in group $k=1$, $VAR(d_t^{k=1})$ is the variance of the number of failures of trade at time t in group $k=1$ and Z is the test statistic with approximately standard normal distribution under H_0 . If the Z statistic in equation (3) is beyond the lower or upper $\alpha/2 \times 100$ percentile of the standard normal distribution, then we reject the H_0 and we conclude that the two samples are from populations with different survival rates.

3.2 Data

The dataset used in this study consists of firm-level export transaction data of all seafood products from Norway for the period 2004-2021 which is acquired from Statistics Norway (SSB). A total number of 3179300 export declarations are available in the database. One declaration can have multiple commodity type, which results in 4498827 observations on commodity level. For the period of study, we have 190 importing countries, 990 exporting firms and 61 156 importing firms. The commodity list in the dataset follows the nomenclature of the Norwegian Customs Tariff, as from 1988 based on the combined tariff/statistical nomenclature, the Harmonized System (HS) and UN standard international trade classification (SITC-Rev. 4)³. Comparing the trade pattern in the beginning of the period to the end of the period, some differences in the trade pattern appear. In 2021, Norwegian seafood export was directed towards 146 countries (of which 133 countries have annual trading volume higher than 0.5 million NOK) and 238215 declarations. In 2004 the total number of trade transactions was fewer with 130135 declarations and exported towards 137 different countries. In this dataset, a large drop in the number of trade transactions towards Russia is recognisable. From being one of the core markets in 2004, there are only a few reported export transactions during 2015-2021 which is due to import ban of Russia on food items after the Ukraine crisis in 2014. On the other hand, US and Canada, and more countries in Asia have become more important markets for Norwegian seafood products. To provide the right database, we had the challenge of a complicated coding system for the importer as the manual registration of the company names in the declarations. This leads to names being spelled differently depending on the declarants' preferences and that caused having different anonymised code for the same importers through the SSB anonymisation algorithm. On top of SSB's own algorithm, we applied our algorithms to cluster the names optimizing homogeneity within and heterogeneity between the defined IDs that we received from SSB. Finally, this problem was solved by creating a unified code for the importers of salmon from Norway in the SSB database.

Having defined unique identification codes for the importers and exporters, we have followed two approaches for this study for data preparation. In the first approach, the whole export and import are aggregated at the level of a year-exporting firm-importing firm which we will call *firm-level aggregated data structure*. In the second approach, the same aggregation is conducted for certain major seafood products at the year-exporter firm-importer firm level that we call *firm-commodity level aggregated data structure*. Later, the spell structure is imbedded into the datasets to have the time to event data structure. Furthermore, the four clusters of 2004-2017, 2018, 2019, 2020 and 2021 are identified in the datasets. In this way, we could recognize

³ The commodity list of external trade from Statistics Norway (SSB):

<https://www.ssb.no/en/utenriksokonomi/utenrikshandel/artikler/statistisk-varefortegnelse-for-utenrikshandelen>

which trade spells are ended or survived in 2004-2017, 2018, 2019 and 2020. We have not considered the trade spells in 2021 as they are censored and we do not know if they continued or not after 2021. We compare the survival rate of these four primary time clusters (see equation (2)) to see if the survival rate has changed. Furthermore, the survival rates of these three time-clusters are compared by log-rank test (see equation (3)). The results of the analysis of the firm-level aggregated data structure is explained in detail. Table 1 shows the number of trade spells in different datasets for aggregated and commodities levels in different time clusters. The six firm-commodity level data groups namely; salmon whole (fresh or chilled & frozen), salmon fillet (fresh or chilled & frozen), cod whole (fresh or chilled whole) and mackerel whole (frozen whole) are selected considering a number of trade spells more than 6000 in the datasets⁴.

Table 1: The number of spells in firm-aggregated and firm-commodity levels in different time clusters

	2004-2017	2018	2019	2020
Firm level aggregated	91512	13398	14166	13378
Salmon; fresh or chilled (whole)	27074	5561	5861	5479
Salmon; frozen (whole)	7899	418	511	402
Salmon fillet; (fresh or chilled)	5963	829	861	836
Salmon fillet; frozen	4678	631	718	719
Mackerel; frozen (whole)	8760	1002	1006	1356
Cod; fresh or chilled (whole)	7028	773	679	532

Source: study findings

4 Results

The results of the survival rate analysis of the firm-level aggregated data structure is analysed in detail in this section. The results for six major commodity groups are only presented in graphs.

4.1 Firm-level aggregated data structure

As we have seen in Table 1 in the former section, there are 117 369 trade spells available in the firm-level aggregated dataset from which 14 442 are in the censored category or survived in 2021. 78% of the trade relations at the firm level are in one spell category and 10% at two spells. Table 2 shows the number of spells with their length in four-time clusters of firm-level aggregated dataset. The average length of the spells in cluster 2004-2017 clusters is shorter. The 2021 covers the censored spells and we cannot say a lot about them. However, we see the length of spells for the three clusters of 2018, 2019, 2020 is increasing compared to 2004-2017. We can see a significant increase in the length of the spells for the year before the pandemic and pandemic year in comparison to 2004-2017 cluster. These slight differences are repeated in survival rates and log-ranked tests. Additionally, the same phenomenon is observed for the majority of commodity-firm level aggregations.

⁴ This selection is based on page limitations here in this contribution. The results of the survival rate of other seafood products such as cod fillet (frozen), cod whole (frozen), cod klippfish (whole), cod stockfish (whole), smoked salmon (whole and fillet) can be provided upon the request.

Table 2: The distribution of the spells considering their length for four different time clusters and the share at risk at each spell length.

	2004-2017		2018		2019		2020	
	No of spells	Share at risk (%)	No of spells	Share at risk (%)	No of spells	Share at risk (%)	No of spells	Share at risk (%)
1	91512	100,00%	13398	100,00%	14166	100,00%	13378	100,00%
2	32066	35,04%	7049	52,61%	7417	52,36%	7500	56,06%
3	16024	17,51%	4586	34,23%	4953	34,96%	4977	37,20%
4	9404	10,28%	3181	23,74%	3518	24,83%	3648	27,27%
5	5834	6,38%	2254	16,82%	2555	18,04%	2737	20,46%
6	3867	4,23%	1601	11,95%	1863	13,15%	2065	15,44%
7	2691	2,94%	1265	9,44%	1356	9,57%	1541	11,52%
8	1888	2,06%	1045	7,80%	1089	7,69%	1143	8,54%
9	1317	1,44%	831	6,20%	907	6,40%	927	6,93%
10	932	1,02%	664	4,96%	724	5,11%	772	5,77%
11	687	0,75%	527	3,93%	579	4,09%	618	4,62%
12	499	0,55%	427	3,19%	459	3,24%	495	3,70%
13	357	0,39%	351	2,62%	372	2,63%	393	2,94%
14	251	0,27%	282	2,10%	306	2,16%	326	2,44%
15	-	-	219	1,63%	246	1,74%	270	2,02%
16	-	-	-	-	196	1,38%	217	1,62%
17	-	-	-	-	-	-	172	1,29%

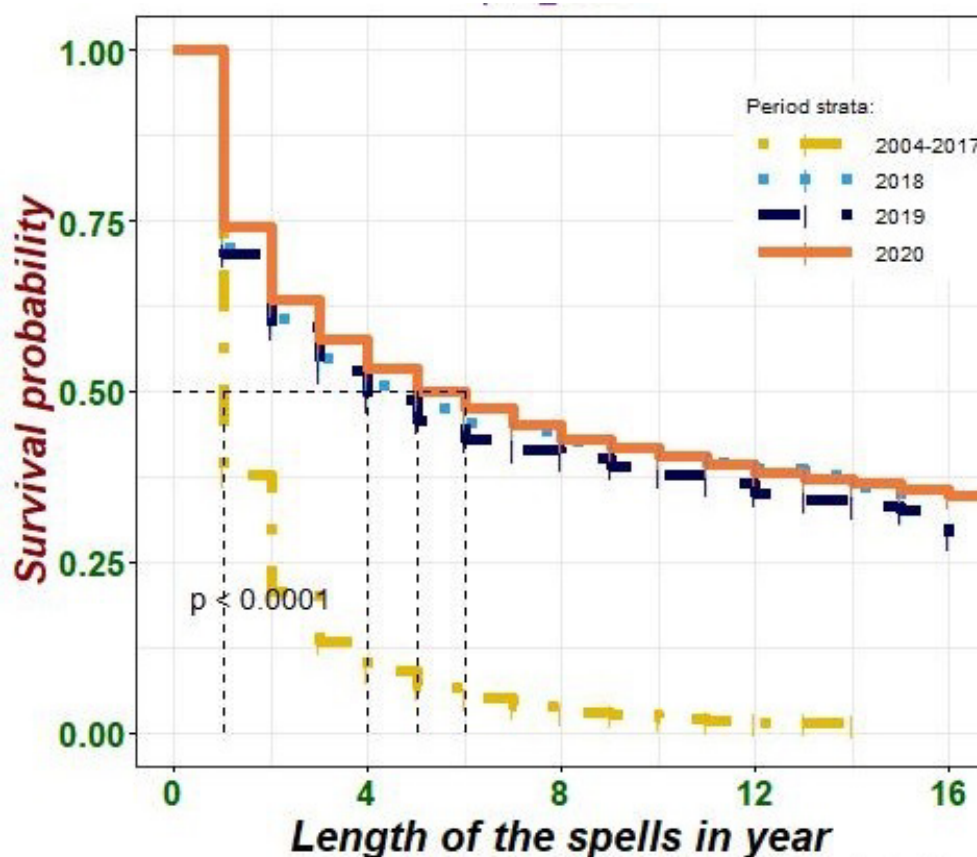
Source: study findings

Figure 3 shows the average survival rates estimated by equation (2) for three different time clusters in relation to the length of the spells. As we can see, there is no major difference in the three later survival curves. This significance of the difference has been tested by a log-rank test (see equation (3)). The survival curve of 2004-2017 is significantly different at a 1% level from 2018, 2019 and 2020. Even the 2019 and 2020 survival curves are significantly different at 1% from each other. The 2020 survival curve is slightly higher than the other three clusters. In both Table 2 and Figure 3. This level of difference although shows a pattern of changes, especially for the first year of the pandemic (2020) compared to the year before that (2019) and other years (2004-2018), it cannot be sufficient evidence to conclude that we observe a dramatic change. As it is presented above, the average length of the spells is varying. Although it is not possible to disconnect these significant differences from the pandemic, it is hard to claim that the huge behaviour changes have taken place.

4.2 Firm-commodity-level aggregated data structure

Figure 4 shows the survival rate of 6 different commodity categories namely; salmon whole (fresh/chilled & frozen), salmon fillet (fresh/chilled & frozen), cod whole (fresh/chilled) and mackerel whole (frozen). They show similar patterns as the firm level aggregated data structure. In all cases except one, the survival curves of 2018, 2019 and 2020 are higher than for 2004-2017. There are cases that survival rates for the 2019 time-cluster are higher than for 2020. This is the case for few spells in frozen mackerel (whole) and salmon fillet (fresh or chilled). Generally speaking, we cannot find a global pattern to claim that we can recognise firm strategy changes due to pandemic for specific products. The same curves are tested with log-rank tests.

Figure 3: The survival rate of trade relations in three different time clusters for firm level aggregated data structure

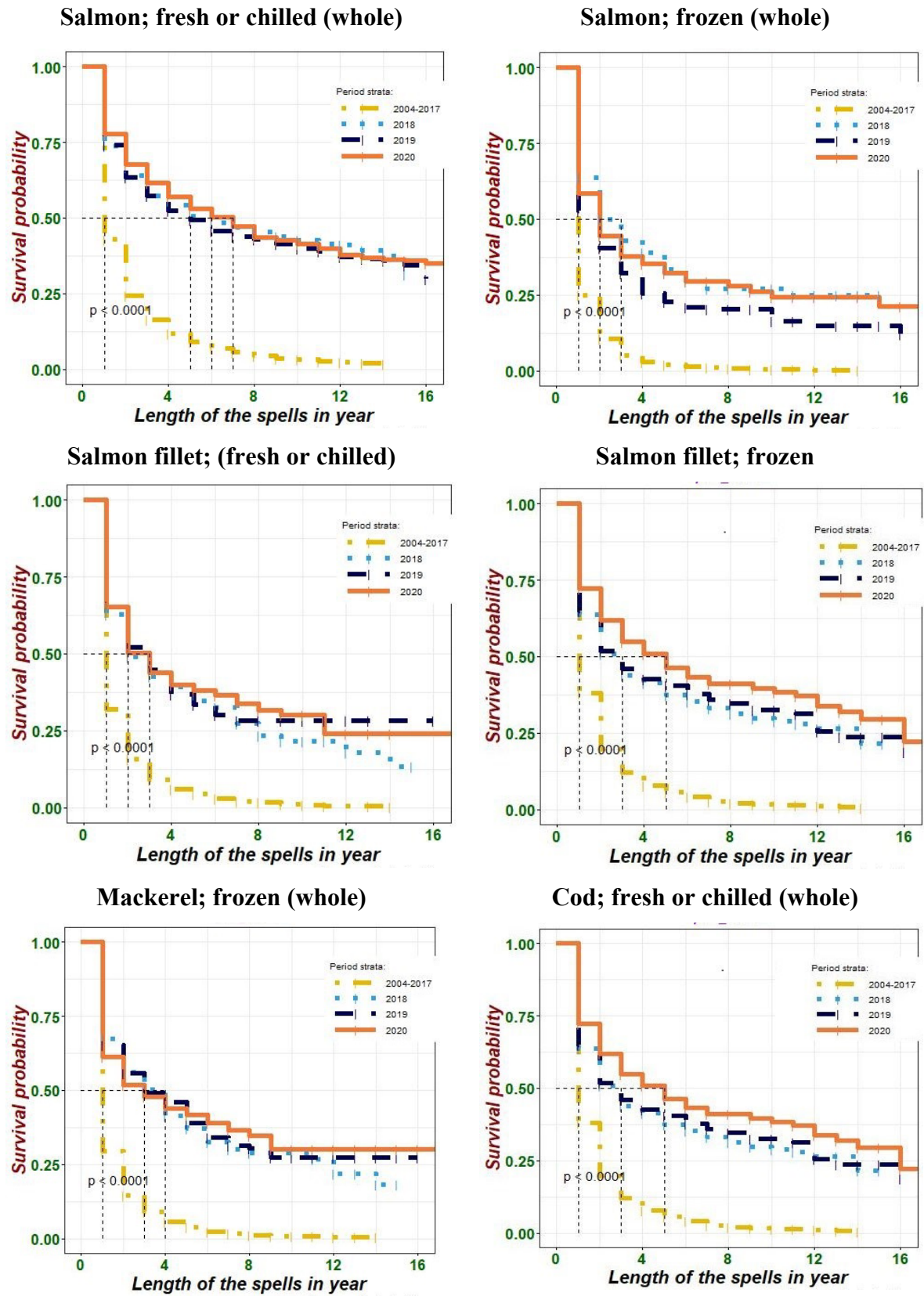


Source: Study findings

The results of the log-rank tests show that the survival rates in all three clusters of 2018, 2019 and 2020 are significantly different at 1% from 2014-2017. However different patterns can be observed between 2018, 2019 and 2020 clusters. For instance, in the case of salmon fillet (fresh or chilled) and frozen mackerel (whole), no significant differences are observed between the 2018, 2019 and 2020 clusters. The results of the log-rank tests show that the survival rates of the salmon whole (fresh or chilled) in clusters of 2018 and 2019 are significantly different to 2020 at 1%. For salmon whole (frozen), the survival rate of 2019 and 2020 time-clusters are significantly different at 5%. The 2018 and 2020 time-clusters are not significantly different. In the case of salmon fillet (frozen), only the survival rates of 2018 and 2020 time-clusters are significantly different at 5%.

By considering the results of the log-rank tests and the estimated survival rates for each time period cluster in Figure 4, we can conclude that we see a significant difference between all of commodities for the 2020 cluster period and the 2004-2017 cluster period. The same pattern is also found at the firm-level aggregated data structure. Nevertheless, for the other time clusters, the most similar pattern is found between the firm-level aggregated data structure and salmon whole (fresh or chilled). This is the major exported commodity from Norway and its pattern is repeated in the firm-level aggregated survival rates. We can conclude that the difference between the 2020 cluster period and the 2004-2017 cluster period is something obvious that cannot be neglected. However, some significant differences for some commodities are observed between 2019 and 2020 time-clusters.

Figure 4: The survival rate 6 category firm-commodity level aggregated data structure



Source: study findings

5 Conclusion

The resilience of the Norwegian seafood industry to the COVID-19 pandemic and the continuation of the trade at the level before the pandemic in 2020 and 2021 has attracted the attention of scholars to find the reason for this resilience. As the trade duration of the Norwegian salmon industry at the firm-level was short-lived before the pandemic, in this study, we have analysed the possible changes in this trade duration pattern to see if the firms have changed their duration pattern as a strategy of increasing resilience. Therefore, we have studied the survival rate of the trade by employing firm-level trade transaction data of seafood products of Norway consisting of 3179300 export declarations for the period 2004-2021. We have applied the non-parametric Kaplan-Meier estimator of survival rate on aggregated data at the firm and commodity-firm level data. Six different major commodity groups in Norway's seafood trade portfolio are considered for commodity-firm level analysis. Four time-clusters of 2004-2017, 2018, 2019 and 2020 are considered for comparison and the log-rank test is employed for their comparison. The results of the estimated survival rates show that there are statistically significant differences between 2004-2017 and 2018, 2019 and 2020 clusters at the firm level and firm-commodity level aggregation. However, this difference between 2018, 2019 and 2020 is not large enough in its magnitude. Therefore, we cannot conclude that there is a change in duration pattern and we cannot firmly claim that an increased trade survival strategy is followed by firms to increase their resilience against disruptions caused by the COVID-19 pandemic.

Different reasons can be discussed for this finding. The first reason could be the availability of few competitors for many seafood exports of Norway such as salmon. Atlantic salmon can be farmed in certain coastal areas of the world where seawater temperature and other natural conditions are favourable for the biological/morphological characteristics of the species. This is mainly limited to Norway and Chile. Therefore, it is possible to imagine that part of the seafood export is not exposed to international competition. Additionally, it is imaginable that many larger exporting firms in Norway are flexible enough to adapt themselves to demand shocks. There are studies available that show that the demand from restaurants for seafood products is reduced and substituted by increases from retail sectors.

In this study, we have tried to test the possible changes in trade patterns. Nevertheless, the potential domain of analysis in our approach is limited as we could not test further covariates or include the heterogeneous structure of the productivity of exporters in this model. In the next step, we will employ more comprehensive models such discrete-time hazard model to test the potential covariates by integrating the censored observations of 2021 into the regression.

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AGRICULTURAL PRODUCTION

IRRIGATION EXPANSION IN AFRICA – A COMPARATIVE ECONOMY-WIDE STUDY ON BENIN AND KENYA

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Abstract

This study investigates the welfare implications of expanding irrigation schemes in Africa, taking Benin and Kenya as case studies. To this end, we apply a comparative static computable general equilibrium model. Through the setup of scenarios, we distinguish the effects of the (short-term) construction phase and (long-run) irrigation expansion. While outcomes for the two cases differ in the details, we find for both countries that the construction phase results in negative welfare effects for most households if the schemes are financed through increasing income tax rates. Yet, these losses can be overcompensated in the operation phase of the irrigation schemes, due to the expansion of export-oriented agriculture and related multiplier effects. To achieve a pro-poor distribution of welfare fair access for poor households to the newly irrigated land is crucial.

Keywords

Irrigated Agriculture, Agricultural Investment, Computable General Equilibrium Modelling

1 Background

Agriculture is a pivotal sector in most economies of Sub-Saharan Africa (SSA), sustaining livelihoods and contributing to national development. However, the vulnerability of rainfed crop production to climate risks and the anticipated decline in yields due to climate change in many regions, have prompted discussions on potential coping strategies. A key proposal is the expansion of irrigation schemes, recognized for facilitating more reliable and higher yields and the prospect of multiple harvests (SCHUENEMANN ET AL. 2018). Also irrigated agriculture has been found to significantly enhance the techno-economic efficiency of farmers (HOUNGUE AND NONVID, 2021) and thus has been found to allow for a manifold increase of income compared to rainfed agriculture (HAGOS ET AL. 2009). Accordingly, investment in irrigation could contribute to improving GDP in SSA (HAGOS ET AL., 2009) due to higher agricultural employment (GOSSELIN, 2010). While many researchers have shown the beneficial effects of irrigated agriculture in comparison to rainfed cropping on the farm-level, there are only few studies providing ex-ante assessments of the economy-wide implications of expanding irrigation schemes in SSA. Exemptions include SCHUENEMANN ET AL. (2018), and SIDDIG ET AL. (2021), who investigate this for the case of Malawi and Sudan, respectively. However, in both studies the investment costs are not considered.

Two typical countries in SSA in which irrigation expansion is high on the policy agenda are Benin in the West of the continent and Kenya in the East. In the face of climate uncertainties and the imperative to enhance food security, both nations have set ambitious targets to expand irrigated agriculture.

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In Kenya vegetative agriculture accounts for about 12% of GDP (ELNOUR ET AL., 2022) while only 2.2% (216,000 ha) of the total cropland (9,8 Mio ha), were equipped for irrigation by 2020. The current plan of the Kenyan government is to increase this area by another 200,000 ha over the period from 2022 to 2026 (MWSI, 2022), while Kenya's total irrigation potential is estimated at 1,3 Mio ha (MWSI, 2022).

In comparison in Benin, crop production, even contributes to about 22% of the GDP (KINKPE ET AL., 2022) and is marked by substantial subsistence production (DRG-MAEP, 2016). In 2019, only 25,000 ha, constituting 0.6% of the total cropland, were equipped for irrigation (FAO, 2023). The Beninese government aims to triple the irrigated agricultural area by equipping an additional 50,000 ha by 2026 (PAG, 2021), while the total irrigation potential for Benin is estimated at 375,000 ha (DRG-MAEP, 2016).

The estimated budgets required to finance the establishment of the described irrigation schemes for both countries are detailed in Table 1. Given the high costs involved (about 4.3% and 10.5% of annual GDP in Kenya and Benin, respectively, this raises the question for a quantification of the benefits, which can be obtained from it.

As crop production is of high relevance to the overall economy and features strong forward and backward linkages with other sectors in both countries, we address this question using a computable general equilibrium (CGE) model. More specifically, this research aims at answering the following research questions: 1) To what extent will the planned irrigation development sustain agriculture, livelihoods, and economic growth in the two respective economies? 2) In how far these effects differ between the two countries and why? And finally, 3) What would be the effects of exploiting the overall irrigation potential on both economies.

Table 1: Estimated investment costs for developing the planned irrigated area in Benin and Kenya

Cost items	Mapping to sectors in database	Benin (50,000 ha)		Kenya (200,000 ha)	
		Total costs	Cost per hectare	Total costs	Cost per hectare
		[Million USD]	[USD]	[Million USD]	[USD]
Research and capacity development	Education	17.07	341	186.79	934
Management	Other Services/Public administration	76.80	1,536	269.72	1,349
Enhancing inclusivity	Social services		-	9.80	49
Construction	Construction	1279.97	25,599	3344.81	16,724
TOTAL		1373.84	27,477	3811.12	19,056

Source: Authors' compilation based on DOSSOUHOU (2023), MWSI (2022) and expert estimates

2 Modelling Approach

2.1 Databases

This analysis is based on two recently developed, detailed social accounting matrices (SAMs) for Kenya and Benin. The SAMs are based on ELNOUR ET AL. (2022) for Kenya and KINKPE ET AL. (2022) for Benin. For this study, both SAMs have been extended and updated with support of the National Statistical Offices of both countries. The SAMs have been designed in a consistent way in order to facilitate comparison. Of special relevance for this analysis is the agricultural sector, which is depicted by about 20 activities and commodities in both SAMs. Further, both SAMs include eight production factors: two types of capital (agricultural and not), two land types (irrigated and not) and four labour categories, classified based on skill level

(skilled and unskilled) and gender (male and female). Households are categorised into four groups, depending on location (rural and urban) and income level (poor and non-poor).

With respect to irrigated land, in Benin mainly maize, rice, vegetables & spices as well as pulses and tubers are grown under irrigation. In Kenya also wheat, other cereals and fruits are irrigated. In both countries the mentioned crops are also grown under rainfed conditions. Yet, irrigated land is more productive as a) it allows for multiple harvests for most crops and b) produces higher yields per harvest. The respective productivity factors have been determined based on expert assessments (multiple harvests) and published yield data (DSA-MAEP, 2022; FRIELER ET AL., 2017; MÜLLER ET AL., 2022) and range from 1.6 for tubers in Benin and 6.0 for oil seeds in Kenya. This difference in productivity is captured via satellite accounts.

In Kenya, irrigated land is almost exclusively owned by private and mostly rural households, while in Benin irrigated land is owned to 60% by farming enterprises and cooperatives and the remainder is split among household groups, with rural non-poor households owning the second largest share (17%).

2.2 Model setup

To analyse the economy-wide impacts of increasing the irrigated area, we use the Static Applied General Equilibrium (STAGE) Model (McDONALD AND THIERFELDER 2015), which is a CGE model, allowing to depict the economic transactions between different agents in one economy in a set of equations founded on microeconomic theory. In the model, production is depicted by a four-level nest of Constant Elasticity of Substitution (CES) and Leontief production functions. At the top level, aggregate value-added, and intermediate inputs are combined using a CES function with an elasticity of 0.5. On the second level, broad production factor categories (labour, capital and land) are aggregated using CES functions with an elasticity of 0.6, whereas the intermediate input component is aggregated using a Leontief production function. Aggregate primary factors (i.e., labour and land) are further differentiated using CES functions. Thereby, on the third level labour is composed of skilled and unskilled labour, and on the fourth level both classes are further subdivided into labour provided by female and male workers. On both levels relatively high elasticities of 2 and 3, respectively are assumed. Land is subdivided into rainfed and irrigated land, which are assumed to be very close substitutes (elasticity of 30), given that all irrigated crops are grown also on rainfed land in the base situation.

The final products are supplied to local and foreign markets, based on relative prices, as determined by a Constant Elasticity of Transformation (CET) function with an elasticity of 2, assuming a relatively high possibility for producers to switch between markets. The same holds true for imports which are considered relatively close substitutes for domestic products, modelled by an Armington-function with a substitution elasticity of 2.

Households supply production factors to productive activities through factor markets in exchange for wages that constitute a significant portion of their incomes. After paying taxes and making savings, households spend their income on purchasing products. Households maximise their utility subject to Stone-Geary utility functions, selecting the optimal mix of commodities and services while considering consumer prices, preferences, and income constraints.

2.3 Closure rules/ Macroeconomic assumptions

For both countries we assume that all production factors are fully employed and mobile between those sectors using them in the base situation. The model numéraire for the scenarios is the CPI and the model is savings-driven, meaning investments depend on available savings by households, enterprises, the rest of the world and the government. Yet, we assume that the government debts may not be further increased to avoid transferring welfare effects in future periods, which are not modelled. Thus, the government savings are fixed exogenously. This way, any

additional any policy implemented in the model is financed through an endogenous, equiproportional increase of income tax on households⁴.

2.4 Scenarios

We analyse three scenarios differentiated according to the time-horizon considered. Results are compared to the reference situation, representing the Kenyan and Beninese economies of 2019 as depicted in the respective SAMs (Section 2.1).

Short-run scenario (Invest): This scenario represents the phase of developing the additional irrigation schemes. In accordance with the respective development plans of both countries (for Kenya: NISS (MWSI, 2022) for Benin: PAG 2021-2026 (2021)), it is assumed that the investment period is 5 years. Further it is assumed that the total costs of 3.8 Billion USD for Kenya and 1.4 Billion USD for Benin are distributed equally over the years, while the benefits from the additional irrigated area only materialize after this period.

As the development of the irrigation schemes is realized by the respective governments, we implement this in the model by a shock to the government expenditure as detailed in Table 3. This results in a rise in government expenditure of about 6.5% in both countries throughout the five years. These additional expenditures are financed through an increase of the household income tax rates. This way, this scenario allows to capture and single out the economic effects of the investments required for expanding the irrigation capacity as indicated in the respective national plans.

Medium-run scenario (Irrigation): This scenario shows the effects resulting from the additional irrigated cropland (in Benin 50,000 ha, for Kenya 200,000 ha) on the respective economies. As the policy documents do not mention from where this additional cropland is sourced, based on national expert's assessments in this analysis it is assumed that: For Kenya the additional land is sourced from previously used rainfed land, while for Benin the additional land is sourced to 80% from unexploited areas (e.g. rangelands) and 20% from rainfed land. The ownership of the newly irrigated land is distributed among private households only and according to their shares of irrigated landownership in the base situation.

Long-run scenario (Potential): As a potential assessment, we additionally implement a long run scenario going beyond the current planning horizon. In this scenario it is assumed that the irrigated area is expanded to reach 310,523 ha in Benin and 1,116,720 ha in Kenya, which constitutes an expansion by 80% of the total additional irrigation potential of each country. As a potential-analysis, we do not directly consider the investment costs required to reach this potential, but apply the Pareto principle and assume that the marginal costs of increasing the irrigated area until this level would be constant (and might increase considerably only for the remaining 20% of the potential which are hence excluded from this analysis). This would mean, that the financing period (Invest scenario) would simply need to be extended accordingly (by 22.5 years for Kenya 28.6 years for Benin) to obtain the required funds.

The benefits from establishing the irrigation schemes are implemented in the model by land-shocks. Thereby the supply of irrigated land is increased, while rainfed land is decreased accordingly (Table 2). As the share of irrigated land is very small in the base reference situation (Kenya 2.2%, Benin, 0.4%), the shock is very large in relative terms, while the reduction of rainfed land is minor, especially in Benin where most of the additional irrigatable land is

⁴ The only difference in model setup between the two countries refers to the exchange rate: while for Kenya we apply flexible exchange rate regime closure, Benin is part of a currency union (CFA franc). This currency again is pegged to the Euro. As Benin is only a small economy within the combined CFA franc-Euro-Zone, any changes in the Beninese economy will hardly impact the exchange rate. Thus, for Benin we apply a fixed exchange-rate-regime. To balance the foreign account the trade balance is kept flexible. A sensitivity analysis shows that domestic production and welfare are only marginally affected by the fixed exchange-rate regime.

sourced from previously unused land reserves. The land is distributed among households equi-proportionally.

Table 2: Percentage change in land availability

	Land type	Invest	Irrigation	Potential
Be- nin	Irrigated	0	203.1	1241.5
	Rainfed	0	-0.2	-1.1
Ke- nya	Irrigated	0	92.6	417
	Rainfed	0	-2.1	-9.3

Source: Authors' calculations

An innovation of this paper constitutes the capturing of the costs of water provision associated with the expansion of the irrigation schemes. As, according to national experts, the farmers themselves will be in charge of operating and maintaining the irrigation schemes once they are established, these costs need to be included in the production structure of the respective cropping activities. Instead of implementing separate rainfed and irrigated activities, which would require considerable additional work and data, we adjust the intermediate input consumption of the existing cropping activities, which benefit from the additional irrigation. Specifically, we shock the input-output coefficient of these activities, increasing the share of water expenditure in total intermediate consumption at the same rate as the increase in irrigated land.

All scenario setups have been developed in a transdisciplinary co-design process and the analysis has been co-conducted in the framework of a long-term capacity building project for policy analysis using economic models in Benin and Kenya. Finally, outcomes were discussed extensively with national experts of the two countries from the relevant ministries and national statistical offices.

3 Results

3.1 Domestic production

In the short run (*Invest* scenario), the construction sector substantially grows in both countries, driven by increased government demand for constructing irrigation projects. As shown in **Figure 5**, for Benin this increase is more than 4 times larger than for Kenya in relative terms. While in both countries the construction sector constitutes about 6% of the GDP, the difference is mainly due to the stronger shock in case of Benin, where the additional government demand equals about 15% of the sector's output, while it is only 5% in Kenya.

With respect to the other sectors, Figure 1 shows that in Kenya also the forestry and the mining sector grow at similar rates. This is because in Kenya the construction sector consumes 96% of forestry and 79% of mining outputs as intermediate input. Similarly, in Benin, the construction sector uses 44% of mining as intermediate input. Consequently, expanding the construction sector also drives up production in these sectors. In contrast, the output of other sectors (e.g., crops, livestock, fishing, and services) drops in both countries. This can be ascribed to the increased prices of production factors (see Section 3.2) and the declining demand from households, which face increased tax rates (see Section 3.3).

In the medium-run (*Irrigation* scenario), introducing irrigation schemes boosts crop production in both countries, particularly for land-intensive crops, which profit most from the additional supply of this factor (Figure 6). The overall expansion of crop production also triggers positive multiplier effects in upstream (e.g., food processing) and downstream (e.g., private services, mainly trade and transport) activities, as shown in Figure 1. These effects are more prominent for Benin. In both countries, the growth in crop sectors also contributes to a minor increase in livestock production due to cheaper feed (Figure 1).

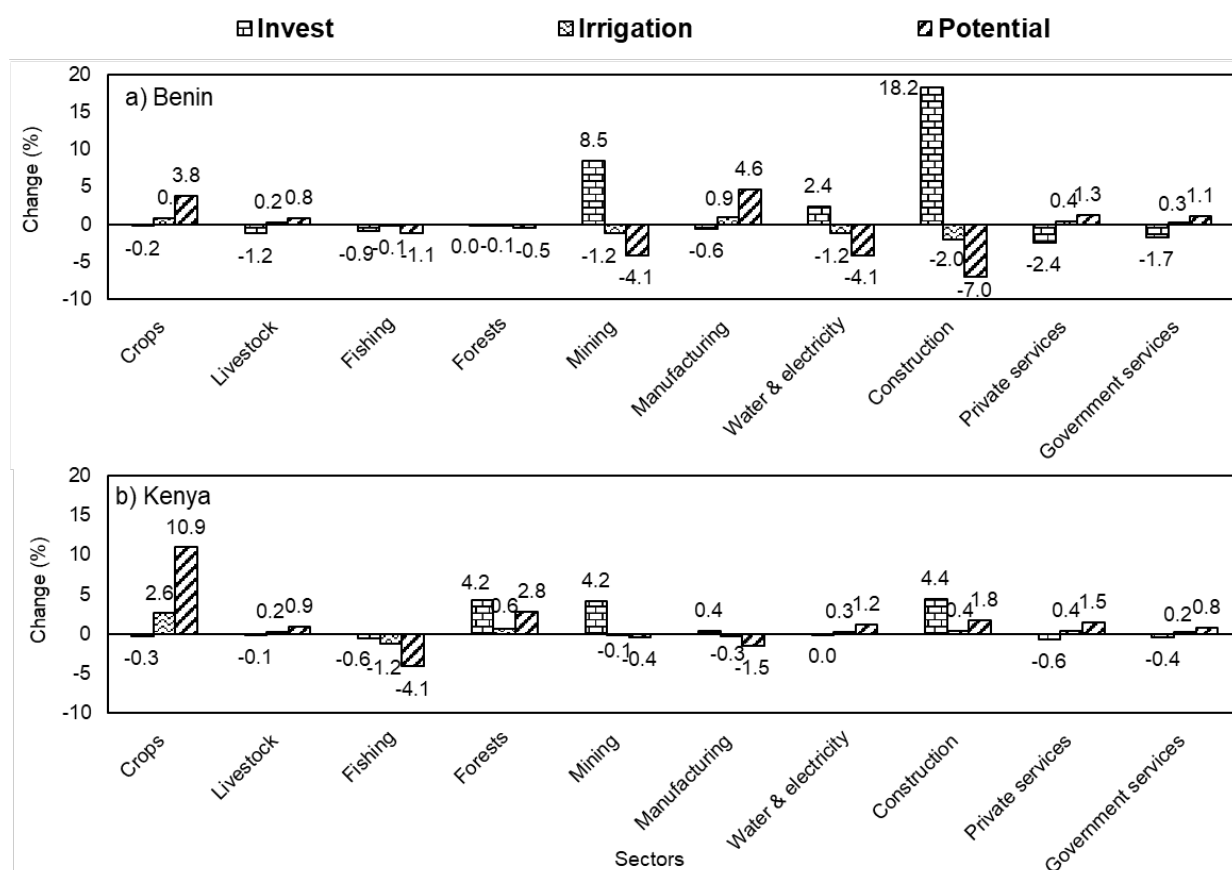
Surprisingly, crops with a considerable export share experience substantial growth in both countries despite not being cultivated on irrigated land. These crops benefit indirectly from the

drop in the price of rainfed land (Section 3.2) and a stable producer price, which remains relatively unaffected by the decline in domestic prices caused by the expanded supply. For Benin, these crops are cashews and cotton, cultivated on rainfed land, with 75% and 96% of their total production being exported, respectively. Similarly, tea is grown in Kenya on non-irrigated land, with approximately 65% of the total production being exported.

The long-run effects (*Potential* scenario) mirror the direction of the medium-run impacts in both countries, but with greater magnitude. When comparing the long-run effects in both countries, it is evident that overall crop production grows by 4% in Benin and almost 11% in Kenya. The latter is mainly attributed to a significant increase in tea production, which accounts for 37% of total crop production and is largely exported. The overall higher growth in crop production in Kenya compared to Benin is also due to the higher land intensity of cropping compared to Benin, where crop-production is more labour intensive.

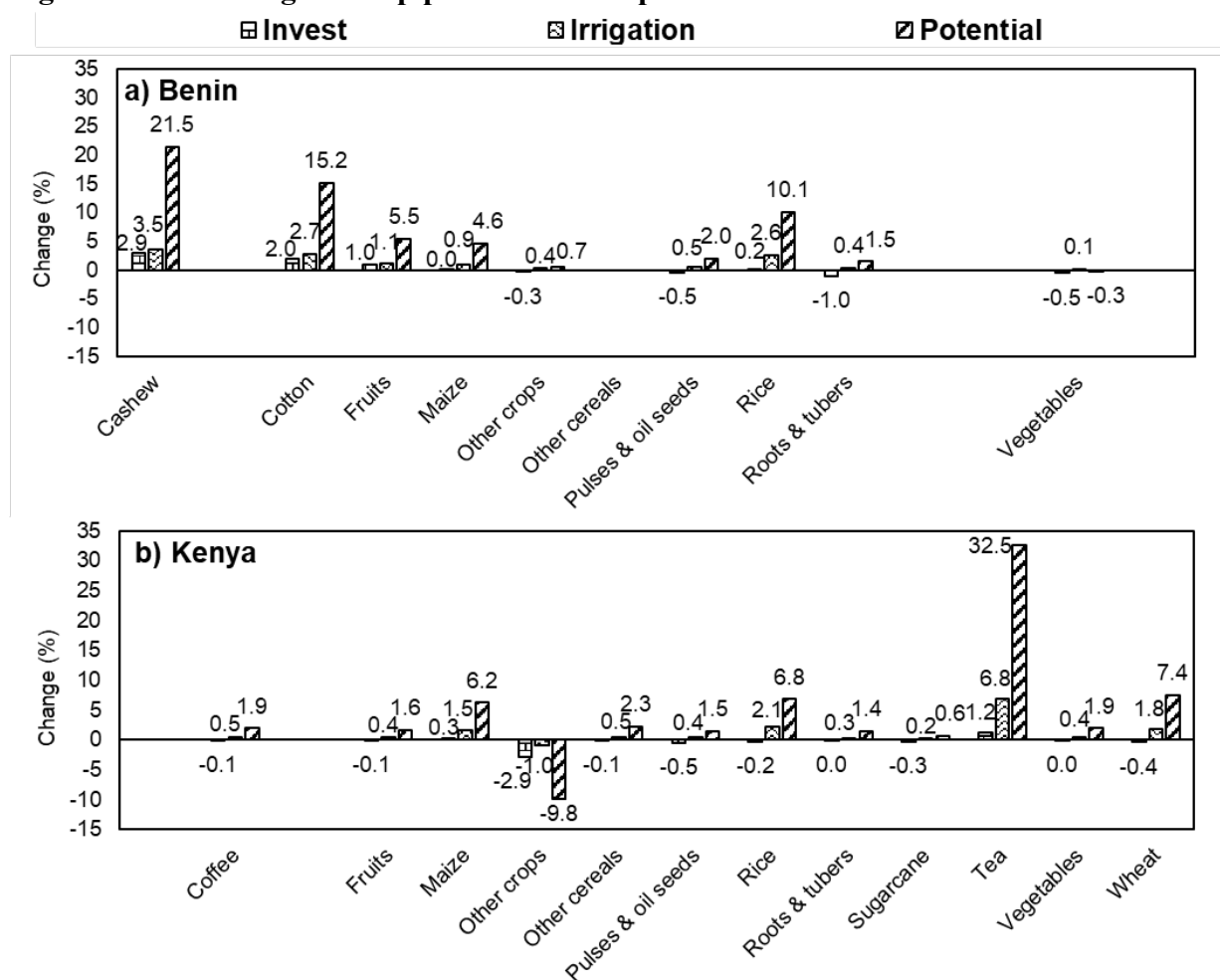
With respect to other sectors, similar impacts on livestock, fishing, and mining in both countries can be observed, yet the magnitude varies between the two countries. For instance, the decline in the fishing sector is less pronounced in Benin than in Kenya. This difference can be attributed to the significant rise in agricultural factor prices (labour and capital are extensively used by the fishing sector) in Kenya compared to Benin. The impacts on other sectors (forests, manufacturing, water and electricity, and services) vary between the two countries. This outcome can be attributed to distinctions in the input-output linkages between crop production sectors and these industries (intermediate inputs), as well as competitive effects in factor markets influenced by the expansion of crop production. For instance, in Benin, manufacturing production rises due to the growth of processing sectors, particularly cashews and cotton. Conversely, in Kenya, manufacturing production declines due to an upsurge in the price of non-agricultural capital, which is intensively utilized by this sector.

Figure 1: %-change of domestic production compared to the reference scenario



Source: Author's calculations based on simulation results

Figure 2: Change of crop production compared to the reference situation



Source: Authors' calculations based on simulation results

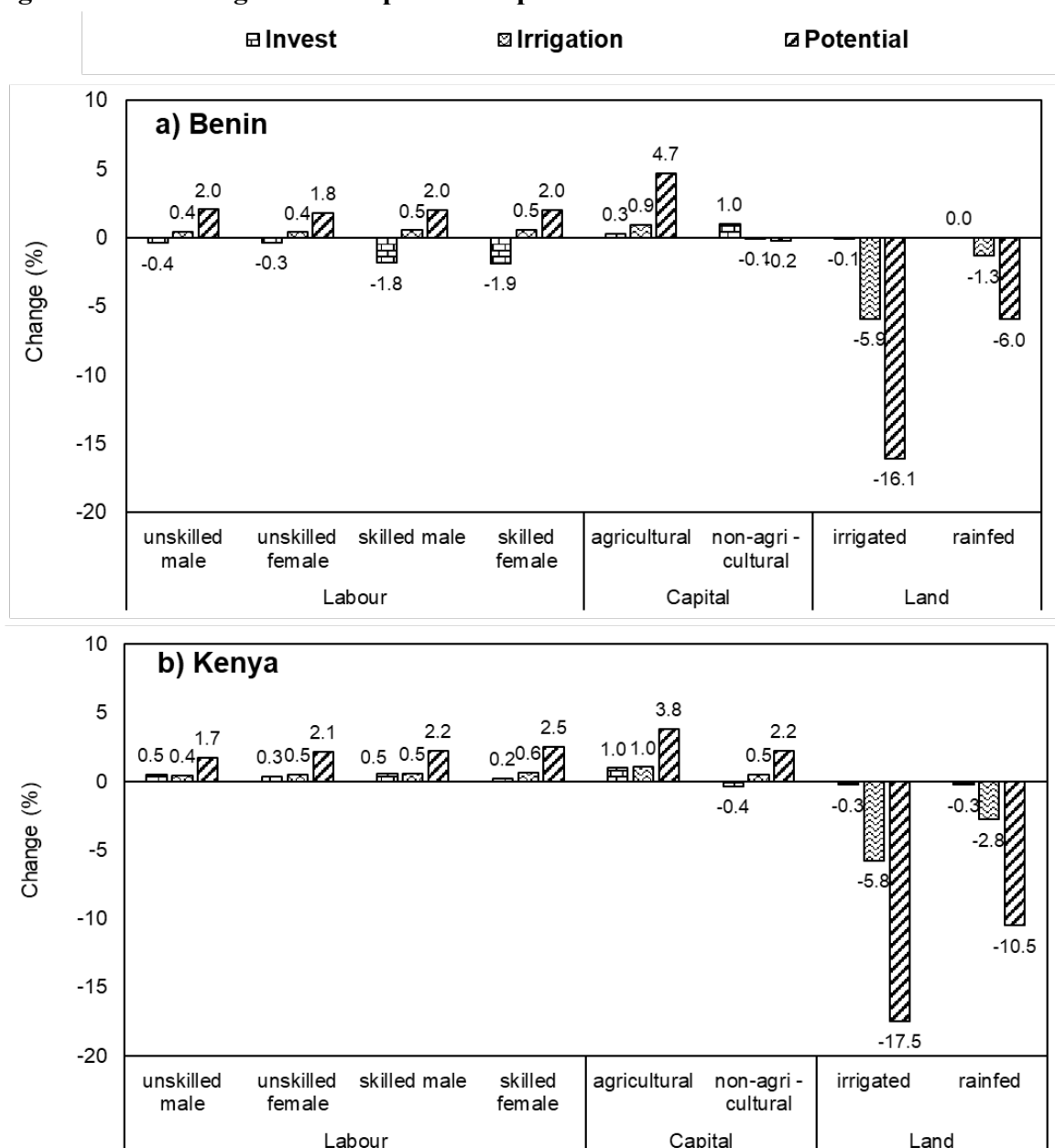
3.2 Factor prices

In the *Invest* scenario, factor prices experience only minor changes, as illustrated in Figure 3. Given the differences in factor intensity of the expanding construction sector between the two countries, the price of non-agricultural capital in Benin increases, in Kenya mainly labour is demanded more and thus becomes more expensive. Kenya's construction sector is typically labour-intensive and therefore, the investment phase will be accompanied by large absorption of mainly unskilled labour. However, the price of agricultural capital increases even more in Kenya. This is a second-round effect caused by the increase of the forestry sector, which is quite capital intensive.

In the *Irrigation* scenario, labour and capital prices experience a slight increase due to the growth in crop production. In contrast, due to the expansion of irrigated area, land prices for irrigated and rainfed land fall strongly in both countries (Figure 3). The latter is due to the high substitutability between the two types of land.

The long-run effects (*Potential* scenario) align with those observed in the medium-run (*Irrigation* scenario). Yet, the effects are much stronger in both countries, with irrigated land prices dropping by more than 15% and rainfed land prices falling by 5-10%, due to the much higher expansion of irrigated land.

Figure 3: Change of factor prices compared to the reference situation



Source: Authors' calculations based on simulation results.

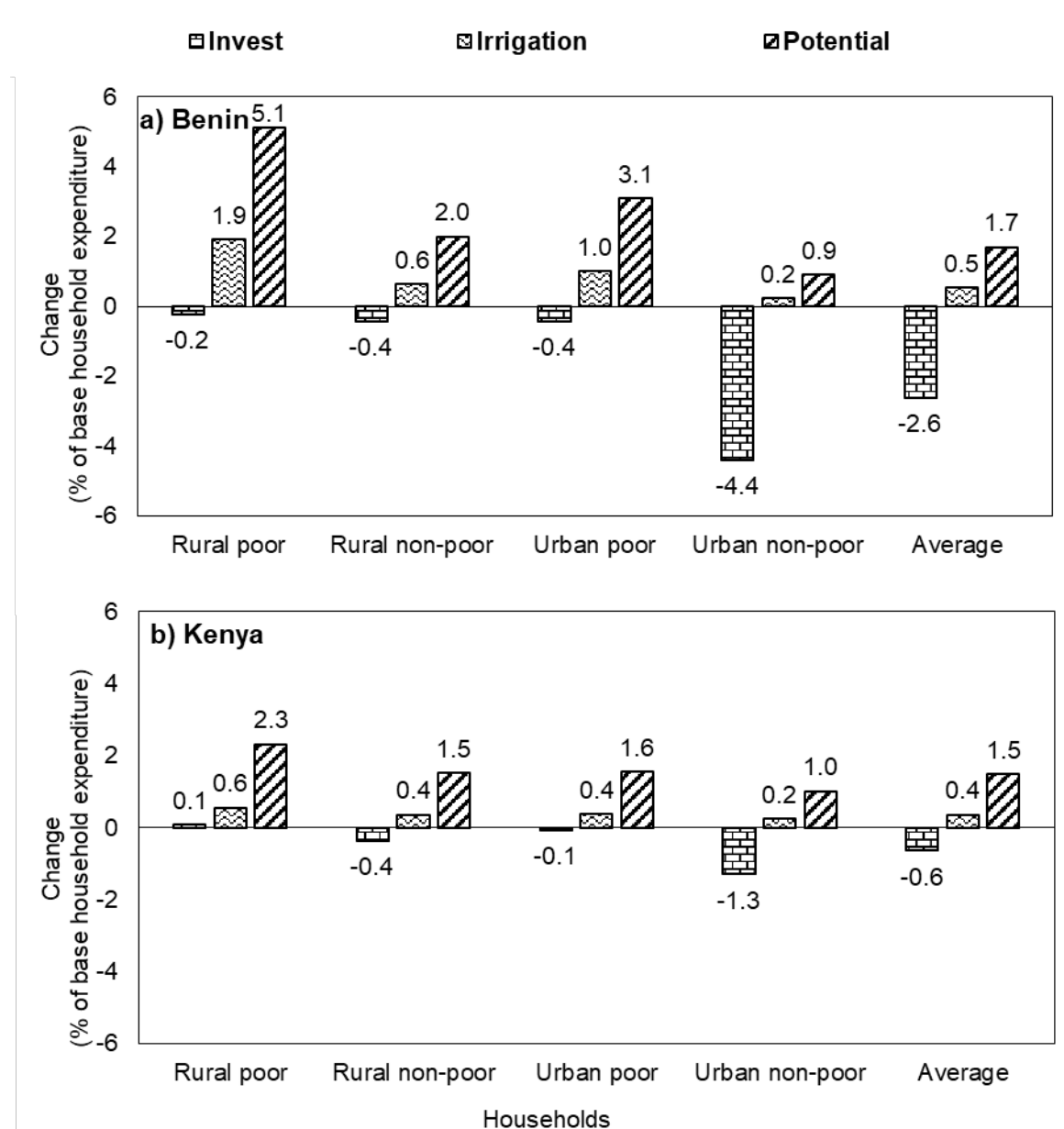
3.3 Household welfare

Figure 4 illustrates the three scenarios' impacts on household welfare measured as a change of Equivalent Variation (EV)⁵. As can be seen, the *Invest* scenario, largely impacts negatively on households' welfare. This is due to the increase in income tax-rates required to fund the expansion of irrigation schemes, while their benefits are not yet realized. The tax rates increase by 2.6 percent-points in Benin and 0.5 percent-points in Kenya, reducing the disposable income available to households for consumption. As in both countries urban non-poor households carry the highest tax burden, this household-group experiences the strongest reduction in welfare. In Kenya, rural poor households experience marginal gains. This is because of the slight increase

⁵ EV refers to a change in income that would have an equivalent effect on utility as all observed price and income changes combined.

in unskilled labour wages due to the expanding construction sector and hence income, outweighing the negative impact of the raised tax rates, given the low average tax rate (or limited tax base) within this household category.

Figure 4: Change in equivalent variation as a share of household expenditure in the reference situation



Source: Authors' calculations based on simulation results

In the *Irrigation* scenario the tax-rates are again lowered close to the reference rates. As Figure 4 shows, the increased supply of irrigated land enhances household welfare in both countries. The highest welfare gains are observed among rural poor households, as they benefit most from the additional factor income from irrigated land, which in relative terms contributes most to the income of this household group in both countries. Additionally, the decline in crop prices contributes to the positive effects, particularly benefiting poor households with a significant share of expenditure on food.

In the *Potential* scenario the effects become more pronounced, with welfare gains reaching up to 5.1% and 2.3% of base expenditure for rural poor households in Benin and Kenya, respectively (Figure 4). These welfare gains are mainly driven by the positive income effects, due to

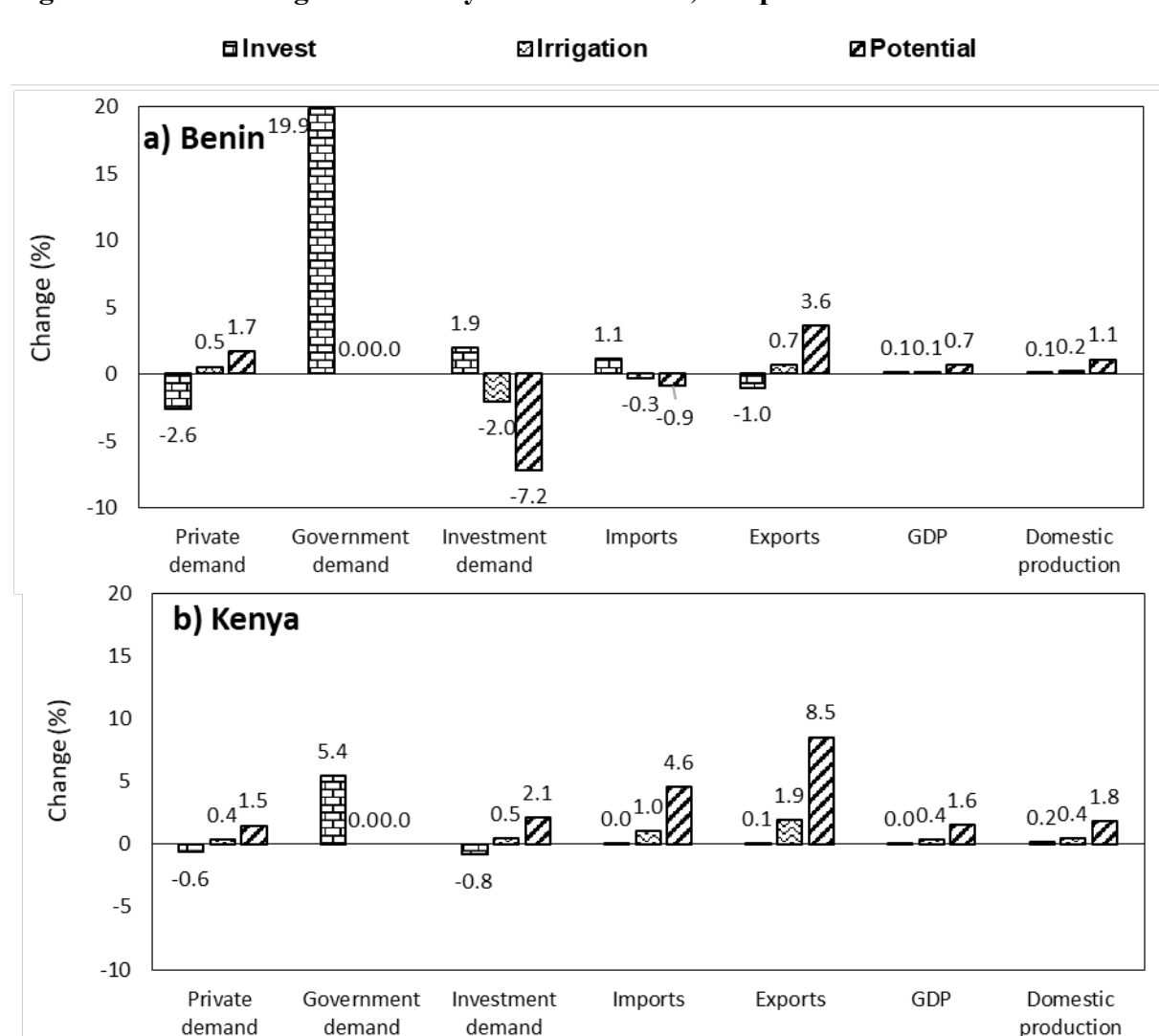
the additional irrigated area becoming available. The variation between the countries can mainly be explained by the relatively higher irrigation potential in Benin, where irrigated land supply grows more than 12-fold, while it only grows about 4 times in Kenya (compare Table 2)⁶.

3.4 Economy-wide indicators

Turning to macroeconomic indicators, Figure 5 shows how in the *Invest* scenario government demand rises strongly due to additional allocations for constructing irrigation schemes. To fund these expenditures, income taxes on households are raised, leading to a decrease in private demand.

In the medium- and long run (*Irrigation* and *Potential* scenarios), with the establishment of the irrigation project government demand falls back to levels as observed in the reference situation in both countries. Simultaneously, private household demand rises slightly due to increased household income and relatively stable consumer prices.

Figure 5: % change of economy-wide indicators, compared to the reference situation



Source: Authors' calculations based on simulation results

Furthermore, exports grow in both countries, primarily driven by expanding shipments of agricultural products. In the case of Benin, the exports of cotton and cashews increase, improving

⁶ To test this, we ran an additional scenario for Benin in which we applied an equal land supply shock as in Kenya and found the results to be much more similar: EV of poor rural households would reach 3.0% of base expenditure in this case.

the trade balance and given the closure setup with a fixed exchange rate reducing capital inflow from the rest of the world. In Kenya, predominantly exports of tea expand, providing the means to finance additional imports, particularly in the categories of petroleum, chemicals, and manufactured goods.

The positive impacts on household income also contribute to the growth of domestic production and hence also gross domestic product (GDP). For Kenya both indicators increase stronger, despite the relatively lower expansion of irrigated land (Table 2). This is caused by the exchange rate regime in Benin resulting in lower capital inflow and hence lower investments.

4 Discussion and Conclusions

Different from findings of previous research for Malawi (SCHUENEMANN ET AL, 2018), the outcomes of this study suggest that expanding irrigated agriculture in Benin and Kenya is promising for economic growth and improved household welfare. Both countries experience positive impacts post-establishment of irrigation schemes. The distribution of welfare impacts is largely driven by the allocation of the newly irrigated land. To achieve a pro-poor distribution as suggested by this study, it will be crucial for policy makers to ensure that poor households participate fairly in the allocation of the newly irrigated land⁷. In line with SIDDIG ET AL. (2021) and HIGGINBOTTOM ET AL. (2021), this study shows that focussing on the production of export crops on the newly irrigated areas brings about the highest welfare effects, as these crops do not face a downward sloping domestic demand curve and hence falling prices with increasing production. Yet, the benefits of developing additional irrigation schemes do not only stem from the expansion of irrigated agriculture, but also from rainfed agriculture, benefiting indirectly from the increased availability of highly productive irrigated land. Also, multiplier effects in downstream and upstream sectors as well as an increased household demand for services and other commodities contribute to the overall positive economic effects. A sectoral analysis would miss these implications.

Yet, the *Invest* scenario suggests that in the short term, during the development of the irrigation schemes the welfare effects are negative for most household groups. It needs to be considered, however that this scenario stands for a period of five years, while the *Irrigation* scenario represents the several decades long lifetime of the irrigation schemes, as maintenance is included in the irrigation costs. Further, if a share of the required funds can be sourced by international donors as anticipated in the government plans, the short-term losses can be further reduced. To build more irrigation schemes as simulated in the *Potential* Scenario, the investment period simply would need to be prolonged accordingly.

While overall outcomes are similar and positive for both countries, nuanced differences exist particularly in gender dynamics and environmental considerations. In Benin, men marginally benefit more from employment patterns, whereas in Kenya, women, who are especially engaged in tea harvesting, stand to gain slightly more. Also, the equitable ownership distribution of newly irrigated land among sexes remains pivotal in both contexts. This shows that despite of similarities between countries in terms of relevance of the agricultural sector and irrigation potential, each case needs to be analysed individually to derive meaningful conclusions.

Also, environmental risks, including carbon release and biodiversity loss, differ based on the characteristics of the converted land—rangelands in Benin and savanna-land in Kenya—requiring tailored strategies for sustainable development. Yet, potential adverse environmental implications of increasing the agricultural area, e.g. on water resources are not considered in this

⁷ In fact, a sensitivity analysis for the case of Benin shows, that if the newly irrigated land was distributed according to the distribution in the reference situation (60% belonging to enterprises), the overall welfare gains for households would be much smaller and welfare impacts would be even negative for poor rural households, as 64% of the additional enterprise income is invested and 24% goes to owners abroad, while only 6% to mainly non-poor domestic households, leading to much lower multiplier effects.

study. If, different from what is anticipated, larger areas of savanna-land are converted into irrigated crop land, negative implications in terms of carbon release, biodiversity loss and ecosystem services would need to be studied in more detail. In fact, it has been estimated that up to 248 tons of CO₂ are emitted from turning one hectare of African savanna-land into crop land (WEST ET AL., 2010; SEARCHINGER ET AL., 2015). Yet, authors also found that turning sparsely vegetated areas into irrigated croplands could also result in more carbon storage (WEST ET AL., 2010).

To achieve the positive effects shown in this paper and avoid eventual bottlenecks, governments of these countries could work on implementing mechanisms to ensure overproportional access to the newly irrigated land for poor households, aligning with national development plans. Diversifying funding sources by raising some funds from international organisations, donors, and the private sector (enterprises) would help to mitigate negative impacts on household welfare during the construction period. Additionally, careful consideration of environmental effects through thorough analyses and compensatory measures is recommended in both countries to address potential negative externalities associated with the expansion of irrigated agriculture. One measure to be further investigated in this context could be the establishment of agroforestry systems, which have been found to reach higher carbon sequestration rates than annual crops or natural grasslands (MUTHURI ET AL. 2023).

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THE EFFECTS OF DIGITAL YIELD MONITORING ON GREENHOUSE GAS EMISSIONS IN THE UNITED STATES

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Abstract

The motivation for adopting digital technologies in agricultural production primarily lies in enhancing farm productivity and realizing associated economic benefits. A potential secondary benefit is the reduction of greenhouse gas emissions. This study examines the impact of digitalization on greenhouse gas emissions per unit of output and per unit of cultivated area within the United States agricultural sector.

Digitalization is proxied by the adoption of digital yield monitoring technology – a measure of digitization that is the foundation for other digital production practices. We focus on the greenhouse gas nitrous oxide (N_2O), which is directly associated to the application of N-fertilizer. The analysis employs a Group Fixed Effects estimation on a panel dataset covering 28 U.S. states across five time points between 1996 and 2010. The study explores the relationship between the adoption of digital yield monitoring in crop production and N_2O emissions.

The findings indicate that digitalization is associated with reductions in nitrous oxide emissions both per unit of output and per unit of cultivated area. This suggests that digitalization in agricultural production could help balance the trade-off between the need to increase production and the imperative to reduce emissions.

However, while emissions per unit of output and per unit of cultivated area decrease with increasing levels of digitalization, overall greenhouse gas emissions from the agricultural sector may have increased during the same period. This increase may be attributed to other technological or policy innovations, but the results also leave scope for potential rebound effects. Such considerations underscore the importance of conducting analyses at the global level and across a broader range of greenhouse gases to assess both the direct and indirect effects of digitalization on emissions.

Keywords

Variable rate technologies, Digital yield monitoring, Precision agriculture, Greenhouse gas emissions, Nitrous oxide emissions, Crop production technology.

1 Introduction

Implementing digital technologies when employing precision agriculture methods can play a key role in boosting productivity in agricultural crop production, making it one potential response to address the global challenges of the double burden of under nutrition and micronutrient deficiency (MEENAKSHI, 2016; GÓMEZ ET AL., 2013), declining agricultural area due to global warming (MALL ET AL., 2017; ZHANG AND CAI, 2011), as well as world population growth (DIJK ET AL., 2021). At the same time, such technologies affect the greenhouse gas (GHG) emissions from agriculture. This study therefore seeks to determine the climate effects of digitalization in food crop production. While some studies exist at the micro level, these

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analyses do generally “not report observed impacts, but rather possible impacts based on experimental data or model predictions”, as FINGER ET AL. (2019, p. 322) state it. To the best of our knowledge, this is the first study to rely on observational data at a high level of aggregation and an extended period of time and space to study the climate impacts of digitalization in crop production.

Direct effects include more efficient use and therefore reductions of energy intensive inputs, such as fertilizer, plant protection, gasoline, and feed (D’ANTONIO ET AL., 2023). For example, GPS-led, self-driving tractors use less fuel (D’ANTONIO ET AL., 2023; SHOCKLEY ET AL., 2011; JENSEN ET AL., 2012) and plant-specific input application requires less inputs (RAJ ET AL., 2021; FINGER ET AL., 2019; UNDP, 2021). Those reductions suggest lower emissions per unit of output as a consequence of increased levels of digitalization. However, direct effects also include the energy use of those technologies themselves, including the fixed costs and emissions of the initial set-up of machinery and digital infrastructure, data processing capacities, and powerful mobile networks, as well as the variable costs and emissions of using these technologies (GARCÍA-MARTÍN ET AL., 2019). Those suggest an increasing effect of digitalization on emissions.

Indirect effects result from cost reductions as a consequence of the direct effects: Increasing levels of digitality require investments in sensors, software, training, etc., and lead to reductions in the quantities and therefore expenses for other inputs. The fact that digitalization does take place at all suggests that the savings from input reductions dominate over the costs of setting up and operating the digital infrastructure. These cost reductions lead to an increase in output quantity which can even cause a net increase of emissions - a phenomenon known as the *rebound effect* or the Jevons Paradox (BRYNJOLFSSON AND MCAFEE, 2014; PAUL ET AL., 2019)⁴. The consequence of such output expansion is adjustments in imports and exports.

This analysis sets out to investigate the first component of these dynamics, the direct effects of digitalization in agricultural production on emissions from cultivated area. The empirical analysis relies on a panel dataset at the US State level from 28 states over five waves, collected between 1996 and 2010, to estimate the relationship between digital yield monitoring, which approximates digitalization in the agricultural sector⁵, and the emissions of nitrous oxide in agricultural production, which is the most effective climate gas emitted in crop cultivation. To account for time-varying, unobserved heterogeneity, the study employs a Group Fixed Effects estimation procedure (BONHOMME AND MANRESA, 2015). Results suggest that digitalization in the production of corn, wheat, and soy reduces the nitrous oxide emissions per production area and the digitalization in the production of corn reduces the emissions per unit of output.

The following sections first provide an overview of specific technologies and how these may affect energy use and emissions. The subsequent empirical section lays out the empirical model and discusses endogeneity concerns and the data before presenting and discussing the results. A final section summarizes and concludes.

2 Digitalization in crop production and GHG emissions

The introduction of precision farming is motivated by the ideal of providing each individual plant with precisely the input that it needs at each point in time. The convergence to this ideal requires three components: The availability of data at high spatial and temporal resolution on

⁴ A second pathway of the rebound effects through effects on average worker productivity (BRYNJOLFSSON AND MCAFEE, 2014) plays primarily a role when looking at macroeconomic dynamics, such as digitalization in the entire economy. The effect is minor at this sectoral analysis, especially when analyzing the agricultural sector.

⁵ The term digitization implies the conversion of analog information into a digital format while digitalization refers to the use of digital technologies for data processing. Digital yield monitoring is categorized as a process of digitization. However, as we will argue below, this technology is usually used in combination with other digital technologies, allowing us to rely on digital yield monitoring as a proxy of digitalization in agriculture more generally.

the plant and its environment (soil, air, temperature, water availability, sunlight, etc.), data processing capacities to predict the specific plant's needs at each point in time, and the mechanical equipment required for variable rate technologies, i.e., plant-specific input application (SPÄTI ET AL., 2021). While all of these have existed for long (FRANZEN AND MULLA, 2015), the digital technologies available since the last quarter of the 20th century enabled substantial developments in all three of these components for plant-specific treatment in recent decades (FINGER ET AL., 2019). Given that some of these components are complements (SCHIMMELPFENNIG AND EBEL, 2016), which causes the use of several of them to be applied in combination with each other (MILLER ET AL., 2019), the measurement of one technology allows for more general conclusions on the process of digitalization in agricultural production. The following paragraphs first describe and give examples for digital yield monitoring which is the key variable under consideration in this analysis. We then provide a brief overview and examples for the second and third stage components. They all have in common that they have the potential to reduce GHG emissions - but also to increase them. We conclude this section with an overview of the existing literature on environmental effects of these technologies.

The first component and basic requirement for precision farming, the availability of data at high resolution, can be collected from a close, intermediate, or remote distance. Close and intermediate distance sensors are mounted on agricultural machinery, either at the surface level, which provides data at high resolution with little measurement error but is the most resource-requiring technology, or at the top, for example on the operator's cab (GANDORFER, 2005). Remote sensing includes satellite imagery and light detection and ranging (LiDAR) technology, i.e., images from low-flying airplanes and unmanned aerial vehicles (UAVs, RIVERA ET AL., 2023; RAJ ET AL., 2019). Depending on the specific technology under consideration, the energy needed in production and operation of these technologies can be substantial. These include, for example, the replacement of agricultural machinery, the fuel burnt by UAVs and airplanes in LiDAR flights, or launching satellites into the stratosphere (DALLAS ET AL., 2020). This analysis relies on the adoption rates of any type of digital yield monitoring technology. Given that such technologies are adopted with the single purpose of generating data to be used in the further cultivation process, the spread of digital yield monitoring is closely related to the spread of digitalization more generally in crop production.

The second component in precision agriculture are data processing capacities. While this data processing did traditionally take place in the farmer's head, cloud service providers allow today for the flexible use of large computing capabilities only when needed without requiring individual firms to set up their own data processing infrastructure (PAVÓN PULIDO ET AL., 2017). At the same time, such server farms use large amounts of energy and are substantial contributors to overall GHG emissions (KOPP ET AL., 2023; SHEHABI ET AL., 2011; UDDIN ET AL., 2015). For example, about 1.8% of all energy use in the United States is allocated to data centers (SIDDIK ET AL., 2021).

In terms of the mechanical equipment required for variable rate application of inputs, solutions for different application technologies have been developed. These include, firstly, microcontrollers which adjust the flow of the agrochemical to be distributed (SPÄTI ET AL., 2021). In fertilizer application, the amount brought on the field by vertical spiral conveyors can be specified via "a variable-rate pulse width modulation control system" (CHEN ET AL., 2018). The flow dosage of disc fertilizer spreaders can be set by dynamically changing a) the feed gate opening size and b) by adjusting the speed of the fertilizer conveyor through its electric motor (ZHANG ET AL., 2012).

While this study focuses on the consequences of technology innovations in crop production, digitization and digitalization also occur in animal husbandry with technologies such as autom-

atized milking robots, digital herd management, and animal-specific feeding regimes and milking frequency, among others. An overview on digital technologies in animal husbandry is provided by GROHER ET AL. (2020).

Some existing studies analyze the effects of such digital technologies on both productivity and the environment. Benefits in variable rate nitrogen fertilization exist by reducing fertilizer quantities, but are small in magnitude (SPÄTI ET AL., 2021). The same authors find that high-tech solutions, such as drone technology, do not provide a particular benefit compared to lower-tech methods, such as standard nitrogen sensors. D'ANTONIO ET AL. (2023) find that guidance systems in tractors have the potential to reduce herbicide use by 30% and fuel use by 11.5%.

A recent summary on the environmental effects is provided by FINGER ET AL. (2019, Section 4.2), who conclude that the vast majority of studies finds that digital technologies in agricultural production generally reduce the stress on the environment through several channels. However, what these studies have in common is that they are from a relatively small geographical scale or based on data from laboratory experiments. Those include a one-year observation of two single fields of maize in southern Bavaria (Germany) by SEHY ET AL. (2003) who find a reduction of nitrous oxide emissions from the fields subject to precision farming. The studies from SHOCKLEY ET AL. (2011) and JENSEN ET AL. (2012) conclude that automatic tractor guidance systems reduce fuel use and associated CO_2 emissions, with the first of these studies relying on data from the observation of one single farm in Kentucky while the latter models expected effects, based on results from studies that rely on experimental data. PAMPOLINO ET AL. (2007) find that variable rate technologies can increase yields while reducing nitrogen fertilization, based on on-farm experiments on 80 farms in three countries in south and southeast Asia.

The design of such studies does not allow for the identification of dynamic developments at the macroeconomic scale. The study at hand fills this gap by analyzing developments at the aggregate level.

3 Empirical analysis

To quantify the relation between digitalization and emissions in crop production, we conduct two sets of estimations: The first set derives the relationship between digitalization and nitrous oxide emissions per unit of output while the second set assesses the relation between digitalization and emissions per production area. In each estimation, we measure digitization in two ways, namely a) as the average between digitization in three most dominant crops in the states under consideration and b) with digitization in these three crops entering separately.

To account for time-varying, unobserved heterogeneity, the analysis employs a Group Fixed Effects (GFE, BONHOMME AND MANRESA, 2015) approach to estimate the effects of digitization on GHG emissions from agriculture.

3.1 Econometric Model

The econometric model for assessing these relations is given by equation (1):

$$\Omega_{s,t} = \beta_0 + \beta_1 \text{digi}_{ymi,s,t} + \varepsilon_{s,t}, \quad (1)$$

in which $\Omega_{s,t}$ represents the dependent variable in state s at time t in the respective estimation and takes the values $\Omega \in \{N_2O/q; N_2O/a\}$. N_2O stands for nitrous oxide emissions, q for total output, and a for the cultivation area in the respective state. $\text{digi}_{ymi,s,t}$ indicates the share of the cultivated area in state s on which digital yield monitoring technologies are employed at time t . This variable is measured in two ways: We conduct the analysis both at the aggregate level to save degrees of freedom and also at the disaggregate level to exploit all information available. So $\text{digi}_{ymi} \in \{all; \sum_i(c_i)\}$, in which *all* stands for the average across the three most widespread crops in the states under consideration, and $\sum_i(c_i)$ captures the level of digitization for the three crops separately. The β parameters are coefficients to be estimated and $\varepsilon_{s,t}$ captures random,

zero-centered, and normal-distributed deviations from the estimated relation between RHS and LHS variables.

One general challenge in these estimations is the relatively low number of observations (details in data description below). This low sample size is caused by the analysis' focus on US states that actually produce substantial amounts of field crops and by the data for the relevant module in the USDA agricultural survey on digitization being collected only every three years, on average. To account for the small sample size, we conduct statistical simulations with 1,000 repetitions. Such a bootstrapping procedure allows for the construction of more accurate confidence intervals and hypothesis tests by resampling from the observed data with replacement, effectively generating a high number of pseudosamples (EFRON AND TIBSHIRANI, 1994).

3.2 Endogeneity concerns

To address omitted variable bias due to unobserved heterogeneity between states, one would typically rely on fixed effects estimation techniques (WOOLDRIDGE, 2010). However, such an approach implicitly assumes that this heterogeneity remains constant over time. Given the time span of this study of 15 years, this may be too strong an assumption. To account for unobserved, time-varying heterogeneity, we include time-varying fixed effects. However, assigning one fixed effect for each state-year combination would result in over specification of the model as one would end up with as many fixed effects as there are observations in the model. Instead, we make the assumption that groups of states that display similar dynamics in their observables also behave similarly in their unobservables. This allows the estimation of time-varying, joint *Group Fixed Effects* for groups of states which display similar dynamics in their observables (BONHOMME AND MANRESA, 2015). This estimation technique assigns time-specific dummy variables to each group-year combination. Given that emissions are specific to crop types, we create interaction terms between crops and the state groups, resulting in an extension of the group-fixed effects, as introduced by BONHOMME AND MANRESA (2015), to what we call *Group-Crop Fixed Effects*. The equation to be estimated is given by equation (2):

$$\Omega_{s,t} = \beta_0 + \beta_1 \text{digi}_{ymi,s,t} + GFE_{c,g,t} + \varepsilon_{s,t}, \quad (2)$$

in which $GFE_{c,g,t}$ stands for the Group Fixed Effect of crop type c in state group g at time t .

3.3 Robustness checks

The relation between digitalization and emissions may be non-linear, given the combination of fixed emissions from setting up the digital infrastructure and the variable emissions from operating it (KOPP ET AL., 2023). In the first set of robustness checks, we therefore enter the variables in all equations in the form of their natural logarithm.

Some observations in the digitization data are missing (more information below). When these missing observations occurred in the middle of the study period, i.e., when there were observations before and after, we linearly interpolated the missing values and used these data for a second set of robustness checks. The third set of robustness checks relies on an alternative econometric method, namely a simple Fixed Effects estimator (WOOLDRIDGE, 2010). Finally, all estimations are also conducted without the bootstrapping procedure.

3.4 Data

The empirical analysis relies on yield monitoring as a proxy of digitalization in crop cultivation, given that this technology is one of the foundations that are required for implementing precision farming applications, such as site specific fertilization, pesticide application, seeding, etc. The

U.S. Department of Agriculture (USDA) provides data on the spread of yield monitoring technology, measured as the share of the planted area per state that is subject to this technology⁶. Only the 28 states that are the biggest producers of soy, corn, and wheat collect data on digital yield monitoring. This selection of states yields data on digital yield monitoring for 67% of the entire cropland area in the USA and more than 98% of the entire area that are dedicated to these crops, and also more than 98% of the total output of these crops. Data on production quantities in the form of bushels of crop per state per year were taken from the USDA as well⁷.

Figure 1 illustrates the production quantities of the three crops under consideration all over the US in Panels 1a, 1c, and 1e. Panels 1b, 1d, and 1f indicate the data availability for digital yield monitoring, with darker colors representing states with more observations between 1996 and 2010.

Nitrous oxide emissions that emerge from crop cultivation are measured as metric tons of CO_2 equivalents (CO_2e) and were obtained from the U.S. Environmental Protection Agency (EPA)⁵. Agricultural N_2O emissions are primarily caused by the application of nitrogen fertilizer (47 percent of all agricultural N_2O emissions), the use of manure (13 percent), decomposition of crop residues left on fields (16 percent), and other, minor causes, such as the burning of crop residues or of savanna (MARASENI AND QU, 2016, based on data from the USA for 2012). The data used for this analysis include exclusively the N_2O emissions from soil management on cropland. These data are illustrated in Figure 2.

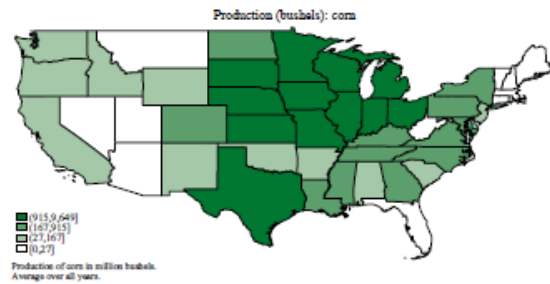
Data on production quantities, cultivated area, and nitrous oxide emissions are available for every year of the entire time range and for every US state. The binding constraint for the observations entering the analysis is the data on digital yield monitoring in the three crops under consideration. The panel includes five waves, stretching from 1996 until 2010. From year 2011 onward, the USDA agricultural survey does not include anymore the module that captures information on digitization. The dataset is limited by some missing observations. Missing observations for state-year combinations that yielded information on digital yield monitoring for at least one crop were replaced by zero if the area of the crop with missing info was less than 20 percent in that state in the respective year. This procedure leaves us with a total of 75 individual state-year observations for the empirical analysis with all variables. The data for each wave on digital yield monitoring were not collected in exactly the same cropping season. In these instances, we pooled the observations for the digitization measure of up to three years. Table 1 displays for each crop the year of data collection, to which panel wave these data were aggregated for this analysis, and the number of states with digitization observations per panel wave and crop.

⁶ <http://data.ers.usda.gov/reports.aspx?ID=17883>.

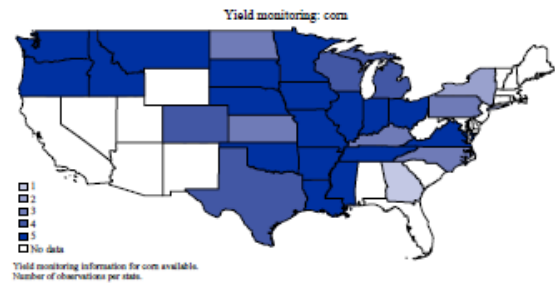
⁷ <http://quickstats.nass.usda.gov/#34012A4E-19B9-3024-8DE5-6A2216C46001>. www.epa.gov/ghgemissions/state-ghg-emissions-and-removals.

Figure 1: Production quantities and levels of digital yield monitoring.

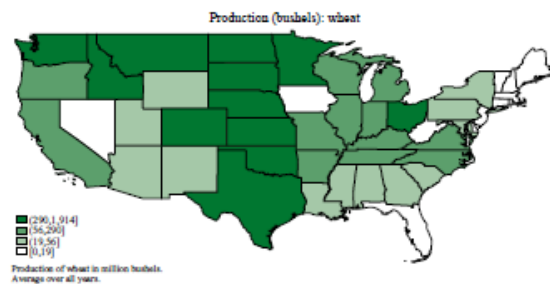
(a) Corn production.



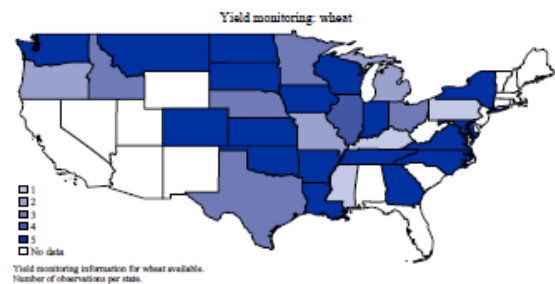
(b) DYM in corn.



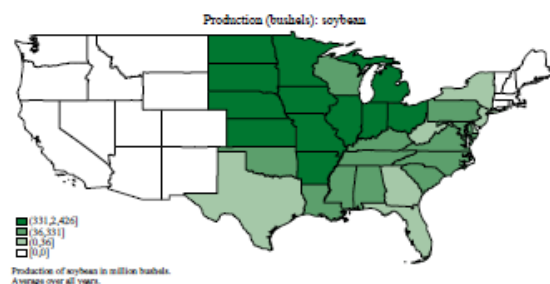
(c) Wheat production.



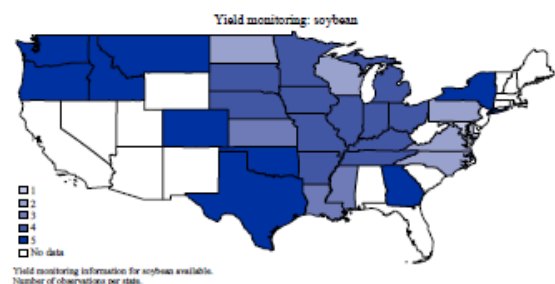
(d) DYM in wheat.



(e) Soy production.



(f) DYM in soy.



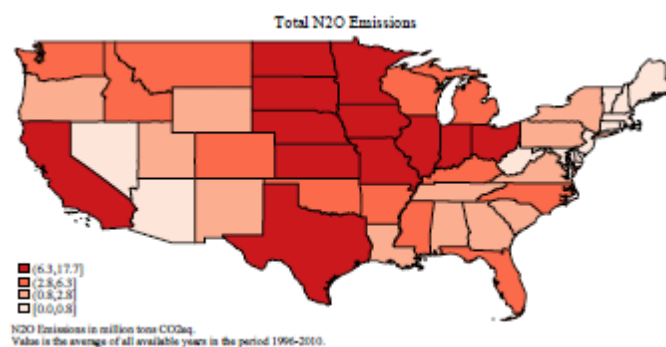
Source: Own production, based on data from U.S. Department of Agriculture.

Notes: Data displayed are for averages for the years 1996-2010.

The green maps illustrate production while the blue maps indicate the data availability for digital yield monitoring, with darker colors representing states with more observations.

Data on digital yield monitoring are available at the crop level, while data on nitrous oxide emissions are available at the state level, so the unit of analysis for the relationship between digitalization and emissions is state-year. Summary statistics are provided in Table 2.

Figure 2: Nitrous oxide emissions.



Source: Own production, based on data from U.S. Environmental Protection Agency. *Notes:* Data display averages for the years 1996-2010.

Table 1: Years of data collection by crop.

	Year of data collection (Number of reporting states)			Observations per wave
	Corn	Wheat	Soy	
Wave 1	1997 (20)	1996, 1997 (23)	1996, 1997 (20)	9
Wave 2	1998 (20)	1998 (23)	1998 (24)	15
Wave 3	1999, 2000, 2001 (28)	2000 (30)	1999, 2000, 2002 (22)	20
Wave 4	2005 (28)	2004 (28)	2006 (25)	23
Wave 5	2010 (28)	2009 (9)	2010 (27)	8
Total	124	113	118	75

Table 2: Summary statistics.

	N	Mean	SD	Min	Max	Median
N2O (million t CO2eq)	75	6.49	4.66	1.22	18.52	4.41
Yield monitoring corn (%)	75	0.16	0.18	0.00	0.67	0.13
Yield monitoring wheat (%)	75	0.11	0.13	0.00	0.58	0.07
Yield monitoring soybean (%)	75	0.16	0.18	0.00	0.59	0.11
Area share corn (%)	75	0.18	0.17	0.00	0.51	0.14
Area share soybean (%)	75	0.20	0.17	0.00	0.46	0.21
Area share wheat (%)	75	0.23	0.21	0.00	0.63	0.11
Area corn (thousand acres)	75	1034.09	1441.48	5.87	5024.85	261.53
Area soybean (thousand acres)	75	1036.13	1271.09	0.00	4325.08	489.67
Area wheat (thousand acres)	75	820.94	913.91	7.69	3655.66	416.83
Production corn (million bushels)	75	363.46	540.25	1.97	2152.33	75.32
Production soybean (million bushels)	75	104.73	144.24	0.00	510.80	39.65
Production wheat (million bushels)	75	81.04	77.16	1.00	344.70	57.60

Sources: Own production, based on data from USDA and EPA.

3.5 Results

The estimation results are displayed in Table 3. The orders of magnitude are discussed in the upcoming subsection. Robustness checks are provided in the appendix⁸ and indicate that signs and orders of magnitude are highly robust across all estimations.

Table 3: Regression results: N2O Emissions

	N2O em. per production		N2O em. per area	
	(1)	(2)	(3)	(4)
Yield mon. all	-0.060*** (0.009)		-0.005*** (0.001)	
Yield mon. wheat		-0.024*** (0.007)		-0.003** (0.001)
Yield mon. corn		-0.002 (0.008)		-0.003** (0.001)
Yield mon. Soy		-0.020 (0.014)		-0.004* (0.002)
Observations	75	75	75	75
R2	0.898	0.742	0.694	0.551
Grouped Fixed Effect	Yes	Yes	Yes	Yes
Joint significance p-value		0.000		0.000

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

⁸ Not included in this conference paper due to space constraints. Available from the authors upon request.

3.6 Discussion

The results suggest that increased levels of digitization in crop cultivation are associated with a decrease in the amount of nitrous oxide that is emitted per produced bushel (Table 3, Columns 1 and 2) and per area cultivated (Table 3, Columns 3 and 4), on average *ceteris paribus*. While the effects per area are about the same for all three crops under consideration, the reductions in N_2O emissions per output are largely driven by digitization in corn.

Given that all variables enter either in levels or as percentages, the economic significance can be derived straight forward from the results tables. Nitrous oxide emissions are measured as million ton CO_2 equivalents per year and digitization as the percentageshare of cultivated area under digital yield monitoring. The results suggest that a ten percentage points increase of the area cultivated with the use of digital yield monitoring is associated with a decrease of CO_2 equivalents by 500kg per acre and by 600kg per 100 bushel of output on average, *ceteris paribus*⁹.

4 Conclusion

Both increasing and decreasing effects of digitalization in crop production on GHG emissions are plausible. To understand which set of effects dominate, this empirical study applies a Group Fixed Effects estimator to a panel dataset from 28 US states over five waves from within 15 years. The results indicate that the productivity gains of digital yield monitoring in crop production reduce direct emissions of nitrous oxide per unit of output and per area cultivated.

While this study focuses on effects per output and per cultivation area, there might also be changes of total nitrous oxide emissions going together with the increasing use of digital technology. However, other dynamics that took place in parallel and that we cannot control for, such as the widespread adoption of genetically modified crops or the U.S. Renewable Fuel Standard, prevent a clear cut of associating potential increases of total nitrous oxide or aggregate greenhouse gas emissions to increases of the spread of digital technology. More research is needed here.

Given that digital yield monitoring is usually applied in combination with other digital technologies, the results of this study likely hold also for other digital technologies applied in this context and can be interpreted as a general effect of digitalization in agriculture.

Having said this, all findings apply primarily to the effects of digitalization in crop cultivation in the United States. The findings should not be uncritically generalized to other farming systems with divergent capital and/or natural resource endowments.

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⁹ Calculated as $10\% * 0.06 * 1,000,000 \text{ t } CO_2eq / 1,000,000 \text{ bushels} * 100$
and as $10\% * 0.005 * 1,000,000 \text{ t } CO_2eq / 1,000 \text{ acres}$.

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SUSTAINABLE DEVELOPMENT OF PEATLAND

OPPORTUNITY COSTS OF REWETTING AGRICULTURALLY USED ORGANIC SOILS IN GERMANY

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Abstract

Reducing GHG emissions from agriculturally used organic soils through rewetting makes current land use practices unfeasible and thereby causes costs that go beyond the technical measures of rewetting. Farmers have to forgo the profits that could be achieved with the drained use of organic soils. We estimate the opportunity costs based on a crop-type map generated with remote sensing technologies combined with standard gross margins for the short-term and tenure fees for the long term at the municipality level.

We estimate the average short-term opportunity costs of rewetting one hectare of organic soil ranging from 580 € in Brandenburg to 2.030 € in Lower Saxony. Relating the short-term opportunity costs to the GHG mitigation potential of rewetting organic soils yields mitigation costs between 20 and 68 €/t CO₂eq. This is substantially below the estimated economic welfare losses of 237 € per ton of CO₂ emitted (UBA, 2023b).

Recently introduced federal state-specific interventions for peatland protection measures under the second pillar of the “Common Agricultural Policy” (CAP) cover the average short-term opportunity costs of rewetting if combined with other CAP second pillar interventions. However, the interventions do not capture the high variability of opportunity costs within a federal state. Our results contribute to the design of region- and farm-type-specific compensation measures to make rewetting attractive to farmers. Furthermore, they are relevant for a cost-benefit analysis of rewetting agriculturally used organic soils. Finally, they can inform debates on rewetting organic soils in other EU member states.

Keywords

land use analysis, agricultural income, peatland protection measures, CAP

1 Introduction

Peatlands cover 3 to 4% of the global land area (OLSSON et al., 2019). Due to drainage, about 12% of this area is no longer naturally water-saturated (UNEP, 2022). Whenever peatlands are drained, the soil organic carbon gets decomposed, resulting in carbon dioxide emissions that account for about 5% of total global greenhouse gas (GHG) emissions (OLSSON et al., 2019).

In Germany, about 1.3 million hectares of agricultural land are located on drained organic soils (TIEMEYER et al., 2020). Although this is only 7% of the total agricultural land (DESTATIS, 2021a), it is responsible for more than 40% of the total GHG emissions from agriculture and agricultural land use (UBA, 2023a). Therefore, halting carbon decomposition processes by rewetting organic soils became important in the scientific and political discourse about reducing agricultural GHG emissions (BMUV, 2022; GRETHE et al., 2021).

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Farmers and other stakeholders currently relying on the drained use of organic soils have a critical perspective on rewetting organic soils (BUSCHMANN et al., 2020). Reasons for this include the high costs and the irreversibility of rewetting, as well as the uncertainty about the feasibility and economic viability of wet land use alternatives such as paludiculture (LATACZ-LOHMANN et al., 2019). Farmers fear losing their favored occupation or at least expect a deterioration in the current income situation (NORDT et al., 2022).

As the rewetting of organic soils only aims at raising the water table to the soil surface and not necessarily at restoring the natural conditions of a peatland, there are wet land use alternatives available that may contribute to compensate for the opportunity costs incurred. One can distinguish two economically promising types of wet land use alternatives. Rewetted peatlands could be used in paludiculture, which is characterized by the peat-conserving cultivation of plants adapted to wet conditions (WICHTMANN and JOOSTEN, 2007). A second opportunity is to build photovoltaic plants on peatlands (FAKHARIZADEHSHIRAZI and RÖSCH, 2023). Theoretically, either the profits from producing biomass in paludiculture or the profits from generating energy with photovoltaic plants have the potential to compensate for the opportunity costs associated with the termination of drainage-based land use activities (BÖHM et al., 2022; WICHMANN et al., 2022). However, neither the large-scale application of paludiculture nor the installation of photovoltaic plants on rewetted peatlands has been implemented at scale yet.

It follows, that wet land use practices currently do not provide a sufficient income alternative for farmers. As long as this is the case, additional financial transfers could increase the willingness of farmers to rewet (BUSCHMANN et al., 2020; SCHÄFER et al., 2022). Financial transfers can be provided either by the private sector in terms of purchasing carbon credits to voluntarily offset GHG emissions or by the public sector in terms of subsidies paid for the provision of public services (WICHMANN, 2018).

The largest public agricultural funding instrument in the European Union is the “Common Agricultural Policy” (CAP) (Regulation (EU) 2021/2115). Interventions intended to compensate for income losses resulting from the rewetting of organic soils are implemented under the second pillar of the CAP (EL-0101-03/-04) and are paid annually. Such payments are often accompanied by one-off payments covering initial investment costs (PABST et al., 2018; BMEL, 2023). In addition to the second pillar interventions of the CAP the “European Regional Development Fund” is used to cofinance investments in peatland protection measures (WICHMANN, 2018). In the coming years, the German “Action Program for Natural Climate Protection” (Aktionsprogramm Natürlicher Klimaschutz) will become an important national instrument to finance costs related to peatland protection measures (BMUV, 2023).

Determining appropriate levels of income compensation requires knowledge of the opportunity costs of rewetting and, thus, of the current use and profitability of drained organic soils. Abandoning drainage-based land use on organic soils affects crops that are directly marketed (e.g., wheat) and forage crops (grassland, silage maize) predominantly used to feed the farm’s own livestock. If losses in forage areas cannot be compensated by exceeding the roughage production elsewhere, farmers are forced to reduce the number of ruminants kept (SCHALLER, 2014). This is particularly the case in regions with a high share of organic soils in the total agricultural area (KRIMLY et al., 2014). Consequently, the opportunity costs of forage areas are related to the income generated with ruminants dependent on the roughage from the rewetted area, while the opportunity costs of land cultivated with marketable crop types solely depend on the income generated with these crop types.

Shortly after rewetting, and thus after abandoning drainage-based land use activities, the opportunity costs exceed the foregone income. This is because not all of the cost components can be eliminated immediately (RÖDER and OSTERBURG, 2012). Fixed costs (e.g., machinery, employees, buildings) do not directly depend on the scope and intensity of production processes

and cannot be eliminated immediately after the discontinuation of a production process. It follows that the foregone gross margins (revenues minus variable costs) can be taken as an indicator of the short-term opportunity costs. In contrast, the foregone profits (revenues minus all costs, including family owned labor and capital which may be used in other activities) indicate the long-term opportunity costs of rewetting organic soils (RÖDER and OSTERBURG, 2012). We use current tenure fees as a proxy for these profits.

Our study aims to enhance the knowledge about the agricultural use of peatlands and the opportunity costs of rewetting organic soils at the municipality, county, and federal state levels in Germany. Our analysis builds upon previous studies that determined opportunity costs either based on data with a lower spatial resolution (KOPPENSTEINER et al., 2023; RÖDER and GRÜTZMACHER, 2012; RÖDER and OSTERBURG, 2012) or only for selected regions of Germany (KRIMLY et al., 2014; SCHALLER, 2014). Our results contribute to the current discourse about potential areas for peatland protection measures. Furthermore, we provide data to determine appropriate levels of income compensation that economically incentivize farmers to rewet their land. In this context, we compare our results with the corresponding CAP interventions and derive conclusions for future interventions.

2 Material and methods

2.1 Research area

We analyze the whole area of organic soils according to the German definition (TIEMEYER et al., 2020; UBA, 2023a). Organic soils consist of the soil types peatland (soil organic matter (dry mass) $\geq 30\%$, thickness ≥ 30 cm) and peaty soil (soil organic matter (dry mass) $\geq 15\%$, thickness 10 - 40 cm (Ad-hoc-AG Boden et al., 2005)). TEGETMEYER et al. (2021) compiled a map according to this definition of organic soils for the whole of Germany (in the following: *organic soil map*). Since only 73% of all organic soils are agriculturally used (TIEMEYER et al., 2020), forests, shrublands, settlements, and other non-agricultural land use categories located on organic soils are excluded from the analysis.

2.2 Land use analysis

Estimating the opportunity costs of rewetting organic soils requires detailed knowledge of their current use, as the profitability depends on the land use that is to be abandoned. The site-specific identification of land use has been a major obstacle in the past (KOPPENSTEINER et al., 2023; RÖDER and OSTERBURG, 2012; WICHMANN et al., 2022). The data either has a limited differentiation of crop types (“Digital Basic Landscape Model”, major land use categories), a low spatial resolution (“Agricultural Census”, county level is the highest spatial resolution) or is difficult to access (“Integrated Administration and Control System”, strict data protection requirements).

The working group THÜNEN EARTH OBSERVATION (2023) overcomes these limitations: Based on remote sensing technologies, BLICKENDÖRFER et al. (2022) have developed a method to create raster maps depicting cultivated crop types at a site-specific spatial resolution with an overall accuracy of about 80%. TETTEH et al. (2021) developed a method to delineate the field boundaries using majority voting to identify the most likely crop cover from the raster map and to further increase the accuracy. The result is a *parcel-based vector crop type map* (in the following: *crop type map*) that depicts a single crop type for each field. Our analysis is carried out using the crop type map for the year 2020. Interannual variations due to crop rotations are expected to balance out on average.

In addition to analyzing the cultivated crop types, ruminant husbandry is highly dependent on regional forage areas and therefore included in the analysis. The *crop type map* does not provide information about livestock densities nor distinguishes between cereal and silage maize. Infor-

mation to estimate these parameters is taken from THÜNEN AGRARATLAS (2022). The *agricultural atlas* depicts harmonized estimations of land use and livestock densities at the municipality level (GOCHT and RÖDER, 2014). When estimating the number of ruminants dependent on forage from organic soils, information about the share of silage maize used as a forage crop and silage maize used as a fermentation substrate for biogas plants is required. This information is taken from the “German Maize Committee” which annually commissions surveys (c. 2.000 surveyed farms) to estimate the shares of biogas and forage maize at the federal state level (KYNETEC, unpublished).

The *organic soil map*, the *crop type map*, and the *agricultural atlas* are merged and analyzed in ArcGIS ArcMap 10.8.2. This produces a dataset with information on the crop type cultivated on each parcel located on organic soils and the municipality in which each parcel is located. Each parcel indicated by the *crop type map* as being cultivated with maize is divided by the municipality-specific share of silage and cereal maize given in the *agricultural atlas*. The fraction of silage maize is further divided based on its intended use, taking into account the federal state-specific shares of biogas and forage maize obtained from KYNETEC (unpublished).

To allocate the number of ruminants kept in a municipality (*agricultural atlas*) to its forage area, the average net energy yield of the different forage crop types is considered. For this purpose, a total fictive net energy yield of all forage areas within a municipality is determined by multiplying the area of each forage crop type (*agricultural atlas*) by the corresponding average net energy yield per hectare (DILGER and FAULHABER, 2006). In the second step, the total number of ruminants, categorized by ruminant type, kept within the municipality (*agricultural atlas*) is divided by the total fictive net energy yield. The result is a municipality-specific number of ruminants, categorized by ruminant type, fed with one fictive energy unit. This number is multiplied by the fictive net energy yield of each forage parcel located on organic soils and gives the number of ruminants, categorized by ruminant type, dependent on roughage from the parcel. The land use data obtained at the parcel level is aggregated to higher regional levels.

2.3 Short-term opportunity cost analysis

The short-term opportunity costs of abandoning drainage-based land use activities on organic soils are determined based on the land use data generated at the municipality level (chapter 2.2) and the crop type and ruminant type specific standard gross margins published by KTBL (2023) at the administrative district level (NUTS 2) and averaged over five years (2016/17 – 2020/21). Standard gross margins are based on product-related revenues and exclude decoupled subsidies (SAUER and HARDEWEG, 2019). This is in line with the recent CAP regulation, whereby organic soils retain their general subsidy eligibility if they are rewetted and used with wet land use alternatives (Regulation (EU) 2021/2115).

The short-term opportunity costs of rewetting a parcel previously cultivated with a certain crop type equal the standard gross margin that could be earned with this crop type. Consequently, the average short-term opportunity costs of rewetting are a weighted combination of all the standard gross margins corresponding to the crops that are to be abandoned. This approach neglects the possibility of farms adjusting their production program. This leads to an overestimation of the short-term opportunity costs, as farmers could adjust their production programs in order to maintain the most profitable production activities. However, this approach circumvents the need for farm individual data (KRIMLY et al., 2014).

To account for the different degrees to which ruminant husbandry is affected by rewetting, a range of short-term opportunity costs is given. The lower boundary of short-term opportunity costs assumes that the rewetting of forage areas has no impact on ruminant husbandry. Forage areas are treated as surplus forage areas. The standard gross margins for surplus forage areas provided by KTBL (2023) are applied. The upper boundary assumes that losses in the forage area cannot be compensated at all. In this case, the short-term opportunity costs of a forage area

equal the sum of the standard gross margins that could be earned with the ruminants assigned to that area (SCHALLER, 2014).

2.4 Long-term opportunity cost analysis

The long-term opportunity costs of rewetting agriculturally used organic soils are estimated based on tenure fees provided by DESTATIS (2021b). This follows the approaches of RÖDER and OSTERBURG (2012) and SCHALLER (2014). DESTATIS (2021b) distinguishes the tenure fees by the land use categories arable land, permanent grassland, and other agricultural areas at the federal state level for 2020. Regional differences, which undoubtedly exist, cannot be adequately reflected in this. However, a more detailed spatial resolution that distinguishes between land use categories is not available for all federal states. The tenure fees are weighted based on each land use category's share in the total productive agriculturally used area on organic soils at the municipality level.

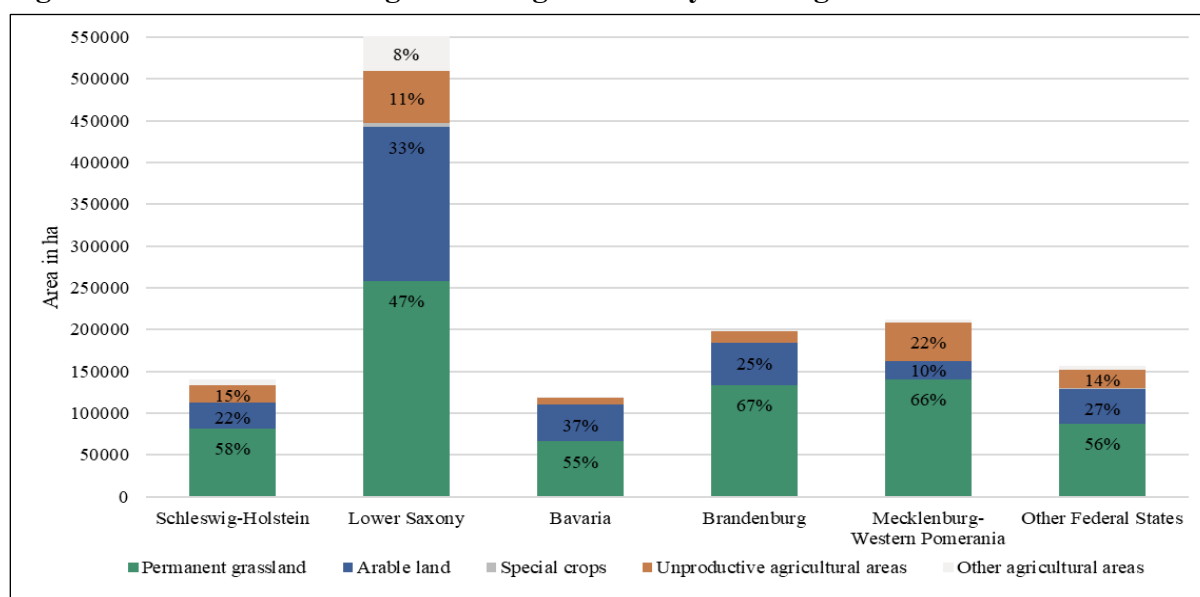
3 Results

3.1 Agricultural land use of organic soils

To place the results about the agricultural use of organic soils in context, they are compared with the agricultural land use on all soils (mineral and organic). The reference data for this comparison is taken from the Agricultural Census 2020 (DESTATIS, 2021a; THÜNEN AGRARATLAS, 2022). Organic soils are unequally distributed among the German federal states. Almost 90% of the organic soils are located in five out of 16 federal states: Lower Saxony (40% of total agriculturally used organic soils), Mecklenburg-Western Pomerania (15%), Brandenburg (14%), Schleswig-Holstein (10%), and Bavaria (9%).

Agriculturally used organic soils can be divided into five land use categories (Figure 1). Permanent grassland covers two-thirds of the productive agricultural area. Arable land and special crops account for the other third. This is in contrast to the total agricultural area in Germany, where permanent grassland accounts for less than one third of total agricultural land.

Figure 1: Land use categories on agriculturally used organic soils



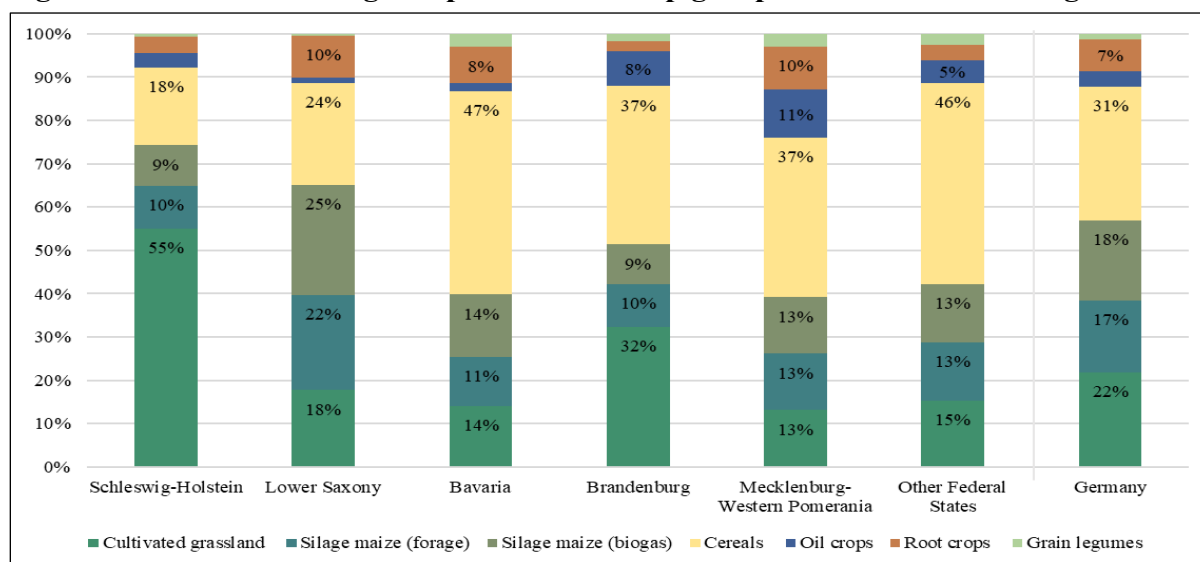
Source: Own illustration and calculations, based on DESTATIS, 2021a; TEGETMEYER et al., 2021; THÜNEN EARTH OBSERVATION, 2023.

In addition to the large proportion of permanent grassland used for roughage production, the arable land on organic soils is also predominantly used to cultivate arable forage crops (57%, Figure 2). Cereals are the main crop group with the second-largest share of arable land located

on organic soils (31%). The remaining 12% is split between the main crop groups of root crops (7,5%), oil crops (3,5%), and grain legumes (1%).

In Figure 2, the main crop group of arable forage crops is divided by its crop types and by the use of silage maize. This differentiation allows to exclude the silage maize cultivated for biogas production from the forage area used to produce roughage for ruminant husbandry (real forage area: permanent grassland, cultivated grassland, silage maize (forage)).

Figure 2: Arable forage crops and main crop groups of arable land on organic soils

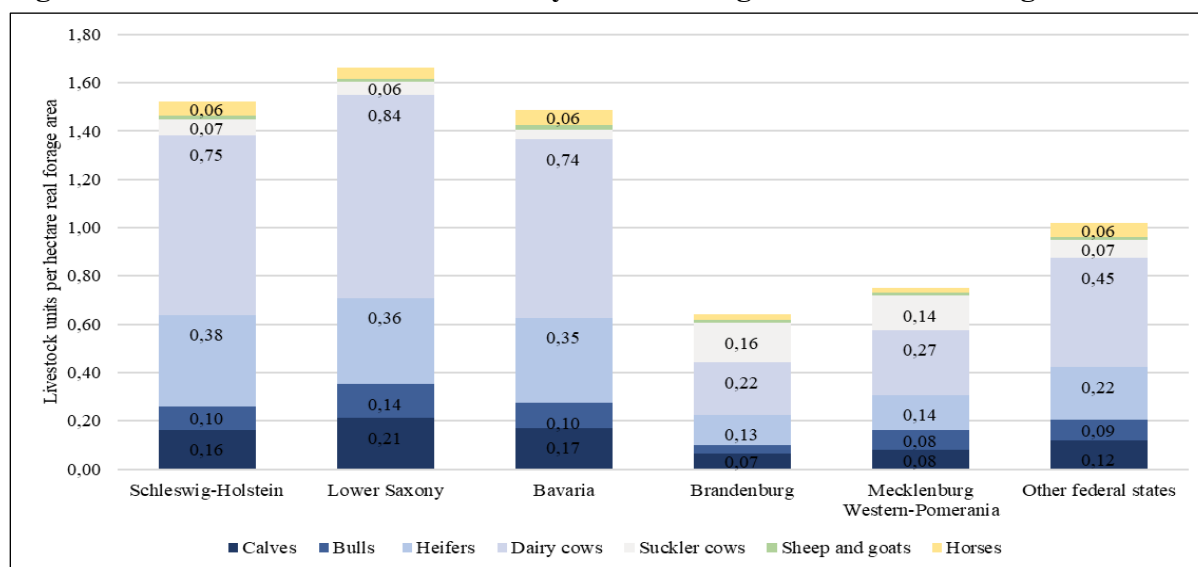


Source: Own illustration and calculations, based on KYNETEC, unpublished; TEGETMEYER et al., 2021; THÜNEN AGRARATLAS, 2022; THÜNEN EARTH OBSERVATION, 2023.

3.2 Ruminant husbandry on organic soils

Forage crops (excl. biogas maize) are cultivated on 80% of all productive agriculturally used organic soils in Germany. Approximately 13% of all ruminants in Germany, are fed with roughage from organic soils. Lower Saxony is the federal state with the most ruminants dependent on roughage from organic soils and with the highest ruminant livestock density per hectare of real forage area on organic soils (1,66 LU/ha, Figure 3). Similar livestock densities can be observed in Schleswig-Holstein and Bavaria. Ruminant husbandry in Brandenburg and Mecklenburg-Western Pomerania is characterized by low livestock densities and a high share of suckler cows.

Figure 3: Ruminant livestock density on real forage area located on organic soils



Source: Own illustration and calculations, based on KYNETEC, unpublished; TEGETMEYER et al., 2021; THÜNEN AGRARATLAS, 2022; THÜNEN EARTH OBSERVATION, 2023.

3.3 Average opportunity costs of rewetting agriculturally used organic soils

The average short-term opportunity costs vary between 190 and 2.142 €/ha*a (Table 1). The overall average of short-term opportunity costs (upper boundary) amounts to 1.457 €/ha*a. Within the same region, rewetting permanent grassland typically results in lower short-term opportunity costs than rewetting arable land. This is due to low market prices paid for surplus roughage (KTBL, 2023) and lower livestock densities compared to arable forage areas. Furthermore, certain marketable crops (e.g., potatoes) generate higher standard gross margins per hectare than ruminant husbandry. In the German average, the short-term opportunity costs (upper boundary) of rewetting a hectare of arable land amount to 1.651 €/ha*a. This exceeds the short-term opportunity costs of rewetting permanent grassland by about 500 €/ha*a.

Regardless of the crop type aggregation considered, the average short-term opportunity costs of Schleswig-Holstein, Lower Saxony, and Bavaria are substantially higher than those of Brandenburg and Mecklenburg-Western Pomerania. One reason is the higher ruminant livestock density. Furthermore, dairy cows generating high standard gross margins are the dominant ruminant type. Another reason is the generally higher soil productivity of land in the western and southern federal states, which is reflected by higher standard gross margins per crop type as well as higher tenure fees.

Larger proportions of arable crop types with high standard gross margins (potatoes, wheat, cereal maize) are the reason for higher short-term opportunity costs (lower boundary) of rewetting arable land in Lower Saxony and Bavaria compared to Schleswig-Holstein. The arable land on organic soils in Brandenburg is predominantly covered by crops with low standard gross margins (rye, sunflowers, cultivated grassland), while the arable land of Mecklenburg-Western Pomerania is to a larger extent covered by wheat, potatoes, and rapeseed, which are arable crop types providing comparatively high standard gross margins.

The average long-term opportunity costs amount to 341 €/ha*a for Germany as a whole. At 330 to 420 € per hectare, the opportunity costs in Lower Saxony, Schleswig-Holstein, and Bavaria are more than twice as high as in Mecklenburg-Western Pomerania and Brandenburg.

Table 1: Average opportunity costs of rewetting agriculturally used organic soils

Average opportunity costs in €/ha*a	Short-term						Long-term
	Productive agricultural area incl. special crops		Productive arable land excl. special crops		Permanent grassland		Productive agricultural area incl. special crops
	lower boundary	upper boundary	lower boundary	upper boundary	lower boundary	upper boundary	
Schleswig-Holstein	560	1.662	717	2.142	478	1.461	371
Lower Saxony	907	2.028	1.070	2.016	379	1.644	422
Bavaria	887	1.731	1.123	1.692	481	1.516	331
Brandenburg	271	578	333	647	187	492	141
Mecklenburg-Western Pomerania	307	768	855	1.262	190	659	180
Germany	646	1.457	881	1.651	318	1.156	341

Source: Own calculations based on DILGER and FAULHABER, 2006; DESTATIS, 2021b; KTBL, 2023; KYNETEC, unpublished; TEGETMEYER et al., 2021; THÜNEN AGRARATLAS, 2022; THÜNEN EARTH OBSERVATION, 2023.

Remark: Data land use: 2020, data standard gross margins: 2016-2021, data tenure fees: 2020.

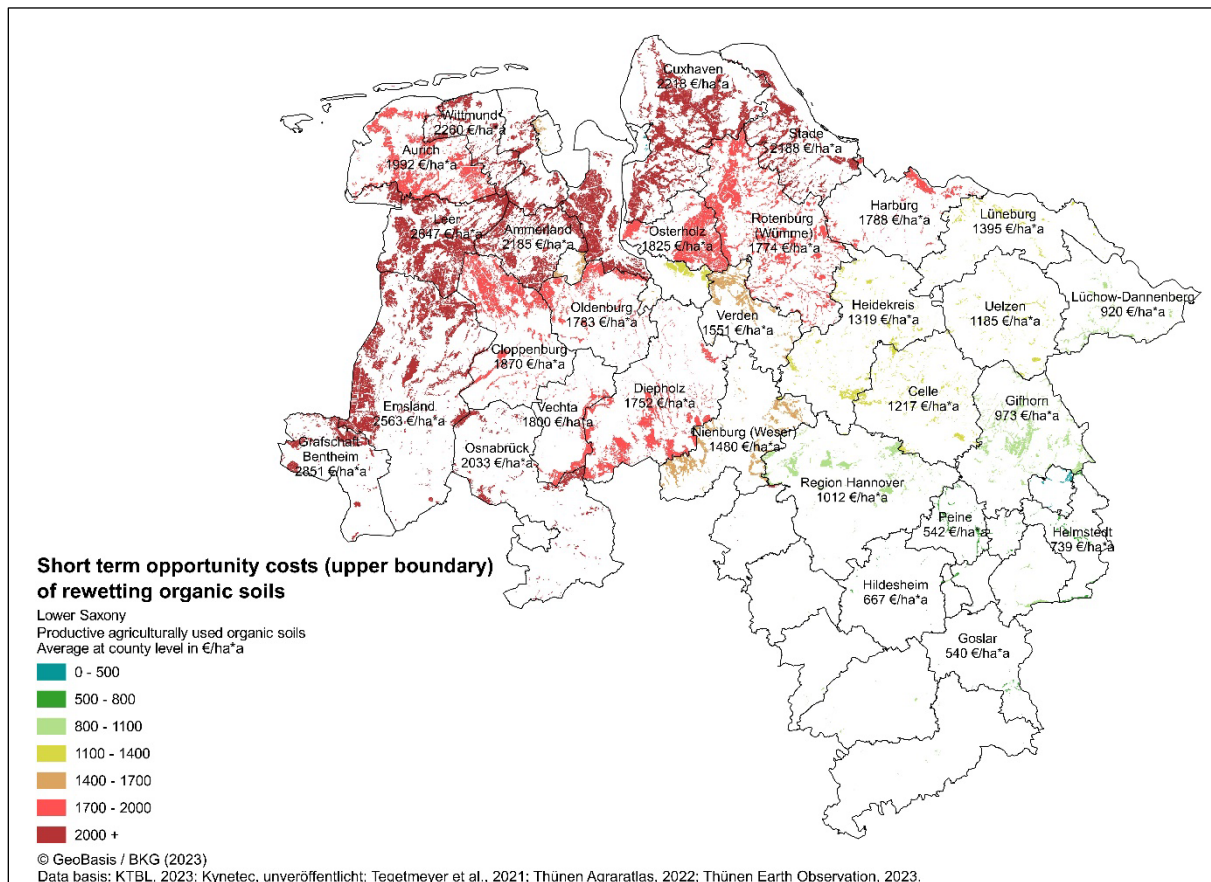
3.4 Total opportunity costs

The immediate rewetting of all agriculturally used organic soils would incur a total of between 740 million € and 1,6 billion € of short-term opportunity costs per year, depending on the necessary reductions in ruminant livestock. Annual long-term opportunity costs of about 325 million € are about half of the lower boundary of short-term opportunity costs and 20% of the upper boundary of short-term opportunity costs in Germany.

3.5 Regional differences

Differences in organic soil use and associated opportunity costs do not only occur between the federal states but also at higher spatial resolutions. The informative value of averages at the federal state level is therefore limited. Nevertheless, due to content limitations, we cannot present all of the regional differences here.

Figure 4: Short-term opportunity costs (upper boundary) of rewetting organic soils in the counties of Lower Saxony



Source: Own illustration and calculations, based on DILGER and FAULHABER, 2006; TEGETMEYER et al., 2021; THÜNEN AGRARATLAS, 2022; KTBL, 2023; THÜNEN EARTH OBSERVATION, 2023; KYNETEC, unpublished.
 Remark: crop type aggregation: productive agricultural areas incl. special crops.

In Lower Saxony, for example, there is a (north-)west to southeast gradient in the proportion of organic soils in the total agricultural area as well as in the opportunity costs (Figure 4). Organic soils in the Northwest are characterized by intensive dairy cow husbandry, resulting in average short-term opportunity costs (upper boundary) between 1.700 and 2.650 €/ha*a. Lower live-stock densities, as well as suckler cow husbandry, characterize the organic soil use in the South-east. Accordingly, short-term opportunity costs (upper boundary) are substantially lower, varying between 500 and 1.000 €/ha*a. The cultivation of cereals, and especially potatoes, is an important form of organic soil use in the western counties of Lower Saxony (Grafschaft Bentheim, Emsland). Furthermore, calf and beef fattening are the dominant forms of ruminant husbandry dependent on forage from organic soils (Emsland, Cloppenburg). Accordingly, short-term opportunity costs (upper boundary) are high (1.850 – 2.850 €/ha*a).

There is also a gradient in opportunity costs in Schleswig-Holstein and Mecklenburg-Western Pomerania. While the decreasing ruminant livestock density from west to east is the reason for lower short-term opportunity costs in the eastern counties of Schleswig-Holstein, in Mecklenburg-Western Pomerania, it is a shift in the dominant ruminant types. In the western counties, dairy cows dominate the organic soil use, in the eastern counties suckler cows dominate.

4 Discussion

4.1 Opportunity costs and GHG mitigation potential

To contextualize the opportunity costs of rewetting organic soils, we relate them to the associated GHG mitigation potential given by Tiemeyer et al. (2020) and to GHG mitigation costs

in other sectors. The European Union has established an European Emission Trading System (EU ETS), which limits GHG emissions from certain energy-intensive sectors. In 2023, the average EU ETS price was about 84 €/t CO₂eq (UBA, 2024). In the federal states rich in organic soils, the short-term opportunity costs (upper boundary) of GHG mitigation through rewetting range from 20 to 68 €/t CO₂eq (Table 2, Column 3) and are thus below the EU ETS price.

Table 2: GHG mitigation costs of rewetting productive agriculturally used organic soils

GHG mitigation costs Productive agricultural area incl. special crops	Average short-term opportunity costs (upper boundary) in €/ha*a	Average GHG mitigation potential in t CO ₂ eq/ha*a	Average GHG mitigation costs in €/t CO ₂ eq
Schleswig-Holstein	1.662	28,6	58,2
Lower Saxony	2.028	29,9	67,9
Bavaria	1.731	29,7	58,3
Brandenburg	578	28,6	20,2
Mecklenburg- Western Pomerania	768	27,4	28,0
Germany	1.457	29,1	50,1

Source: Own calculations based on DESTATIS, 2021b; DILGER and FAULHABER, 2006; KTBL, 2023; KYNETEC, unpublished; TEGETMEYER et al., 2021; THÜNEN AGRARATLAS, 2022; THÜNEN EARTH OBSERVATION, 2023; TIE-MEYER et al., 2020.

The GHG mitigation costs given for rewetting organic soils (Table 2) omit the initial costs of rewetting, including the technical and administrative measures required to raise the water table, as well as the initial costs of implementing paludiculture, if applicable. Wichmann et al. (2022) provide a rough estimate for the initial costs of rewetting (4.000 €/ha) and the implementation of paludiculture (10.000 €/ha). Assuming a payback period of 30 years and an interest rate of 3% increases the GHG mitigation costs of rewetting by about 7 €/t CO₂eq if the initial rewetting costs are considered. Implementing paludiculture increases the costs by about 18 €/t CO₂ eq. This yields a range of GHG mitigation costs between 27 and 75 €/t CO₂eq, including the initial costs of rewetting, and a range between 45 and 93 €/t CO₂eq if the implementation of paludiculture is additionally included. Thus, if the implementation of paludiculture is included, the GHG mitigation costs of the federal states with the highest short-term opportunity costs slightly exceed the current EU ETS price. This price is expected to rise up to 130 – 160 €/t CO₂eq, however, by 2030 (PAHLE et al., 2022). Furthermore, revenues from paludiculture potentially offset at least a part of the implementation and opportunity costs (SCHÄFER et al., 2022).

4.2 Short-term opportunity costs and compensating CAP second pillar interventions

The comparison with GHG abatement costs of EU ETS companies highlights the economic efficiency of rewetting organic soils. In contrast to realizable process changes in EU ETS companies, there are currently almost no profitable wet land use alternatives. In light of estimated economic welfare losses of 237 € per further ton of CO₂ emitted (UBA, 2023b), this may justify governmental support for rewetting. In the latest revision of the CAP, four out of the five federal states rich in organic soils have introduced interventions for peatland protection measures intended to economically incentivize the rewetting of organic soils by compensating for the opportunity costs incurred (EL-0101-03). To assess their incentivizing effect, the subsidy rates of the interventions are compared with the average opportunity costs of rewetting (Table 3).

Since the second pillar interventions of the CAP are designed at the federal state level, the required management commitments, the subsidy rates, as well as the ability to combine differ-

ent interventions vary (BMEL, 2023). All interventions related to organic soils require continued use of at least one annual mowing of the grown biomass. Mecklenburg-Western Pomerania and Brandenburg distinguish the subsidy rates of peatland protection measures according to the targeted water table. We focus on the highest possible target because we assume complete discontinuation of drained land use activities in our opportunity cost analysis. Where applicable, we consider the combination of interventions for the rewetting of organic soils with interventions for the extensification of permanent grassland since the rewetting of grassland necessarily comes at the expense of extensifying its use. If not indicated, interventions have a commitment period of five years.

Table 3: Average short-term opportunity costs of rewetting agriculturally used organic soils and compensating CAP second pillar interventions

Federal State	Intervention	Subsidy rate	Short-term opportunity costs	
			Lower boundary	Upper boundary
Lower Saxony	Permanent grassland Targeted minimal water table: 20 cm below surface, + Sustainable use of permanent grassland Sum	536 €/ha + 453 €/ha = 989 €/ha	379 €/ha	1.644 €/ha
	Arable land Targeted minimal water table: 20 cm below surface, + Conversion of arable land to permanent grassland (7 years) Sum	536 €/ha + 2.569 €/ha = 3.105 €/ha	1.070 €/ha	2.016 €/ha
Bavaria	Permanent grassland Targeted minimal water table: 20 cm below surface (12 years) + Sustainable use of permanent grassland Sum	900 €/ha + 125 €/ha = 1.025 €/ha	481 €/ha	1.516 €/ha
	Arable land Cultivation of paludiculture (12 years) OR targeted minimal water table: 20 cm below surface (12 y) + Conversion of arable land to permanent grassland Sum (average over 12 years)	= 2.200 €/ha 900 €/ha 3.300 €/ha = 2.275 €/ha	1.123 €/ha 1.123 €/ha	1.692 €/ha 1.692 €/ha
Brandenburg	Permanent grassland Targeted minimal water table: 10 cm below surface + Targeted minimal water table in winter half-year: at surface + Sustainable use of permanent grassland Sum	199 €/ha + 48 €/ha + 165 €/ha = 412 €/ha	187 €/ha	492 €/ha
	Arable land Cultivation of paludiculture Sum	= 350 €/ha	333 €/ha	647 €/ha
Mecklenburg-Western Pomerania	Permanent grassland Targeted minimal water table: 10 cm below surface + Sustainable use of permanent grassland Sum	450 €/ha + 190 €/ha = 640 €/ha	190 €/ha	659 €/ha
	Arable land Targeted minimal water table: 10 cm below surface + Cultivation of paludiculture Sum OR Targeted minimal water table: 10 cm below surface + Conversion of arable land to permanent grassland Sum	450 €/ha + 450 €/ha = 900 €/ha 450 €/ha + 1.300 €/ha = 1.750 €/ha	855 €/ha 855 €/ha	1.266 €/ha 1.266 €/ha

Source interventions: Own composition based on BMEL, 2023; LM M-V, 2022; ML NIEDERSACHSEN, 2023; MLUK BRANDENBURG, 2023b; MLUK BRANDENBURG, 2023c; STMELF BAYERN, 2024.

Source opportunity costs: Own calculations based on DESTATIS, 2021b; DILGER and FAULHABER, 2006; KTBL, 2023; KYNETEC, unpublished; TEGETMEYER et al., 2021; THÜNEN AGRARATLAS, 2022; THÜNEN EARTH OBSERVATION, 2023. Remark: Crop type aggregations: permanent grassland, productive arable land excl. special crops.

All interventions compensate for at least the lower boundary of short-term opportunity costs, with a few even compensating for the upper boundary. However, the short duration of the interventions results in a low planning horizon, which remains a major obstacle (Nordt et al., 2022), that only Bavaria addresses with commitment periods of 12 years. Another obstacle is the subsidies paid for the drainage-based use of organic soils, which we have not considered in our analysis. Regarding the first pillar interventions of the CAP, it could be argued that these payments will continue even after a field is rewetted and, therefore, have no impact on our results (Regulation (EU) 2021/2115). In contrast, second pillar interventions subsidizing sustainability measures on drained organic soils may not be continuable in case of rewetting and therefore reduce the incentive effect of interventions for peatland protection measures.

In conclusion, the interventions that are already in place can provide a real incentive for rewetting if the commitment period is extended, if they are accompanied by sufficient programs

to cover the initial costs of rewetting, and if counter-incentive subsidies are phased out. Additionally, funding for innovative land use alternatives, such as planted paludiculture, requires higher subsidies.

5 Conclusion and Outlook

With our analysis, we provide an overview of the diverse agricultural use of organic soils in Germany. Differences can be observed between federal states as well as the counties and municipalities within a federal state. Our land use analysis increases the accuracy of previous national organic soil use analyses because it captures differences in cultivation patterns at the field level. Nevertheless, uncertainties remain regarding the determination of ruminant livestock dependent on forage from organic soils. The inclusion of remote sensing data depicting the intensity of grassland use may address this issue (SCHWIEDER et al., 2022).

Based on the results of our land use analysis, we have derived the opportunity costs of discontinuing drainage-based agricultural activities on organic soils when rewetting them. From an economic efficiency perspective, it is advisable to rewet large parts of the organic soils because the average costs per ton of carbon dioxide equivalent mitigated are below or at most around the GHG mitigation costs of other sectors, e.g., EU ETS industries.

We provide a lower and an upper boundary of short-term opportunity costs. The range between both values is relatively wide. The range could be narrowed if the opportunities for adaptation in case of rewetting are further investigated. Since it seems to be impossible to conduct this at the farm level in national analyses, it might be a first step to analyze the relation between the proportion of organic soils in the total area farmed and the ability of farms to shift their production programs with the highest profitability to unaffected areas (KRIMLY et al., 2014).

Regarding rewetting premiums under the CAP, it's unclear to what extent farmers will accept the new programs. Our analysis shows that the planned compensation payments are close to the average short-term opportunity costs calculated in this study. However, providing financial compensation is often not enough to accept a program. Other factors, such as the right of farmers to dispose of their land, legal aspects, and land owner structure, can hinder the success of these programs. These factors can lead to low uptake rates, as seen in the past for short rotation coppice. In addition, area-based payments with premiums determined at the federal state level are unlikely to reflect the heterogeneity of opportunity costs incurred in different regions of a federal state. They can lead to loss of effectiveness and generate windfall profits when predominantly the least productive organic soils, often characterized by comparatively high water tables, are rewetted. This lowers GHG mitigation and increases mitigation costs. In this context, premiums per ton of carbon dioxide equivalent mitigated could increase the economic efficiency of money spent (SCHÄFER et al., 2022). To apply such a system, an assessment framework is needed to determine the GHG mitigation potential of rewetting on a per-ton basis.

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NATURE SANCTUARY, AGRICULTURAL PRODUCTION SITE OR OPPORTUNITIES FROM INNOVATIVE LAND USE? HOW POLITICAL ACTORS FRAME THE FUTURE USE OF GERMAN PEATLANDS

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Abstract

Drained peatlands are a major source of agricultural greenhouse gas emissions in Germany. To eliminate a large proportion of these emissions, they need to be rewetted, which requires substantial change in land use. Respective plans are causing conflict between stakeholders and are subject of a political debate. This article analyses frames in the debate on the future use of currently drained peatlands in Germany by studying public textual communications from political stakeholders between 2019 and 2022. Three main frames are identified: (1) an environmental frame, emphasising environmental protection, which is most commonly used by environmental interest groups, the government and in party communication; (2) an entrepreneurial frame, portraying farmers as change makers, which is mainly used by a landscape management association, but also in government communication; (3) a socio-economic threat frame, which perceives farmers as threatened by peatland rewetting policies, and which is mainly present in farmers' associations. While the environmental and socio-economic threat frames assign land users a passive role in the transformation process, the entrepreneurial frame portrays land users as agents of change and stresses the opportunities resulting from innovations in land use. These findings can inform policy making and help to improve communication on the future use of peatland.

Keywords

Frame analysis, peatland rewetting, policy debate, land-use conflict.

1 Introduction

In Germany, peatlands cover 1.8 Million hectares of land and account for 5 % of Germany's total land area (UBA, 2023; DESTATIS, 2022). The ability to accumulate and store carbon when they have high water levels makes peatlands large carbon sinks. When peatlands are drained, they become a source of greenhouse gas (GHG) emissions, because the organic material decomposes and carbon dioxide is released (JOOSTEN et al., 2016; LIMPENS et al., 2008). Over 70% of Germanys peatland is used and drained for agricultural production (UBA, 2023). GHG emissions from these peatlands account for more than 40 % of total GHG emissions from agriculture (including agricultural land use) and for about 5 % of all GHG emissions in Germany (UBA, 2023). This makes them increasingly relevant in the political debate on GHG mitigation in Germany (EWERT and ABEL, 2021), which has also manifested in recent policy-making (e.g., National Peatland Protection Strategy, Action Programme for Natural Climate Protection) (BMU, 2021; BMUV, 2022a, 2022b).

As peatlands have both high economic and environmental value, and often these are in trade-off with each other, their future use involves land use conflicts (CHAPMAN et al., 2003). Rewetting peatlands requires a drastic change in the way the land is used, as current agricultural production methods in Germany cannot be continued under wet conditions (GRETHE et al.,

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2021: 71; SCHALLER, 2014: 30). Any future use of rewetted peatlands for agriculture would require new production methods and products, including new post-harvest value chains. Such wet production alternatives are summarised under the term paludiculture. Currently, farmers who are willing to change their production methods to paludiculture face various economic risks such as lack of value chains and lack of experience (SCHALLER, 2014: 30). As a result, a policy debate has developed about the feasibility of peatland rewetting³ for reducing agricultural GHG emissions and how rewetted peatland can be used in an economically viable way.

Although there are many studies on land-use conflicts (FISCHER and MARSHALL, 2010; KAUFMAN and SMITH, 1999; PINTO-CORREIA et al., 2019) and also some on peatland-use conflicts in particular (O'RIORDAN et al., 2015; ZIMMERMANN et al., 2022), there is a lack of understanding about the specifics of the debate around agriculturally used peatlands.

Against this background, this paper seeks to better understand the positions of actors in the political debate in order to support a successful transition towards sustainable peatland use by addressing the following research question: How do political actors frame the future use⁴ of currently drained agricultural peatlands in the German national debate? To answer this question, a qualitative content analysis was carried out informed by frame theory. Based on this, the debate is structured and the implications of the identified frames are discussed and contextualised.

SCHÖN and REIN (1991: 262) found that actors construct the problems in a policy controversy through a particular lens, a frame, “in which facts, values, theories and interests are integrated”. So how actors frame a debate tells us something about their interpretation of the issue. We used their following definition for the term ‘frame’: “A frame is a perspective from which an amorphous, ill-defined problematic situation can be made sense of and acted upon” (SCHÖN and REIN, 1991: 263).

Frame theory is useful as words not only describe reality, they can also shape reality which makes it interesting to look at the meaning and the context of what is being said or written (HAJER, 2019: 433–434). Often, this meaning is not explicitly apparent and rather needs to be extracted by the researcher from an implicit context and narrative (WAGENAAR, 2015: 18). Identifying frames in a content analysis has the potential to make messages visible that most people would pick up, consciously or unconsciously, but that cannot be identified by only analysing the stated facts and figures (ENTMAN, 1993: 57).

The frames identified can be part of the foundation on which conflict can be reduced. When actors in a policy debate become aware of their own and other actors’ frames, they are engaging in what SCHÖN and REIN (1994) call ‘frame reflection’. Understanding frames in a land-use conflict can be useful because frames influence and inform the perceptions of conflicting parties which reduces their motivation to inform themselves in the situation specifics (KAUFMAN and SMITH, 1999). When frames are applied to different sets of situations, a poor fit may result in solutions that do not address the real demands and conditions (KAUFMAN and SMITH, 1999: p. 166). This mismatch can lead to non-optimal solutions in a conflict. Therefore, understanding frames that are used gives stakeholders an opportunity to reflect on and adjust their own frames, increase the quality of their decisions and find better solutions.

As a result of frame reflection, reframing can occur, which is an act of alternation in which existing frames are adapted, extended or mixed to form a new frame (KAUFMAN and SMITH,

3 In the material analysed, the terms peatland *protection* and *rewetting* are not clearly distinguished from each other. We use the term rewetting as it is the central measure for protecting soil organic matter in order to reduce GHG-emissions. Other dimensions of protection may include biodiversity and landscape water management.

4 In this paper the term *peatland use* refers to all types of use, including recreation and nature conservation, unless otherwise specified. This definition is particularly important with regard to the research question and title. However, the focus of this paper is not on intact peatlands, but rather on agriculturally used peatlands, where drainage and ‘dry’ cultivation methods reduce the carbon content, resulting in significant CO₂ emissions.

1999; SCHÖN and REIN, 1994). It has the potential to resolve policy debates, but it might also have the opposite (e.g., reinforce a stalemate) or other effects (SCHÖN and REIN, 1994).

Land management disputes have been studied through the lens of frames (DELSHAD and RAYMOND, 2013; FISCHER and MARSHALL, 2010; KAUFMAN and SMITH, 1999; ZIMMERMANN et al., 2022) and other analytical concepts such as discourse analysis (CARMENTA et al., 2017; O'RIORDAN et al., 2015; PINTO-CORREIA et al., 2019; CLARE et al., 2013) by a wide range of scholars. But only few studies have focused on the disputes on peatland use (O'RIORDAN et al., 2015; ZIMMERMANN et al., 2022). Particularly, studies with a focus on potential changes in use by rewetting to mitigate climate change are missing. This paper contributes to filling this knowledge gap and provides a better understanding of the debate, its participants and its implications. The methodological approach to gain these insights is described in the next chapter.

2 Data and methods

We conducted a qualitative content analysis after MAYRING (2000) as it provides the capability to produce systematic, intersubjectively verifiable and at the same time adequately detailed and meaningful interpretations of communication.

A number of policy documents such as the German government's National Peatland Protection Strategy or the EU's Nature Restoration Law have been a response to public debate, but more importantly they have themselves triggered a debate on peatland use and put the issue on the public political agenda. These triggers of the debate function as indicators for the identification of material for the analysis and determine the relevant time period from 2019 until 2022, with a few exceptions of documents outside this period due to their relevance to the research question. At the same time, the policy documents are also part of the political debate themselves, so some of them were included in the analysed material.

The data analysed are public textual communications (e.g., press releases, party programs, open letters and a coalition agreement) published by political actors involved in the national debate on the future use of currently drained peatlands in Germany. Document analysis makes sense, as official documents are “a site of claims to power, legitimacy and reality” (LINDLOF and TAYLOR, 2011: 232). The authors have published the documents on their websites aiming at both the general public and journalists. Actors' websites and other sources were searched using search bars and the Google search function, mainly using search terms such as ‘Moor’ and ‘Moorschutz’ to collect data. Only original publications (primary data) by actors were included. In addition, to be included, documents had to contain some form of statement or positioning by the actor, presumably with the intention of influencing the peatland debate. Material that merely described the technicalities of peatland use, for example, was excluded. 49 documents were analysed in total. This sample does not allow for quantitative generalisations about the peatland debate, but it does allow for the development of hypotheses about elements and content, as well as in-depth insights into the debate (DENScombe, 2010).

A frame analysis (REIN and SCHÖN, 1996) was applied to these documents using MAXQDA with a combination of frames derived from literature and directly from the data where the literature did not fit. This process was guided by MAYRING's (2000) step model of deductive category application, which describes an iterative coding process that moves back and forth between theory, data, and revision of codes and categories.

Germany's constitution as a federal republic with 16 states is reflected in the structure of political actors. Some actors are purely state specific, but most of the regional actors have umbrella organisations active at the national level. For the purpose of this research, the focus was on established political actors and stakeholders in the peatland and agricultural debate that are active on a national level. The actors are grouped into five categories depending on their main points of interest and organisation type: government, political parties, agricultural interest groups, environmental interest groups, and other actors (see Table 1). This grouping is based

on the assumption that actors belonging to one group use the same or similar frames (CLARE et al., 2013; COLLIER and SCOTT, 2009; NORRIS et al., 2021; PINTO-CORREIA et al., 2019) with the exception of political parties and the “other” group actors.

Table 1: Overview of actors and their used frames

Political Actor	Environmental	Benefits f. Land Users	Entrepreneurial	Socio-Economic Threat	Land User/ Owner Rights
Government					
Coalition agreement 2021	x				
Federal Ministry for Food and Agriculture (BMEL)/Klöckner				x	x
Federal Ministry for Food and Agriculture (BMEL)/Özdemir	x	x	x	x	
Federal Ministry for the Environment, Nature Conservation, Nuclear Safety (BMU)	x	x	x	x	x
Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)	x	x	x		
Political Parties					
Christlich Demokratische Union (CDU)/ Christlich-Soziale Union (CSU)			x	x	
Bündnis 90/Die Grünen	x		x		
Sozialdemokratische Partei Deutschlands (SPD)	x				
Agri Interest Groups					
Arbeitsgemeinschaft bäuerliche Landwirtschaft (AbL)			x	x	x
Bund Ökologische Lebensmittelwirtschaft (BÖLW)	x				
Deutscher Bauernverband (DBV)				x	x
Deutscher Raiffeisenverband (DRV)				x	
Environmental Interest Groups					
Bund für Umwelt und Naturschutz Deutschland (BUND)	x				
Deutscher Naturschutzring (DNR)	x	x	x		
Deutsche Umwelthilfe (DUH)	x				
Naturschutzbund (NABU)	x	x			
World Wide Fund for Nature Germany (WWF DE)	x				
Other					
Deutscher Verband für Landschaftspflege (DVL)	x		x	x	
Succow Foundation	x	x	x		

Source: author's work

3 Results

Three main frames and two subframes were observed in the data. (1) An ‘environmental frame’ with a subframe, which we call ‘benefits for land users’ (2) an ‘entrepreneurial frame’ and (3) a ‘socio-economic threat frame’ with a subframe ‘land user/owner rights’. In this chapter, we first describe each frame and subframe, and elaborate on how specific aspects are viewed under

each frame. We then give an overview of which actors and categories of actors use which frames.

3.1 The environmental frame

The environmental frame has a focus on GHG emissions and other environmental problems caused by drainage and the lack of protection of peatlands. „*Moorschutz ist als naturbasierte Lösung für wirkungsvollen Klimaschutz und zur Erreichung anderer Umweltziele wie z.B. Bio-diversitäts- und Gewässerschutz dringend nötig.*“ (DNR et al., 2021). Rewetting is emphasised as being beneficial for climate change mitigation and associated with enhanced biodiversity and contributions to other environmental protection goals. The preferred uses expressed in this frame are nature conservation and recreation, with agricultural use preferably extensive and on less valuable (for nature conservation) peatlands. Aspects that are more typical of other frames, such as the need to involve land users or to provide sufficient funding for a peatland friendly and wet peatland use, are also mentioned in this frame. However, it is distinct from the other two frames in that it does not describe land users as agents of change, as the entrepreneurial frame does, but rather assigns land users a passive role through its wording choices. The lack of defensiveness to change, which is a key element of the socio-economic threat frame, is absent from the environmental frame. What is unique to this frame is the perceived need for regulatory action on peatland rewetting and the associated expectation for policy makers to impose stricter rules on peatland use.

The benefits for land users/owners frame is a subframe of the environmental frame. It also emphasises environmental aspects but highlights the positive climate adaptation effects and other environmental benefits that peatland rewetting has for land users, in addition to climate change mitigation. Agriculture is described as not only contributing to climate change but also being affected by it, and a change in peatland use is seen as necessary if land users are to continue to use the land successfully. An example for such a positive effect of rewetting peatland that is named is that more water in the landscape resulting from rewetting also means that more water is available for agricultural production in the surroundings.

3.2 The entrepreneurial frame

Actors using the entrepreneurial frame conceptualise land users as change makers and agents who have solutions for wet production. „*Die Akteur*innen sind erste gemeinsame Schritte der Moor-Transformation gegangen und wollen nun vorangehen, um das Erarbeitete zu sichern und auszubauen.*“ (GMC and DVL, 2022). They would only need funding and institutions from policy makers to make the change possible. Land users are viewed as food but also environmental service providers (e.g., climate farmers) who get paid for those services by the public. A positive attitude towards changes in peatland use as well as farmers having agency in the process is ex- or implicitly expressed. While the need to protect the environment and, in particular, the need for climate change mitigation is also part of this frame, the main focus is on how land users can realise their potential to contribute to climate protection and what conditions they need to be able to do so.

3.3 The socio-economic threat frame

The socio-economic threat frame associates the rewetting of organic soils and the protection of peatlands first and foremost with increased social and economic problems for land users and society. „*Mit Blick auf die [...] Moorschutzstrategie [...] mahnt der Deutsche Bauernverband (DBV), die Wirtschafts- und Lebensperspektiven von Landwirten und Bürgern in Mooregebieten nicht zu gefährden.*“ (DBV, 2018). The reduced ability to make a living from land use due to increased environmental restrictions is presented as an existential threat to land users, as is the

perceived inability to pass on the generational heritage of the farm to the next generation. Alternative uses such as paludiculture are not considered as promising business opportunities. A defensive attitude towards changes in peatland use is explicitly or implicitly expressed, and the importance of land user participation in a transformation process is emphasised, but with the explicit expectation that policy makers should provide solutions for future peatland use. Reference is made to the historic labour-intensive drainage of peatlands, and it is argued that this was an achievement demanded by society in the past. The argument is that today's farmers are the descendants of those who did the draining and should not be disadvantaged or penalised because of their history. Furthermore, rewetting peatland is mentioned in terms of threatening food security for society at large and worsening the living conditions of the rural population.

The land users rights frame is a subframe of the socio-economic threat frame. It also emphasises socio-economic concerns, but with reference to the property rights of land users and owners. Concerns are raised about mandatory rewetting of peatlands and the need for conservation measures to be strictly voluntary is expressed. It also includes the viewpoint that neighbouring landowners and users should not be negatively affected by peatland rewetting.

3.4 The use of frames in the debate by stakeholders

Table 1 provides an overview of which frames were observed in the documents of different stakeholders. Their relative importance, though, strongly varies. The environmental frame, for instance, could be identified in the majority of documents, but environmental actors almost exclusively used this frame. In the documents of the Succow Stiftung and the government, the environmental frame is also the most prominent one, but these actors' documents are less consistent in the use of frames. Political parties show a wide variety of frames with differences between parties, but overall they use both the environmental and the entrepreneurial frame most often in their communication. The Deutscher Verband für Landschaftspflege (DVL) is the only actor, which predominantly uses the entrepreneurial frame.

Government documents are the only documents with text segments fitting more than one frame. In total, ten text segments in the respective group of documents were coded with more than one frame (e.g., environmental frame plus entrepreneurial frame). The main frame used by agricultural interest groups is the socio-economic threat frame. Yet, not every actor in this category strictly adheres to this frame (Table 1). For example, the BÖLW uses the environmental frame too and the AbL uses both the entrepreneurial and the socio-economic threat frame.

The results suggest that actors in certain actor groups, such as environmental and agricultural interest groups, tend to frame similarly. At the same time, there are exceptions within groups and in many documents, more than one frame was found.

4 Discussion

4.1 The environmental frame

The environmental frame, being the most used and widespread frame in our analysis, can also be found in other land-use conflicts such as the biofuels debate and the peatland conflicts over turf cutting (CLARE et al., 2013; COLLIER and SCOTT, 2009; DELSHAD and RAYMOND, 2013; ZIMMERMANN et al., 2022). Elements of the environmental frame such as the demand for increasing regulation and protection efforts are also present in the policy debate on the peatland conservation network in Finland (ALBRECHT, 2018). The main reason for the current peatland debate in Germany are the GHG emissions caused by drainage, which is an environmental issue. It is therefore logical that such a frame is present in this and other environmental debates.

While the environmental frame reflects the scientifically well-researched need to rewet peatlands (JOOSTEN et al., 2016; WBAE and WBW, 2016) it falls short of a realistic vision of how a transformation process can work and what it entails. By implicitly placing land users in a

passive and subordinate position, actors using this frame display a top-down approach to environmental protection, which can foster challenges to the legitimacy of peatland rewetting. This has been highlighted by O'RIORDAN et al. (2015) in their work on power, discourse and participation in the turf cutting conflict in Ireland and also appears in this analysis in the form of the land user/owner rights subframe. In addition, a top-down approach may lead to an underestimation of the potential for environmental services and wet production methods to be developed and delivered by and with land users (O'RIORDAN et al., 2015). The benefits for land users subframe is less present in the literature.

4.1 The entrepreneurial frame

The entrepreneurial frame, or similar versions of it, can also be found in other land-use conflicts such as the climate mitigation and nature conservation land use debates in the Netherlands, analysed by NORRIS et al. (2021), and in Portugal, analysed by PINTO-CORREIA et al. (2019). Both author teams found that some stakeholders in the respective land-use conflicts see land users as stewards of the land, paid for the provision of environmental services. Emphasising this economic and environmental opportunity is also central to the entrepreneurial frame in the German debate on the future use of peatlands.

This frame presents peatland rewetting as a win-win issue. Peatland rewetting and wet production methods are seen as an opportunity for the agricultural sector to contribute to the reduction of GHG-emissions and biodiversity while remaining economically viable. It is the only one of the three frames found that highlights the knowledge and innovative capacity of land users. A corresponding narrative allows farmers to proactively participate in and shape the transformation process, rather than simply following the regulations and policies devised by government or environmental actors (O'RIORDAN et al., 2015).

4.3 The socio-economic threat frame

The socio-economic threat frame, or elements of it, can be found in much of the literature on other land-use conflicts (CLARE et al., 2013; COLLIER and SCOTT, 2009; NORRIS et al., 2021; PINTO-CORREIA et al., 2019; ZIMMERMANN et al., 2022). As an example, with its focus on the need to use peatlands economically and the rejection of regulatory protection measures, this frame is similar to what CLARE et al. (2013) found in the wetland-use conflict in Canada. In the socio-economic threat frame, the climate relevance of drained peatlands and the positive effect of rewetting on the reduction of GHG emissions is not denied. With that it shares a common basis with the other frames. However, the defensive stance on peatland rewetting and the passive role it assigns to land users and owners can complicate a constructive solution-finding process in which land users actively shape their own future and the future of peatland use (KNICKEL et al., 2009).

The land user/owner subframe is defensive and sees peatland rewetting as a threat, like the socio-economic frame, but argues not from a socio-economic perspective but rather from a landownership rights perspective. This subframe, or elements of it, have also been found by other researchers in peatland-use conflicts (ALBRECHT, 2018; NORRIS et al., 2021; O'RIORDAN et al., 2015). For example, O'RIORDAN et al. (2015) concluded that an emphasis on land user rights was encouraged by a top-down approach to peatland protection in their study of the policy process of turf cutting in Ireland. The appearance of this subframe could therefore be an indicator that a top-down approach is also present or perceived or at least assumed by certain stakeholders in the debate on the future use of peatlands in Germany. This is despite the fact that most actors regularly mention that the transformation process needs the participation of land users.

4.4 Actors and their frames

In this section we discuss how frames are used by the actor categories, we put this in the context of other literature and discuss how these insights could be used for constructive communication in the conflict. In general, our assumption that actors belonging to a category (except political parties and others) would frame similarly turned out to be correct (Table 1). However, some actors deviate from the mainstream in their category, as discussed in the following.

The distribution of frames used in documents from governmental actors comes closest to the overall distribution of frames used by all other actors combined. In the government documents analysed, many text passages contained elements of two or more frames. This points to a characteristic of government institutions in a democracy: Government actors typically combine frames in this way and use hybrid frames (FLIGSTEIN and MCADAM, 2011; REIN and SCHÖN, 1996) in their attempt to balance prevailing interests (DAVENPORT and CRONIN, 1987).

The socio-economic threat frame is predominantly used by agricultural interest groups. This is in line with the authors' *a priori* expectations and the literature (CLARE et al., 2013; NORRIS et al., 2021; PINTO-CORREIA et al., 2019). The cost of this framing is that in doing so, agricultural interest groups place themselves and their members in a position with limited ability to actively shape the future use of agricultural peatlands since they depict themselves as being dependent on government action for problem solving. This is a position rewarded by at least some success over decades of CAP subsidies and disaster funds (e.g., for extreme weather events such as droughts). Land users are accustomed to, and to some extent have come to rely on, politics to guide and buffer the economic conditions they face. This lock-in effect (COLEMAN et al., 1996: 276) is a result of the policy feedback process, i.e. the mutual influence between the content of policy (e.g., direct payments) and the process of policy making (e.g., CAP reform) (PIERSON, 1993).

As farmers are entrepreneurs, another way for them to respond to changing conditions would be to develop new business ideas and to focus their political demands, e.g. on the state to provide an enabling environment, which is represented in the entrepreneurial frame. However, this frame has not been much used by agricultural interest groups in the material analysed. A similar observation was made by PINTO-CORREIA et al. (2019) in the Portuguese Montado. They found that the 'stewardship' discourse, which shares key characteristics of the entrepreneurial frame, tends to depend on broader societal expectations of farmers rather than being commonly expressed by farmers themselves.

One key to finding common ground and working towards conflict resolution is for actors to adapt their current frames (i.e., reframing) (REIN and SCHÖN, 1996). For this to be successful, actors must first understand their own and other frames (i.e., frame reflection) (SCHÖN and REIN, 1994). Second, a reframing is required, resulting in a frame that allows for successful transformation and does not leave land users feeling disempowered and unable to participate. Such a frame would include the agency of land users as well as the climate relevance of agricultural peatlands, and combine the two to see peatlands as an opportunity for agriculture to meet increasing climate targets. Finally, building on this common ground, effective knowledge sharing and cooperation is possible.

But even if the actors in this debate find more common ground through reframing, a clear and reliable path for transformation is still needed. This is the responsibility of policymakers (CARMENTA et al., 2017). In order for peatland policies to be effective and to foster an entrepreneurial mindset, policy makers and other stakeholders need to ensure that what land users and environmental experts bring to the table is adequately taken into account and a long term strategy for rewetting is developed (GRETHE et al., 2021).

4.5 Reflection on limitations

There are limitations to the conclusions that can be drawn from the results of this research. Only a small part of the overall political debate was analysed. The frames found in the publications of national level organizations that were the subject of this research may not fully reflect the frames used by their individual members or federal state organisations. And due to the material selection criteria and the national focus, some actors (e.g. some political parties, regional actors) were excluded, even though these actors may use a different framing that potentially is important in other parts of the debate, taking place at regional level or beyond text documents.

It is also important to note that there is an imbalance in the available and published material on peatland use between the different actors. This is reflected in the material analysed, with different amounts of material between but also within the actor groups. The majority of documents analysed come from actors with a strong environmental focus

In essence, the findings of this research, particularly the three frames, should be treated as hypotheses that require further testing and research in other parts of the debate, as well as further differentiation among actors.

5 Conclusion and outlook

It has become evident that the analysed part of the debate in Germany is not simply two opposing sides with either an environmentalist or a productivist focus. Instead, there are three main frames, with subframes and overlaps within the frames used by actors in the debate. In particular, the entrepreneurial frame, which combines environmental and economic aspects, appears to be something like a potential consensus frame between the two others, the rather opposing socio-economic frame and the environmental frame.

As a common basis, all actors and interest groups engaged in this section of the debate recognise the climate relevance of drained agricultural peatlands and generally accept that rewetting will reduce emissions. All actors also agree that peatlands should continue to be used more or less productively. And most actors agree that this transformation should not and could not be done without land users having a say and being part of the process of reducing emissions from peatlands. Although, there are different views between the frames on the role of land users in the process of transforming drained peatlands to productively used, rewetted peatlands. Land user participation is also a recurring theme in other land-use conflicts analysed in the literature. However, an unexpected finding in this paper is that almost all actors highlight the importance of involving land users, not just those representing local stakeholders such as agricultural interest groups. Yet, while actors using the environmental and socio-economic threat frames express participation in terms of land users being presented with solutions or being taken along by policy makers, actors using the entrepreneurial frame present land users as proactive agents of change deriving economic opportunities resulting from innovative land use.

The findings are only a snapshot of frames that can be found in this debate and they are likely to evolve over time. In the recent past, there are indications for a process of reframing that may result in a more integrated frame comprising rewetting peatland as an opportunity for agriculture to meet increasing climate targets as well as the agency of land users and the need for wet use business cases. Several public events at regional level (e. g. LANDVOLK NIEDERSACHSEN LANDESBAUERNVERBAND E.V., 2022; TOURISTIKAGENTUR TEUFELSMOOR-WORPSWEDE-UNTERWESER E.V., 2023) sketch a path in such a direction, being supported by farmers' representatives as well as scientists and environmental stakeholders. Yet, although such a "corridor of consensus" between scientists and stakeholders has emerged more frequently in the German debate on the future of agriculture in the recent past (ZKL, 2021; KOMPETENZNETZWERK NUTZTIERHALTUNG, 2020), it has hardly been used by policy-makers to legitimise more science-based policy-making. Thus, even if a more integrated frame evolves and helps actors with different interests to find solutions, it will remain a key task for policy makers to make use of

the convergence between stakeholders and to prevent a further erosion of land users' trust in a reliable and transparent transformation path with sufficient public funding (GRETHE, 2023). Otherwise, especially land users may have few incentives to move away from the socio-economic threat frame.

Finally, the results of our analysis improve the understanding of explicit and implicit views on the future use of agricultural peatlands. This can inform policy making and facilitate communication between stakeholders and thereby contribute to a successful transformation of peatland use, while it remains the role of the government to carefully design policy frameworks, taking into account how different stakeholders have engaged in the debate and which key aspects of a potential consensus could be taken up.

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HEMMNISSE, LÖSUNGSANSÄTZE UND FINANZBEDARF FÜR DIE FÖRDERUNG VON PALUDIKULTUR

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Zusammenfassung

Die Einhaltung der deutschen und internationalen Klimaschutzziele bis 2030, 2045 und 2050 erfordert die substanzielle Reduzierung von Treibhausgas (THG)-Emissionen in allen Sektoren. Entwässerte Moorböden tragen in Deutschland trotz geringem Flächenanteil von nur 7 % der gesamten landwirtschaftlichen Nutzfläche mit einem Anteil von 44 % überproportional zu den gesamten deutschen Emissionen aus Landwirtschaft und landwirtschaftlich genutzten Böden bei. Die vollständige Wiedervernässung sämtlicher Moorböden ist daher ein flächeneffizienter Beitrag zum Klimaschutz. Während der Ausstieg aus der Entwässerung eine paradigmatische Exnovation darstellt, wird die Weiterführung der Bewirtschaftung durch torferhaltende Paludikulturen als eine vielversprechende Innovation zur Erhöhung der Umsetzungschancen angesehen.

Aus dem Ziel der THG-Neutralität sowie naturschutzfachlichen Einschränkungen wird ein theoretisches Flächenpotenzial für eine nasse Moorbodenbewirtschaftung im Umfang von etwa 1 Million Hektar abgeleitet. Darauf ausgerichtet wird der fiskalische Finanzbedarf für die Wiedervernässung sowie die Umstellung auf Paludikultur in einem Szenario „Paludi-Anreize“ berechnet. Die zielgerichtete Förderung von Paludikultur mittels finanzieller Anreizinstrumente erfordert zugleich den Abbau bestehender Hemmnisse durch regulative Ansätze und flankierende Maßnahmen.

Auf der Basis derzeitiger Kosten von Wiedervernässung und Etablierung von Paludikultur wird der fiskalische Finanzbedarf als politische Diskussionsgrundlage ermittelt. Neben Förderungen von Investitionen und unterstützenden Begleitmaßnahmen wird eine Klimaschutzprämie kalkuliert, die die Wiedervernässung der Flächen anreizen soll. Der Gesamtumfang für das Szenario „Paludi-Anreize“ liegt bei 21,2 Mrd. € (2022 – 2049), wovon fast zwei Drittel auf eine Klimaschutzprämie entfallen. Der volkswirtschaftliche Nutzen durch die Wiedervernässung übersteigt mit 67,5 Mrd. € vermiedener Klimafolgeschäden deutlich den Finanzbedarf.

Keywords

Paludikultur, Wiedervernässung, Finanzbedarf, Transformation

1 Einleitung

Organische Böden, d.h. Moorböden und andere kohlenstoffreiche Böden², nehmen in Deutschland 1,9 Mio. ha ein (5,4 % der Landfläche) und sind weitestgehend entwässert für land- und forstwirtschaftliche Nutzungen, Siedlungen und Infrastruktur sowie Torfabbau. Durch die Entwässerung wird über Jahrhunderte im Torf gespeicherter Kohlenstoff oxidiert und resultiert in THG-Emissionen in Höhe von 54 Mio. t CO₂e pro Jahr (UBA 2023). Über 70 % der Moorböden werden landwirtschaftlich genutzt, das entspricht knapp 7 % der gesamten landwirtschaftlichen Nutzfläche Deutschlands. Dieser geringe Flächenanteil trägt mit 44 % überproportional zu den gesamten deutschen Emissionen aus Landwirtschaft und landwirtschaftlich genutzten Böden

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² Im Weiteren werden die Begriffe „organische Böden“ (Moore, Moorfolgeböden, Anmoore) und „Moorböden“ synonym verwendet.

bei (UBA 2023). Durch eine großflächige Anhebung der Wasserstände genutzter Moorböden in Flur können THG-Emissionen wesentlich reduziert und ein effizienter Beitrag zu den Klimaschutzzielen geleistet werden.

Das Bundes-Klimaschutzgesetz (KSG) sieht vor, dass Deutschland bis zum Jahr 2045 treibhausgasneutral werden soll. Die im KSG festgelegten Ziele für den LULUCF-Sektor³ umfassen eine Steigerung der Senkenleistung auf – 40 Mio. t CO₂e und implizieren, dass bis 2045 weitestgehend alle Moore in Deutschland wiedervernässt sein müssen (TANNEBERGER ET AL. 2021). Bis zum Jahr 2030 sollen die Emissionen aus Moorböden um 5 Mio. t CO₂e gegenüber ca. 53 Mio. t (Stand 2019) reduziert sein (BLZV 2021). Demnach muss bis zum Jahr 2030 ein Flächenumfang von ca. 250.000 ha vernässt werden (NORDT ET AL. 2022). Um dieses Ziel zu erreichen, sind sehr ambitionierte Maßnahmen erforderlich.

Mit der Wasserstandsanhhebung in Flur ist eine Weiterführung der herkömmlichen landwirtschaftlichen Nutzung weitestgehend nicht mehr möglich. Mit einer Umstellung auf Paludikultur, d.h. der torferhaltenden Bewirtschaftung nasser und wiedervernässter Moore (WICHTMANN ET AL. 2016), können die Flächen jedoch in land- und forstwirtschaftlicher Produktion gehalten werden. Paludikultur stellt eine Alternative zur Nutzungsaufgabe vernässter Flächen dar und wird als eine von der Wissenschaft initiierte, komplexe Nachhaltigkeitsinnovation beschrieben (ZIEGLER 2020, ZIEGLER ET AL. 2021). Eine Transformation der Nutzung von Moorböden ist erforderlich, um die Klimaschutzziele zu erreichen. Diese Transformation ist eine gesellschaftliche Herausforderung, die über die betriebliche Ebene hinaus auch eine Anpassung der politischen und rechtlichen Rahmenbedingungen erfordert sowie sozio-kulturelle Traditionen und Wertvorstellungen berührt. SOMMER & FRANK (2024) betrachten den Ausstieg aus der Moorrenthwässerung auch als eine Exnovationsaufgabe, die systematische Änderungen in vier Governance-Dimensionen (Diskurs, Politikinstrumente, Akteure, Gerechtigkeit) erfordert und benennen Paludikultur als wichtigen Innovationspfad für eine sozio-technische Transformation der Moorbewirtschaftung.

Der folgende Text leistet einen Beitrag zur Diskussion der Ausgestaltung der Exnovationsgovernance und der Innovationsförderung im Bereich landwirtschaftlich genutzter Moore. Aufbauend auf dem vom Umweltbundesamt geförderten Projekt „Anreize für Paludikultur zur Umsetzung der Klimaschutzziele 2030 und 2050“ (NORDT ET AL. 2022, WICHTMANN ET AL. 2022, SCHÄFER ET AL. 2022) werden der potentielle Flächenumfang für eine Umstellung auf Paludikultur dargestellt (Kapitel 2), Hemmnisse und mögliche Lösungsansätze der Umsetzung zusammengefasst (Kapitel 3 und 4) sowie ein mögliches Szenario zur Finanzierung der Umstellung auf Paludikultur skizziert (Kapitel 5).

2 Flächenpotentiale für die Umstellung auf Paludikultur in Deutschland

Zur Erreichung der Klimaschutzziele 2045 ist eine vollständige Vernässung der Moorböden erforderlich. Ein großer Teil der vernässten Flächen kann weiterhin land- und forstwirtschaftlich genutzt werden. Die Ableitung von Flächenpotentialen für Paludikultur ist über die Betrachtung der möglichen Bewirtschaftungsverfahren und naturschutzrechtlichen Einschränkungen möglich. Anbau-Paludikulturen (Schilf, Rohrkolben, Anbaugräser, Torfmoos, Erle) werden im Unterschied zu natürlich aufwachsender Biomasse gezielt etabliert. Nasswiesen-Paludikultur ist eine Form der Grünlandnutzung mit hohen Wasserständen, wobei sich die Artenzusammensetzung des Bestands sukzessive an den Wasserstand anpasst oder bereits angepasst ist. Für Mecklenburg-Vorpommern wurden Eignungsklassen für die Umsetzung von Paludikultur anhand des vorliegenden Schutzstatus der Fläche abgeleitet (LM MV 2017, TANNEBERGER ET AL. 2020); für Schleswig-Holstein, Brandenburg und Baden-Württemberg wurde dieser Ansatz

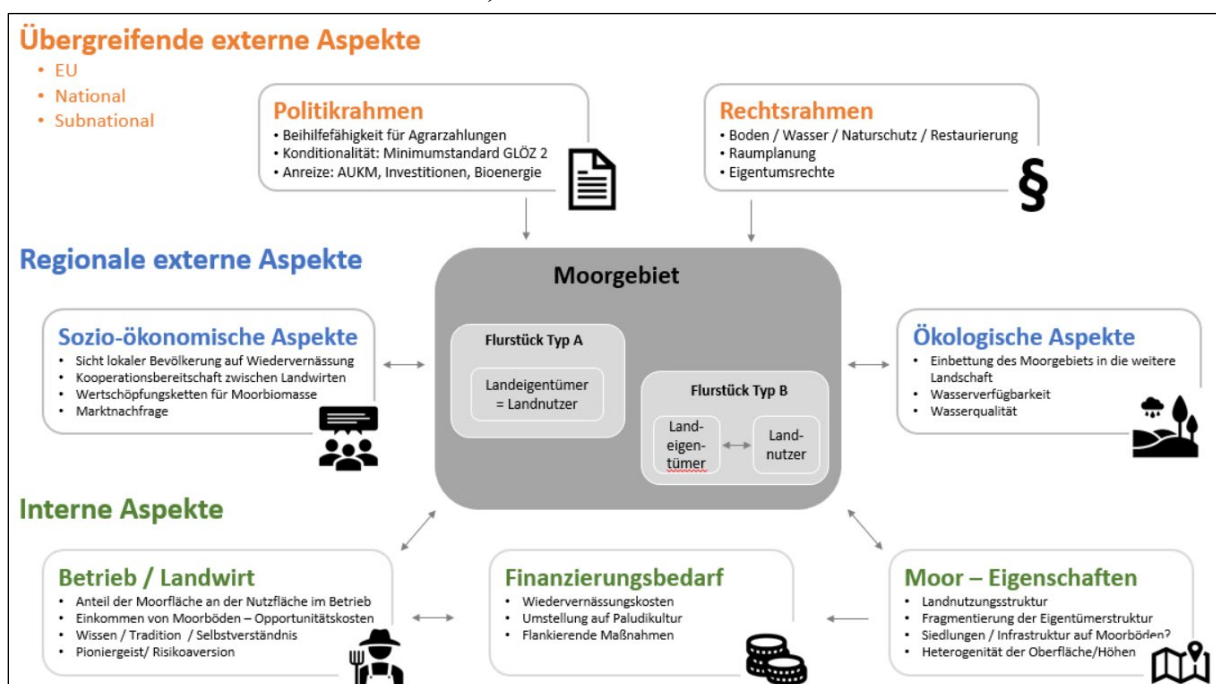
³ Land Use, Land-Use Change and Forestry (Sektor Landnutzung, Landnutzungsänderung und Forstwirtschaft)

landesspezifisch angepasst (NERGER & ZEITZ 2021). Die Bearbeitung beschränkte sich auf Niedermoorböden. Die vier Eignungsklassen sind definiert als: 1 – jede Form von Paludikultur ohne Prüfaufgabe möglich, 2 und 3 – Anbau-Paludikultur mit Prüfaufgabe und Nasswiese möglich bzw. nur Nasswiese und mit Prüfaufgabe, sowie 4 – nicht geeignet. Je nach betrachtetem Bundesland wurden der Klasse der Nicht-Eignung 0,2 % – 20 % der landwirtschaftlich genutzten (Nieder-)Moorböden zugeordnet (LM MV 2017, NERGER & ZEITZ 2021). Entsprechend kann Paludikultur aus naturschutzrechtlicher Sicht auf mindestens 80 % der analysierten Flächen umgesetzt werden. Das entspräche, übertragen auf eine deutschlandweite Kulisse landwirtschaftlich genutzter Moorböden von insgesamt 1,3 Mio. ha, etwa 1 Mio. ha Flächenpotential für Paludikultur (NORDT ET AL. 2022). Neben Paludikultur kann auch die Installation von Photovoltaik-Anlagen in Zusammenhang mit dauerhafter Wasserstandsanhhebung gemäß der Novelle des Erneuerbaren Energien Gesetzes (EEG 2023) erfolgen und landwirtschaftlichen Betrieben und Landeigentümern eine alternative Einkommensperspektive bieten.

3 Hemmnisse für die Umsetzung von Paludikultur

Die großflächige Umsetzung der klimafreundlichen Moornutzung wird durch eine Vielzahl von Hemmnissen behindert. Abbildung 1 gibt einen Überblick über das komplexe sozio-ökologische System externer und interner Aspekte, welche die Bewirtschaftung von Mooregebieten bestimmen.

Abbildung 1: Einflussfaktoren der Moorbodenbewirtschaftung (nach WICHMANN & NORDT 2024)



Neben den rechtlichen, ökonomischen und sozialen Hemmnissen gibt es darüber hinaus weitere einschränkende Faktoren wie z. B. die flächenkonkrete Wasserverfügbarkeit. Zentrale Hemmnisse umfassen folgende Bereiche, die in NORDT ET AL. (2022) ausführlich erläutert werden:

- Ein wesentliches Hindernis für die Umsetzung von Paludikultur ist die derzeitige Europäische **Gemeinsame Agrarpolitik (GAP)**. Agrarzahlen erfolgen für entwässerungsbasierte Moorbewirtschaftung. Andererseits ist die Beihilfefähigkeit von Anbau-Paludikultur im Detail ungeklärt, wodurch Landwirte und Bewilligungsbehörden verunsichert sind.

- Die bestehenden **rechtlichen Rahmenbedingungen** sind auf ein entwässerungsbasiertes Landnutzungssystem ausgerichtet und berücksichtigen bisher nicht die besondere Rolle organischer Böden, z. B. im Boden-, Wasser-, und Naturschutzrecht.
- Auf der **Betriebsebene** fehlt es an Wissen über Paludikultur und an Beratungsangeboten für innovative Nutzungsoptionen. Es entstehen zumeist hohe Investitionskosten bei der Umstellung auf Paludikultur. Abhängig von Region, Standort und bisheriger Betriebsausrichtung besteht eine weite Spanne der Opportunitätskosten.
- Aktuell besteht eine hohe Unsicherheit zu **Verwertungsmöglichkeiten und der Nachfrage nach Paludikultur-Biomasse**. Es müssen z. T. neue Produktionswege und Absatzmärkte etabliert werden, für die jedoch (noch) keine ausreichenden Rohstoffmengen bereitgestellt werden können („Henne-Ei-Problem“).
- Mit der Umsetzung von Paludikultur ist eine Anhebung des Wasserstands verbunden. Diese benötigt oftmals **aufwändige Planung und aktives Wassermanagement**, welches schlagübergreifend in hydrologisch zusammenhängenden Einheiten auf Landschaftsebene erfolgen sollte. Der Abstimmungs- und Koordinierungsbedarf ist bei Wiedervernässung groß, da neben Wasserverteilungskonflikten Interessenskonflikte bei Nachbarn und Landeigentümern bestehen.
- Die Umstellung auf nasse Bewirtschaftung stellt einen Paradigmenwechsel dar. **Vorbehalte** von Landnutzenden und -eigentümern sowie der Anwohnerschaft reichen von Angst vor Wertverlusten bis hin zu emotionaler Verbundenheit mit der Kulturleistung der Entwässerung.
- **Finanzierungsbedarf:** Für Wiedervernässung und Etablierung von Paludikultur sind kostenintensive Planungs- und Genehmigungsverfahren, Baumaßnahmen, betriebliche Umstrukturierungen sowie ggf. Flächenkäufe oder Kompensationszahlungen notwendig.

4 Lösungsansätze

Die zahlreichen Hemmnisse erfordern unterschiedliche und vielseitige Lösungsansätze. Diese können in drei Gruppen gegliedert werden (WICHMANN ET AL. 2022):

- Regulative Ansätze mit Anpassung politischer und rechtlicher Rahmenbedingungen
- Flankierende Maßnahmen
- Anreiz-Instrumente für die Nutzungsumstellung und finanzielle Unterstützung von Paludikultur in der Markteinführungsphase.

Identifizierte **regulative Ansätze** reichen von der EU-Ebene bis zu regionalen Vorschriften. Klimapolitische Ziele sollten stärker in die Agrar- und Strukturförderung einbezogen und klimaschädliche Subventionen abgebaut werden. Für landwirtschaftlich genutzte organische Böden sollten Direktzahlungen für entwässerungsbasierte Nutzungen auslaufen und der Mindeststandard GLÖZ⁴ 2 mit einem Mindestschutz für organische Böden gestärkt werden. Die Klimaschutzfunktion von organischen Böden sollte im Bodenschutzgesetz aufgenommen und die „Gute fachliche Praxis“ für eine torferhaltende Moornutzung rechtssicher umgesetzt werden. Die mit der Agrarreform 2023 vorgesehene Beihilfefähigkeit für Anbau-Paludikultur und Nassgrünland ist rechtssicher herzustellen. Ebenso ist eine klar formulierte (nationale) Ausnahmeregelung zur Grünlandumwidmung für die Anlage von Anbau-Paludikulturen herzustellen.

Für ein aktives Wassermanagement und einen Wasserrückhalt wären die Aufgabenbereiche der Wasser- und Boden-Verbände und Unterhaltungsverbände in zugrundeliegenden Bundes- und Landesgesetzen sowie Verbandssatzungen zu erweitern.

⁴ Mindeststandards zum Erhalt eines guten landwirtschaftlichen und ökologischen Zustands (GLÖZ)

Weitere regulative Ansätze beziehen sich auf die Raumordnung mit der Festsetzung von Vorrang-/Vorbehaltsgebieten für naturbasierten Klimaschutz auf Moorböden, die naturschutzrechtliche Klärung des Umgangs mit Paludikultur-Beständen, die z. B. nach Etablierung unter den gesetzlichen Biotopschutz fallen könnten, die Integration von Paludikultur in Ökokontierung und Kompensation, oder die Erweiterung und priorisierte Anwendung des Instruments der Flurneuordnung für Moorklimaschutzverfahren (HIRSCHELMANN ET AL. 2023).

Auf der Seite der Weiterverarbeitung der Biomasse und Produktanwendung wären regulative Ansätze z. B. die Berücksichtigung von Flächenemissionsbilanzen von Baustoff-Rohstoffen im Gebäudeenergiegesetz (GEG) oder die befristete Vereinfachung von Zulassungsverfahren während der Markteinführungsphase von Paludikultur-Baustoffen.

Zu den **flankierenden Aktivitäten**, die die Umsetzung von Paludikultur positiv beeinflussen können, zählen die Durchführung von Forschungsprojekten, vorbereitende Gebietsstudien (vgl. KOPPENSTEINER ET AL. 2023), der Aufbau von Beratungskapazitäten sowie die Aus- und Weiterbildung von Fachkräften für alle Ebenen – in Landwirtschaft, Fachplanung, Genehmigungsbehörden, Projektträgern und Baufirmen. Betrieblichen Herausforderungen kann u.a. mit der Entwicklung eines neuen Berufsbildes („Moorklimawirt“) und der Stärkung von kooperativen Strukturen begegnet werden.

Um dem „Henne-Ei-Problem“ zu begegnen, sind verschiedene Zielgruppen zu informieren, um eine Nachfrage nach Rohstoffen und Produkten aus Paludikultur aufzubauen. Verschiedene Start-ups im Bereich der Hochmoor- und Niedermoor-Paludikultur und eine Kooperation marktführender Unternehmen als „Allianz der Pioniere“⁵ sind aktuelle Beispiele für den anstehenden Übergang von der Nischenphase zu einer Diffusionsphase.

Bisher gibt es erste, vereinzelte Förderprogramme für Moorbodenschutz, aber noch keine umfassende, abgestimmte, unmittelbar auf den Klimaschutz ausgerichtete Förderung zur Bewirtschaftung vernässter Moore und zur Weiterverarbeitung der Biomasse. **Förderansätze** können direkt an der Fläche ansetzen, auf der Paludikultur etabliert wird; am landwirtschaftlichen Betrieb, der Paludikultur betreibt und entsprechende materielle und immaterielle Ausstattung benötigt; am verarbeitenden Unternehmen, welches neue Produkte entwickelt, produziert und vermarktet; am Produkt selbst, dessen klimafreundliche Eigenschaften einen positiven Effekt haben (WICHMANN ET AL. 2022).

Die vorhandenen Instrumente bewirken derzeit noch keine relevante Lenkungswirkung bei den betrieblichen Entscheidungsträgern. Geeignete Instrumente zur Förderung der Umsetzung von Paludikultur sind im Ansatz bereits vorhanden, beispielsweise über die 2. Säule der GAP oder Innovations- und Investitionsförderungen, müssen jedoch teilweise zielgerichtet weiterentwickelt werden (SCHÄFER ET AL. 2022). Zusätzlich sind neue Förderinstrumente und deren ausreichende finanzielle Ausstattung notwendig, etwa eine (Moor-)Klimaschutzprämie oder eine aufkommensneutrale Einbindung von Mooren in ein Emissionshandelssystem. Nicht zuletzt ist auch eine klare Kommunikation der politischen Klimaschutzziele, der Auswirkungen auf Moorregionen und die zeitliche Perspektive von Umsetzungsschritten mit positiven sowie negativen Anreizinstrumenten erforderlich, um Planungssicherheit und Handlungsfähigkeit zu schaffen.

Für Produkte aus Paludikulturen bestehen die gleichen Herausforderungen in der Markteinführung und -diffusion wie für andere Innovationen. Als mögliche Instrumente zur Förderung der Diffusion von Innovationen könnten beispielsweise Reallabore zur Stimulierung von Folgeinnovationen oder Transformationsregionen zur Erprobung von Systeminnovationen angewendet werden (vgl. CLAUSEN & FICHTER 2021).

⁵ <https://www.tomorrow.org/allianz>

5 Finanzbedarf

In einem **Szenario** wurde der notwendige Umfang des fiskalischen Finanzbedarfs für ein umfassendes Anreiz-Programm für Wiedervernässung und Paludikultur ermittelt. Es beruht auf den Annahmen, dass

- bis zum Jahr 2050 eine vollständige Wiedervernässung landwirtschaftlich genutzter Moorböden erfolgt, von denen ein Flächenanteil von 80 % in Paludikultur überführt wird,
- eine Kombination von ausgewählten, sich ergänzenden Förderinstrumenten umgesetzt wird,
- durchschnittliche Kostenansätze auf derzeit vorhandenen Daten beruhen und
- eine über die Zeit abnehmende Förderhöhe erfolgt.

Das Szenario umfasst zwei Förderphasen, eine Übergangsphase mit höheren Förderanreizen (2022 – 2029) und eine Etablierungsphase mit reduzierten Förderraten (2030 – 2049). Die wesentlichen Kosten der Wiedervernässung und der Umstellung auf Paludikultur lassen sich unterteilen in Kosten für die Wasserstands-anhebung, Paludikultur-spezifische Einrichtungskosten und Opportunitätskosten (Tabelle 1).

Tabelle 1: Übersicht über wesentliche Annahmen und Kosten für das Szenario „Paludi-Anreize“.

Kostengruppe	Kostenansatz	Förder-instrument ²	Begleitende Maßnahmen mit zusätzlichem Finanzierungsbedarf	Anteil Finanz-be-darf
Wasserstands-anhebung	Ø 4.000 €/ha ¹	Investitions-förderung (Förderrate: 100 %; 75 %)	Monitoring	16 %
Paludikultur-spezifische Kosten	Ø 10.000€/ha ¹	Investitions-förderung (Förderrate: 50%; 25%)	Beratung, Forschung & Entwicklung, Kapazitäts-aufbau Verwaltung, Förderung Erntetechnik und Verwertungsanlagen	24 %
Ausgleich Opportunitätskosten, Anreize für Pioniere	Prämie: 55 € bzw. 100 € je reduzierte Tonne CO ₂ ²	Degressive Klimaschutz-prämie: 100€ bis 3,57 €/t CO ₂		60 %

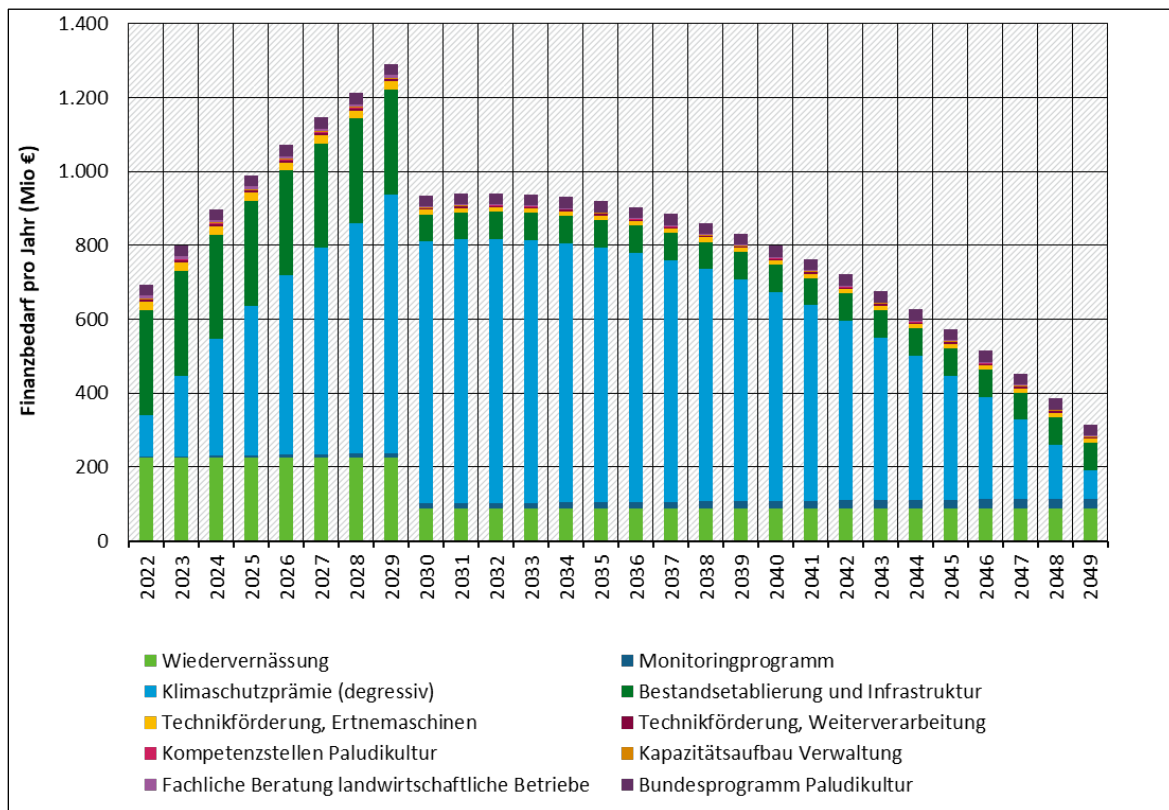
¹WICHMANN ET AL. (2022), ²SCHÄFER ET AL. (2022)

Der Ansatz zum Ausgleich von Opportunitätskosten basiert auf einzelwirtschaftlichen Opportunitäts- und Vermeidungskosten in Höhe von 15 – 90 € je reduzierte Tonne CO₂ (RÖDER ET AL. 2015, LATACZ-LOHMANN ET AL. 2019, WICHMANN ET AL. 2022). Der in der Kalkulation angesetzte untere Wert von 55 € je reduzierter Tonne CO₂ orientiert sich an den Opportunitäts- und Vermeidungskosten extensiv wirtschaftender Betriebe und wurde exemplarisch gemäß dem Tarif im Brennstoffemissionshandelsgesetz übernommen. Der obere Wert von 100 € je reduzierter Tonne CO₂ orientiert sich an den Opportunitäts- und Vermeidungskosten intensiv wirtschaftender Betriebe (SCHÄFER ET AL. 2022) und wurde als Ausgangswert für die Berechnung des Finanzbedarfs angewendet. Er stellt einen echten Anreiz für Pioniere dar, aufgrund der degressiven Ausgestaltung mit im Zeitverlauf kontinuierlich sinkendem Wert bis zu 3,57 €/t CO₂ im Jahr 2049 (Abbildung 2, EBD.).

Im Ergebnis wurde ein fiskalischer Finanzbedarf von 21,2 Mrd. € für den Zeitraum 2022 – 2049 berechnet. Davon entfallen 7,85 Mrd. € auf die Übergangsphase (2022 – 2029) und 13,36 Mrd. € auf die Etablierungsphase ab 2030. Dem gegenüber stehen vermiedene Schadenskosten von 67,5 Mrd. €, bei einer Einsparung von 20 t CO₂e je ha und einem Schadenskostenansatz von 195 € je t CO₂e (vgl. MATTHEY & BÜNGER 2020). Ein geringer Anteil von 16 % (3,39 Mrd. €) des Finanzbedarfs entfallen auf die investive Förderung zur Wasserstands-anhebung, 24 %

(5,03 Mrd. €) auf die Förderung von Paludikultur-spezifischen Kosten sowie begleitenden Maßnahmen. Den größten Anteil des Finanzbedarfs umfasst die nach dem „Prinzip der Freiwilligkeit“ angelegte Klimaschutzprämie (60 %, 12,79 Mrd. €, Abbildung 2).

Abbildung 2: Darstellung des jährlichen Finanzbedarfs im Szenario „Paludi-Anreize“ und Anteil der jeweiligen Fördermaßnahmen (nach SCHÄFER ET AL. 2022).



Zusätzlich ist die Klimaschutzprämie (Bonus) in dem vorgestellten Szenario gekoppelt an eine sukzessive Einführung einer CO₂-Steuer (Malus) ab dem Jahr 2030. Damit werden Anreize für frühes Handeln trotz größerer Unsicherheit gesetzt. Die degressiv ausgestaltete Klimaschutzprämie sollte mit einer langfristig angekündigten, später einsetzenden Einführung einer CO₂-Steuer verbunden werden, um die Planungssicherheit bei den landwirtschaftlichen Betrieben zu gewährleisten.

Der hohe Anteil der Klimaschutzprämie an dem Finanzbedarf beruht vor allem auf dem Prinzip der Freiwilligkeit, bei der davon ausgegangen wurde, dass die landwirtschaftlichen Betriebe und die Landeigentümer derzeit noch nicht verpflichtet werden können, an Wiedervernässungsmaßnahmen teilzunehmen. Demzufolge muss die Klimaschutzprämie die durch die Agrarförderung für entwässerungsbasierte Nutzung erhöhten Opportunitätskosten kompensieren. Der Großteil des kalkulierten Finanzbedarfs dient somit nicht der Förderung von Paludikultur, sondern der einvernehmlichen Herbeiführung der Akzeptanz einer Wiedervernässung von Moorböden.

Das Konzept der Paludikultur wurde vor dem Hintergrund entwickelt, dass gerade die Auflassung, und der damit verbundene Verlust der Produktions- und Ertragsfunktion der Moorböden große Raumwiderstände hervorruft (WICHTMANN ET AL. 2016) und damit die notwendigen Flächenumfänge für die Wiedervernässung zur Erreichung der Klimaschutzziele nicht realisiert werden können (BARTHELMES ET AL. 2021). Ein alternatives Szenario zur Reduktion von THG-Emissionen aus entwässerten Moorböden ohne die Umstellung auf Paludikultur könnte zur Auflassung bisher produktiv genutzter Flächen führen. Daraus resultierte ein um 24 % niedri-

gerer Finanzbedarf mit gleichen Kosten für Wasserstandsanhebung und Ausgleich der Opportunitätskosten (Tabelle 1). Ein weiteres Szenario könnte die Wasserstandsanhebung und anschließende Flächennutzung mit Photovoltaik beinhalten. Hierzu fehlt es bislang an praktischen Erfahrungen und realen Kostenansätzen, obwohl Landwirte und Flächeneigentümer hohe Erwartungen an diese Option haben. Aktuelle Forschungsprojekte⁶ bemühen sich darum, Daten zu erheben, um eine Basis für (zukünftige) Entscheidungen zu „PV auf Moor“ zu schaffen.

6 Fazit und Ausblick

Aus betriebswirtschaftlicher Sicht besteht aktuell kein ausreichender Anreiz, die entwässerungsbasierte Nutzung der Moore aufzugeben und in eine klimafreundliche Nutzung einzusteigen. Zudem fehlt es an klaren Signalen, dass sich dies in Zukunft ändern wird. Auch variieren die einzelbetrieblichen Opportunitätskosten und THG-Vermeidungskosten stark, wobei die Direktzahlungen für die entwässerungsbasierte Moornutzung bei den Opportunitätskosten einen einheitlichen Sockelbetrag bilden.

Belastbare Daten zu relevanten Kostenpositionen und -dimensionen bei der Umstellung auf Paludikultur sind erforderlich, um wirksame Anreizinstrumente zu schaffen. Für die Umsetzung von Paludikultur bestehen derzeit noch große Lücken an Erfahrung, Erprobung und belastbaren Daten. Zudem weisen die Kosten der Wiedervernässung und Nutzungsumstellung eine hohe Spannbreite auf. Eine Verbesserung der Datengrundlage wird nicht zuletzt durch die zehnjährigen Pilot-, Modell- und Demonstrationsvorhaben zu Moorbodenschutz und Paludikultur möglich werden, die 2022 und 2023 bundesweit gestartet sind. Eine weiterreichende Umsetzung soll durch einschlägige 2023 und 2024 veröffentlichte Förderrichtlinien im Rahmen des Aktionsprogramms Natürlicher Klimaschutz unterstützt werden.

Instrumente, mit denen die Umsetzung von Paludikultur gefördert werden können, sind vielfältig, nicht nur weil betriebliche Investitionen bei den landwirtschaftlichen und weiterverarbeitenden Betrieben erforderlich sind, sondern gleichzeitig auch die Nachfrage nach Paludi-Biomasse und -produkten stimuliert werden muss. Im vorgestellten Szenario „Paludi-Anreize“ wurde der höchste Anreizbedarf jedoch für die Herbeiführung der Akzeptanz der Wiedervernässung landwirtschaftlich genutzter Moorböden berechnet, z. B. in Form einer Klimaschutzprämie. Ohne eine umfassende Exnovationsstrategie, die die Anpassung rechtlicher Rahmenbedingungen und die Umsetzung flankierender Maßnahmen einschließt, können weder bestehende noch neue Förderinstrumente ihre Wirksamkeit entfalten.

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⁶ <https://moorwissen.de/moor-pv.html> und <https://www.natur-und-erneuerbare.de/projektdatenbank/moor-pv-potenzialflaechen-und-naturschutzfachliche-wirkungen/>

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CAP SUPPORT

PLANNING THE EVALUATION OF CAP STRATEGIC PLANS 2023-2027: EXAMPLES FROM AUSTRIA AND GERMANY

Andrea Pufahl¹ and Franz Sinabell

Summary

Since 2023, market related measures including direct payments (Pillar 1) and rural development (RD) policies (Pillar 2) of the Common Agricultural Policy (CAP) have been implemented via national CAP Strategic Plans (CSP) 2023-27. The latter are to be evaluated by Member States (MSs), following an evaluation framework defined by the European Commission (EC). MSs were required to set up an *evaluation plan* comprising all evaluation activities, their time-line and data requirements until the ex-post evaluation in 2031. MSs can plan their evaluation activities with a considerable degree of freedom. The resulting differences are illustrated using the examples of the *evaluation plans* of Germany and Austria. Both plans were approved by the EC and comply with the necessary requirements. Evaluation activities are scheduled to 2025 to 2027 (interim) and 2030/2031 (ex-post). Germany will commission evaluation studies on one or more *specific objective* (SO), while Austria structures its evaluation along 36 topics related to *key evaluation elements*, specific topics and further supplementary studies. Relevant data for monitoring and evaluation are collected in both MSs. Austria has taken further action to identify and close existing data gaps and improve its already advanced data management structure. In Germany, a comprehensive approach for a central management of evaluation data on the national level is still missing since CSP programming at federal level did not include data management aspects. The biggest challenge for both countries will be to realize a timely and high-quality interim CSP evaluation given the limited data of the few funding years.

Keywords

Agricultural Policy, CAP Strategic Plans, Evaluation, Evaluation Plan, Germany, Austria

1 Introduction

An overhauled Common Agricultural Policy (CAP) was introduced in the EU in 2023. Since then, Member States (MS) have been implementing the CAP into their national policies via CAP Strategic Plans (CSP) 2023-27. The CSPs specify which CAP objectives are to be addressed at national level and which interventions and financial resources are used to achieve them. The *new delivery model* offers a MS large degrees of freedom to adapt the CAP to its own needs and preferences. A novelty of the present programming period is the joint programming and implementation of market related measures and direct payments (Pillar 1) and rural development (RD) policies (Pillar 2) under a single national CSP. This required MSs with a regionalised RD approach, as Germany, to integrate their regional RD programs into a national CSP. The integration of both pillars into a single planning document led to unified requirements in terms of programming, monitoring and evaluation.

The European Commission (EC) is committed to the Better Regulation Strategy aiming at an evidence-based policy making, to simplify and to improve policies (EC, 2021). This applies in particular to the Cohesion Policy and the CAP. These two policies account for 62 % of all EU expenditures (NextGenerationEU not included) allocated within the current multiannual financial framework 2021-27 (BACHTRÖGLER, et al., 2021). Whereas programmes financed from

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Structural Funds are rarely disputed in the public, the CAP is most controversially debated in society. The European Court of Auditors regularly criticizes that the effectiveness of the CAP is not substantiated by evaluations (ECA, 2021, 2017, 2016). Therefore, the EC is ambitious to prove that the CAP is achieving its objectives. This concern is reflected in the legislation governing the CSP 2023-27 which introduced the *new delivery model*.² Besides more flexibility to tailor the CAP to the *needs* of MSs, it strengthens the performance-based implementation of CAP. The achievement of set policy targets must be monitored annually. When deviations occur, MSs have to explain them and take actions to re-adjust their CSP.

When evaluating their CSPs, MSs shall assess the *effectiveness, efficiency, relevance, coherence, Union added value* and *impacts* in relation to set CAP *general* and *specific objectives* (SOs). Additionally, the EC conducts a performance assessment and evaluation at EU level (see Art. 140, 141 of CSP regulation (EU) 2021/2115). The new implementation mode via CSP has far-reaching consequences for the evaluation: For the first time, Pillar 1 and Pillar 2 interventions are evaluated together. This opens the opportunity to analyse their joint impact on objectives such as income, competitiveness, environmental and climate issues. Until 2022, CAP evaluation requirements for MSs applied to Pillar 2 interventions only, while the evaluation of Pillar 1 was a task of the EC.

MSs were required to set up an *evaluation plan*. The *evaluation plan* shall comprise all evaluation activities, their timeline, data requirements and further administrative and communicative aspects until the *ex-post evaluation* in 2031. The implementing regulation (EU) 2022/1475 specifies minimum requirements regarding the frequency, time and content of the evaluation of CSPs. Some provisions are binding per se, e. g. the use of *impact indicators* defined in the *performance monitoring and evaluation framework* (PMEF; EC, 2023b). Provisions regarding the timing, structure and content of the evaluation are to be tailored to MS's interests and needs.

The *evaluation plans* of Austria and Germany mirror the state of evaluation planning one year after the approval of the CSP. They show how both countries made their choices to implement the evaluation framework provided by the EC (BML, 2023; BMEL, 2023). The two plans vary with respect to their content and level of detail: The *evaluation plan* for the CSP Austria was drawn upon a detailed evaluation concept developed on behalf of the federal ministry (SINABELL et al., 2023).³ The *evaluation plan* for the German CSP covers the most relevant topics but remains vague in many aspects, since a detailed evaluation concept was not available by the time setting up the *evaluation plan*. It is developed at the time of writing this manuscript.

A central task of the *evaluation plan* is to ensure sufficient activities for data collection and management. As the evaluation of the CAP through MSs has been an ongoing task since 2000, a great deal of data is being collected already. The *ex-post evaluation* of the period 2014-22 will be carried out when the *interim* evaluation of the CSP will start. Although some data gaps remain to be closed, an increasing focus is on an improved data management and data enrichment. The latter involves the collection and integration of data from different sources (EEH and EC, 2020). This especially applies to farm-level data, since more than 93 % of CAP support in the EU is targeted to farm enterprises (BECKER et al., 2022: 36).

The topics of this contribution are: The EU requires an *evaluation plan*, albeit with a considerable degree of freedom for the MSs. The resulting differences are illustrated using the examples of the *evaluation plans* of Germany and Austria. Both countries have in-depth evaluation expertise of previous RD programs and used this knowledge for the evaluation planning of their CSP. Particular attention is paid to the state of data management and planned activities to improve it.

² Throughout the manuscript, terms in italic are those that have a special meaning because they are defined in EU regulations.

³ Authors of this article were involved in the development of the evaluation concept for the CSP Austria.

The reminder of the paper is as follows: Section 2 illustrates the intervention and evaluation logic of the CSPs considered. Section 3 describes provisions for the evaluation of CSPs through MSs and how Austria and Germany considered them in their *evaluation plans*. Section 4 presents a data management concept for the evaluation of the CSP Austria. Section 5 concludes.

2 Programming and evaluation logic of the CSP Austria and Germany

The main purpose of the evaluation is to assess the contribution of the CSP to the achievement of set CAP objectives. The three *general*, nine *specific objectives* (SOs) and one *cross-cutting objective* are displayed on the left side of figure 1. Each *general objective* is substantiated through three (SOs). The *cross-cutting objective* (CCO) ‘modernisation of agriculture and rural areas through knowledge sharing, innovation and digitalisation’ is anchored horizontally in all SOs. In their CSPs, MSs specified these objectives based on their national *needs* and determined which interventions and financial resources to be used to achieve them. The CSP regulation offers various *types of intervention* (a new term equivalent to *measures* in previous programmes periods), such as direct payments (Art. 21) and investments (Art. 73 and 74), from which MSs could choose. The so-called *intervention logic* is the backbone of a CSP. The implementing regulation further details that SOs are to be evaluated by using defined *key evaluation elements* and specific topics (Figure 1 to the right).

Figure 1: CAP general and specific objectives (SO) and corresponding evaluation elements

Regulation on CAP Strategic Plans ¹⁾		Implementing regulation ²⁾	
General objectives	Specific objectives (SO)	Key evaluation elements	Specific topics
(a) Competitive agricultural sector to ensure food security	(a) Farm income	Farm income	Resilience
	(b) Market orientation	Market orientation	
	(c) Value chain	Farmer's position in the food chain	
(b) Environmental and climate protection	(d) Climate	Climate change mitigation	Climate change adaptation
	(e) Natural resources	Efficient management of natural resources	
	(f) Biodiversity	Reversing biodiversity loss	
(c) Socio-economy of rural area	(g) Young farmers	Farmers renewal	Business development
	(h) Employment, growth, gender, social inclusion	Rural sustainable economy	
	(i) Societal demands	Gender equality and social inclusion	
Cross-cutting objective	Cross-cutting objective: Knowledge & innovation	Quality and safety food	Local development
		Agricultural Knowledge and Innovation System (AKIS) and digital strategy	
			Environmental and climate architecture
			Added value of LEADER
			AKIS
			CAP networks

Sources: 1) Art. 5 and 6 of CSP regulation (EU) 2021/2115, 2) Annex I and Art. 2(d) of the implementing regulation (EU) 2022/1475.

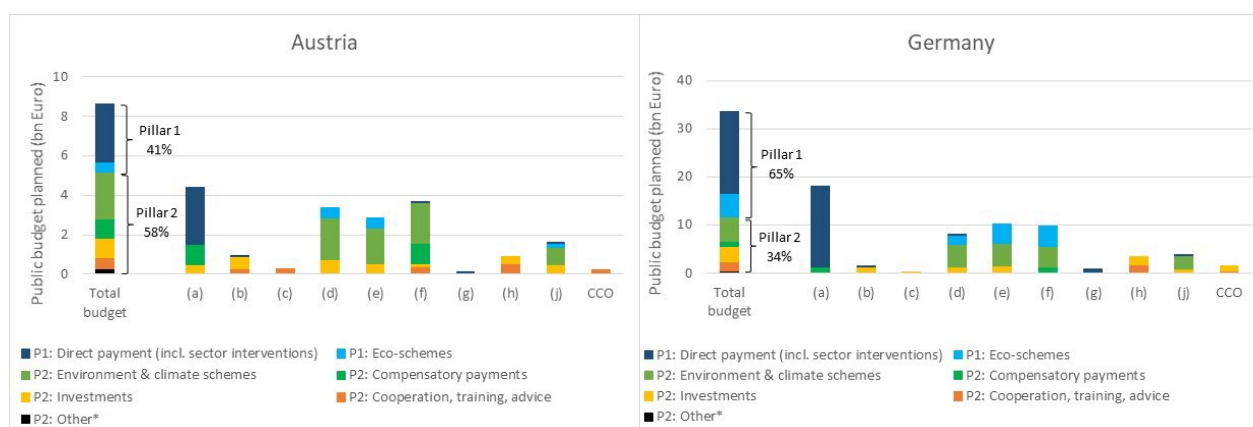
Figure 2 displays the core structure of the interventions of the CSP Germany and Austria. The detailed *intervention logics* – a mapping of how interventions contribute to the attainment of objectives – are rather complex, given the 98 interventions of the Austrian CSP and the 45 German interventions. For the sake of simplicity, the *interventions* are grouped by *types of interventions*. Figure 2 depicts total public expenditures, including EU and national spending, by *type of interventions* and SOs addressed. The bar ‘total’ indicates the total budget of the CSP. The preceding columns illustrate, how this budget is allocated to SOs. Note that one and the same *type of intervention* may contribute to more than one SOs. Therefore, the budget summed over all SOs exceeds the total budget.

The CSPs of Austria and Germany comprise a budget of 8.7 billion Euro and 33.5 billion Euro (EU and national funds) for the period 2023-27, respectively. The budget share of Pillar 1 amounts to 65 % in Germany and is considerably lower in Austria (41 %). Both MSs implement direct payments, eco-schemes and sector interventions under Pillar 1. Intervention types under

Pillar 2 comprise RD investments, mainly for farms and rural infrastructure, RD environment & climate interventions, which also include animal welfare measures, RD compensatory payments in areas with specific disadvantages and areas facing natural constraints or other specific constraints and support for RD cooperation, training and advice. The latter include support for LEADER, the European Innovation Partnership (EIP-Agri) as well as training and advisory support. Other interventions of minor financial relevance comprise risk management tools (not implemented in the Austrian CSP) and the setting-up of young farmers. In both MS, acreage related payments targeted to farm enterprises, including direct payments, RD environment and climate schemes, eco-schemes and compensatory payments, account for roughly 80 % of the national CSP budgets.

Although the budget share of the *intervention types* differs among Germany and Austria, the *intervention logic* and the financial priority of SOs are rather similar. In both MSs, around half of the CSP budget is spent on SO (a) ‘viable farm income’, mainly through direct and compensatory payments. The second largest budget share is allocated to RD environment & climate types of interventions and eco-schemes targeted to the SOs (c) ‘climate protection’, (d) ‘natural resources’ and (f) ‘biodiversity’. RD investments on farms and for nature renaturation add to the portfolio of SO (d) ‘climate’ and (e) ‘natural resources’. Accompanying interventions for SO (f) ‘biodiversity’ include RD compensatory payments and, to a minor extend, RD support for cooperation, training and advice and sector interventions.

Figure 2: Intervention logic of the CSP 2023-27 Austria and Germany: Total public expenditures by type of interventions and specific objectives addressed



Source: EC (2024). Note: (a) farm income, (b) market orientation, (c) value chain, (d) climate, (e) natural resources, (f) biodiversity, (g) generational renewal, (h) rural areas, (i) societal demands, cross-cutting objective: knowledge & innovation.

The institutional context plays a central role when implementing EU into national policies. Although Austria and Germany are both federal states, the competencies for the national agricultural policy are distributed very differently. In Austria, Pillar 1 and Pillar 2 have always been implemented at national level by the Federal Ministry of Agriculture, Forestry, Regions, and Water Management (BML). All interventions of the CSP are implemented throughout Austria (horizontally). The programming of the CSP Austria required a closer collaboration of ministry units, of which most were familiar with CAP programming and evaluation requirements. In Germany, the Federal Ministry for Food and Agriculture (BMEL) is responsible for implementing Pillar 1, while the constitutional responsibility for Pillar 2 lies with each of the 16 state ministries.⁴ Only Pillar 1 is implemented horizontally, whereas not all Pillar 2 interventions are

⁴ The CSP is implemented by 13 states in all 16 states. The CSP in the three city states of Bremen, Hamburg and Berlin are implemented by neighbouring states.

available in each state. Furthermore, programmed Pillar 2 interventions comprise very different sub-interventions on state level and vary with respect to funding conditions and the amount of support granted. Drawing up the CSP Germany required, above all, coordination, cooperation, and compromises between institutions which have previously acted independently. The lead for programming and evaluating the CSP had to be taken the federal ministry, although its staff lacked practical experience in CAP programming and evaluation.

To monitor the progress towards set objectives, the *performance monitoring and evaluation framework* (PMEF) has been established (EC, 2023a). The PMEF consists upon a broad set of *output, result, context and impact indicators*. These indicators are set in relation to the input (public funds) during evaluation. Output und result indicators will be monitored through *annual performance reviews*, while the evaluation is focused on the quantification of *impact indicators*.

The *intervention logic* determines which intended objectives are to be achieved by a certain *intervention*. In the evaluation, the *intervention logic* of the CSP is examined "backwards", i. e. which contribution or *impact* a certain *intervention* has made towards the achievement of SOs. The *intervention logic* of the CSP lacks two important features that have to be accounted for during the evaluation: Firstly, many CSP *interventions* have unintended and possibly adverse effects on other objectives. For instance, the enhanced Standards of Good Agricultural and Environmental Condition (GAEC-Standard) are likely to have an unintended negative impact on farm income, that needs to be considered under SO (a) 'viable farm income'. Most unintended effects are theoretically to be expected and well described in the literature. Thus, it is straightforward to consider them adequately when planning the evaluation. Secondly, MS were not obliged to set impact targets in their CRP (e. g. that greenhouse gas emissions from agriculture are to be decrease by 10 % until 2030 due to the CSP). Impact targets would have established a quantitative reference against which CSP impacts are to be assessed. This shortcoming is to be remedied in the evaluation by establishing qualitative judgment criteria, the so-called *factors of success*.

3 CAP evaluation provisions and their implementation in Austria and Germany

General provisions regarding the scope and timing of evaluations are made in Art. 140 of the CSP regulation. The implementing regulation further specifies them and provides minimum requirements for the structure and content of evaluation plans. The expected content of *evaluation plan* is detailed further through guidelines of the EUROPEAN EVALUATION HELPDESK FOR THE CAP (EC, 2023a, 2023b). Table 1 lists required and recommended contents of the *evaluation plan*, related legal provisions and how Austria and Germany intend to put them into work through their national *evaluation plans*.

The *evaluation plans* for the CSP 2023-27 are significantly more demanding in terms of content than the *evaluation plans* for RD programs 2014-22. Firstly, because the legal provisions regarding their content have been more detailed than previously. This indicates the efforts of the EC to illustrate how *evaluation plans* should be alike. And secondly, although the EC "only" provides an evaluation framework, it includes new elements, such as the *key evaluation elements* to assess (see Figure 1). The adaptation of this framework to national conditions in part required a content-related discussion how to do this. In this way, the EC has – intended or unintended – ensured that the MS have to deal very seriously with the very complex evaluation requirements.

3.1 Evaluation plans, their objectives and needs

The scope and structure of the evaluation is to be described in the first chapter of the *evaluation plan*. MSs shall assess the *effectiveness, efficiency, relevance, coherence, Union added value and impacts* of their CSP in relation to the three *general objectives* and ten SOs. When assessing the *effectiveness*, MS shall use the 17 *key evaluation elements* that further structure the SOs

(Annex I of implementing regulation, see figure 1 right side). For instance, the two key elements to be assessed under SO (a) 'viable farm income' are 'farm income' and 'farm resilience'. The overall impact of the CSP, the three *general objectives* and all SOs must be assessed in the *ex-post evaluation* only.

Table 1: Evaluation provisions and corresponding contents of the evaluation plans for the CSPs of Austria and Germany

Section of the evaluation plan	Content of evaluation plan	Austria	Germany
1. Evaluation objectives and needs	Specific objectives ^{1) 2)}	yes	yes
	Specific topics ¹⁾	yes	to be decided later
	Support studies	yes	no support studies planned
	Evaluations questions	formulated	formulated
	Indicative factors of success are defined	formulated	not formulated
	Evaluation structure	Evaluation studies, related to key elements, specific topics & supplementary studies	Evaluations studies by one or more SOs
	Evaluation concept	available	under development
2. Governance und structure	Main bodies and responsibilities	Federal Ministry Republic of Austria for Agriculture, Forestry, Regions and Water Management (BML)	Federal Ministry of Food and Agriculture (BMEL): Coordination of evaluation BMEL: SO a BMEL & states: SOs d, e, f, g States: SOs b, c, h, i & cross-cutting
	National evaluation	yes	yes
3. Stakeholder mapping		³⁾	³⁾
4. Timeline	Evaluation during implementation ¹⁾	mainly in 2026/27, for a period of 12 to 18 months	mainly 2025/2026, for a period of 12 to 18
	Ex-post evaluation ²⁾	2030/31	2031
5. Data and information	Data availability	relevant data are collected	relevant data are collected
	Institutional arrangements for data provision	Data pool of BML	central: monitoring data decentral: IACS data, disaggregated data for monitoring and evaluation
	Identification of data gaps and remedy actions	yes	no
6. Communication ...		³⁾	³⁾
7. Resources, ...		³⁾	³⁾

Notes: ¹⁾ Art. 2 of the implementing regulation; ²⁾ Art. 3 of the implementing regulation, black font: Minimum requirements of evaluation according to Annex II of implementing regulation, grey font: additional content of evaluation plan, not legally required; ³⁾ These topics are elements of *evaluation plans* but are not covered in this manuscript.

Sources: BMEL (2023), BML (2023).

During the period of implementation, SOs are to be evaluated together, in groups or individually as stand-alone evaluation. If relevant, MSs may evaluate specific topics recommended in the implementing regulation or initiate other support studies of national interest. Specific topics recommended in the implementation regulation include the environmental and climate architecture, the added value of LEADER, CAP networks and the Agricultural Knowledge and Innovation Systems (AKIS, see figure 1).

All SOs will be covered in evaluation studies in Germany and Austria. What differs among both MSs is how the evaluation is structured along SOs: In Austria, the evaluation is structured along the *key evaluation elements*. Out of 36 evaluation studies planned to be commissioned, 25 evaluation studies are related to SOs. The *key evaluation elements* of SO (d), (e), (f) and (h) are differentiated further in the *evaluation plan* of Austria since they are too broad to enable a focused evaluation. For instance, the only *key evaluation element* under SO (e) ‘natural resources’ will be evaluated by four evaluation studies on water quality, water quantity, soil erosion/carbon sequestration and air quality. In Austria, four out of 36 evaluation studies are planned to synthesise evaluation results by *general objectives* and for the entire CSP. All *specific topics* recommended (see figure 1) and supplementary topics of national interest will be evaluated. The latter include a synthesis study on CAP impacts on organic farming, a study on the quantification of the counterfactual situation without CAP support and on simplification of administrative implementation (BML, 2023: 14ff).

The evaluation of the German CSP is organized along SOs (BMEL, 2023: 15). One or more SO evaluations will be commissioned centrally by the federal government. The coordination of the evaluation is shared among the federal government and the states. The federal government has the sole responsibility to evaluate the SO (a) ‘farm income’. Specific objectives related to environment and climate (SOs d, e, f) and ‘generational renewal’ (SO g) are evaluated under the joint responsibility of the federal government and the states. The states have the sole responsibility for the evaluation of the SOs (b), (c), (h), (i) and the cross-cutting objective (ibid, p8). Six indicative *evaluation questions*, to be answered for each SO, are formulated in the *evaluation plan*. The *evaluation questions* cover all *evaluation criteria* as well as administrative issues (ibid, p4). Although it seems to be straightforward to cover administrative issues in the evaluation per SO, a horizontal approach would be more adequate because administrative costs are linked to the way *interventions* are implemented and not to the SOs targeted by them.

3.2 Timing

The CSP shall be evaluated twice until 2031: An *interim* evaluation is to be conducted during the period of implementation, followed by the *ex-post evaluation* in 2031. The results of the evaluation during the implementation period shall be available for the national discussion of the next CAP period. The programming of CSP 2028 to 2035 will start in 2026 and evaluation results need to be available by then. This might be possible in Germany as major parts of the *interim* evaluation are scheduled to 2025/2026. In Austria, most parts of the CSP will be evaluated in 2026/2027. *Ex-post evaluation* results (and data) of the RD programme 2014-22 will be used for the *interim* evaluations. Evaluation studies will be commissioned with a duration of 12 to 18 months, separately for the *interim* and *ex-post evaluation*. As the *interim* evaluation is carried out three to four years after the start of the programming period, causal effects will very likely not be identified. However, most of current interventions have already been in place in the previous period 2014-22. It is thus reasonable and recommended to use data from 2022 and earlier in the *interim* evaluation (Art. 2(e), implementing regulation). Therefore, robust findings on the *effectiveness* of *interventions* may be achievable already in the *interim* evaluation.

The evaluation of SOs within a 12 to 18 month-period is ambitious and requires two essential prerequisites to be met: Firstly, the content of the evaluation must be clearly described and commissioned on time. Secondly, the data required for evaluation must have been collected and made available to evaluators timely and in a suitable structure. Both aspects are tackled in the *evaluation plans* or will be made explicit in the evaluation concept.

3.3 Data and information

An essential prerequisite for realising short evaluation periods concerns the availability and management of data which are needed to analyse CAP impacts. Many data are already available

and being used for evaluation. Remaining gaps may concern data that are not yet collected or not yet available for evaluation purposes. Closing data gaps is much more challenging, especially if missing data is not yet collected and concern regulatory areas outside the agricultural administration.

As part of the evaluation concept for the CSP Austria, data gaps were identified in two ways (SINABELL et al., 2023): Firstly, persons previously involved in evaluations were asked to report their experiences in an online survey. Data collected for non-evaluation purposes but relevant for CAP evaluation could be identified in this way. These include, for instance, data on beneficiaries of CAP training interventions, data on irrigation and the use of antibiotics in livestock husbandry. Secondly, gaps in administrative and technical data were identified during the detailing of evaluation topics. At the time of writing this manuscript, missing administrative data are collected through expanded data queries in the Digital Funding Platform⁵ or within the Integrated Administration and Control System (IACS) (BML, 2023: 31). Missing technical data, e. g. on the relationship between water and nutrient retention through relevant interventions, will be surveyed through specific evaluation studies. Data gaps for the evaluation of the CSP Germany were not identified and described in detail. Any existing data gaps are to be closed through additional surveys as part of the evaluation studies (BMEL, 2023: 19).

Available data needs to be stored in an efficient manner such that evaluators can easily access them. Since the evaluation of the CSP usually involves many evaluators, it would be a waste of resources if the same data would be picked up a from the data-holding institution and processed more than once. Austria therefore set up a *data pool* during the last funding period, through which administrative data is accessible for evaluators and other stakeholders. The structure of the *data pool* as well as points for its further development are illustrated in section 4.

In Germany, almost all disaggregated monitoring and evaluation data is collected and held on state level. Since the data collection does not follow a uniform system with identical indicators and data structures, there are 13 different sets of monitoring and IACS data. Since a comprehensive approach for an adequate management of evaluation data is missing on the national scale, there are isolated attempts to improve the situation. These include the national compilation of aggregated monitoring data for the *annual performance reviews* (BMEL 2023: 19). However, the latter are of limited relevance for evaluation purposes. It is planned to also include disaggregated data for monitoring and evaluation⁶ in this national compilation approach. For the evaluation of national climate and nitrate policies, IACS data of the federal states are currently being compiled and transferred into a standardized data format (ERASMI et al., 2023). This subsequently homogenized data could be used for the CAP evaluation, provided the federal states agree that they may be used for the purpose of CAP evaluation, too.

4 Data management for monitoring and evaluating the CSP Austria

A database, which has been built up incrementally in recent years and refined with each programming period has contributed to the availability of coherent panel data of high validity for many evaluation questions. The CAP *data pool* in Austria contains comprehensive databases and interfaces to important data collection systems not only on variables relevant for agricultural policy but also controls from various domains (e. g. structural funds). In 2023, the *data pool* was expanded to include the digital funding platform managed by the paying agency and other relevant evaluation data. The following list of data is available or will be made available within the data pool (BML, 2023: 36f):

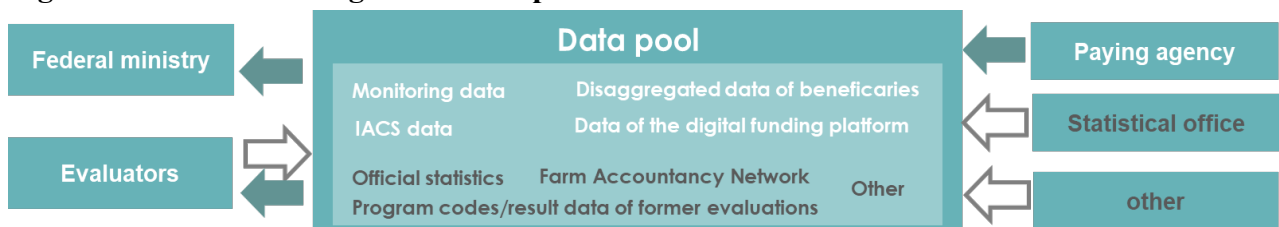
⁵ The Digital Funding Platform comprises project-level data for investment and human capital interventions.

⁶ According to Annex IV to VII of the implementing regulation

- IACS data containing georeferenced information for all area and animal-based CAP payments, such as direct payments interventions and animal-based rural development interventions,
- RD project data, starting in the year 2000,
- Data of the digital funding platform containing all non-IACS interventions of the CSP as well as sector interventions,
- Data to be submitted as part of the *annual performance reports* of the CSP, including annually updated monitoring data and milestones of the result indicators and
- Disaggregated data on beneficiaries according to Art. 10 of the implementing regulation.

The *data pool* is operated by the Federal Institute of Agricultural Economics, Rural and Mountain Research (BAB) on behalf of the federal ministry BML. BAB is responsible for the updating of the databases, the securing of functioning interfaces as well as for training and supporting data users. The latter include staff of the ministry, section agriculture, as well as commissioned evaluators and coordinators.

Figure 3: Data management concept for CAP evaluation in Austria



Source: SINABELL et al. (2023). Notes: white letters = existing *data pool*, grey letters = more advanced *datapool*. The evaluation concept for the CSP Austria proposes various starting points to further improve the already advanced management of monitoring and evaluation data with the *data pool* (Sinabell et al., 2023). For future evaluations, efforts should be made to broaden the coverage of data sets in a one-stop shop. To this end, data should be compiled on a standardized platform with coherent links, especially in institutions assigned to the BML (among them research institutes that monitor soil and water quality). The aim should be to provide valid panel data for many evaluation topics. The existing metadata in the *data pool* will be systematically supplemented. Furthermore, unique datasets are developed at great expense in most evaluation studies. These data sets can be used for subsequent evaluations if they are collected centrally. It is planned to become a standard practice for the data and codes used for econometric analyses to be included in evaluation reports as supplementary data. Such an approach as practiced in quality journals is expected to improve the quality of evaluation studies and enhance the validity of results.

Other improvements proposed in the evaluation concept relate to data that is difficult to access. This includes data previously recorded in pdf documents or data in unstructured reports. Such data should be made available either in databases or in a structured form e. g. as a data table. Structured data will pave the way for integrating previously unstructured data into the *data pool*, which is clearly structured and highly standardized. Machine Learning methods for information retrieval from text-based documents (e. g. BACHTRÖGLER, et al., 2020) may be useful to retrieve information from previous periods.

A second strand of previously inaccessible data sets are those relevant for evaluation but were not used before because they have been collected for other purposes (e. g. data on antibiotics use per farm). After all, public funds are used for this purpose, which are also useful elsewhere. Institutions that are not yet familiar with this issue should be encouraged by appropriate contractual arrangements to grant access to independent evaluation and provide data for evaluation purposes, even if this has not happened in the past. In return, it should be possible to address questions that are in the interest of the organization collecting the data as part of the evaluation. Such data sharing across various policy domains would help to avoid an eminent nuisance of

farmers who have to provide identical information for various administrative bodies and certification firms.

In order to enable a high degree of data availability while ensuring that data protection obligations are not violated, the data should be classified according to sensitivity. The proposals developed in the evaluation concept for improving the data management of evaluation data were not included in the *evaluation plan* for the CSP Austria. The reason is that the development and further enhancement of the *data pool* is a process that will go on until the ex-post evaluation will start.

5 Discussion

An evidence-based policy making and its improvement requires regular evaluation. This applies to the CAP as it is the financially most important Community policy. The CAP 2023-27 is implemented via national CSPs that must be evaluated twice until 2031. MS shall assess the *effectiveness, efficiency, relevance, coherence, Union added value* and *impacts* of their CSP in relation to the three *general objectives* and *specific objectives*. The novelty of the CAP evaluation is, that Pillar 1 and Pillar 2 interventions are being evaluated together for the first time. The EC established a *common evaluation framework* to ensure a comparable evaluation of the CSP by MS. Within this framework, MS can set their own priorities and tailor evaluation activities to their own needs. All activities necessary for planning the evaluation of the CSP is to be laid down in an *evaluation plan*. We analysed the *evaluation plans* for the CSP Austria and Germany with respect to the structure and timing of the evaluation, the content of the evaluation and the data management. Other elements (e. g. stakeholder mapping) were not addressed in this manuscript.

The largest difference among the CSP evaluation of Germany and Austria lies in the structure of the evaluation: Germany structures the evaluation of its CSP along the ten *specific objectives*, while Austria uses the *key evaluation elements* under each *specific objective* to structure the evaluation. At this level, *evaluation questions* will be answered and *evaluation criteria* are to be assessed. Central provisions for the CSP evaluation are addressed in the *evaluation plans* of both MS. The *evaluation plan* of Austria provides detailed information about the content of evaluation and associated activities as it was based upon a detailed *evaluation concept* which was developed in collaboration between evaluators and staff from implementing organisations and administration. In contrast to this, the *evaluation plan* of Germany remains vague in many details.

Both MSs will evaluate their CSP twice, between 2025 and 2027 and 2030/2031. The *interim* evaluation in Austria will succeed the *ex-post evaluation* of the RD program 2014-22. Results of the latter shall be used for the *interim* evaluation as well. *Evaluation studies* will be tendered for a short period of 12 to 18 months to external evaluators, separately for the *interim* and *ex-post evaluation*. The biggest challenge for both MSs will be to realize a timely and high-quality interim CSP evaluation given the limited timeframe and few funding years. This requires a clear definition of the content of evaluation studies, the availability of necessary data and an effective data management.

Austria has already taken action to identify and to close existing data gaps and to improve the already advanced data management. In Germany, a comprehensive approach for an adequate management of evaluation data on the national level is missing. The responsibility to collect and store administrative data lies with the 13 implementing states. Thus, administrative data is not only scattered in the republic but it is also not comparable, since different data concepts and definitions of indicators are used. As things stand, each evaluation team will have to query and process administrative data from each state separately. This will result in additional workloads that further shortens the time available for evaluation. Therefore, establishing a single coherent

data pool would avoid redundancies and make funds available for specific enquiries. The greatest challenge for Austria will be to synthesize the results of the 36 evaluation topics by *specific* and *general objectives*. For this purpose, studies synthesising evaluation results by *general objective* and for the entire CSP will be tendered as well.

Austria had excellent starting conditions for setting up a national CSP, as Pillar 1 and 2 policies have always been implemented at national level. Working structures within the federal ministry could be adopted quickly to new demands. The process of programming and evaluation is led by a ministry with a clear political mission. Although the evaluation is also considered as a duty towards the EC, there is an interest to use evaluation results in the national policy context to adjust policies in case necessary because the staff that was responsible to define the *needs* for the CSP is in many cases the same that is in charge of implementing *interventions*. An indication for this is, that evaluation topics of national interest are specified in the *evaluation plan*.

In Germany, CAP policies have been implemented by the federal government (Pillar 1) and federal states (Pillar 2) separately ever since. The evaluation of a CSP required that the federal government, less familiar with CAP evaluation requirements, overtook the lead and moderated its own interests and the diverse interests of the 16 states involved. The shared responsibility among the national government and the states is also mirrored in the evaluation structure. For the evaluation of the *specific objectives*, clear responsibilities have been defined between the federal and state governments. When this manuscript was written, topics that should be dealt with on programme level and extend over *several specific* objectives, have not been adequately anchored in the *evaluation plan*. This applies to the assessment of general CAP objectives in the *ex-post evaluation* and horizontal topics as *administrative cost* and *simplification for beneficiaries*.

The present analysis raises the question if *evaluation plans* are an appropriate instrument to encourage MS to plan ahead their CSP evaluation at an early stage. The obligation to set up an *evaluation plan* required a serious reflection of how legal evaluation provisions are to be implemented in the national context. In this way, the EC has – intended or unintended – ensured that the MS have to deal very seriously with the complex evaluation requirements. A first assessment of the scope and content of evaluation plans of MSs shows considerable heterogeneity (EU CAP NETWORK, 2024). Current *evaluation plans* are therefore to be seen as an evolving instrument of the EC to incentivize MSs to engage in *evaluation* activities at an early stage of the programming period.

Literature

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MARKETS

THE IMPACT OF PRODUCT DIFFERENTIATION ON EXPORTS OF AGRICULTURAL AND FOOD PRODUCTS: EVIDENCE FROM GEORGIA

Ketevan Melkadze¹, Helena Engemann and Yaghoob Jafari

Summary

Product differentiation may involve higher production costs, but simultaneously, it could enhance consumers' perception of the product's value. Product differentiation can either boost or decline exports depending on which effect dominates. This article examines the role of product differentiation in exports of agriculture and food products using Georgian agri-food exports as an example. We utilize two different measures of product differentiation and estimate their impacts using empirical gravity equations with the Poisson Pseudo Maximum Likelihood estimator. The analysis revealed that product differentiation is associated with increased export of agricultural and food products. This highlights the significance of employing strategies for product differentiation to enhance the export of agricultural and food products.

Keywords

Product differentiation, agri-food export, Georgia, PPML.

Introduction

The growing importance of product differentiation in the agricultural and food industry (McCluskey and Winfree, 2022) driven by innovative technologies and creative approaches in industrial nations, as well as its relevance in trade, especially in developing countries, necessitates an examination of its role (Agritrade, 2012). Distinguishing a product through unique features may result in increased production expenses; however, it can also elevate the perceived value of the product for consumers. The impact on exports depends on whether the positive or negative effect is more prominent. Should countries view product differentiation as an export strategy? Answering this question helps policymakers formulate policies in line with the enhanced competitiveness of the agri-food sector and the potential for further growth. The analysis is also of direct relevance for firms whose profitability is driven by product differentiation. This paper analyzes the impact of product differentiation on exports in agri-food sector at the example of the Georgian agri-food industry. Georgia is an interesting case study to examine this issue because it is a small economy with high import dependence on agricultural products but with the potential for sectoral export expansion (WORLD BANK, 2022). Agri-food exports accounted for more than half (52%) of the total output of the agricultural sector in 2022 (NATIONAL STATISTICS OFFICE OF GEORGIA, 2023).

Product differentiation can impact exports, as differentiated products may better align with diverse consumer preferences and/or concurrently heighten consumers' perceived value of the product. However, setting a product apart with distinctive features may lead to higher production costs. The effect on exports hinges on whether the positive or negative impact is more pronounced.

We contribute to the literature in three different ways. First, this study is the first empirical attempt to analyze the impact of product differentiation on exports. Second, this study uses two alternative measure of product differentiation that can be used to analyze the impacts. Based on

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the literature several measures may be utilized to measure product differentiation. RAUCH's (1999) classification of products is widely used and tested in empirical literature. Rauch classifies products into three groups: organized exchange goods (homogeneous), goods with reference prices (semi-differentiated), and differentiated goods (RAUCH, 1999). The second measure used in this work is the product-level trade elasticities calculated by FONTAGNÉ et al. (2022) as an indicator of product differentiation since they show that product differentiation drives the magnitude of trade elasticities. Specifically, highly differentiated products have lower trade elasticities in absolute terms (FONTAGNÉ et al., 2022). This work is unique, and to our knowledge, there is no existing research analyzing the impact of product differentiation using alternative measures on trade. Third, this paper analyzes the determinants of export flows under three distinct classifications of products: homogeneous, semi-differentiated, and differentiated.

2 Trade theories and product differentiation

Product differentiation in trade models

Various trade theories have been developed during the last two centuries which vary based on their assumptions to explain patterns of trade (RICARDO, 1817; HECKSCHER, 1919; OHLIN, 1933). Classical trade models (Ricardo and Heckscher Ohlin trade models) assume that product are homogeneous and consumer preferences are identical, and therefore these models do not consider the importance of product differentiation. In Ricardo's framework differences between countries' technology are the reason for trade and in the Heckscher-Ohlin model the differences in resource endowment explain trade patterns. Armington model is indeed developed to highlight the importance of product quality differentiation to produce a better picture of the international trade flows. In this model, products are differentiated depending on the country of the origin but the role of products differentiated within each nation is still ignored in Armington-based models.

KRUGMAN (1979) developed a new theory in which trade in horizontally differentiated products takes place due to increasing returns to scale in a monopolistic competition market². As Krugman's model assumes that firms are homogeneous, in the Krugman model and other closely related models (HELPMAN and KRUGMAN, 1985), products are considered equally substitutable. Therefore, these models do not account for a significant portion of trade in vertically differentiated products, which involves ranking goods according to their objective quality (AYUDA et al., 2022). MELITZ (2003) developed a trade theory in which productivity-heterogeneous firms produce horizontally differentiated products. As firms in Melitz have different productivity, several attempts have been made to introduce vertical product quality differentiation into Melitz model and to enhance our understanding of trade patterns.

Measuring product differentiation

Measuring product differentiation is challenging. SARKER and SURRY (2006) categorize differentiation into three main types: national, vertical, and horizontal. National differentiation, as per ARMINGTON's (1969) model, distinguishes between agricultural products based on their country of origin. Vertical differentiation entails the classification of goods based on their inherent quality, while horizontal differentiation considers consumers' subjective opinions and preferences when evaluating products (SARKER and SURRY, 2006).

BASTOS and SILVA (2010) consider RAUCH's (1999) work as an important step forward in the empirical study of product differentiation. They have shown that Rauch's classification is well-suited to capture quality differentiation (BASTOS and SILVA, 2010). RAUCH (1999) classified

² The theory of product differentiation was first introduced in CHAMBERLIN'S (1933) work on monopolistic competition. According to this theory, consumers have product preferences in the same industry, and companies use new technologies and innovative methods to differentiate their products in the marketplace (HARROD, 1933).

all commodities into three product categories: homogeneous goods, semi-differentiated goods, and differentiated goods. Homogeneous goods refer to the organized exchange goods (e.g., corn, oil, wheat, etc.) as consumers may neither know nor care about the supplier of the goods they are buying (HERMAN and LEE, 2019). Semi-differentiated products are those with reference prices (e.g. prices are listed in catalogs) and have some unique characteristics (e.g., quality may vary by source country), but are fundamentally substitutable (HERMAN and LEE, 2019). Differentiated products exhibit numerous common traits with comparable items but distinguish themselves through a distinctive selling feature. Rauch's classification is frequently used in the literature and therefore we use it as a primary measure of product differentiation.

The alternative measure is trade elasticities for highly detailed products whereas the trade elasticities provide information on the elasticity of substitution between products within those narrowly defined categories. The use of trade elasticities as a proxy for the degree of differentiation also follows the findings by FONTAGNÉ et al. (2022), who note that homogeneous products have higher trade elasticities than differentiated products in absolute terms.

3 Methodology

We analysed the impact of product differentiation on exports of agriculture and food products from Georgia. We utilize two measures of product quality differentiation (Rauch classification and trade elasticities) in a gravity framework using data at the Harmonized System (HS) 6-digit product level. We employ the Poisson Pseudo Maximum Likelihood (PPML) estimator technique, and our study encompasses the years 2000 to 2020.

A widely used method for analyzing panel data is the PPML estimator, which, unlike the log-linearized gravity model, accounts for heteroscedasticity and zero export values (SILVA and TENREYRO, 2006). The log-linearized model truncates zero-export observations, while PPML allows the inclusion of zero-export observations in the estimation model (HELPMAN et al., 2008).

The first model uses Rauch's classification of product differentiation. To test the effects of product differentiation on agri-food exports, differentiated and semi-differentiated product dummies were generated, which means that homogeneous product category was considered as a reference for comparison. The sign of these regression coefficients (α_1 and α_2) is expected to be positive and significant. The empirical form of the gravity equation is as follows:

$$\begin{aligned} \text{Logexports}_{ijt}^k &= \alpha_0 \\ &+ \alpha_1 \text{Differentiated}^k + \alpha_2 \text{Semi\_differentiated}^k \\ &+ \alpha_3 (\text{LogGDP}_{it}) + \alpha_4 (\text{LogGDP}_{jt}) + \alpha_5 \text{LogD}_{ij} \\ &+ \alpha_6 \text{Contiguity}_{ij} + \alpha_7 \text{FTA}_{ijt} + \alpha_8 \text{CIS}_{jt} + \alpha_9 \text{EU}_{jt} \\ &+ \alpha_{10} \text{Embargo}_t + \alpha_{11} \text{WTO}_{jt} + u_{ijt}^k \end{aligned} \quad (1)$$

Where k is the HS 6-digit product category. i represents Georgia, j represents the importing country, and the export year t varies between 2000 to 2020. exports_{ijt}^k is an export value of k product from Georgia (i) to importing country (j) at year t in thousands of current USD.

$$u_{ijt}^k = \mu_j + \delta_t + \varepsilon_{ijt}^k \quad (2)$$

where u_{ijt}^k is a total error term which combines μ_j unobserved individual effects, δ_t - unobserved time effects and ε_{ijt}^k - a random error.

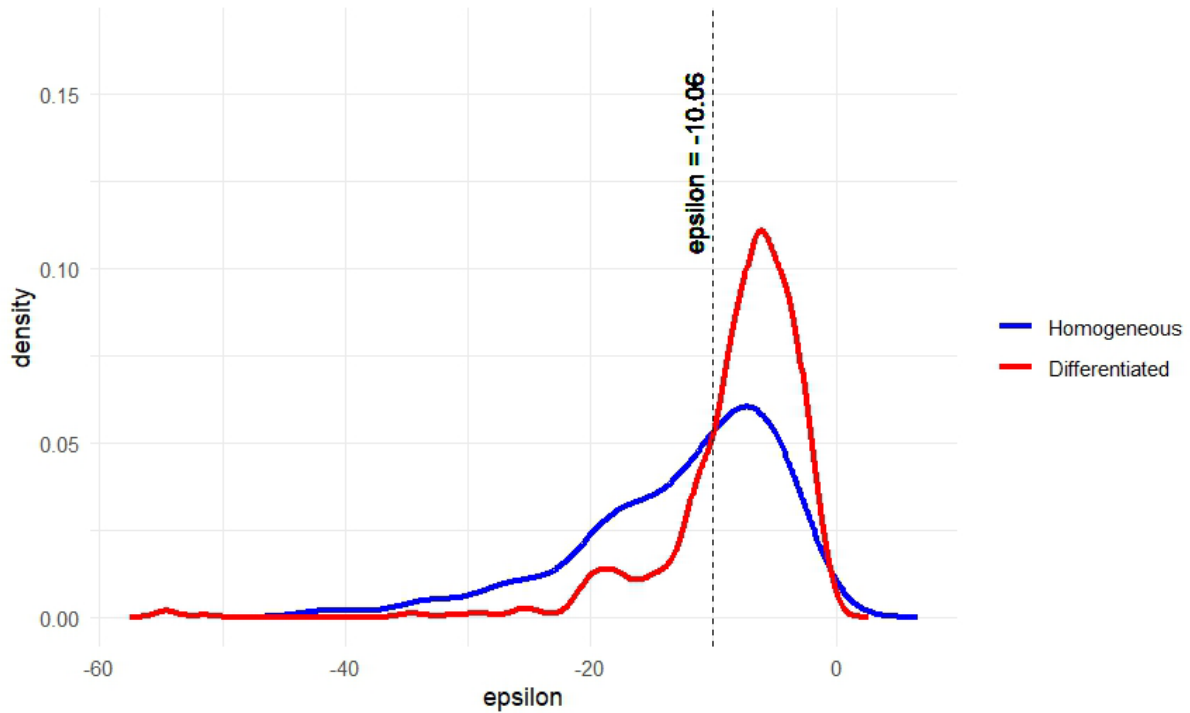
For the second model, we use the data from FONTAGNÉ et al. (2022) on the calculated trade elasticities for 6-digit HS products. The empirical form is the same as above.

$$\begin{aligned} \text{Logexports}_{ijt}^k &= \beta_0 + \beta_1 \text{LogInverseElasticity}^k + \beta_2 (\text{LogGDP}_{it}) \\ &+ \beta_3 (\text{LogGDP}_{jt}) + \beta_4 \text{LogD}_{ij} + \beta_5 \text{Contiguity}_{ij} + \beta_6 \text{FTA}_{ijt} \\ &+ \beta_7 \text{CIS}_{jt} + \beta_8 \text{EU}_{jt} + \beta_9 \text{Embargo}_t + \beta_{10} \text{WTO}_{jt} + \varphi_{ijt}^k \end{aligned} \quad (4)$$

Here, $\text{InverseElasticity}^k$ is the inverse of absolute value trade elasticities of product k.

Figure 1 shows that differentiated products tend to have smaller trade elasticities in absolute terms compared to homogenous products. Therefore, β_1 was expected to be positive and significant.

Figure 1: Distribution of trade elasticities for homogeneous and differentiated products based on Rauch's classification.



Source: Own representation based on Rauch's (1999) and FONTANGE et al. (2022) data.

4 Data sources and preparation

Trade flow data at the 11-digit level HS are provided by the National Statistics Office of Georgia. The data on exports from Georgia covers the period 2000-2020 for Chapters 01-24, 41, 43, 50-53 from HS.

Data for the period 2000-2020 on geographic distances between capitals, trade agreements, exporter and importer GDPs, and the EU and WTO membership were extracted from the CEPII geography database. After selecting the exporter country of Georgia and excluding data points where gravity variables were missing for all observation years, the final gravity variables dataset contains 3,608 observations for 164 destination countries.

Rauch uses two types of aggregations, conservative and liberal. In the liberal aggregation, all marginal goods are placed in the less differentiated of the two possible classifications, while in the conservative aggregation, they are placed in the more differentiated classification. We use both in our analysis to see if there are noticeable differences. Since the Rauch classification was provided in SITC4 format, we map this to HS6 using the R package "concordance". The Rauch dataset for 6-digit HS product codes contains 5,183 observations. After selecting only agricultural product categories the dataset is reduced to 1,002 observations.

Data on trade elasticities at the product level are obtained from FONTAGNÉ et al. (2022). This dataset contains trade elasticities calculated at 1% significant tariff elasticity, i.e., tariff elasticity parameters that were significant at a 1% statistical significance level. The original trade elasticity data contain 5,050 estimated trade elasticities for HS 6-digit product categories. Since only agri-food products are used, this number is reduced to 985.

Variables for the distance between Georgia and the importing country and GDPs were log-transformed. A variable for CIS membership (Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Uzbekistan) was also created since Georgia was a member of CIS until 2008. Finally, A dummy variable was created for the Russian embargo for 2006-2011 for all products and destinations.

Export data were used in all models. After aggregation at the 6-digit level and data cleaning, we obtained 846 unique products and 94,300 observations. The data were rectangularized and missing values for exports were replaced with zeros. After rectangularization, we have all combinations for HS 6-digit products for each destination country and period. Therefore, the expanded observations are now 2,415,420.

Table 1: Total exports, unique products, and destination countries by years based on the original export data.

<i>Year</i>	<i>Total Export (1000 USD)</i>	<i>Unique HS 6-digit Products</i>	<i>Unique Destination Countries</i>
2000	34817	163	51
2001	32724	154	50
2002	32326	139	52
2003	39626	171	61
2004	50728	220	59
2005	52669	246	69
2006	60344	214	61
2007	69652	171	60
2008	78398	201	59
2009	77205	209	71
2010	95711	220	74
2011	101324	238	75
2012	104582	296	74
2013	120010	319	77
2014	125353	311	78
2015	129009	317	77
2016	141814	342	86
2017	155512	358	90
2018	174835	375	92
2019	184031	414	95
2020	185134	401	92

After merging these data with the gravity variable data, we get 1,990,170 observations for 117 importing countries. We combined these data with Rauch's data for the first and the elasticity data for the second model. After combining with Rauch's classification data, we obtained 1,761,669 observations for 717 6-digit products. After combining the same data with the elasticity data, we obtained 1,587,222 observations for 646 unique 6-digit products. We lost on average 22 products per year and 11 destination countries per year. However, combined data covers at least 81% of the total annual export value (Table 2).

Table 2: Total exports, unique products, and destination countries by years based on final combined data.

<i>Year</i>	<i>Total Export (1000 USD)</i>	<i>Unique HS 6-digit Products</i>	<i>Unique Destination Countries</i>
2000	28524	125	41
2001	26786	114	43
2002	26334	112	45
2003	32399	140	49
2004	41396	184	51
2005	45997	209	60
2006	52519	180	52
2007	58773	143	49
2008	64751	161	47
2009	71363	201	61
2010	88648	211	63
2011	95821	232	65
2012	101035	288	62
2013	114300	306	66
2014	116977	297	67
2015	117305	300	66
2016	126708	322	74
2017	137168	340	75
2018	160577	360	81
2019	167594	402	79
2020	171479	389	79

5 Results and discussion

As described above, the first model was tested for both the liberal and conservative classifications of agri-food products. First, the PPML without fixed effects was applied to the data. Then, the fixed effects for the importer country and time were added. To test whether the model was correctly specified or if there were omitted variables, incorrect functional form, or other issues, we used the RESET test. P-value in the first specification without any fixed effects, suggesting there is a mild indication of potential specification issues, but it's not strong enough to be statistically significant at the 5% level. However, all other model specifications with fixed effects successfully passed the reset test, which means that models are correctly specified. The results of liberal classification can be found in Table 3.

Table 3: Impact of product differentiation (with Rauch's liberal classification) on exports

<i>VARIABLES</i>	<i>CLUSTERED BY PANEL_ID</i>	<i>WITH IM- PORTER FIXED EFFECTS</i>	<i>WITH IMPORTER AND TIME-FIXED EFFECTS</i>	<i>WITH IM- PORTER-TIME FIXED EFFECTS</i>
<i>DIFFERENTIATED_LIB</i>	-0.172 (0.126)	-0.172 (0.125)	-0.173 (0.125)	-0.173 (0.126)
<i>SEMI-DIFFERENTIATED_LIB</i>	0.767*** (0.135)	0.767*** (0.144)	0.767*** (0.144)	0.768*** (0.144)
<i>LOGGDP_GEORGIA</i>	0.469*** (0.0944)	0.738*** (0.119)	0.739*** (0.120)	0.742*** (0.119)
<i>LOGGDP_IMPORTER</i>	0.480*** (0.0566)	0.286 (0.220)	0.286 (0.220)	0.283 (0.219)
<i>LOGDIST</i>	-1.096*** (0.130)			
<i>CONTIGUITY</i>	-0.724** (0.322)			
<i>WTO</i>	-0.136 (0.133)	-0.0962 (0.118)	-0.0967 (0.118)	-0.0963 (0.118)
<i>EU</i>	-0.296 (0.265)	0.360 (0.285)	0.360 (0.284)	0.362 (0.281)
<i>FTA</i>	1.081*** (0.219)	0.230*** (0.0626)	0.230*** (0.0628)	0.226*** (0.0622)
<i>EMBARGO</i>	-0.146** (0.0726)	-0.259** (0.122)	-0.259** (0.122)	-0.258** (0.122)
<i>CIS</i>	1.091*** (0.295)			
<i>CONSTANT</i>	-8.621*** (1.517)	-16.33*** (3.357)	-16.33*** (3.356)	-16.21*** (3.341)
<i>OBSERVATIONS</i>	1,672,761	1,642,647	1,642,647	1,039,724
<i>RESET P-VALUE</i>	0.0666	0.523	0.522	0.542

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The results show that the coefficient of the dummy variable for differentiated products is negative and statistically insignificant. In contrast, the coefficient of the dummy variable for semi-differentiated products is positive and statistically significant. This means that semi-differentiated products mainly drive agri-food export growth. Exports of semi-differentiated products are associated with an approximately $[\text{Exp}(0.77) - 1] \times 100 = 116$ % increase in export value compared to homogeneous products, all else being equal.

A relatively different picture was obtained in the case of conservative aggregation. This time our hypothesis was rejected and, in all specifications, we obtained a statistically significant and negative coefficient for differentiated products. In particular, on average, the export value for differentiated products is approximately 31% lower compared to homogeneous products, all else being equal. In the case of semi-differentiated products, we get that the export value of this category is on average 67% higher than the export value of homogeneous products.

Table 4: Impact of product differentiation (with Rauch's conservative classification) on exports

<i>VARIABLES</i>	CLUSTERED BY PANEL_ID	WITH IMPORTER FIXED EFFECTS	WITH IMPORTER AND TIME-FIXED EFFECTS	WITH IMPORTER- TIME FIXED EF- FECTS
<i>DIFFERENTIAL- TED_CON</i>	-0.365*** (0.128)	-0.365*** (0.105)	-0.366*** (0.105)	-0.366*** (0.106)
<i>SEMI-DIFFERENTIAL- TED_CON</i>	0.505*** (0.135)	0.505*** (0.121)	0.504*** (0.121)	0.505*** (0.121)
<i>LOGGDP_GEORGIA</i>	0.469*** (0.0944)	0.738*** (0.119)	0.739*** (0.120)	0.743*** (0.119)
<i>LOGGDP_IMPORTER</i>	0.480*** (0.0566)	0.286 (0.220)	0.286 (0.220)	0.281 (0.219)
<i>LOGDIST</i>	-1.096*** (0.130)			
<i>CONTIGUITY</i>	-0.724** (0.322)			
<i>WTO</i>	-0.136 (0.133)	-0.0962 (0.118)	-0.0968 (0.118)	-0.0967 (0.118)
<i>EU</i>	-0.296 (0.265)	0.360 (0.285)	0.359 (0.284)	0.362 (0.283)
<i>FTA</i>	1.081*** (0.220)	0.230*** (0.0626)	0.230*** (0.0627)	0.226*** (0.0622)
<i>EMBARGO</i>	-0.146** (0.0726)	-0.259** (0.122)	-0.259** (0.122)	-0.258** (0.122)
<i>CIS</i>	1.091*** (0.295)			
<i>CONSTANT</i>	-8.470*** (1.518)	-16.18*** (3.367)	-16.18*** (3.366)	-16.05*** (3.353)
<i>OBSERVATIONS</i>	1,672,761	1,642,647	1,642,647	1,039,724
<i>RESET P-VALUE</i>	0.0679	0.340	0.339	0.352

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

It is also worth noting that the influence of Georgia's GDP on export growth decreases as we move from a homogeneous product to a differentiated one, while the influence of the destination country's GDP increases. This might be because differentiated products often rely more on niche markets and specific consumer preferences rather than general economic conditions of the exporting country. However, the negative impact of distance as a measure of transportation costs is highest for homogeneous products and lowest for semi-differentiated products. Homogeneous products are likely to be traded in higher volumes, so transportation costs can be a more substantial burden. The influence of free trade on export growth was highest for semi-differentiated products, while the influence of the Russian embargo on exports was not significant for products in the same category (Table 5). The highest influence of free trade agreements on semi-differentiated products indicates that these products benefit significantly from reduced trade barriers.

Table 5: Determinants of exports across different product categories

<i>VARIABLES</i>	HOMOGENEOUS	SEMI-DIFFERENTIATED	DIFFERENTIATED
<i>LOGGDP_GEORGIA</i>	0.563*** (0.144)	0.480*** (0.145)	0.331** (0.164)
<i>LOGGDP_IMPORTER</i>	0.451*** (0.0675)	0.463*** (0.0895)	0.566*** (0.0856)
<i>LOGDIST</i>	-1.304*** (0.171)	-0.963*** (0.203)	-1.195*** (0.216)
<i>CONTIGUITY</i>	-0.413 (0.348)	-0.892* (0.499)	-0.517 (0.443)
<i>WTO</i>	-0.262 (0.196)	-0.141 (0.198)	0.00637 (0.278)
<i>EU</i>	-0.239 (0.265)	-0.274 (0.456)	-0.373 (0.312)
<i>FTA</i>	0.447** (0.220)	1.343*** (0.367)	1.087*** (0.292)
<i>EMBARGO</i>	-0.228** (0.0923)	-0.0675 (0.115)	-0.254** (0.106)
<i>CIS</i>	0.818*** (0.297)	1.201** (0.494)	1.046*** (0.394)
<i>CONSTANT</i>	-7.543*** (2.401)	-8.887*** (2.399)	-7.551*** (2.457)
<i>OBSERVATIONS</i>	536,590	580,917	555,254

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In the alternative model specification, product-level trade elasticities were used to measure product differentiation, as differentiated products tend to have smaller trade elasticities in absolute terms. We used the inverse of absolute value trade elasticities. The bigger the inverse value, the greater the product differentiation. We tested the model specification using the RESET test to check for omitted variables and model functional forms, which suggested the model was correctly specified.

Table 6 shows that we have a positive and significant coefficient on the inverse of absolute trade elasticity, which suggests that products with higher levels of differentiation (smaller trade elasticities in absolute terms) are associated with increased exports from Georgia. In particular, a 1% reduction in trade elasticity in absolute terms is associated with a 0.51% increase in export value. This is consistent with the theory that differentiated products tend to have lower trade elasticities and can command higher prices in export markets.

Table 6: Impact of product differentiation (inverse trade elasticities) on exports

<i>VARIABLES</i>	CLUSTERED BY IMPOR- TER	WITH IM- PORTER FIXED EFFECTS	WITH IMPORTER AND TIME-FIXED EFFECTS	WITH IMPORTER- TIME FIXED EF- FECTS
<i>LOG_INVERSE ELASTI- CITY</i>	0.508***	0.508***	0.508***	0.508***
	(0.0713)	(0.0713)	(0.0713)	(0.0712)
<i>LOGGDP_GEORGIA</i>	0.342*	0.616***	0.616***	0.617***
	(0.175)	(0.131)	(0.131)	(0.130)
<i>LOGGDP_IMPORTER</i>	0.488***	0.313	0.312	0.315
	(0.0806)	(0.225)	(0.225)	(0.225)
<i>LOGDIST</i>	-1.111***			
	(0.195)			
<i>CONTIGUITY</i>	-0.800**			
	(0.383)			
<i>WTO</i>	-0.115	-0.169	-0.168	-0.168
	(0.161)	(0.131)	(0.131)	(0.132)
<i>EU</i>	-0.320	0.403	0.401	0.394
	(0.427)	(0.294)	(0.295)	(0.292)
<i>FTA</i>	1.119***	0.241***	0.241***	0.238***
	(0.392)	(0.0690)	(0.0691)	(0.0692)
<i>EMBARGO</i>	-0.0920	-0.222*	-0.222*	-0.223*
	(0.164)	(0.126)	(0.126)	(0.126)
<i>CIS</i>	1.081**			
	(0.469)			
<i>CONSTANT</i>	-5.343	-13.57***	-13.56***	-13.50***
	(3.325)	(3.318)	(3.320)	(3.321)
<i>OBSERVATIONS</i>	1,507,118	1,493,552	1,493,552	923,859
<i>RESET P-VALUE</i>	0.471	0.203	0.202	0.203

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The control variables included in the model also showed interesting results. As the results show, the growth of the export of agro-food products from Georgia is mainly determined by the gross domestic product of the country, while the gross domestic product of the destination country does not take any part in the growth of exports, which is logical because Georgia is a country with a small economy. In addition, it appeared that during the period of the Russian embargo (2006-2011), the export of agricultural products from Georgia was on average 20-23% lower, and the free trade agreements increased the value of the export of agricultural products by an average of 26-27%.

6 Conclusions

By demonstrating that product quality differentiation - both horizontal and vertical - is a crucial element in explaining trade patterns, this study represents the first empirical attempt to analyze the impact of product differentiation on export patterns.

The initial model specification utilizes Rauch's liberal and conservative classifications, which are widely used in empirical literature on product differentiation (Serrano and Pinilla (2014); Biesebroeck et. al (2022)). The results indicate that semi-differentiated agri-food products are

the primary drivers of export growth from Georgia. These products show a significantly positive effect on export value compared to homogeneous and fully differentiated products, particularly under both liberal and conservative classifications.

Although Rauch's classification has been empirically proven to capture vertical product differentiation, it may not fully address contemporary complexities in product differentiation, suggesting a need for updated measures (Bastos and Silva, 2010). Category composition may change over time - particularly when a product previously considered homogeneous or semi-differentiated experiences improvements in quality or other characteristics, potentially reclassifying it as a differentiated product. Therefore, we adopted an alternative approach.

The alternative model, which uses trade elasticities as a measure of product differentiation, reveals that products with higher levels of differentiation (i.e., lower trade elasticities) are positively associated with increased export value. This finding is consistent with economic theory, suggesting that more differentiated products command higher prices and contribute more significantly to export growth.

Our results highlight the importance of understanding and applying product differentiation strategies to increase Georgian agricultural and food exports in the global market. Thus, Georgia's export strategy should prioritize promoting highly distinctive products in terms of both quality and quantity. Active participation in international exhibitions and the creation of a unified national brand are essential steps toward increasing global recognition of Georgian products as superior or unique.

These findings should be considered in light of certain limitations. While the analysis used very granular, 6-digit export product data, the focus was limited to the agri-food sector, which is generally more homogeneous compared to industries such as manufacturing. A more comprehensive study including products from all industries would yield more reliable results regarding the impact of product differentiation on export levels. Additionally, it is crucial to ensure that the selected metrics accurately capture the extent of product differentiation. Future research should consider alternative or additional measures of product differentiation, as Rauch's classification may evolve; a product once classified as homogeneous may now be considered differentiated.

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PREFERENCE SHIFT AND TRADE POLICIES AS BOOSTERS OF POULTRY-PROCESSING DEVELOPMENT IN BENIN?

Agossoussi Thierry Kinkpe¹, Harald Grethe, Jonas Luckmann

Abstract

Poultry meat is a cheap protein source for human consumption and its production has a lower carbon footprint in comparison to other animals. Therefore, poultry meat is a protein source to be promoted. This meat is highly imported in Benin, despite the local potential of production. There is a newly established poultry-processing sector in Benin, which needs support to be able to compete with these imports. To analyze the economy-wide effects of poultry-processing development in Benin, we conducted an empirical study to support our Computable General Equilibrium (CGE) analysis. We simulate the economy-wide effects of preference shifts and trade policies in the poultry meat sector for Benin. Results show that preference shift has a high potential of decreasing poultry meat imports, protecting the domestic market, and boosting domestic production. This is then an internal shift in consumer behavior which allows the protection of infant industries as the traditional infant industry protection instruments (trade policies) do. Combining the preference shift with trade policies produces bigger production and trade effects. We conclude that working on preference shifts can be a serious alternative to trade restriction policies in infant industry protection.

Keywords

Consumer behavior, Infant industry, Tariff or Ban, West Africa

1 Introduction

Poultry farming for meat purposes is an important economic activity in Benin, providing more than 1% of the national Gross Domestic Product (GDP) and more than 4% of the agricultural GDP (KINKPE et al., 2022). It is a complementary income source for smallholder farmers. Poultry products constitute the second main protein source for consumers (FAOSTAT, 2021; WORLD BANK, 2021; USDA, 2014). The domestic production is low related to the demand, which is met with additional huge imports of frozen poultry meat (FAOSTAT, 2021; WORLD BANK, 2021).

Despite its relative importance, the poultry sector has benefited from little policy and research attention. In 2021, a study on the sector showed that the huge imports of frozen chicken impacts negatively the domestic sector which cannot compete price-wise with the low-value imported frozen poultry meats (KULLA et al., 2021). In fact, most of the imports are made of low-value chicken parts (ready-to-cook), especially from the European Union (EU) and to some extent from Brazil (INSAE, 2018). As low-value parts in the countries of origin, these products are typically exported at very competitive prices. Consequently, they distort the market in the destination countries. While the imports are mainly chicken legs and wings, the domestic production is the whole bird, without further differentiation. Hence, the price per kilogram of imported poultry meat is (far) below the market price of the domestic product (KULLA et al., 2021). As a result, the domestic production of poultry has not increased relative to the population growth, while imports have highly increased (FAO, 2015). Furthermore, even if the imported frozen

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poultry meat is well conserved during its transportation, the good conservation may be problematic in the destination country due to cooling chain problems (unstable electricity), which can create microbiological issues (DAHOUENON AHOUSI et al., 2008) and therefore, health issues. Moreover, the repetitive crises occurring in the world these last years, bring the awareness of populations, especially in the global south countries to the fact that relying on food imports can be problematic in some circumstances.

Poultry is among the cheapest sources of protein with relatively low GHG emissions per kg of protein due to the good feed conversion. Its GHG emissions related to beef production (the other major meat in Benin) are much lower. In addition, well-developed processing chains would reduce health risks due to hygienic issues resulting e.g. from the importation of frozen chicken parts. Therefore, if the domestic production potential exists, it would be better to develop it.

Poultry-processing into ready-to-cook poultry meat started in Benin to fill the production gap (KULLA et al., 2021). The sector is still small but progressing. It can be considered as an infant industry regarding all the above-described international competition situation (KRUEGER and TUNCER, 1982; GREENWALD and STIGLITZ, 2006; GOVERS, 2012).

To boost the poultry-processing sector, Benin government integrates a huge modern slaughterhouse project in the Glo Djigbé Industrial Zone (GDIZ), which construction is in progress in Benin (GDIZ, 2021). This project could support domestic poultry-processing and make ready-to-cook poultry meat available for consumers. In that regards, Benin government is also planning to ban poultry meat imports from 31 December 2024 on (ADJIMEHOSSOU, 2023), in order to protect the domestic production. Marketing campaign is nationally organized to support the domestic product value-chains. The October month is dedicated to the “*consommons local*” (let’s consume domestic products) concept in West-African Economic and Monetary Union (WAEMU) country members including Benin. Fairs are organized for better awareness and promotion of domestic products (BENIN GOVERNMENT, 2022).

So far, there is no research targeting to study the economy-wide effects of these governmental intentions and projects. As the poultry-processing is a newly established activity in Benin, we first conduct an empirical study to understand better the sector, and to be able to model it suitably. Through this empirical study, we understand better the sector and collect some suggestions from the actors. Based on the information collected, we tackle the following research question: can preference shift and trade policies contribute to boosting the poultry-processing development in Benin?

In the method section, after detailing the theoretical framework of this paper, we provide more details on the poultry sector in Benin. Then, we describe the database used for the modeling as well as the model settings used. We provide the information on the simulated scenarios based on the empirical study to close the method section. In the result and discussion section, we first detail the information collected from the empirical study before exposing the simulation results. We close this section with a general discussion of the results. We close the paper by concluding remarks and policy implications.

2 Method

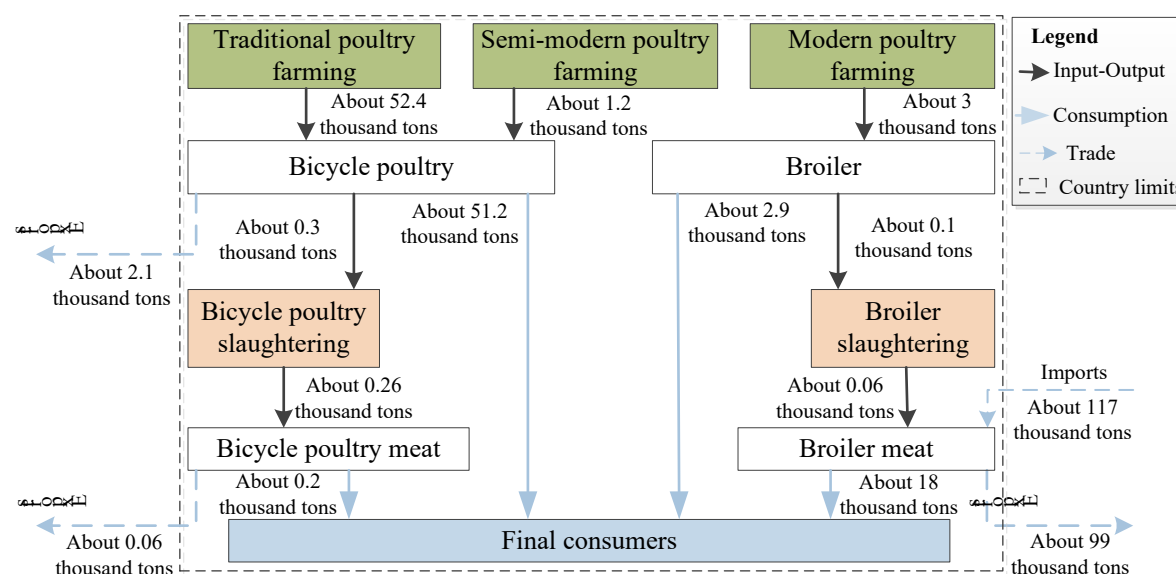
2.1 Poultry sector in Benin

In Benin, three poultry production systems can be distinguished: traditional, semi-modern and modern (KULLA et al., 2021). The traditional system produces about 90% of the total production while the semi-modern system produces less than 2%, and the modern system produces about 8% (Figure 1). Traditional and semi-modern systems are raising mostly traditional breeds called “*bicycle poultry*” (Figure 1). In the traditional system, which is practiced by almost all rural

households, no antibiotics are used. The animal diet consists of kitchen waste and harvest residues. In the semi-modern system, some extra feed is provided. The modern system, producing mostly imported breeds called “broiler” (Figure 1), is not industrialized. The size of the flock is relatively small (typically 1000-5000 heads) (KULLA et al., 2021). Labor is used intensively. Benin consumers purchase either the live poultry and do the slaughtering and related works themselves or the ready-to-cook poultry meat (Figure 1). More than 99% of total domestic poultry production is purchased alive without intermediate processing steps (KINKPE et al., 2022).

The domestic poultry (meat) production is far lower than the demand (FAOSTAT, 2021; WORLD BANK, 2021). Therefore, poultry meat is highly imported to meet the demand (Figure 1). In 2018/2019 about 117 thousand tons of poultry meat were imported by Benin (FAOSTAT, 2021). Most of the imported poultry meat is either broiler chicken parts (wings and legs), which are almost not consumed in the European Union (EU) countries producing them or meat from reformatted laying hens which are not consumed in the EU because of its low quality (KULLA et al., 2021). These meats (low-value in the producing countries) are exported to Benin at very cheap prices and compete strongly with the domestic sectors. They are particularly attractive to the consumers because of the price but also because there are ready-to-cook. Consumers, especially in urban areas are decreasingly interested in doing the slaughtering and related works before cooking the meat (KULLA et al., 2021). The poultry-processing into meat starts in Benin and produce “bicycle poultry meat” and “broiler meat” (Figure 1) but the sector is still very small and cannot compete with the imported meat in the above-mentioned conditions. Therefore, the current situation is in favor of imports and impacts negatively the domestic sectors (KULLA et al., 2021). Also, due to the price conditions, more than 80% of the poultry meat imported by Benin is re-exported, especially to Nigeria (USDA, 2014) because of the proximity and the attractiveness of the Nigerian market in that regards (smuggling). The bicycle poultry itself as well as a small share of its meat are also exported (Figure 1). The smuggling of imported poultry meat to Nigeria has created discord between Benin and Nigeria in the past because Nigeria is currently protecting its domestic market from overseas imports of frozen broiler meat.

Figure 1. Poultry sector in Benin



Source: Own compilation based on survey data and secondary data (USDA, 2014; FAOSTAT, 2021; KULLA et al., 2021; KINKPE et al., 2022).

2.2 Database

We use a 2019 Social Accounting Matrix (SAM) for Benin (KINKPE et al., 2022) with a high degree of disaggregation of agriculture and the food-processing sector. This SAM is a snapshot of Benin's economy as a whole and the transactions between different institutions in 2019. For the purpose of this study, this SAM was further disaggregated based on Figure 1 (see section 2.1).

The final SAM used for simulations contains 125 accounts: 46 activities (including a traditional poultry farming, a semi-modern poultry farming and a modern poultry farming; bicycle poultry-processing and broiler processing as suggested by the sector description); 3 margins; 50 commodities (including 2 bicycle poultry commodities produced respectively by the traditional and the semi-modern poultry farming systems, a broiler produced by the modern poultry farming system, a bicycle poultry meat and a broiler meat); 2 labor factors (unskilled and skilled), 2 capital factors (agricultural, non-agricultural), 2 land factors (annual crop land, permanent crop land and pasture); enterprises; 10 private household groups (5 rural income quintiles and 5 urban income quintiles); government and the rest of the world; 6 tax accounts (direct tax, production tax, value-added tax, sales tax, import tariff and export tax) and a saving-investment account.

2.3 Model and closure rules

As agriculture (in general) is a large sector in Benin and poultry farming (in particular) is a relatively large sector, distributed all over the country, having implications on the use of production factors, we use a Computable General Equilibrium (CGE) model based on the Static Applied General Equilibrium - STAGE model (MCDONALD and THIERFELDER, 2015) for the analyses. The production function is expanded to consider capital and land disaggregation as suggested by KINKPE et al. (2023). The above-described SAM (see section 2.2) is used as database to calibrate the CGE model

The two labor categories (skilled and unskilled) are modeled as fully mobile. Capital is fully mobile within a sector but cannot move from one sector to another.

The land is also fully mobile within a sector but is specific to that sector. Annual crop land; permanent crop land and pasture are clearly distinguished for that reason. We fix the annual crop land to the annual crops to avoid its movement to the poultry farming (when this will develop) as this movement is not likely to happen in reality. A certain level of annual crop production is needed to ensure food security. In addition, poultry farming cannot easily be combined with annual crop farming on the same land, as the animals would destroy the crops. Therefore, Benin government would certainly make sure that a certain amount of land is kept under annual crops. As far as permanent crops and animal husbandry are concerned, they can share the same land at the adult stage of the permanent crops. At that stage, animals would not be able to destroy the trees anymore.

As Benin belongs to the West-African Economic and Monetary Union (WAEMU) using a currency called FCFA, which is pegged to Euro with a fixed parity, we use a fixed Exchange Rate (ER) closure with a flexible trade balance. The model is investment-driven with a fixed investment share in total demand. The internal balance (government savings) is fixed and the income tax rate on households is flexible to collect more tax from high-income households to finance the policies. The Consumer Price Index (CPI) is the numeraire in the economy (fixed). Benin is assumed to be a small country (fixed world market prices).

2.4 Empirical studies and scenario development

To support the simulations with empirical evidences, we organized an empirical study (survey) in Benin. We collected data from poultry processors using semi-structured interviews. As the

poultry processors are not well known, we used the snowball method for the sampling. That way, we met in total 11 processors. To deeply understand the poultry-processing sector in Benin, the discussions with the processors were about the poultry-processing activity, the market potential for the domestic poultry meat, challenges and policy options suggested.

Here, we give an overview (of this study) on which, is based the scenario development for the simulations. According to poultry processors, the domestic demand for poultry meat is high and expanding. They argue that the government should promote domestic poultry meat to reach a preference shift from imported to local poultry meat and prevent / restrict the imports of frozen broiler meat by increasing the tariff rate.

Assuming that the government takes such measures, we simulate a preference shift from imported poultry meat to local poultry meat by shifting 12.1 thousand tons (about 30% of total poultry meat demand) of household demand for imported broiler meat (in the base situation) to the local poultry meat (bicycle), which is known as healthier and preferred by consumers for its taste (KULLA et al., 2021). This is the short-run preference shift. Furthermore, we assume that with the preference shift, the domestic poultry-processing sector will develop and demand more poultry in the long-run. Therefore, poultry farming will be more productive because of learning-by-doing (dynamic economies of scale). With the same housing, labor, and equipment, more poultry will be produced. Therefore, we simulate a 10% increase in productivity of the three poultry farming activities. This scenario is called PSHIFT+PROD and shows the effects of the preference shift in the long-run. To facilitate the understanding of the impact path, the long-run preference shift (PSHIFT+PROD) scenario is implemented in two steps. We first implement only the shift in preference (PSHIFT), which shows the effects of the demand shift only and can be considered as short-run preference shift. In the second step, we add the productivity increase on top of the PSHIFT to have the full PSHIFT+PROD scenario.

On top of the PSHIFT+PROD, we simulate two trade policies. First, we implement a tariff policy as suggested by the actors by doubling the import tariff rate on imported frozen broiler meat (PSHIFT+PROD+TARIFF). Second, we ban the import of frozen broiler meat (PSHIFT+PROD+BAN) as Benin government is willing to do from December 2024. For this last scenario, Benin is supposed to have a flexible world market price for the frozen broiler meat, so that this price can adjust endogenously to allow the import ban. That way, this last scenario allows also determining the price of the imported frozen poultry meat which allows to stop its import. The details of the four scenarios are presented in Table 1.

Table 1. Scenarios for poultry meat

Scenario	Household demand for bicycle poultry meat (thousand tons)	Household demand for broiler meat (thousand tons)	Total productivity of poultry farming (%)	Import tariff rate on frozen poultry meat (% points)	Imports of frozen poultry meat (%)
PSHIFT	+12.1	-12.1			-
PSHIFT+PROD	+12.1	-12.1	+10		-
PSHIFT+PROD+TARIFF	+12.1	-12.1	+10	+7.5	-
PSHIFT+PROD+BAN	+12.1	-12.1	+10		-85

Source: Own compilation.

3 Results and discussion

3.1 Economy-wide effect of poultry slaughtering development through preference-shift and trade policies

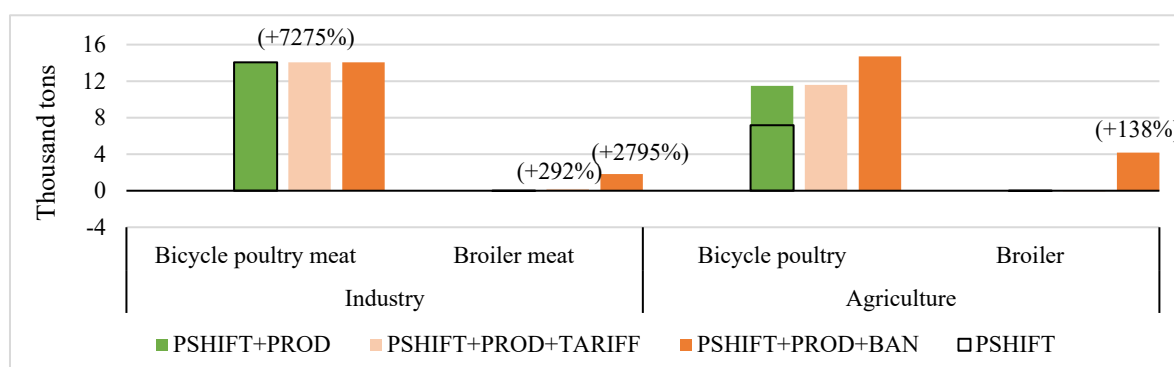
3.1.1 Domestic demand and consumer price effects

The preference shift of consumers in the long-run (PSHIFT+PROD) increases the consumer demand for bicycle poultry meat by about 12 thousand tons and lowers the consumer demand for broiler meat by about the same quantity. This is fully translated to the total domestic demand for domestic bicycle poultry meat (Figure 2) as it is 100% produced domestically and almost 100% consumed by domestic consumers. As far as domestic broiler meat is concerned, its total domestic demand does not change significantly (Figure 2). As bicycle poultry is the main intermediate input to domestically produced poultry meat, its domestic demand increases accordingly while the domestic demand for broiler decreases slightly because of decrease of broiler meat demand.

The effect of the preference shift in the short-run (PSHIFT) on the poultry meats (bicycle and broiler) demand is roughly the same as the effect of PSHIFT+PROD (long-run) while more than one-third of the effect on bicycle poultry farming is from the productivity increase induced by the preference shift in the long-run (Figure 2).

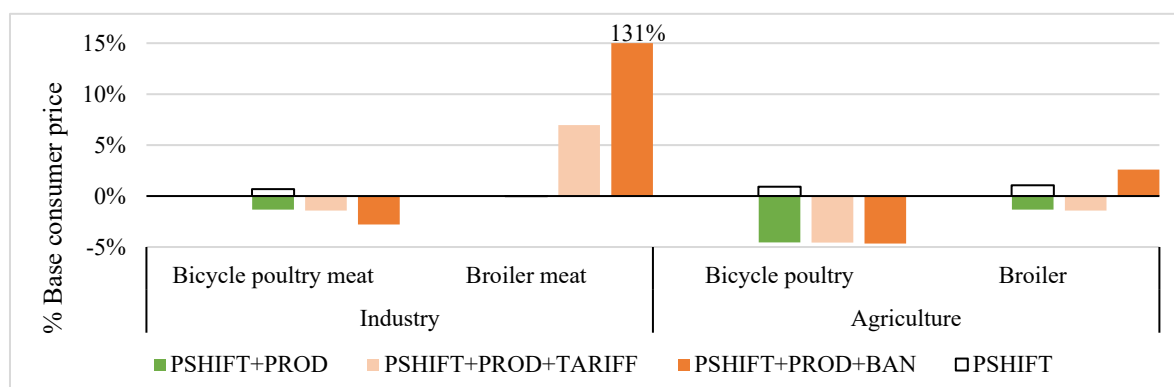
Trade policies on broiler meat (double import tariff under PSHIFT+PROD+TARIFF and import ban under PSHIFT+PROD+BAN) do not affect significantly the domestic demand of bicycle poultry meat which stabilizes at almost the same level as with only the preference shift, even though the domestic demand for bicycle poultry itself increases with these policies (Figure 2) to increase the domestic bicycle poultry meat production. These trade policies allow higher domestic demand of broiler (meat and alive) (Figure 2).

Figure 2. Change in domestic demand for domestic product (1000 tons)



Source: Own compilation based on simulation results.

Figure 3. Domestic consumer price change (%)



Source: Own compilation based on simulation results.

Under the long-run preference shift (PSHIFT+PROD), the consumer price of bicycle poultry meat decreases because of lower bicycle poultry price and the broiler meat price decreases because of lower domestic demand (Figure 3). The consumer prices of poultry (bicycle and broiler) decrease because of higher productivity in poultry farming (Figure 3) which more than compensates for the effect of demand shown by the increasing prices under the short-run preference shift (PSHIFT) scenario (Figure 3).

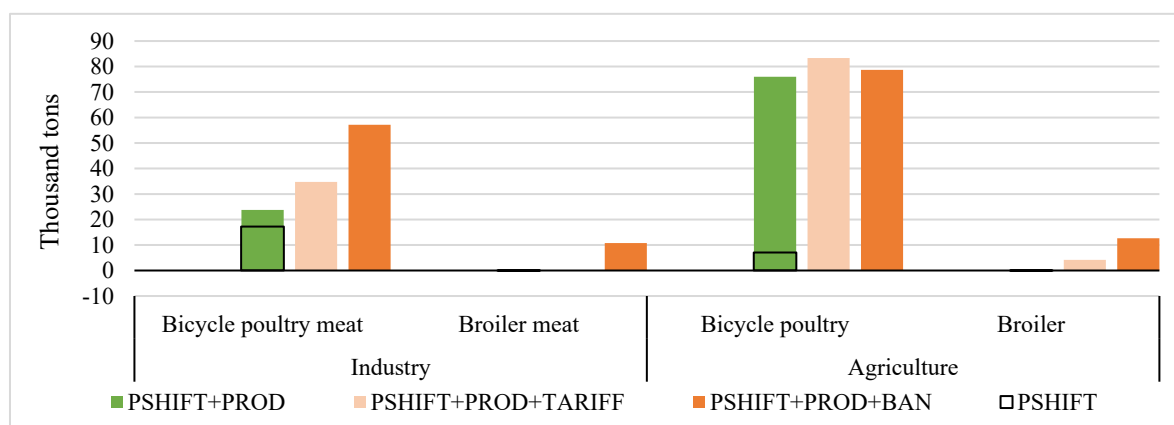
With a double import tariff (under PSHIFT+PROD+TARIFF), the broiler meat price increases accordingly. This price more than doubles (Figure 3) under the import ban (PSHIFT+PROD+BAN) as it becomes very scarce on the market. At the same time, the bicycle poultry meat price decreases under these two trade policies (Figure 3) because of the efficiency gain in poultry farming and the boost of bicycle poultry production. Therefore, broiler meat import restriction policies allow increasing the broiler meat price on the domestic market and lowering the bicycle poultry meat price on the domestic market increasing its competitiveness and its demand for exports increases.

3.1.2 Production and cost effects

With the long-run preference shift (PSHIFT+PROD) from broiler meat (mostly imported) to bicycle poultry meat (domestically produced), the domestic bicycle poultry meat production increases by about 24 thousand tons in comparison with the base (Figure 4) and the domestic broiler meat production increases just slightly because of higher productivity. Accordingly, bicycle poultry production is almost 76 thousand tons higher.

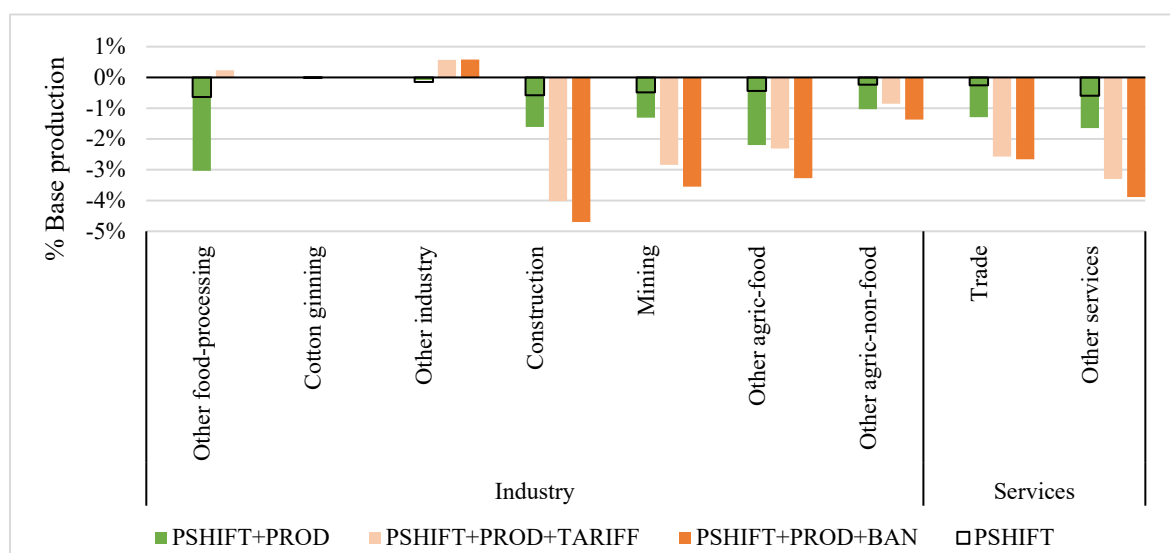
Doubling the import tariff on broiler meat (PSHIFT+PROD+TARIFF), maintains the broiler meat production at almost a status quo level (Figure 4). As far as import ban on broiler meat is concerned (PSHIFT+PROD+BAN), it allows increasing the domestic broiler meat production by 10 thousand tons (Figure 4), which is about 157 times the base quantity. At the same time, these trade policies allow producing respectively additional bicycle poultry meat of about 11 thousand tons under double tariff and almost 33 thousand tons under import ban on broiler meat (Figure 4). The production of the bicycle poultry itself under these trade policies does not change much to fit the additional bicycle poultry meat production under these trade policies. Therefore, it appears that these trade policies allow boosting the poultry-processing sector and consumers increase their consumption of ready-to-cook domestic poultry meat and decrease their consumption of live poultry.

Figure 4. Production change for the targeted commodities (1000 tons)



Source: Own compilation based on simulation results.

Figure 55. Production change for other commodities (%)



Source: Own compilation based on simulation results.

In general, the production of other commodities declines (Figure 5) because of competition for production factors. Production of other industry increases slightly (Figure 5) because these capital-intensive industries benefit from the lower non-agricultural capital price (Figure 7).

Poultry prices decline under long-run preference shift (PSHIF+PROD) because of higher productivity. The short-run preference shifts (PSHIFT) increases the domestic demand of poultry and therefore its price. Broiler price increases under import ban (PSHIF+PROD+BAN) on broiler meat because of higher domestic demand of broiler for processing. Bicycle poultry meat price decrease, showing the price responsiveness of the bicycle poultry supply. Even though the broiler meat price declines under long-run preference shift and double import tariff, it increases under the import ban because of higher domestic demand of that meat.

Producer prices of other industrial and service sectors decline on average, even though their productions decline. This is because of lower production costs due to lower non-agricultural capital price (Figure 7). In contrast, prices of other agricultural sectors increase because of higher production costs due to higher labor and agricultural capital prices (Figure 7).

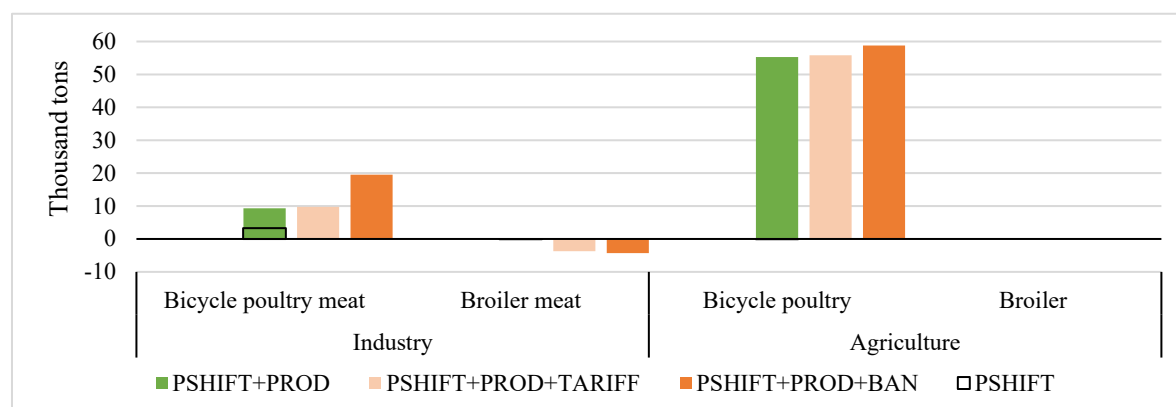
3.1.3 Trade effects

With the shift in consumer preferences, broiler meat imports decline by about 52%. With additional trade policies, these imports decrease by 67% (under double tariff) to 85% (import ban).

Accordingly, broiler meat exports, of which a large share (more than 80%) consists of imported poultry meat (from the Global North) smuggled to Nigeria (USDA, 2014), declines by more than 4 thousand tons under these trade policies (Figure 6). These exports are replaced by the export of domestic bicycle poultry meat, which is about 10 thousand tons higher under double tariff on broiler meat and about 20 thousand tons higher under import ban on broiler meat (Figure 6). The exports of bicycle poultry itself increase because of higher production.

As smuggling from Benin to Nigeria has been for long a factor of discordance between the two countries, higher production and export of domestically produced poultry meat can be considered as an element of a good trade relationship between the two countries, which are naturally big trading partners with about 800 km of shared border and therefore, a factor of good regional integration.

Figure 6 Export change (1000 tons)



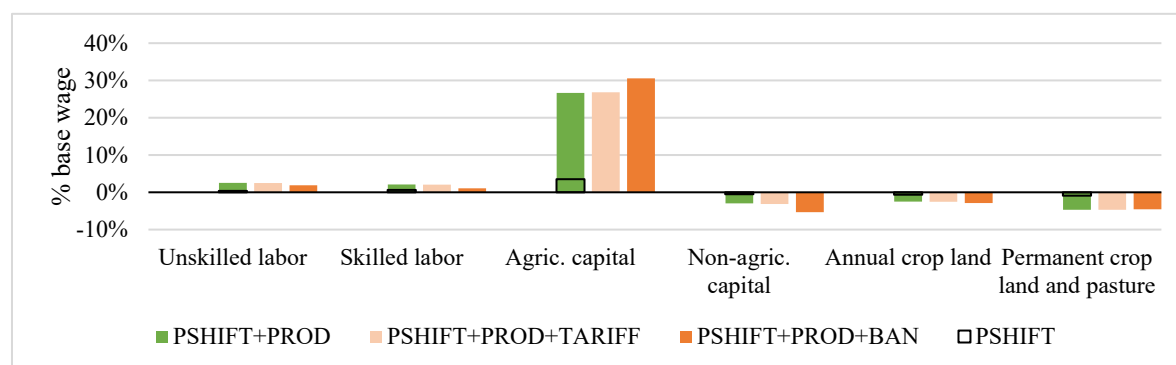
Source: Own compilation based on simulation results.

The trade deficit declines by 50% under PSHIFT+PROD and 53% under PSHIFT+PROD+TARIFF. It decreases by almost 100% under PSHIFT+PROD+BAN. This means that, under import ban on broiler meat, Benin would almost turn into a net exporting country because of higher total exports and lower total imports. Trade policies on broiler meat are therefore quite relevant for a reduction of the trade deficit in Benin.

3.1.4 Employment, income and welfare effects

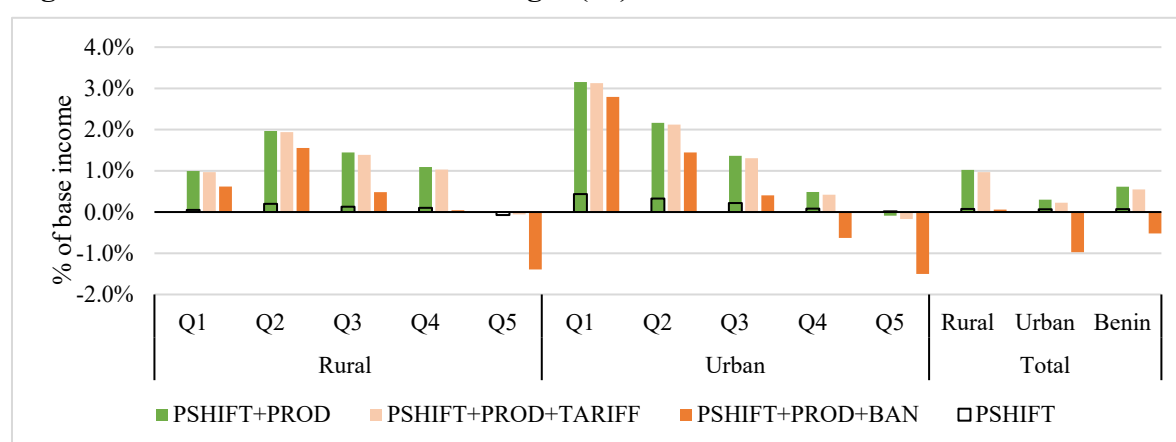
Higher production of domestic poultry and its meat, increases wages as well as prices of agricultural capital (Figure 7), resulting in more income for households owning these production factors. In fact, most household groups in rural and urban areas gain income (Figure 8) because of higher wages (Figure 7). Although the agricultural capital price is increasing much stronger, it represents less than 4% of rural household income and less than 1% of urban household income, while labor wages represent 54% and 50% of urban and rural household income, respectively. In addition, the land prices decline, lowering income effects on low-income rural households which in relative terms receive more income from land than other rural household groups.

Figure 7. Factor wage changes (%)



Source: Own compilation based on simulation results.

Figure 8. Household income changes (%)



Source: Own compilation based on simulation results.

High-income households (quintile 5) in both rural and urban areas lose income under the simulated policies (Figure 8), mainly due to the higher decline of the price of non-agricultural capital, which provides the highest share of their income. This is especially clear with the PSHIF+PROD+BAN scenario, under which the non-agricultural capital price declines the most (Figure 8). On average, the total household income effect is higher in rural areas than in urban areas because of higher positive effect on unskilled labor price and to a lesser extent because of the highest positive effect on agricultural capital, 68% of which is own by rural households.

The welfare effects (measured as Equivalent Variation Including Changes in Savings (EVICS) as suggested by (KINKPE et al., 2023)) to consider the full income effects in the welfare calculation) have the same feature as the income effects. This shows that the net effects of the simulations would be positive for most household groups.

3.1.5 Nutrition and healthy diet effects

Under each scenario, a substantial share of imported frozen poultry meat consumption is replaced by meat from domestic poultry. Even if the cooling chains work during the transportation of imported frozen poultry meat from its origin to its destination port, it is not sure how effective the cooling chains in the destination country (Benin) are. Therefore, a replacement by local poultry meat is likely to benefit human health.

The domestic consumption of poultry increases by 13% (under PSHIFT) to 34% (under PSHIFT+PROD+BAN). However, the domestic consumption of other animals decreases by 1% (under PSHIFT) to 5% (under PSHIFT+PROD+BAN) such that the overall domestic consumption of animals (alive) increases by 4% (under PSHIFT) to 9% (under

PSHIFT+PROD+BAN). This shows an increasing animal protein intake and therefore an increasing nutritional security. In addition, total food consumption under the scenarios increases by 0.2% to 1.3% showing an increased nutrient intake.

3.2 General discussion

We demonstrate that with preference shifts towards domestic poultry meat and trade policies protecting the domestic market, poultry production and processing in Benin would grow substantially and imports would fall. These may thus be relevant factors in enhancing the domestic sector. But whether learning-by-doing and economies of scale would be realized, depends on many other factors. For a successful development of an infant industry, the potential productivity gain should be high, the use of traditional technology should be avoided, and production factors should be available (SAURÉ, 2007; THOM and GRETHE, 2019). The poultry sector in Benin fulfills these conditions: domestic demand for poultry meat is high and consumers prefer domestic poultry with high potential demand for ready-to-cook domestic poultry meat (KULLA et al., 2021), while the current import share of poultry meat is high (FAOSTAT, 2024b, 2024a). Further, the Beninese government is investing in large scale slaughterhouses, modernizing current processing technologies (GDIZ, 2021). Therefore, conditions are met such that protection would foster the growth of the domestic poultry sector.

The preference shift simulated in this paper has import restriction effects (as protective trade restriction policies do) as well as domestic production boosting effects (better than trade restriction policies do). The idea of inducing preference shifts as a tool to support infant industries is an extension of the infant industry argument, which is centered around trade policies (BALDWIN, 1969; GREENWALD and STIGLITZ, 2006; KRUEGER and TUNCER, 1982; PANAGARIYA, 2011; SAURÉ, 2007; RODRIK and SUBRAMANIAN, 2005; ZAMANI et al., 2023).

In this paper, we demonstrate that the effect of doubling import tariff of poultry meat is relatively small. The tariff itself decreases the imported poultry meat consumption but does not per se incentivize the domestic poultry meat consumption. Therefore, the tariff policy alone is not very effective in the case of poultry meat in Benin. In such a context, the preference shift shows better effectiveness.

As trade restriction policies can be problematic vis-à-vis the regional and international trade rules, softer ways can be used to restrict poultry meat import in Benin and countries like Benin. One way would be to set up quality standards. This may result in declining imports and better opportunities for the domestic poultry sector because good-quality poultry meat is not cheap in the Global North. Thus, the price of imported poultry meat in Benin and countries like Benin under strict quality standards would be close to the domestic price or even higher than it. Setting up quality standards and assuring the related control would however need additional logistics. New control laboratories and/or better equipment to the existing laboratories may be needed as well as highly qualified and devoted human resources which may need additional investment.

We model a shift in consumer preference, which is a long-run process. This paper shows the development potential of this long-run shift. A share of the poultry production growth is driven by the productivity increase that we assume to be driven by the preference shift (in the long-run) because of the learning-by-doing process that the higher demand for domestic poultry would induce. Also, the expenditure related to marketing campaigns such as the “*consommations local*” (let’s consume domestic products) campaign to reach preference shifts is not explicitly considered in our analysis. Considering these expenditures would imply higher consumption of services by the government and induce growth in the services sector with additional positive effects. This growth is likely to increase the non-agricultural capital price and therefore, mitigate the negative income effect on high-income households (Q5) shown in Figure 8, as this

factor provides a high share of income to these households. On the other hand, these government expenditures would have to be funded either through expenditure cuts elsewhere or additional taxes. These aspects could be the focus of further research.

4 Conclusion and policy implication

The research question targeted by this paper is “can preference shift and trade policies contribute boosting the poultry-processing development in Benin?” We use CGE modeling based on empirical data to answer this question.

Simulations results show that a shift in demand from broiler meat (almost hundred percent imported) to bicycle poultry meat highly appreciated by consumers, would contribute substantially to domestic sector development and a reduction of broiler meat imports. In this context, doubling import tariffs only has a relatively small effect on domestic consumption and production. This suggests that setting up a higher tariff without working towards shifting preferences and enhancing productivity would not have strong effects on domestic production and mainly harm consumers due to the higher prices. The import ban on broiler meat does not allow substantial additional domestic bicycle poultry production but it does boost the bicycle poultry-processing sector, resulting in a shift from live poultry to ready-to-cook poultry meat consumption. Therefore, the preference shift can be considered an alternative to trade policies in boosting infant industries. The import ban also boosts the domestic broiler sector. Import trade policies also can lead to increased exports of domestic poultry meat and are thereby likely to improve trade relationships between Benin and its biggest neighbour, Nigeria, as Nigeria is highly protecting its domestic market and restricts frozen broiler meat imports. That way, they contribute to decreasing the trade deficit of Benin which may even turn into a surplus (in case of a total import ban). Finally, the development of the domestic poultry-processing sector may contribute to human health and nutritional security by avoiding problems from interrupted cooling chains and enhancing overall food uptake.

Based on these results and in line with suggestions from domestic poultry processors, the government of Benin could: (i) provide (more) public infrastructure and services supporting the development of domestic poultry farming and processing (education, extension services, access to credit and others). This would support the domestic poultry farming sector to increase efficiency and hence production. Moreover, higher domestic poultry production is likely to make the sector more price-competitive because of external economies of scale. Access to credit would support the domestic poultry farming and processing sectors to invest more to increase also production and productivity; (ii) strongly support a consumer preference shift toward domestic poultry meat by setting up, supporting, or increasing marketing campaigns around this product; (iii) set up quality standards to restrict imports of frozen poultry meat as it may be more difficult to increase import tariffs or to ban imports because of the different regional and international trade agreements of which Benin is a member. Good quality standards would increase the price of imported poultry meat on the domestic market (as good-quality poultry meat is not cheap in the Global North) making the domestic poultry meat more price-competitive vis-à-vis the imported poultry meat. That being said, it may also be complicated to implement the quality standards set up because of the logistics needed for it. Feasibility studies can help in identifying the optimal way of implementation. To avoid harming the domestic sector, the quality standards implemented need to consider, on the one hand, the quality standards currently achieved by the domestic sector and on the other hand, what can be (potentially) achieved.

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NACHHALTIGE AGRARPRODUKTION

WELCHEN EINFLUSS HAT DER SCHULUNTERRICHT AUF DAS WISSEN VON JUGENDLICHEN ÜBER LANDWIRTSCHAFT? EINE EMPIRISCHE UNTERSUCHUNG IN EINEM BAYERISCHEN LANDKREIS

Nikolas Bublik¹, Franziska Mittag, Sebastian Hess

Zusammenfassung

Im Rahmen einer empirischen Studie im Landkreis Weißenburg-Gunzenhausen wurde zunächst ermittelt, welche Informationen Schüler*Innen auf Grundlage des Lehrplanes zum Thema Landwirtschaft vermittelt werden sollen. Anschließend wurde im Rahmen einer Befragung das abrufbare Faktenwissen der Probanden zum Thema Landwirtschaft überprüft, wobei der individuelle Wissensstand im Schulfach Mathematik als Kontrolle diente. Weitere Einflussfaktoren auf den landwirtschaftlichen Wissensstand wurden mittels Poisson-Regressionsmodellen untersucht. Ergebnisse zeigen, dass das landwirtschaftliche Wissen von Schüler*Innen sowie jungen Schulabgänger*Innen durch kognitive und demographische Faktoren beeinflusst wird. Außerdem führt der Besuch landwirtschaftlicher Praxisbetriebe zu einem signifikant höheren Wissen über Landwirtschaft, während die subjektive persönliche Nähe zur Landwirtschaft keinen statistisch signifikanten Einfluss auf das Faktenwissen hatte. Insgesamt unterstreichen die Ergebnisse die Bedeutung einer umfassenden und objektiven Schulbildung für den individuellen Wissensstand zu Fragen des Ernährungssektors.

Keywords

Landwirtschaft, Bildungssystem, Inhaltsanalyse, Poissonregression

1 Einleitung

Die von der OECD in einem dreijährigen Rhythmus durchgeführte PISA-Studie zeigte seit 2000 stetig sinkende Kompetenzen deutscher Schülerinnen und Schüler² in den Bereichen Mathematik, Lesekompetenzen und Naturwissenschaften. Die Erhebung im Jahr 2022 offenbarte in diesen Kompetenzbereichen die schwächsten Ergebnisse seit Beginn (OECD 2023). Ebenfalls im Rahmen der PISA Studie kritisch beleuchtet wurde der Mangel an Lehrkräften: 73 % der Schüler besuchten Schulen, an denen der Unterricht durch einen eklatanten Mangel an Lehrkräften beeinträchtigt wurde.

Die PISA-Studie zeigt jedoch nicht nur einen Rückgang der Schülerkompetenzen, sondern auch Defizite in der Umsetzung von Lehrplaninhalten (OECD 2023). Dies wird unter anderem besonders im Bereich Landwirtschaft und Ernährung deutlich, welcher trotz fest verankerter landwirtschaftlicher Inhalte in den Lehrplänen verschiedener Fächer womöglich unzureichend behandelt wird. Laut HEMMER & VAN DER LINDEN (2019) sind die Themen Landwirtschaft und Ernährung mit einem hohen Stellenwert in den Lehrplänen der Fächer Geografie und Biologie von Gymnasium und Realschule verankert, in den Verbundfächern der Mittelschule wird dieser Themenkomplex als ausbaufähig eingestuft.

BICHOPINK & BRANDES (2002) stellen jedoch in diesem Zusammenhang heraus, dass Themen mit Agrar- und Ernährungsbezug trotz der festen Verankerung im Lehrplan eine untergeordnete

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² Aus Gründen der besseren Lesbarkeit wird im Folgenden von Schülern gesprochen, wobei dies alle Geschlechter einschließt.

Rolle in der Unterrichtsgestaltung an deutschen Schulen einnehmen. Damit im Einklang stehen die Ergebnisse von INFORMATION.MEDIEN.AGRAR (2022), welche im Rahmen einer online-Befragung zeigen, dass 63 % der Lernenden mit der Tiefe der Diskussion über landwirtschaftliche Inhalte im Unterricht unzufrieden sind und sich eine intensivere Auseinandersetzung mit agrarbezogenen Themen wünschen. Eine Vermittlung von fundiertem landwirtschaftlichen Wissen im Schulunterricht ist bedeutsam: Werden landwirtschaftliche Praktiken, insbesondere im Bereich der Tierhaltung, nur unzureichend verstanden (bspw. aufgrund fehlenden Hintergrundwissens), so werden diese häufig als grausam und unmenschlich wahrgenommen, aber dabei womöglich fehlgedeutet (RICHARDS et al. 2000).

In diesem Kontext ist auf eine zunehmende Distanzierung zwischen Gesellschaft und Landwirtschaft zu verweisen: BALMANN et al. (2016) stellen heraus, dass die breite Gesellschaft oft ein entfremdetes Bild von der modernen Landwirtschaft besitzt. Trotz einer positiven Grundhaltung gegenüber Landwirtschaft und landwirtschaftlichen Praktiken unterliegt die Agrarbranche einer pauschalen scharfen Kritik bspw. in Bezug auf Rückstände in Lebensmitteln, Monokulturen, den Einsatz chemisch-synthetischer Pflanzenschutzmittel oder den Tierhaltungsverfahren (BERKES et al. 2020). Häufig liegt dies an einem unzureichenden Hintergrundwissen sowie fehlenden Kontaktpunkten und Dialogmöglichkeiten mit der landwirtschaftlichen Praxis (BERKES et al. 2020). Potenziale, ein fundiertes Hintergrundwissen im Bereich Landwirtschaft zu schaffen, Dialogmöglichkeiten mit Akteuren der landwirtschaftlichen Praxis bspw. durch Exkursionen zu bieten und damit der fortschreitenden Distanzierung zwischen Gesellschaft und Landwirtschaft entgegenzuwirken bieten sich bereits im Schulunterricht, bleiben jedoch oft ungenutzt (SCHÜTTE & BUSCH 2016).

Es soll daher untersucht werden, welchen Wissenstand Schüler an bayerischen Schulen über Landwirtschaft haben und welche Faktoren diesen beeinflussen. Dazu sollen auf Basis einer Pilotstudie im Landkreis Weißenburg-Gunzenhausen folgende Hypothesen überprüft werden:

H₀: Ein ausgeprägter Fokus auf landwirtschaftliche Lerninhalte im Schulunterricht ist ein wichtiger Faktor, der zusammen mit individuellen demographischen und kognitiven Merkmalen zum Wissensstand über Landwirtschaft bei Schülern und jungen Schulabgängern beiträgt.

H_A: Das Wissen über landwirtschaftliche Themen von Schülern und jungen Schulabgängern wird nicht durch die im Schulunterricht vermittelten Inhalte, sondern durch außerschulische Aktivitäten mit Landwirtschaftsbezug beeinflusst.

2 Theoretischer Hintergrund

Zahlreiche Studien analysierten bereits landwirtschaftliche Lehrplaninhalte und die Gestaltung des Schulunterrichts in verschiedenen Bundesländern in Deutschland.

Zu nennen sind dabei Schütte & Busch (2016), welche die Umsetzung des Themas Landwirtschaft im Schulunterricht in Niedersachsen untersuchten. Die Ergebnisse zeigen, dass landwirtschaftliche Inhalte vor allem in den Fächern Geografie und Biologie vermittelt wurden, wobei Tierhaltung, das Leben im ländlichen Raum und der Strukturwandel in der Landwirtschaft als Kernthemen galten. Lehrkräfte legten Wert darauf, die Auswirkungen der Landwirtschaft auf die Umwelt zu verdeutlichen und die Herkunft von Lebensmitteln zu thematisieren. Dabei wurden häufig Schulbücher und Internetquellen zur Unterrichtsgestaltung genutzt.

Bei einer inhaltlichen Analyse von Schulbüchern verschiedener Bundesländer stellte Lathan (2020) heraus, dass diese vielfältig, motivierend und schülerorientiert sein sollten. Die Fokussierung auf Heimatregionen wurde betont, wobei es jedoch Probleme bei inhaltlicher Korrektheit und wertneutraler Darstellung gab. Neben einer Analyse der Schulbücher wurde ebenso der Lehrplan analysiert. Die Anzahl der Nennungen des Themas im Lehrplan variiert beträchtlich zwischen den Bundesländern, wobei Bayern mit insgesamt 16 Nennungen führend ist. Eine weitere Analyse von Lathan (2019) zeigt eine Differenzierung der Schwerpunkte innerhalb der Landwirtschaftsthematik in den Lehrplänen der Bundesländer: beispielsweise fehlen Themen

wie Pflanzenschutz oder Gentechnik in bayerischen Schulbüchern gänzlich. Eine explizite Analyse des Themas Landwirtschaft im Schulunterricht sowie im Lehrplan mit Fokus auf den Freistaat Bayern erfolgte lediglich von Hemmer & van der Linden (2019), worin jedoch der hohe Stellenwert von landwirtschaftlichen Inhalten im Lehrplan sowie im Schulunterricht betont wird.

Umgesetzt wird der Lehrplan im Unterricht von der Lehrkraft. Doppelmaier et al. (2020) zeigen einen Zusammenhang zwischen Werteorientierung der Lehrkraft und Einstellung zur Landwirtschaft in Österreich auf. Eine wertsensible Kommunikation, zum Beispiel durch Verwendung positiver Begriffe über Landwirtschaft, hat einen Einfluss auf die Einstellung. Dies ist von Bedeutung, da nach Hänze (2002) die Vermittlung landwirtschaftlicher Inhalte im Unterricht auf deren Einstellung beruht. Schütte & Busch (2016) weisen einen geringen Einfluss der Einstellung der Lehrkräfte auf die Unterrichtsgestaltung nach.

Neben der Unterrichtsgestaltung durch Schulbücher, Lehrplan und Lehrkraft wurden ebenso das daraus resultierende Wissen von Schülern zur Landwirtschaft und die damit verbundenen Vorstellungen analysiert: Hamann (2004) untersuchte Schülervorstellungen zur Landwirtschaft und zeigte auf, dass die Größe des Wohnortes keinen direkten Einfluss auf das Wissen über Landwirtschaft hatte. Das Wissen der Schüler im Bereich Tierhaltung überstieg das im Pflanzenbau; die Umweltfolgen der Landwirtschaft waren hingegen wenig bekannt.

Nkembe (2012) erforschte das Wissen von amerikanischen Dritt- bis Fünftklässlern und stellte fest, dass Basiswissen vorhanden war, wobei städtisch lebende Schüler besser informiert waren als jene, die auf dem Land aufgewachsen sind. Schule, Familiengespräche und Bücher wurden als Quellen zur Wissensvermittlung im landwirtschaftlichen Kontext am häufigsten genannt.

Die Gesellschaftsstudie von Zander et al. (2013) über Erwartungen an die Landwirtschaft zeigte, dass nur 11,9 % der Befragten ein gutes Wissen über Landwirtschaft hatten. Mergenthaler et al. (2016) stellte in diesem Zusammenhang jedoch heraus, dass ein höheres Wissen über Landwirtschaft (im speziellen über landwirtschaftliche Nutztierhaltung) nicht zu einer positiveren Bewertung von landwirtschaftlichen Produktionsprozessen führt. So kann eine isolierte Wissensvermittlung Kritik an der Landwirtschaft fördern (Mergenthaler et al. 2016).

3 Empirische Methoden und Analyserahmen

3.1 Pilotstudie

Die Datenerhebung mit einer direkten Befragung von Schülern an den Schulen ist mit erheblichen bürokratischen Anforderungen und hohen Transaktionskosten im Hinblick auf den Erhalt einer Genehmigung verbunden. Um diese Schwierigkeiten zu umgehen, wurde zur Analyse des Wissensstandes und der Wissensvermittlung zum Thema Landwirtschaft an bayerischen Schulen auf das Konzept der Pilotstudie zurückgegriffen. Dabei ist einschränkend anzumerken, dass das Hauptziel nicht darin besteht, eine hohe Repräsentativität der Ergebnisse zu erreichen, sondern vielmehr darin, exemplarisch anhand aktueller gesellschaftlicher und sozialwissenschaftlicher Entwicklungen Trends aufzuzeigen und Grundlagen für künftige Forschungsarbeiten zu legen. Um die Komplexität der Thematik im Rahmen einer Pilotstudie zu bewältigen, wurde ein Mixed-Methods-Ansatz gewählt, der qualitative und quantitative Forschungselemente integriert. Zunächst wurden eine qualitative und quantitative Inhaltsanalyse der Lehrpläne weiterführender Schulen im Freistaat Bayern im Kontext der Behandlung des Themas Landwirtschaft durchgeführt. Diese Analyse bildet die Grundlage für eine im zweiten Schritt durchgeführte quantitative Datenerhebung im Landkreis Weißenburg-Gunzenhausen.

3.2 Inhaltsanalyse

Im Rahmen dieser Inhaltsanalyse soll untersucht werden, wie der Themenbereich Landwirtschaft in den bayerischen Lehrplänen verankert ist, um in einer anknüpfenden Befragung im Rahmen der Lehrplanfragen Inhalte abzu prüfen, die gemäß des Lehrplans vermittelt werden sollten. Den zentralen Gegenstand der systematischen Inhaltsanalyse nach Mayring & Fenzl (2019) stellt Kommunikationsmaterial verschiedener Formen dar, welches quantitativ und qualitativ untersucht wird. In der folgenden Analyse wird der Lehrplan als Kommunikationsmaterial für Unterrichtsanhalte an bayerischen weiterführenden Schulen verwendet. Da laut Lathan (2019) landwirtschaftliche Themen überwiegend in den Fächern Geografie und Biologie vermittelt werden, fokussiert sich die Analyse auf eben jene Fächer, sowie deren Gegenstücke in der Wirtschafts- und Mittelschule: Wirtschaftsgeographie (WiGe), Geschichte-Politik-Gesellschaft (GPG) sowie Natur und Technik (NuT). Berücksichtigt werden dabei alle Jahrgangsstufen, in denen das jeweilige Fach unterrichtet wird. Im Rahmen dieser Arbeit wurden die Lehrpläne vom online-Auftritt des bayerischen Staatsinstituts für Schulqualität und Bildungsforschung bezogen (ISB, 2023).

Zuerst wurde eine diktionsär basierte quantitative Inhaltsanalyse mit Hilfe der Software MAXQDA durchgeführt. Zentrum der Methode bildet ein Kategoriensystem, in welchem die in Tabelle 1 dargestellten Kategorien mit den entsprechenden Suchbegriffen gebildet wurden (Boelmann 2018). Hierbei wurde der Fokus auf landwirtschaftsnahe Suchbegriffe gelegt und dadurch der Begriff „Ernährung“ sowie damit verbundene Begrifflichkeiten außen vor gelassen, um explizit die Verankerung des Themas Landwirtschaft im Lehrplan aufzuarbeiten.

Tabelle 1: Suchbegriffe/Diktionsär der quantitativen Inhaltsanalyse

Kategorie	Suchbegriffe
Landwirtschaft	Landwirtschaft, Bauernhof, Agrar
Ackerbau	Acker, Getreide, Gemüse, Obst, Sonderkultur, Nutzpflanze, Pflanzenzucht
Tierhaltung	Nutztier, Tierhaltung, Tierzucht
Nachhaltigkeit	nachhaltig, regional, saisonal

Quelle: eigene Darstellung.

In einem zweiten Schritt erfolgte die qualitative Inhaltsanalyse, welche nach MAYRING & FENZL (2019) drei verschiedene Möglichkeiten bietet: die Zusammenfassung, Explikation sowie die Strukturierung. Zentrales Element ist das Kodieren, d.h. die Vergabe von Stichworten, die sich aus den Textfragmenten ergeben. Die Bildung der Codes erfolgte zunächst induktiv orientiert an LATHAN (2019). Im Rahmen der weiteren Analyse bildeten sich zudem deduktiv hinzukommende Codes. Induktive Forschung leitet allgemeine Prinzipien aus spezifischen Beobachtungen ab, während deduktive Forschung von allgemeinen Prinzipien ausgeht und spezifische Hypothesen oder Vorhersagen formuliert, die empirisch überprüft werden können (MAYRING & FENZL 2019). Im Rahmen dieser Arbeit wurde überwiegend mit den Elementen Zusammenfassung und Strukturierung gearbeitet, da die Inhaltsanalyse die Grundlage der später folgenden Befragung darstellte.

3.3 Befragung

Zielgruppe der online-Befragung waren 16-25-jährige Schüler und Schulabgänger. Durchgeführt wurde die Befragung mittels der Software UniPark QuestBack und über soziale Medien ab dem 27.03.2023 für eine Dauer von vier Wochen geteilt. In diesem Zeitraum wurde die Befragung 132-mal aufgerufen und 100 Personen beendeten die Befragung komplett, was einer Beendigungsquote von ca. 75 % entspricht.

Im Rahmen der Befragung lag der Fokus auf den Schularten Mittelschule, Realschule, Wirtschaftsschule und Gymnasium in Klassen 5-10, was darin begründet ist, dass Grundschüler

aufgrund ihres Alters aus datenschutzrechtlicher Sicht schwierig zu befragen sind und im Hinblick auf die Verständlichkeit der Fachfragen ein separates Untersuchungsdesign hätte entwickelt werden müssen. Fachober- und Berufsschule wurden vernachlässigt, da diese Schularten aufgrund der zahlreichen Wahlmöglichkeiten von Fächern und Modulen in der Oberstufe sehr heterogen sind und kaum allgemeine Aussagen über diesen Schultyp zulassen. Ähnlich verhält es sich mit der gymnasialen Oberstufe (Klassen 11-13). Die Befragung wurde in vier Kategorien gegliedert. In einem ersten Abschnitt wurden die Teilnehmenden zu grundlegenden demographischen Faktoren, beispielsweise Alter, Klassenstufe oder Berufsstand, zuletzt besuchte Schulart oder Geschlecht befragt. In Abhängigkeit der Antworten zu Schulart und Klassenstufe wurden im darauffolgenden Teil entsprechende Fachfragen zur Landwirtschaft sowie Kontrollfragen aus dem Bereich Mathematik auf Basis des entsprechenden Lehrplanes gestellt. Die durch die qualitative Inhaltsanalyse herausgearbeiteten, laut Lehrplan zu vermittelnden Kompetenzen stellen die Grundlage der Befragung dar, wobei bei der Fragengenerierung selbst öffentlich zugängliche Unterrichtsmaterialien zugezogen wurden.

Mathematik wurde als Kontrollfach gewählt, da dieses in jeder Schulart und Klassenstufe Teil des Lehrcurriculums ist und sich somit konstante Kontrollfragen ableiten ließen. Hintergrund eben dieser Fragen war es, den Zusammenhang zwischen Wissen über Landwirtschaft und den kognitiven Fähigkeiten der Befragten zu prüfen. Tabelle 2 zeigt Beispielfragen aus den jeweiligen Bereichen auf:

Tabelle 2: Beispielfragen der Befragung

Themenbereich	Beispielfragen
Lehrplanfragen	Ordne die Aussagen der konventionellen oder biologischen Landwirtschaft zu: <i>„Die Futtermittel für die Tiere werden möglichst auf dem eigenen Betrieb erzeugt.“</i> <i>„Hier dürfen GVO (gentechnisch veränderte Organismen) eingesetzt werden.“</i> <i>„Die hier produzierten Lebensmittel sind in der Regel günstiger.“</i>
Kontrollfragen Mathematik	Welches mathematische Gesetz wird hier dargestellt? $a+b=b+a$ Wie viel sind 10 dm in mm?
Landwirtschafts-fragen im Fragebogen der vorliegenden Untersuchung	Sind folgende Aussagen richtig oder falsch? <i>„Der Landwirt muss täglich nach seinen Tieren sehen.“</i> <i>„Kälber bleiben in der Milchproduktion noch lange bei (...) den Kühen.“</i> <i>„Die Landwirte dürfen so viel Dünger und Gülle auf die Felder fahren, wie sie möchten. Es gibt hier keine Regeln.“</i>

Quelle: eigene Darstellung.

Es wurde der Lehrplan des letzten Jahres, in dem laut der Lehrplananalyse landwirtschaftliche Inhalte vermittelt wurden, herangezogen. Der dritte und vierte Abschnitt wurde wieder allen Befragten gestellt: Orientiert an ZANDER et al. (2013) folgten zunächst allgemeine Fragen zur Landwirtschaft und danach sowohl demographische Fragen als auch Fragen über die Nähe zur Landwirtschaft oder die Bezugsquellen landwirtschaftlichen Wissens.

3.4 Ökonometrisches Modell

Die im vorherigen Abschnitt beschriebene absolute Anzahl der falsch beantworteten Landwirtschaftsfragen stellt in der folgenden ökonometrischen Analyse die abhängige Variable dar. Diese Zähldaten bilden keine stetige statistische Verteilung, weshalb keine Regressionsanalyse auf Basis einer Kleinstquadrateschätzung angewendet werden kann, da diese (besonders bei abhängigen Variablen mit geringem Mittelwert) zu verzerrten Standardfehlern und Teststatistiken führt (COXE et al. 2009; GARDNER et al. 1995). Dies liegt darin begründet, dass die Verwendung von Zähldaten die Annahmen der „Conditional Normality“ und der Homoskedastizität im Hinblick auf die Fehlerterme der Kleinstquadrateschätzung verletzen (COXE et al. 2009).

Abgesehen davon sind die verwendeten Daten nicht normalverteilt, sondern folgen einer Poissonverteilung mit folgender Wahrscheinlichkeitsmassenfunktion:

$$P = (Y = y|\mu) = \frac{\mu^y}{y!} e^{-\mu}$$

, wobei P die Wahrscheinlichkeit angibt, dass ein gewisser Wert y der Variable Y auftritt, die anhand dieser Parameter poisson-verteilt ist. In der weiteren Analyse ist Y die Anzahl falsch beantworteter Landwirtschaftsfragen und μ das arithmetische Mittel von Y .

Unter Berücksichtigung der poisson-verteilten Zählraten wird in den Modellen 1 und 2 eine Poissonregression durchgeführt, die nach COXE et al. (2009) wie folgt geschätzt wird:

$$\ln(\hat{\mu}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n$$

, wobei $\hat{\mu}$ der vorhergesagte Wert für Y bei den gegebenen Einflussfaktoren X_1 bis X_n ist.

Die abhängige Variable kann nur Werte zwischen 0 und 6 annehmen. Da bis jetzt noch nicht auf diese Zensurierung der Datenstruktur in der Modellschätzung eingegangen wurde, soll dies im folgenden Modell 3 (Censored Poisson Regression) berücksichtigt werden. Die Zensurierung wird nach FAMOYE & WANG (2004) wie folgt berücksichtigt:

$$y_i = \begin{cases} L_i & \text{if } y_i^* \leq L_i \\ y_i^* & \text{if } L_i < y_i^* < U_i \\ U_i & \text{if } y_i^* \geq U_i \end{cases}$$

, wobei y_i grundsätzlich die beobachtete interval- zensierte abhängige Variable ist und y_i^* eine unzensurierte latente abhängige Variable. Wenn y_i nicht zensiert ist, entspricht sie der latenten Variable y_i^* . Wenn y_i zensiert ist, wird nur der zensierte Wert beobachtet, wobei L_i den Wert der unteren Zensurierung und U_i den Wert der oberen Zensurierung angibt. Basierend auf dieser Zensurierung und der bereits beschriebenen Poisson-Verteilung der Daten wird wie in FAMOYE & WANG (2004) beschrieben eine zensierte Poisson-Regression geschätzt. Die Schätzung wird mit stata 18.0 durchgeführt.

In allen Modellen werden bis auf wenige Ausnahmen die gleichen Regressoren verwendet, die in Tabelle 3 dargestellt werden.

Tabelle 3: Übersicht der Codierung der im Modell verwendeten Variablen

Thema	Variable	Skalierung	Codierung
Vorbildung	Schulart	kategorial	1 = Gymnasium; 2 = Realschule; 3 = Mittelschule; 4 = Wirtschaftsschule; 5 = sonstige
	Erinnerung	binär	1 = ja; 2 = nein
	Ausflug	kategorial	1 = mehrmals; 2 = einmal; 3 = nein
demographische Faktoren	Alter	kardinal	
	Geschlecht	kategorial	1 = männlich; 2 = weiblich; 3 = divers; 4 = keine Angabe
	Bezug	kategorial	1-5; 1 = größte Nähe
kognitive Faktoren	Lehrplanfragen	kategorial	1-7
	Selbsteinschätzung	kategorial	1 = sehr gut; 2 = gut; 3 = mittelmäßig
	Mathefragen	kategorial	1-7

Quelle: eigene Darstellung

4 Ergebnisse

4.1 Inhaltsanalyse

Die im Rahmen der Inhaltsanalyse des Lehrplans erarbeiteten Ergebnisse bilden die Grundlage der Fragen zu den Lehrplaninhalten innerhalb der Befragung. Aus diesem Grund wird hier nicht weiter auf die Ergebnisse der qualitativen Inhaltsanalyse eingegangen, da diese sich in den Lehrplanfragen widerspiegeln und für diese Arbeit lediglich als Zwischenschritt fungierten. Daher liegt der Fokus auf den Ergebnissen der quantitativen Inhaltsanalyse.

Tabelle 4 zeigt die absoluten Häufigkeiten der jeweiligen Suchbegriffe im Lehrplan geordnet nach Schulart, Fach und Klassenstufe. So tritt der Begriff Landwirtschaft im Lehrplan des Fachs Biologie im Gymnasium in den Jahrgangsstufen 8 bis 10 insgesamt zwei Mal auf. Auffällig ist insgesamt, dass landwirtschaftliche Inhalte vor allem im Fach Geographie am Gymnasium und an der Realschule zu finden sind. Nur geringfügig sind Themen im Bereich der Tierhaltung im Lehrplan verankert, wohingegen der Themenbereich Ackerbau etwas häufiger zu finden ist. Der Bereich der Nachhaltigkeit ist in allen Schularten in fast allen Unterrichtsfächern am häufigsten vertreten, was durch eine starke Allgemeinhaltung dessen zu begründen ist. Nicht jeder Treffer stellt eine Verpflichtung dar, die Inhalte im Unterricht zu erwähnen. Mitunter handelt es sich um Wahlmöglichkeiten für die Lehrkräfte.

Tabelle 4: Ergebnisse der quantitativen Inhaltsanalyse (absolute Worttreffer)

Schulart	Fach	Klassen	Landwirtschaft	Ackerbau	Tierhaltung	Nachhaltigkeit
Mittelschule	GPG	5-10	2	1	0	9
	NuT	5-10	0	1	0	4
Realschule	BIO	5-8,10	0	4	4	7
	GEO	5-9	28	3	0	21
Wi- schule	WiGe	9-10	4	0	0	7
Gymnasium	BIO	8-10	2	0	0	7
	GEO	5,7,10	13	0	0	28

Quelle: eigene Darstellung; GPG=Geschichte Politik Geographie; NuT=Natur und Technik; BIO=Biologie; GEO=Geographie; WiGe=Wirtschaftsgeographie; Wi-schule=Wirtschaftsschule

4.2 Statistische Auswertung der Befragung

Insgesamt beteiligten sich 100 Schüler sowie junge Schulabgänger an der Befragung. Da jedoch aufgrund einer Filtereinstellung nicht alle Teilnehmenden die für die folgende Modellschätzung wichtigen Lehrplanfragen beantworteten, beträgt die auswertbare Stichprobengröße $n = 66$.

Tabelle 5: Beschreibende Statistik über die Stichprobe

	Variable	Mittelwert	Std.-fehler	Minimum	Maximum
abhängig	Landwirtschaftsfragen	1.9697	1.3697	0	6
	Schulart	1.7879	0.9367	1	4
	Geschlecht	1.4091	0.4954	1	2
	Alter	20.7576	2.9875	15	25
	Lehrplanfragen	5.9697	1.3470	2	7
	Mathefragen	4.9848	0.9526	3	7
	Bezug	1.9697	0.8033	0	5
	Erinnerung	1.5909	0.4954	1	2
	Ausflug	2.4545	0.6369	1	3
	Selbsteinschätzung	2.1364	0.6537	1	3

Quelle: eigene Darstellung

In Tabelle 5 ist die beschreibende Statistik über die Stichprobe dargestellt. Es ist abzulesen, dass die Variable Landwirtschaftsfragen, die im Folgenden als abhängige Variable verwendet wird, nur Werte zwischen 0 und 6 annehmen kann. Des Weiteren indiziert der Mittelwert von 1.9697, dass der Anteil falsch beantworteter Landwirtschaftsfragen sehr gering ist. Außerdem ist ein Großteil der Befragten im Hinblick auf die Lehrplanfragen in den Kategorien sechs und sieben zu finden, was ein sehr gutes bis gutes Wissen zu den laut Lehrplan vermittelten landwirtschaftlichen Inhalten zeigt.

Im Tabelle 6 werden nun die Ergebnisse der Modellspezifikationen zum Testen der Hypothesen dargestellt. Geschätzt wurden drei verschiedene Modellspezifikationen, wobei die Modelle 1 bis 3 die Zähldatenstruktur berücksichtigen und Modell 3 zusätzlich die trunkierte Datenstruktur miteinbezieht.

Tabelle 6: Ergebnisse der aus der Befragung abgeleiteten Modellen

Variablen	(1): Countdata Poisson mit robusten Standardfehlern	(2): wie (1) ohne Mathefragen	(3): Censored Countdata Poisson mit robusten Standardfehlern
Schulart	0.019 (0.072)	0.026 (0.075)	0.025 (0.088)
Alter	0.052** (0.025)	0.051* (0.026)	0.024 (0.025)
Geschlecht	0.242 (0.194)	0.221 (0.188)	0.674*** (0.197)
Lehrplanfragen	-0.190*** (0.071)	-0.192*** (0.068)	-0.018 (0.070)
Mathefragen	0.039 (0.084)		0.112 (0.087)
Bezug	0.065 (0.105)	0.066 (0.113)	0.106* (0.059)
Ausflug	-0.246** (0.117)	-0.230** (0.112)	-0.397*** (0.143)
Erinnerung	0.101 (0.200)	0.081 (0.182)	0.524*** (0.179)
Selbsteinschätzung	0.144 (0.131)	0.127 (0.124)	0.415*** (0.150)
Constant	0.112 -1.190	0.376 (0.979)	-2.289* -1.212
Freiheitsgrade	9	8	9
AIC	220.844	218.986	213.259
Wald chi ²	37.12	36.65	45.42
Prob > chi ²	0	0.080	0
Log-Pseudolikelihood	-100.422	-100.493	-96.630

Quelle: eigene Darstellung; abh. Variable in allen Modellen = Landwirtschaftsfragen; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Standardfehler in Klammern

Den Ergebnissen kann entnommen werden, dass sich die Variablen hinsichtlich ihrer statistischen Signifikanzen zwischen den Modellen unterscheiden. Die Koeffizienten unterscheiden sich in ihren absoluten Werten, jedoch nicht in deren Vorzeichen.

Die Lehrplanfragen sind im Modell 1 statistisch signifikant, woraus sich zeigt, dass je mehr Lehrplanfragen korrekt beantwortet wurden, umso weniger Fehler bei den Landwirtschaftsfragen gemacht wurden. Die Variable Ausflug zeigt statistische Signifikanzen in den Modellen 1-3: Wenn ein oder mehrere Ausflüge zu einem Bauernhof im Rahmen der Schullaufbahn gemacht wurden, so wurden mehr Landwirtschaftsfragen richtig beantwortet. Teilnehmende, die sich erinnern, das Thema Landwirtschaft im Schulunterricht behandelt zu haben, zeigen nach dem Modell 3 ein besseres Wissen über Landwirtschaft im Allgemeinen. Ebenfalls im Modell 3 waren die Selbsteinschätzung sowie das Geschlecht als Einflussgrößen auf die abhängige Variable statistisch signifikant.

Die Unterschiede in den Signifikanzen innerhalb dieser drei Modelle lassen sich auf die für die Modellspezifikation notwendigen Annahmen und die Regressorenauswahl zurückführen. Dass Modell 3, wie eingangs erläutert, das präferierte Modell zur Beschreibung der Daten ist, wird auch durch die Gütekriterien verdeutlicht.

Die beiden Poisson Countdata sowie das Censored Countdata Poisson Modell weisen ähnliche AIC-Werte auf. Im Vergleich aller Modelle zeigt Modell 3 jedoch den niedrigsten AIC-Wert und damit die beste Anpassung. Dies wird ebenso durch den Wald χ^2 -Test sowie den Log Pseudolikelihood-Wert bekräftigt.

Um außerdem der geringen Stichprobengröße von $n=66$ gerecht zu werden, wurden die vorliegenden Daten anhand eines Generalized Maximum Entropy (GME)-Modells analysiert, welches laut GOLAN et al. (2004) konsistentere Schätzer für kleine Stichproben erzielt. Anhand der gewonnenen Gütekriterien (Pseudo- $R^2 = 0.0238$; Model Entropy = 90.8) zeigt sich jedoch, dass durch diese Modellschätzung der Sachverhalt schlechter modelliert wird als mittels der hier dargestellten Poisson-Modelle, weshalb auf eine weitere Ergebnisdarstellung und -diskussion verzichtet wird.

4.3 Weitere Ergebnisse der Befragung

Im Rahmen der Befragung wurden weitere, für das Themenfeld relevante Informationen abgefragt, welche nun kurz skizziert werden sollen.

Auf die Frage, ob sie gerne mehr über das Thema Landwirtschaft im Schulunterricht lernen würden, antworteten 91 % der Teilnehmenden mit „Ja“. In diesem Zusammenhang wurde abgefragt, welche Kanäle und Informationsquellen die Umfrageteilnehmer zum Thema Landwirtschaft nutzen. 11 % der Befragten beziehen ihre Informationen über Landwirtschaft hauptsächlich aus dem Schulunterricht. Bücher spielen für 25 % der Befragten eine wichtige Rolle als Informationsquelle. Social-Media-Plattformen wie Instagram und TikTok werden von 34 % genutzt, während das Fernsehen von 41% als relevante Quelle angegeben wird. 46 % der Befragten zieht YouTube-Videos heran. Besonders herausstechend ist der Einfluss von persönlichen Netzwerken, da 61% der Befragten angaben, dass nahe Verwandte eine bedeutende Informationsquelle über Landwirtschaft für sie darstellen. Den höchsten Prozentsatz erreicht die Kategorie "Gespräche mit Landwirten" mit 68 %, was die Bedeutung von direkten Interaktionen und Erfahrungen mit Landwirten als aussagekräftige Informationsquelle über die Landwirtschaft unterstreicht.

Ein Teil der Befragung, den alle Teilnehmenden zur Beantwortung (unabhängig von Klassenstufe und Schularart) vorgelegt bekommen hatten, orientierte sich an einer Studie von ZANDER et al. (2013). Tabelle 7 zeigt im Vergleich den Anteil korrekter Antworten zur jeweiligen Fragestellung. Es ist erkennbar, dass die Fragen von Teilnehmenden dieser Befragung besser beantwortet werden konnten als bei ZANDER et al. (2013). Ähnliche Muster sind bei Fragen zu täglichen Tierkontrollen und der Entwicklung landwirtschaftlicher Betriebe erkennbar, bei denen hohe korrekte Antwortraten vorliegen. Mit Ausnahme einer Frage zu Ausläufen in der Schweinehaltung zeigt diese Studie insgesamt höhere korrekte Antwortraten im Vergleich zu ZANDER

et al. (2013). Die geringen Antwortwerte bei Fragen zur Fütterung mit gentechnisch veränderten Organismen deuten darauf hin, dass die Thematik des Gentechnikeinsatzes möglicherweise ausführlicher im Schulunterricht behandelt werden sollte, obwohl sie bereits teilweise in bestimmten Lehrplänen verankert ist, wie die Lehrplananalyse zeigt. Beispielfragen hierzu können den Landwirtschaftsfragen in Tabelle 2 entnommen werden.

Tabelle 7: Vergleich der Ergebnisse dieser Arbeit mit der Literatur (% korrekter Antworten)

Frage-thematik	diese Arbeit	ZANDER et al. (2013)
Tägliche Tierkontrolle	97	69
Milchviehhaltung	86	46
Düngung von Feldern	100	53
Spieltrieb von Schweinen	81	66
Fütterung mit genetisch veränderten Organismen	51	31
Auslauf in der Schweinehaltung	39	46
Blühender Raps ist violett	85	
Entwicklung der Anzahl landw. Betriebe	98	64

Quelle: eigene Darstellung; Daten nach ZANDER et al. (2013)

5 Diskussion

Die im Landkreis Weißenburg-Gunzenhausen durchgeführte Pilotstudie diente der qualitativen und quantitativen Untersuchung der Verankerung des Themas Landwirtschaft im Lehrplan sowie der Analyse des Wissens Jugendlicher über Landwirtschaft. Dabei konnte auf Basis der Inhaltsanalyse herausgestellt werden, dass die verschiedenen Aspekte Tierhaltung, Ackerbau und Nachhaltigkeit unterschiedlich stark und häufig im Lehrplan verankert sind, was sich mit den Ergebnissen von LATHAN (2019) und HEMMER & VAN DER LINDEN (2019) deckt. HEMMER & VAN DER LINDEN (2019) betonen den hohen Stellenwert landwirtschaftlicher Themen im Schulunterricht und empfehlen eine Verknüpfung mit dem Themenkomplex Ernährung, um die Informationen somit für die Schüler greifbarer zu machen.

Hervorzuheben ist außerdem, dass der Lehrperson im Rahmen der pädagogischen Umsetzungsfreiheit ein großer Gestaltungsspielraum im Unterricht gegeben wird. Der Einfluss der Lehrperson wurde bereits in separaten Arbeiten beschrieben und daher in der vorangegangenen Analyse nicht berücksichtigt (DOPPELMAIR et al. 2020; SCHÜTTE & BUSCH 2016; HÄNZE 2002). HEMMER & VAN DER LINDEN (2019) betonen, dass, wenngleich zahlreiche Unterrichtsmaterialien zum Thema Landwirtschaft seitens verschiedenster Institutionen und Verbände bereitgestellt werden, es Aufgabe der Lehrkraft bleibt, diese kritisch zu prüfen.

Im Hinblick auf die Ergebnisse der quantitativen Befragung konnte nur der „Ausflug zum Bauernhof“ als signifikant positiver Einfluss auf das Wissen über Landwirtschaft in allen drei Modellen bestätigt werden, was sich mit HAMANN (2004) deckt, welche ebenfalls die Bedeutung von Bauernhofbesuchen hervorhebt. Personen, die angaben, mehrmals landwirtschaftliche Praxisbetriebe besucht zu haben, zeigen ein höheres Wissen über Landwirtschaft, was die Wichtigkeit derartiger Exkursionen als Bestandteil des schulischen Curriculums für das Verständnis landwirtschaftlicher Themen unterstreicht. Dem steht gegenüber, dass der „Bezug“ der Teilnehmenden zur Landwirtschaft in keinem der Modelle einen statistisch signifikanten Einfluss zeigt, was sich ebenfalls mit den Ergebnissen von HAMANN (2004) und NKEMBE (2012) deckt.

Der in Modell 3 statistisch signifikant positive Einfluss der „Erinnerung“ zeigt die Bedeutung des Diskutierens landwirtschaftlicher Inhalte im Unterricht, da die Teilnehmenden, die sich an die Vermittlung derartiger Inhalte erinnern konnten, auch ein breiteres Wissen über Landwirtschaft als Ganzes zeigten.

Vor dem Hintergrund der kognitiven Fähigkeiten der Befragten zeigen jene, die sich selbst als gute oder sehr gute Schüler einschätzten, ein erhöhtes Wissen über Landwirtschaft.

Auf Basis der Ergebnisse der quantitativen Datenanalyse lässt sich zusammenfassend sagen, dass die Nullhypothese *„Ein ausgeprägter Fokus auf landwirtschaftliche Lerninhalte im Schulunterricht ist ein wichtiger Faktor, der zusammen mit individuellen demographischen und kognitiven Merkmalen zur Variation im Wissensstand über Landwirtschaft bei Schülern und jungen Schulabgängern beiträgt“* nur teilweise verworfen werden kann. Ein ausgeprägter Fokus auf landwirtschaftliche Lerninhalte sowie bessere kognitive Fähigkeiten führen zu einem höheren Wissen über Landwirtschaft, wohingegen nur in einigen Modellen ein signifikanter Einfluss der demographischen Faktoren „Alter“ und „Geschlecht“ ermittelt werden konnte und der demographische Faktor „Bezug“ zur Landwirtschaft in keinem der Modelle statistisch signifikant ist. Der Einfluss außerschulischer Aktivitäten, der in der Alternativhypothese als starke Determinante genannt wurde, konnte auch hier bestätigt werden.

Neben den Bauernhofausflügen werden weitere wichtige Informationen aus Sicht der Befragten am häufigsten über Gespräche mit Landwirten oder nahen Verwandten bezogen, was jedoch mit der Datenerhebung in einem ländlich geprägten Umfeld zusammenhängen kann, da in dieser Umgebung Gespräche mit Landwirten leichter zu realisieren sind als in städtischem Umfeld. Dennoch ist hervorzuheben, dass der Bezug zur Landwirtschaft – wie in dieser Studie sowie der Literatur gezeigt – keinen Einfluss auf das Wissen über Landwirtschaft besitzt. Der Schulunterricht stellt mit 11 % im Gegenzug die am wenigsten genannte Informationsquelle dar. Dies deckt sich nur teilweise mit den Ergebnissen von INFORMATION.MEDIEN.AGRAR (2022), worin Fernsehen (75 %) und Internet (64 %) als häufigste Informationsquelle genannt werden; der Schulunterricht wird nur von 43 % der Befragten als Informationsquelle angeführt.

Die Ergebnisse dieser Studie sollten daher in größeren Stichproben und auch unter Berücksichtigung urbaner Einzugsgebiete überprüft werden.

6 Schlussfolgerung

Die vorliegende Studie konnte zeigen, dass der Bezug bzw. die persönliche Nähe zur Landwirtschaft keinen statistisch signifikanten Einfluss auf das landwirtschaftliche Faktenwissen haben. Dieses Ergebnis unterstreicht die Bedeutung einer objektiven Wissensvermittlung im Unterricht an weiterführenden Schulen, bspw. in Form von Unterrichtsthemen, aber insbesondere auch durch Exkursionen zu landwirtschaftlichen Praxisbetrieben.

Es bleibt jedoch Aufgabe der Lehrkraft, alters- und reifegerecht Wissen zu vermitteln sowie die Schüler zur individuellen Meinungsbildung zu ermutigen. Obwohl gemäß den Ergebnissen dieser Studie eine Verankerung landwirtschaftlicher Inhalte in den Lehrplänen der jeweiligen Schularten durchaus gegeben scheint, obliegt die Ausgestaltung und die Vermittlung eben dieser Inhalte im Rahmen der pädagogischen Umsetzungsfreiheit der Lehrkraft selbst. Sofern ein hoher objektiver Informationsstand über Agrar- und Ernährungsfragen als Voraussetzung für eine nachhaltige Transformation der Landwirtschaft unterstellt und damit als öffentliches Gut verstanden wird, sollte es im Interesse staatlicher Stellen und landwirtschaftlicher Interessenvertretung liegen, Lehrkräfte bei der Umsetzung zu unterstützen. Dies könnte z.B. durch die Bereitstellung leicht zugänglicher Weiterbildungsmöglichkeiten, entsprechender Unterrichtsmaterialien und Exkursionsmöglichkeiten zu Praxisbetrieben geschehen.

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WAS KOSTET STREIFENANBAU? ERSTE ERGEBNISSE AM BEISPIEL VON WINTERWEIZEN

Sören Thalmann¹, Joachim Aurbacher

Zusammenfassung

Der Trend zu immer größeren Bewirtschaftungseinheiten im Ackerbau wird aus Umweltgesichtspunkten kritisch gesehen. Trotz der unbestreitbaren Vorteile für die maschinelle Bewirtschaftung wird die Habitateignung für Insekten eher kleinstrukturierten Agrarlandschaften zugeschrieben. Einen Kompromiss könnte der Streifenanbau bieten, der die Kulturen der Fruchtfolge gleichzeitig auf dem Feld in Streifen platziert, so dass weiterhin eine maschinelle Bewirtschaftung möglich ist.

Im Rahmen des vorliegenden Artikels soll die Wirtschaftlichkeit des Streifenanbaus bewertet werden. Dazu wird das Modell CULTIVASIM-Streifenanbau genutzt, das die Bewirtschaftungskosten anhand des notwendigen Zeitaufwandes berechnet und zusätzlich Rand- und Vorgewendeverluste berücksichtigt. Das Modell wird auf die Fragestellung angepasst, indem die für den Streifenanbau spezifischen Effekte der zusätzlichen Randverluste, der kleineren Flächen pro Kultur und der zusätzlichen Fahrten zum Feld sowie von Streifen zu Streifen berücksichtigt werden. Der Streifenanbau wurde auf insgesamt neun Betrieben mit unterschiedlicher Betriebsstruktur, Fruchtfolge und Flächengeometrie in Praxisversuchen in Hessen erprobt. Durch Erhebung von Fahrschemata und Arbeitsgeschwindigkeiten sowie erster Ertragsschätzungen konnten die notwendigen Parameter für das Modell festgelegt werden.

Die Ergebnisse zeigen, dass kleinere Streifenbreiten zu höheren Verlusten durch Randeffekte führen, während sich die Vorgewendeverluste nicht gravierend ändern im Vergleich zur Reinkultur. Eine höhere Fahrtzeit zwischen den Streifen und eine steigende Anzahl der angebauten Kulturen beeinflussen ebenfalls die Wirtschaftlichkeit des Streifenanbaus negativ. Bei höchstens vier Kulturen, Flächengrößen um 5 ha und Streifenbreiten von mindestens 20 m belaufen sich die Deckungsbeitragsverluste in der Größenordnung von 70 €/ha. Damit könnte der Streifenanbau als Alternative zum Reinkulturanbau, dann attraktiv werden, wenn dieser Verlust durch Fördermaßnahmen ausgeglichen würde oder positive Umwelteffekte wie eine verbesserte Bestäuberleistung oder Erosionsschutz quantifizierbar und für den landwirtschaftlichen Betrieb nutzbar wären. Eine Integration von landwirtschaftlicher Produktion und aktivem Umweltschutz wäre so möglich.

Keywords

Streifenanbau, Kosten, Biodiversität

1 Einführung

Die heutige Landwirtschaft trägt maßgeblich zum Verlust der Artenvielfalt bei. Durch die geringe Diversifikation von Anbausystemen fällt es besonders Bestäuberinsekten schwer, über das ganze Jahr hinweg Nahrung zu finden. In landwirtschaftlichen Gebieten, in denen die Biodiversität jedoch zugenommen hat oder zu mindestens beibehalten wurde, wird mit einer höheren und stabileren Produktivität von bestäuberabhängigen Pflanzen gerechnet (AIZEN et al.

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2019). In Untersuchungen konnte gezeigt werden, dass mit einer Zunahme der Anbaudiversifizierung auch eine Zunahme der Bestäuberaktivität verzeichnet wurde. Auch korreliert mit einer Abnahme umweltschädlicher landwirtschaftlicher Praktiken eine Zunahme der Bestäuberpopulationen (AIZEN et al. 2019). Dabei stellt die Ausweitung der intensiven Landwirtschaft selbst eine der Hauptursachen für den Rückgang der Bestäuber da. Zum einen werden Lebensräume zerstört und fragmentiert und zum anderen führt der Einsatz von Insektiziden und Herbiziden zu Artensterben (PALMA et al. 2016). Neben der Art der angebauten Kulturpflanzen ist jedoch vor allem die Heterogenität der Lebensräume entscheidend für den Erhalt der Artenvielfalt. Die Vielfalt im Lebensraum ermöglicht auch eine Vielfalt in Bestäubergemeinschaften und damit eine effizientere und stabilere Bestäubungsdienstleistung (TSCHARNTKE et al. 2021). Der Anbau von bestäuberabhängigen Kulturpflanzen in Reinform hingegen kann Bestäuberinsekten schädigen, da große Trachtlücken entstehen und das Nahrungsangebot nicht ausreichen kann (AIZEN et al. 2019).

Die Bedeutung der Bestäubungsleistung ist auch für die Landwirtschaft selbst in den letzten Jahren gewachsen. Durch die Ausdehnung des Anbaus von bestäuberabhängigen Kulturpflanzen ist der Schutz der Insekten und vor allem der Bestäuberinsekten so essenziell wie noch nie (AIZEN et al. 2008). Bedingt durch steigende Attraktivität und höhere Deckungsbeiträge hat der Anbau von bestäuberabhängigen Nutzpflanzen wie Ölsaaten, Nüsse und Obst zugenommen (GALLAI et al. 2009). Dies wiederum führt zu einer Inanspruchnahme der globalen Bestäuberkapazität (AIZEN et al. 2009). Reicht die Bestäuberleistung in einer Region nicht aus, so müssten kostenaufwändige Ersatzmaßnahmen vorgenommen werden wie Stilllegung, Hecken oder Blühstreifen (GARIBALDI et al. 2013). Eine weitere, produktionsintegrierte Methode, die Diversifizierung der Landschaft zu erhöhen, könnte jedoch der Streifenanbau sein, da neben dem Strukturreichtum auch die Schlaggröße einen wesentlichen Einfluss auf die biologische Vielfalt und somit auch auf die Bestäuberinsekten ausübt. Bei Streifenanbau werden die Kulturen, die normalerweise im Rahmen der Fruchtfolge nacheinander als Reinkultur angebaut würden, gleichzeitig jeweils als Streifen auf einem Feld angebaut. Die Breite der Streifen orientiert sich an der Bearbeitungsbreite der Pflegemaßnahmen; das Vorgewende wird jährlich von einer anderen Kultur belegt. Neben den hier präsentierten Ergebnissen des Projektes „BeeContour“ aus Hessen mit Streifenanbau gemäß dem Fruchtfolgeschema werden bereits ähnliche Anbausysteme im Projekt „Ackerbau in Streifen“ (Göttingen und Kiel; Schwerpunkt auf Weizen und Raps) und dem österreichischen Projekt „ARGE Streifenanbau“ untersucht, um die Landwirtschaft in Zukunft nachhaltiger zu gestalten bei Beibehaltung der Produktionsfunktion.

2 Material und Methoden

2.1 Versuchsanlage und Datengrundlage

Im Projekt BeeContour werden die Streifen entsprechend der Arbeitsbreite der Pflegearbeiten des Betriebes angelegt (im Projekt 9-45 m). Dabei werden die Kulturen genauso wie in Reinkultur nach guter fachlicher Praxis von den jeweiligen Versuchs- und Praxisbetrieben bewirtschaftet. Neben zwei Versuchsbetrieben der Justus-Liebig-Universität Gießen (Typ A) sind sieben Praxisbetriebe (Typ B) aus Hessen vertreten. Bei der Auswahl der Praxisbetriebe wurde darauf geachtet, dass sowohl ökologisch wirtschaftende als auch konventionelle und Biogasbetriebe beteiligt sind. Der Niederschlag an den verschiedenen Standorten beträgt im Mittel der letzten 30 Jahre 767 mm pro Jahr. Auf den Typ A-Betrieben wurden die Streifen grundsätzlich mit einheitlicher Länge angelegt. Auf dem A-Betrieb Rauischholzhausen (1A) wurden jedoch zwei Anlagen, einmal mit 15 m Breite (1A1) und einmal mit einer Streifenbreite von 45 m angelegt (1A2, siehe Abbildung 1). In Rauischholzhausen wird eine 5-gliedrige Fruchtfolge und auf dem ökologisch wirtschaftenden Betrieb Gladbacherhof (2A) eine 7-gliedrige Fruchtfolge angebaut. Auf den Typ B-Betrieben wird auf den konventionellen und Biogasbetrieben eine viergliedrige Fruchtfolge und auf dem ökologischen Betrieb (6B) eine sechsgliedrige

Fruchtfolge genutzt, wobei die Streifenlänge durch die Schlaggeometrie vorgegeben ist. Auf allen Betrieben werden als zwingende Fruchtfolgeglieder Winterweizen, und als Blühkultur Winterraps (konventionell), Ackerbohne (ökologisch) oder Sorghum (Biogas) angebaut. Zusätzlich sollen alle Betriebe jeweils Referenzflächen mit den Kulturen, die im Streifenanbauversuch angebaut wird, in Reinkultur anbauen. Da alle Betriebe Winterweizen anbauen, konzentriert sich diese Auswertung auf diese Kultur. Alle Betriebe wurden durch das Projekt mit GPS-Trackern ausgestattet und berichteten dem Projekt ihre Ackerschlagkartei sowohl zur Streifenanbaufläche als auch zur Referenzfläche.

Abbildung 1: Versuchsfläche Rauischholzhausen im Frühjahr 2023, im Vordergrund Streifen mit 15 m Breite und im Hintergrund Streifen mit 45 m Breite (eigene Darstellung)



Neben den agronomischen und betriebswirtschaftlichen Daten werden auch die Diversität und Abundanz der Bestäuberinsekten erfasst. Diese Ergebnisse sind jedoch nicht Gegenstand des vorliegenden Artikels.

2.2 Kostenberechnung mit CULTIVASIM

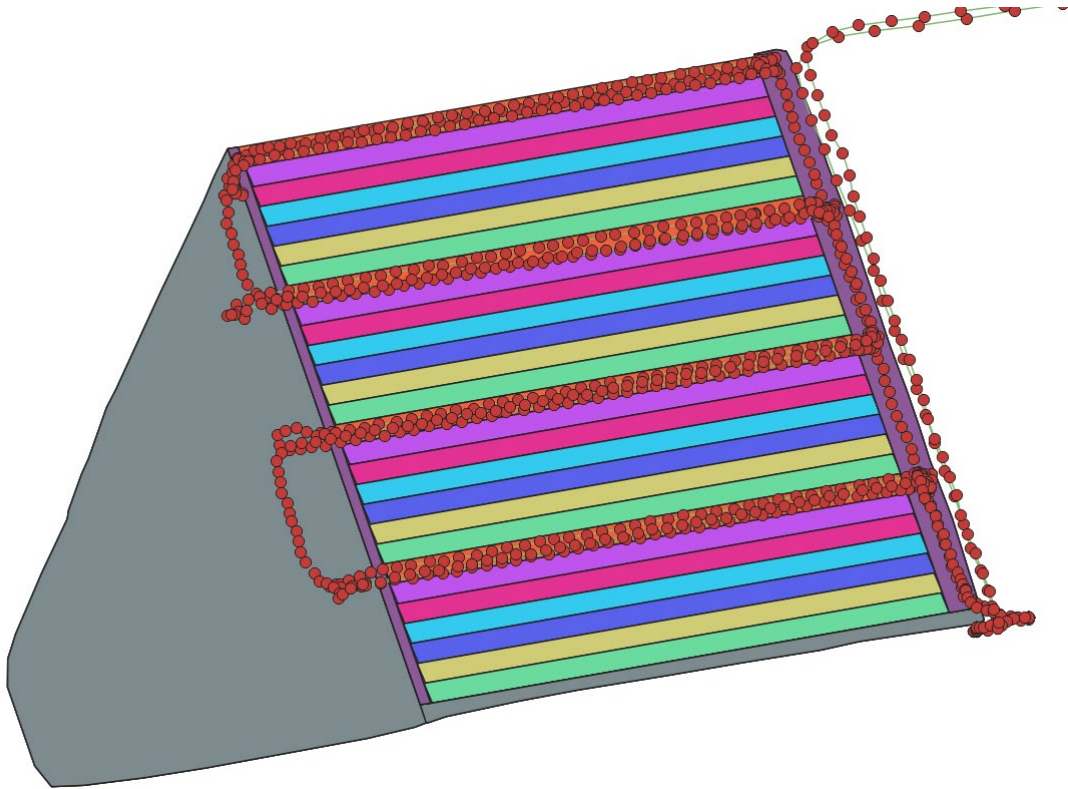
Die Kosten und Leistungen des Streifenanbaus wurden mit einer angepassten Version des Modells CULTIVASIM bewertet (AURBACHER und DABBERT 2009). Das Modell simuliert den Zeitaufwand für die Bewirtschaftung der Ackerschläge unter Berücksichtigung der Form des Schlages, der notwendigen Arbeitsgänge, der Charakteristika der eingesetzten Maschinen (u. a. Arbeitsbreite, Geschwindigkeit und Wendezeiten). Die verwendeten Daten sind für alle Betriebe standardisiert, z.B. sind die gewählten Arbeitsbreiten für Bodenbearbeitungsgeräte 3 m, für die Pflegemaßnahmen 21 m und für den Mähdrescher 4,5 m, die angenommenen Geschwindigkeiten sind Arbeitsgang spezifisch und liegen meist zwischen 4 und 9 km/h. Es berücksichtigt zusätzlich die Ertragsverluste im Vorgewende und in den Randzonen.

Die Datenerhebung umfasst Ackerschlagkarteien, Ertragsdaten, Arbeits- und Maschinenkosten. CULTIVASIM integriert diese Daten in eine räumliche Repräsentation der Schläge und berechnet dabei die schlagspezifischen Deckungsbeiträge (AURBACHER 2010). Die hinterlegten Daten für Maschinenkosten sowie der unterstellte Lohnansatz basieren auf KTBL (2022).

Im folgendem wird die Anpassung des CULTIVASIM-Modells für den Streifenanbau dokumentiert. Dabei wird berücksichtigt, dass durch den Streifenanbau erhöhte Fahrzeiten zwischen

den Streifen anfallen (FZS), sowie dass durch die kleineren Bewirtschaftungseinheiten relativ erhöhte Rüst- und Wegezeiten entstehen. Ferner werden die zusätzlichen Randverluste an den Streifenrändern, die durch eine suboptimale Bewirtschaftung entstehen, berücksichtigt. Die zur Parametrisierung des Modells notwendigen Daten wurden durch Felderhebungen auf Typ A- und Typ B-Betrieben gewonnen. Insbesondere wurden die Fahrgeschwindigkeiten auf den Wegstrecken sowie auf dem Feld durch GPS-Tracker gemessen (siehe Abbildung 2).

Abbildung 2: Darstellung der Streifenanbaufläche 2A mit erfassten Datenpunkten durch den GPS-Tracker für den Arbeitsgang „Kartoffeln anhäufeln“



(Quelle: eigene Darstellung)

Das Modell CULTIVASIM wurde wie folgt angepasst. Die Maschinenkosten wurden über die Berechnung der Gesamtzeit (GZ) berechnet, die die Summe aus Hauptzeit (Hauptfeld), Hauptzeit (Vorgewende), Wendezeit (Hauptfeld), Wendezeit (Vorgewende), Verlustzeit, sowie Rüst- und Wegezeit ist. Die Gesamtzeit wurde für die Gesamtheit aller Streifen einer Kultur berechnet. Dazu wurde z.B. für die Berechnung der Hauptzeit (Hauptfeld) die Fläche des Hauptfeldes durch die Zahl der Kulturen (N) geteilt. Die Gesamtzeit wird nun nicht mehr auf die Gesamtfläche des Schlages, sondern nur noch auf den auf die jeweilige Kultur betreffenden Anteil bezogen. Somit wurde der höhere Anteil an Rüst- und Wegezeiten automatisch berücksichtigt. Die Berechnung der Wendezeit (Hauptfeld) wurde an die nur teilweise Bearbeitung der Schlagbreite (B_s) angepasst. Bei den Vorgewenden wurde unterstellt, dass in jedem Jahr jeweils eine Kultur der Streifen im (kompletten) Vorgewende angebaut wird. Die Berechnung der Hauptzeit (Vorgewende) und Wendezeit (Vorgewende) verbleiben an sich unverändert, wurden jedoch dann durch N geteilt und letztlich auf die Kulturfläche bezogen. Insofern handelt es sich um eine Durchschnittsberechnung über die Jahre. Des Weiteren wurde ein weiterer Bestandteil der Gesamtzeit hinzugefügt, der die notwendige zusätzliche Fahrzeit von einem Streifen zum nächsten beinhaltet (FZS). Dabei wird unterstellt, dass die dafür notwendige Fahrstrecke der Summe der Breite aller anderen Streifen außer der aktuell bewirtschafteten Kultur entspricht. FZS wird dann gemäß Gleichung (1) berechnet.

$$FZS = \frac{(N-1)}{N} \cdot \frac{SVG}{2} \cdot \frac{1}{V_{ZS}} \quad (1)$$

Dabei ist N die Anzahl der Kulturen, SVG die Summe der Vorgewendelänge (Summe über beide Seiten) und V_{ZS} die Fahrgeschwindigkeit bei der Querfahrt. Während die Berechnung der Vorgewendeverluste aus dem Originalmodell unverändert übernommen wurde und lediglich der Verlustfaktor durch die häufigeren Überfahrten angepasst wurde, wurde die Berechnung des Randanteils (RTEIL) im Hauptfeld, der von Ertragsverlusten betroffen ist, wie folgt angepasst. Da nicht nur die Ränder außen am Feld, sondern auch die Randzonen, an denen die Streifen aneinanderstoßen berücksichtigt werden mussten, wurden zunächst die durchschnittliche Länge der Streifen (LS) und die Zahl der Streifen je Kultur (ZS) wie folgt berechnet.

$$LS = \frac{A}{B_F} - 2 \cdot B_{VG} \quad (2)$$

Dabei ist A die Fläche des Schlages, B_F die Breite des Feldes (gemessen rechtwinklig zur Fahrtrichtung) und B_{VG} die Breite des Vorgewendes.

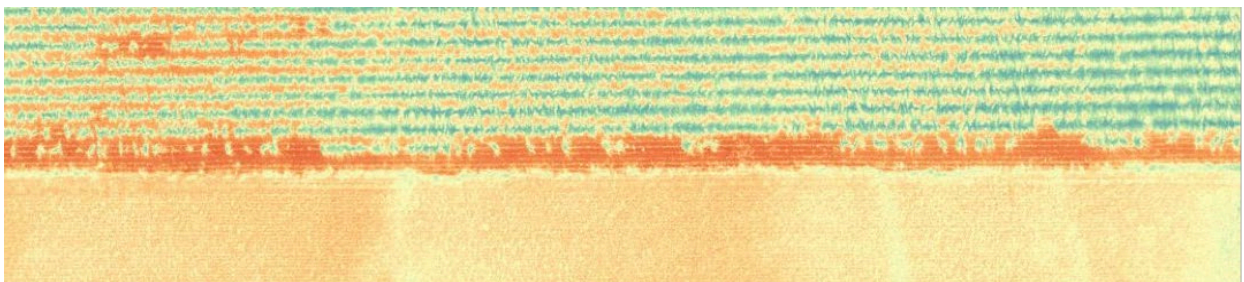
$$ZS = \frac{B_F}{N \cdot B_S} \quad (3)$$

Hierbei ist B_S die Breite der Streifen. Somit ergibt sich der Randanteil mit Ertragsverlusten (RTEIL) wie folgt.

$$RTEIL = \frac{2 \cdot ZS \cdot LS \cdot B_R}{A/N} \quad (4)$$

Dabei ist B_R die Breite des durch Ertragsverlust betroffenen Randstreifens (hier 2 m). Im Randteil wurde zunächst ein Ertragsverlust von 10 % unterstellt. Der Ertragsverlust wurde durch Ernteerhebungen im Feld ermittelt, die beeinträchtigte Streifenbereiche durch Drohnenaufnahmen verifiziert (siehe Abb. 3).

Abbildung 3: Ertragsverlustzonen dargestellt durch den NDVI (Normalized Difference Vegetation Index) am Übergang zwischen zwei Streifen (oben Mais, unten Weizen), aufgenommen am 04.07.2023 auf der Versuchsfläche 1A1



(Quelle: Lennart Scheer)

Die resultierenden Ergebnisse ermöglichen die Berechnung von Bewirtschaftungskosten und Deckungsbeiträgen im Streifenanbau im Vergleich zu einheitlich bewirtschafteten Feldern. Zunächst wurden die Kosten- und Deckungsbeitragsunterschiede für die auf den Versuchsflächen vorgefundene Situation berechnet. Des Weiteren werden verschiedene Szenarien, nämlich Variationen der Randverluste, der Vorgewendeverluste und der Zahl der Kulturen berechnet (Sensitivitätsanalyse).

3 Ergebnisse

3.1 Hauptvarianten

Die Ergebnisse zeigen, dass der Streifenanbau die Kosten für die einzelnen Betriebe erhöht, insbesondere aufgrund des gestiegenen Arbeitszeitaufwands. Zusammen mit den zusätzlichen Randverlusten sinken damit die Deckungsbeiträge. Die Deckungsbeitragsrückgänge liegen somit zwischen 36,10 €/ha und 284,82 €/ha. Die Ergebnisse variieren je nach Flächenstruktur und durchschnittlicher Flächengröße der Betriebe (Tabelle 1). So weist beispielsweise der Betrieb 5B die geringste zusätzliche Arbeitszeit pro Hektar durch den Streifenanbau auf, hauptsächlich bedingt durch die breiten Streifen und die geringe Entfernung zu den Feldern. Im Gegensatz dazu zeigt der Betrieb 2A höhere Kosten, bedingt durch schmalere Streifen, mehr Fahrten zwischen den Streifen und eine größere Entfernung zum Feld.

Tabelle 1: Streifenanbau der Kultur Weizen mit 10 % Randverlust und 20 % Vorgehendeverlust im Vergleich zu einem Anbau in Reinkultur der verschiedenen Betriebe

Betrieb	Schlaggröße [ha] (A)	Kulturen (N)	Hof-Feld-Ent- fernung [km]	Streifenbreite [m] (Bs)	DB Reinkultur [€/ha]	DB Streifenanbau [€/ha]
1A1	6,40	5	0,75	15	553	479
1A2	6,50	5	0,75	45	569	519
2A	4,77	7	5	9	599	314
3B	11,98	4	0,75	21	561	517
4B	7,72	4	0,75	24	541	493
5B	13,36	4	0,75	24	602	565
6B	7,52	6	0,75	9	660	555
7B	4,89	4	0,75	15	560	490
8B	5,55	4	5	21	561	442
9B	2,12	4	0,75	15	529	409

Quelle: Eigene Berechnungen

Die relativen Wegezeiten sind stark von der Hof-Feld-Entfernung und der Flächengröße abhängig. Deutliche Unterschiede in den Wegezeiten zeigen sich insbesondere zwischen Betrieben mit geringer und großer Entfernung zu den Streifenanbauflächen (2A vs. 6B). Des Weiteren werden die Auswirkungen von Randverlusten auf die Deckungsbeiträge der einzelnen Kulturen betrachtet. Hierbei zeigt sich, dass Streifenbreite und -anzahl den Anteil der Randeffekte beeinflussen. Betriebe mit schmalen Streifen zeigen höhere Randeffekte und somit niedrigere Deckungsbeiträge (5B vs. 7B). Die Randeffekte sind auch visuell sichtbar (Abbildung 3); Randbereiche von Kulturen weisen aufgrund von suboptimaler Düngerapplikationen und Abdrift von Pflanzenschutzmitteln geringere Erträge auf.

3.2 Sensitivitätsanalysen

Aufgrund der Unsicherheit einiger Modellparameter wurden Sensitivitätsanalysen angestellt und dabei die Einflussfaktoren Randverluste, Vorgehendeverluste und Zahl der Kulturen eingehender betrachtet. Tabelle 2 zeigt die Effekte unterschiedlicher Randertragsverhältnisse. Der Deckungsbeitrag für einen Randverlust von 10 % in den äußeren 2 Metern des Streifens beträgt für 1A1 rund 479,32 €/ha, während der DB für 1A2 etwa 519,04 €/ha beträgt. Der höhere DB von 1A2 ist auf die größere Streifenbreite von 45 m zurückzuführen.

Tabelle 2: Einfluss unterschiedlicher Annahmen für Randverluste (im 2 m-Bereich) auf die Deckungsbeiträge (DB) für Winterweizen in Reinkultur und drei Szenarien für den Streifenanbau (Vorgewendeverluste 20 %; Anzahl Kulturen wie in Tab. 1)

Betrieb	DB €/ha Reinkultur Randverluste 10 %	DB €/ha Streifen Randverluste 0 %	DB €/ha Streifen Randverluste 10 %	DB €/ha Streifen Randverluste 20 %
1A1	553	509	479	448
1A2	569	529	519	508
2A	599	533	476	419
3B	561	540	517	494
4B	541	513	493	473
5B	602	586	565	544
6B	660	616	555	494
7B	560	523	490	457
8B	561	551	442	503
9B	529	451	409	389

Quelle: Eigene Berechnungen

Die Randeffekte von 10 % verändern die DB für 1A1 um 30,36 €/ha und für 1A2 um nur 10,58 €/ha. Bei einem Randeffekt von 20 %, welcher durchaus bei Weizen zu erwarten ist, ergibt sich ein Verlust von 60,71 €/ha, bei 15 m-Streifen und bei einer Streifenbreite von 45 m nur einen Verlust von 21,17 €/ha.

Auch die Ertragseffekte im Vorgewende sind unsicher, da durch das häufige Befahren höhere Verluste zu erwarten sind. Die Effekte der Varianten 0 %, 20 % und 30 % sind in Tabelle 3 dargestellt. Durch die Erfahrungen im Projekt kann im Vorgewende mit einem Verlust von 20 % gerechnet werden. Dies führt zu einer Reduzierung der Deckungsbeiträge bei 3B um 58,95 €/ha und bei 6B um 23,62 €/ha. Der Betrieb 6B wirtschaftet ökologisch und hat nur ein Vorgewende mit 9 m Breite im Gegensatz zum konventionellen Betrieb 3B mit einem Vorgewende von 21 m Breite.

Den Einfluss der Anzahl der Kulturen im Streifenanbausystem auf den Deckungsbeitrag zeigt Tabelle 4. Da die Anzahl der Kulturen Flächen 1A1 und 5B gleich ist, sind die Unterschiede minimal. Für den Vergleich von Reinkultur mit vier Kulturen ist der Unterschied für 1A1 bei 61,23 €/ha und für 5B sinkt der Deckungsbeitrag um 36,10 €/ha.

Tabelle 3: Einfluss unterschiedlicher Annahmen für Vorgewendeverluste auf die Deckungsbeiträge (DB) für Winterweizen in Reinkultur und drei Szenarien für den Streifenanbau (Randverluste 10 %; Anzahl Kulturen wie in Tabl. 1)

Betrieb	DB [€/ha] Reinkultur Vorgewendeverluste 20 %	DB [€/ha] Streifen Vorgewendeverluste 0 %	DB [€/ha] Streifen Vorgewendeverluste 20 %	DB [€/ha] Streifen Vorgewendeverluste 30 %
1A1	553	538	479	449
1A2	569	568	519	494
2A	599	503	476	462
3B	561	576	517	488
4B	541	560	493	459
5B	602	596	565	550
6B	660	579	555	548
7B	560	545	490	463
8B	561	565	527	508
9B	529	478	420	391

Quelle: Eigene Berechnungen

Tabelle 4: Einfluss der Zahl der Kulturen auf die Deckungsbeiträge (DB) für Winterweizen in Reinkultur und drei Szenarien für den Streifenanbau (Randverluste 10 %; Vorgewendeverluste 20 %)

Betrieb	DB [€/ha] Reinkultur	DB [€/ha] Streifen 4 Kulturen	DB [€/ha] Streifen 6 Kulturen	DB [€/ha] Streifen 8 Kulturen
1A1	553	491	469	448 €/ha
1A2	569	528	508	487
2A	599	521	491	462
3B	561	517	503	489
4B	541	493	473	454
5B	602	565	555	543
6B	660	574	555	538
7B	560	490	464	437
8B	561	527	505	482
9B	529	420	369	314

Quelle: Eigene Berechnungen

Dieser Unterschied liegt vor allem an der größeren Streifenbreite auf Betrieb 5B. Da somit die Querfahrten von Streifen zu Streifen pro ha seltener auftreten, sinken die Deckungsbeiträge nicht so stark.

4 Diskussion und Fazit

Die Ergebnisse in Kapitel 3 zeigen die Auswirkungen des Streifenanbaus auf die Deckungsbeiträge. In allen Betrieben führt der Streifenanbau wie zu erwarten zu einem Anstieg der Bewirtschaftungskosten und einem Rückgang der Deckungsbeiträge für Winterweizen. Betrieb 2A,

dessen Versuchsfläche sich durch ihre große Entfernung von der Hofstelle, einer geringen Streifenbreite von 9 m und einer weiten Fruchtfolge auszeichnet, zeigt besonders hohe Streifenanbaukosten. Die geringe Streifenbreite führt zu einem erhöhten Anteil von Randverlusten und die Entfernung zu hohen Wegekosten, die sich auf wenig Fläche verteilen. Im Gegensatz dazu weisen die Ergebnisse des Betriebs 5B, gefolgt von 1A2 mit einer größeren Streifenbreite, geringerer Entfernung und einer kurzen Fruchtfolge die geringsten Deckungsbeitragsverluste auf. Die Ergebnisse zeigen, dass vor allem die Streifenbreite einen großen Einfluss auf die Deckungsbeitragsverluste hat. Während die Randverluste bei Reinkulturen fast zu vernachlässigen sind, spielen sie insbesondere bei sehr schmalen Streifen eine große Rolle, da dann ein nennenswerter Teil des Feldes (bis zu 25 %) von den Randeffekten betroffen ist. Der Vergleich der Flächen 1A1 und 1A2, die sich nur in der Streifenbreite unterscheiden zeigt, dass sich der DB-Verlust bei den 45 m-Streifen nahezu halbiert (Tabelle 1). Dies wird zusätzlich belegt durch die Sensitivitätsanalyse (Tabelle 2), die zeigt, dass insbesondere bei den schmalen Streifen der Großteil der Deckungsbeitragsverluste durch die Randverluste verursacht werden (Vergleich Randverluste 0 % zu 20 % vs. Reinkultur). Die exakte Quantifizierung dieser Randverluste bedarf deshalb weiterer eingehender Untersuchungen. Die Sensitivitätsanalysen zu den Vorgewendeverlusten (Tabelle 3) zeigen, dass auch diese einen relevanten Einfluss auf die Deckungsbeiträge haben. Allerdings treten diese auch bei Reinkultur in etwa in derselben Höhe auf. Es wäre lediglich zu hinterfragen, ob das Ertragsniveau von 80 % weiterhin realistisch ist oder ob nicht Verluste >20 % unterstellt werden müssten. Wie erwartet fällt der Effekt größer aus auf kleinen Flächen mit breiterem Vorgewende (2A und 3B vs. 5B und 6B), dies ist jedoch genauso auch bei Reinkulturen der Fall.

Die Erhöhung der Zahl der Kulturen senkt c.p. ebenfalls die Deckungsbeiträge (Tabelle 4). Gründe sind die geringere Anbaufläche pro Kultur, auf die sich die Rüst- und Wegezeiten verteilen sowie die erhöhte Fahrzeit zwischen den Streifen. Der Effekt der Wegezeiten könnte sich allerdings dann relativieren, wenn berücksichtigt würde, dass ein Betrieb mehrere Flächen in derselben Gemarkung bewirtschaftet, die nahe beieinanderliegen und in einem Zug bearbeitet werden können. Der Effekt der Rüstzeiten würde dennoch verbleiben. Aus betriebswirtschaftlicher Sicht lässt sich schlussfolgern, dass größere Streifenbreiten (ab 20 m) und eine überschaubare Fruchtfolge (4 Kulturen) zusammen mit einer ausreichenden Schlaggröße (5 ha) die Kosten für den Streifenanbau im Rahmen von ca. 70 €/ha halten können (siehe Betriebe 1A2, 3B, 4B, 5B und 7B). Ab welcher Streifenbreite jedoch die gewünschten Umwelteffekte noch bewirkt werden können, muss durch ökologische Begleitforschung aufgeklärt werden.

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DER EINSATZ VON DROHNEN UND VERGLEICH MIT ANDEREN FERNERKUNDUNGSMETHODEN IM PFLANZENBAU

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Abstract

The uses of remote sensing technologies are becoming increasingly important also for agriculture. Aerial images from satellites, aircraft and drone flights can provide information for resource-saving crop production. The applications of remote sensing technologies are very diverse. Plant populations can be recorded, and biomass maps can be created over large areas in a short time, weed nests or drought stress can be identified and deficiencies in nutrient supply can be assessed. With the help of aerial photos, defective drainage pipes, overgrown hedges, storm damage at the edge of the forest and damage caused by wildlife can still be identified. Drones can also be used to detect wild animals e.g. deer fawn in front of grassland mowing and to record the quantity of silage and sugar beet piles. The range of aerial drone services in the agricultural sector is still limited. Interested farmers therefore must ask themselves whether their own investment in a flying drone would be profitable. As part of the AgriSens-Demmin project, the Neubrandenburg University of Applied Sciences, the University of Halle Wittenberg and the KTBL, among others, addressed this question at the operational level. The first results of the investigations carried out are presented below. The first steps to get started with remote sensing are explained using the example of a multicopter drone and the working time required for a drone flight and the processing of aerial images to create an NDVI biomass map are described. Furthermore, the average annual costs of a drone flight are shown as an example for a 1,000-hectare arable farm in Mecklenburg-Western Pomerania and compared with the expenses for remote sensing data from aircraft flights and satellite use. Finally, further possible applications specifically for drones are described e.g. wild animal detection, assessment of damage to crops, e.g. in silage maize cultivation, and quantity recording, e.g. of sugar beet piles.

Keywords

Fernerkundungsverfahren, Drohnen, Pflanzenbau, Schadenbegutachtung

1. Einleitung

Die Einsatzmöglichkeiten von Fernerkundungstechnologien sind von zunehmender Bedeutung auch für die Landwirtschaft. Luftbilddaufnahmen von Satelliten, Flugzeug- und Drohnenbefliegungen können wertvolle Informationen für eine ressourcenschonende Pflanzenproduktion liefern. Die Anwendungsmöglichkeiten der Fernerkundungstechnologien sind sehr vielfältig. Aus der Luft können Pflanzenbestände erfasst und Biomassekarten in kurzer Zeit großflächig erstellt, Unkrautnester oder auch Trockenstress erkannt und Mängel in der Nährstoffversorgung beurteilt werden (BENDIG et al., 2014; GUAN et al., 2019; ZHANG et al., 2019; GASPAROVICA et al., 2020; TAO et al., 2020; ISTIAK et al., 2023). Mit Hilfe von Luftbildern können weiterhin defekte Drainageleitungen, eingewachsene Hecken, Sturmschäden am Waldrand und Wildschäden erkannt werden. Drohnen können darüber hinaus zur Detektion von Wildtieren vor der Grünlandmahd und zur Mengenerfassung von Silage- und Zuckerrübenhaufen eingesetzt werden (KTBL, 2021). Darüber hinaus werden unter Aspekten des Naturschutzes bereits Möglich-

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keiten zur teilautonomen Bewertung von Biodiversitätskriterien, beispielsweise der Anteil bestimmter Pflanzenarten auf landwirtschaftlich genutzten Flächen, diskutiert (SCHÖTTKER et al., 2023).

Noch ist das Angebot an Dienstleistungen mit Drohnen im Bereich der Landwirtschaft begrenzt und kostenintensiv. In einer deutschlandweiten Recherche konnten nur 20 Anbieter von Dienstleistung mit Drohnen im Agrarbereich ermittelt werden (ELLMANN UND STROHFELDT, 2023). Eine in Italien durchgeführte Untersuchung zu Kosten von Fernerkundungstechnologien zur Erstellung von Biomassekarten ergab Aufwendungen in Höhe von 75 EUR pro ha für den Einsatz von Drohnen (SOZZI et al., 2021). Daher stellt sich für Interessierte die Frage einer eigenen Investition. Aber auch diese sollte sich rechnen.

In der landwirtschaftlichen Praxis stellt sich beim Einsatz von Fernerkundungstechnologien die Frage zu Nutzen und Kosten der Anwendung. Im Rahmen des Projektes AgriSens-Demmin beschäftigten sich die Hochschule Neubrandenburg, die Universität Halle Wittenberg und das KTBL unter anderem mit dieser Fragestellung. Nachfolgend werden erste Ergebnisse der durchgeführten Untersuchungen vorgestellt.

Zu Beginn wird der Einstieg in Maßnahmen zur Fernerkundung am Beispiel einer Multirotor-Drohne erläutert und der standardisiert erfasste Arbeitszeitbedarf für einen Drohnenflug und die Verarbeitung von Luftbildern zur Erstellung einer NDVI-Biomassekarte² beschrieben (FRISCH et al., 2021). Darauf aufbauend werden die durchschnittlichen jährlichen Kosten³ (MUBHOFF UND HIRSCHAUER, 2020) einer Drohnenbefliegung beispielhaft für einen 1.000 ha großen Ackerbaubetrieb in Mecklenburg-Vorpommern dargestellt und mit den Aufwendungen für Fernerkundungsdaten aus Flugzeugbefliegungen und der Satellitennutzung verglichen. Abschließend werden in drei Anwendungsbeispielen (Wildtierdetektion, Befliegung von Fehlstellen im Silomais, Mengenerfassung von Zuckerrübenmieten) weitere Einsatzmöglichkeiten speziell für Drohnen beschrieben.

2. Methodische Vorgehensweise

2.1 Befliegung mit Drohnen

Um eine Drohne selbst fliegen zu dürfen und zu können sind zahlreiche Schritte zu unternehmen, die nachfolgend in 13 Abschnitten dargestellt werden (Tabelle 1). Zum Einstieg gehört die Qualifikation zur Berechtigung der Verwendung einer Drohne (1, 2). Dabei erfordert die höchstzulässige Abflugmasse des Fluggerätes unterschiedliche Qualifikationsmaßnahmen. Zum Flug von Drohnen der Klasse C1 mit einem Abfluggewicht von bis zu 900 g ist die Durchführung eines Onlinetestes erforderlich (1). Für größere Drohnen der Klasse C2 (Startgewicht bis 4 kg) ist ein Drohnenführerschein notwendig (2) (KTBL, 2021). Ferner beeinflusst der angestrebte Verwendungszweck des Fluggerätes die Art der Analysesoftware (4). Zur automatisierten Prozessierung von Einzelaufnahmen in Orthomosaiks eines Feldes eignen sich kommerzielle Programme von Anbietern wie Pix4D und Agisoft Metashape. Biomasse-Indizes können in der Opensource Software QGIS berechnet werden. Zum Betrieb der Drohne ist diese zu versichern und beim Luftfahrtbundesamt (LBA) zu registrieren (5, 6). In Abhängigkeit der Region können weitere Genehmigungen zum Flug erforderlich sein (7). Vor dem Flug empfiehlt sich eine gezielte Flugvorbereitung (8). Diese beinhaltet die Planung der Route, die Vorbereitung der Technik (Ladezustand der Akkus prüfen) und die Kontrolle der Wetterbedingungen. Be-

² normalisierter differenzierter Vegetationsindex

³ $DK_{app} = \frac{AW - RW}{N} + \left[(AW - RW) \times f_{i_{kalk};N} + RW \right] \times i_{kalk} + \frac{1}{N} \times \sum_{t=1}^N BK_t$; $f = \frac{q^N}{q^N - 1} - \frac{1}{N(q-1)}$

N: Nutzungsdauer in Jahren, i_{kalk} : kalkulatorischer Zins, BK_t : Betriebskosten (Reparaturkosten, Betriebsstoffe, Versicherungen), $f_{i;N}$: Faktor für den durchschnittlich zu verzinsenden Anlagewert, AW : Anschaffungswert im Jahr Null einschließlich Montage, R_W : Restwert ($R_W = 0$)

fliegungen können in zwei unterschiedlichen Flugkonfigurationen durchgeführt werden, manuell und automatisiert. Automatisierte Flüge werden im Rahmen der Flugvorbereitung in einer Flugmission konfiguriert. Die Drohne fliegt dabei anhand festgelegter Kriterien vollständig autonom eine definierte Strecke ab. Vor jedem Flug sollten die Wetterbedingungen geprüft werden. Bei starkem Wind kann es dazu kommen, dass die Drohne zu schnell bzw. zu langsam fliegt. Bei konstantem Aufnahmetakt der Kamera wird in Abhängigkeit der Fluggeschwindigkeit eine unterschiedliche Anzahl Aufnahmen je Flugrichtung erzeugt. Dadurch kann es zu Problemen in der Prozessierung der Daten zur Erzeugung des Orthomosaiks kommen. Darüber hinaus erhöht starker Gegenwind den Energieverbrauch des Multirotor. Weiterhin können sich ungünstige Wetterbedingungen nachteilig auf die Flugsicherheit während der Befliegung auswirken. Um das Risiko für Kollisionen mit anderen Verkehrsteilnehmern im Luftraum zu minimieren, eignet sich die Verwendung von speziellen Programmen in denen Flugobjekte⁴ im Umfeld der Befliegungsfläche sichtbar auf einer Karte dargestellt werden. Prinzipiell dürfen Drohnen in Deutschland auf Sichtentfernung (visual line of sight operation, VLOS) geflogen werden. Nach Abschluss der Flugvorbereitung wird der Multirotor in Betrieb genommen. Dazu werden Fluggerät und Fernsteuerung einzeln aktiviert, gekoppelt und ggf. die Software des Multirotors aktualisiert (9 bis 11). Anschließend kann der Multirotor gestartet und ein Funktionstest der Steuerelemente durchgeführt werden (12). Damit ist die Betriebsbereitschaft des Fluggerätes hergestellt (13) (Tab.1).

Tabelle 1: Maßnahmen zum Einstieg in die Befliegung mit Drohnen

Nr.	Maßnahmen	Beschreibung
1	EU-Kompetenznachweis	Online bei EASA, LBA (5 h Lesezeit; 30 min Prüfung)
2	EU-Fernpiloten-Zeugnis	Beim LBA zum Drohnenführerschein anmelden, Lehrgang über 2 Tage mit 12 h Theorie und 12 h Praxis
3	Drohne/Zubehör	Drohne und Zubehör bestellen Angebote anfordern und vergleichen,
4	Flugauswertungsprogramm	ca. 30 min Download- und Installationszeit (QGIS; optional Google Earth Pro; Pix4D, Agisoft Metashape)
5	Haftpflichtversicherung abschließen	Seit 2017 besteht eine Versicherungspflicht für private und gewerblich betriebene Drohnen, Angebote prüfen
6	Registrierung der Drohne	Online-Anmeldung, 1 h Registrier- und Einrichtungszeit
7	(ggf.) Flug in Flugverbotszonen anmelden	Antrag für Flugverbotszone stellen (Antrag bei der zuständigen Luftfahrtbehörde stellen, oder Kommandantur im militärischen Bereich)
8	Flugvorbereitung	Polygone zur Befliegung einer beliebigen Fläche in Planungssoftware wie z.B. Mission Planer (ARDUPILOT) erstellen, optional einzelne Mission im Freihand-Modus auf dem Controller erstellen, Akkus laden, Flugbedingungen prüfen
9	Controller starten	Controller in Betrieb nehmen
10	Drohne aktivieren	Drohne anschalten, in der Ausgangsposition abstellen
11	Drohne und Controller	ggf. Hinweisen im Controller folgen
12	Flugtest	Drohne testen (Steigen auf 10 Meter, dann: Vorwärts/Rückwärts/Links/Rechts, Sinken in die Ausgangsposition)
13	Betriebsbereitschaft zur ersten Befliegung hergestellt	

Quelle: Eigene Darstellung

⁴ Flugzeuge, Hubschrauber, Segelflieger, Paraglider

Unabhängig davon, ob man eine Drohne selbst fliegt oder ob eine entsprechende Dienstleistung angeboten werden soll, sind Informationen über den Zeitbedarf des Drohneneinsatzes von Interesse bzw. Grundlage für eine Kostenkalkulation der Dienstleistung. Hierzu wurden eigene Erhebungen durchgeführt.

2.2 Erfassung des Arbeitszeitbedarfs zur Befliegung mit Drohnen

Zur Erfassung der Arbeitszeitbedarfe für einen Drohnenflug wurden zwei unterschiedliche Drohnenmodelle verwendet. Genutzt wurde eine Multirotor- und Starrflügler-Drohne. Die Multirotor-Drohne ist insbesondere zur Befliegung kleinerer Flächen geeignet (27 ha/h). Mit dem Starrflügler können im Gegensatz dazu höhere Flächenleistungen (60 ha/h) erreicht werden. Beide Drohnen waren mit einer Multispektralkamera zur Aufnahme der Luftbilder ausgestattet. Die Befliegungen wurden auf dem Versuchsfeld der Universität Halle und auf einem Partnerbetrieb im Forschungsprojekt AgriSens in der Nähe von Demmin zwischen Frühjahr 2022 und Sommer 2023 durchgeführt. Zur Datenerhebung wurden jeweils definierte Abschnitte der Felder befliegen und die dabei durchgeführten Arbeitsschritte in mehrfacher Wiederholung gemessen. Die Auswertung der Luftbildaufnahmen erfolgte in den Programmen⁵ Quantum GIS und Agisoft Metashape. Verwendet wurden weiterhin die Anwendungen UAV-Forecast zur Abfrage der Wetterinformationen und die Droniq App zur Darstellung von Luftfahrzeugen im Untersuchungsgebiet. Die Berechnung der jährlichen Kosten erfolgte in Microsoft Excel 2016 (Tab. 2).

Tabelle 2: Übersicht der verwendeten Materialien

Materialien	Beschreibung	Verwendungszeit
Drohne	DJI Inspire 2 (Multirotor-Drohne)	
	WingtraOne GEN II (Starrflügler-Drohne)	Befliegung
Multispektralkamera	Modell MicaSense RedEdge MX-Dual	Beurteilung von Pflanzen
	UAV-Forecast	Wetterinformation
Programme	Droniq App	Flugsicherheit
	Agisoft Metashape	Datenprozessierung
	Quantum GIS (Version 3.28.0 RC)	Berechnung des NDVI
	Microsoft Office Professional Plus 2016	Auswertung, Dokumentation

Quelle: Eigene Darstellung

3. Ergebnisse

3.1 Arbeitszeitbedarf für eine Befliegung mit Drohnen

Die zwischen den verwendeten Drohnentypen bestehenden Unterschiede in der Flächenleistungen spiegeln sich im Arbeitszeitbedarf wider. Zur Flugvorbereitung, Befliegung, Datenauswertung und Wartungen der Drohnen wurden Arbeitszeitbedarfe zwischen 6,80 h/100 ha (Multirotor-Drohne) und 4,50 h/100 ha (Starrflügler-Drohne) ermittelt. Auf die Flugvorbereitung entfallen in Abhängig des Drohnentyps zwischen 11 % und 16 % der Arbeitszeit. Für den Flug und die Flugnachbereitung, sowie Wartung der Drohnen entfallen insgesamt 70 % (Multirotor-Drohne) und 47 % (Starrflügler-Drohne) des Arbeitszeitbedarfs. Für die Datenübertragung- und -auswertung werden weiterhin zwischen 19 % und 38 % der Arbeitszeit notwendig. Die Übertragung und Auswertung der Daten ist abhängig von der insgesamt befliegenen Fläche (Anzahl

⁵ QGIS (kostenlos), Agisoft Metashape (gebührenpflichtig)

der Luftbilder), sowie von der Übertragungs- und Verarbeitungsgeschwindigkeit der verwendeten Hard- bzw. Software. Der Auswertung in Tabelle 3 liegt eine Fläche von 16 ha zugrunde. Wobei die einzelnen Arbeitsschritte in mehrfacher Wiederholung gemessen wurden.

Tabelle 3: Arbeitszeitbedarf zur Erstellung von NDVI-Biomassekarten mit Drohnen

	Multirotor-Drohne	Starrflügler-Drohne
Flugvorbereitung	11 %	16 %
Flug	55 %	32 %
Flugnachbereitung	7 %	8 %
Datenübertragung, Datenauswertung	19 %	38 %
Wartung der Drohne	8 %	7 %
Arbeitszeitbedarf	6,80 h/100 ha	4,50 h/100 ha

Quelle: Eigene Erhebungen

Die Ergebnisse der Arbeitszeitanalyse deuten darauf hin, dass Starrflügler-Drohnen aufgrund der höheren Flächenleistung arbeitswirtschaftlich effizienter zu betreiben sind als Multirotor-Drohnen. In der nachfolgenden Analyse wird daher anhand eines praktischen Beispiels geprüft, in welchem Umfang sich die beschriebenen Vorteile in der Flächenleistung auf die durchschnittlichen jährlichen Kosten auswirken könnten.

3.2 Kosten der Befliegung von 1.000 ha Ackerland

Im nachfolgend Praxisbeispiel werden die durchschnittlichen jährlichen Aufwendungen für die Investition (Kapitalkosten) in eine Multirotor- bzw. Starrflügler-Drohne und die weiteren Kosten für die regelmäßige Befliegung (einmal pro Jahr) für einen 1.000 ha großen Ackerbaubetrieb dargestellt. Diese werden mit den Aufwendungen für die Nutzung von Satellitendaten bzw. der Befliegung mit einem Kleinflugzeug verglichen.

Für die Investition in die verwendeten Drohnenmodelle ist ein Kapitalbedarf von 15.192 € für die Multirotor-Drohne bzw. 44.080 € für den Starrflügler notwendig. Die jährlichen Kapitalkosten, die Summe aus Abschreibung (AfA) und Zins, liegen zwischen 4.016 € (Multirotor-Drohne) und 9.048 € für den Starrflügler (Tab. 4).

Im Gegensatz dazu, sind zur Nutzung des Satelliten und Kleinflugzeugs keine umfangreichen Investitionen notwendig. Damit entstehen hier keine Kapitalkosten. Der Einsatz der Drohnen ist mit Energiekosten für die Akkuladungen der Fluggeräte und mit Fahrkosten verbunden. Für diese werden bei beiden Drohnenmodelle pauschal 50 € p.a. angesetzt. Für die An- und Abfahrt zum Flughafen wurde ein Betrag von 35 € p.a. kalkuliert. Darüber hinaus entstehen für die einmalige Befliegung des Betriebes mit einer Cessna Charterkosten in Höhe von 376 € p.a.

Der Einsatz der vier Fernerkundungsverfahren ist weiterhin mit Lohnkosten⁶ verbunden. Diese betragen in der günstigsten Variante 121 € bzw. 179 € für Satellit und Flugzeug und in der teuersten Variante 801 € und 1.202 € zur Befliegung mit einer Starrflügler- oder Multirotor-Drohne, jeweils für die jährlich einmalige Befliegung von 1.000 ha Ackerland. Insgesamt betragen die durchschnittlichen jährlichen Kosten der vier Verfahren zwischen 0,20 €/ha (Satellit) und 10,18 €/ha (Starrflügler-Drohne) (Tab. 4).

⁶ Lohnkostenansatz 21 EUR / Arbeitskraftstunde

Tabelle 4: Kapitalbedarf und durchschnittliche jährliche Kosten für die Nutzung von Fernerkundungstechnologien am Beispiel des 1.000 ha Ackerbaubetriebs

Verfahren	Einheit	Satellit ¹⁾	Flugzeug ²⁾	Multirotor-Drohne	Starrflügler-Drohne
Kapitalbedarf insgesamt	€			15.192 €	44.080 €
Kapitalkosten (Abschreibung, Zinsen)	€ p.a.			4.016 €	9.048 €
Energie für Akkuladungen; Fahrkosten PKW	€ p.a.		35 €	50 €	50 €
Lohnkosten (21 €/Akh)	€ p.a.	121 €	179 €	1.202 €	801 €
Schulungsmaßnahmen zur Fernerkundung	€ p.a.	82 €	67 €	260 €	292 €
Charterkosten Flugzeug	€ p.a.		376 €		
Summe jährlicher Kosten	€ p.a.	204 €	658 €	5.528 €	10.191 €
Kosten, € pro ha	€/ha	0,20 €	0,66 €	5,52 €	10,18 €

Quelle: Eigene Berechnungen, Anm.: ¹⁾ Sentinel-2; ²⁾ Cessna einmotoriges Passagierflugzeug

Der Blick auf die relative Verteilung der einzelnen Kosten lässt die Unterschiede zwischen den vier Fernerkundungsverfahren nochmals deutlich werden. Die beiden Drohnenvarianten zählen wegen der hohen Anschaffungskosten zu den teuersten Fernerkundungsverfahren; hier entfallen bereits 72 % bzw. 88 % der jährlichen Aufwendungen auf die Kapitalkosten (AfA und Zins). In der Variante Satellit und Flugzeug entfallen die höchsten prozentualen Anteile auf die Positionen Lohnkosten (60 % von 204 € p.a.) zur Auswertung der Satellitenbilder bzw. für Miete des Flugzeuges (57 % von 658 € p.a.). Der Anteil der Lohnkosten beträgt beim Starrflügler 8% (von 801 € p.a.) und bei der Multirotor-Drohne 22 % (von 1.202 € p.a.) (Tab 5).

Tabelle 5: Summe der jährlichen Kosten und Anteile verschiedener Kostenpositionen in Abhängigkeit von der jeweiligen Fernerkundungstechnologie

Position	Satellit	Flugzeug	Multirotor-Drohne	Starrflügler-Drohne
Summe jährlicher Kosten für die Befliegung von 1.000 ha Acker, € p.a.	204 €	658 €	5.528 €	10.191 €
Anteile einzelner Kostenpositionen:				
Kapitalkosten (Abschreibungen, Zinskosten)			72 %	88 %
Energie für Akkuladungen; Fahrkosten PKW		6 %	1 %	1 %
Lohnkosten	60 %	27 %	22 %	8 %
Schulungsmaßnahmen zur Fernerkundung	40 %	10 %	5 %	3 %
Charterkosten Flugzeug		57 %		
Summe	100 %	100 %	100 %	100 %

Quelle: Eigene Berechnungen

Neben den dargestellten unterschiedlich hohen Kosten können für die Wahl eines geeigneten Fernerkundungsverfahrens weitere Merkmale wie beispielsweise die Qualität der Luftbilder, die Flächenleistung und der Schwierigkeitsgrad in der Anwendung von Bedeutung sein. Trotz der im Anwendungsbeispiel geringen Flächenkosten und hohen Flächenleistung für Satellitenbilder ist die Qualität der Luftbilder häufig gering. Neben der niedrigen Bildauflösung von 10 x 10 Metern, bei einer Flughöhe von 786 km, im Vergleich zu Flugzeug und Drohne mit 80 x 80 cm bzw. 7 x 7 cm Auflösung, kann die Qualität durch Wolkenbedeckung zum Aufnahmezeitpunkt stark reduziert sein. Eine deutlich bessere Bildqualität liefern Aufnahmen aus Flugzeug bzw. Drohne, diese fliegen unter normalen Witterungsbedingungen in einer Höhe von 1.000 m bzw. 100 m über dem Boden und werden daher weniger stark durch Wolkenbedeckung limitiert. Weitere Unterschiede bestehen im Schwierigkeitsgrad der Anwendung. Zur Erstellung von Schrägluftbildern ist Übung erforderlich, da die Aufnahmen während des Fluges aus dem Seitenfenster des Flugzeuges durchgeführt werden. Darüber hinaus kann der Aufnahmewinkel zwischen den verschiedenen Schrägluftbildern variieren und die Vergleichbarkeit zwischen verschiedenen Aufnahmezeitpunkten eingeschränkt sein. Im Gegensatz dazu können Drohnenaufnahmen in einer standardisierten Technik (Aufnahmewinkel der Kamera, Flughöhe, Fluggeschwindigkeit u.a.) durchgeführt werden, sodass eine sehr hohe Vergleichbarkeit

der Aufnahmen gegeben ist. Die Anwendung von Drohnen ist jedoch insgesamt schwieriger, mit höheren jährlichen Kosten verbunden und geht mit einer geringeren Flächenleistung einher (Tab. 6).

Tabelle 6: Vergleich der getesteten Fernerkundungstechnologien in den Kategorien Qualität, Flächenleistung, Kosten, Anwendbarkeit

Verfahren	Sentinel-2 Satellit	Flugzeug	Multirotor- Drohne	Starrflügler- Drohne
Qualität der Luftbilder	+	+++	+++++	+++++
Flächenleistung ha pro Stunde	+++++	+++	+	++
Kosten pro ha	+	+	+++	+++++
Anwendbarkeit/Schwierigkeitsgrad	+	+++	++++	+++++

Quelle: Eigene Darstellung; Anm.: Skalierung von + sehr gering bis +++++ sehr hoch

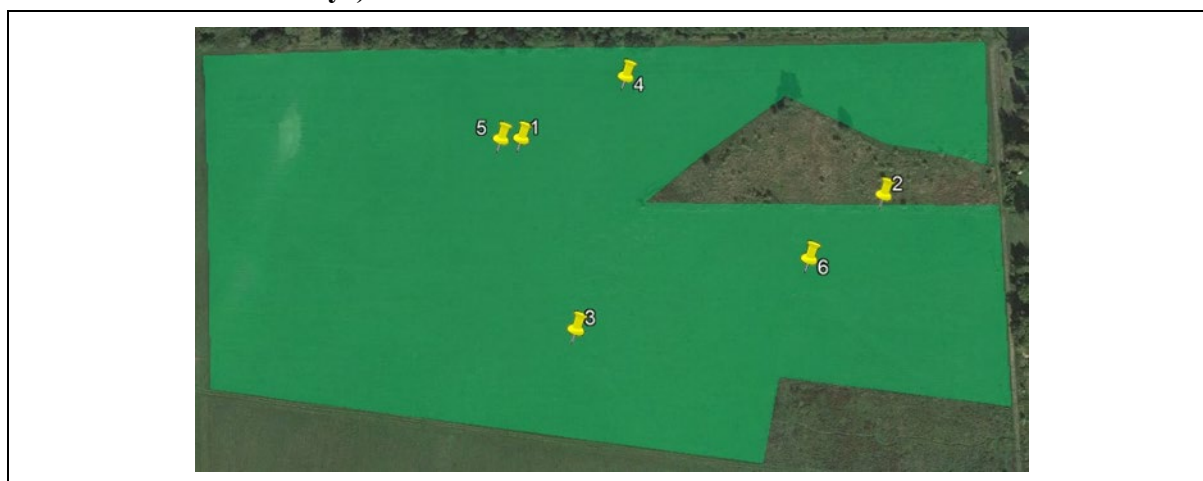
Auf Basis der dargestellten Unterschiede zwischen den betrachteten Fernerkundungsverfahren lassen sich verschiedene Anwendungsbereiche beschreiben. Für einen ersten Überblick über die Betriebsflächen oder größere Einheiten können Satellitenbilder aufgrund der geringen Kosten und einfachen Anwendung besonders vorteilhaft sein. Um dagegen kostengünstig eine deutlich bessere Aufnahmequalität zu bekommen sind aus dem Flugzeug aufgenommene Schrägluftbilder geeignet. Mit Hilfe eines Flugzeuges können große Flächen in kurzer Zeit beflogen und eingeschätzt werden. So können beispielsweise Unterschiede in der Bestandsentwicklung der Pflanzen, Auswirkungen von Bodenverdichtung, pflegebedürftige Hecken und defekte Drainagen gut sichtbar gemacht werden. Daher können in diesem Verfahren Schwachstellen auf dem Feld mit wenig zusätzlichem Aufwand aufgedeckt werden. Um präzise verfahrenstechnische Maßnahmen zu planen sind Drohnenaufnahmen besonders geeignet. Diese bieten sich aufgrund der hohen Auflösung und standardisierten Aufnahme insbesondere für ökologisch sensible Maßnahmen in Düngung, Pflanzenschutz und Aussaat an. Die teilflächenspezifische Bewirtschaftung ist zukünftig auch die Basis für eine ökonomische Optimierung.

Neben den bisher beschriebenen Einsatzgebieten von Drohnen in der pflanzenbaulichen Praxis sind weitere Anwendungen wie die Wildtierdetektion, die Erfassung von Wildschäden bzw. Auflaufschäden und die Mengenerfassung z.B. von Zuckerrübenmieten möglich. Diese Anwendungsbeispiele wurden im Rahmen des Forschungsprojektes ebenfalls untersucht und werden im Folgenden beispielhaft skizziert.

3.3 Arbeitszeitbedarf und Kosten der Wildtierdetektion

Die Suche von Wildtieren vor der Grünlandmahd im Frühjahr ist Teil der guten fachlichen Praxis in der Landwirtschaft. Eine zunehmende Anzahl von Betrieben nutzt dazu auch Drohnen mit Wärmebildkameras. Da die Wildtierdetektion in der Praxis häufig von Jagdpächtern und freiwilligen Helfern unterstützt wird, sind die Arbeitszeitbedarfe und damit verbundenen Lohnkosten in Praxis häufig unbekannt. Im Arbeitszeitanalysen zum Einsatz von Multirotor-Drohnen wurde daher der Arbeitszeitbedarf für eine exemplarische Rehkitzsuche unter Praxisbedingungen erhoben und die Lohnkosten kalkuliert. Die Untersuchung wurde auf einem landwirtschaftlichen Betrieb im östlichen Mecklenburg-Vorpommern durchgeführt. Der Betrieb nutzt eine handelsübliche Multirotor-Drohne mit Wärmebildkamera zur Suche von Rehkitzen vor der Grünlandbewirtschaftung. Die Erhebung der Arbeitszeitbedarfe wurde mit Hilfe von Kunststoff-Dummys auf einer Fläche von 15,20 ha in zweifacher Wiederholung durchgeführt. Zur Abbildung der ortsüblichen Rehkitzverteilung wurden die Flugprotokolle von früheren, insgesamt 40 Befliegungen in der Region ausgewertet und anschließend eine Verteilung von 3 Kitzen auf 15 ha zugrunde gelegt (Abb. 1).

Abbildung 1: Untersuchungsgebiet zur Erhebung der Arbeitszeitbedarfe für die Wildtierdetektion (Beispielfläche 30 ha, Platzierung von 6 Kunststoff-Dummys)



Quelle: Eigene Darstellung

Zur Erfassung des Arbeitszeitbedarfs der Rehkitzsuche wurde ein Arbeitskraftbedarf von zwei Personen angenommen (Drohnenpilot und Rehkitzsucher auf der Fläche). Die Befliegung wurde im autonomen Flugmodus der Drohne durchgeführt. Dazu wurde das Polygon der Befliegungsfläche in der Steuerungssoftware hinterlegt und die Flugroute bei Sichtkontakt mit einem Dummy unterbrochen. Erfasst wurden die Arbeitsschritte Anrücken vor dem Flug, Testflug, Flug, Suche am Boden, Abrücken nach dem Flug und Wartung. Die Zeitbedarfe für die Hin- und Rückfahrten zur Wiese und die Verbringung der Rehkitze an den Waldrand nach der Mahd wurde mit Streckenangaben aus Google Maps geschätzt. Insgesamt wurde ein Zeitbedarf von 45 Minuten für insgesamt zwei Arbeitskräfte kalkuliert. Die Lohnkosten betragen insgesamt 13,79 € für eine Beispielfläche mit 15 ha bzw. 0,86 €/ha (Tab. 7).

Tabelle 7: Erhebung der Arbeitszeitbedarfe zur Wildtierdetektion im Grünland (Beispielfläche 15 ha)

	Arbeitsschritt	Dezimalstunden	Arbeitskraftbedarf, AK insgesamt	€ pro Arbeitsschritt
1	Fahrt zur Wiese	0,01	2	0,43 €
2	Anrücken vor dem Flug	0,06	2	2,60 €
3	Testflug	0,02	2	0,73 €
4	Flug	0,28	1	5,92 €
5	Suche am Boden	0,00	2	- €
6	Abrücken	0,05	2	1,96 €
7	Fahrt zum Betrieb	0,01	2	0,43 €
8	Wartung	0,07	1	1,48 €
9	Fahrt zur Wiese/zum Betrieb	0,01	2	0,23 €
	Summe	0,50		13,79 €
	Arbeitskraftbedarf insgesamt, h	0,66		
	Arbeitskraftbedarf, Akh/ha	0,04		
	Lohnkosten, €/ha (21 €/h)	0,86 €		

Quelle: Eigene Berechnung

3.4 Schadensermittlung bei Wildschäden bzw. Auflaufschäden

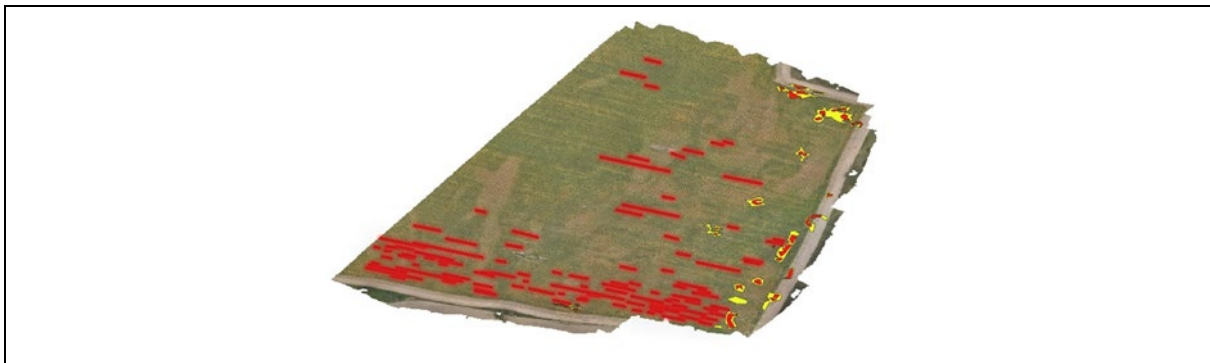
Im nächsten Anwendungsbeispiel wurden Fehlstellen im erntereifen Silomais mit Hilfe einer Multirotor-Drohne kartiert und der entgangene Ertrag ökonomisch bewertet. Ursache von solchen Fehlstellen können Wildschäden sein oder bereits durch eine fehlerhafte Bestellung verursacht worden sein. Untersucht wurde eine Fläche von 10 ha mit einer mittleren Bodenbonität von 26 Bodenpunkten, die durch Wildschweine geschädigt wurde. Der Zustand wurde mit einer DJI Mavic 3T Multirotor-Drohne im September 2023 aufgenommen. Zur Auswertung des Bild-

materials wurde Quantum GIS genutzt. Die Fehlstellen im Pflanzenbestand wurden differenziert nach Fehlstellen in der Pflanzenreihe (gelb) und Fehlstellen in der Fläche (rot). Insgesamt wurden Fehlstellen im Umfang 0,40 ha bzw. 4 % der erfassten Gesamtfläche dokumentiert. Zur Datenerhebung und Auswertung wurde ein Arbeitszeitbedarf von zwei Stunden benötigt (Abb. 2). Die Auswertungsmethoden entwickeln sich jedoch weiter. Der Einsatz von KI kann helfen noch genauer Ergebnisse in kürzerer Zeit zu erhalten (Maes and Steppe, 2019).

Auf Grundlage der mittleren Bodenbonität des Feldes wurde mit Hilfe von Richtwerten aus der Literatur ein Ertragspotenzial von 214 dt Frischmasse (FM)/ha unterstellt (Hanff and Lau, 2021). Der Ertragsverlust wird auf insgesamt 85 dt FM geschätzt. Zur Berechnung der entgangenen Leistung wurde ein innerbetrieblicher Verrechnungspreis von 3,50 €/dt FM angenommen. Die Schadenshöhe beträgt somit 298 €.

Im Zuge der Datenauswertung konnten dem Praxisbetrieb zusätzliche Informationen zu den Ertragsschwankungen auf den Teilflächen des Feldes gegeben werden. Eine standardmäßige Befliegung von Maisflächen vor der Ernte kann dazu beitragen Schwachstellen in der Bewirtschaftung aufzudecken.

Abbildung 2: Erfassung von Schadflächen im Silomais; Orthomosaik mit eingezeichneten Schadflächen gelb = Fehlstellen in der Pflanzenreihe (n = 98 Linien), rot = Fehlstellen in der Fläche (n = 20 Polygone); Aufnahme vom 22.09.2023



Quelle: ELLMANN, 2023

Die Problematik, dass ein z.B. ein Landwirtschaftlicher Sachverständiger bei der Schadenaufnahme vom Boden aus unter Umständen sehr viel Zeit aufwenden müsste, um ein Schadensausmaß einigermaßen exakt erfassen zu können, zeigt sich auch am folgenden Beispiel „Feldaufgang bei Zuckerrüben“ (Abb. 3). Hier war vom Boden aus zunächst schwer zu erkennen, welcher Teil der Fläche verzögert aufgelaufen war. Das Luftbild, vom Kleinflugzeug aus aufgenommen, zeigt das tatsächliche Schadensausmaß deutlich. Ein weiteres Luftbild, kurz vor der Ernte (05.10.2022; hier nicht abgebildet) zeigt, dass der gesamte Rübenbestand tatsächlich verspätet aufgelaufen war. Die wegen der verkürzten Wachstumszeit geringeren Gewichte der betreffenden Rübenkörper konnten am Boden stichprobenartig ermittelt werden und das Schadensausmaß über die zuvor aus dem Luftbild ermittelten Flächenanteil hochgerechnet werden. Dieses Beispiel zeigt, dass besonders in Kombination von GPS-Koordinaten gekennzeichneten punktuellen Datenerhebungen (z.B. Fotos, Messungen usw.) mit Luftbildern von Drohen oder auch mit Kleinflugzeugen valide Daten zum Zustand einzelner Felder (ungleichmäßiger Saataufgang, Bearbeitungsunterschiede, Unkrautnester u.a.) gewonnen werden können.

Für den landwirtschaftlichen Gutachter, sei es als Wildschadenschätzer oder als landwirtschaftlicher Sachverständiger bedeutet dies meistens nicht nur eine Zeitersparnis, sondern macht eine sachgerechte Schadensermittlung erst möglich.

Abbildung 3: Verzögerter Feldaufgang auf einem Zuckerrübenschlach; Aufnahme vom Boden aus (links; 27.05.2022) und Schrägluftbild aufgenommen aus einem Kleinflugzeug (rechts; 15.06.2022)

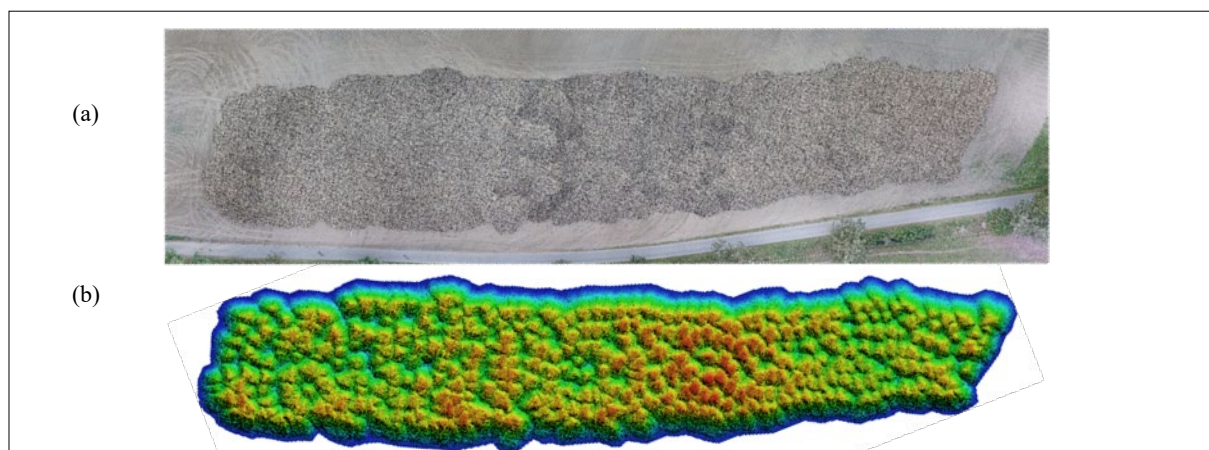


Quelle: FUCHS und WEIER, 2022

3.5 Mengenerfassung im Höhenmodell

Im letzten hier dargestellten Anwendungsbeispiel wird der praktische Einsatz einer Multirotor-Drohne zur Mengenerfassung von Schüttgütern am Beispiel der Zuckerrübenenernte eines landwirtschaftlichen Betriebes im Norden Mecklenburg-Vorpommerns beschrieben. Der Betrieb nutzt seit vielen Jahren Drohnen zur Befliegung der Agrarflächen und hat bereits umfangreiche Erfahrung im Einsatz dieser Technologie sammeln können. Genutzt werden eine Multirotor- und Starrflügler-Drohne insbesondere zur Vorbereitung teilflächenspezifischer Maßnahmen in Düngung und Pflanzenschutz. Jedes Jahr werden 10.000 ha mit Drohnen beflogen. Über die Beantwortung pflanzenbaulicher Fragestellungen hinaus nutzt der Betrieb eine Multirotor-Drohne zur Vermessung von Zuckerrübenmieten nach der Ernte. Auf diese Weise können die Rübenenerträge ohne spezielle Ertragserfassung auf der Erntemaschine erfasst und feldweise dokumentiert werden. Zur Vermessung einer Zuckerrübenmiete kalkuliert der Betriebsleiter mit einem Arbeitszeitbedarf von insgesamt 1,50 Stunden, davon entfallen 15 Minuten auf die GPS-gestützte Befliegung vor Ort und etwa 75 Minuten auf die Datenauswertung im Büro. In diesem Analyseschritt werden die Luftbildaufnahmen des Zuckerrübenhaufens zu einem Orthomosaik zusammengefasst und die Erntemenge mit Hilfe eines Höhenmodells berechnet (Abb. 4).

Abbildung 4: Luftbild (a) und Höhenmodell (b) einer Zuckerrübenmiete



Quelle: HARBORT, 2023

Weitere Anwendungsbereiche bestehen in der Vermessung von Hackschnitzellagern, Fahrsiloanlagen und der Mengenerfassung von Mistlagerstätten am Feldrand. Mit Hilfe der im Höhenmodell ausgewerteten Drohnendaten lassen sich Ernte- und Verkaufsmengen erfassen, Futterreserven im Silostock dokumentieren und die Ausbringung von Festmist zielgenauer planen.

4. Fazit und Schlussfolgerungen

Der Einsatz von Fernerkundungstechnologien wie Satellit, Kleinflugzeug und Drohne bietet vielfältige Anwendungsmöglichkeiten für die Landwirtschaft. Im Rahmen der durchgeführten Analysen konnte gezeigt werden, dass die Wahl des Fernerkundungsverfahrens von der spezifischen Fragestellung abhängig ist und mit unterschiedlich hohen Kosten verbunden sein kann. Für einen schnellen Überblick sind kostenfreie Satellitenbilder besonders geeignet. Diese stehen je nach Standort des Betriebes bis zu einmal wöchentlich zur Verfügung. Um jedoch kurzfristig einen genaueren und flächenhaften Überblick über die Feldbestände erhalten zu können, ist die Befliegung mit einem Kleinflugzeug vorteilhaft. Mit diesem lassen sich in kurzer Zeit große Flächen erfassen und pflanzenbaulich einschätzen. Zur Vorbereitung ökonomisch besonders relevanter Maßnahmen in Düngung, Pflanzenschutz und Aussaat sind jedoch möglichst hochaufgelöste Luftbilder zu nutzen. Zu diesem Zweck ist die Befliegung mit Drohnen geeignet. Mit diesen können zu anbauspezifischen Befliegungszeitpunkten insbesondere teilflächen-spezifische Bewirtschaftungsmaßnahmen vorbereitet und geplant werden. Darüber hinaus können Wildtiere vor der Grünlandmahd detektiert, Verfahrensfehler und Wildschäden auf dem Feld dokumentiert und Schüttgüter vermessen werden (Tab. 8).

Tabelle 8: Beispielhafte Befliegungszeitpunkte für Multirotor- und Starrflügler-Drohnen nach Kultur und Befliegungszweck

Kultur	Befliegungszeitpunkt	Befliegungszweck
Winterraps	November, Februar, März,	Erkrankungen (Kohlhernie), Düngerfehler
Zuckerrüben	April, Mai, September	Luftbilder mit Legefenstern, Mietenplatz für Lohnunternehmen festlegen, Erntemenge erfassen
Grünland	April, Mai, Juni	Wildtierdetektion
Wintergetreide	Mai, Juni	Erkrankungen, Trockenstellen, Drainagen
Silomais	Juni, September	Wildschäden

Quelle: Eigene Darstellung

Noch ist das Angebot an Dienstleistungen mit Drohnen relativ begrenzt und oftmals sehr teuer. Daher ist für technisch versierte Landwirte und Berater die Anschaffung einer eigenen Drohne und das Angebot von Dienstleistungen über den eigenen Betrieb hinaus durchaus eine bedenkenswerte Alternative. Für einen möglichst effizienten Einsatz der unterschiedlichen Fernerkundungsverfahren in der Landwirtschaft können Schulungs- und Beratungsangebote zukünftig von hoher Bedeutung sein. So können Anwendungsfehler reduziert und zusätzliche Kosten vermieden werden.

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FOOD WASTE

THE EFFECT OF FOOD PRICES ON FRUIT AND VEGETABLE FOOD WASTE IN PRIVATE HOUSEHOLDS

Vicky Heijnk¹, Sebastian Hess

Abstract

Despite numerous studies on private households' food waste behaviour, the effect of food prices on food waste generation is still not well understood. This study provides empirical estimates on the effect of food prices on avoidable fresh fruit and vegetable food waste. This is the first time that results of this kind, based on an extensive and recent dataset, are being presented. We used data on the waste of 35 fresh fruit and vegetable food items documented in food waste diaries by 6,696 different households observed in 2016/17 and 2020 in Germany. We applied a mixed-effects model to account for the crossed data structure between observed food items and participating households. After controlling for time and seasonality effects as well as for household-specific characteristics, we find a 10% higher food price to be associated with 1% less waste of fresh fruit and vegetables. In an extended version of our mixed-effects model, we disentangled this effect for two kinds of price variation and their association with food waste: We distinguish *price differences between* food items and *price changes within* food items over time. We find a significant and severe negative effect of price differences between fresh fruit and vegetable food items: A 10%-price difference *between* two food items is associated with 7% less food waste for the more expensive food item. In contrast, we do not identify any relevant effect of price changes within a food item over time. We discuss potential implications for policy proposals like a reduction of the value-added tax rate for fruits and vegetables.

Keywords

Food waste, price elasticity, fruit and vegetables, mixed-effects model

1 Introduction

Halving per capita food waste (FW) by 2030 is a declared target (12.3) within the United Nations' Sustainable Development Goals (SDGs) (UN, 2015). In view of the increasing nutritional needs of a growing world population, resource scarcity and climate change, the objective of reducing FW is undisputed. Loss or waste of food can occur at various stages of the food value chain (BELLEMARE et al., 2017). The majority of FW in more affluent countries is generated in private households, of which fresh fruit and vegetables (FAV) are the main component in terms of weight (ANANDA et al., 2022; CALDEIRA et al., 2019; PRIEFER et al., 2016). A distinction is usually made between avoidable (edible) and unavoidable (inedible) FW (ROODHUYZEN et al., 2017).

In the last few years, there has been an enormous increase in research on FW (PRINCIPATO et al., 2021). A major stream of the existing literature deals with the quantification of FW amounts (XUE et al., 2017). Per capita FW in households in Germany is estimated to be 56 kg per year (HÜBSCH, 2021). Another central stream of FW literature examines influencing factors, which are considered diverse and complex (ASCHEMANN-WITZEL et al., 2015; QUESTED et al., 2013). In these studies, however, little attention has been paid to the influence of food prices on FW. Some have investigated the relation of price-reduced suboptimal foods and FW (ASCHEMANN-

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WITZEL et al., 2017), price orientation or sensitivity of consumers and FW (ASCHEMANN-WITZEL et al., 2018; VESELÁ et al., 2023) or the effect of retail price *promotions* on household FW (TSALIS et al., 2021). However, the effect of “regular” food prices on FW appears to be an understudied aspect, even though the assumption that food prices affect FW generation seems reasonable considering the acknowledgement that price plays a crucial role in consumer decisions (CATTANEO et al., 2021; GORTER et al., 2021; PARFITT et al., 2010). Empirical evidence on this relationship is particularly important when it comes to policy or market environments and instruments that influence food prices or aim to reduce FW. For example, a proposal to promote FAV consumption for healthier diets by removing value-added taxes (VAT) on fresh FAV (0 % rate)² is being discussed in Germany (DANIEL, 2023). However, despite the suspected positive effects on health, the FW effects of a policy of this kind remain unclear because evidence in the existing literature on the food price-FW relationship appears inconclusive.

According to a qualitative study by VAN GEFFEN et al. (2016), participants in several European countries mentioned that low food prices contribute to consumer FW. In Germany, some even assessed food prices in this context as being “too cheap”. Thus, it could be hypothesised that a further VAT reduction on FAV might have negative side effects in terms of more FW. However, barely any quantitative research has been conducted on the effect of food prices on FW. Estimates of the food price elasticity of demand for wasting food input calories have been reported by LANDRY & SMITH (2019), and range from -1.35 to -1.5. They applied a household production model of FW and proxy FW by using the difference between observational data on food stock usage and consumption by US households in 1977. In view of changing economic conditions and societal trends, these estimates may now be outdated. AURELI et al. (2021) refer to more recent FW data from 2018, but do not estimate the food price elasticities of FW. Instead, they applied principal component analysis to several food groups and found a negative correlation of 0.5 between wasted amounts of a food group and its average price per kilogram. In contrast, two other related studies with hypothetical experimental settings did not find a statistically significant effect of varying (hypothetical) prices of a certain food item on the decision to waste that food item (DUSORUTH & PETERSON, 2020; ELLISON & LUSK, 2018).

Hence, the results of these quantitative studies appear inconclusive regarding the potential effect of food prices on FW. We aim to address this research gap by estimating the effect of food prices on avoidable FW for FAV based on recorded acts of FW in German households in 2016/17 and 2020. The use of a recent data set and a sample of 6,696 households distinguishes our work from the few previous quantitative studies that have investigated the effect of prices on FW. We address the crossed data structure of the FW observations between both households and food items by applying mixed-effects (ME) models. In an extended model-version, we combine the ME model with a within-between (WB) model to disentangle the estimated price effect into two kinds of price variation and their association with FW. We distinguish *price differences between* food items and *price changes within* food items over time which is a distinctive feature of this study. Our work is the first to present results of this kind and constitutes a starting point for subsequent empirical analyses on the effect of food prices on FW which may have relevant implications for policy. The remaining sections of this paper are structured as follows: section 2 introduces data and methods used, section 3 presents and discusses descriptive and empirical results, and section 4 concludes with a summary.

² Following a reform of the EU VAT Directive, which will come into force in 2025, it is possible to remove VAT (i.e. 0 % rate) on certain goods including food items in the EU (Scholle, 2022).

2 Material and methods

2.1 Data collection and sample

We used data from the survey “Systematic monitoring of food waste from private households in Germany”, which was commissioned by the German Federal Ministry of Food and Agriculture (BMEL) and carried out by GfK SE (HÜBSCH, 2021; HÜBSCH & ADLWARTH, 2017).³ A first wave was conducted in 2016/2017 and a second wave in 2020, each comprising 12 months (24 months overall). Roughly evenly distributed over the calendar months, different households were asked to keep FW diaries for two weeks (14 days). Some of the households participated in both, others in only one of the two waves (unbalanced panel). With the help of a code number system, the documented FW was assigned to a predefined food item, and an assignment was made as to whether the FW was avoidable or unavoidable. In addition, the participants were asked to report the corresponding FW amount. The weight of the wasted food items could either be measured or estimated with the help of a data sheet. Alternatively, households could report the number of units of wasted food items, which were then transferred into grams by GfK SE using conversion tables. Various methods for measuring waste are used in the literature, all of which have different advantages and disadvantages. In order to collect data on FW at household level, FW diaries are commonly used (XUE et al., 2017). Nevertheless, one has to be aware that inaccuracies can occur with such self-reported data due to measurement errors, social desirability or observational bias including behavioural changes among respondents due to participation in the study, which is also known as the “Hawthorne effect” (PODSAKOFF et al., 2003; XUE et al., 2017). More information on the methodology and study design, as well as results of this survey, can be found in HÜBSCH & ADLWARTH (2017) and HÜBSCH (2021).

The complete original dataset comprised 505,166 observations of FW acts from 9,849 different households in 116 classified food categories. Firstly, since we were only interested in the price effect on *avoidable* waste, we excluded all observations of FW acts that were classified as *unavoidable* FW. Unfortunately, the dataset initially contained no information about purchased food quantities or about the food prices of purchased and/or wasted foods. Thus, we are unable to assess whether a household that did not report any avoidable FW purchased a certain food item in the first place. However, we argue that we are interested in the overall price effect on fresh FAV FW, regardless of the extent to which the price affects FW directly or indirectly via the food purchasing channel. To proxy the price of wasted food items, we used monthly price data for 2016, 2017 and 2020 from the consumer price index of the Agricultural Market Information company (AMI), which provides continuously monitored price levels of several food items in the German retail sector (AMI, 2024). The price data we used refer to conventional food items and are a weighted monthly average across all German regions and all types of retail stores. As much as possible we assigned fresh FAV food items used in the FW data from GfK SE to the fresh FAV food items used in the AMI consumer price index.⁴

The use of these price proxies instead of the actual food prices paid by the reporting household has the advantage that we circumvent one possible source of price endogeneity: It is plausible to assume that low-quality FAV food items are offered for a cheaper price (MILLICHAMP & GALLEGOS, 2013), and at the same time that more of it is thrown away due to the lower quality. As we are not able to control for the unobserved food quality level, such a relation could lead to omitted variable bias (ANTONAKIS et al., 2010). Inspired by HAUSMAN et al. (1994), who used food prices at neighboring locations as instruments to address price endogeneity, we use the average food price across regions. The use of these average prices in our statistical analyses

³ We are grateful to the Thünen Institute for Market Analysis, in particular to Dr. Thomas Schmidt, for making the data available to us and for the efforts to clarify all our questions.

⁴Our findings turned out to be robust against excluding food items for which the allocation of prices was based on approximately equal and not exactly the same food item designations. The results of this robustness check and a corresponding matching table cannot be presented, however, due to the limited length of the manuscript, but they are available upon request.

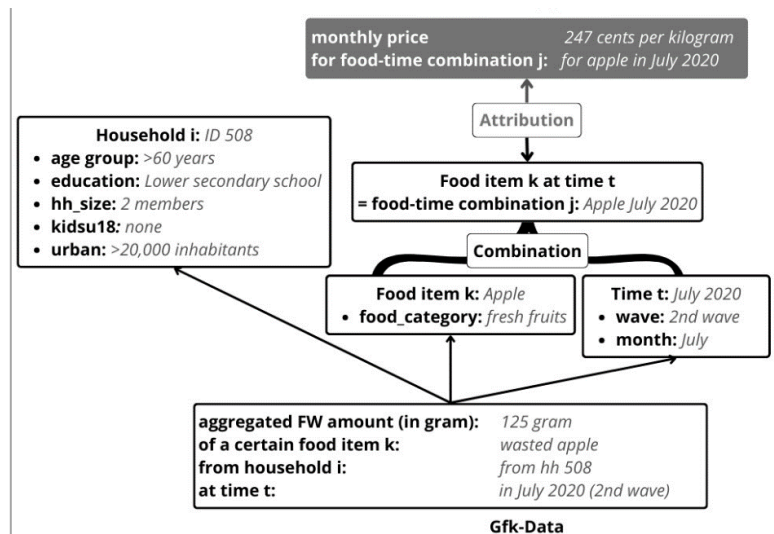
should ensure that a possible link between food prices, food quality and food waste does not bias our statistical estimation results with respect to the effect of food prices on FW.

We decided to focus on FAV for a number of reasons. We assumed that the FW data documented in the two-week FW diaries are least prone to observational bias for *perishable* food items such as fresh FAV. Moreover, FAV represent the main component in terms of weight of FW, and would be directly affected by the proposed 0% VAT rate (see section 1). Finally, we also found that FAV had the most straightforward assignment between GfK FW data and the AMI price data. We excluded all other observations of FW acts, which left us with 35 FAV food items in the dataset. Accordingly, this would give 35 food items, each with 24 monthly

price observations, resulting in a total of $35 \times 24 = 840$ food-time combinations with corresponding food prices. However, for some of these food items, AMI price data were not available for all 24 months under observation. Thus, the FW observations for corresponding food items in corresponding months without price data (missing values) could not be considered in the statistical analysis. In all, we observed 746 food-time combinations with corresponding different food prices. Given that our main interest is the food price effect on FW and we have monthly food prices per food item for each wave, we used these 746 food-time combinations, which are nested in the 35 food items, as an additional grouping layer for the FW observations (see Fig. 1). Subsequently, for each wave we aggregated the recorded avoidable FW amounts in grams per household and food item, which made the FW data compatible with the monthly price data provided by AMI. Thus, in our final dataset one observation of a FW act corresponds to the reported overall FW amount for a specific food item within a certain household, within a month or, more precisely, within the two-week observation period within this month. Ultimately, we were left with a final dataset of 20,204 FW observations from 6,696 different households for 35 fresh FAV food items. Given the two different waves in which data were collected, the dataset contains 8,357 different household *observations* with 746 food-time combinations. Figure 1 illustrates the data processing and the resulting data structure using the example (in light grey and italics) of 125 grams of wasted apple in July 2020 by household 508.

For both waves, in our final household sample represented by the head of the household, older respondents were more strongly represented: almost half of the respondents were aged over 60 and fewer than 20 % were under 40. In terms of education, around 47 % stated that they do not have an upper secondary education, while one third had a university degree. Most households had two members, and a large majority (88 %) of the observed households were located in urban areas (> 20,000 inhabitants). Information on sex or gender of the (head of the) household has not been made available to us, which is why we were unable to take this into account. Out of our final sample of 35 food items, 21 food items (60 %) were classified as fresh fruit and 14 food items (40 %) as fresh vegetables. The average food price across all 35 food items and the months in which food item-specific price data were available (746 food-time combinations in all) was € 3.19 per kilogram, with a standard deviation of € 2.64. The lowest price was 66 cents per kilogram for potatoes in November 2020, and the highest was € 19.83 per kilogram

Figure 1: Illustration of data processing and data structure



for blueberries in October 2016. Food prices differed between food items, but also varied “within” food items over the 24-month observation period.

2.2 Variable description

Table 1 describes the variables used in our statistical analysis, including their coding. As described in section 2.1, we constructed our continuous dependent variable, namely the “avoidable FW amount per household and food item (in grams)” (av_FW) by aggregating the observed FW quantity of fresh FAV at household and food item level per month.⁵

Table 1: Description of variables

<i>Classification</i>	<i>Variables</i>	<i>Description</i>
Dependent variable	<i>av_FW</i>	Avoidable FW amount per household and food item (contin.: in grams)
Independent variables	<i>age_group</i>	Age group (categorical: 1 = < 40 years, 2 = 40-59 years, 3 = ≥ 60 years)
	<i>educ</i>	Highest level of education achieved (categorical: 1 = (lower) secondary school, 2 = upper secondary school, 3 = university graduate)
<i>related to household</i>	<i>urban</i>	Living environment of the household (dummy: 0 = rural, 1 = urban (>20,000 inh.))
	<i>hh_size</i>	Number of household members (continuous)
	<i>kidsu18</i>	Indicator for children under 18 living in the household (dummy: 1 = yes; 0 = none)
	<i>wave2020</i>	Survey wave (dummy: 0 = 1 st wave (2016/2017), 1 = 2 nd wave (2020))
<i>related to food-time combination</i>	<i>month</i>	Observed month (categorical: 1 = January, (...), 12 = December)
	<i>food_cat</i>	Food category (dummy: 0 = vegetables, 1 = fruit)
	<i>price</i>	Monthly AMI food price (continuous: in cents per kilogram)
	<i>m_price</i>	Food item-specific mean price over the observational period (contin.: cents per kg)
	<i>d_price</i>	Food item-spec. deviation from mean price in a certain month (contin.: cents per kg)

Independent variables: household-specific variables

A unique household ID (hh_id) was assigned to each of the 6,696 households. We controlled for sociodemographic heterogeneity within the sample by including several household characteristics as predictors: the age group of the head of the household (age_group) and the highest level of education he or she achieved (educ), as well as an urbanity dummy (urban) to indicate whether a household is located in a more rural or urban area. Furthermore, we controlled for the number of household members (hh_size) and for children under 18 living in the household (kidsu18). Unfortunately, we were neither able to include information on sex nor on household income as this could not be made available to us.

Independent variables: food-time-specific variables

A unique food item ID (food_id) was assigned to each of the 35 food items. In addition, each food-time combination, i.e. the observation of a certain food item in a certain month, was also assigned a unique ID (food-time_id). Related variables for time and/or food items were considered in our analyses: a wave dummy (wave2020) to account for whether an observation of a FW act originates from the first wave of data collection (2016/2017) or the second (2020). We controlled for seasonal influences by including a categorical month variable (month) that indicates the month in which a FW act was reported. In addition, we used a binary categorical variable (food_cat) to indicate whether a food item is classified as a vegetable (including potatoes and mushrooms) or as a fruit, as defined in the AMI consumer price index data.

In terms of food-time, we also observed the variable of our main interest, namely the monthly food price in cents per kilogram of a specific food item (price). In an extended model version, which is explained in more detail in section 2.3, we alternatively use the food item-specific

⁵ We also examined the food price elasticity of fresh FAV FW in a caloric metric. Since the results barely differed, we focused on the gram-based model. Results on the calorie-based model are available upon request.

mean price over the whole observational period (m_price) and the food item-specific deviation from that mean price in the corresponding month of observation (d_price).

2.3 Statistical modelling

2.3.1 Mixed-effects model

The structure of our data differs from a conventional econometric panel dataset in so far as each of the 20,204 FW observations belongs to a *combination* of one of the 6,696 households and one of the 746 food-time combinations, which in turn belong to one of the 35 food items. Such a data structure can be referred to as being “crossed” between households and food-time combinations, which in turn are “nested” in the 35 food items (see also Fig. 1). In other words, FW observations from the same household can be attributed to different food-time combinations (i.e. food items), and FW observations of a certain food-time combination (i.e. food item) can come from different households. This kind of data structure can violate the assumption of ordinary regression models that responses are conditionally independent given the covariates: it is possible that a certain household systematically misestimates the quantities of all their wasted food items, or that the quantity wasted of a particular food item is systematically misestimated by all wasting households. Thus, applying ordinary linear regression would be inefficient and potentially biased (DIELEMAN & TEMPLIN, 2014; RABE-HESKETH & SKRONDAL, 2022). To obtain more accurate inferences regarding the food price effect on FW, we need to explicitly take into account that our data structure has several layers. To do so, we used mixed effects (ME) models (also known as multilevel models), which can be viewed as generalisations of econometric panel data models as they allow for direct estimation of coefficients on variables (= “fixed effects” in the ME model terminology) related to different layers of data categorisation (i.e. households and food-time combinations/food items), and at the same time attribute unexplained variability to the different layers (“random effects” in ME model terminology) (MCNEISH & KELLEY, 2019; MELAMED & VUOLO, 2019; RABE-HESKETH & SKRONDAL, 2022).

In our model, we treated household (hh_id), food-time combination ($food\_time\_id$) and food item ($food\_id$) as random factors, and ended up with a ME model for cross-classified FW observations by households and food-time combinations, of which the latter are nested in food items. Our model specification for the avoidable fresh FAV FW amount for household i and food-time combination j , which is nested in food item k , can be denoted as:

$$(1) \quad \ln\_av\_FW_{ijk} = \alpha_0 + \begin{array}{l} \beta_1 age\_group_i + \beta_2 educ_i + \beta_3 urban_i + \beta_4 hhsz_i + \beta_5 kidsu18_i + \\ \beta_6 wave2020_{jk} + \beta_7 month_{jk} + \beta_8 food\_cat_{jk} + \beta_9 \ln\_price_{jk} + \\ \zeta_i + \zeta_{jk} + \zeta_k + \\ \varepsilon_{ijk} \end{array} \quad \begin{array}{l} \text{Household variables} \\ \text{Food-time comb. variables} \\ \text{Random intercepts} \end{array}$$

where α_0 is the generic intercept and the β s are the coefficients on the included covariates related to household i or related to food-time combination j nested in food item k , respectively, as described in Table 1. ζ_i is the random intercept for household i , ζ_{jk} is the random intercept for food-time combination j nested in food item k , and ζ_k represents the random intercept for food item k . Due to the crossed data structure, the household-specific random intercept ζ_i is shared across all food-time combinations jk (nested in food items k) for a given household i . Analogously, the food-time-specific random intercept ζ_{jk} and the food item-specific random intercept ζ_k are shared across all households i for a given food-time combination jk . ε_{ijk} is the residual error term. For our statistical analyses, we performed a logarithmic transformation with the outcome variable avoidable FW amount ($\ln\_av\_FW$) and food price ($\ln\_price$).

It would also have been possible to include a random slope in our mixed-effects model specification to assess whether the food price effect on FW is equal across food items (RABE-HESKETH

& SKRONDAL, 2022). It turned out that the associated random effect had a small variance relative to the magnitude of the estimated price coefficient. Based on an insignificant likelihood ratio test statistic ($\text{Prob} > \chi^2 = 0.45$ (gram-based) and $\text{Prob} > \chi^2 = 0.08$ (calorie-based)), we concluded that the price effect is the same for each food item and decided against including a random slope for food price in order to keep the model parsimonious (MATUSCHEK et al., 2017; MCNEISH & KELLEY, 2019; STEELE, 2010).

2.3.2 Within-between mixed-effects model

In total, our dataset contains 35 different food items and food item-specific monthly prices for up to 24 months (two waves of 12 months each). Accordingly, we observe two kinds of price variation, namely price differences between food items and price changes within food items over time. In the “basic” ME model, a weighted average of price differences between food items and price changes within food items is used, based on the assumption that there would be no difference between their effects. However, if this assumption is violated, the estimates are biased and cannot really be interpreted meaningfully (RAUDENBUSH & BRYK, 2002; SCHUNCK, 2013).

Indeed, it is easy to imagine that the effect of price differences between food items (i.e., the effect of generally high prices relative to other food items on FW like a € 12.52 mean price for raspberries) would differ from the effect of price changes within food items (i.e., effect of a high price for a food item relative to other months on FW like € 3.30 for tomatoes in February 2017). Instead of estimating a weighted average for the effect of price differences between food items and price changes within food items, we extended our ME model to combine it with the so-called within-between (WB) model (BELL et al., 2019; MCNEISH & KELLEY, 2019). To do so, instead of the standard price variable (price) as in the basic ME model, we included two price-related variables as predictors in our model: the food item-specific mean price across all the observed months (m_price) to capture the effect of price differences “between” food items and the food item-specific deviation from this mean price in each observed month ($d\_price = price - m\_price$) to capture the effect of price changes within food items (ALLISON, 2009; MCNEISH & KELLEY, 2019; SCHUNCK, 2013). The coefficient on the m_price represents the estimated effect of price differences between food items, and indicates how a change in the food item-specific mean price is associated with a change in the food item-specific mean avoidable FW. The coefficient on the d_price represents the estimated effect of price changes within a food item. This indicates how on average a within-food item change in food price is associated with a within-food item change in avoidable FW (SCHUNCK, 2013; SNIJDERS & BOSKER, 2012). Thus, the WB-ME-model allows the effects of price differences between food items and price changes within food items to be disentangled, which we believe provides us with valuable insights related to our main effect of interest, namely the food price effect on avoidable FW. Also for the WB-ME model, we logarithmized the price variables.⁶ Estimations of the ME models were carried out using the statistical software R (R CORE TEAM, 2023) and the linear ME modelling package “lme4” (BATES et al., 2015). All tests and estimated coefficients were examined at a statistical significance level of 5 %.

⁶ For the m_prices , this was straightforward. To obtain log values for the d_price , we first logarithmized the *absolute* value of the deviation from the mean price and then multiplied this value with -1 for all negative deviations. In one case, for plums in October 2010, we observe a zero-deviation from the mean price and insert zeros for the corresponding $\ln\_dprice$ variable.

3 Results & Discussion

3.1 Descriptive statistics on analysed fresh FAV FW

The following descriptive statistics are based on the final sample of 20,204 FW observations for which we could attribute monthly price data from 35 fresh FAV food items. During the observation period of one month, or more precisely two weeks, FW from as few as 1 to as many as 24 of the 35 fresh FAV food items included was recorded within one household. The majority of households (65 %) reported that they had only thrown away one or two of these food items. On average, 2.4 different FAV food items were wasted in a household during the observed two weeks. In terms of the total FW from all 35 food items within the two-week observational period, the average household recorded an avoidable FW of 705 grams, which corresponds to an average waste of 331 calories and € 1.44 in monetary value. Compared with the Italian sample used by AURELI et al. (2021) for which the converted household averages of FW for two weeks amounted to 699 grams and € 1.84, our numbers appear relatively close. However, the two studies are not directly comparable because AURELI et al. (2021) included many more food categories, and the data collection was not based on FW diaries but on a recall methodology. In general, it should be noted that we only included selected fresh FAV food items in our analyses, and FW observations from the months for which we have price data. In addition, our household sample cannot be considered representative for the entire population (see section 2.1), and underreporting due to measurement errors, social desirability or observational bias is a well-known problem with self-reported data (PODSAKOFF et al., 2003).

However, since our main interest is the food price effect on FW and not the quantification of FW for the whole of Germany, this should not distort our results critically if the underreporting is not systematic (WOOLDRIDGE, 2020).

3.2 Mixed-effects model results

Table 2 presents the results of the ME models for avoidable FW of fresh FAV. As described in section 2, we present a “basic” ME model (ME) with the standard food price variable, and a combined WB-ME model with a differentiation for effects of price differences between food items versus effects of price changes within food items. For both models, parameter estimates on the included predictors (“fixed effects”) are reported in the upper part of the

Table 2: ME and WB-ME models of avoidable fresh FAV FW

ln av FW	ME		WB-ME	
Fixed effects	Coeff.	s.e.	Coeff.	s.e.
age_group: 40-59 years	-0.02	0.03	-0.02	0.03
age_group: ≥ 60 years	-0.06	0.03**	-0.06	0.03**
educ: upper sec. school	-0.04	0.02*	-0.04	0.02*
educ: univ. grad.	-0.08	0.02***	-0.08	0.02***
urban: > 20,000 inh.	-0.05	0.03*	-0.05	0.03*
hh_size	0.02	0.01	0.02	0.01
kidsu18	-0.05	0.03	-0.05	0.03
wave2020	-0.08	0.02***	-0.08	0.02***
month: February	0.01	0.05	0.01	0.05
month: March	0.00	0.05	0.00	0.05
month: April	-0.03	0.05	-0.03	0.05
month: May	0.04	0.05	0.04	0.05
month: June	0.11	0.05**	0.11	0.05**
month: July	0.10	0.05**	0.10	0.05**
month: August	0.19	0.05***	0.20	0.05***
month: September	0.13	0.05***	0.13	0.05***
month: October	0.05	0.05	0.05	0.05
month: November	0.07	0.05	0.07	0.05
month: December	0.05	0.05	0.05	0.05
food_cat: fruits	0.29	0.19	0.46	0.15***
ln_price	-0.10	0.04**		
ln_m_price			-0.69	0.12***
ln_d_price			-0.01	0.00**
constant	5.49	0.27***	8.65	0.64***
Random effects	(Interc.) Var.		(Interc.) Var.	
hh_id	0.21		0.21	
food_item	0.29		0.17	
food-time_id:food_item	0.01		0.01	
residual	0.85		0.85	
AIC	57739.64		57718.98	
number of obs.	20,204		20,204	

Coefficients are given in the first column; standard errors are given in the second column; * p<0.1, ** p<0.05, *** p<0.01

table: estimated coefficients (Coeff.) are presented in the first column and standard errors (s.e.) in the second column (** for $p < 0.05$). Estimated variance component parameters (“random effects”) are reported below. To assess (relative) model fit, we provide Akaike Information Criterion (AIC) values calculated with the R package ‘AICcmodavg’ (MAZEROLLE, 2023) at the bottom of the regression table (PINHEIRO & BATES, 2000).

Estimated random effects in the mixed-effects model

The observed variability in reported avoidable FAV FW can be attributed roughly equally to differences between the households observed ($\text{Var}(\text{hh\_id}) = 0.21$) and differences between the food items included ($\text{Var}(\text{food\_item}) = 0.29$). This suggests that the application of an ME model was reasonable for our data, and that pooled OLS would probably have been inconsistent. For food-time combinations nested within food items, the estimated variance was close to zero. However, a highly significant likelihood ratio test statistic ($\text{Prob} > \chi^2 = 0.00$) supported our decision to include the food-time combinations in our models as an additional grouping layer.

Estimated fixed effects in the mixed-effects model: household variables

With respect to the household characteristics included, we found a significant negative effect of higher age and higher education. Compared with the reference age group of under 40-year-olds, households with heads aged over 60 reported 6 % less FW on average. This is in line with the findings of a qualitative study by VAN GEFFEN et al. (2016) in which older generations, who might have experienced poverty or food shortages in post-war periods, are generally perceived as less wasteful.

The statistically significant negative effect of education increased in size and significance with a higher level of education. For university graduates, the observed FW amount was significantly smaller compared with the reference group of (lower) secondary school graduates. On average, we found that university graduates waste 8 % less fresh FAV. There are several mechanisms that might determine the education-FW relationship: one line of argument is that more educated households have more food literacy. Better knowledge about how to appropriately store and efficiently use food items could lead to less FW (ELLISON & LUSK, 2018; LANDRY & SMITH, 2019; VAN GEFFEN et al., 2016). Another line of argument might be that a relationship between education and FW is (partly) driven by a correlation of education with income (WOLLA & SULLIVAN, 2017). Higher income involves higher opportunity costs of time. Higher opportunity costs for efficiently planned meals and thoughtful use of food could result in more FW (LANDRY & SMITH, 2019). Simultaneously, higher opportunity costs for accurately *reporting* generated FW (e.g. in FW diaries) could lead to systematic underreporting of FW in higher income (educated) households, which could (misleadingly) give the impression of less FW in these households. In any case, future studies should also include household income to avoid potential omitted variable bias and disentangle the effects of higher education from the effects of higher income on FW.

Estimated fixed effects in the mixed-effects model: food-time combination variables

Out of the variables referring to the period of the FW observations, the wave2020 dummy had a negative effect. In 2020, the documented FW amount was on average 8 % lower compared with the first wave in 2016/17. This could reflect societal trends towards greater awareness of avoiding FW (VAN GEFFEN et al., 2016). In particular, however, the COVID-19 pandemic and corresponding containment measures (e.g. lockdowns) that prevailed in 2020 have been found to have had a negative effect on FW (ANANDA et al., 2023). Apart from the year of observation, some months were also found to have a significant effect. Compared with the reference month of January, FW was 10-20 % higher in all summer months from June to September. Due to the higher consumption of fruit in the summer months (STELMACH-MARDAS et al., 2016), and the

greater perishability of food in higher temperatures (ZAINALABIDIN et al., 2019), this result appears plausible. Similarly, GRANT et al. (2023) found that significantly more fruit is wasted in summer.

Finally, we turn to the effect that is our main interest: the food price effect. According to the basic ME model, we estimated a significant negative price effect on fresh FAV FW. This finding supports the results of qualitative research in European countries, where food prices have been identified as negative determinants of FW (GARSKE et al., 2020; PRIEFER et al., 2016; VAN GEFFEN et al., 2016). However, in two experimental studies with a hypothetical setting, no statistically significant effect of a higher (compared with a lower) food price on the decision to waste a certain food item was found (DUSORUTH & PETERSON, 2020; ELLISON & LUSK, 2018). We found FAV FW to be fairly inelastic in response to food price. We estimate that a 10 % higher food price is associated with 1 % less FW of the corresponding food item. Analogously, a 10 % higher food price per 100 calories is associated with 1 % less wasted calories of the corresponding food item. As there are barely any quantitative empirical studies on the effect of food price on FW, our results can only be compared with those of other studies to a limited extent.

For 1,142 Italian households, AURELI et al. (2021) found a negative correlation of -0.5 between recalled avoidable household FW in 20 food groups (in grams) and corresponding average unitary prices in July 2018. They conclude that the lower the price of a food group is, the greater the corresponding FW amount. However, they only refer to data from one specific month. Hence, only the effect of relative prices between different food groups at one point in time was examined, rather than the effect of price changes within a food group over time. Moreover, even though fresh FAV were each considered as a separate food group in their analysis, no differentiation was made between specific FAV food items within these broad food groups. Consequently, the results are not directly comparable to our findings as we examined specific food items and only focused on fresh FAV food items. LANDRY & SMITH (2019) estimated food price elasticities of FW for a calorie-based model with data from 2,113 US households collected between April and June in 1977. LANDRY & SMITH (2019) find FW to be responsive to food prices based on elasticity estimates ranging from -1.35 to -1.5. These estimates are substantially larger than our estimate of -0.1. However, the study design of LANDRY & SMITH (2019) is essentially different: Most striking is that their data is 40 years older than our data and that they examine *total* food calories wasted in relation to *total* food value per calorie instead of fresh FAV food-item *specific* data. Nevertheless, our price effect appears to be comparatively small. This changes when we disentangle the general price effect into an effect of price differences between food items and an effect of price changes within food items by estimating the WB-ME model.

Within-between model

Turning to the WB-ME model, we observe that the AIC values are lower for the WB-ME models compared to the basic ME model, indicating a relatively better model fit for the WB-ME models (PINHEIRO & BATES, 2000). Moreover, it is remarkable that the variance attributed to differences between the food items is substantially smaller. We computed price averages and deviations at the food item level to include them in the WB-ME models. Thus, it seems plausible that variability between observed food items would be absorbed. With respect to the fixed effects, apart from the price effect, estimated parameters were very similar between the basic ME model and the extended WB-ME model. Only the estimated effect of the food category (fruits versus vegetables) changed. While no significant effect was found in the basic ME model, the effect became statistically significant and increased in magnitude when analysing the WB-ME model. The amount of FW was on average 46 % higher for food items belonging to fresh fruit

compared with vegetables. Apart from this, the significance and effect sizes of the control variables were almost identical between the ME and WB-ME model.

The WB-ME model revealed interesting insights when we examined the food price effect on FW. The effect of price differences between food items ($\ln\_m\_price$) was highly significant and of much greater size than the estimated price effect in the basic ME model. According to the gram-based model version, a food price difference of 10 % between two food items is associated with 7 % less FW from the more expensive food item compared with the cheaper one. Findings of this magnitude are closer to the results of AURELI et al. (2021) and LANDRY & SMITH (2019), which makes sense insofar as these studies basically only considered price variation in terms of price differences between food items.

In contrast, the estimated effect of price changes within food items ($\ln\_d\_price$) was only marginally significant and close to zero. This would mean that a food price deviation from the mean price per gram of a certain food item is not associated with significantly less or more FW from the corresponding food item. This result may seem surprising. However, apart from seasonal variations that were controlled for, food prices were relatively stable during the period of observation. Shortly afterwards, when the war in Ukraine started in spring 2021, there was food price inflation (MBAH & WASUM, 2022). Unfortunately, this food price increase is not reflected in our dataset anymore. A follow-up study with additional data on FW and food prices for the period after food price inflation as well could provide valuable insights into whether the effect of price changes within food items is indeed negligible or whether the present study's findings are driven more by limited variation in the underlying price data. However, it does not seem far-fetched for the price difference between food items to play a more decisive role than price changes within food items over time. It is easy to imagine that even if the prices of relatively cheap food items, such as apples and potatoes, go up, they are still handled with less care than more expensive food items, such as berries and avocados. In addition, an insignificant effect of price changes within food items, and the considerations discussed, are consistent with the *insignificant* price effects found by ELLISON & LUSK (2018) and DUSORUTH & PETERSON (2020). Both studies investigated whether a (hypothetical) higher price for a certain food item has an influence on the decision to waste the corresponding food item. This kind of price variation corresponds to a price change within a food item, for which no relevant effect was identified in our analysis either.

4 Conclusions

We quantitatively investigated the effect of food prices on fresh fruit and vegetable food waste. By applying a mixed effects model with random intercepts, we accounted for the crossed structure of the observed food waste data between households and food items. Consistent with the few studies on the effect of food prices on food waste that have been carried out to date, our findings suggest that food prices have a negative effect on the wastage of fresh fruits and vegetables in general: We find the response of fresh fruit and vegetable food waste to food prices to be significantly negative, but inelastic: We estimate a 10% higher food price to be associated with 1% less food waste.

Following the recommendations of the German Scientific Committee on Agricultural Policy (WBA, 2012), PRIEFER et al. (2016) advocate that the *reduced* VAT rate of 7 % on food items should be withdrawn, i.e. it should be raised to the standard rate of 19 % to increase appreciation of food items and reduce FW. This request is in contrast to the proposal to completely abolish VAT on FAV (i.e. introduce a VAT rate of 0 %) so as to promote FAV consumption (DANIEL, 2023). Based on the findings of a negative food price effect on FAV FW, it could be expected that a corresponding decline in FAV food prices induced by the reduction in VAT would lead to higher amounts of FAV FW. However, such a measure would apply to all FAV food items

equally, which means that price differences between food items would largely remain unchanged. According to our extended WB-ME model, a price difference *between* two food items of 10% is associated with 7% less food waste for the more expensive food item, whereas the effect of *price changes within* a fruit or vegetable food item over time is almost negligible and not of economic relevance. That is, price differences between foods have a stronger effect on the amount of FW than price changes for a particular food over time. Consequently, our results suggest that if the VAT on FAV were abolished, which would correspond to a price decrease within food items, any unintended negative side effects in terms of higher FAV FW are not to be expected. However, an abolished VAT on FAV would at the same time correspond to a change in the price difference between FAV and non-FAV food items. Further research is required to understand if our results also apply to food items from and across other food categories. Corresponding results can lead to insights on what overall effect price variations (e.g. due to changes in VAT on FAV) might potentially have on FW. The characteristics of the dataset imposed some challenges and limitations on our work, such as the self-reporting of the FW data and the lack of food purchase (and food price) or household income data. This also meant that we had to exclude all non-FAV food items from our analyses, particularly in order to ensure an adequate allocation of monthly food prices to FW observations. These limitations must be kept in mind when assessing our results and prevent us from drawing final conclusions on the effect of food prices on FW e.g. with respect to definite policy recommendations.

Nevertheless, our work contributes to what has so far been an understudied aspect of food waste research which is of high political and economic relevance. Ultimately, our findings and results based on improved datasets could inform the efficient design of future food policies like the optimal value added tax rate for food items to be aligned with the Sustainable Development Goal of reducing food waste.

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REDUCING FOOD WASTE: HOW BEEF COLOR INFLUENCES CONSUMER BUYING DECISIONS

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Summary

Discoloration of beef products leads retailers to either offer discounts or discard beef, as consumers tend to reject discoloration. This practice contributes to food waste and wastage of economic and natural resources. This study analyzes U.S. consumer preferences for beef based on meat color. A mixed methods design including a discrete choice experiment and focus group discussions is applied to understand consumer willingness to pay (WTP), the effects of price discounts as well as color preference of beef shoppers. Results show that consumers perceive, prefer, and see color nearly linearly across days. Consumer WTP is negative for all days of retail display and decreases with an increase in discoloration. Focus group participants associate a bright cherry color with beef quality and eating satisfaction. Most participants reject discoloration and link a brownish beef color to concerns about food safety and product quality. Still, informative marketing measures in addition to price discounts may help to shift some consumers' purchasing behavior and reduce meat waste at the retail level.

keywords

Meat color, consumer preferences, mixed-methods approach

1 Introduction

Reducing food waste is crucial for creating sustainable food systems (SEARCHINGER et al. 2018). About one-third of global food production is lost or wasted annually, causing economic losses of US\$1 trillion per year along the supply chain in addition to environmental costs of about US\$700 billion and social costs of US\$900 billion globally (FAO 2014). Meat is an important component of food items that are wasted as it is highly perishable and primarily associated with the environmental impact of food waste (LIPINSKI 2020; FAO 2014).

Meat consumers often associate visual appearance at the time of purchase at retail with product quality (HENCHION et al. 2014; LUSK et al. 2018). Recently, ALTMANN et al. (2022) reported that meat color strongly influences consumer purchase decisions. Consumers in Western industrialized countries often prefer a bright cherry red beef color (ALTMANN et al. 2023; MEYERDING et al. 2018) and consider brownish or other colors hues of beef discoloration. Discoloration of beef can lead to rejection (FEUZ et al. 2020) and is associated with a low willingness to pay (WTP) for these products (GREBITUS et al. 2013). Therefore, beef turning brownish red to brown is typically discounted or even discarded by retailers (RAMANATHAN et al. 2022), although it could be microbiologically safe for consumption in most cases (RAMANATHAN et al. 2021). RAMANATHAN et al. (2022) also reported that 194,700 tons of edible beef are discarded annually in United States (U.S.) food retail stores due this practice.

The objective of this study was to analyze consumer attitudes, preference and their willingness to pay (WTP) for beef based on meat color. A mixed methods design, including a discrete choice experiment as well as focus group discussions, was developed. Consumer preferences,

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WTP, and the effects of price discounts were examined with a hypothetical discrete choice experiment conducted using digital photos of steaks with different color (associated with day of retail display), price, and discount labels in retail packaging. In addition, qualitative focus group discussions were conducted in order to assess consumers' beef color perceptions and their future purchasing ambitions in more detail. A profound understanding of consumer preferences for color will assist retailers in successfully marketing discolored beef to reduce food waste at the retail level.

2 Materials and Methods

A mixed methods design, including a hypothetical discrete choice experiment as well as focus group discussions, was developed.

2.1 Survey design

A consumer survey on beef purchasing behavior was conducted using Qualtrics software (XM, Seattle, WA, USA) on iPads (10th generation) between June and August 2023. Survey participants ($n = 389$) were recruited at supermarkets or other food purchase facilities in different neighborhoods throughout Fort Collins and Laporte, Colorado. The study was approved by the Colorado State University Institutional Review Board (IRB#4446). Descriptive statistics of the resulting sample ($n = 315$) are summarized in Table A1.

The survey included three sections: 1) color perception, 2) self-declared beef purchasing behavior and attitudes, and 3) a hypothetical discrete choice experiment. Additionally, the standardized questionnaire collected sociodemographic information as well as data on respondents' self-declared beef purchasing and consumption behavior based on short statement batteries. The comprehensibility of the questionnaire was checked by means of a pre-test with 94 colleagues and students participating in courses at the Department of Animal Sciences, Colorado State University. Screen acuity regarding color perception was tested using a condensed form (i.e., with one test image) of the ishihara test at the beginning of the survey.

A discrete choice experiment (DCE) was conducted to determine consumer preferences for discolored beef steaks in retail packaging. Three product attributes: 1) beef color, 2) price, and 3) discount sticker and their respective levels were included in the choice experiment using digital photos of packaged beef steaks. A d -optimal 12 choice design was created using Ngene (Choicemetrics, Version 1.1) with two product alternatives each and one opt-out option ("I choose neither of these alternatives") to refrain from forced choices. An example choice set is presented in **Figure 1**. The order of the choice sets, as well as the position of the two product alternatives, varied randomly for each respondent, while the position of the opt-out option was presented last in every choice situation. Respondents were placed into a theoretical shopping situation using a standard cheap talk script and asked to consider their actual budget when making purchasing or non-purchasing decisions. They were informed that they would be presented with a choice of 12 beef steaks, all of which were within their expiry date.

Figure 1: Example of a choice set shown to participants.



I would not purchase
any of those steaks

Source: Own presentation.

2.2 Model specification and data analysis

Based on the ishihara test results, a total of five participants (1.59%) were excluded from the sample prior to analyzing the choice data. Thirteen participants (4.13%) opted not to purchase any beef steak across all 12 choice scenarios, expressing a preference for alternative beef cuts. These individuals were also excluded from subsequent analysis. In total 297 participants' responses were analyzed.

Discrete choice modeling is based on utility theory, which assumes that the overall benefit (utility) of a product to its user (consumer) is deterministic and a sum of that product's attributes. Consequently, in a discrete choice experiment, participants choose the product returning their highest utility at the lowest cost. In this way, utility maximization of product attributes can be assumed to explain consumer behavior (MCFADDEN 1986). The Mixed Logit Model (MLM) accounts for repeated choices and allows preferences to vary randomly and independently amongst consumers (REVELT UND TRAIN 1998). The model assumes that a portion of the utility is deterministic, based on known attributes, and the remainder is random. The deterministic portion is assumed to be linear so that individual i 's marginal utilities of observable attributes associated with alternative j can be summed:

$$(1) U_{ijt} = ASC + \alpha Price_{ijt} + \beta_i X_{ijt} + z_i \delta_j + \varepsilon_{ijt}$$

where ASC is the alternative specific constant (opt-out option); α is fixed marginal utility of price, $Price_{ijt}$ given the price of alternative j for individual i in scenario t . β_i are random utility coefficients X_{ijt} , a k -dimensional vector of observed non-monetary product attributes (i.e. color, sales tag) and their respective levels for alternative j , individual i and choice scenario t . δ_j are fixed alternative-specific coefficients for case-specific variables (z_i). ε_{ijt} is an i.i.d. error term that follows a type I extreme value distribution.

Consumers preferences for steak color, price as well as discount were modelled using mixed logit models (MLM). Zero days of retail display and no discount sticker were used as reference levels to determine the marginal utility and WTP. The Hemmersley integration sequence was specified using 3,500 points. The third-choice option, “no-buy,” was selected as the base alternative. The mixed logit model accounted for the presence of a sale sticker as a binomial (1= discount sticker; 0 = no discount sticker) and is specified below:

$$(2) U_i = ASC + \beta_i \text{listedprice} + \beta_i 4\text{days} + \beta_i 7\text{days} + \beta_i 9\text{days} + \beta_i \text{Discountsticker} + \varepsilon_{ijt}$$

Listed price was fixed and all other variables were considered random.

Willingness to pay in preference space for the beef color was calculated according to Hensher et al. (2015):

$$(3) WTP = - \frac{\beta_{\text{attribute}}}{\beta_{\text{price}}}$$

with 1000 Krinsky repetitions to calculate confidence intervals.

2.3 Qualitative focus group discussions

Qualitative research enables the acquisition of profound insights into the societal perspectives of individuals or groups, facilitating the exploration of overarching relationships within the context of real-life behavioral actions (FLICK et al. 2007). In order to understand consumer attitudes and their perception with regard to beef color and discoloration, qualitative focus groups were therefore conducted in addition to the consumer survey. Through active engagement with one another, participants in the focus groups articulated their perspectives and offer spontaneous reactions to a designated topic, in this case, beef color (FLICK et al. 2007).

In January 2024, four qualitative focus group sessions were carried out, each comprising seven to ten beef consumers. This research was approved by the Colorado State University Institutional Review Board (IRB#5092). The purpose was to thoroughly examine consumers' perceptions of beef color and gain a comprehensive understanding of their perspectives. The focus group guideline included open questions regarding meat buying behavior, beef color preferences, beef quality perceptions, discoloration in beef, meat shelf life, as well as food and meat waste prevention. Focus group participants were also given a scientific definition of meat discoloration. Each focus group session was recorded in audio format and later transcribed for further analysis and documentation. A qualitative content analysis according to MAYRING (2000) was applied to evaluate the text material. Thematic categories were established, deducting the corresponding codes from the text material. The codes were combined into four main categories and 11 sub-categories, whereby the codebook was developed jointly by two researchers using MAXQDA.

3 Results

3.1 Consumer preferences

Statistically significant ($P < 0.05$) results of a mixed logit model (MLM) are presented in **Table 1**. Preference heterogeneity within the total sample was demonstrated by statistically significant ($P < 0.05$) standard deviations of the random attributes (4, 7, and 9 days of retail display color levels and discount stickers). A negative and significant coefficient for listed price aligns with utility theory that the increasing price negatively affects participants' welfare and, therefore,

preferences. The positive and significant ($P < 0.001$) constant coefficients for choices 1 through 2 (per choice set) indicate that survey participants chose to engage and would “purchase” one out of the two beef steaks instead of choosing the base alternative “I would not purchase any of those steaks.” The negative and significant coefficients for 4, 7, and 9 days of retail display demonstrate that beef consumers perceive discrete differences in beef color and prefer color nearly linearly across days. As coefficients were negative, color level 0 was the most preferred, followed by levels 4 and 7. The steak that discolored over 9 days of retail display was the least preferred.

Table 1: Mixed Logit Model estimates of coefficient means and standard deviations (SD) for the total sample (n = 297)

Variable	Total participants (n=297)		
	Coefficient	Standard error (SE)	p-value
Listed price	-0.13	0.01	***
4 days of retail display	-0.67	0.09	***
7 days of retail display	-1.31	0.11	***
9 days of retail display	-2.65	0.16	***
Discount sticker	0.88	0.10	***
SD			
4 days of retail display	0.73	0.11	***
7 days of retail display	0.99	0.11	***
9 days of retail display	1.80	0.17	***
Discount sticker	1.33	0.09	***
Constant alt1	4.51	0.25	***
Constant alt2	4.38	0.25	***
Log likelihood	-1277.48		

Significances levels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Source: Own estimations based on choice data

On average, consumer WTP in preference space (**Table 2**) was negative for all days of retail display and decreased nearly proportionately with an increase in discoloration. For a steak that was in retail display (and discolored) for 4 days, respondents in this study were willing to pay \$5.09 per lb. less compared to a steak with 0 days of retail display. The WTP was the lowest for 9 days of retail display, and the respondents will only spend \$20 per lb. less compared to 0 days of retail display. As the average price for the steaks presented was \$15.99 per lb., the results imply that the respondents would have to be financially compensated for choosing a steak left for 9 days in retail display. Full results can be found at THIES et al. (2024).

Table 2: Willingness to pay (WTP) for different days of retail display based on Mixed Logit Model estimates (n = 297)

Variable	Total sample n=297		
	WTP	Lower bound	Upper bound
4 days of retail display	-5.08	-6.65	-3.52
7 days of color display	-9.89	-12.21	-7.58
9 days of retail display	-20.05	-24.74	-15.28

Source: Own estimations based on choice data

3.2 Associations with discoloration

Four main categories (i.e., “beef purchasing behavior, beef color perception, food and meat waste awareness, and future buying decisions based on beef color”) as well as 11 sub-categories were identified based on the text material of the qualitative focus group sessions.

Focus group participants associated a bright cherry beef color with beef quality, food safety and eating satisfaction. Beef consumers expected a cherry red steak to be more fresh than the brownish counterpart. They were also assuming a red beef steak to be more tender and thought that color indicates juiciness. Furthermore, the anticipation of a premium-quality steak was in line with the interviewees' acquired product expectations, marked by a distinctive cherry-red steak color.

“If I'm paying the full price, I want it to be bright red.”

Participants perceived a beef steak as a premium product for which they were willing to pay a higher price if the product meets their requirements and expectations. The majority of participants stated they rejected discoloration in beef steak and linked a brownish color to concerns about food safety, toughness, and dryness. Beef consumers were assuming that “there's something off at the very least” with brownish beef steaks. They supposed that a discolored beef steak would taste differently compared to a steak of a cherry red color. Participants further believed that a brownish discoloration indicated a shorter shelf life. They were convinced that beef color was an indicator for incorrect product handling during storage.

“Maybe it wasn't at the correct temperature. Maybe it was like frozen and then thawed.”

In some cases, participants even linked beef color to animal handling and assumed that cattle had been treated incorrectly before or during slaughter. They concluded that a brownish discoloration of steaks was a representation of bruising.

Still, participants suggested a potential shift in their purchasing behavior, contingent upon receiving information on discoloration in beef and on the occurrence of meat waste at the retail level. Beef consumers mentioned that they were not aware that product quality and eating satisfaction were not affected by discoloration in beef steaks. After being provided with a definition of discoloration many participants stated that they would now consider to buy a brownish steak if they could be guaranteed by an independent body that the meat was still safe to eat. At the same time, the participants expected a price discount for any form of discoloration in beef.

“If you could confirm it's safe, I mean, I said I would buy it if it was a little brown, but if it's really brown, if you could confirm it's safe and the juiciness, tenderness is still not affected, then I would definitely buy it, especially if it was discounted, I mean, too.”

4 Discussion and concluding remarks

When purchasing beef, consumers often view color as an indicator of freshness and wholesomeness (MANCINI AND HUNT 2005). Despite this, only limited studies have examined the consumer preferences and acceptance of different beef color levels (ALTMANN et al. 2023). GREENE et al. (1971) showed that U.S. consumers reject fresh beef with a brown metmyoglobin level of over 40%. Similarly, CARPENTER et al. (2001) reported a close link between beef color preferences and likelihood to buy, but not between color preferences and eating satisfaction.

This study offers crucial and contemporary insights into the purchasing behavior of beef consumers, specifically concerning their color, price, and discount preferences based on quantitative and objective color measurements. Results of the discrete choice experiment showed that beef consumers perceive discrete differences in beef color and prefer color nearly linearly across days of retail display. A steak that has had the chance to discolor over 9 days was least preferred by consumers. Accordingly, the WTP of beef shoppers decreased with increasing days of retail display, as what can be considered discoloration increased. In fact, according to our hypothetical experiment, consumers would require financial compensation to consider purchasing a steak with discoloration associated with 9 days of retail display.

Similar to the current study, Grebitus et al. (2013) used a choice experiment focusing on various ground beef attributes modifiable through packaging. The participants in their study favored a light red color and cherry red color compared to a brownish red color and were willing to pay the highest price for cherry red ground beef. HOLMAN et al. (2017) provided a more intricate examination of beef color preferences by conducting a web-based survey using digital photographs of beef steaks (*longissimus lumborum*) with predetermined colorimetric values. Their survey aimed to explore international beef color acceptability on a six-level interval scale. The authors found that consumers considered beef color to be acceptable, with a^* value² being equal to or above 14.5. The findings of our current study indicated that beef steaks in retail display for up to 7 days could still be marketable with a price discount; the color measurements for 7 days of retail display had an a^* value of 17. In our study, consumers required compensation to consider purchasing steaks that were displayed for 9 days, yet still with an a^* value of 14.

Moreover, results of the choice experiment revealed that discount stickers did not reduce the utility gained through a product purchase (i.e., coefficients were not negative). Therefore, a discounted beef price might not be necessarily associated with a negative quality, or at the very least the perception of saving money offsets concerns around negative quality. Certainly, participants in the focus groups for this study expressed an expectation for a discounted price when it came to brown-discolored beef steaks. Additionally, they expressed a willingness to consider purchasing slightly discolored steaks as a cost-saving measure.

Targeted marketing measures, including informative measures could be used in addition to price discounts to address beef buyers, ensuring timely sales of beef products in retail to reduce food waste. Findings from the focus group sessions indicated a favorable response among participants to additional information regarding food safety and beef discoloration. Many, but not all, expressed their intention to consider purchasing such beef products during their next grocery shopping trip. Individual participants also responded positively to the discussion about the potential reduction of meat waste through the purchase of brown-discolored beef.

The findings of this research could be translated into appropriate marketing measures including consumer education on beef quality and safety in order to potentially reshaping long-term consumer perceptions of beef quality and preferences and thereby combating meat waste and its associated resource wastage.

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² Beef color was measured and evaluated for lightness (L^*), redness (a^*), and yellowness (b^*).

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Appendix

Table A1. Descriptive statistics for demographic variables in the total sample (n = 315)

Variable	Level	Total sample (%)	Census 2022 (%)
<i>Age in years</i>	18-24	17.5	16.0
	25-34	25.7	16.5
	35-44	13.7	16.0
	45-54	11.4	14.9
	55-64	13.7	15.7
	65-74	11.8	12.5
	≥75	6.4	8.3
<i>Gender¹</i>	Female	53.0	50.4
	Male	45.7	49.6
	Non-Binary	0.6	
<i>Hispanic origin</i>	Hispanic	11.4	19.1
	Not Hispanic	88.6	80.9
<i>Ethnic heritage²</i>	White	88.8	75.5
	American Indian or Alaskan Native	2.2	1.3
	Black or African American	2.3	13.6
	Asian	2.5	6.3
	Native Hawaiian or other Pacific Islander	0.3	0.3
<i>Education (highest degree or level of school you have completed²)</i>	Middle Eastern	0.6	
	Less than high school	0.6	
	High school/GED	6.4	37.3
	Some college degree	15.6	16.4
	2-year degree	4.1	10.1
	4-year degree	38.4	22.6
	Graduate degree	34.9	13.3
<i>Income (net monthly household income)^{1,3}</i>	< \$ 29,999	14.0	
	\$ 30,000 – \$ 59,999	17.1	
	\$ 60,000 - \$ 89,999	16.2	
	\$ 90,000 - \$ 119,999	14.0	
	\$ 120,000 - \$ 149,999	10.8	
	≥ \$ 150,000	21.3	
<i>Household size¹</i>	1 person	13.0	28.9
	2 people	45.1	34.7
	3 people	20.0	15.1
	4 people	14.3	12.3
	5 people	5.7	5.6
	More than 5 people	1.6	3.4

¹ Total percentages do not sum up to 100% due to participants having the option of choosing not to answer this question.

² Total percentages exceed 100% due to participants having the option to check all ethnic heritages that apply.

VULNERABILITÄT UND RISIKEN

VULNERABILITÄT DER DEUTSCHEN NUTZTIERHALTUNG IM FALLE EINER ENERGIEMANGELLAGE

Sebastian Kleingräber¹, Josef Efken

Zusammenfassung

Die landwirtschaftliche Primärproduktion ist ein wichtiger Ausgangspunkt für die Sicherstellung einer ausreichenden Nahrungsmittelversorgung im Katastrophenfall. Die Auswirkungen von Krisen und Katastrophen auf die Landwirtschaft selbst wurden bisher wenig untersucht. In dieser Arbeit werden die Folgen eines längerfristigen, flächendeckenden Stromausfalls (Blackout) auf die Nutztierhaltung in Deutschland untersucht, um vulnerable und zeitkritische Produktionsfaktoren und -prozesse zu identifizieren. Elf Experten und Berater aus der konventionellen und ökologischen Tierhaltung schätzen die Futter- und Tränkwasserversorgung die Belüftung und das Melken als besonders anfällig und zeitkritisch ein. Während in der Rinderhaltung aufgrund größerer Futtervorräte und offener Ställe kaum zeitkritische Prozesse bei Stromausfall auftreten, ist die Schweine- und Geflügelhaltung vor allem in zwangsbelüfteten Ställen auf eine schnelle Frischluftzufuhr angewiesen. Darüber hinaus wird die Fütterung in diesen Ställen oft elektrisch betrieben. Weiterhin wird in der Schweine- und Geflügelhaltung häufig Mischfutter eingesetzt, das innerhalb weniger Tage nachgeliefert werden muss. Die leitfadengestützten Interviews haben zudem gezeigt, dass keine einheitliche Einschätzung über die Verbreitung und Dimensionierung von Notstromaggregaten sowie das Vorhandensein von Notfallplänen in den landwirtschaftlichen Betrieben vorherrschen. Die Arbeit zeigt zudem, dass weiterer Forschungsbedarf hinsichtlich der Resilienz landwirtschaftlicher Betriebe gegenüber Energiemangellagen und anderen Krisensituationen besteht.

Keywords

Blackout, Ernährungssicherheit, Kritische Infrastrukturen, Nutztierhaltung, Risikomanagement

1 Einleitung

Die Auswirkungen eines langanhaltenden, flächendeckenden Stromausfalles (Blackout) können fatale Folgen für weite Teile des öffentlichen Lebens sowie für große Teile der Kritischen Infrastrukturen² (KRITIS) haben. Für einen solchen Blackout kommen verschiedene Ursachen in Frage. Diese reichen von den Folgen extremer Wetterereignisse bis hin zu menschlichem oder technischem Versagen, ausgelöst etwa durch Cyber- und Terrorangriffe (BRINKMANN et al., 2010; PETERMANN et al., 2011). Das tatsächliche Schadensausmaß ist von unterschiedlichen Faktoren, wie etwa der Vorbereitung und dem Ausmaß der Resilienz der einzelnen Akteure, abhängig. Studien des Bundesamtes für Bevölkerungsschutz und Katastrophenhilfe (BBK) haben die Auswirkungen verschiedener Krisensituationen auf nationale Akteure aufgezeigt (BBK, 2021a; DEUTSCHER BUNDESTAG und BBK, 2017).

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² Das Bundesministerium für Inneres und Heimat (BMI) definiert KRITIS als „[...] Organisationen und Einrichtungen mit wichtiger Bedeutung für das staatliche Gemeinwesen, bei deren Ausfall oder Beeinträchtigung nachhaltig wirkende Versorgungsengpässe, erhebliche Störungen der öffentlichen Sicherheit oder andere dramatische Folgen eintreten würden“ (BMI, 2009: 3). Neben dem Sektor Ernährung gehören ebenfalls die Sektoren Energie, Finanz- und Versicherungswesen, Gesundheit, Information und Telekommunikation, Medien und Kultur, Staat und Verwaltung, Transport und Verkehr sowie Wasser zu den KRITIS (BBK, 2021b).

Im KRITS-Sektor Ernährung bilden die landwirtschaftliche Primärproduktion selbst sowie vor- und nachgelagerten Bereiche die Rohstoffgrundlage dieses Sektors. Aufgrund des hohen Selbstversorgungsgrades mit Nahrungsmitteln von 86 % (2022) in Deutschland (BLE, 2024), hätte ein plötzlicher Ausfall der landwirtschaftlichen Primärproduktion voraussichtlich gravierende Auswirkungen auf die kurz- bis mittelfristige Sicherstellung einer ausreichenden Nahrungsmittelversorgung. Verschiedene Organisationen und Richtlinien, wie das "Sendai Framework for Disaster Reduction 2015-2030" der Vereinten Nationen (Vereinte Nationen, 2015) und der "Notfallplan zur Sicherstellung der Lebensmittelversorgung und Ernährungssicherheit in Krisenzeiten" der Europäischen Kommission (Europäische Kommission, 2021), setzen Anreize und definieren Ziele, um die Risiken bei einem Ausfall kritischer Infrastrukturen zu reduzieren. Bezogen auf die landwirtschaftliche Primärproduktion sind vor allem tierhaltende Betriebe von einem solchen Stromausfallszenario betroffen. Im Gegensatz zu reinen Acker- und Gemüsebaubetrieben ist die Tierhaltung mit einer besonderen Fürsorgepflicht gegenüber den Nutztieren verbunden, zudem spielt die elektrische Energie eine große Rolle im täglichen Betriebsablauf. Die vorliegende Arbeit konzentriert sich daher auf die Prozesse in der Rinder-, Schweine- und Geflügelhaltung, die von einem Blackout betroffen wären. Dabei werden die folgenden drei Forschungsfragen adressiert:

- 1) Welche Bereiche und Prozesse des täglichen Produktionsablaufs sind bei einem Blackout in landwirtschaftlichen Betrieben mit Nutztierhaltung besonders vulnerabel?
- 2) Welche Zeiträume ergeben sich für die einzelnen Produktionsrichtungen und -faktoren, bevor ein kritischer Zustand erreicht ist?
- 3) Wie ist der Status Quo der landwirtschaftlichen Betriebe hinsichtlich präventiver Maßnahmen?

2 Stand des Wissens

Der Schutz kritischer Infrastrukturen auf nationaler Ebene ist seit 2004 Gegenstand verschiedener Länder- und Ressortübergreifender Krisenmanagementübungen (LÜKEX). Während bei den verschiedenen LÜKEX Übungen der Sektor Ernährung erfasst ist, werden mögliche negativen Auswirkungen auf die Landwirtschaft selbst häufig nur unspezifisch aufgeführt. So weist der Auswertungsbericht zur LÜKEX Übung des Jahres 2018 zum Thema „Gasmangellage in Süddeutschland“ auf unterschiedliche Herausforderungen der Ernährungswirtschaft, wie etwa Engpässe bei Bäckereien und Schlachthöfen, hin. Dabei wird jedoch lediglich angemerkt, dass im Falle einer Gasmangellage Auswirkungen auf geflügelhaltende Betriebe bestehen können und Kennzahlen in diesem Bereich bisher nicht zur Verfügung stehen (BBK, 2019).

Die konkreten Auswirkungen eines Blackouts auf die Nutztierhaltung wurden in wissenschaftlichen Studien bisher wenig untersucht. Eine Ausnahme hiervon bildet die Dissertation von ZYLKA (2021). In der Arbeit wurde basierend auf einer Befragung von 14 landwirtschaftlichen Betrieben und elf Veterinärämtern eine erste Kritikalitäts-, Vulnerabilitäts- und Risikoanalyse der verschiedenen Prozesse in der Nutztierhaltung durchgeführt. Neben der Ableitung von Handlungsempfehlungen zur Stärkung der Resilienz nutztierhaltender Betriebe konnte die Dissertation die Anzahl an Prozessen aufzeigen, welche im Falle eines Blackouts auf den Betrieben gestört sind (ZYLKA, 2021). LASSEN (2013) beschäftigt sich mit der Nutztierhaltung im Falle einer durch eine Sonneneruption ausgelösten großflächigen Störung der Stromversorgung. Auch hier wird auf die Vielzahl betroffener Bereiche und Prozessen hingewiesen. Darüber hinaus wird auf die Folgen einer gestörten Kommunikationstechnik eingegangen. Gleichzeitig gilt die Stromversorgung in Deutschland im globalen Vergleich als besonders zuverlässig (BMWK, 2017). So war jeder Endverbraucher im Jahr 2022 durchschnittlich lediglich 12,2 Minuten von einem Stromausfall betroffen (BUNDESNETZAGENTUR, 2023). Gleichzeitig sind sich Experten jedoch uneinig, ob etwa der Ausbau erneuerbarer Energien einen positiven oder negativen Ein-

fluss auf die Netzstabilität besitzt (CZOCK et al., 2023; LEHMANN et al., 2016). Aufgrund verschiedener Sicherheitsmechanismen, wie etwa dem (n-1) Kriterium zur Sicherstellung ausreichend redundanter Stromnetze (HAB et al., 1981), wird angenommen, dass großflächige und langanhaltende Ausfälle der Stromversorgung als eher unwahrscheinlich gelten (HAACKE und ENDREß, 2022; SCHÄFER, 2024).

3 Methodik

Aufgrund des explorativen Ansatzes dieser Arbeit und der geringen Anzahl an Publikationen zu diesem Thema, wurde ein qualitativer Forschungsansatz gewählt. Zur Beantwortung der aufgeführten Forschungsfragen wurde die Methode des leitfadengestützten Interviews gewählt. Diese Methode ermöglicht einen tiefen Einblick in die persönlichen Perspektiven und Erfahrungen der Teilnehmenden (FLICK, 2014; HELFFERICH, 2014). Darüber hinaus eignet sich diese Form der Datenerhebung für Themen, die auf detaillierte Aspekte des Prozesswissens abzielen und sich durch einen hohen Detaillierungsgrad auszeichnen (BOGNER et al. 2014).

Ziel der Expertenauswahl war es, Interviewpartner zu identifizieren, die sich insbesondere durch langjährige Berufserfahrung in den jeweiligen Bereichen sowie durch spezifische Kenntnisse der Tierhaltungsverfahren auszeichnen (HELFFERICH, 2014; PRZYBORSKI und WOHLRABSAHR, 2008). Ausgangspunkt für diesen Auswahlprozess waren Kontakte zum Bundesministerium für Ernährung und Landwirtschaft, die sich mit dem Thema Krisenvorsorge in der Nutztierhaltung beschäftigen. Ausgehend von diesen Kontakten wurden im Schneeballverfahren Experten kontaktiert und ausgewählt. Insgesamt konnten auf diese Weise elf Experten aus den Bereichen konventionelle und ökologische Rinder-, Schweine- und Geflügelhaltung gewonnen werden (Tabelle 1).

Um die Vergleichbarkeit der Ergebnisse zu gewährleisten, wurde ein identischer Leitfaden für die Interviews verwendet (HELFFERICH, 2014). Der Interviewleitfaden war in fünf Blöcke gegliedert:

1. Energie
2. Betriebsmanagement
3. Futter und Wasser
4. Vor- und nachgelagerte Bereiche
5. Unterstützung Dritter

Die Interviews fanden im Zeitraum vom 28.11. bis 16.12.2022 statt. Die Dauer der Interviews variierte zwischen 48 Minuten und 2 Stunden 23 Minuten. Die Experten wurden während des Interviews mit dem Szenario eines plötzlichen, großflächigen Stromausfalls von drei bis sieben Tagen konfrontiert.

Tabelle 1: Expertenübersicht

Kürzel	Themenbereich	Konventionell/ ökologisch	Berufserfahrung (Jahre)	Region	Datum	Länge (h)
I1	Geflügel	ökologisch	40	Niedersachsen	28.11.2022	00:48:54
I2	Schwein	konventionell	26	Niedersachsen	29.11.2022	01:58:33
I3	Schwein	konventionell	30	Nordrhein-Westfalen	30.11.2022	01:03:57
I4	Rind	konventionell	21	Sachsen	02.12.2022	02:23:06
I5	Schwein	konventionell & ökologisch	18	Schleswig-Holstein	05.12.2022	02:05:42
I6	Schwein	konventionell	17	Niedersachsen	05.12.2022	01:30:29
I7	Rind	konventionell	27	Niedersachsen	06.12.2022	00:58:36
I8	Geflügel	konventionell & ökologisch	30	Hessen	09.12.2022	01:01:57
I9	Rind	konventionell	19	Mecklenburg-Vor- pommern	13.12.2022	01:01:47
I10	Geflügel	ökologisch	31	Schleswig-Holstein	15.12.2022	00:55:57
I11	Schwein/Geflügel	konventionell & ökologisch	29	Baden-Württemberg	16.12.2022	01:53:41

Quelle: Eigene Darstellung

Die Interviews wurden aufgezeichnet, transkribiert und Mithilfe der qualitativen Inhaltsanalyse nach Mayring (2015) unter Zuhilfenahme der Software MAXQDA analysiert. Die Kategorienbildung erfolgte vor Beginn der Auswertung deduktiv auf Basis der vorhandenen Literatur. Im Verlauf der Auswertung wurden die bestehenden Kategorien induktiv um Aspekte und Bereiche ergänzt, die in den Interviews zusätzlich angesprochen wurden (Mayring, 2015). Insgesamt wurden 16 Haupt- und 24 Unterkategorien ermittelt, von denen in diesem Papier fünf Haupt- und zehn Unterkategorien mit unmittelbarem Bezug zu den Forschungsfragen dargestellt werden (vgl. Tabelle 2, S. 5). Zur Auswertung der Ergebnisse und zum Vergleich der Kategorien nach Untergruppen von Tierarten und Haltungsformen wurden Segmentmatrizen erstellt (Kuckartz, 2018). Die indirekten Aussagen der Experten werden unter Nennung des Kürzels und der Textpassage des Interview angegeben.

4 Ergebnisse

Die vorgestellten Ergebnisse konzentrieren sich auf die vier Unterkapitel 4.1 Notstromversorgung, 4.2 Fütterung und Wasserversorgung, 4.3 Lüftung sowie 4.4 Notfallpläne und Kompensationsfähigkeit. Während das erste Unterkapitel in die Abschnitte Verbreitung, Dimensionierung und Inbetriebnahme von Notstromaggregaten unterteilt ist, sind das zweite und dritte Unterkapitel nach den Haltungsformen Rinder-, Schweine- und Geflügelhaltung gegliedert. Die Ergebnisse der Kapitel 4.2 und 4.3 sind im Anschluss an Kapitel 4.3 in Tabelle 3 zur besseren Übersichtlichkeit und Vergleichbarkeit zusammengefasst. Im vierten Unterkapitel erfolgt eine parallele Betrachtung der verschiedenen Betriebsformen.

Tabelle 2: Übersicht über die Haupt- und Unterkategorien und Anzahl der codierten Textsegmente

Hauptkategorie	Anzahl	Unterkategorie	Anzahl
1 Vorbereitung Blackout auf den Betrieben	35		
2 Gestörte Prozesse im Betriebsablauf	45		
		2.2 Melken	13
		2.4 Lüftung	35
		2.5 Futtermittel	77
		2.6 Wasserversorgung	36
		2.7 Manuelle Lösung	23
		2.8 Besser aufgestellte Betriebsformen	40
3 Notstromaggregate	9		
		3.1 Dimensionierung Notstrom	12
		3.2 Überprüfung/Inbetriebnahme Notstrom	20
		3.3 Verbreitung Notstrom	27
4 Notfallpläne	14		
5 Vor- und Nachgelagerte Bereiche	34		
		5.1 Futtermühlen	16

Quelle: Eigene Darstellung

4.1 Notstromversorgung

Nach Einschätzung der Experten wird die Inbetriebnahme der Geräte unterschiedlich häufig trainiert. Während vor allem in der Geflügelhaltung eine regelmäßige Überprüfung der Geräte stattfindet (I1:34,38), ist in der Schweinehaltung unklar, ob und inwieweit die Inbetriebnahme der Geräte regelmäßig überprüft und geübt wird (I2:49; I6:13). Ein Experte gibt jedoch an, dass ökologisch wirtschaftende Geflügelbetriebe hier eine Ausnahme darstellen. So sind auf diesen Betrieben Notstromaggregate grundsätzlich weniger stark verbreitet. Ein Experte schätzt, dass viele Betriebe aufgrund von Angst vor Schäden an verschiedenen Komponenten der IT & EDV-Infrastruktur Notstromaggregate bzw. die Inbetriebnahme inklusive des Anschlusses an das eigene Stromnetz nicht testen (I4:15). Schwierigkeiten werden auch bei einem Blackout gesehen, wenn sich Unternehmen ein Notstromaggregat teilen. Diese Form der Erfüllung gesetzlicher Vorgaben ist in der Praxis weit verbreitet (I5:13). Viele landwirtschaftliche Betriebe verfügen über eine eigene Tankstelle, so dass die Kraftstoffversorgung für dieselbetriebene Notstromaggregate oder Traktoren mit einem zapfwellenbetriebenen Notstromaggregat gegeben ist (I3:19; I4:15). Die mögliche Einsatzzeit der Geräte im Notfall hängt somit direkt von den Kraftstoffreserven auf den Betrieben ab.

4.2 Fütterung und Wasserversorgung

Die Fütterung und die Wasserversorgung sind bei einem kurzfristigen Stromausfall (bis zu sechs Stunden) für die **Rinderhaltung** wenig relevant (I4:13,23), längere Zeiträume werden jedoch als kritisch angesehen. Die Fütterung in der Rinderhaltung erfolgt in der Regel über dieselbetriebene Maschinen, die keinen Strom benötigen. Ausnahmen bilden Komponenten, die in Hochsilos gelagert und elektrisch ausdosiert werden sowie Lockfutter für automatische

Melk- (I4:15) und Fütterungssysteme (I7:15). Bei Betrieben mit eigener Hofmischung sind die Vorräte größer als bei Betrieben mit Zukauffuttermitteln. In der Regel beträgt der Lieferzeitraum bei Zukauffuttermitteln aber auch hier circa 14 Tage (I4:27). Bei Betrieben, die eigene Kraftfuttermittel vorrätig halten, sind die Reserven größer (I9:41). Zudem sind Mineralfuttermittel aufgrund der unregelmäßigen Anlieferung oft über mehrere Monate verfügbar (I4:23). Das Grundfutter ist auf den Betrieben für längere Zeiträume vorrätig. Es wird versucht, immer einen Puffer von wenigen Monaten vorzuhalten. Je nach Jahreszeit können die Vorräte aber auch nur für wenige Wochen oder aber für mehr als 1,5 Jahre reichen (I4:25; I7:21; I9:39). Rationen in der Rinderhaltung können kurzfristig nur in geringem Umfang umgestellt werden. Möglich wäre hier, den Anteil an Kraftfutter langsam innerhalb von 14 Tagen zu reduzieren und auslaufen zu lassen (I4:27; I7:49). Auch in der Kälberaufzucht spielt die Futterversorgung über elektrische Tränkeautomaten eine wichtige Rolle (I7:19). Milchaustauscher für die Kälberfütterung sind in der Regel für mehrere Wochen vorrätig, könnten jedoch durch Frischmilch ersetzt werden (I9:45). Die Fütterung von Hand ist in der Rinderhaltung aufgrund der großen Futtermengen nicht möglich. Bei der Wasserversorgung benötigen die Umwälzpumpen zur Aufrechterhaltung der Tränkwasserversorgung eine permanente Stromversorgung, welche in der Regel nicht in die Notstromversorgung eingebunden ist (I4:13).

Die Fütterung großer **Schweinebestände** ist aufgrund der zu bewegenden Mengen und der Stallbauweise manuell kaum möglich (I2:33,69). Der Antrieb der Fütterungsanlagen erfolgt in der Regel elektrisch (I2:43). Bei einem Ausfall der Futterversorgung kann es innerhalb weniger Stunden zu Caudophagie und anderen Formen des Kannibalismus kommen (I11:19,50). Das Futter wird häufig in Silos gelagert, die über eine elektrische Entnahme verfügen (I2:43).

In den tierhaltungsintensiven Regionen Nordwestdeutschlands dominiert die Form des Mischfutterzukaufs gegenüber der Form der Eigenmischung (I2:45; I5:17; I6:32; I11:25,27). In anderen Regionen liegt dieser Anteil bei bis zu 90 % Eigenmischung (I3:23,75; I6:102; I11:27). Der Lieferrhythmus des Mischfutters variiert stark. Hierbei reicht die Spanne von mehrmals pro Woche bis zu einmal alle 3 Wochen (I2:45; I4:23; I5:19; I6:30; I11:25). Aber auch in Betrieben mit Eigenmischung reichen die Zukaufkomponenten (Eiweiß- und Mineralfutter) nur für wenige Tage oder Wochen (I11:25). Die Eigenmischbetriebe sind daher mittelfristig ebenfalls auf eine Nachlieferung angewiesen (ebd.). Im Falle eines Blackouts könnten betroffene Schweinehalter zunächst die Ration strecken und die Tiere nur am Erhaltungsbedarf füttern, ggf. Raufutter einmischen sowie schonend Komponenten austauschen (I5:21; I6:34). Die Trinkwasserversorgung der Schweine wird in Abhängigkeit der Außentemperatur als zeitkritisch angesehen und muss innerhalb weniger Stunden erfolgen (I5:46; I6:36; I11:19,33). Je nach regionalen Gegebenheiten erfolgt die Wasserversorgung in der Schweinehaltung über das Wassernetz oder eine Brunnenanlage. Die landwirtschaftlichen Strukturen sind dabei regional und innerhalb der Produktionsausrichtungen unterschiedlich (I2:37; I3:27; I5:23; I9:49; I6:36; I11:33,122). Im Falle eines Blackouts kann die Wasserversorgung des Tierbestandes über das öffentliche Netz unter Umständen durch Umstellungen und Improvisationen sichergestellt werden (I2:35).

Die Futterversorgung in der **Geflügelhaltung** muss innerhalb weniger Stunden erfolgen, um Kannibalismus und Federpicken zu vermeiden (I1:20; I8:11; I11:50). Ein Experte schätzt, dass auf ausbleibende Futterlieferungen lediglich mit einer Nottötung der Tiere reagiert werden kann (I10:27). Eine alternative maschinelle Einbringung des Futters ist aufgrund der baulichen Gegebenheiten in den Ställen oft nicht möglich. Auch eine manuelle Einbringung des Futters ist vor dem Hintergrund der zu bewegenden Mengen bei großen Tierzahlen nicht umsetzbar (I1:26; I8:73). Eine weitere Herausforderung stellt der Futterzugang dar, da dieses oft in Silos gelagert und über elektrisch angetriebene Systeme entnommen wird (I1:26). Die Futtervorräte hängen von der Stallgröße ab und reichen von einer zweitäglichen bis hin zu einer vier wöchigen Belieferung (I1:24; I11:27). In der Geflügelhaltung dominiert die Form des Mischfutterzukaufs

(I11:25,27; I8:19,23; I10:29, 33). Nur in wenigen Betrieben werden Ergänzungsfuttermittel zugekauft und mit hofeigenen Komponenten (Mais, Weizen) vermischt (I8:23; I10:29). Im Gegensatz zu konventionell wirtschaftenden Betrieben, mischen etwa ein Drittel der ökologisch wirtschaftenden Betriebe das Futter selbst, wobei das Mahlen und Mischen elektrisch erfolgt (I1:28). Die Wasserversorgung stellt hier eine der größten Herausforderungen während eines Blackouts dar (I10:9; I11:19), da die manuelle Wasserversorgung nur in kleineren Haltungssystemen realisierbar ist (I8:41).

4.3 Lüftung

In der Nutztierhaltung stellt die Stallbelüftung grundsätzlich einen kritischen Faktor dar, in der **Rinderhaltung** ist dies allerdings weniger relevant (I7:15; I11:17,19). Eine Ausnahme bilden jahreszeitlich bedingte besonders heiße Tage und längere Hitzeperioden, vor allem mit Bezug auf die Milchviehhaltung (ebd.).

In der **Schweinehaltung** wird die Frischluftversorgung als dringendstes und zeitkritischstes Problem angesehen (I2:31,47; I3:19; I4:15,17; I5:52; I11:17). Hervorzuheben sind hier insbesondere zwangsbelüftete Ställe (Luftwäscher, Zentralabsaugung, Deckenlüftung, Unterdrucklüftung etc.) (I2:47; I3:27; I5:52; I6:23). Diese sind jedoch häufig so konzipiert, dass im Notfall Zu- bzw. Abluftklappen automatisch geöffnet werden und eine Notbelüftung auf diese Weise für kurze Zeit sichergestellt werden kann (I5:17,52). Längere Ausfallzeiten der Lüftung, können jedoch unabhängig von der Stallbauform zu erheblichen Verlusten im Tierbestand führen (I2:31; I3:19; I5:52; I6:23; I11:19).

Tabelle 3: Vergleich der Ergebnisse zwischen den unterschiedlichen Haltungsformen

	Futter	Wasser	Belüftung
Rind	- In der Regel Fütterung mit Maschinen (Diesel) - Grundfutter für längere Zeiträume (Wochen bis Monate) - vorhanden Kraft- und Mineralfutter oft für mehrere Wochen vorrätig	- zeitkritisch - oft nicht in Notstromversorgung eingebunden	- untergeordnete Rolle
Schwein	- Manuelle Versorgung nur in kleineren Haltungssystemen möglich - Fütterungen in der Regel elektrisch - Ausfall kann schnell zu Verhaltensproblemen führen - Lagerung oft in Silos mit elektrischer Entnahme - enger Lieferrhythmus (Tage/Wochen) - Maßnahmen: Ration strecken, Erhaltungsbedarf füttern	- zeitkritisch - Anschluss Wasser- oder eigenes Brunnen, regional große Unterschiede - Manuelle Versorgung nur in kleineren Haltungssystemen möglich	- dringendstes Problem, besonders bei Zwangslüftung - Ausfälle können zu erheblichen Verlusten führen - Alternative in kleinen Ställen durch Öffnen von Türen und Fenstern - Außenklimaställe weniger anfällig
Geflügel	- Manuelle Versorgung nur in kleineren Haltungssystemen möglich - Fütterungen in der Regel elektrisch betrieben - innerhalb weniger Stunden Risiko von Verletzungen der Tiere - Maschinelle/manuelle Einbringung oft nicht möglich - Lagerung oft in Silos mit elektrischer Entnahme - Vorräte variieren stark - enger Lieferrhythmus (Tage/Wochen)	- zeitkritisch - Brunnen und Wassernetz verbreitet, Mehrheit der Betriebe an Wassernetz angeschlossen, Wasserqualität wichtig - Manuelle Versorgung nur in kleineren Haltungssystemen möglich	- dringendstes Problem, besonders bei Zwangslüftung - Ausfälle können zu erheblichen Verlusten führen - Öffnen von Türen und Fenstern meist nicht möglich - wenig Zwangslüftungen in Legehennenhaltung - Alternative in kleinen Ställen durch Öffnen von Türen und Fenstern - Außenklimaställe weniger anfällig

Quelle: Eigene Darstellung

So nennen die Experten verschiedene Praxisbeispiele der letzten Jahre, bei denen Störungen in der Frischluftzufuhr drastische Folgen für die Tierbestände hatten. Durch einen Ausfall von Alarmsystemen wurde so eine Fehlfunktion oder einen Ausfall der Lüftung nicht oder nicht rechtzeitig angezeigt (I3:19; I2:81; I5:52; I6:23). Eine alternative Form der Stalllüftung, wie das Öffnen von Türen oder Fenstern, ist je nach Stallbauart eine Möglichkeit, die Frischluftzufuhr kurzfristig sicherzustellen. Durch den unkontrollierten Luftstrom und die dadurch entstehenden unterschiedlichen Klimazonen innerhalb des Stalles steigt jedoch die Gefahr der Erkrankungen von (Saug-)Ferkeln und bei längerer Änderung des Luftstroms auch der Erkrankung von Sauen und Mastschweinen (I2:47; I5:17). Wie in der Schweinehaltung ist auch in der Geflügelhaltung, insbesondere der Mast, die Sicherstellung einer ausreichenden Frischluftzufuhr und Abluftabfuhr sensibel (I1:16; I4:15,17; I8:11; I11:17). Bei mangelndem Luftaustausch kann es innerhalb kürzester Zeit zum Tod der Tiere kommen (I1:16; I8:11). Ein Großteil der Geflügelställe in der konventionellen und teilweise auch in der ökologischen Mast (I1:18) ist daher auf eine Zwangsbelüftung durch Unterdruck angewiesen (I1:18; I8:11), wobei eine manuelle Lüftung durch Öffnen von Türen und Fenstern in den meisten Fällen nicht möglich ist. (I1:18). Eine Ausnahme bilden Ställe mit Außenklimahaltung und kleine Stallanlagen, in denen die Tiere je nach örtlichen Gegebenheiten unabhängig von Lüftungsanlagen Frischluft erhalten (I1:18; I8:11).

4.4 Notfallpläne und Kompensationsfähigkeit

Das Vorhandensein von **Notfallplänen** bzw. die Vorbereitung der Betriebe auf einen Blackout wird von den Experten unterschiedlich wahrgenommen. Während ein Experte davon ausgeht, dass es in Betrieben mit Rinderhaltung keine Notfallpläne gibt (I7:39), ist ein anderer Experte der Meinung, dass in der Rinderhaltung vor allem Haupterwerbsbetriebe im Gegensatz zu Nebenerwerbsbetrieben auf einen Blackout vorbereitet sind und über Notfallpläne verfügen (I4:21). Diese Vorbereitungen auf Krisensituationen sind jedoch in vielen Fällen veraltet, da insbesondere in den letzten 20 Jahren andere Interessen verfolgt wurden (ebd.). Wiederum andere Experten sind der Meinung, dass die Betriebe nur selten über allgemeine Notfallpläne verfügen (I1:40; I8:33). Dies gilt sowohl für kleinere als auch für größere Betriebe (I1:40) sowie für ökologisch und konventionell wirtschaftende Betriebe (I10:9). Darüber hinaus glaubt ein Experte, dass geflügelhaltende Betriebe eher über Notfallpläne verfügen als schweinehaltende Betriebe (I11:11). Lediglich ein Experte meint, dass es Vereinbarungen mit den Mitarbeitern für den Fall eines Blackouts gibt. Wie diese konkret ausgestaltet sind, hängt jedoch stark von den individuellen betrieblichen Gegebenheiten ab (I9:69). Ein Experte gibt an, dass grundsätzlich unterschiedliche Notfallpläne vorhanden sind. Diese ergeben sich vor allem aus verschiedenen Vorgaben, wie zum Beispiel der ITW oder den Anforderungen der QS-Zertifizierung. Diese Notfallpläne sind jedoch eher auf kleinere Störungen im Betriebsalltag, wie kurzfristige Stromausfälle und Tierseuchen, als auf einen kompletten Blackout ausgelegt (I3:53).

Weiterhin geben die Experten an, dass es einige Betriebsformen gibt, welche die negativen Auswirkungen eines Blackouts besser kompensieren können als andere, wobei es keine „one fits all“ Lösung geben kann. So kann kaum eingeschätzt werden, ob ökologisch oder konventionell wirtschaftende Betriebe grundsätzlich eine höhere **Kompensationsfähigkeit** besitzen (I11:68,72). Vielmehr ist der betroffene Produktionsfaktor oder der betroffene Prozess entscheidend. Während beispielsweise Ställe mit Außenklimahaltung, Vorteile bei der Frischluftversorgung und der alternativen Futterbereitstellung durch die bessere Befahrbarkeit mit Maschinen bieten (I5:114; I11:68), sind diese Haltungsformen im Bereich der Wärmeversorgung und Isolierung (insbesondere im Abferkelbereich) benachteiligt (I5:64). Zudem lassen sich Unterschiede bezüglich der Kompensationsfähigkeit zwischen großen und kleinen Betrieben finden (I8:73; I11:68). Während vermutet wird, dass größere Betriebe in Bezug auf die Notstromversorgung generell besser aufgestellt sind (ebd.), meinen anderen Experten, dass gerade kleinere Betriebe im Gegensatz dazu weniger abhängig von regelmäßigen Futternachlieferungen

sind (I8:73). Kleinere Betriebe haben weiterhin den Vorteil, dass aufgrund der geringeren Mengen in der Futter- und Wasserversorgung viele Arbeiten kurzfristig manuell erledigt werden können (I8:73; I11:92). Eine wichtige Unterscheidung, welche es bei der Beurteilung von vermeintlich besser aufgestellten Betriebsformen zu berücksichtigen gilt, ist die Diskrepanz zwischen der Anzahl der Tiere und der Anzahl der Betriebe. So steht, insbesondere in der Geflügelhaltung, der überwiegende Teil der Tiere in wenigen, großen Betrieben (I8:73). Grundsätzlich sind sich mehrere Experten einig, dass die Selbsthilfe- und Improvisationsfähigkeit der Landwirte, unabhängig von der Tierart, als hoch eingeschätzt werden können (I3:43, 45; I5:64; I6:63; I11:52).

5 Diskussion

Die vorliegenden Ergebnisse zeigen ein heterogenes Bild der landwirtschaftlichen Nutztierhaltung bei Stromausfall. Mit Fokus auf die erste Forschungsfrage (*Vulnerable Bereiche und Prozesse*) decken sich die Ergebnisse weitgehend mit den Angaben aus der Literatur (Kapitel 2), welche die Belüftung sowie die Versorgung mit Wasser und Futter als besonders zeitkritisch und vulnerabel identifizieren. Es gilt hierbei jedoch zu beachten, dass es auch weitere Bereiche und Prozesse, wie etwa die Versorgung mit Tierarzneimitteln, die Kadaverentsorgung und fehlende Kommunikationsmöglichkeiten zu berücksichtigen gilt (LASSEN, 2013; ZYLKA, 2021).

In Bezug auf die zweite Forschungsfrage (*Kritische Zeiträume der Produktionsrichtungen und -faktoren*) ist zwischen Rinderhaltung sowie Schweine- und Geflügelhaltung zu unterscheiden. Die Ergebnisse dieser Studie deuten darauf hin, dass die Rinderhaltung bei einem Stromausfall von wenigen Stunden nur gering betroffen ist. Hier wirken sich insbesondere die Unabhängigkeit von der Frischluftversorgung und die großen Grundfuttervorräte positiv aus. Auch die Versorgung der Tiere mit diesen Futtermitteln ist bei ausreichenden Treibstoffreserven nicht auf eine Stromversorgung angewiesen. Einschränkungen dieser positiven Ausgangslage ergeben sich vor allem in der Milchviehhaltung, die aufgrund des Melkprozesses auf eine funktionierende Stromversorgung angewiesen ist. Bei einem längeren Ausfall der Melktechnik in der Milchviehhaltung ist daher mit Tierleid zu rechnen (ZYLKA, 2021). Für Schweine und Geflügel stellt dagegen bereits ein kurzfristiger Stromausfall ein erhebliches Risiko dar. Am zeitkritischsten ist hier die Stallbelüftung. Gerade bei zwangsbelüfteten Ställen betragen die Zeiträume, die ohne funktionierende Stromversorgung überbrückt werden können, nur wenige Minuten bis Stunden. Darüber hinaus ist die Fütterung der Tiere bei Stromausfall ein anfälliger Prozess, insbesondere für Betriebe, die auf regelmäßige Futterlieferungen angewiesen sind. In der Geflügelhaltung ist der Anteil der Betriebe mit engmaschigen Futterlieferungen deutlich höher, wobei die Lagerkapazitäten von wenigen Tagen bis zu einigen Wochen reichen. Des Weiteren kann argumentiert werden, dass bereits die Dosierung des Futters aus den Vorratsbehältern und der anschließende Transport des Futters in die Tröge bei einem Stromausfall einen vulnerablen Prozess darstellt, der nur unter bestimmten Voraussetzungen (kleine Betriebe, Außenklimaställe) alternativ gelöst werden kann. Eine Gemeinsamkeit aller Haltungsformen ist der Tränkwasserbedarf, welcher innerhalb weniger Stunden sichergestellt werden muss. Hohe Außentemperaturen verkürzen diesen Zeitraum, insbesondere für Schweine- und Geflügelhalter.

Die dritte Forschungsfrage (*Status quo der Vorbereitung*) kann im Rahmen dieser Arbeit nicht abschließend geklärt werden. Hinweise der Experten zu einer steigenden Anzahl von Notstromaggregaten in der Praxis können als positiver Effekt für den grundsätzlichen Grad der Vorbereitung interpretiert werden. Gleichzeitig wirken sich besonders die unklaren Futtermittelreserven in der Schweine- und Geflügelhaltung negativ aus. Hinsichtlich der Dimensionierung der vorhandenen Aggregate sind sich die Experten weitgehend einig, dass diese überwiegend für den kurzzeitigen Einsatz vorgesehen sind. Bei diesen Einsätzen, die das Maß von wenigen Stunden nicht überschreiten, steht nur die Aufrechterhaltung der unbedingt notwendigen Aufgaben im Vordergrund. Die Experten sind sich auch bei der Verbreitung von Notfallplänen und

dem Grad der Vorbereitung der Betriebe auf einen solchen Stromausfall uneinig. Während Notfallpläne aufgrund gesetzlicher und freiwilliger Verpflichtungen vorhanden sein können, wird die Eignung dieser Pläne für ein Blackout-Szenario als gering eingeschätzt. Im Gegenzug werden jedoch die Flexibilität und Selbsthilfefähigkeit der Landwirte in Krisensituationen besonders hervorgehoben.

Die Auswahl sowie Anzahl der interviewten Experten limitieren die Aussagekraft dieser Studie. Ziel der Arbeit ist es, einen ersten, möglichst breiten Überblick über die Strukturen der nationalen Nutztierhaltung in Bezug zu den Herausforderungen bei Energieknappheit zu geben. Die anhand der Experteninterviews gewonnenen Ergebnisse können jedoch nicht als repräsentativ für die Grundgesamtheit angesehen werden, (MEUSER und NAGEL, 2009). Gleichzeitig war jedoch bereits nach elf Interviews ein Sättigungspunkt erreicht, so dass davon auszugehen ist, dass eine Erhöhung der Anzahl der Experteninterviews keine zusätzlichen Erkenntnisse gebracht hätte (GUEST et al., 2006). Eine weitere Limitation stellt die Auswahl der Experten dar. Trotz des breiten Spektrums an Experten aus weiten Teilen des Bundesgebietes mit Fokus auf die bedeutenden Tierhaltungsregionen kann nicht ausgeschlossen werden, dass Informationen und Inhalte, die für die Untersuchung relevant gewesen wären, nicht aufgedeckt wurden.

6 Schlussfolgerungen und Ausblick

Im Rahmen dieser Arbeit wurde eine explorative Expertenbefragung zu den Auswirkungen eines Blackouts auf die nationale Nutztierhaltung durchgeführt. Nutztierhaltende Betriebe sind aufgrund ihrer Fürsorgepflicht gegenüber den Tieren besonders von einem Blackout betroffen. Gleichzeitig leistet die Nutztierhaltung einen wichtigen Beitrag zur Sicherstellung einer ausreichenden Nahrungsmittelproduktion in Deutschland. Zukünftig gilt es zu untersuchen, welche Auswirkungen ein Ausfall der Nutztierhaltung auf die Ernährungssicherheit hätte.

Es konnte gezeigt werden, dass sich die Herausforderungen zwischen den Haltungsformen Rind, Schwein und Geflügel aufgrund der notwendigen Frischluftversorgung und der Ausstattung der Betriebe mit Futtermitteln stark unterscheiden. Aber auch innerhalb der Haltungsverfahren selbst ergeben sich je nach individueller Betriebsstruktur heterogene Herausforderungen und Lösungskompetenzen. Um die gewonnenen Erkenntnisse weiter zu festigen und auszubauen, wäre eine quantitative Datenerhebung auf Betriebsebene sinnvoll. Informationen über die Verbreitung von Notstromaggregaten und die regelmäßige Bevorratung von Futtermitteln könnten dazu beitragen, den Status quo der Vorbereitung und die Resilienzzeiträume in der Nutztierhaltung besser beurteilen zu können. Die gewonnenen Erkenntnisse können auch auf andere Krisenszenarien wie z.B. einen Reaktorunfall oder langanhaltende Hitze-, Dürre- und Kälteperioden übertragen werden.

Für die Zukunft bleibt zu klären, ob präventive Maßnahmen auf den Betrieben Teil des einzelbetrieblichen Risikomanagements sind oder ob staatliches und politisches Handeln erforderlich ist. Dabei sind die geringe Eintrittswahrscheinlichkeit eines Blackouts sowie resilienzsteigernde Maßnahmen auf anderen Ebenen, wie z.B. bei den Stromerzeugern und Netzbetreibern, zu berücksichtigen. Gleichzeitig ist es sinnvoll, die Wahrnehmung der Landwirte sowie der verantwortlichen Behörden für die Auswirkungen eines solchen Stromausfalls sowie für resilienzsteigernde Maßnahmen zu schärfen, um zukünftig negative Auswirkungen eines Blackouts auf die Nutztierhaltung und den KRITIS-Sektor Ernährung zu minimieren.

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ERZEUGERGEMEINSCHAFTEN IN DER WEINBRANCHE IM SPANNUNGSFELD DER TEILABLIEFERUNG

Hannah Katharina Thissen, Frederik Nikolai Schulz¹, Jon H. Hanf

Zusammenfassung

Die Teilablieferung stellt ein vielfach diskutiertes Konzept des Trauben-Sourcings in Kooperationen der Weinbranche dar. Bislang wurde es ausschließlich im Bereich der Winzergenossenschaften betrachtet. Aus diesem Grund legt dieser Beitrag den Fokus auf die Teilablieferung in Erzeugergemeinschaften (EZG). Ziel ist es, die Motivationen und Beweggründe von teilabliefernden Mitgliedern vor dem Hintergrund organisationaler Problemstellungen wie opportunistischem Verhalten zu analysieren. Hierfür wurde ein qualitativer Forschungsansatz in Form einer Gruppendiskussion mit Mitgliedern einer deutschen Erzeugergemeinschaft gewählt. Die Ergebnisse deuten darauf hin, dass Maßnahmen zur Qualitätssicherung und das gegenseitige Vertrauen zwischen Traubenproduzenten und EZG dazu beitragen, die negativen Auswirkungen von Qualitätsunsicherheit zu mildern. Darüber hinaus zeigt die Gruppendiskussion auf, welche Rolle soziale Dynamiken zur Reduzierung von opportunistischem Verhalten einnehmen. Letztlich legen die Ergebnisse nahe, dass sich die Einstellung zur Teilablieferung sowie deren Auswirkungen im Setting der Erzeugergemeinschaft gegenüber der traditionellen Genossenschaft unterscheiden könnten.

Keywords

Erzeugergemeinschaften, Teilablieferung, Kooperationen, Weinbranche, Opportunismus

1 Einleitung

In der Weinwirtschaft stehen Kooperationen wie Genossenschaften und Erzeugergemeinschaften vor einer Vielzahl von Herausforderungen. Der starke Wettbewerb auf dem Weinmarkt führt seit Jahrzehnten zu einem zunehmenden Rückgang der bewirtschafteten Rebflächen und der Mitgliederzahlen. Zusammen mit den organisatorischen Problemstellungen im Kontext von Kooperationen verdeutlichen diese Entwicklungen die Relevanz von innovativen Strategien und einer stetigen Anpassung an immer komplexere Marktbedingungen. Die Praxis der Teilablieferung von Trauben stellt in diesem Kontext ein besonders diskutiertes Thema dar, das nicht nur in der wissenschaftlichen Literatur auf Interesse stößt, sondern auch von einigen Kooperationen selbst kritisch diskutiert wird (BONROY et al., 2019; FARES und OROZCO, 2014; HANF et al., 2019). Teilablieferung beschreibt dabei die offizielle und inoffizielle Möglichkeit für Mitglieder einer Kooperation, lediglich einen Teil ihrer produzierten Trauben an den gemeinschaftlichen Geschäftsbetrieb anzuliefern und den Rest individuell zu vermarkten. Vielfach wird in diesem Zusammenhang etwa kritisch auf die Möglichkeit hingewiesen, dass Mitglieder hochwertiges Traubenmaterial selbstständig vermarkten, während minderwertige Qualitäten an die Kooperation geliefert werden.

Das Spannungsfeld der Teilablieferung wurde dabei bislang insbesondere im Kontext von Winzergenossenschaften diskutiert (HANF et al., 2019; BITSCH und HANF, 2023; SCHILLING et al., 2019). Kooperationen im deutschen Agrarsektor beschränken sich jedoch nicht nur auf die Rechtsform der eingetragenen Genossenschaft (eG). So haben sich in der Weinbranche bereits

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vor Jahrzehnten auch Kooperationen in Form von Erzeugergemeinschaften (EZG) gebildet, welche sich nicht nur in ihrer Rechtsgrundlage von Genossenschaften unterscheiden.

Dieser Beitrag konzentriert sich daher auf die Analyse der Problemstellungen, die mit der Teilablieferung innerhalb von Erzeugergemeinschaften einhergehen. Hierfür sollen insbesondere die Beweggründe von Traubenproduzierenden, die an einer Teilablieferung in Erzeugergemeinschaft beteiligt sind, genauer untersucht werden. Es wurde ein qualitativer Forschungsansatz unter Einbezug einer Gruppendiskussion in einer deutschen Wein-Erzeugergemeinschaft im Anbaugebiet Rheinhessen gewählt.

Kapitel 2 widmet sich den Prinzipien, den rechtlichen Rahmenbedingungen sowie der heutigen Bedeutung von Erzeugergemeinschaften in der Weinbranche. In Kapitel 3 wird anschließend das Konzept der Teilablieferung vorgestellt sowie anhand der grundlegenden Problemstellungen vier Herleitungen formuliert. Kapitel 4 stellt die Methodik der Gruppendiskussion, deren Durchführung sowie Auswertung vor. Die zuvor formulierten Herleitungen werden auf Grundlage der Ergebnisse der Gruppendiskussion in Kapitel 5 analysiert. Der Beitrag schließt mit einer Diskussion und einem Fazit.

2 Erzeugergemeinschaften in der deutschen Weinbranche

2.1 Rechtlicher Rahmen und heutige Bedeutung von Erzeugergemeinschaften

Mit Inkrafttreten des Marktstrukturgesetzes, dem ersten Gesetz „zur Anpassung der landwirtschaftlichen Erzeugung an die Erfordernisse des Marktes“, hat die unternehmerische Kooperation in der deutschen Agrarwirtschaft im Jahr 1969 eine Ausdifferenzierung erfahren. Insbesondere in der Forst- und Weinwirtschaft wurden seither vielfach Erzeugergemeinschaften unter der Rechtsform des wirtschaftlichen Vereins (w. V.) gegründet (WESCHE und WOLFF, 2020). Durch das Ziel, die Landwirtschaft durch die Bildung von Erzeugergemeinschaften zu stärken, wurde ein übergeordneter Rechtsrahmen entwickelt, der 2013 in das Agrarmarktstrukturgesetz (AgrarMSG) sowie 2021 in das Agrarorganisationen-und-Lieferketten-Gesetz (AgrarOLkG) überführt wurde. Seit 2013 agieren Erzeugergemeinschaften auf juristischer Ebene als *Erzeugerorganisationen*². Dieser Rechtsrahmen ist grundlegend für jegliche Form der unternehmerischen Kooperation in der deutschen Agrarwirtschaft und damit auch für die Genossenschaft: Nach § 3 Absatz 1 der Agrarorganisationen-und-Lieferkettenverordnung (AgrarOLkV) wird eine Erzeugerorganisation dann anerkannt, wenn es sich um eine „juristische Person des Privatrechts oder des öffentlichen Rechts oder eine Personenvereinigung des Privatrechts“ handelt. Der Blick auf die Rechtsformen der deutschen Agrarbranche offenbart, dass der wirtschaftliche Verein (w. V.) bei jenen Unternehmen dominiert, die unter dem Namen „Erzeugergemeinschaft“ agieren (WEMBER et al., 2021). Dies gilt auch für die deutsche Weinbranche. Im Gegensatz zum Idealverein verfolgt dieser keine ideellen Ziele. Sein Satzungszweck richtet sich auf einen *wirtschaftlichen* Geschäftsbetrieb (WESCHE und WOLFF, 2020). Seine Rechtsfähigkeit erhält der wirtschaftliche Verein nach § 22 BGB durch staatliche Verleihung.

2.2 Prinzipien der Kooperationsform Erzeugergemeinschaft

Das ursprüngliche Marktstrukturgesetz (§ 1 Absatz 1 MStrG) aus dem Jahr 1969 beschreibt den Zweck einer Erzeugergemeinschaft wie folgt:

Erzeugergemeinschaften im Sinne dieses Gesetzes sind Zusammenschlüsse von Inhabern landwirtschaftlicher oder fischwirtschaftlicher Betriebe, die gemeinsam den Zweck verfolgen, die Erzeugung und den Absatz den Erfordernissen des Marktes anzupassen.

² Bestehende Erzeugergemeinschaften mussten ihren Namen nicht ändern.

Die Förderung der Mitgliedsbetriebe durch Selbsthilfe, wie sie etwa im Genossenschaftsgesetz normiert ist, ist dem wirtschaftlichen Verein und damit den Erzeugergemeinschaften fremd. Ihre Zweck- und Zielsetzung legen sie eindeutig auf Grundlage des ursprünglichen Agrarmarktstrukturgesetzes aus. Diese lautet wie folgt (§ 8 AgrarOLkV):

1. Sicherstellung einer planvollen und insbesondere in quantitativer und qualitativer Hinsicht nachfragegerechten Erzeugung,
2. Bündelung des Angebots und Vermarktung der Erzeugung ihrer Mitglieder,
3. Verringerung der Produktionskosten und Stabilisierung der Erzeugerpreise.

Mit diesem deutlichen Fokus auf eine *Marktorientierung* unterscheiden sich Erzeugergemeinschaften von anderen Kooperationsformen wie etwa eingetragenen Genossenschaften, deren Zweck sich nach den in § 1 Absatz 1 des Genossenschaftsgesetzes festgelegten genossenschaftlichen Wesens-, Organisations- und Verhaltensprinzipien (RINGLE, 2007) richtet und damit insbesondere nach der *Förderwirtschaftlichkeit*.

2.3 Entwicklungen im Bereich der Erzeugergemeinschaften

Der Blick auf alle Erzeugnisbereiche der deutschen Agrarbranche offenbart, dass der wirtschaftliche Verein noch vor der eingetragenen Genossenschaft die wichtigste Rechtsform darstellt. In den Bereichen Obst-, Gemüse- und Weinbau sind Erzeugergemeinschaften heute hinter Genossenschaften die zweitwichtigste Kooperationsform (WEMBER et al., 2021). Zu den strukturellen Entwicklungen von Erzeugergemeinschaften in der Weinbranche liegen nur wenige Daten vor. Exemplarisch soll an dieser Stelle das Bundesland Baden-Württemberg hervorgehoben werden, in dem Weinbau-Kooperationen traditionell einen hohen Stellenwert besitzen. Dort sank die Zahl der Erzeugergemeinschaften von 55 im Jahr 2010 auf 45 im Jahr 2019 (LANDTAG VON BADEN-WÜRTTEMBERG, 2020). Rückläufig war in diesem Zeitraum auch die Zahl der Mitgliedsbetriebe, während die bewirtschaftete Rebfläche leicht ausgedehnt werden konnte. Die Zahl der baden-württembergischen Winzergenossenschaften hat sich im Zeitraum von 2010 bis 2019 von 95 auf 66 reduziert (LANDTAG VON BADEN-WÜRTTEMBERG, 2020). Der große regionale Unterschied im Bereich der Weinbaukooperationen wird in der vergleichenden Betrachtung des größten deutschen Weinanbaugebiets Rheinhessen deutlich: Dort existierten im Jahr 2009 insgesamt neun Winzergenossenschaften und zwei Erzeugergemeinschaften (GUTHIER, 2022).

Insgesamt bleibt festzuhalten, dass der Strukturwandel Erzeugergemeinschaften in der deutschen Weinwirtschaft ebenso wie die Genossenschaft als deutlich relevantere Kooperationsform betrifft – die Zahl der Betriebe sinkt, es kommt zu Betriebsfusionen und zu einem Rückgang der Mitgliedschaften. Da sich die Wettbewerbsintensität auf dem deutschen Weinmarkt auf einem konstant hohen Niveau befindet, ist nicht absehbar, dass sich an diesen Entwicklungen in naher Zukunft etwas ändern wird. Dieser Umstand verstärkt die Bedeutung von neuartigen Konzepten zur Steigerung der Wertschöpfung wie der Teilablieferung.

3 Teilablieferung als strategisches Spannungsfeld in der kooperativen Weinproduktion

3.1 Das Konzept der Teilablieferung

Teilabliefernde Betriebe in Weinbaukooperationen wählen aus strategischen Gründen die Teilablieferung ihrer Traubenernte, anstatt die gesamte Ernte abzugeben. Mögliche Vorteile dieser Praktik bestehen darin, dass sie den Mitgliedsbetrieben ermöglicht, ihre betriebliche Wertschöpfung zu erhöhen. Zudem kann die Teilablieferung einen Beitrag zum Entgegenwirken des Rückgangs der Rebflächen und der Mitgliederzahlen leisten (BITSCH und HANF, 2023). Während Vollablieferer ihre gesamte Traubenernte der Kooperation zur Verfügung stellen, was

diese zur Hauptfinanzquelle macht (HANF et al., 2019), beschränken Teilablieferer ihre Lieferungen auf Ernten ausgewählter Parzellen. Die stetige Verbesserung der genauen Erfassung dieser Flächen unterstützt die Rückverfolgbarkeit der Trauben, obwohl technische und kostenbezogene Grenzen dies erschweren können.

Kritische Stimmen aus Verbands- und Kooperationsleitungen zu Teilablieferungen existieren, obwohl das Genossenschaftsgesetz diese Praxis grundsätzlich nicht rechtlich einschränkt und sie in einigen Winzergenossenschaften erfolgreich praktiziert wird (SCHILLING et al., 2019). Für Erzeugergemeinschaften sieht die AgrarOLkV grundsätzlich eine Andienungspflicht von 90 Prozent vor (§ 10 Absatz 2). Diese kann jedoch durch eine Zwei-Drittel-Mehrheit in der Hauptversammlung aufgehoben werden.

Hauptbedenken im Bereich der Teilablieferung sind die mögliche Nutzung der Kooperation als Abnehmer für qualitativ schlechtere Trauben durch Teilablieferer, was die Weinqualität potenziell beeinträchtigen könnte (AIASSA et al., 2018; HÄRLE und HANF, 2015). Trotzdem bieten Teilablieferungen Flexibilität und eine Risikostreuung für die Traubenproduzenten, die sowohl von Auszahlungen der Kooperation als auch von alternativen Vermarktungswegen profitieren. Zudem eröffnen sie Sicherheiten wie garantierte Abnahmen bestimmter Traubenmengen und -sorten sowie die Möglichkeit zur Expansion ohne erhebliche Eigeninvestitionen (BITSCH und HANF, 2023). Allerdings kann die Praxis – je nach Qualitätskontrolle und Mitgliederanzahl – zu Überproduktion und Qualitätsverlusten führen, obgleich erfolgreiche Implementierungen von Teilablieferungsverfahren in einigen deutschen Winzergenossenschaften beobachtet wurden.

3.2 Spannungsfelder im Bereich Teilablieferung

3.2.1 Interessenkonflikte

Winzerkooperationen, einschließlich Erzeugergemeinschaften und anderen kooperativen Modellen, stehen vor der Herausforderung, Produktion, Qualität und opportunistisches Verhalten zu managen (HÄRLE und HANF, 2015). Die Mitglieder, die zugleich Eigentümer und Lieferanten sind, erzeugen eine komplexe Dynamik, die das Management erschwert. Es entstehen oft divergierende Ziele zwischen den Traubenproduzenten und der Kooperation selbst: Während Traubenproduzenten ihre Kosten minimieren und gleichzeitig ihre Erträge maximieren wollen, strebt die Kooperation danach, den Wein zu möglichst hohen Preisen zu verkaufen, was direkt mit der Traubenqualität verknüpft ist. Diese unterschiedlichen Prioritäten – Kostenminimierung aufseiten der Traubenproduzenten und das Streben nach hoher Qualität durch die Kooperation – führen zu einem grundlegenden Konflikt. Traubenproduzenten profitieren am meisten von niedrigen Produktionskosten und hohen Auszahlungen, während die Kooperation eine hohe Traubenqualität benötigt, um den Wein zu höheren Preisen vermarkten zu können, was wiederum höhere Produktionskosten für die Traubenproduzenten bedeutet. Dieser Konflikt zwischen dem individuellen und dem kollektiven Interesse stellt eine zentrale Herausforderung für die Organisation und Zusammenarbeit innerhalb dieser Kooperationsstrukturen dar (HANF et al., 2019). Des Weiteren erschweren Kontrollprobleme und die Diversifizierung der Aktivitäten und Angebote die Etablierung eines ausgewogenen und profitablen Portfolios, das den Bedürfnissen der Mitglieder gerecht wird und wirtschaftlich tragfähig ist.

Herleitung 1.1: Teilablieferer verfolgen eine Strategie der ökonomischen Gewinnmaximierung, indem sie die Flexibilität nutzen, um Teile ihrer Ernte auf dem freien Markt zu höheren Preisen zu verkaufen.

Herleitung 1.2: Unterschiedliche Interessen und Strategien von Teil- und Vollablieferern führen zu inhärenten Konflikten innerhalb der Erzeugergemeinschaft, die das Potenzial haben, die kollektive Stabilität und den Erfolg der Kooperation zu beeinträchtigen.

3.2.2 Qualitätsunsicherheiten

Opportunismus in Weinbaukooperationen äußert sich darin, dass Mitglieder ihre Informationsvorteile ausnutzen, indem sie qualitativ minderwertige Trauben liefern, um persönliche Vorteile zu erlangen. Dieses Problem wird durch die eingeschränkte Fähigkeit der Kooperationen, die Produktqualität effektiv zu kontrollieren, verschärft, was ein hohes Maß an Vertrauen in die Integrität der angelieferten Produkte erfordert und zu adverser Selektion führt. Hochwertige Trauben werden oft auf dem freien Markt verkauft, wodurch die Qualität der an die Kooperation gelieferten Trauben sinkt und Unsicherheit über die Produktqualität entsteht (FARES und OROZCO, 2014; FURUBOTN und RICHTER, 2010; WILLIAMSON und STREISSLER, 1990). Um Opportunismus und Qualitätsunsicherheiten entgegenzuwirken, setzen Kooperationen auf strengere Qualitätskontrollen und transparente Bewertungssysteme. Diese Maßnahmen zielen darauf ab, faire Anreize für die Lieferung hochwertiger Trauben zu schaffen und somit das moralische Risiko sowie adverse Selektion zu verringern (FARES und OROZCO, 2014; BONROY et al., 2019). Die begrenzte Überwachungsfähigkeit und das Informationsgefälle zwischen Kooperation und Mitgliedern erschweren jedoch die Durchsetzung effektiver Qualitätskontrollen und erfordern ein verstärktes Vertrauen in die angelieferten Produkte. Innerhalb von Weinbaukooperationen, die ihre Mitglieder als sowohl Produzenten als auch Eigentümer umfassen, entsteht eine komplexe Dynamik, die zu moralischem Risiko führen kann. Diese Problematik wird durch die eingeschränkten Möglichkeiten der Kooperationen, die Produktionsqualität ihrer Mitglieder effektiv zu überwachen, weiter verschärft. Solch eine begrenzte Kontrollfähigkeit bietet einen fruchtbaren Boden für opportunistisches Verhalten, bei dem Mitglieder möglicherweise versucht sind, ihre Informationsvorteile auszunutzen, indem sie minderwertige Trauben liefern, um persönliche Vorteile zu erlangen. Dieses Phänomen wird durch die Annahme unterstrichen, dass Akteure zur Informationsverzerrung neigen, um ihre eigenen Interessen zu schützen (FARES und OROZCO, 2014; FURUBOTN und RICHTER, 2010; WILLIAMSON und STREISSLER, 1990).

Herleitung 2: Teilabliefernde Traubenproduzenten neigen eher zu opportunistischem Verhalten, indem sie qualitativ minderwertige Trauben an die Erzeugergemeinschaft liefern, um ihre hochwertigeren Trauben auf dem freien Markt zu verkaufen.

3.2.3 Strategien zur Qualitätssicherung

Um den Herausforderungen von Opportunismus und Qualitätsunsicherheit entgegenzuwirken, entwickeln Weinbaukooperationen gezielte Strategien, die auf der Implementierung von strengeren Qualitätskontrollen und transparenteren Bewertungssystemen basieren. Diese Maßnahmen sollen eine faire Entlohnung für hochwertige Traubenlieferungen sicherstellen und dadurch Anreize für die Produktion qualitativ hochwertiger Trauben setzen. Zusätzlich können Anreizsysteme, die Qualität über Quantität stellen, dazu beitragen, das moralische Risiko und die adverse Selektion zu verringern. Die Effektivität solcher Strategien hängt jedoch stark von der Fähigkeit der Kooperation ab, eine Balance zwischen den vielfältigen Interessen ihrer Mitglieder und den qualitativen Anforderungen des Marktes zu finden (FARES und OROZCO, 2014; BONROY et al., 2019).

Herleitung 3: Effektive Qualitätskontrollen und transparente Bewertungssysteme innerhalb der Erzeugergemeinschaften sind zentral, um die negativen Auswirkungen von Opportunismus und Qualitätsunsicherheit zu verringern.

3.2.4 Kooperativen als Gemeinschaft

SCHILLING et al. (2019) zeigen, dass in Winzergenossenschaften eine starke Verbundenheit und Identifikation mit der Organisation, insbesondere wenn diese als leistungsfähig wahrgenommen wird, zur Förderung von Gemeinschaftssinn beiträgt. Mitglieder, die die Genossenschaft als

Erweiterung ihres eigenen Betriebs sehen, empfinden ihre individuellen Ziele als repräsentiert, was die Bindung stärkt. Kleinere Genossenschaften weisen oft eine engere Mitgliederbindung auf, wobei die Zufriedenheit mit Auszahlungspreisen und Dienstleistungen entscheidend für die Stärkung dieser Bindung ist. Diese Identifikation fördert eine Kultur der Zusammenarbeit und des gegenseitigen Vertrauens, was für die Stabilität und den Erfolg der Kooperation essenziell ist (BITSCH et al., 2020). Diese Untersuchung bezog sich nur auf Genossenschaften. Es stellt sich die Frage, ob dies auch auf Erzeugergemeinschaften übertragbar ist, deren Ziele sich wie in Kapitel 2 dargestellt deutlich stärker an marktlichen Bedingungen orientieren.

Herleitung 4: Trotz der individuellen wirtschaftlichen Interessen fördern soziale Dynamiken und ein starker Gemeinschaftssinn innerhalb der Erzeugergemeinschaft eine Kultur der Zusammenarbeit und des gegenseitigen Vertrauens.

4 Methodik

4.1 Gruppendiskussion

Als Erhebungsmethode wurde ein explorativer Ansatz in Form einer ermittelnden Gruppendiskussion gewählt, da die Teilablieferung noch ein vergleichsweise neues Konzept in der Weinbranche darstellt, das bislang im Kontext der Erzeugergemeinschaft unberührt geblieben ist. Die ermittelnde Gruppendiskussion ermöglicht es dabei, Daten durch die Interaktionen der Gruppenmitglieder zu gewinnen, wobei die Thematik durch das Interesse der forschenden Person bestimmt wird (LAMNEK, 2005). Ziel ist es, Informationen über die Meinungen und Einstellungen einer Gruppe zu einem bestimmten Thema zu erhalten, die Herausbildung einer Gruppenmeinung anzuregen oder kollektive Orientierungsmuster und konjunktive Erfahrungen zu rekonstruieren (HEINZEL, 2012). Die Forschenden bestimmen dafür das Setting und bilden einen Rahmen für die Inhalte des Gesprächs. Die Diskussion wird durch die Forschenden meist mit einer offen gestellten Eingangsfrage eröffnet. Während der Gruppendiskussion sollte die Gruppe im Gespräch dann innerhalb ihres eigenen Relevanzsystems eine gemeinsame kulturelle und kommunikative Praxis aufarbeiten, um einen möglichst reibungslosen Redefluss herzustellen (BOHNSACK, 2010). Die Organisation des Diskurses sowie die Themengliederung geschehen also größtenteils durch die Gruppe selbst.

4.2 Stichprobe

Die Stichprobe umfasst eine Gruppe von Traubenproduzenten (n=10, männlich) einer Erzeugergemeinschaft (EZG) in Rheinhessen, von denen vier Teilablieferer und sechs Vollablieferer sind. Die gewählte Erzeugergemeinschaft (w.V.) hat 203 Mitglieder, die zusammen eine Rebfläche von etwa 2500 Hektar bewirtschaften. Die Mitgliederstruktur ist heterogen, wobei die Rebflächen der einzelnen Mitglieder zwischen knapp einem Hektar und 180 Hektar variieren.

Um eine möglichst hohe Heterogenität in Bezug auf Alter und Betriebsgröße zu erzielen, die die Vielfalt innerhalb der EZG widerspiegelt, wurde die Auswahl der Mitglieder mit der Geschäftsführung der Erzeugergemeinschaft abgestimmt. Teilablieferung nimmt innerhalb der Erzeugergemeinschaft eine untergeordnete Rolle ein, jedoch wurden bei der Auswahl der Mitglieder bewusst überproportional viele teilabliefernde Betriebe angesprochen, um ein möglichst ausgewogenes Meinungsbild zu den Ablieferungsformen zu erzielen.

Hauptsächlich werden die Produkte an große Kellereien an Rhein und Mosel geliefert, wobei vor allem Fasswein vertrieben wird. Jährlich werden durchschnittlich zwischen 45 und 50 Millionen Liter Fasswein verkauft. Die Erzeugergemeinschaft orientiert sich mit diesem Schwerpunkt auf ein Marktsegment, das durch ein hohes Absatzvolumen charakterisiert ist. In diesem Kontext wird Wein hauptsächlich für den breiten Markt produziert. Die Produktionsmethoden und Qualitätskontrollen sind auf die Anforderungen dieses Marktes abgestimmt, anstatt auf die speziellen Bedürfnisse des Premiumsegments einzugehen. Diese Orientierung am Markt ist in

Weinbaukooperationen wie Erzeugergemeinschaften und Genossenschaften oft vorzufinden (DILGER, 2009; PENNERSTORFER und WEISS, 2013). Während der Erntezeit können täglich bis zu 1 Mio. kg Trauben angenommen werden. Die Mitglieder können Trauben, Most und Wein liefern, wobei in den meisten Fällen der Auszahlungspreis durch die Masse der angelieferten Menge und das Mostgewicht bestimmt wird. Die Mitglieder der Erzeugergemeinschaft haben zudem Zugang zu einem Berater für Arbeiten im Weinberg. Zur Qualitätskontrolle werden die Trauben bei der Annahme begutachtet, aber selten zurückgewiesen. Angelieferter Wein wird im hauseigenen Labor untersucht.

4.3 Durchführung der Gruppendiskussion

Die Gruppendiskussion fand am 16. Januar 2024 in den Räumlichkeiten der Erzeugergemeinschaft statt. Die Teilnehmer wurden im Vorfeld grob über den Ablauf der Gruppendiskussion informiert und wussten, dass sich die Diskussion auf Teil- und Vollablieferung beziehen würde. Der Inhalt sowie die konkrete Forschungsfrage waren ihnen jedoch nicht bekannt, um eine ehrliche und unvoreingenommene Diskussion mit spontanen Antworten zu ermöglichen, aus der die Meinungen der Traubenproduzenten heraus interpretiert werden konnten. Zur besseren Auswertung wurden die Diskussion per Audioaufnahme aufgenommen, wozu zuvor die Einverständniserklärung von den Traubenproduzenten eingeholt wurde. Die Gruppendiskussion umfasste eine Stunde und 15 Minuten. Für die Datenerhebung zur Beantwortung der Forschungsfrage wurde vorab ein Leitfaden entwickelt, der als strukturelle Basis für die Durchführung der Gruppendiskussion diente. Nach einer einleitenden Warm-up-Phase, in der sich die Diskussionsleitung vorstellte und allgemeine Fragen zur letzten Lese stellte, um eine Vertrauensbasis mit den Teilnehmern aufzubauen, leitete eine offen formulierte Frage in die Hauptdiskussion über.

4.4 Datenauswertung

Die Datenauswertung basierte auf der dokumentarischen Methode, entwickelt in den 1980er Jahren von Mangold und Bohnsack als ein Ansatz der qualitativen Sozialforschung. Diese Methode erweist sich als besonders geeignet für die Analyse von Gruppendiskussionen und zielt darauf ab, geteilte Orientierungen durch die Analyse von implizitem Wissen zu erfassen, das den Befragten nicht direkt bewusst ist (BOHNSACK et al., 2001). So wird angegeben, ob es sich in der Diskursorganisation um *inkludierende* oder *exkludierende* Modi handelt. Die inkludierenden Modi basieren laut PRZYBORSKI (2004) auf einer gemeinsamen Rahmenorientierung der Gruppe. Sie führen zu einer Konklusion des Themas und bringen die gemeinsame Orientierung der Gruppe zum Ausdruck. Ist sich die Gruppe dabei offensichtlich einig, so spricht man von einer *parallelen* oder *konsensualen* Diskursorganisation. Teilt die Gruppe zwar die gleiche Rahmenorientierung, es werden aber dennoch unterschiedliche Meinungen geäußert und es kommt teilweise auch zu Streit, so handelt es sich um einen *antithetischen* Diskurs (PRZYBORSKI, 2004). Bei den exkludierenden Modi der Diskursorganisation werden die Rahmenorientierungen der Gruppenmitglieder nicht geteilt, da diese offen eine unterschiedliche Position vertreten, sodass Themen oftmals durch Themenwechsel oder Abbruch der Diskussion beendet werden. Unterschieden wird hier nochmals zwischen *divergenten* und *oppositionellen* Diskursorganisationen. Im Vergleich zur oppositionellen Diskursorganisation kommt es bei der divergenten scheinbar zu einer Einigung. Die Gruppe stellt jedoch nur oberflächlich eine Einigkeit her und lässt es nicht zum offenen Streit kommen. Dahinter verbirgt sich jedoch eine Rahmeninkongruenz bezüglich der impliziten Orientierungen.

5 Ergebnisse

5.1 Interessenkonflikte im Bereich Teilablieferung

Herleitung 1.1: Teilablieferer verfolgen eine Strategie der ökonomischen Gewinnmaximierung, indem sie die Flexibilität nutzen, um Teile ihrer Ernte auf dem freien Markt zu höheren Preisen zu verkaufen.

Aufseiten der befragten Teilablieferer wurde die Entscheidung gegen eine Vollablieferung in erster Linie durch eine höhere Wertschöpfung im Rahmen der Teilablieferung begründet. Ein zentrales Argument ist dabei, dass der Grundpreis, der von der Erzeugergemeinschaft für Trauben gezahlt wird, oft unter dem liegt, was sie für Flaschenwein abzüglich aller zusätzlichen Kosten erzielen können. Fraglich bleibt, inwiefern die eingesetzte Arbeitszeit berücksichtigt wird. Generell setzt die Realisierung höherer Verkaufspreise außerhalb der Kooperation erweitertes Know-how, hohe Traubenqualitäten, eine Differenzierungsstrategie sowie ausreichend Zeit und Kapital voraus. Die befragten Vollablieferer merkten hingegen an, dass auch sie durch die Teilnahme an speziellen Qualitätsprojekten Premiumpreise erzielen können. Beispielhaft für die Vorzüge der Teilablieferung steht die Aussage eines Traubenproduzenten, wonach die von ihm angebaute Rebsorte Sauvignon Blanc in der Vergangenheit nicht an die EZG abgeliefert wurde, weil sie dort als „divers“ klassifiziert wurde. Aufgrund dessen lag der Auszahlungspreis unter jenem für populäre Weißweinsorten wie Müller-Thurgau, obwohl auf dem Markt für rheinhessische Trauben eine signifikante Nachfrage nach Sauvignon Blanc bestand. Mit geringem Mehraufwand konnte der Traubenproduzent somit außerhalb der Kooperation einen erheblichen Premiumpreis für seine Trauben erzielen.

Als weitere Motive für die Nutzung der Teilablieferung abseits der Mitgliedschaft wurden die nötigen monetären Leistungen in Form der Anteilszeichnung beim Eintritt in die EZG genannt wie auch die Tatsache, dass Weinbau nur im Nebenerwerb betrieben wird. In Bezug auf die Präferenz, selbst als Teilablieferer zu agieren, ließen sich exkludierende Modi der Diskursorganisation erkennen. Die Gruppe teilte somit keine gemeinsame Rahmenorientierung, sondern die Gruppenmitglieder vertraten offen unterschiedliche Positionen. Da die Teilnehmer die persönlichen Einstellungen ihrer Gegenüber akzeptierten, kann auch eine divergente Diskursorganisation attestiert werden (BOHNSACK und SCHÄFFER, 2007).

Deutlich wurde jedoch ebenso, dass die Entscheidung für die Teilablieferung und gegen die Vollablieferung nicht allein auf monetäre Gründe zurückzuführen ist. So wurde als ein weiterer zentraler Grund der Verlust der Selbstständigkeit im Rahmen der Vollablieferung thematisiert. Beispielhaft hierfür steht folgende Aussage: „Vollablieferer können nicht mehr zurückkehren; es ist ein riesiger Schritt, Vollablieferer zu werden, da man sich damit ein Stück weit abhängig macht.“ Darüber hinaus wurde die Verteilung von Risiko sowie die Absicherung durch eine eigene Produktionsstätte thematisiert. Besonders markant für die Entscheidung für oder gegen die Vollablieferung ist folgende Aussage: „Wenn du Vollablieferer bist, hast du einen Schlussstrich gezogen.“ In diesem Punkt waren sich alle Teilnehmer der Diskussion einig, sodass auch hier wieder eine parallele Diskursorganisation attestiert werden kann.

Zusammenfassend scheinen ökonomische Aspekte die Entscheidung für die Teilablieferung grundlegend zu beeinflussen. Die Ausführungen zum Verlust der Selbstständigkeit zeigen jedoch, dass auch andere Motive von hoher Relevanz sind.

Herleitung 1.2: Unterschiedliche Interessen und Strategien von Teil- und Vollablieferern führen zu inhärenten Konflikten innerhalb der Erzeugergemeinschaft, die das Potenzial haben, die kollektive Stabilität und den Erfolg der Kooperation zu beeinträchtigen.

Die Analyse der Einstellungen gegenüber des gewählten Ablieferungsmodells zeigt ein heterogenes Bild, wobei die individuellen Einstellungen nicht auf ein erhöhtes Konfliktpotenzial hindeuten. Auf Seiten der Vollablieferer wurden einerseits persönliche Motive hervorgehoben,

etwa durch strukturelle Veränderungen im eigenen Weinbaubetrieb in Form von kurzfristigen krankheitsbedingten Betriebsübergaben. Darüber hinaus sahen die vollabliefernden Mitglieder in erster Linie durch die Ablieferung ihres gesamten Traubenmaterials große individuelle Vorteile durch die Verlagerung der gesamten Verarbeitung in die EZG. Betont wurde hierbei etwa der geringere Arbeitseinsatz sowie der Wegfall von administrativem Aufwand, etwa in Form der Weinkontrolle. Ein Vollablieferer thematisierte das Lieferantenkonto, welches für ihn bei der EZG als eine Art zweites Bankkonto fungiert und zur Steuerung der Liquidität des eigenen Betriebes beiträgt. Vorteile werden darüber hinaus in den fortlaufenden Bonuszahlungen sowie in der allgemein pünktlichen Auszahlung zum Jahresende gesehen. Diese Sicherheiten betrachteten die befragten Traubenproduzenten als klaren Vorteil gegenüber Betrieben, welche ihre Trauben nach dem Herbst auf dem freien Markt verkaufen.

Gleichzeitig betonen die teilabliefernden Traubenproduzenten die Wichtigkeit von verfügbaren Alternativen zur EZG. Nach Ansicht der Befragten ist es daher seltener ein einfaches Entscheiden für die EZG als vielmehr ein Abwägen der Vor- und Nachteile sowie der Alternativen wie beispielsweise der Kellerei. Hervorzuheben ist, dass die Entscheidung für die Ablieferung bei der EZG neben den ausschließlich monetären Aspekten auch durch rein praktische Motive beeinflusst wird, wie etwa die schmale Traubenannahme einer nur zwei Kilometer entfernten Kellerei. Thematisiert wurde hierbei, dass es Traubenproduzenten mit großen Anhängern dort kaum möglich ist zu rangieren und die Trauben nur zu einer Seite abgekippt werden können. Dieser Aspekt verdient aus Sicht der Befragten umso mehr Aufmerksamkeit, da sich dadurch die Wartezeit an der Traubenannahme verlängert. Hingewiesen wurde mit Blick auf die immer kürzeren Leseperioden hingegen auf die Notwendigkeit einer hohen Schlagkraft.

Insgesamt verlief der Diskurs in diesem Abschnitt kurz antithetisch. Somit wurden vorerst unterschiedliche Meinungen der Gruppenmitglieder vorgetragen, hinter denen sich dann jedoch letztlich eine gemeinsame Rahmenorientierung der Gruppe verbarg, weshalb dieser antithetische Diskurs auch zu den inkludierenden Modi der Diskursorganisation gezählt wird.

Auf Grundlage der gesammelten Informationen zeigt sich, dass Voll- und Teilablieferer in erster Linie individuellen Motiven nachgehen, welche die andere Gruppe grundsätzlich nicht tangieren. Somit deuten die Ergebnisse nicht darauf hin, dass die mit den beiden Ablieferungsmodellen verbundenen Interessen und Strategien ein erhöhtes Konfliktpotenzial aufweisen.

5.2 Qualitätsunsicherheiten im Bereich Teilablieferung

Herleitung 2: Teilabliefernde Traubenproduzenten neigen eher zu opportunistischem Verhalten, indem sie qualitativ minderwertige Trauben an die Erzeugergemeinschaft liefern, um ihre hochwertigeren Trauben auf dem freien Markt zu verkaufen.

Im Rahmen der Gruppendiskussion wurde auch das in der Mustersatzung für Winzergenossenschaften des Deutschen Raiffeisenverbands normierte Verbot der Teilablieferung thematisiert. Konkret wurden auch die Vollablieferer auf ein solches Szenario in ihrer EZG angesprochen. Bemerkenswert erscheint, dass einige Vollablieferer dieses grundsätzlich ablehnen.

Stattdessen wurde die Rolle der Teilablieferer, die Trauben an andere Weingüter verkaufen, als wichtig für den Pachtmarkt erachtet, da dies die Nachfrage und somit die Pachtpreise beeinflusst. Darüber hinaus betonte ein anderer Vollablieferer, dass die EZG insgesamt von der Premiumqualität der Teilablieferer profitiert, besonders wenn diese fertig ausgebaute Weine liefern. Ein Teilablieferer, der auch Flaschenwein vermarktet, unterstrich, dass er seine Weinberge gleichwertig pflegt, ohne Unterschiede zwischen denen für die EZG und denen für Flaschenweine zu machen, sondern lediglich den Überschuss, den er nicht als Flaschenwein verkaufen kann, an die EZG abgibt.

Bezüglich der Einstellung der Vollablieferer zu den Teilablieferern ließen sich in der Gruppendiskussion zu jeder Zeit inkludierende Modi der Diskursorganisation feststellen. Alle Befragten

beteiligten sich an der Diskussion. Die Gruppe wies somit eine geteilte Rahmenorientierung in Hinblick auf das Thema auf und war sich diesbezüglich einig, weshalb gar von einer parallelen oder konsensualen Diskursorganisation gesprochen werden kann (BOHNSACK und SCHÄFFER, 2007).

Die gesammelten Erkenntnisse lassen schlussendlich nicht darauf schließen, dass die Teilablieferung in der EZG mit einem erhöhten opportunistischen Risiko sowie minderwertigen Traubenqualitäten verbunden ist. Vielmehr deuten die Informationen eher darauf hin, dass sich beide Gruppen – Voll- und Teilablieferer – den Vor- und Nachteilen des jeweiligen Systems bewusst sind und dies respektieren.

5.3 Strategien zur Qualitätssicherung im Bereich Teilablieferung

Herleitung 3: Effektive Qualitätskontrollen und transparente Bewertungssysteme innerhalb der Erzeugergemeinschaften sind wichtig, um die negativen Auswirkungen von Opportunismus und Qualitätsunsicherheit zu verringern.

Dieser Themenbereich wurde nicht ausführlich in der Diskussion besprochen, da in der Erzeugergemeinschaft der Bedarf von Anreizsystemen wie bereits besprochen nicht zu bestehen scheint. Es wird ein einheitlicher Preis ausgezahlt und die Traubenproduzenten schätzen eine Abnahmegarantie seitens der EZG. Zwar gibt es die Möglichkeit, an sogenannten „Projekten“ mitzuwirken, für die ein Premiumpreis bei Anlieferung der Trauben ausgezahlt wird, allerdings dienen diese nicht zur Minimierung von Opportunismus, sondern ermöglichen sowohl Voll- als auch Teilablieferern mehr Handlungsspielraum.

5.4 Kooperationen als Gemeinschaft

Herleitung 4: Trotz der individuellen wirtschaftlichen Interessen fördern soziale Dynamiken und ein starker Gemeinschaftssinn innerhalb der Erzeugergemeinschaft eine Kultur der Zusammenarbeit und des gegenseitigen Vertrauens.

Während der Gruppendiskussion ließ sich ein starker Zusammenhalt unter den teilnehmenden Mitgliedern der Erzeugergemeinschaft feststellen. Deutlich wurde dies durch die hohe allgemeine Zustimmung gegenüber den eingebrachten Thesen sowie mit Blick auf die respektvollen Reaktionen auf abweichende Einstellungen. Vollablieferer unterstützten die strategischen Entscheidungen der Teilablieferer, als solche zu agieren. Die Zufriedenheit der Mitglieder bezüglich der EZG bezog sich nicht nur auf diese als Institution, sondern auch als Zusammenschluss einzelner Akteure. Im Vorfeld der Diskussion verdeutlichte der Austausch zu den Agrardemonstrationen den starken Zusammenhalt unter ihnen. Insgesamt blicken alle Teilnehmer zufrieden auf die Kooperation in der EZG. Keiner erwog einen Wechsel, und es wurde deutlich, dass die EZG den Traubenproduzenten bei der Erreichung ihrer Ziele hilft, sei es durch Zeiterparnis, Nutzenmaximierung sowie den Wegfall von Bürokratie und administrativem Aufwand.

6 Diskussion

Die Ergebnisse verdeutlichen die Heterogenität der Mitglieder und ihre unterschiedlich strukturierten Betriebe. Es zeigte sich ein Abwägen zwischen Voll- und Teilablieferung mit vielfältigen Motiven auf beiden Seiten. Während Teilablieferer die höhere Wertschöpfung durch den Verkauf auf dem freien Markt suchen, schätzen Vollablieferer die einfache Finanzierung, den geringeren bürokratischen Aufwand und die Abnahmesicherheit durch die EZG. Die positive Bewertung der EZG, besonders während der kurzen Leseperiode 2023, unterstreicht deren Stellenwert als Sicherheits- und Stabilitätsgarant in herausfordernden Zeiten. Trotz unterschiedlicher Meinungen deuten die Erkenntnisse der Gruppendiskussion auf einen starken Zusammenhalt unter den Traubenproduzenten hin, was die allgemeine Zufriedenheit mit der EZG bekräftigt. Die Gruppendiskussion erwies sich als interaktiver Prozess, der nicht nur zur Reflexion individueller Meinungen beiträgt, sondern auch ein kollektives Verständnis fördert. Dies bildet

die Grundlage für effektive Zusammenarbeit und Entscheidungsfindung. Zudem zeigte die Diskussion, dass Opportunismus und Qualitätsunsicherheit zwar in den Handlungen der Traubenproduzenten erkennbar sind, jedoch nicht als dominant negative Phänomene bestätigt wurden. Stattdessen reflektieren die Ergebnisse eine Balance zwischen individuellen Entscheidungen und den kollektiven Interessen der EZG. Dies deutet darauf hin, dass Maßnahmen zur Qualitätssicherung und das gegenseitige Vertrauen zwischen Traubenproduzenten und EZG die negativen Auswirkungen von Qualitätsunsicherheit mildern können. Die Diskussion zeigt auf, wie soziale Dynamiken und der Zusammenhalt unter den Traubenproduzenten opportunistisches Verhalten reduzieren und eine Kultur der Qualität und des Vertrauens fördern können. Insgesamt zeigt sich, dass trotz der Vielfalt der Motivationen und Strukturen eine starke Gemeinschaft existiert, die die Attraktivität und den Erfolg kooperativer Vereinigungen in der Weinwirtschaft unterstützt. Schlussendlich erwies sich die Gruppendiskussion als Erhebungsmethode hierbei als geeignet und zielführend. Durch die Zusammensetzung der Gruppe als Realgruppe ähnelte die Situation einer alltäglichen Gesprächsrunde, die eine lockere Gesprächsatmosphäre bewirkte.

Mit einem ersten Blick auf die Kooperationsform der Erzeugergemeinschaft ist somit auch die Grundlage für einen Vergleich mit der Genossenschaft gelegt, die im Rahmen des Konzepts der Teilablieferung bereits deutlich stärker beleuchtet wurde. Die in diesem Beitrag gesammelten Erkenntnisse deuten darauf hin, dass hinsichtlich der Einstellungen zur Teilablieferung Unterschiede zwischen beiden Kooperationsformen bestehen könnten. Wie die in Kapitel 2 dargestellten Prinzipien der Erzeugergemeinschaft zeigen, ist diese Kooperationsform deutlich durch eine Marktorientierung gekennzeichnet, was sich auch auf die Entscheidung für den Eintritt in diese Art der Kooperation auswirkt. Wie aufgezeigt, deuten diese Rahmenbedingungen schlussendlich darauf hin, dass die mit der Teilablieferung verbundenen Problemstellungen abgemildert werden könnten. Diese qualitative Betrachtung wirft ein erstes Schlaglicht auf die Teilablieferung in Erzeugergemeinschaften der Weinbranche, erfährt jedoch Limitationen in der geringen Größe der Stichprobe und durch den Fokus auf ein einzelnes Unternehmen. Für eine höhere Validität und Repräsentativität der Ergebnisse bedarf es künftig breiter angelegter Befragungen.

7 Fazit

Ziel dieser Arbeit war es, die Motivationen und Beweggründe von Traubenproduzenten zu identifizieren, die sich für die Teilablieferung ihrer Trauben an Erzeugergemeinschaften entscheiden. Durch eine Gruppendiskussion mit Traubenproduzenten einer Erzeugergemeinschaft in Rheinhessen wurden vielfältige Gründe und Anreize für Teil- oder Vollablieferungen beleuchtet. Diese Untersuchung ermöglichte wichtige Einblicke in die Kooperationsdynamiken der deutschen Weinwirtschaft. Weiterführende Forschung könnte sich insbesondere mit Blick auf einen Vergleich verschiedener Kooperationsformen im Rahmen des Konzepts der Teilablieferung als fruchtbar erweisen. Limitationen der durchgeführten Analysen bestehen in der begrenzten Auswahl der Befragten, wobei aufgrund des explorativen Charakters der Fokus explizit auf eine der größten und ältesten Erzeugergemeinschaften in Deutschland gelegt wurde.

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HOW SUSTAINABLE IS SUBSIDIZATION AND BUNDLING FOR INDEX INSURANCE? A QUANTITATIVE IMPACT ANALYSIS ALONG A GLOBAL PROGRAM DATABASE

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Abstract

The subsidization of insurance premiums, a usual practice for fast scaling of index-based insurance, is controversial considering the heavy burden on public budgets, potential market distortions and the normative debate over benefit incidence. Recently, loan-bundling or other forms of financial and non-financial service bundling have been suggested as a more sustainable approach to out-scaling. So far, there is no quantitative cross-country analysis comparing the effectiveness of both subsidization and bundling approaches; existing research is limited to qualitative discussions or isolated case-studies.

This study empirically measures the causal impact of premium subsidization and product bundling on the continued success of index insurance schemes worldwide, hence controlling for bias resulting from other project and environmental heterogeneities. We conduct a PSM approach along a self-compiled database of 131 insurance schemes worldwide. Our approach is unique in providing quantitative causal effects across a large number of projects worldwide.

Our results confirm the significant contribution of subsidy schemes to project survival, which increases the likeliness of project survival by 22 percentage points. At the same time, a similar positive effect is found for bundling (23 percentage points), meanwhile not for loan bundling in particular.

Our findings contribute to the discussions on identifying sustainable support mechanisms and development pathways for index insurance markets by demonstrating the high potential of non-loan bundling approaches in sustainably upscaling financial climate risk management.

Keywords

Agricultural Insurance, Basis Risk, Premiums Subsidies, Risk Management

1 Introduction

With approximately 265 million policies sold in 2020, agricultural insurance has become an important tool to manage climate risk (HAZELL et al., 2021). Since a World Bank Survey in 2007 (MAHUL & STUTLEY, 2010), this constitutes a 30% increase in collected premiums. Meanwhile, increases in number of policies and volumes of insurance premiums are largely driven by state-led, subsidized insurance schemes in China and India. Due to staggering market development in high-income countries, global market penetration, as approximated by premiums as a percentage of agricultural GDP, remains unchanged at below 1% (HAZELL et al., 2021)

High hopes were pinned on technical innovations related to index-based insurance, schemes where payments are triggered by an index highly correlating with yield losses. This innovation was to solve challenges pertinent to traditional loss-based insurance, which relies on physical field inspections leading to high transaction costs (considering the high geographic dispersion of insured farmers) and the lack of transparency in loss adjustment and indemnity calculation processes. Index-based insurance was intended to reduce the cost, and increase the speed and transparency of loss adjustment by replacing physical inspection with automatic triggers based

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on ground-based weather data, satellite imagery, or other objective data being highly correlated to actual yields (BARNETT et al., 2008; HAZELL, 1992; SKEES, 2008).

Meanwhile, especially in the early years of index insurance introduction, most of the programs suffered problems of basis risk (JENSEN et al., 2018; MUSSHOF et al., 2011). Basis risk arises when actual harvest default is not identical with estimated values based on which insurance is providing outputs. Area-yield insurance for instance, initially praised for reducing moral hazard (MIRANDA, 1991), relies on official yield statistics in a certain region, which may strongly deviate from individual farm yield. Additionally, its accuracy may be subject to reporting bias or explicit manipulation. Weather indices based on climate station data may suffer from substantial basis risk, especially when the index is based on is located far from the target farm or yield data used for insurance design. One practical challenge is the low density of weather stations in many developing countries, making satellite data a preferable choice (ELTAZAROV ET AL., 2021). At the same time, satellite data can be problematic due to the unavailability of high-resolution pictures for longer periods, increasing the focus on the downscaling of available low-resolution data (ELTAZAROV et al., 2023a). Accurate index design, including the choice of data, critical growth periods, appropriate area aggregation, and other technical details is therefore of utmost importance (BUCHELI et al., 2020; ELTAZAROV et al., 2023b).

While technical challenges related to the index choice might be reduced with advances in remote-sensing technology, index-based insurance proved unable to overcome one persistent problem of all insurance schemes: Despite the cost-reduction in loss adjustment, marked-based insurance premiums are typically still well above farmers' willingness-to-pay (WTP), especially so in LMCs. As discussed by CARTER (2013), one reason for high prices is the unavailability of reliable historical yield data, which leads to so-called uncertainty loadings on the side of insurance companies and expensive premiums. Second, the systemic nature of climate risks and related capital requirements lead to financial loadings (XU et al., 2010). Furthermore, the profit margins of private insurers are added to the fair premiums, decreasing the attractiveness of insurance against other financial or production-side risk management tools. The general agreement is that market-premiums for index insurance are likely to remain expensive (CARTER et al., 2017), hindering swift scaling out beyond main state-led markets like China and India (COLE et al., 2013; GINÉ & YANG, 2009; HILL et al., 2013; TAKAHASHI et al., 2016).

In attempts to make premiums more affordable, many country governments and donors subsidize premiums to a level at or below the WTP of farmers. Subsidies undeniably allow fast out-scaling of a pilot and are assumed to lead to learning effects with the target customers (CAI et al., 2020) as well as direct beneficiaries of the respective schemes (COLE & XIONG, 2017; ELABED & CARTER, 2014; JENSEN & BARRETT, 2017). It has also been suggested that subsidization may be a reasonable approach to make up for the higher basis risk in index insurance schemes (CLEMENT et al., 2018).

Meanwhile, the efficiency of insurance subsidization is debated controversially: For once, artificially low premiums reduce the willingness to pay market rates for future unsubsidized schemes, also called price anchoring (LIESIVAARA & MYRÄ, 2014), as well as providing distortions to farming activities, potentially leading to risky decision-making and unprofitable farming activities (GOODWIN & SMITH, 2013; MAHUL & STUTLEY, 2010). Second, subsidy-driven demand may mask design or implementation flaws of the respective programs, ultimately supporting inefficient and unsustainable programs while crowding out more efficient private initiatives (HAZELL & VARANGIS, 2020). Third, on a more political side, subsidized schemes constitute a considerable transfer of taxes toward farmers and private insurance companies (LUSK, 2017).

This paper focuses on the challenge of the long-term sustainability of subsidization: The financial burden related to the high loss ratio of agricultural insurance (ratio of indemnity payments

vs. collected premiums) turns out to be financially unsustainable for many national governments (MIRANDA & FARRIN, 2012). Even under existing government commitments, economic instabilities can thus lead to a revocation of subsidies, resulting in an immediate drop in coverage. One of many examples is Hungary, where a termination of the relatively moderate premium subsidies led to a collapse of local agricultural insurance markets within a year (BIELZA et al., 2006). While budgetary instabilities may be more likely in Low and Middle-Income countries (LMCs), changing political priorities can affect decision-making also in high-income countries.

Subsidies are not the only tools to increase insurance demand, as argued prominently (MAHUL & STUTLEY, 2010). As advocated for by CARTER et al. (2017), bundling insurance with other financial and non-financial services might make index insurance more attractive and sustainable due to the involvement of other non-governmental actors like banks or vertical companies. This study researches into the effect of subsidization and bundling schemes on long-lasting project success.

Previous quantitative analyses on this question have been based on isolated case studies (MISHRA et al., 2023; RICOME et al., 2017), which do not capture cross-country and -program heterogeneities in product design and project implementation. This study provides the first comprehensive quantitative analysis on the impact of premium subsidization of index-insurance schemes along a unique database of 131 index insurance programs worldwide. Our database provides systematic quantitative and qualitative information on past and ongoing initiatives, which allows extracting quantitative variables on important product parameters, including premiums subsidization, as well as project outcomes.

Our results confirm the significant positive contribution of subsidy schemes to index insurance project survival, despite potential sustainability issues. Meanwhile, bundling approaches, in particular input supply schemes, contract farming, and extension services were found to be even more effective for long-term project success than the effect of subsidization among the studied projects. These findings have implications for future insurance policy design. Primarily, our findings support the notion of putting a higher focus on well-designed product bundling schemes rather than continued support of subsidized schemes with unknown benefit incidence across participants and the insurance industry.

2 Literature review

Within existing literature, the pros and cons of insurance subsidies and the optimal design of subsidies are typically discussed along qualitative case-study approaches. MAHUL AND STUTLEY (2010) establish and review a database of traditional and index-based insurance pilots and recommend targeted premium subsidies, differentiating between commercial agriculture and traditional farming systems. MIRANDA AND FARRIN (2012) analyze selected country cases to derive lessons learned for developing countries, with a focus on loan bundling. HESS AND HAZELL (2016) review various case studies to illustrate non-subsidy policy support for index insurance, advising for additional research to assess their long-term effect on out-scaling. HAZELL AND VARANGIS (2020) study a number of country cases and point out the need for careful subsidy design to achieve cost-effectiveness, reducing adverse incentives and reducing the financial burdens to governments or NGOs. In a series of key informant interviews and case studies, SCOTT et al. (2022) find that ill-designed subsidization schemes in some cases provide insufficient incentives for insurance uptake and point out the need to involve local stakeholders in subsidy design as well as argue for conditional subsidy transfers. MARR et al. (2016) suggest a lack of studies with regard in particular to financial interventions for adoption decisions. Existing empirical literature on the individual level can be categorized into ex-ante and ex-post studies:

First, there are several ex-ante experimental studies, in particular for African countries: RICOME et al. (2017) follow a modeling approach to compare the effect of premiums subsidies with unconditional cash transfer or credit on expected income and production among Senegalese groundnut farmers. CECCHI et al. (2024) conducted a framed field experiment on the effect of loan bundling on insurance take-up in an insurance game, finding that ambiguity diversion increased the willingness to pay for standalone insurance due to unfamiliarity with the bundled product. CAI et al. (2020) determine the ex-post effect of subsidies on insurance take-up in China, finding that subsidies increase future insurance take-up through their influence on pay-out experiences. This experience is however continuously updated with recent experience on payouts and disasters unless farmers receive an educational treatment. DOUGHERTY et al. (2021) conducted an RCT in Ghana, finding that bundled insurance can increase demand for credit by reducing moral hazard and related transaction costs. Other studies highlight potential side-effects of subsidization: For instance, WONG et al. (2020) confirmed along an RCT in Ethiopia that subsidization raised short-term and unstable demand increases, but resulted in long-term investment effects in combination with input vouchers. In Ghana, MISHRA et al. (2023) find a positive effect of bundling joint liability lending with micro-insurance increases on the adoption of fertilizer.

Secondly, a small number of observational and experimental studies analyze ex-post effects. YI et al. (2020) analyze observational data on the introduction of subsidies on demand for insurance for corn in the US, finding that subsidy-related elasticities of demand for corn insurance tend to be larger in riskier regions at relatively higher coverage levels. VAN ASSELDONK et al. (2022) analyzed observational data of insurance holders in Zambia, finding that bundled insurance design may help short-term upscaling of a product, but was associated with a substantial amount of mid-term dropouts due to the low financial resilience of the scheme and its policy-holders. LAVORATO et al. (2020) support the notion of a positive, although inelastic, effect of the subsidy level on the demand for crop insurance along a panel data sample in Brazil. Furthermore, O'DONOGHUE (2014) and YU et al. (2018) conducted natural experiments on the impact of premium subsidies on crop acreage and production in the US, finding a positive, large acreage response to premium subsidies. STOEFLER AND OPUZ (2022) find positive demand effects of subsidization on demand for an index insurance scheme in Burkina Faso.

Our review illustrates that the generally positive effects of both premium subsidization on index insurance demand, adoption, and managerial decisions are undisputed. For loan bundling, existing findings are a bit more ambiguous. Among the existing body of research, we found no works comparing the benefits of public subsidies against that of loans or other forms of product or service bundling in quantitative terms. Both interventions have not been tested and evaluated quantitatively at scale (HAZELL & VARANGIS, 2020). Even more important, no works so far are quantitatively comparing performance across national settings. Insurance adoption and hence program success is co-determined by several product- and country-specific properties, urging us towards venturing beyond isolated project evaluations and conduct a quantitative assessment of suitable interventions along a larger number of quantitative program observations.

3 Empirical Approach

3.1 Data

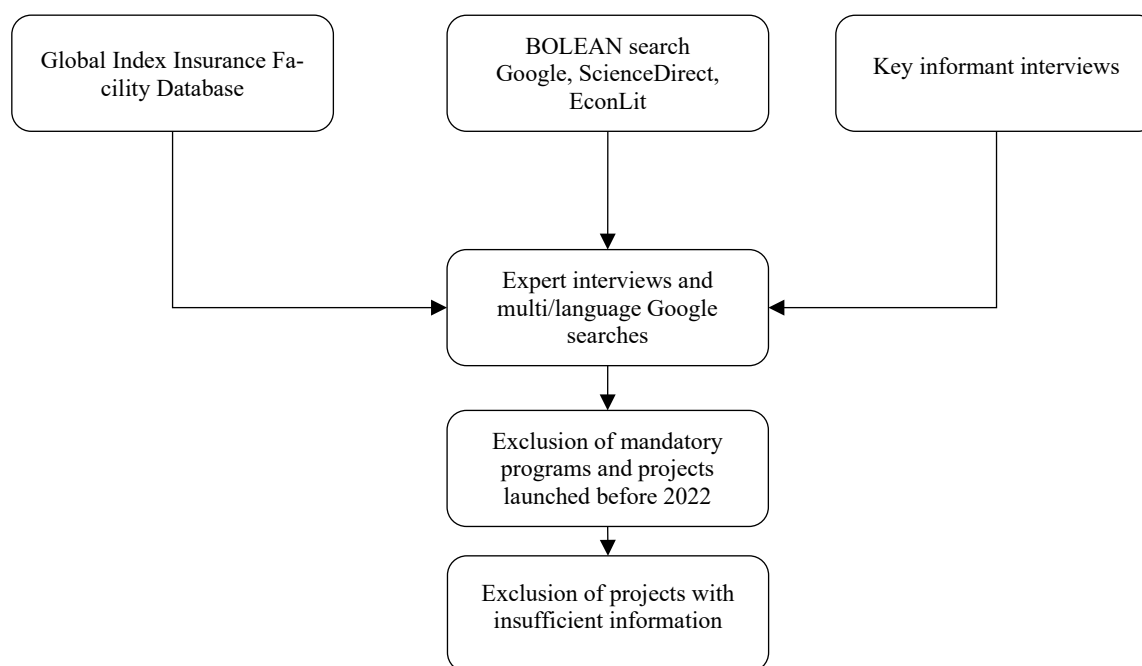
For generating a database, we followed a multi-step approach, which is visualized in Figure 1, to compile a list of all known implementation activities in terms of index-based insurance programs. Research started along the database of index insurance projects featured on the homepage of the Global Index Insurance Facility (managed by World Bank Group), the ClimateWise Compendium of Disaster Risk Transfer Initiatives in the Developing World (ClimateWise, 2011) as well as several comprehensive studies featuring lists of index insurance projects or dedicated case studies (HAZELL et al., 2021; HESS & HAZELL, 2015; ITURRIOZ & ARIAS, 2010;

MAHUL & STUTLEY, 2010; MIRANDA & FARRIN, 2012; SIMOES, 2021). Second, we conducted a Boolean search on Google as well as online databases “Science Direct” and “EconLit” along the keywords “index”, “climate” and “insurance” (connected with “AND” in the advanced search). In the following search, the keyword “climate” was replaced by the keywords “weather” and “index insurance”. To narrow down the results, the terms “index insurance” (as title), “demand” and “distribution” were added. Third, we conducted a series of interviews with key informants from countries with known index insurance initiatives.

In the second step, we filled the information gaps of initial findings with a multi-language search involving the name of the program, involved actors, and the country in question. If available, we directly approached project coordinators of the respective insurance products. Two different interview methods were applied: 1) expert interviews along a self-administered questionnaire distributed via email; and 2) qualitative, interviewer-administered telephone/video-conference interviews. In the third step, selected case studies were presented at international workshops and conferences, and related feedback was included in the database. We only considered programs launched no later than 2022, as project performance can only be reasonably assessed after at least two marketing seasons.

From our initial list of 141 identified projects, we omitted ten observations for which critical information was missing or seemed outdated and could not be verified by additional sources. Furthermore, at the time of publication of this database, there were several new pilots in their initial stages without having reached the actual implementation phase and were therefore excluded from this database. Ultimately, we collected complete information on 131 insurance programs in 53 countries worldwide. The database is made available in the Appendix of this Paper.

Figure 1: Database compilation procedure



Source: own illustration

Considering the relatively small size of our sample, we conducted a post-hoc power analysis to determine the statistical power of the planned analysis. Based on COHEN (1988), we implemented a power analysis for a general linear model as well as for a logit model with the R packages `pwr()` and `pwrss()`. The analysis indicated that our dataset of 126 observations is large enough to deliver sufficient power for our analysis.

The 131 programs were located in 52 different countries, most of them in Asia (52) or Africa (45). Figure 2 (see appendix) illustrates the spatial dispersion of the selected pilot programs. 50 programs were concluded or merged/integrated into other schemes while 81 programs were still active. The most insured crop was maize (35 programs), followed by rice (29), cotton (19) and wheat (16). There were nine livestock products, and ten schemes insuring pasture. Finally, 29 products provided cover for any type of crop production, i.e. multi-crop insurance. Drought was the most frequently covered risk, included in 75 products, followed by products covering excess rain or floods (50 products), nine frost covers, seven hot spell covers, five storm covers, and two products covering plant diseases. 23 products covered general production risks.

From our sample, 70 (53%) of the programs received premium subsidization. In total, 61 (47%) of the programs were bundled with various financial and non-financial services, among them 40 with loans, 18 with input supply, five with contract farming, and eight with extension services or other benefits.

3.2 Measures

For estimating treatment effects, we considered one dependent variable, four independent variables, and a number of control variables, all based on extensive literature research. All model variables are exhibited in Table 1:

Project survival. Recent coverage information (e.g. number of participants or hectares covered) was one of the most difficult parameters to retrieve, as especially private programs often stop project updates after the pilot phase for entrepreneurial reasons. Furthermore, there is no universal measure for coverage, as some projects report the number of insurance contracts, the number of individuals or households covered, the acreage insured, or the sum insured. Furthermore, all of these indicators would need to be put in proportion to the rural population, production value of a specific crop, or seed for a specific crop. As acreage or sum insured is typically not reported by separate crops, we quickly dropped this approach. To obtain a reliable outcome variable, we therefore decided on a binary outcome variable describing whether or not the product within the project is still being marketed at the time of data collation (i.e. winter 2024).

Subsidization is likewise measured as a binary variable. The main reason for this decision is data consistency: While most projects report the level of subsidization as a percentage of the market premium, this level is typically rather variable over the project duration. Furthermore, many schemes introduce a cap on overall subsidies per contract or determine the individual level of subsidy based on neediness (i.e. per capita farm income) or acreage. Projects that received a premium subsidy at earlier stages but had that subsidy terminated within 1-2 seasons of project conclusion are still considered within the treatment group for this estimation.

Bundling. For a few years, bundled approaches have been proposed for their ability to provide incentives to participants beyond premium pricing (MUKHERJEE et al., 2017). As reported by Indexinsurance Forum (2017), for instance the food and beverage corporation PepsiCo introduced an index-based insurance for Indian farmers in 2007. In detail, PepsiCo offers farmers higher procurement prices when they cover their production by index insurance, the price advantage being equivalent to approximately 50% of insurance premiums. In parallel, PepsiCo developed a routine of distributing weather information and important farming information via smartphone apps. Within our database, we observe various bundling approaches, most frequently loan bundling (40 products), but also bundling with input supply, i.e. provision of production inputs at reduced prices (18 products), various extension services (eight programs), contract farming (five) programs, or a combination thereof.

For determining the impact of subsidization and product/service bundling on program success, we need to consider several important policy aspects that may have contributed to premium subsidization, bundling, and project success:

Donor support. Capacity building and marketing/outreach activities are crucial determinants of index insurance projects to secure the trust of potential customers, in particular at the piloting stage. Especially community-training and outreach activities are however typically not within the core activities of private insurance companies (MIRANDA & FARRIN, 2012). Very often, the extent of these activities is determined by the involvement of non-profit donor agencies. Since the extent of these training and outreach activities is often latent and hard to quantify, we, therefore, control for the involvement of a non-profit donor agency as a binary variable.

Index design. Another main determinant of product success is the nature and design of the index that serves as a trigger for indemnity payouts. The two main factors determined by index design are speed of payouts as well as basis risk. While the speed of payout is mostly relevant for customer satisfaction, high basis risk can either lead to insufficient payouts, resulting in a loss of trust on the side of actual and potential customers, or very high loss ratios (ratio of paid claims to earned premiums) and hence endanger the financial stability of the insurer. Within our estimation, we control for four different types of index design: First, so-called area-yield indexes that estimated farm-level losses based on average regional yield losses. This method not only ignores within-region differences in weather shocks, leading to high basis risk. Furthermore, it also entails a long settlement process, as individual settlement relies on the availability of regional yield statistics – ultimately insured farmers have to wait for the compilation of regional yield data, delaying payouts considerably. Second, weather indices based on weather station data, aiming at reducing basis risk by having payouts triggered by the actual weather condition in the vicinity of the insured farmer and speeding up the settlement process. One major shortcoming however is the low density of weather stations in most developing countries (ELTAZAROV et al., 2021), leading to high basis risk. Furthermore, the lack of historical data from more recently established weather stations leads to high risk-loadings and high premiums (MIRANDA & FARRIN, 2012). Third, satellite-based weather, vegetation or soil moisture indices. As documented in manifold ways, basis risk can be decreased by involving high-resolution remote-sensing data or combining remote-sensing data with information from weather stations or other ground-based sensors. Finally, hybrid approaches combining area-yield approaches with weather or vegetation indices, often due to a lack of trust of third parties in the accuracy of pure weather indices. In these cases, double-triggers can complicate settlements, while the area yield statistics remain a bottleneck in terms of speed of settlement.

As further **controls** we introduce the GDP of a country upon project launch, considering that most projects, even those with seed money, at some point have to become either self-supporting via market-based premiums or subsidized by local governments. In both cases, per capita GDP is assumed to be formative for the level of state or private support an insurance scheme is likely to receive. This notion is for instance empirically supported by DAMANIA et al. (2023), who find a positive relationship between GDP and total support for agriculture. To control for a conducive policy environment for sustainable project support, we also introduce a control for (perceived) corruption, the Corruption Perception Index (CPI) issued by Transparency, ranging from 1-10, the highest value indicating the lowest level of perceived corruption. Due to a change in the definition of the CPI from 2012 on, older CPI values were rescaled to conform to the current value range. To control for the fact that the survival rate of a project decreases over time, we introduce a control for the launch year of the project. Finally, we introduced a control for political unrest, by calculating a trigger based on the Global Peace Index (GPI). If the 15-year average of the GPI went beyond a critical value of 2.5 or exceeded 2.75 within the past three years, the respective country was considered under political unrest. A combination of extreme value and long-time averages as critical values was made as the exact end date of each of the projects was not known in all cases.

Table 1: Summary Statistics

Variable	Description	Levels	Obs	Mean	SD	Min	Max
status_d	Product currently actively marketed	0=no 1=yes	131	0.62	0.49	0.00	1
subsidy_d	Premium subsidization	0=no 1=yes	131	0.53	0.50	0.00	1
combined_d	Product or service bundling	0=no 1=yes	131	0.47	0.50	0	1
combined_loan	Loan bundling	0=no 1=yes	131	0.31	0.46	0	1
combined_other	Other product or service bundling	0=no 1=yes	131	0.19	0.39	0	1
type_c	Index type	1=area-yield; 2=hybrid area-yield and WII; 3=station-based WII; 4=satellite-based index	131	3.02	1.06	1	4
donor	Involvement of an international donor at the onset	0=no 1=yes	131	0.56	0.50	0	1
GDP_log	National GDP at project onset	in \$PPP	131	7.80	1.29	5.26	11.32
CPI	Corruption perception index	0 (highest level of corruption) -10 (lowest level of corruption)	131	37.53	16.54	11	90
GPI_d	Global peace index above the threshold	0=no 1=yes	131	0.17	0.38	0	1
year	Year of project launch	year	131	2013	5.76	1999	2021

Source: own data

3.3 Propensity Score Matching

For estimating the effect of subsidies and products on project success, we utilize a propensity-score-matching approach. The reason for this choice is the assumption the provision of subsidies as well as opportunities for product bundling for a specific product might be driven by previous pilot performance: While some projects receive premium subsidies from the onset (usually since the local government or an international donor is initiating the respective pilot in the first place), other projects receive a subsidy only after a successful pilot phase. Therefore, we need to control for the endogeneity of subsidization concerning latent project performance, which affects ultimate project success. The same mechanism can be observed for product bundling, which is often only approved after a successful piloting phase.

Propensity score matching is a frequently used approach to achieve covariate balance in the treatment group and hence allows casual interpretation of a potentially endogenous treatment within cross-sectional data (ROSENBAUM & RUBIN, 1983). Matching approaches aim to remove the differences in average outcomes for differences in pre-treatment properties. For this study, we define four treatments and treatment groups: T1: premium subsidies, T2: bundling, T2.1: loan bundling in particular, T2.2 other forms of bundling. The control groups are composed of those programs not receiving the respective treatment.

For propensity score matching, we first assume that the probability p for a treatment w based on $\mathbf{x}$ is bounded away from zero and one, also called the overlap condition. In other words, the covariates should not perfectly predict the treatment.

$$0 < p(\mathbf{x}) < 1$$

Second, we assume that the selection for treatment is unconditional is independent of outcome y , conditional on covariates $\mathbf{x}$:

$$(y(0); y(1)) \perp\!\!\!\perp w | \mathbf{x}$$

Under this assumption, the average treatment effect ATE among the whole sample on outcome y is defined as

$$ATE = E(y|w = 1) - E(y|w = 0)$$

In our case, we are interested in the average treatment effect on the treated units (ATT), assuming that some units did not ever have a chance to be treated, for instance, due to country-specific legislation (WOOLDRIDGE, 2010).

The ATT is defined as follows:

$$ATT = E[(y|w = 1) - E(y|w = 0)]|w = 1$$

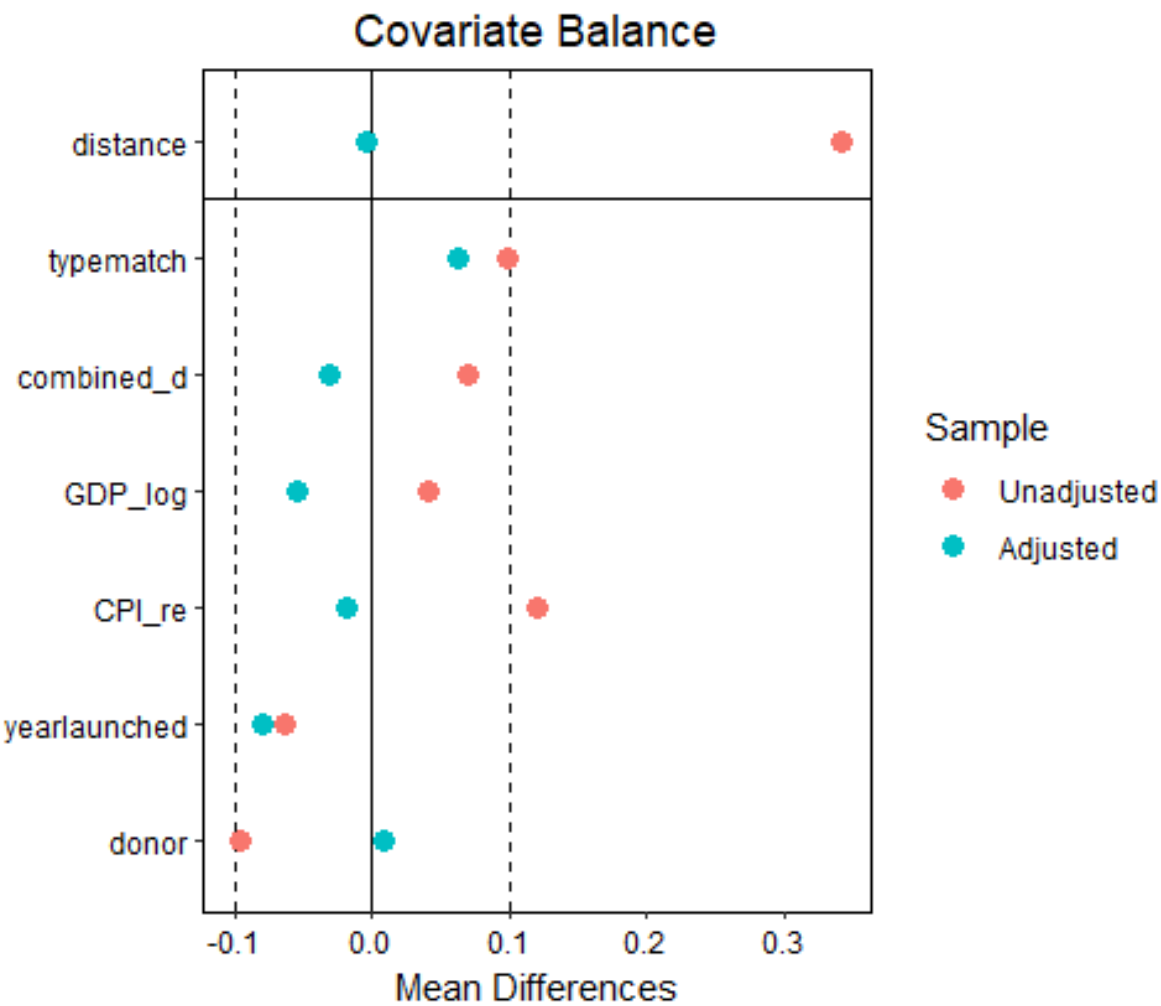
For matchings, we are choosing a nearest-neighbor approach, one of the most common approaches, which matches programs in the treatment and control groups based on the similarity of their propensity score. Meanwhile, this approach may not yield precise results if the distance between neighbors is rather large, also it tends to discard a relatively large number of observations (STUART, 2010), reducing estimation power if the size of the treatment group is reduced (HO et al., 2007). As a comparison, we therefore also use optimal full matching, which distributes all units to subclasses, each containing one treatment or one control unit as well as one or several counterfactual control or treatment units. The chosen number of subclasses and distribution of units to subclasses aim at minimizing the sum of distances within a subclass. Overall, this method has the advantage of discarding fewer observations, in particular on the side of control units (STUART, 2010).

For the calculation of propensity scores and matching we employed R's `matchit()` package. To estimate the treatment effect and its standard error, we fit a linear probit regression model with project success as a binary outcome and the treatment defined as the allocation of subsidies and product bundling, respectively. Further, we include several control variables and the full matching weights and cluster-robust standard errors with pair membership as the clustering variable. To fit the outcome, we used the `glm()` function including. In the next step, we used the `avg_comparisons()` function to conduct g-computation for measuring the ATTs along clustered standard errors.

4. Results

Figure 3 illustrates the standardized mean differences for all covariates, a common test for the balance of the match between treated and untreated units (THOEMMES & KIM, 2011). For the adjusted sample all standardized mean differences are situated below the threshold of 0.1. Furthermore, all eCDF statistics are situated below 0.25. Hence our matching approach can be considered to provide adequate balance. As the full matching approach uses all treated and all control units, we did not lose any units of our sample. For this and other treatments, logistic full matching delivered the best balance. For the sake of brevity, the balance plots for the other treatments are not reported within this paper but can be obtained upon request.

Figure 3: Covariate balance – Love plots (treatment: subsidization)



Source: own calculations

Tables 2 reports the average treatment effects on the treated for four treatments. For the full matching logistic model, we find a significant positive effect of subsidies (T1) on project success ($SE=0.0725$, $p=0.00276$). The ATT estimate of 0.217 means that receiving premium subsidies increased the odds of remaining operational by a statistically significant increase of the probability of project success by about 22 percentage points for those programs initially receiving a program subsidy.

Bundling in general (T2) turned out to have a significant impact on the success of projects in our database ($SE=0.232$, $p=0.0748$) as well. Projects were by 23 percentage points more likely to survive the pilot phase if they were bundled at all, *ceteris paribus*. For a more detailed view, we first assess the effect of loan bundling (T2.1), the most common type of bundling. For this treatment, we could not find a statistically significant impact on the outcome variable. When testing other form of bundling approaches (other than loan bundling) as a treatment variable (T2.2), we find a highly significant ATT ($SE=0.0585$, $p<0.0001$) of 0.281, indicating a higher likeliness by 28 percentage points of these programs to remain actively marketed.

Table 2: ATT results for the impact of subsidization and product bundling on project success

ATT	Contrast	Estimate	Std. Error	z	Pr(> z)	S	2.5 %	97.5 %
Subsidization	1 - 0	0.217***	0.073	2.99	0.003	8.5	0.075	0.359
Product bundling	1 - 0	0.232*	0.131	1.78	0.075	3.7	-0.023	0.488
<i>Loan bundling</i>	1 - 0	-0.032	0.077	-0.409	0.682	0.6	-0.182	0.119
<i>Other bundling</i>	1 - 0	0.281***	0.059	4.8	<0.001	19.3	0.166	0.395

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5. Discussion and Conclusion

In this study, we aimed to test the impact of subsidies and bundling on the success of index-based insurance pilots. Based on a PSM approach, we controlled for the endogeneity of subsidy allocation and bundling based on previous pilot performance to isolate average treatment effects among the treated units. As indicated in our results section, we find that the subsidy was associated with an increase of the probability of project success, as defined as project survival until the current day, by about 22 percentage points. Also the effect of bundling turned out to be significant, bundling in general being associated with an increase in the probability of project success by 23 percentage points. Apparently this effect was mostly driven by the significant ATT of input, contract farming and extension bundling (T2.2), which can be translated into a 28 percentage point increase of project survival. Loan bundling (T2.1) remained without significant effects on project survival.

While we dedicated extensive efforts to the identification of index insurance pilots and the retrieval of related information, a bigger sample would certainly help to increase the robustness of our results. Furthermore, we have to acknowledge the fact that the current market development is very dynamic. Future updates of the database could support the refinement of our results and allow additional analysis.² Nevertheless, our findings provide a distinctive message: Despite concerns over its sustainability, subsidization remains a powerful tool in securing project success, especially in LMCs.

However, the mere success of subsidized index insurance in terms of project survival does not touch upon questions of cost-efficiency and distribution effects. Except for one case (Spain), subsidized programs all subsidized at least 50% of the premium cost. Some of the programs in our database receive 80% (e.g. Kazakhstan or China) or even up to 90-100% premium subsidization (e.g. Burkina Faso and Brazil). Even if governments and donor agencies can maintain this level of budget transfers in the long run, the impact of such subsidized schemes should also be compared to potential other development and direct transfer projects. After all, index insurance subsidization constitutes, in essence, a redistribution of tax-payers money not only to farmers but foremost private insurance companies and related service providers (GOODWIN & SMITH, 2013). As argued by BUCKWELL et al. (2017), such support may be valid for supporting underdeveloped insurance but should not constitute continued support to established structures. On a side note, the benefit incidence of index insurance premium subsidies is also affected by the fact that many large insurance companies and related service providers are typically located and run in high-income countries, implying a (perhaps) unintended drain of development funds towards other high-income regions or sectors. Finally, one needs to consider the potential distortions introduced by subsidized schemes on planting patterns and land use (SMITH & GOODWIN, 2013). It has been argued that especially subsidized insurance (traditional or index-based)

² The database established in the scope of this study is available online. Potential additions and updates from the readership are most welcome.

may keep climatically unsustainable production on life-support and provide adverse incentive against climate adaptation (JØRGENSEN et al., 2020) .

On the other hand, our findings support the realization that loan-bundling in reality has many caveats: For once, loan-bundling has been found to not affect or even decrease the demand for loans, as compared to standalone loan products (GINÉ & YANG, 2009; KARLAN et al., 2011). Also, there are concerns over potential crowding-out effects of index insurance on loan-markets (CLARKE & DERCON), which may reduce the support of financial institutions for loan-bundled products in the long run. Especially the latter point may explain the lack of effect in terms of project success within our dataset.

These results have three implications for insurance program design: First, the greatest care should be given with regards to the design of subsidies, as also prominently argued by HAZELL AND VARANGIS (2020) to avoid undesired distortions concerning land use and planting pattern, but also the scheme's sustainability to long-term budgetary fluctuations.

Second, our results indicate that loan bundling approaches require certain improvements, as we could not find any clear positive contribution to project success within our sample – in contrast to other forms of product/service bundling. MIRANDA AND FARRIN (2012), for instance, suggest shifting indemnity payments to lenders to avoid crowding-out effects in the loan sector and hence increase the support of banks to loan-bundled schemes.

Third, in times of increasing pressure on public budgets, we call for more research into assessing both distribution effects and marginal production and income returns to subsidy transfer allocation. While being successful as such, the benefit of insurance subsidization needs to stand up to comparison to alternative approaches, like catastrophic payments, subsidized credit schemes, or subsidies for climate-smart technologies. However, it should be mentioned that many schemes bundled with loans, inputs supply, contract farming or extension services, require additional subsidization, loan-bundled schemes being the type of index insurance receiving the highest level of subsidization on average (HESS & HAZELL, 2016) .

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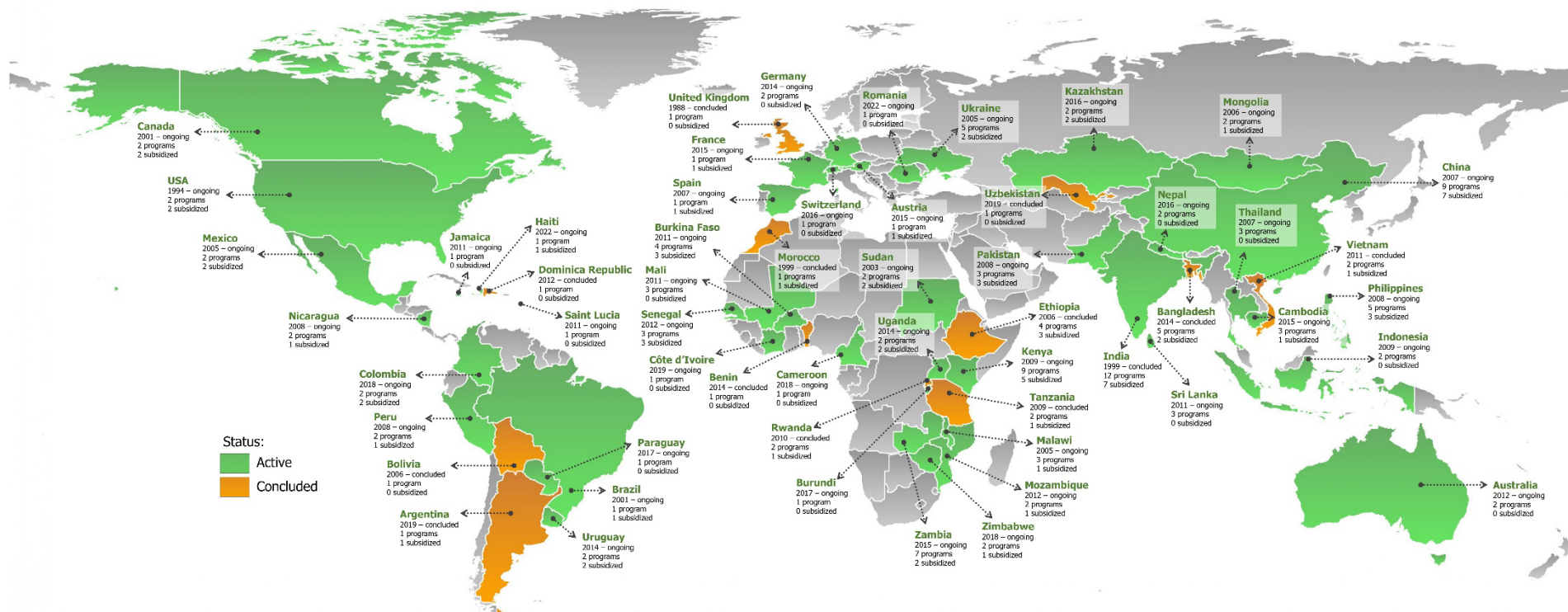
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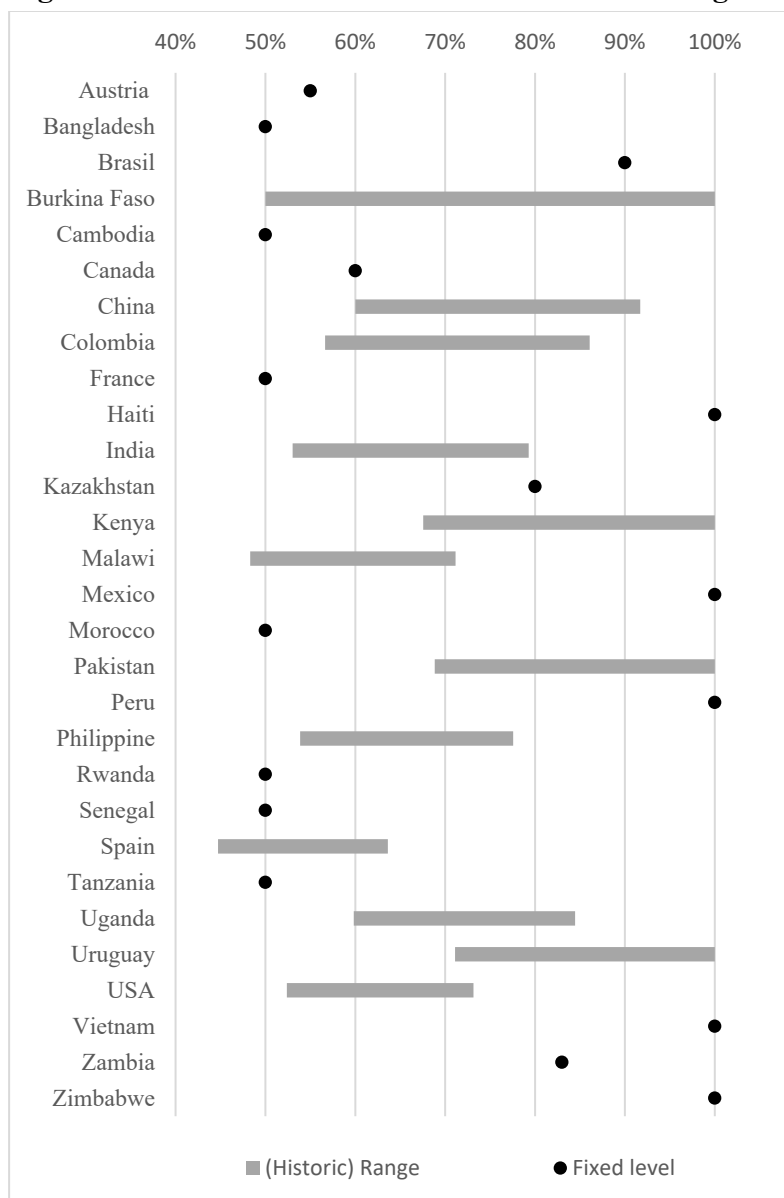
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Figure 2: Analyzed country pilots



source: own compilation

Figure 6: Premium subsidization levels and ranges



source: own data and illustration

AGRICULTURAL FACTOR MARKETS

ALTERNATIVES TO DIESEL IN AGRICULTURE? FARMERS' PERCEPTIONS OF ALTERNATIVE FUEL TRACTORS IN GERMAN AGRICULTURE

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Summary

The ongoing discussion about agricultural diesel subsidies, an increased focus on reducing greenhouse gas emissions and decreasing dependence on fossil fuels has led to heightened interest in alternative fuels. Given the critical role of agriculture in both the consumption and production of energy, understanding the factors that influence farmers' decisions to purchase an alternative fuel tractor is paramount. This study aims to identify constructs that influence German farmers' intentions to purchase alternative fuel tractors, applying the Unified Theory of Acceptance and Use of Technology (UTAUT) framework. An online survey conducted in 2022 yielded 141 usable responses from German full-time farmers, and the UTAUT model was estimated using Partial Least Squares Structural Equation Modelling (PLS-SEM). Farmers perceive alternative fuel tractors as particularly suitable for low-energy farm and field work, but lower driving ranges relative to conventional diesel tractors are the main barrier to adoption. General performance expectancy and social influence emerged as the most potent drivers of farmers' intentions to purchase alternative fuel tractors. The paper contributes original insights into the factors influencing technology adoption in agriculture and provides practical implications for policymakers and agricultural machinery manufacturers. The results guide strategies to encourage alternative fuel tractor adoption and suggest directions for future sustainable agriculture research.

Keywords

Unified Theory of Acceptance and Use of Technology; Partial Least Squares Structural Equation Modelling; Alternative Fuels; Technology Adoption; Agricultural Machinery

1 Introduction

In agriculture, diesel fuel is mainly used to power tractors and agricultural machinery. However, achieving larger reductions of diesel fuel consumption in agriculture requires the development and diffusion of new environmentally friendly technologies such as powering agricultural machinery with alternative fuels (LOMBARDI AND BERNI 2021; BAGAGIOLO et al. 2022). Alternative fuels may vary by production process and origin, but what they all have in common is that they are produced from renewable energy sources, thus alleviating concerns surrounding limited fossil fuel energy.

Farmers have a special role to play in the production and consumption of some alternative fuels. On the one hand, farmers need large amounts of fuel to produce agricultural goods, making them potential consumers (e.g. ECKEL et al., 2020). On the other hand, farmers can act as suppliers by producing raw materials used for alternative fuels (e.g. CHERUBINI, 2010). As such, the opinions of farmers are of great importance in the successful establishment of alternative fuel concepts in agriculture, especially due to the dual nature of their role (HOLST et al., 2020). This is particularly pertinent given the need for alternative fuels to meet the demands of the European Green Deal (EUROPEAN COMMISSION, 2021).

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Despite the growing interest in alternative fuels in the agricultural industry, only a limited number of studies have focused exclusively on farmers and their attitudes towards these fuels as both suppliers and consumers. LOMBARDI AND BERNI (2021) have analyzed Italian farmers' willingness to pay for a multi-functional full electric battery tractor. They showed that, besides socio-demographic and farm characteristics, increasing investment and maintenance costs decrease farmers' willingness to pay. Most importantly, they showed that engine power is a major determinant of farmers' willingness to adopt an electric fuel tractor. More recently, BAGAGIOLO et al. (2022) showed that Italian farmers have a higher interest in using biomethane and e-fuel than in hydrogen. Furthermore, costs and refueling were perceived as the main technical barriers for the adoption. BESSETTE et al. (2022) showed that organic small-scale vegetable and fruit growers in the USA would prefer a battery electric tractor over a diesel tractor as they perceive them as being more environmentally friendly, while expressing concerns regarding performance, costs and maintenance. Most recently, SOK AND HOESTRA (2023) showed that working time and range as well as operational and purchase costs are the most important attributes of an electric tractor for Dutch farmers, while emissions is the least important of the barriers presented for selection in the survey. Furthermore, they showed that negative feelings concerning (environmental) policies may hinder the potential widespread adoption in the near future. The research question emerged from the recognition of a gap in the existing literature regarding the adoption of alternative fuel technologies in agriculture.

Previous studies, such as those by LOMBARDI AND BERNI (2021), BESSETTE et al. (2022), and SOK AND HOESTRA (2023), have explored specific aspects of this issue by focusing on electric tractors. BAGAGIOLO et al. (2022) is the only study focusing on more than one alternative fuel by asking for a ranking of these and of barriers to adoption. Still, an overarching study focusing on farmers' perceptions of alternative fuels in general and the factors influencing their intentions to buy alternative fuel tractors, has been lacking. As most alternative fuel tractors are still in development, initial perceptions and attitudes, even regarding potential costs, are of great importance for an effective dissemination in the future. Hence, the overall research question arises: What are the key latent factors that influence farmers' intentions to purchase alternative fuel tractors?

To the best of the authors' knowledge, there is no overarching study to answer the research questions of how farmers perceive alternative fuels in general and specifically, what drives their intention to buy tractors using such fuels. Furthermore, literature about potential barriers and on-farm application of alternative fuel tractors is scarce. Therefore, this study aims to fill these research gaps by pursuing the objective of understanding the causal relationship between constructs based on the Unified Theory of Acceptance and Use of Technology (UTAUT) (VENKATESH et al., 2003) framework and farmers' intention to buy an alternative fuel tractor. Hence, the problem being addressed is the limited understanding of the factors influencing farmers' intentions to purchase alternative fuel tractors. Despite the growing interest in alternative fuels in agriculture, few studies have focused on farmers' perceptions and attitudes towards alternatives fuels in a holistic manner. This problem is important due to the dual role of farmers as both potential consumers and suppliers in the alternative fuel market. With agriculture accounting for a notable percentage of greenhouse gas emissions, understanding farmers' intentions is crucial for the successful adoption of environmentally friendly technologies like alternative fuel tractors. Evaluating and understanding the causal relationship between the constructs of the UTAUT and farmers' intention to buy an alternative fuel tractor therefore allows us to identify levers that will facilitate adoption and improve marketing activities.

Thus, this article adds the following to the literature: this is the first article focusing on the general adoption of alternative fuels in agriculture. To be specific, perceived barriers to the use of alternative fuels in agriculture are assessed. Furthermore, areas of farm work were recorded, which, from the farmers' point of view, are particularly suitable for the practical use of alternative fuel tractors. Moreover, this is the first study to identify constructs influencing farmers'

intention to buy alternative fuel tractors. In this study, the UTAUT framework was adapted and extended to this context.

2 Hypotheses Generation

The development of our hypotheses under the UTAUT framework is informed by the intersection of innovation and sustainability. We hypothesize that the attributes of alternative fuel tractors, such as their environmental benefits and innovative features, play a crucial role in shaping farmers' purchase intentions, which are conceptualized in the statements of our UTAUT adaptation. The corresponding statements to the derived constructs and the broader associated literature are shown in Table 1.

Performance expectancy (PE) refers to the extent to which potential users of a new technology or practice believe that their job performance is enhanced, which positively influences the intention to use the technology or practice. Given that alternative fuels are not a direct improvement on diesel engines, but rather a substitute, it is reasonable to expect that potential users will anticipate comparable or superior performance. Moreover, for alternative fuels to be widely accepted among potential users, their costs should be lower or on par with those of diesel fuel. Additionally, the driving experience, including factors such as steering, acceleration, and comfort, should be similar to, or better than, that of diesel fuel tractors. Hence, the following hypothesis is generated:

H1: General Performance Expectancy (GPE) has a statistically significant positive effect on the Intention to Buy an Alternative Fuel Tractor (INT)

Alternative fuels also promise to be an environmentally friendly alternative to fossil fuels. Moreover, there is a special connection with regard to the production of some alternative fuels and agriculture, as farmers can be producer and consumer of the final product and by-products. Agricultural by-products can be utilized in the production of alternative fuels, which facilitates sustainable value creation. Conversely, by-products generated during fuel production can also be repurposed for agricultural production such as fertilizer or animal feed, thereby representing a more sustainable and efficient use of existing resources. Therefore, expectations concerning the ecological performance of alternative fuels, in addition to their general performance, may play a distinct role in the decision to purchase an alternative fuel tractor. Accordingly, the following hypothesis will be tested:

H2: Ecological Performance Expectancy (EPE) has a statistically significant positive effect on the Intention to Buy an Alternative Fuel Tractor (INT)

Effort Expectancy (EE) is defined as the degree of ease potential users associate with using a new technology or practice. EE positively impacts a users' intention to use a new technology or practice. Alternative fuel tractors should be as easily refueled and maintained as diesel fueled tractors. Otherwise, farmers would have serious disadvantages switching to alternative fuels. Hence, expectations regarding refueling and service costs might influence the willingness to buy alternative fuel tractors which is reflected in the following hypothesis:

H3: Effort Expectancy (EE) has a statistically significant positive effect on the Intention to Buy an Alternative Fuel Tractor (INT)

The extent to which potential users of a new technology or practice believe that important people think that they should use a new technology or practice, is defined as social influence (SI) in the UTAUT model by SI positively influences the intention to use a new technology or practice. Likewise, it can be expected that positive attitudes towards alternative fuel tractors of colleagues or experts also increase farmers' intention to buy an alternative fuel tractor. This relationship is presented in the following hypothesis:

H4: Social Influence (SI) has a statistically significant positive effect on the Intention to Buy an Alternative Fuel Tractor (INT)

Facilitating conditions (FC) can be characterized as the degree potential users perceive the present infrastructure supports the adoption of a new technology or practice. Alternative fuels are relatively new to the market, which is why political planning certainty with regard to the legal framework can influence the decision to invest in a tractor with an alternative fuel system. Likewise, a sufficient infrastructure to refuel the tractor is needed to trigger the purchase intention. Hence, the following hypothesis is tested in the model:

H5: Facilitating Conditions (FC) has a statistically significant positive effect on the Intention to Buy an Alternative Fuel Tractor (INT)

Table 1: Constructs, indicators and associated statements

Construct	
Indicator	Statement
<i>General Performance Expectancy</i>	
gpe1	I think that by using alternative fuel tractors I can achieve identical daily outputs (e.g. ha/h) as with diesel fuel
gpe2	The fuel costs per hour of operation or area worked are lower than those of a tractor powered by a diesel engine
gpe3	The driving experience and comfort of tractors with alternative fuels during use are comparable to the characteristics of a diesel tractor.
<i>Ecological Performance Expectancy</i>	
epe1	I think that the use of alternative fuels can reduce the greenhouse gas emissions of my farm and thus have a positive environmental impact
epe2	Regionally renewable resources, such as rapeseed oil or biomass, can be used to produce alternative fuels, allowing energy to be produced in a more environmentally friendly manner
epe3	By using alternative fuels, resources can be used more efficiently, as secondary products from the production of alternative fuels can also be used as e.g. animal feed or farm fertilizer
<i>Effort Expectancy</i>	
ee1	Refueling of alternative fuel tractors is similarly fast as for diesel tractors
ee2	The use of alternative fuels is associated with increased service costs (e.g. maintenance of fuel lines or tank cleaning)
<i>Social Influence</i>	
si1	According to agricultural media reports, which I trust, alternative fuels are a serious alternative for diesel fuels
si2	People in my private environment are of the opinion that I should use alternative fuel tractors
si3	According to expert opinions, which I trust, alternative fuels are a good, serious alternative to diesel fuels
<i>Facilitating Conditions</i>	
fc1	The existing regulatory framework (e.g. fuel tax or driving bans) gives me sufficient planning security to invest in alternative fuel technologies in the long term
fc2	The subsidy programs available on the market create sufficient incentive for me to invest in alternative fuel systems in the long term
fc3	I consider the existing refueling infrastructure for alternative drives to be insufficient and should therefore be expanded
<i>Intention to Buy an Alternative Fuel Tractor</i>	
int1	I am planning to buy a tractor with alternative fuel in the near future
int2	I already have concrete plans to purchase a tractor with an alternative fuel concept

Sources: VENKATESH et al. (2003); BAGAGIOLO et al. (2022); BESSETTE et al. (2022); FRENZEL et al. (2021); SOK AND HOESTRA (2023); LOMBARDI AND BERNI (2021)

3 Material and methods

3.1 Structure of the Questionnaire and Data Acquisition

An online survey was conducted in the second quarter of 2022. Participation of farmers was voluntary and participating farmers agreed that their data would be processed anonymously². Farmers were invited to participate through personal contact. Additionally, the survey link was shared in social media groups dedicated to agricultural discussions. The link was also emailed to agricultural training farms, whose addresses were available online. Upon receiving the link, farmers were encouraged to participate in the survey. The initial page of the survey provided detailed information about the study's objectives.

The questionnaire was divided into four parts. In the first part, the farmers received a short explanation about alternative fuels, to ensure a comparable knowledge of participants, which reads as follows: “Currently, the market for agricultural machinery is dominated by dieselpowered vehicles. However, agriculture already produces raw materials for fuel production (e.g. vegetable oils, sugar and starch) as well as fuels (e.g. biodiesel, rapeseed oil fuels, ethanol or biomethane) or electricity (from e.g. photovoltaics, wind power, biogas) on a large scale. These energy sources and the associated drive systems for mobile machinery are referred in the survey as so-called alternative fuels or alternative fuel tractors”. In the second part, perceived barriers and potential areas of alternative fuel tractor application were queried. In the third part, the 16 statements (see Table 1) for the UTAUT model (see Figure 1) had to be evaluated by each farmer using an equally-spaced 5-point Likert scale (1 = high disagreement; 5 = high agreement). In the last part, socio-demographic and farm related characteristics were assessed. Purposive sampling or judgment sampling for full-time farmers was applied since full-time farmers, only relying on income from agricultural production, are the most likely group of farmers to first invest in alternative fuel tractors in the future.

3.2 Partial Least Squares Structural Equation Modelling

Structural equation modelling (SEM) allows one to estimate cause-effect relationships between independent (exogenous) and dependent (endogenous) constructs. Constructs cannot be observed directly, but must be measured by indicators and then estimated. The indicators are the statements evaluated by the participants in the survey (Table 1). PLS-SEM aims to maximize the explained variance (R^2) of the target construct (e. g. intention to buy an alternative fuel tractor). PLS-SEM is used in this study for the following reasons:

1. PLS-SEM better performs if the sample size is small
2. PLS-SEM allows the use of constructs with only one or two indicators

PLS-SEM models are evaluated in two steps. In the first step, the relationship between indicators and constructs (outer model) are assessed. For the evaluation of the outer model indicator reliability, internal consistency, convergent validity and discriminant validity are estimated (HAIR et al., 2022). Standardized loadings of an indicator should exceed $\lambda = 0.7$ to establish indicator reliability. Loadings above 0.7 mean that 50 % of the indicators' variance is explained by its associated construct. If composite reliability (CR) surpasses a value of 0.7, internal consistency is established in the outer model. This means that all indicators measure the same construct. Average variance extracted (AVE) is the quality criteria for convergent validity and should exceed 0.5. A value above 0.5 for AVE means that the construct explains more than half of the indicators' variance. Discriminant validity can be established by estimating Heterotrait-Monotrait ($HTMT$) correlations between the constructs. Discriminant validity ensures that the constructs are separable from each other and one indicator only represents one construct. *HTMT*

² The survey was deemed unobjectionable by the Ethics Committee as well as the University's Data Protection Representative.

ratios should not exceed 0.9 (HAIR et al., 2022). Variance inflation factors (VIFs) are estimated to control for issues with multicollinearity.

In the second step, the inner model is estimated which represents the relationships between exogenous and endogenous constructs with standardized path coefficients β . t-statistics to check for statistical significance of the β coefficients are estimated by applying a bootstrapping procedure with 10,000 subsamples. Values for R² of the target construct are also estimated as a quality criterion. For this study, SmartPLS 3.2.7 was used to estimate the model (RINGLE et al., 2022)

4 Results

4.1 Descriptive Results

Table 2 shows the descriptive results for the sample. 141 usable records were used. All in all, the sample is slightly biased towards younger, relatively better educated farmers from larger farms with livestock (GERMAN FARMERS' FEDERATION, 2022). With respect to the bias towards larger farms, this was expected as we purposely sampled for full-time farmers only. However, the sample is still valid for the research purpose as full-time farmers from larger farms are most likely the first ones to adopt new technologies and also display the highest interest in new machinery and technologies in agriculture (MICHELS et al., 2020). Furthermore, most farmers in the sample have already heard about alternative fuels for agriculture and a larger share of the sampled farmers is also engaged in renewable energy production.

Table 2: Descriptive statistics of the sample (N = 141)

Variable	Description	Mean	SD	Min	Max	German Average ^a
<i>aware</i>	1, if the farmer has heard of alternative fuel tractors	0.90	-	0	1	-
Socio-demographic and farm characteristics						
<i>age</i>	Farmers' age in years	44.87	13.43	21	71	-
	< 25 years	0.09	-	0	1	0.08
	≥ 25 and ≤ 35 years	0.20	-	0	1	0.15
	> 35 and ≤ 45 years	0.17	-	0	1	0.14
	> 45 and ≤ 55 years	0.16	-	0	1	0.24
	> 55 years	0.36	-	0	1	0.36
<i>arableland</i>	Hectares of arable land managed by the farmer	602.56	783.47	10	3900	-
	< 20 hectares	0.02	-	0	1	0.07
	≥ 20 and ≤ 50 hectares	0.06	-	0	1	0.12
	> 50 and ≤ 100 hectares	0.16	-	0	1	0.19
	> 100 and ≤ 200 hectares	0.21	-	0	1	0.21
	> 200 and ≤ 500 hectares	0.17	-	0	1	0.16
	> 500 hectares	0.45	-	0	1	0.25
<i>Farm_Gas</i>	1, if the farm has its own diesel gas station	0.90	-	0	1	-
<i>Field_Farm_Dist</i>	Field to farm distance in km	4.51	3.26	1	17	-
<i>Gender</i>	1, if the farmer is male	0.89	-	-	-	0.90
<i>Higheredu</i>	1, if the farmer holds a university degree	0.31	-	0	1	0.14
<i>Livestock</i>	1, if the farmer is active in livestock farming besides arable farming	0.78	-	0	1	0.69
<i>Region</i>	Farm location in Germany					
	North = Schleswig-Holstein, Lower Saxony or Mecklenburg Western Pomerania	0.42	-	0	1	0.20
	East = Brandenburg, Saxony, Saxony-Anhalt or Thuringia	0.25	-	0	1	0.07
	West = North Rhine-Westphalia, Hesse, Rhineland Palatinate or Saarland	0.17	-	0	1	0.24
	South = Baden-Württemberg or Bavaria	0.16	-	0	1	0.48
<i>Plough</i>	1, if the farmer uses a plough	0.73	-	0	1	0.57
<i>Tractor</i>	The farmer uses a tractor with... ^b					
	< 100 HP	0.75	-	0	1	-
	≥ 100 and ≤ 250 HP	0.97	-	0	1	-
	> 250 HP	0.50	-	0	1	-
Renewable energy use and production						
<i>Biogas</i>	1, if the farmer is engaged in biogas production	0.31	-	0	1	-
<i>Photovoltaics</i>	1, if the farmer is engaged in photovoltaics	0.79	-	0	1	-
<i>Wind_Energy</i>	1, if the farmer is engaged in wind energy	0.17	-	0	1	-
<i>Thermal_Power</i>	1, if the farmer is engaged in a cogeneration plant	0.14	-	0	1	-
<i>Biofuel</i>	1, if the farmer is engaged in biofuel production	0.03	-	0	1	-
<i>Other</i>	1, if the farmer is engaged in other renewable energy production	0.02	-	0	1	-
<i>Electric_Car</i>	1, if the farmer has an electric car	0.16	-	0	1	-
<i>Electric_Station</i>	1, if the farmer has a loading station for his/her electric car ^c	0.91	-	0	1	-

^a German Farmers' Federation (2022)^b Multiple answers possible^c Mean shown for farmers with variable *electric_car*=1 (N = 23) SD = Standard deviation, HP = Horse power

Figure 1 shows various potential areas of farm work for alternative fuel tractors from farmers point of view. Tractors with alternative fuels are considered practical primarily for non-energyintensive light farm work (90 %) and for transportation over short distances (54 %). In contrast, only a small share of farmers perceives tractors with alternative fuels as being potentially suitable for energy-intensive field work (14 %) and long-distance transportation (16 %). The results could be explained by looking at Figure 2 showing barriers for the adoption of alternative fuel tractors. The majority of farmers (70 %) think that tractors with alternative fuels have relatively lower driving ranges than diesel powered tractors. Further barriers mentioned are high investment costs (60 %) and a lack of sufficient infrastructure for alternative fuels (50 %). The

results resemble SOK AND HOESTRA (2023), who showed that working time and range as well as operational and purchase costs are the most important attributes of an electric tractor for farmers. Contrasting results are presented by BAGAGIOLO et al. (2023) who showed that refueling and costs are the most important barriers.

Figure 1: Potential areas of farm work for alternative fuel tractors from farmers' point of view. Multiple answers possible. (N = 141)

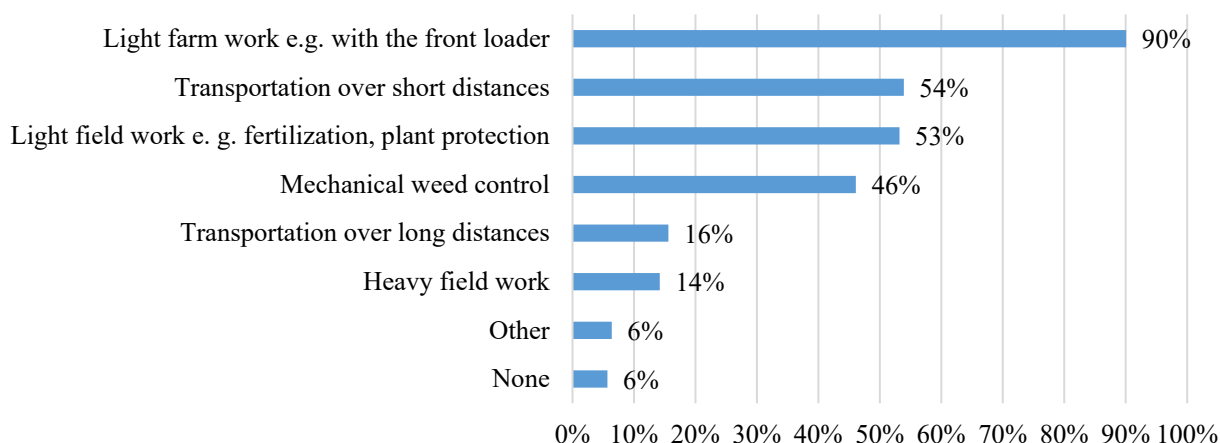
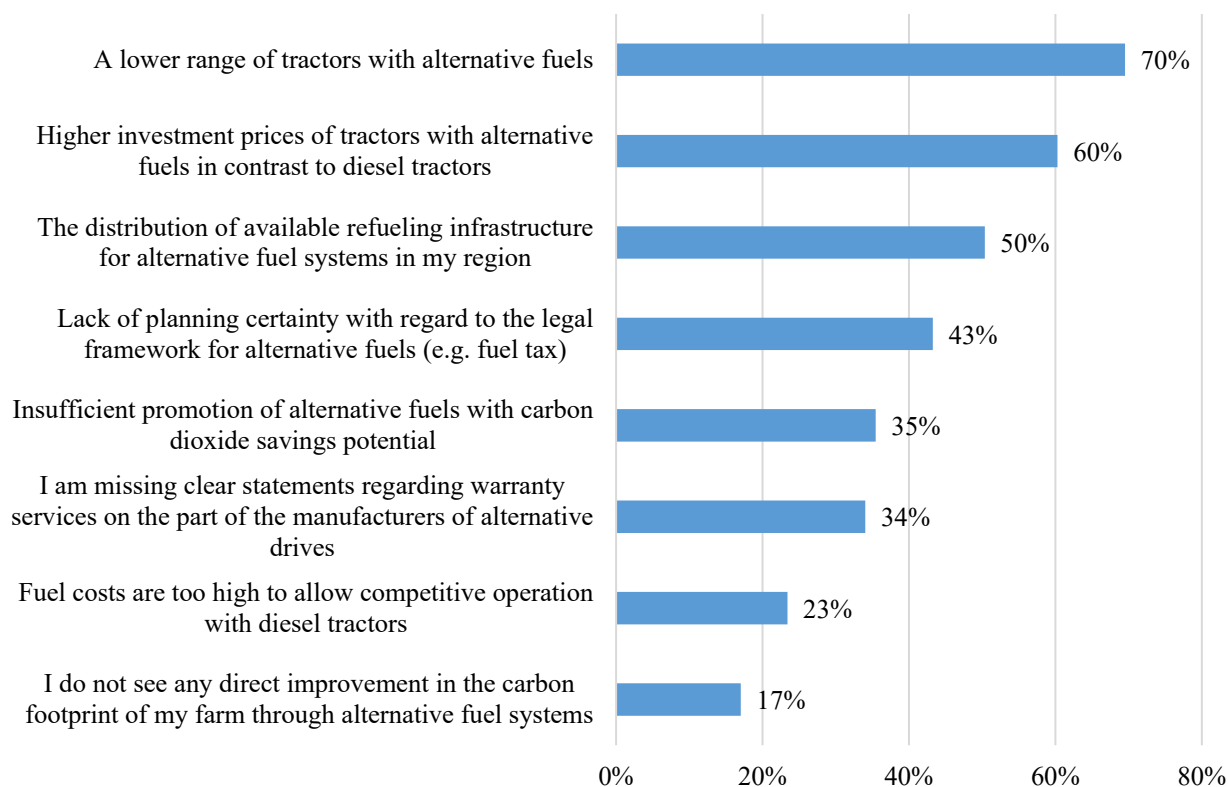


Figure 2: Barriers to the adoption of alternative fuel tractors. Multiple answers possible. (N = 141)



4.2 Estimation results of the UTAUT model

Tables 3 and 4 show the estimation results for the outer model. Three results in Table 3 merit particular attention and are mentioned first. First of all, the construct “Effort Expectancy” did not meet necessary quality criteria. Hence, we decided to split the construct up into two single-item constructs “Effort Expectancy – Refueling” (H3a) and “Effort Expectancy – Service” (H3b)

which is still in line with HAIR et al. (2022) who pointed out that the use of single-item constructs is possible in PLS-SEM. The same holds for the construct “Facilitating Conditions” which we split up into the constructs “Facilitating Conditions – Market” (H5a) and “Facilitating Conditions – Infrastructure” (H5b). Second, the indicator loadings of “epe2” and “epe3” for the construct “Ecological Performance Expectancy” are below the common cut-off level of $\lambda = 0.7$ (HAIR et al., 2022). However, HULLAND (1999) reasoned that only indicators with a loading less than 0.5 should be dropped. HAIR et al. (2022) proposed that indicators should be retained in the model if their drop would negatively affect further model results and validity. Furthermore, bootstrapping results show that both indicator loadings are statistically significant at the 5% significance level. Hence, the indicators were kept in the model. Third, the indicator “gpe3” is also below the common cut-off level of $\lambda = 0.7$ (Hair et al., 2022). We use the above explanation to clarify why the indicator remains in the model. However, the AVE value for the construct “General Performance Expectancy” amounts to 0.496, which is close to the threshold of 0.5 but still below it. FORNELL AND LARCKER (1981, p. 46) argued that if the estimated CR for the associated construct is above the recommended threshold, the “[...] construct is adequate, even though more than 50% of the variance is due to error”. Hence, we see internal consistency established for the construct “General Performance Expectancy”. All other indicator loadings exceed the common threshold of 0.7. Furthermore, all values for CR and AVE exceed the recommended quality criteria thresholds establishing internal consistency and convergent validity. Values for the outer and inner VIFs (max. value of inner VIF = 1.53) indicate that multicollinearity is not at a critical level as no VIF exceeds the threshold of 5. Lastly, the results for HTMT (max. HTMT value = 0.739) do not exceed the threshold 0.9 which establish sufficient discriminant validity for the outer model (HAIR et al., 2022).

Table 3: Outer model results (N = 141)

Construct Indicator	Factor Loadings λ	Mean	SD	OVIF	CR	AVE
<i>General Performance Expectancy</i>					0.742	0.496
gpe1	0.803***	2.772	1.238	1.081		
gpe2	0.793***	2.772	0.997	1.081		
gpe3	0.586***	3.577	1.076	1.121		
<i>Ecological Performance Expectancy</i>					0.747	0.512
epe1	0.947***	3.570	1.125	1.201		
epe2	0.550**	3.503	1.121	1.391		
epe3	0.582**	3.611	1.091	1.550		
<i>Effort Expectancy – Refueling</i>					-	-
ee1	-	2.752	1.135	1.000		
<i>Effort Expectancy – Service</i>					-	-
ee2	-	3.309	0.941	1.000		
<i>Social Influence</i>					0.816	0.596
si1	0.789***	2.819	1.056	1.561		
si2	0.753***	2.268	1.072	1.142		
si3	0.774***	2.711	0.964	1.633		
<i>Facilitating Conditions - Market</i>					0.831	0.711
fc1	0.887***	1.879	0.889	1.224		
fc2	0.797***	1.739	0.870	1.224		
<i>Facilitating Conditions – Infrastructure</i>					-	-
fc3	-	3.839	1.118	1.000		
<i>Intention to Buy an Alternative Fuel Tractor</i>					0.806	0.678
int1	0.907***	1.899	1.047	1.162		
int2	0.730***	1.550	0.930	1.162		

SD = Standard deviation, OVIF = Outer variance inflation factors, CR = Composite reliability, AVE =

Average variance extracted

***p<0.01; **p<0.05; *p<0.1

Table 4 shows the results of the inner model. Explained variance (R^2) of the target constructs amounts to 23.1%. Most of the hypotheses derived in section 2 are supported by the model, with the exception of H3a and H3b, for which the path coefficients are not statistically significant.

Table 4: Results of the inner model (N = 141)

Path	H	Path coefficient β	t-value ^a	p-value	Support H?
GPE → INT	H1	0.195**	2.315	0.010	Yes
EPE → INT	H2	0.171**	1.815	0.037	Yes
EE – Refueling → INT	H3a	-0.060	0.627	0.265	No
EE – Service → INT	H3b	0.027	0.360	0.363	No
SI → INT	H4	0.210**	2.200	0.014	Yes
FC – Market → INT	H5a	0.131**	1.678	0.045	Yes
FC – Infrastructure → INT	H5b	0.091*	1.322	0.093	Yes

EE – Refueling = Effort Expectancy – Refueling, EPE = Ecological Performance Expectancy, FC – Market = Facilitating Conditions – Market, FC – Infrastructure = Facilitating Conditions – Infrastructure, INT = Intention to Buy an Alternative Fuel Tractor, GPE = General Performance

Expectancy, EE – Service = Effort Expectancy – Service, SI = Social Influence

***p<0.01; **p<0.05; *p<0.1

R^2 (INT) = 0.231, Q^2 (INT) = 0.094 ^a Bootstrapping result with 10,000 sub-samples

³ As path coefficients in PLS-SEM are standardized, they allow a comparison in their magnitude.

5 Practical implications, limitations and conclusions

According to the inner model results, increasing the perceived general performance of alternative fuel tractors also statistically significantly increases farmers' intention to buy them (H1, Table 4). Furthermore, the construct is the second strongest predictor² of farmers' intention to buy alternative fuel tractors. This aligns with LOMBARDI AND BERNI'S (2021) findings, where engine power was a major determinant in adopting electric fuel tractors. The notion that farmers expect alternative fuel tractors to perform similarly to diesel tractors resonates with the studies by SOK AND HOESTRA (2023) and FRENZEL et al. (2021), underscoring the importance of meeting these performance expectations. These findings have important implications. Firstly, they suggest that farmers expect alternative fuel tractors to perform at a level comparable to that of diesel-powered tractors. For manufacturers, this implies that the efficiency of alternative fuel tractors must be correspondingly high to stimulate purchase intention. Secondly, the comparable performance of alternative fuel tractors could be utilized for marketing purposes, given the results of the perceived barriers to the use of alternative fuel tractors (Figure 3). Furthermore, this could potentially reduce farmers' perception that alternative fuel tractors are only suitable for low-energy tasks on the farm or field (Figure 2). Ecological performance expectancy encompasses the reduction of greenhouse gas emissions and the effective utilization of agricultural or fuel-production by-products associated with alternative fuel tractors, statistically significantly increases farmers' intention to buy them (H2, Table 4). This also corresponds to the highest approval regarding the associated indicators for the construct

“Ecological Performance Expectancy” in Table 3, mirroring sentiments observed by BESSETTE et al. (2022) among small-scale growers. The results of SOK AND HOESTRA (2023) are however in contrast. Based on our results, it can be expected that farmers are very willing to buy tractors that use alternative fuels to help protect the environment. This environmental consciousness should be addressed by marketing activities. Furthermore, it can be assumed according to the results in Table 3 that they also could be willing to engage in raw material production for alternative fuel production or use the by-products of alternative fuel production. These results have implications for extension services, as they can assist in elucidating the economic benefits of alternative fuel use and making them more appealing to farmers. Nevertheless, it could be worthwhile to investigate the reason for our contrasting results with SOK AND HOESTRA (2023).

One potential explanation could be the ongoing “nitrogen crisis” in the Netherlands mentioned by SOK AND HOESTRA (2023) which could cause general reluctance by the farmers to environmental issues and regulations. A direct country-comparison could shed more light on these contrasting results. The non-statistically significant impact of both “Effort Expectancy” constructs on farmers' intention to purchase an alternative fuel tractor (H3a and H3b, Table 4) raises suspicions. Two possible explanations may be put forward to account for these findings. Firstly, farmers may not be sufficiently familiar with the diverse refueling methods and necessary repair and maintenance procedures for new alternative fuel systems as indicated by the studies of BAGAGIOLO et al. (2022). Secondly, it is more probable that the refueling and maintenance systems differ too much for various alternative fuels. For instance, loading an electric tractor is simpler than refueling a biomethane tractor. Although the effect was not statistically significant, farmers may still benefit from receiving information about refueling and maintenance procedures through marketing activities conducted by manufacturers. Social influence is the strongest statistically significant predictor for farmers' intention to buy an alternative fuel tractor (H4, Table 4). This result implies that agricultural machinery manufacturers could use agricultural magazines or testimonials for marketing purposes and to disseminate knowledge about alternative fuels. Likewise, agricultural professional meetings could be used for marketing activities as they can also stimulate the exchange of experience and knowledge among farmers on the topic. Perceived favorable facilitating conditions are statistically significantly positively associated with farmers willingness to buy an alternative tractor in the future (H5a, Table 4). Hence,

planning certainty regarding the legal framework can stimulate farmers' intention to buy an alternative fuel tractor. This result is also supported by the results in Figure 3. Regarding political implications, farmers express the need for certainty regarding the legal framework surrounding alternative fuels (H5a, Table 4) as noted in the works of SOK AND HOESTRA (2023). Likewise, the expansion of infrastructure for the supply of alternative fuels must be politically supported (H5b, Table 4).

However, it is important to acknowledge the limitations of our research. The focus on German full-time farmers may not fully capture the diverse agricultural contexts across different regions and farming scales. To be specific, the use of this sample could introduce biases, affecting the generalizability of our findings. This limitation opens avenues for future research, highlighting the need for comparative studies across various cultural and farming contexts and suggesting the potential value of longitudinal studies to track the evolving perceptions of farmers as alternative fuel technologies advance. Additionally, hydrogen-powered tractors could be an interesting subject for future research inquiries. By continuing to explore these crucial themes, one can better support the agricultural sector's journey towards a more sustainable and environmentally responsible future.

In summary, for agricultural machinery manufacturers, our findings underscore the importance of aligning tractor performance with farmers' expectations. Demonstrating that alternative fuel tractors can perform comparably to diesel counterparts is crucial. Professional magazines and testimonials could effectively be used for this. Policymakers can leverage the study's insights to formulate policies that support the adoption of alternative fuel technologies in agriculture. Incentives and infrastructure development could accelerate the shift towards more sustainable agricultural practices. Lastly, for farmers, the insights into factors that drive adoption decisions can inform their choices and open avenues for more sustainable farming practices.

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CROP STRAW PELLETS AS INNOVATIVE AND SUSTAINABLE SUBSTRATE ALTERNATIVE FOR GERMAN BIOGAS PLANTS – A SCENARIO-BASED PROFITABILITY ASSESSMENT

Sören Mohrmann¹, Verena Otter

Abstract

Biogas production is still the third most important renewable energy source for electricity generation in Germany. Due to stakeholder interests in using the limited agricultural land for sustainable food production, the cultivation of energy crops is likely to decline in the future. Silage maize, still the most important biogas substrate in Germany, is to be replaced by agricultural residues such as straw, which have played a subordinate role to date. Crop straw processed to pellets has improved fermentation and transport properties and represents an opportunity to substitute traditional renewable energy crops in line with political agendas. Business literature provides little consistency in evidence on the costs of plant-based residuals like straw pellets for biogas production compared to other substrates. Therefore, we raise the research question, how the substrate costs per kilowatt hour change the economic profitability of typical biogas plants in Germany when silage maize is replaced by straw pellets and technical restrictions of the plants are considered. In order to answer this question, field trials on mobile and semi-mobile pelleting and feeding of straw pellets were carried out. The trial data were supplemented by calculatory assumptions in a scenario-based full costs analysis of biogas plants with typical substrate compositions. The results make an important contribution to assessing the suitability of straw pellets as an innovative, sustainable substrate alternative. Plant operators, biogas consultants and political decision-makers receive an overview of the costs of using straw pellets as agricultural residues instead of silage maize and their effects on the profitability of biogas plants with typical substrate compositions as a basis for decision-making.

Keywords

Agricultural residues, biomass, crop straw pellets, scenario-based full cost analysis, pelleting costs, maize cap

1 Introduction

According to current estimates, gross electricity generation from renewable energies totalled 254 billion kilowatt hours (kWh) in 2022, accounting for 46 % of total electricity generation in Germany. Biogas is, as in previous years, with 12 % (30.5 billion kWh) the third most important source of electricity generation after onshore wind and photovoltaics (BMWK, 2023). Biogas and biomethane plants can provide electricity flexibly and in line with demand, thus saving energy system costs for storage or back-up capacities elsewhere. In addition, biomethane offers the possibility of replacing natural gas in the chemical industry more easily than hydrogen (Matschoss et al., 2020; Mertins et al., 2023). At the same time, biogas is not deemed to be very competitive compared to wind and photovoltaics due to the comparatively high production costs per unit of energy (Science Media Center Germany, 2023).

Stakeholder interests regarding food security, species protection, organic farming and natural climate protection, led to the introduction of the maize cap in the German Renewable Energies

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Act (REA) in 2012 to limit the cultivation of energy crops on agricultural land. In 2017, the mass-related substrate input in biogas plants consisted of 6.6 % by-products and biowaste, 44.5 % excrement and 48.9 % renewable raw materials. Maize accounted for 72 % of the renewable raw materials, representing 35.2 % of the total mass input (Daniel-Gromke et al., 2017). In a scenario with a constant number of biogas plants and a reduction in maize cultivation by 5.2 % (45.604 ha) due to the maize cap of 30 % (from 2026), the production of 962.5 GWhel must be replaced by alternative substrates (assumption: 21,104.5 kWhel/hectare of silage maize).

Political agendas continue focussing on residual and waste material for biogas production, although their potential is lower compared to the large-scale cultivation of renewable raw materials such as silage maize. Even if biogenic residues and waste and the additional biomass from modified cultivation systems (e.g. catch crops, nurse crops) can still be utilised to a certain extent, the amount of biogas produced in Germany is likely to decrease in the future (Science Media Center Germany, 2023). Although crop straw is particularly suitable among agricultural plant residues due to its availability in most regions of Germany (Brosowski et al., 2020), it currently does not play a role as biogas substrate (Daniel-Gromke et al., 2020). Based on the methane yield per hectare, 5.2 times the area of crop straw is needed to replace one hectare of silage maize (KTBL, 2013). Straw pellets as an innovative substrate alternative for biogas plants could be a better alternative, as in addition to advantages in fermentation and transportability, they only require 3.3 times as more land due to a higher methane yield compared to unprocessed straw (Loewen et al., 2024). From a practitioners' perspective, the question arises, how the total substrate costs per kWh of biogas plants in Germany change if silage maize - the currently most efficient biogas substrate - is increasingly replaced by such agricultural by-products.

Business literature shows substrate costs for silage maize as single substrate and for mixtures of silage maize combined with other standard substrates (Böhm et al., 2018; Stürmer et al., 2011; Wunsch et al., 2012). Also, single costs for crop straw and straw pellets as plant-based agricultural residues are described, however, without taking process costs for storage and feeding into account (Svensson et al., 2006; Schwarz, 2016; Reinhold, 2014). An initial approach to analyse the influence of the partial replacement of silage maize with crop straw as an agricultural residual on the total substrate costs was conducted by Stockmann et al. (2021) using the example of a 300 kWel biogas plant. They compared the feeding of 100 % silage maize with a substrate mix of 50 % silage maize and 50 % barley straw, without considering additional costs for technology, energy, pre-treatment processes as well as land costs (Stockmann et al., 2021). These were also not considered by Schwarz et al. (2019) when determining the substrate costs of crop straw pellets treated with caustic soda. No details were provided on the technical feasibility (e.g. feed-in, stirring capability) of feeding the substrate mix under consideration to the biogas plant. In the aforementioned studies on straw utilisation, no quality criterion, such as the maximum dry matter content in the biogas digester, was used to consider the technical usability or the maximum technically possible share of straw in the input of existing biogas plants.

Based on the state of the art of scientific literature we raise the research question: How do the substrate costs per kWh change the economic profitability of typical biogas plants in Germany if silage maize is replaced by crop straw pellets, considering the maximum technically possible proportion of straw pellets in the total substrate input?

To answer this question, a total of seven scenarios were defined for a pilot biogas plant with 530 kWel in order to conduct a scenario-based full cost analysis based on field trial data supplemented by data from Biogas Measurement Programme III (BMP III). The results should guide biogas plant operators and consultants regarding which pellet quantities can be used and how that affects the profitability of different typical biogas plants in Germany. In addition, we

can contribute to the political discussion on the design of future REA amendments or other subsidy programmes with regard to the promotion of residual material use, e.g. in the form of crop straw pellets.

The article is structured as follows: In section two, we give an overview of substrate costs in biogas production processes. Subsequently, in section 3 we describe the scenarios considered, data assumptions and the procedure for the scenario-based full cost analysis. In section 4 the results are described and discussed. The article ends with recommendations for action.

2 Substrate costs in biogas production

Accounting for around 50 % of the total costs of biogas production, substrate costs have a significant influence on overall profitability of biogas plants (Mohrmann et al., 2021b). The costs per kWhel for single substrates – mainly for silage maize - and for complete substrate mixes of a biogas plants have already been determined in past practical and scientific studies. The BMP III provides an orientation, indicating average substrate costs of 7.2 ct/kWhel for 49 biogas plants in Germany with total electricity production costs of 18.9 ct/kWhel (Barchmann et al., 2021). For the state of Lower Saxony an average of 10.56 ct/kWh including the digestate transport (9.76 ct/kWh without digestate) was discovered by Schünemann-Plag (2016). Schievano et al. (2015) calculated substrate costs in different growing scenarios only for silage maize in Italy between 8.6 ct/kWhel and 12.3 ct/kWhel. Costs of other standard substrate alternatives like whole silage of cereals, grass and sorghum range between 6.8 ct/kWhel and 15.0 ct/kWhel (Schievano et al., 2015). Böhm et al. (2018) used substrate costs of 7.8 ct/kWhel for both silage maize and whole cereal silage and 11.78 ct/kWhel for ground corn kernels. A cost analysis of substrates in relation to the size of the plant (250 kWhel or 500 kWhel installed production capacity) and the area available around the biogas plant (10 % or 20 % of land) showed that silage maize in monoculture cultivation cause relatively low substrate costs between 7.29 ct/kWhel and 7.81 ct/kWhel. In crop rotation with 50 % silage maize/30 % wheat and millet silage/20 % rye and sunflower silage the cost raises to 9.36 ct/kWhel to 10.11 ct/kWhel (Stürmer et al., 2011). A similar cost level of 9.4 ct/kWhel were reported for crop rotations with 50 % silage maize and 50 % whole plant silage from cereals, sorghum and sunflower (Wünsch et al., 2012).

The range of costs observed for using plant-based agricultural residues as biogas substrate is much greater than for standard energy crops, as the assumptions on purchase costs and transportation distances for straw as well as the definition of production costs (delivery to the biogas plant/delivery to solid input) are not uniform across various studies. Svensson et al. (2006) have shown that ley crops, wheat straw or sugar beet tops cause low costs between 5.7 ct/kWhel and 8.4 ct/kWhel. Cost of 4.61 ct/kWhel were mentioned only for straw harvesting and transport to the biogas plant (<5 km distance) (Schwarz, 2016). Rather low costs of between 2.8 ct/kWhel and 3.3 ct/kWhel were reported in a practical study on unprocessed crop straw from 2018, neglecting additional costs of straw fermentation, such as higher stirring costs (Neumann, 2018). 8 ct/kWhel without and 13 ct/kWhel with storage costs were calculated for crop straw by including harvest and transport cost by Reinhold (2014). Stockmann et al. (2021) compared two substrate mixtures: On the basis of 100 % silage maize (Price: 35 €/t) substrate costs of 8.2 ct/kWhel were calculated. Using 50 % maize combined with 50 % unprocessed barley straw (Price: 60 €/t) the substrate costs rise to 9.2 ct/kWh for the biogas plant. With supply costs for the barley straw of 40 Euro per ton, costs can be reduced to 7.1 ct/kWhel, excluding additional costs for technic, energy consumption, pre-treatment processes or land costs (Stockmann et al., 2021). For crop straw pellets treated with caustic soda a range between 10.6 ct/kWhel and 21.7 ct/kWhel was identified based on substrate costs for straw of 25 €/t (only harvest), 55 €/t and 100 €/t fresh mass (Schwarz et al., 2019). Overall, the literature shows a relatively wide range of estimated or observed substrate costs due to the individuality of the biogas plants and their operating concepts (Grösch et al., 2020)

3 Methods and data

3.1 Field trial data

Due to the novelty of mobile and semi-mobile pelleting processes, data on the machine's performance and energy consumption data during the pelleting of crop straw were recorded initially, using the "Krone Premos" as an example. In addition, the labour time required for feeding straw pellets was recorded and a measurement was carried out for the electricity consumption when feeding straw pellets into the pilot biogas plant located in Relliehausen.

For semi-mobile pelleting from square bales, the pellet quantity in tonnes per time unit (t/h) was determined using the number of bales and the average weight per bale. The pelleting machine has an automatic straw bale opener and a feed table on which up to up to three bales can be deposited. A throughput of 2.17 t/h was determined on the basis of the average pelleting time per bale measured. Considering daily and temporary technical errors in between, an actual throughput of 1.71 t/h was observed, which deviates from the manufacturer's specifications of up to four tonnes. For the full cost analysis, the own results were averaged with the manufacturer's data to a throughput of 2.65 t/h. For the mobile pelleting machine, the performance and consumption data were recorded manually and supplemented by data from the machine terminal on a plot with a size of around five hectares. It was separated between active pelleting time (time in which the machine actively picks up straw from the swath) and inactive time (disruption times, turning time/empty runs in the field, bunkering at the headland of the field, set-up times in the field/on the farm as well as the journey to the field (distance approx. 4 km). The quantities of pellets produced were measured via the weighing unit of the machine bunker. For the cost calculation, the average throughput of 3.65 t/h was used, taking journey and set-up times into account.

The labour input required to feed a biogas plant with straw pellets and other individual substrates was measured during the daily feeding of the solids input with a telescopic loader. Firstly, the start and end points for the time measurement were determined before the feeding was completely recorded over two days by the same person using a stopwatch (REITH, 2018). The results show a feeding capacity of 19.9 t/h for crop straw pellets at 170 m storage-biogas plant distance and 42.8 t/h for silage maize at 40 m distance. These were used to convert the feeding costs per tonne for straw pellets using silage maize based on BELAU et al. (2012). Possible changes in the daily working time during the trials (e.g. increasing working hours required for troubleshooting due to the use of pellets, closer monitoring of the stirring ability), were documented by the responsible employees of the biogas plant. No need for additional activities were identified that could be attributed to the use of crop straw pellets.

The own power consumption of the solids input when feeding straw pellets and other substrates was measured from the steep screw conveyor by a data logger, while the other units were measured manually with a clamp-on amperemeter via the ongoing consumption of mixing augers (left, right) and the tamping auger.

3.2 Full costs analysis

The aim of the scenario-based full cost analysis was to determine the change in the full costs of biogas production in cent per produced electrical kilowatt hour (ct/kWh_{el}) that would result from the use of crop straw pellets instead of silage maize, considering the costs of the whole process from purchase to feeding in the biogas plant.

At first the full costs of straw pelleting from mobile and semi-mobile processing was carried out based on the collected data (see chapter 3.1). Missing data such as storage costs, parts of the machine costs (e.g. for straw baling, bale transport) and the labour rate of 21.5 €/h were supplemented with data from the "Kuratorium für Technik und Bauwesen in der Land-

wirtschaft” (KTBL, 2022, 2023). As there are no empirical values for the use of mobile pelleting machines in practice and science, a capacity utilisation of 555.6 hours per year in total (50 % mobile/50 % semi-mobile use) is assumed. The capacity utilisation for mobile pelleting was extrapolated based on comparable numbers of a square baler with a tandem axle. According to KTBL (2023), the capacity utilisation is 8,333 bales per year, assuming an average capacity of 30 bales per hour. As square balers are only used in summer and a pelleting machine like the “Krone Premos” all year round, these numbers were doubled for the estimations in this study. The diesel price was set at 1.26 €/l without sales tax (Ø 2020-2022) (STATISTISCHES BUNDESAMT, 2023). As part of a sensitivity analysis three procurement options for crop straw pellets were considered to show the influence of different cost levels: Mobile pelleting, mobile pelleting with consideration of crop straw purchase costs from the field of 35 €/t, semi-mobile pelleting and semi-mobile pelleting from straw bales with a purchase price of 100 €/t delivered to the biogas plant.

In the scenario-based full cost analysis, the trial data was supplemented by average values from 31 analysed biogas plants from the BMP III which are technically comparable with the trial biogas plant in Relliehausen. Apart from the revenue, the variable costs for repairs and maintenance, other operating costs as well as the fixed costs for labour and depreciation were used from BARCHMANN et al. (2021). The substrate costs for each substrate mix (see chapter 3.2) were calculated based on the price assumptions from Table 1, which were obtained from an own survey with 309 German biogas plant operators in 2021. Where price information for a substrate was missing, the price was converted equivalent to the price of silage maize on the basis of the methane yield per ton based on KTBL (2013). Storage and ensiling losses of 1 % for crop straw pellets and 12 % for silage maize, whole plant cereal and grass silage were factored into the price assumptions (BELAU et al, 2012). The digestate transport costs were also considered based on the collected survey data.

Table 3 Substrate costs and purchasing distances by region in Germany

Average value per region	Substrate procurement					Digestate	
	Distance	Price silage Maize*	Price grass Silage*	Price cattle slurry	Price cattle manure	Distance	Costs
Unit	km	€/t	€/t	€/t	€/t	km	€/m ³
Livestock region ¹	4.9	38.1	-	3.60	9.70	8.7	5.2
Arable region ²	5.1	37.8	-	3.05	8.05	6.0	4.4
Small-scale livestock region ³	5.5	38.4	25.0	3.63	8.13	5.6	4.1

Source: Own data collection; ¹HH, HB, NI, NW, SH; ²BB, BE, MV, SN, ST, TH; ³BW, BY, HE, RP, SL; *without storage losses of 12 %

The costs of own power consumption as part of the variable costs are strongly dependent on the dry matter content in the digester (OECHSNER et al., 2018). Due to the higher dry matter content of crop straw pellets compared to silage maize, additional costs are to be expected. As the power consumption measurement was only possible for the solids input up to the stuffing screw without the agitator technique in the containers, it was not possible to generate sufficient, generally valid information for a forecasting of the change in the total power consumption when feeding straw pellets. Therefore, the following calculatory approach was developed: First, we compared the dry matter content in the digestate storage and the own power consumption in percent of n=17 biogas plants from BMP III including the trial biogas plant in Relliehausen (BARCHMANN et al., 2021). As the correlation coefficient of 0.53 was relatively high, the mean values for own power consumption and the dry matter content in the digestate storage were set in relation and a factor of 1.01:1 was determined. Accordingly, the development of own power demand between the scenarios was extrapolated on the basis of this factor (HAWK GÖTTINGEN und GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN, 2023).

3.3 Scenario development

In order to provide an overview of the influence of the utilisation of crop straw pellet on the profitability of typical biogas plants in Germany, a total of six sample plants were defined as baseline (V1, V3.1, V4.1, V5.1, V6.1 and V7.1) (see Table 2). These are based on the trial biogas plant Relliehausen with an installed capacity of 530 kW_{el} and an electrical production of 4.4 million kWh electricity per year. In addition, eight scenarios with crop straw pellets in the substrate mix were developed: Scenarios V1-V5 belong to a livestock region with intensive biogas production like in north-west of Germany, V6 to arable farming regions with large-scale structures like in the eastern part of Germany and V7 to small-scale livestock regions like in the southern part of Germany.

As the electrical output always remains the same under the assumptions given, the revenue is unchanged between the scenarios, while focussing on the analysis of the resulting costs. When developing the scenarios, care was taken to ensure that the proportion of maize that can be replaced by straw pellets is at most high enough to assure the stirring ability in practice. The dry matter content (DM %) of the digestate in the final digestate storage was used as an indicator for this. The threshold value was set to approx. 10 %. This roughly corresponds to a maximum dry matter content of 12 % in the biogas digester, which is a maximum for most biogas plants depending on the stirring technology installed (KUSCH und OECHSNER, 2004; REINHOLD, 2019). The dry matter content in the digestate was calculated on the basis of the substrate mixtures fed and their dry matter contents according to the concept for mass and dry matter balancing in agricultural biogas plants by REINHOLD (2005). Noticeable already at this point is that even for substrate mixtures with a low initial dry matter content, such as V5 (high proportion of liquid manure) and V6 (high proportion of sugar beet), no more than 10% straw pellets should be used in the overall substrate mix.

Table 2 Scenarios of the profitability analysis

Scenario		Substrate		Silage maize	Sugar beet	Cattle slurry	Cattle manure	Straw -pellets	DM digestate
		DM %	t/a	%	%	%	%	%	DM % ¹
Pilot Plant „Rel-liehausen“	V1	23.8	15,625	30.0	25.0	25.0	20.0	-	8.5
	V2	26.0	14,678	20.3	26.6	26.6	21.3	5.2	10.0
Livestock region	V3.1	25.0	14,177	60.0	-	40.0	-	-	7.9
	V3.2	28.8	12,816	47.1	-	44.2	-	8.6	10.4
„NaWaRo“ domi-nated	V4.1	32.0	10,190	75.0	25.0	-	-	-	8.1
	V4.2	34.1	9,710	69.8	26.2	-	-	4.0	9.4
	V4.3	35.2	9,497	67.3	26.8	-	-	5.9	10.0
Slurry dominated	V5.1	15.0	29,309	20.0	-	80.0	-	-	6.8
	V5.2	17.1	27,102	6.9	-	86.6	-	6.6	8.4
	V5.3	18.3	26,071	0.0	-	89.9	-	10.1	9.3
Arable region	V6.1	25.1	13,776	50.0	20.0	30.0	-	-	7.4
	V6.2	29.6	12,264	33.8	22.5	33.7	-	10.0	10.3
Small-scale live-stock region	V7.1	26.3	13,743	45.0	-	35.0	20.0	-	8.9
	V7.2	28.6	12,944	36.6	-	37.2	21.2	5.1	10.5

Source: Own data; ¹Calculated based on on REINHOLD (2005)

The amount of digestate in all scenarios was calculated for the total substrate mix based on the fugate factors by KTBL (2013). For straw pellets a fugate factor of 0.36 was determined (LOEWEN et al., 2024). The required storage space for digestate was monetised at 6.1 €/m³ in all scenarios in order to consider the storage space requirements for digestate of nine months

(MOHRMANN et al., 2021a). This assumption is based on a gas-tight digestate storage with construction costs of around 91 €/m³, a depreciation period of 20 years, an interest rate of 3 % and 100 % debt financing.

4 Results & Discussion

The field trials provided important insights into the innovation of straw pelleting in mobile and semi-mobile processes as a new way of utilising straw residue for biogas production. Based on the data collected, mobile pelleting with total costs of 87.42 €/t is the more favourable option compared to the semi-mobile processing (see table Table 3). The methane yield of 251 m³/t straw pellets (LOEWEN et al., 2024) results in power generation costs of 8.2 ct/kWh_{el}, which is in the range of the average costs stated in the business literature. Based on the calculated costs of 87.42 €/t from the trial data, the costs per tonne were extrapolated to 83.55 €/t for larger plots (20 ha) and 90.64 €/t for smaller plot sizes (2 ha) based on data for square balers from the KTBL-machine cost calculator. The semi-mobile variant is relatively expensive due to the higher pelleting costs of 138.1 €/t and the higher storage costs for straw bales of in total 1788.06 €/t and would lead to electricity generation costs of 17.4 ct/kWh_{el}. In practice, since mobile straw pelleting is only possible during the grain harvest in the summer of about 4-6 weeks, a mixed calculation with semi-mobile pelleting is necessary in order to achieve a sufficient utilization of the pelleting machine throughout the year. 50 % mobile and 50 % semi-mobile operation per year would result in average pelleting costs of 132.74 €/t (12.94 ct/kWh_{el}). This corresponds approximately to the maximum costs according to REINHOLD (2014) for unprocessed straw including storage costs. In this case too, the nutrient removal from raw materials was not assessed due to the closed nutrient cycle.

Table 3 Calculation of straw pelleting costs based on the livestock region

	Unit	Mobile pelleting	Semi-mobile Pelleting	Semi-mobile (purchased straw bales)
Pelleting performance	t/h	3.65	2.65	2.65
Straw balling	€/t	-	15.20	-
Bale transport	€/t	-	11.54	-
Straw purchase	€/t	-	-	100.00
Pelleting	€/t	79.57	138.09	138.09
Transport field - biogas plant	€/t	2.91	-	-
Transport pelleting machine to storage location	€/t	-	1.38	1.38
Storing bales (3 month)	€/t	-	8.24	-
Storing pellets (3 month)	€/t	4.32	2.37	5.10*
Interest	€/t	0.62	1.25	1.80
Full costs at biogas plant	€/t	87.42	178.06	246.37
<i>Electricity generation costs**</i>	<i>€/kWh</i>	<i>0.085</i>	<i>0.174</i>	<i>0.240</i>

Source: Own calculations; 4 km field-plant distance, *6-month storage of pellets, **9.97 kWh/m³ methane, 41 % biogas CHP plant efficiency

In addition to the pelleting costs displayed in Table 12, labour costs need to be considered to assess the profitability of straw pellet use.

As no additional workload could be observed for general plant management, no additional costs are to be considered here. Based on trial data, costs of 3.63 €/t were calculated for straw pellet feeding compared to silage maize with 1.69 €/t (BELAU et al, 2012). While the difference per tonne corresponds to 1.94 €/t, the cost of the input, considering the exchange factor of 0.45, is

almost the same as for silage maize at 1.63 €/t. These additional costs per tonne are included in the straw pellet price for crop straw pellets delivered to the solids input (LOEWEN et al., 2024). In the scenarios, based on the analysed data of BMP III, the total annual revenue of each plant amounts to 22.56 ct/kW_{el} and the total annual costs, with the exception of own power consumption and substrate costs, to 9.26 ct/kW_{el} (BARCHMANN et al., 2021). The change in profit for the different biogas plants was calculated in €/kW_{el} for each of the scenarios already presented in chapter 3.3. The differences in the substrate in- and outputs lead to changes in the costs of own power consumption, substrate, digestate and finally to the total power generation costs, which are shown in Table . The own power consumption costs show a spread for the baseline scenarios between 1.12 ct/kW_{el} (V5.1) and 1.56 ct/kW_{el} (V7.1). Depending on the proportion of straw pellets that can be run in accordance with the technical restrictions, the increase in own power consumption is between 20 % and almost 50 % compared to the baseline. This leads to own power consumptions costs for the scenarios with straw pellets in the substrate mix between 1.46 ct/kW_{el} and 1.98 ct/kW_{el}. Especially in V5.3 and V6.2, with a relatively high proportion of straw pellets of 10 %, the own power demand increases sharply. The dry matter content increases by around 40 % compared to the baseline, which results in a correspondingly higher power requirement for stirring and pumping. From the field trials it can be deduced that the higher own power consumption in straw pellet feeding must be due in particular to the agitator technology, as the power consumption of the feeding technology (solid matter feeding up to the tamping screw) was lower in the trials and should enable a cost saving rather than an increase. Finally, the actual change in own power consumption when using crop straw pellets will be very plant-specific, as the biogas plant concepts (type of the digester, agitating equipment) vary greatly (DANIEL-GROMKE et al., 2020).

Table 4 Own power consumption and substrate costs by scenarios

Scenario		Own power consumption costs	Substrate costs				Digestate	Total power generation costs
			Mobile	Mobile (purchased straw)	Semi-mobile	Semi -mobile (purchased bales)	Δ in storage & application	
		ct/kWh _{el}						
Pilot Plant Rellichausen	V1	1.47	8.20					18.92
	V2	1.80	8.07	8.68	9.65	10.84	-0.21	18.91-21.68
Livestock region	V3.1	1.34	8.83					19.43
	V3.2	1.88	8.65	9.53	10.92	12.64	-0.30	19.48-23.46
„NaWaRo“ dominated	V4.1	1.38	9.20					19.83
	V4.2	1.66	9.14	9.44	9.94	10.54	-0.11	19.94-21.34
	V4.3	1.79	9.11	9.55	10.26	11.14	-0.15	19.99-22.02
Slurry dominated	V5.1	1.12	7.69					18.05
	V5.2	1.46	7.39	8.81	11.07	13.85	-0.49	17.60-24.07
	V5.3	1.64	7.25	9.34	12.65	16.73	-0.72	17.42-26.90
Large-scale arable region	V6.1	1.23	8.81					19.30
	V6.2	1.87	8.52	9.50	11.15	13.06	-0.34	19.30-23.84
Smale-scale livestock region	V7.1	1.56	8.80					19.61
	V7.2	1.98	8.72	9.24	10.03	11.04	-0.18	19.78-22.10

Source: Own data collection

Substrate costs are strongly influenced by the use of straw pellets in all scenarios. While the substrate costs in the baseline scenarios range between 7.69 ct/kW_{el} (V5.1) and 9.2 ct/kW_{el} (V4.1), the substrate costs in the pellet scenarios vary between 7.25 ct/kW_{el} and

16.73 ct/kWh_{el}, depending on the purchasing costs for straw pellets. This observation emphasises the importance of a detailed substrate cost analysis for new substrate mixtures. As can be derived from Table , straw pellets from mobile pelleting offer the possibility of keeping the profit almost the same or even achieving a minor economic advantage over the baseline variant: The replacement of silage maize by pellets from mobile pelleting can lead to a substrate cost reduction of 0.7 % to 5.7 % compared to the respective baseline scenario. The low-cost mobile produced pellets can mostly compensate the additional costs for the higher own power consumption with the savings for the digestate application costs and the calculatory costs for the digestate storage. This becomes particularly clear in V5.2 and V5.3, in which not only a very high proportion of silage maize can be replaced, but also the cost savings for digestate application and storage have a disproportionately high impact despite increasing own power demand. In V4.2 and V4.3, the substrate cost advantage does not occur in this way, as the dry matter content is already relatively high and only a small proportion of pellets can be used. The cost increase in own power consumptions cannot be compensated in those scenarios. Additionally, mobile pellets do no longer provide a cost advantage in the substrate mix under the assumption of smaller plot sizes and the associated higher pelleting costs per tonne for mobile pelleting in V7.2. As the results for mobile pelleting show, straw pellets can be a profitable substitute to silage maize under favourable production conditions. However, this is only possible if it is assumed that the nutrients removed from the straw are returned via the digestate application and remain in the nutrient cycle. In comparison to the alternative, energetic utilisation of straw in the form of incineration, where nutrient recycling is technically not possible, this assumption can certainly be justified in the case of biogas utilisation (BROSOWSKI et al., 2020). The assumption of nutrient recirculation must be checked for each individual plant. It applies if the digestate is returned to the corresponding fields which is likely to be the case for the majority of biogas plants that use straw from their own land or straw-supplying farms in the immediate surrounding of the biogas plant. Otherwise, the nutrient removal and possibly a profit margin for the straw seller must be compensated. If purchase costs of 35 €/t for straw are added to the mobile pelleting costs, the substrate costs in the pellet scenarios are between 2.6 % and 21.5 % higher than in the baseline scenarios. Due to the purchase costs, straw pellets from mobile production lose their advantage over silage maize, so that the average substrate costs per kWh increase even in scenarios with a low straw pellet share in the input (V2, V4.2/4.3, V5.2, V7.2).

Compared to mobile pelleting, the costs of semi-mobile pelleting are considerably higher, particularly due to the low throughput per hour and additional machine and labour costs for feeding straw bales. The costs of the substrate mixes with straw pellets from semi-mobile pelleting are between 8.0 % (V4.2) and 64.5 % (V5.3) higher than in the baseline scenarios, depending on the proportion of straw pellets. If pellets are used in the semi-mobile process from purchased square bales, the costs raise sharply and lead to additional costs compared to the baseline of between 14.6 % (V4.2) and 117.6 % (V5.3). In view of the fact that 56 % of straw pellets are traded in the 200-250 €/t price range and 28 % above 250 €/t, regardless of the sales volume, this variant is not an option for biogas production and can only be considered in small proportions as in V4.2 or V4.3 in the case of substrate shortages (HAWK GÖTTINGEN und GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN, 2023).

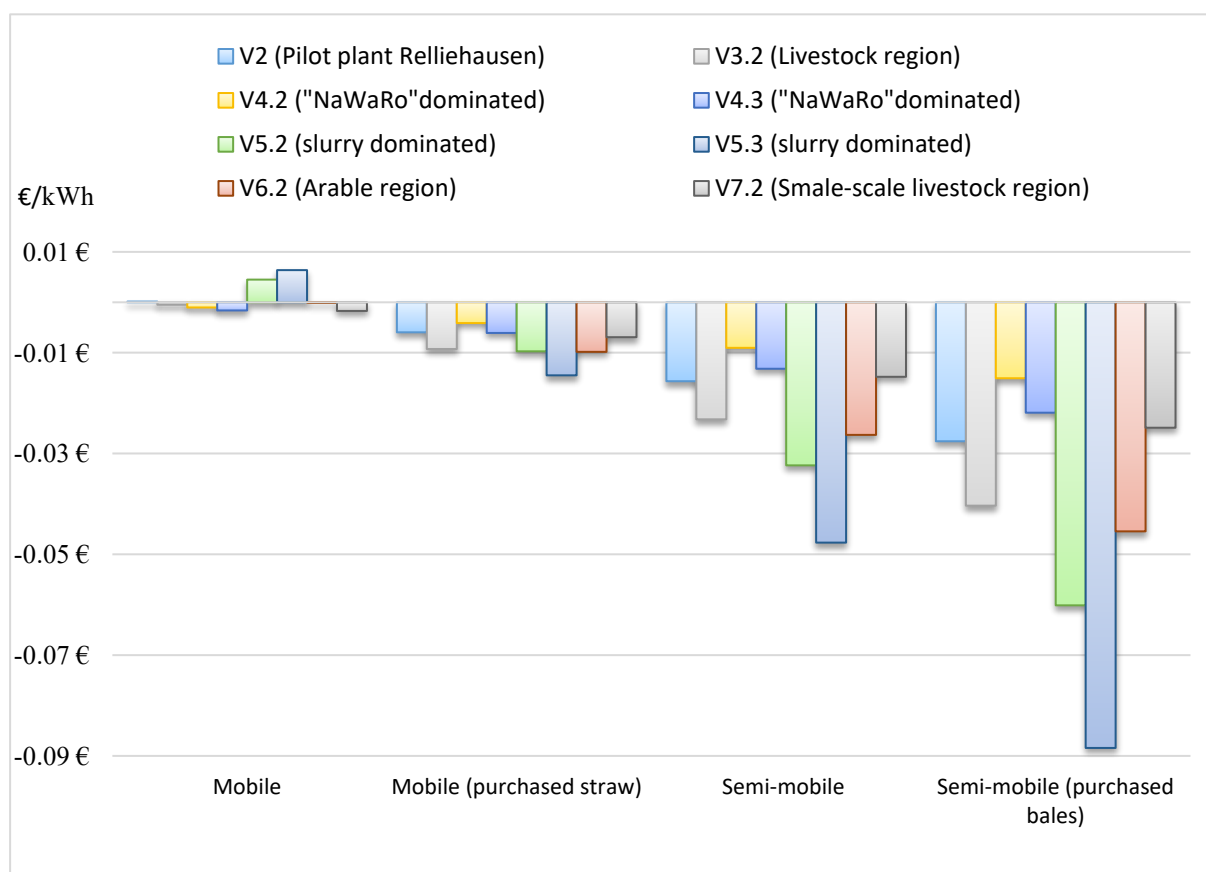
When comparing the change in profit of the pellet scenarios to the baseline scenario (see Figure 25), it is evident that the profit of biogas plants remains more or less stable if silage maize is replaced by straw pellets from mobile production. A slight decrease of a maximum of 0.17 ct/kWh is observed in scenarios V3.2, V4.2, V4.3, V6.2 and V7.2. Scenarios V2 (0.015 ct/kWh), V5.2 (0.45 ct/kWh) and V5.3 (0.64 ct/kWh) show an increase in profit.

For all other pelleting variants, the profit decreases depending on the proportion of straw pellets in the total substrate composition. Assuming an average profit of 3.5 ct/kWh_{el} for the baseline plant scenarios considered here and an average profit of 4.59 ct/kWh_{el} in the BMP III

(BARCHMANN et al., 2021), higher straw pellet shares from partially mobile pelleting of purchased straw no longer result in a profit, but rather a loss.

Straw pellets may be suitable for use - even with higher production costs - if biomethane is to be produced instead of electricity. The revenue of 22.56 ct/kWh_{el} corresponds to a biomethane-equivalent price of 8.4 ct/kWh (based on energy value “Brennwert (Hs)”). At a price level of 9 ct/kWh (Hs) for biomethane from silage maize (Greenhouse gas value (GHG) of +30 CO₂eq/Mj), this would be around 10 ct/kWh (Hs) for straw pellets assuming an estimated GHG reference value of +15 CO₂eq/Mj. If the so-called double counting for residual materials such as straw were to be applied, this would be as much as 14 ct/kWh (HS). Depending on the scenario, the use of straw pellets under otherwise identical conditions from the semi-mobile pelleting of purchased straw would still make economic sense in this case. Important note: The calculation of the GHG reference value must be verified for each individual plant as part of the sustainability certification, as there is no standard GHG reference value for straw pellets, unlike for unprocessed straw or liquid manure.

Figure 1 Change in profit compared to the basis scenario



Soure: Own calculations

Overall, the results of this study provide a detailed overview of various biogas plants with typical substrate mixtures. In practice, the underlying assumptions need to be validated for applicability to every individual biogas plant as the technical equipment, retention times, availability of different substrates as well as transport routes for substrate and digestate transport vary from plant to plant (DANIEL-GROMKE et al, 2020; BARCHMAN et al, 2021). In particular, the electricity requirement - depending on the technical equipment - must be discovered in more detail in further research projects. The calculated rate of increase in own power consumption in this study should only be interpreted as a theoretically determined reference point. The procedure for the monetary valuation of the digestate storage assumes in this study that there is a shortage of storage space for digestate with regard to the minimum storage period of nine months for

landless farms due to the amendment of the Fertiliser Ordinance. If this is not the case in practice, this should be factored out. Finally, the production costs for straw pellets in the mobile and semi-mobile process should also be further validated in order to continue monitoring technical progress and to validate the results of this article.

5 Conclusion

Biogas production plays an important role in Germany as the third largest renewable energy source for electricity generation and for industrial biomethane utilisation as an alternative to hydrogen. Due to political measures such as the introduction of the maize cap, biogas plant operators are under pressure to replace traditional renewable energy crops with residual materials in biogas substrate mixtures, which must be as cost-effective as possible. Among these, crop straw has the greatest potential in terms of quantity, but has so far played a subordinate role as biogas substrate. A new approach is the utilisation of straw as pellets, which represents an innovative opportunity to increase the use of straw as sustainable biogas substrate. The research question “How do the substrate costs per kWh change the economic profitability of typical biogas plants in Germany when silage maize is replaced by crop straw pellets, considering the maximum technically possible proportion of straw pellets in the total substrate input?” was answered using field trial data and a scenario-based full cost analysis.

Overall, under favourable conditions - mobile produced crop straw pellets without incurring the costs of nutrient removal - can be a substrate alternative with almost the same substrate costs as traditional substrates such as silage maize.

The main influencing factor on the profitability of straw pellet use is the pelleting technology and their technical performance. Semi-mobile pelleting incurs much higher production cost compared to mobile pelleting on the basis of the data collected. As soon as the nutrient removal and additional purchase costs are considered, the profitability of straw pellets use declines strongly, as the additional costs for own power consumption and the pellet costs are no longer compensated by the cost savings from digestate application and storage. The profitability of biogas production decreases in all scenarios, except for mobile pelleting, as the quantity of pellets in the substrate mix increases. Even comparatively small proportions of straw pellets with a technically limited share of 4 % to a maximum of 10 % of the mass input show a high influence on the overall profitability of biogas production. Basically, it cannot be generalised that crop straw pellets are a low-cost substrate.

Due to the limited pelleting capacity and the restricted time window during the harvest in summer, a mixed calculation of mobile and semi-mobile pelleting is necessary in practice. Increasing the pelleting performance by reducing technical errors and or process optimizations such as bunkering during mobile pelleting on the move instead of at the headland of the field, can lead to even greater cost savings. Observations by the plant management and feeding of straw pellets in the field trials reveal almost no additional working time required for using straw pellets instead of energy crops. Due to the exchange ratio of straw pellets of 1:0.45, the total feeding costs delivered to the solids input of pellets are almost the same as those of silage maize. However, this depends largely on the storage location and its distance from the solids input. The own power consumption of the solids input up to the tamping screw does not cause additional costs in the field trials, while the own power consumption costs on raise sharply with higher pellets compositions in the substrate mix as the dry matter content in the digester increases.

The study's approach of developing scenarios for biogas plants with typical substrate mixtures can be viewed critically, as the existence of so called “typical biogas plants” is challenged in the literature (STMWI, 2024). Even if the scientific consideration of different, typical substrate combinations in the scenarios can help to provide a general overview of changes in profitability of straw pellet, we would emphasize the importance of customizing such calculations to individual biogas plants in practice due to their heterogeneity of characteristics. Another limitation

is the technical measurability of parameters like the own power consumptions of single process steps. The availability of technical data for such calculations should be further developed in technical studies in order to estimate the additional costs more accurately. To improve both the predictive power for typical biogas plants in Germany and the database for technical parameters, we would suggest to propose feeding trials with straw pellets on plants from the Biogas Measurement Programme III. For the majority of the 61 plants, technical and economic data are available, which provides a good basis for extension. This would also allow for increasing the sample size and collect data and experience with the use of straw pellets on more different types of plants.

In view of the future of biogas production under current political agendas, the following is to be concluded: With regard to the current tenders for existing biogas plants that aim at receiving a follow-up funding based on the REA, it should be noted that with a maximum value of currently 19.83 ct/kWh_{el} - even under the assumption of favourable pelleting conditions - hardly any profit can be achieved without additional revenue (BUNDESNETZAGENTUR, 2024). Better opportunities may exist for some biogas plants in biomethane commercialisation from residual materials. In order to develop power generation from biogas in Germany, which is primarily based on residual and waste materials, and to promote feeding the limited biomass flexibly adapted to the electricity demand in the power grid, a reorientation of the funding framework is necessary (SCIENCE MEDIA CENTER GERMANY, 2023). The political implementation of separate financial support for the use of agricultural residues such as straw pellets, which is disbursed depending on the quantity used or the proportion in the substrate mix, e.g. as part of the REA, can support the further use of innovative and sustainable substrates from agricultural residues in the German biogas sector.

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CONSUMER BEHAVIOUR

NAVIGATING CANNABIS AND WINE: COMPLEMENTARY OR SUBSTITUTE RECREATIONAL CHOICES

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Abstract

Understanding the intricate relationship between wine and cannabis usage is essential for crafting effective substance use policies and interventions. This study adopts an innovative approach to explore whether cannabis and wine act as substitutes or complements. Through an online survey targeting wine drinkers under 60, we collected 523 completed responses, including 215 from cannabis consumers. Our findings reveal that socializing and enhancement are primary motivators for both substances. Frequent cannabis use correlates with increased wine consumption, indicating complementarity for cannabis users. However, wine consumption frequency alone doesn't determine concurrent or separate cannabis use. Individuals consuming cannabis frequently tend to use both substances together, indicating complementarity for cannabis users. Yet, those who drink wine for socializing and enhancement and cannabis for socializing and coping are more likely to separate their consumption. These insights highlight the complexity of substance use dynamics, suggesting that policies or interventions aimed at reducing alcohol and cannabis consumption may have differing impacts across various segments of wine and cannabis consumers.

Keywords

Cannabis, wine, substitute, complement, consumption, consumption motives

1 Introduction

Recent data indicate a decline in wine consumption in Germany since the last seven years (DAVIES, 2022). Concurrently, there has been a significant increase in cannabis use among young adults in Germany over the past fifteen years, with efforts towards legalization underway (LOGAN, 2023). Proponents of legalization posit that cannabis use might serve as a substitute for the misuse of alcohol and other substances, potentially yielding positive outcomes and cost savings, particularly if cannabis has fewer adverse public health effects compared to alcohol and other drugs (SMART and PACULA, 2019). However, it is also conceivable that cannabis and alcohol could be complementary, suggesting that the legalization of nonmedical cannabis among adults could lead to increased alcohol consumption (WEN et al., 2015). This scenario could give rise to additional public health and safety concerns (GUTTMANNOVA et al., 2021; HALL, 2017).

For nearly more than three decades, economists have debated whether alcohol and cannabis serve as substitutes or complements to each other. In a substitute relationship, restrictions on one substance, such as increased price or legal constraints, lead to an upsurge in using the other. On the other hand, in a complementary relationship, changes in the availability of one substance have a corresponding impact on the use of the other substance (O'HARA et al., 2016).

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These hypotheses about alcohol and cannabis usage behaviours stem from differing perspectives. The substitution hypothesis posits that individuals opt for more accessible substances driven by motives like self-medication or stress relief (GREELEY and OEI, 1999; SHER et al., 2007). Conversely, the complement hypothesis suggests the simultaneous use of alcohol and cannabis, often during social interactions, for combined effects such as euphoria. Consequently, restricting one substance's availability inadvertently affects the accessibility and desirability of the other (O'HARA et al., 2016).

Investigating the connection between cannabis and wine consumption is a crucial area necessitating thorough quantitative examination. Understanding the dynamic between alcohol and cannabis holds significant implications for predicting the broader public health impacts stemming from shifts in substance use policies, especially in light of the increasing acceptance of cannabis legalization (O'HARA et al., 2016). Despite existing support for both substitute and complementary relationships between cannabis and alcohol, empirical evidence drawn from individual-level data remains notably scarce, primarily relying on broader macro-level economic or epidemiological data (O'HARA et al., 2016).

Furthermore, research explicitly exploring the substitutability or complementarity of cannabis and alcohol, particularly concerning wine consumption, is lacking. Hence, this study aims to contribute to this underexplored area by analyzing the relationship between the usage of these two potentially addictive substances, specifically investigating conditions under which wine and cannabis act as substitutes or complements. Moreover, we explore the drivers of complementary consumption of wine and cannabis in the sample of wine and cannabis users.

Investigating these nuanced questions by delving into consumers' motivations for substance use would be a valuable extension of current research on complement and substitution hypotheses (GUTTMANNOVA et al., 2021).

While many studies (STEVENS et al., 2021; 2022; BOYLE et al., 2021; O'HARA et al., 2016) on cannabis use motivations have focused on college students or individuals in emerging adulthood, this study extends beyond this specific demographic.

2 Literature Background

The literature presents divergent perspectives on the relationship between alcohol and cannabis use, particularly regarding their potential as substitutes or complements. While some studies suggest a complementary relationship, indicating that alcohol and cannabis often reinforce each other's consumption patterns, others propose a substitution effect, implying that cannabis may replace alcohol in certain contexts, potentially reducing alcohol-related risks (GUNN ET AL., 2022; KAROLY et al., 2023). Policy changes restricting one substance have shown mixed effects, with some studies indicating increased use of the other substance while others observe a decrease (O'HARA et al., 2016; WEINBERGER et al., 2020).

The legalization of cannabis, whether for medical or recreational purposes, has yielded varied effects on usage patterns. While medical cannabis legalization has been associated with increased adult usage, its impact on adolescent consumption remains inconclusive (BAE and KERR, 2020). Conversely, recreational cannabis legalization consistently correlates with heightened adolescent and young adult usage (PASCHALL et al., 2021).

Studies examining the substitution effect among young adults have found mixed evidence, with some suggesting reduced alcohol consumption in areas with liberal cannabis policies (SUBBARAMAN, 2016), while others report increased co-use of cannabis and alcohol following legalization (GARCÍA-RAMÍREZ et al., 2021). Existing evidence on the relationship between cannabis use and other addictive substances, especially regarding substitution or complementarity, remains inconclusive (GUTTMANNOVA et al., 2021). Studies consistently show a positive correlation between cannabis and alcohol use among adolescents and adults (FLEMING et al., 2016). Young adults who use cannabis are more likely also to consume alcohol (YURASEK et al., 2017),

and daily cannabis use is linked to higher daily alcohol intake (GUNN et al., 2018). Furthermore, frequent cannabis users tend to consume alcohol more frequently on average (GUTTMANNOVA et al., 2021). However, recent research by WEINBERGER et al. (2021) suggests complementarity among young adults who use cannabis, with a faster decline in alcohol consumption over 16 years compared to non-cannabis users, supporting the substitution hypothesis.

Alcohol and cannabis use share both physiological and social factors that reinforce their complementary nature (HALL and LYNSKY, 2005). Studies on animal models suggest that these substances activate similar reward pathways in the brain, potentially heightening sensitivity to other addictive substances and fostering a pattern of complementary use (O'HARRA et al., 2016). STEVENS et al. (2021) investigated how motives such as enhancing effects, socializing, responding to offers, and coping influence negative consequences in students who consume both alcohol and cannabis. They found that motives related to enhancing effects, socializing, and responding to offers indirectly contributed to adverse impacts through the use of multiple alcohol products but not cannabis. Conversely, coping motives were associated with using various cannabis products but not alcohol.

Furthermore, their follow-up study (STEVENS et al., 2022) revealed that planned simultaneous use of alcohol and cannabis was primarily driven by socializing and enhancement motives, while unplanned use was more likely motivated by offers or the need to cope with stress. Research suggests that individuals who turn to alcohol and cannabis as coping mechanisms for negative emotions are more likely to substitute one for the other. Both substances are commonly sought after for their ability to alleviate discomfort, attracting those seeking relief (O'HARA et al., 2016).

College students, in particular, are prone to using substances as coping tools, which heightens their risk of substance-related issues (COOPER et al., 1995; SIMONS et al., 2005). O'HARA et al. (2016) discovered that among college students who primarily consume alcohol and cannabis for social purposes, there was a positive correlation between their usage of these substances. Conversely, those who used alcohol and cannabis to cope with stress showed a negative association between the two, indicating substitution. This suggests that the more alcohol they consumed during an event, the less likely they were to turn to cannabis. In a study by BOYLE et al. (2021) involving college students, beyond the conventional motives like socializing and conformity, additional reasons for using cannabis and alcohol were uncovered. Some students engaged in "crossfading," aiming to experience both intoxication and euphoria simultaneously. Others utilized cannabis to reduce alcohol consumption and its associated harm. Furthermore, some students used substances reactively or situationally, often due to their ready availability or being offered to them.

Overall, the literature underscores the multifaceted nature of alcohol and cannabis consumption, influenced by various physiological, social, and contextual factors. While some studies suggest substitution or complementarity between the two substances, the findings remain heterogeneous, highlighting the need for further research to understand these complex dynamics better (RISSE et al., 2020).

3 Materials and Methods

3.1 Research Design

The survey was distributed through Trend Research's online panel, targeting wine drinkers under 60 years old to ensure representation of the German wine-drinking population regarding age and gender. Participants were required to be of legal drinking age (18 years old) and have consumed wine at least once in the past year. Through random sampling, cannabis consumers within the wine-drinking group were identified. The study focused on cannabis users over 18

years old who had used either medicinal or recreational cannabis within the past year. A total of 523 completed surveys were collected, including responses from 215 cannabis consumers.

A 24-item questionnaire based on Cooper's Drinking Motives Questionnaire (DMQ) (1994) was used to assess motives for wine consumption. For participants who reported cannabis use, questions from the Marijuana Motives Measure (MMM) (SIMONS et al., 1998) were included. The MMM is a widely used instrument in cannabis consumption research (O'HARA et al., 2016; SIMONS, 2005). Responses were measured on a scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Consumption frequency for wine and cannabis was evaluated using a 6-point ordinal scale ranging from several times per week (1) to never (6). Wine consumption data were collected separately for five types of wine - red, white, rose, sparkling, and sweet/dessert wines - and for other alcoholic beverages - beer, alcopops, and spirits.

3.2 Methodology

Firstly, a factor analysis using varimax rotation was conducted to reduce the number of variables and identify the underlying structure of the motivation constructs for wine and cannabis consumption. The reliability of the constructs was assessed using Cronbach's α .

Secondly, cross-tabulation, a statistical analysis tool, was utilized to investigate the relationship between cannabis and wine consumption frequencies.

Thirdly, we delve into the factors influencing the wine and cannabis consumed separately compared to a situation when cannabis and wine have ever been consumed simultaneously by estimating a logistic model written in a general functional form as:

$$(1) \quad P(Y_i = 1) = g(X_i\beta) = \frac{\exp(\alpha + X_i\beta)}{1 + \exp(\alpha + X_i\beta)}$$

where $X = (X_1, \dots, X_p)'$ is the vector of covariates, $g(\cdot)$ is a link function that ensure $0 \leq P(Y_i) \leq 1$. More specifically, we estimate logistic regression in the following functional form by the maximum likelihood estimator:

$$(2) \quad \log \left(\frac{P[Cont_i=1]}{1 - P[Cont_i=1]} \right) = \beta_0 + \beta_1 Cons_{w,i} + \beta_2 Cons_{c,i} + \sum_{j=1}^5 \delta_{1j} F_{w,ij} + \sum_{j=1}^4 \delta_{2j} F_{c,ij} + \gamma Z_i + \epsilon_i$$

Where $Cont_i$ is a dependent binary variable, which equals one if an individual i , $i = 1, \dots, n$ has ever consumed wine and cannabis contemporaneously and zero otherwise. The explanatory variables $Cons_{w,i}$ and $Cons_{c,i}$ are dummy variables that measure consumption frequencies of wine and cannabis, respectively, ranging from 1 (at most once a year) to 4 (at least once per week).⁴ From the factor analysis, $F_{w,ij}$ and $F_{c,ij}$ are factor scores characterizing the motivations for wine and cannabis consumption, respectively. Socio-demographic characteristics, including gender, age, income, and education, are captured by a vector Z_i .

The coefficients β_1 and β_2 indicate the association between wine and cannabis consumption frequency on the likelihood of consuming them, respectively. Estimated parameters of δ_{1j} and δ_{2j} measure the influence of various motivational factors of wine and cannabis consumption on the respondents' decision to consume wine and cannabis together or separately. Effects of Socio-demographic characteristics are provided in vector γ for gender, age, income and education. The ϵ_i errors are assumed to have a standard logistic distribution.

⁴ The variable wine consumption frequency is calculated as $Cons_{w,i} = \max\{Wine_{ij}\}$, where $Wine_{ij}$ is the frequency of wine consumption for each individual i , $i = 1, \dots, n$, and wine category j , $j =$ white wine, red wine, rose, sparkling wine, sweet/dessert wine. Moreover, the original scale for $Cons_w$, I and $Cons_{c,i}$ is reversed to ensure the increasing level is associated with higher consumption frequency.

4 Results

4.1 Sample characteristics

All study participants are drinkers of at least one of the five wine types specified in the survey, with a slight majority being female (54.3%). They represent a range of adults aged between 20 and 60, with an average age of 38.3 years. A significant portion of the sample (43%) falls between the ages of 29 and 43; around one-fourth are under 28 years old, and 31.4% are over 44. Most respondents have vocational or upper secondary education (53.3%), and the majority are employed (83%). Regarding personal income, 43% earn less than €36,000 annually, while a quarter earns over €50,000.

Concerning wine consumption habits, over 40% of participants report drinking white wine at least once a week or several times a month. Wine is commonly enjoyed in familial settings (94.1%), at social gatherings and parties (93.1%), and with friends at home (92.9%). Similarly, about 40% of respondents' report using cannabis either frequently or occasionally, with approximately 22% using it several times a week and 18% using it several times a month. Finally, among cannabis and wine users, 53% (115 respondents) have consumed wine and cannabis together, whereas the remaining 100 respondents (47%) have always separated wine and cannabis consumption from each other.

4.2 Results Factor Analysis

Initially, we undertake an analysis to evaluate the variance and deviation of the items, leading to the elimination of those showing minimal deviation from the factor scales. Subsequently, the reliability of the scales and the efficacy of item differentiation is assessed. We evaluate item differentiation before and after removing specific items from the measurement scales. Items demonstrating low deviation, content redundancy, and limited effectiveness in distinguishing between factors are excluded from the final analysis. Consequently, we remove items such as 'I drink wine/consume cannabis because I believe it is healthy for me' and 'I drink wine/consume cannabis because I like the taste' from the final factor analysis of the wine and cannabis consumption motivation scales. Tables 1 and 2 present a comprehensive compilation of measurements detailing the means and standard deviations for each item associated with the respective constructs.

The high Cronbach's alphas for the five dimensions of wine consumption motives and four dimensions of cannabis use motives demonstrate robust internal consistency for each factor (Tables 1 and 2). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, yielding values of 0.95 and 0.94, and the significant Bartlett's sphericity test confirm the suitability of the motivation factor structure. This results in a five-factor solution for wine (Table 1) and a four-factor solution for cannabis (Table 2). All factor-loading scores surpass 0.5, indicating strong correlations between the items and their respective factor groups. With factor loadings and internal consistency (α) levels ranging from 0.82 to 0.94, composite measures for both wine and cannabis are reliably constructed. The five and four factors' solutions collectively explain 75.72% and 71.22% of the total variance for wine and cannabis, respectively, highlighting significant differences between the factors.

Additionally, factor analyses are conducted to examine the motives underlying wine and cannabis consumption, both with and without new items. This aims to validate the factor structure and confirm the suitability of five- and four-factor solutions. For wine consumption, the new items are excluded as the changes in the factor structure are caused by those additions. Notably, the analysis produces a five-factor solution akin to the original findings by SIMONS et al. (1998) (Table 1). Similarly, we perform factor analysis for cannabis consumption motives, excluding new items to ensure a four-factor solution.

Interestingly, this analysis also results in a four-factor solution. However, there are differences in the factor structure between this study and earlier research by SIMONS et al. (1998). The items concerning "expansion," which pertain to broadening awareness, self-confidence, and openness to new experiences, are loaded onto the factor labelled "social." Consequently, we designate the factor as "Social and Expansion." Likewise, items associated with creativity loaded onto the factor named "coping." Thus, we label the factor as "Coping and Creativity." Factor analysis is conducted excluding those items to verify the suitability of a four-factor solution without the expansion and creativity scales. Remarkably, this analysis produces a four-factor solution mirroring the original one. Therefore, it can be deduced that the differences in factor structure between this study and previous research (SIMONS et al., 1998) are likely not due to the additional items introduced here. Instead, these variances may be better explained by two factors: (1) differences in sample composition and (2) the notable correlations observed between social and expansion, as well as coping and expansion items (SIMONS et al., 1998).

In summary, socializing emerges as the primary motivation for wine consumption and enhancement for cannabis use ($\bar{x}$ = 3.38; $\bar{x}$ = 3.52), followed by enhancement for wine ($\bar{x}$ = 3.32) and coping and creativity for cannabis ($\bar{x}$ = 2.85). Coping and expanding creativity are more endorsed for cannabis ($\bar{x}$ = 2.85) than for wine ($\bar{x}$ = 2.83; $\bar{x}$ = 2.82). Conformity does not emerge as a significant factor for either substance.

Table 1: factor analysis results based on wine consumption motives

Wine consumption motives	Mean	Variance	α
		Explained %	
Socializing	3.38	6.23	.87
Enhancement	3.32	3.20	.82
Coping	2.23	48.98	.92
Expansion	2.22	3.91	.91
Conformity	1.87	13.40	.91
Total variance			75.72

Source: authors' estimations. Notes: All factor loadings are significant at $p < .001$: How often do you drink wine for the following reasons? 1 = "never" 5 = "always". N=523

Table 2: factor analysis results based on cannabis consumption motives

Cannabis consumption motives	Mean	Variance	α
		Explained %	
Socializing & Expansion	2.73	49.49	.93
Enhancement	3.52	4.27	.86
Coping & Creativity	2.85	11.55	.90
Conformity	2.01	5.93	.94
Total variance			71.22

Source: authors' estimations. Notes: All factor loadings are significant at $p < .001$: How often do you consume cannabis for the following reasons? 1 = "never" 5 = "always". N=215

4.3 Results Cross-Tabulation

We conduct further analysis to examine the correlation between cannabis and wine consumption frequencies, employing a cross-tabulation approach. Table 3 displays the percentage of respondents by wine and cannabis usage frequencies. Descriptive statistics reveal a non-linear rise in wine consumption among non-cannabis users. Interestingly, there appears to be a simultaneous increase in the percentage of more frequent cannabis users alongside increasing wine

consumption. However, a clear pattern in wine consumption frequency with increasing cannabis use frequency is not evident, except for a slight decline in infrequent wine consumption (x/year) as cannabis usage becomes more frequent. The largest subgroup comprises individuals who are frequent wine drinkers but have never used cannabis, constituting 26% of the sample. Moreover, there seems to be no discernible association between frequent wine consumption and the frequency of cannabis usage among cannabis users (as indicated in the column "x/week").

Table 3: Percentage of wine and cannabis users by their frequency of use.

Cannabis Use	Wine Consumption				Total
	less often	x/year	x/month	x/week	
Never	4.4%	19.3%	9.6%	25.6%	58.9%
less often	0.4%	3.8%	1.3%	5.0%	10.5%
x/year	0.8%	3.1%	4.0%	6.5%	14.3%
x/month	0.0%	1.9%	0.6%	4.8%	7.3%
x/week	0.6%	2.3%	1.0%	5.2%	9.0%
Total	6.1%	30.4%	16.4%	47.0%	100.0%

Source: authors' estimations. N=523.

4.4 Estimation Results

Results of the logistic regression analysis (Table 4, Figure 1) suggest that the more frequent consumption of cannabis increases the probability of consuming wine and cannabis together ($\beta_1=0.47$). However, the frequency of wine consumption is irrelevant for deciding to consume wine and cannabis together or separately, as the estimated parameter for wine consumption frequency is highly statistically significant ($\beta_2=0.03$).

To provide a disaggregated view of the relationship between the frequency of wine and cannabis consumption and the likelihood of consuming them simultaneously, we plot predictive margins in Figure 1. In particular, the probability of contemporaneous consumption steadily increases with the cannabis consumption frequency, whereas for wine, we do not observe a strong association between the two. Those results are confirmed by the test of coefficient equality, which indicates that the null hypothesis of equality of parameters is rejected for cannabis consumption frequencies ($\chi^2(1) = 4.65$, p-value = 0.03) and cannot be rejected for wine consumption frequencies ($\chi^2(1) = 0.54$, p-value = 0.46). That implies that the contemporaneous consumption of wine and cannabis is common among the frequent consumers of cannabis, whereas frequent wine consumers are "not interested" in the contemporaneous consumption of wine and cannabis.

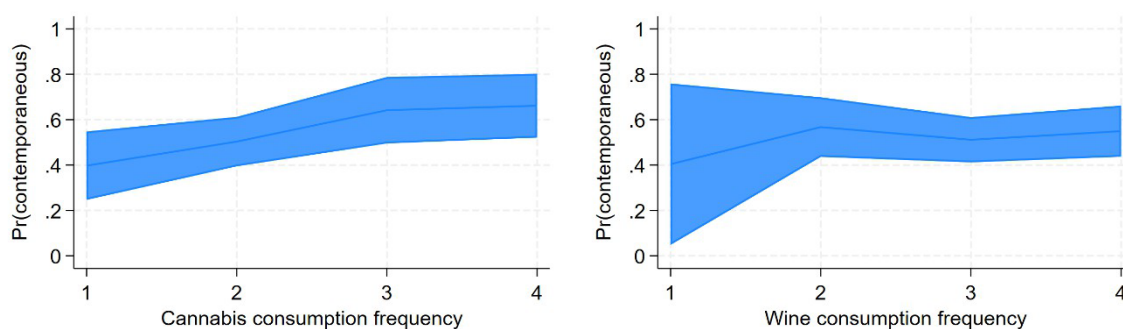
In addition, estimation results in Table 4 indicate that individuals consuming wine for socializing and enhancement reasons ($\delta_{13} = -0.350$ $\delta_{15} = -0.846$, respectively) and cannabis for social & expansion and coping ($\delta_{21} = -0.367$ $\delta_{23} = -0.331$, respectively) are less likely to opt for the contemporaneous consumption and prefer to consume them separately. On the other hand, we find that conformity may positively drive contemporaneous consumption of wine and cannabis ($\delta_{12} = 0.141$ for wine and $\delta_{22} = 0.076$ for cannabis); however, results are highly statistically insignificant at conventional significance levels. Results also suggest that the likelihood of contemporaneous consumption is not influenced by wine factors for coping and expansion and cannabis factors for enhancement.

Among the socio-demographic characteristics, results indicate that men are much more likely than women to consume wine and cannabis together than separately. We do not identify a statistically significant effect of age, income and education on the decision to consume wine and cannabis together or separately. As results suggest, those socio-demographic indicators do not determine the likelihood of consuming wine and cannabis together.

Table 4. Estimation results, logistic regression

Dependent variable = contemporaneous consumption	Estimated parameter	Standard error	P-value
Wine consumption frequency	0.035	0.221	0.875
Cannabis consumption frequency	0.468 ***	0.199	0.018
Factors, wine			
Socializing	-0.350 *	0.190	0.065
Enhancement	-0.846 ***	0.214	<0.001
Coping	-0.125	0.202	0.536
Expansion	-0.055	0.182	0.764
Conformity	0.141	0.216	0.514
Factors, cannabis			
Socializing & Expansion	-0.367 **	0.182	0.044
Enhancement	-0.034	0.186	0.854
Coping & Creativity	-0.331 †	0.217	0.127
Conformity	0.076	0.260	0.771
Socio-demographics			
Female	-0.644 *	0.339	0.058
Age group	-0.027	0.240	0.910
Income	-0.007	0.007	0.291
Education	-0.036	0.260	0.889
Intercept	-0.542	1.063	0.610
Number of observations	215		
Pseudo R ²	0.17		
Log pseudo likelihood	-122.85		

Source: Authors' estimations. Notes: *** $p < 0.01$. ** $p < 0.05$. * $p < 0.10$. † p -value equals 0.13. Robust standard errors in parenthesis. At least, parameter estimates significant at the 13% level are marked in bold.

Figure 1: Predictive margins of cannabis and wine consumption frequencies

Source: authors' estimations and illustrations. Note: shaded area plots 95% confidence intervals. Wine and cannabis consumption frequencies increase in an ascending order from low to high.

5 Discussion and Conclusion

Understanding the dynamic interplay between alcohol and cannabis use is crucial for formulating effective policies and interventions to address substance use (O'HARA et al., 2016). Adopting a novel perspective, this study explores the potential for substitution or complementarity between cannabis and wine. The motivations and pathways underlying the consumption of these substances vary widely. Initially, the study explored the consumption motives for wine and cannabis. Furthermore, the study investigated the substitution and complement relationship by examining the correlation between frequencies of wine and cannabis consumption. A com-

plement relationship suggests that the high frequency of consumption of one substance is associated with the high usage of another. Oppositely, the substitute relationship implies that the high use of the substance is related to less consumption of another substance. Furthermore, the complementarity was explored by identifying the factors influencing contemporaneous consumption of wine and cannabis among respondents who have used cannabis at least once. Additionally, we analyzed differences between wine drinkers who consume wine and cannabis separately and those who use both substances simultaneously.

Our results of factor analysis suggest that socializing and enhancement are the primary motivations for wine and cannabis use, whereas coping and expanding creativity are more endorsed for cannabis than for wine use. Those results are consistent with earlier studies indicating that both substances, wine and cannabis, are frequently utilized to reinforce positive experiences, to improve social interactions and cultivate positive emotions, enjoyment, and overall well-being (FLEMING et al., 2022).

The results of cross-tabulation support the notion of a complementary relationship between wine and cannabis. Notably, our analysis highlights a significant trend: among cannabis users, there is a simultaneous increase in the frequency of both wine and cannabis consumption. This suggests that frequent cannabis use is linked to more frequent wine consumption, indicating complementarity for cannabis users but not for wine users. However, it's important to note that this relationship doesn't necessarily imply causation. Instead, it suggests a correlation between the two behaviours.

As confirmed by the findings of logistic regression, more frequent cannabis consumption increases the likelihood of simultaneous use of wine and cannabis. In contrast, more frequent wine consumption does not necessarily lead to simultaneous consumption of wine and cannabis. This suggests that as cannabis consumption increases, there is a greater probability of simultaneous consumption of wine and cannabis. This observation aligns with the conclusions drawn by GUNN et al. (2019), who found that cannabis use was linked to higher levels of alcohol consumption among frequent recreational users on days when cannabis was used. Such frequent recreational cannabis users may be more susceptible to additional risks associated with co-use (GUNN et al., 2019), or may experience dopaminergic effects from both substances (HALL and LYNKSY, 2005).

Furthermore, the findings show that individuals who consume wine primarily for socializing and enhancement purposes and cannabis for social expansion and coping are inclined to separate their consumption of these substances rather than engage in contemporaneous use. This preference aligns with research findings from O'HARA (2016), PATRICK et al. (2019), and FLEMING et al. (2022), indicating that alcohol consumption is often associated with socializing in social contexts, while cannabis use is commonly linked to coping with stress, anxiety, and negative emotions, as well as addressing social isolation (BUCKNER et al., 2016). Additionally, respondents who reported a stronger inclination to use alcohol or drugs as a coping mechanism for stressful events exhibited a substitute relationship; as they consumed more alcohol on a given occasion, they were less likely to use cannabis (O'HARA et al., 2016). This suggests that when individuals satisfy their needs, such as coping with cannabis and socializing with wine, there is a reduced likelihood of engaging in simultaneous substance use (STONE and KENNEDY-MOORE, 1992; O'HARA et al., 2016).

In conclusion, the research indicates a higher propensity among men to consume wine and cannabis together, contrasting with women who typically use cannabis less frequently (CUTTLER et al., 2016). This result aligns with the findings that men may exhibit a greater inclination towards engaging in risky behaviours such as frequent cannabis use, bingeing, and simultaneous substance consumption, potentially exposing themselves to adverse health and social outcomes (WILKINSON et al., 2018).

The findings of the current study highlight the complexities of addressing substance use in wine consumers. Despite the lower risk of infrequent cannabis use compared to frequent use, simultaneous use of wine and cannabis elevates the likelihood of accidents, alcohol-related consequences, and health issues (LEE et al., 2022; PATRICK et al., 2021). Policies or interventions aimed at reducing alcohol and cannabis consumption may yield varied outcomes among different segments of wine and cannabis consumers. In particular, wine consumers, irrespective of their wine consumption frequencies, are not expected to engage in the simultaneous consumption of wine and cannabis. In contrast, frequent cannabis users, if consuming less cannabis, would reduce their consumption of wine and cannabis together. Therefore, interventions aimed at reducing contemporaneous consumption should target frequent cannabis users rather than frequent wine consumers.

6 Limitations and Future Research

In this study, understanding how wine and cannabis are used, whether as substitutes or complements, is challenging due to insufficient data on usage patterns such as timing and quantity consumed. More research is needed to clarify when and for whom these substances act as complements or substitutes. For instance, individuals may use them as substitutes or in tandem depending on various factors like context and reasons. Exploring these dynamics across different social settings is crucial (WEINBERGER et al., 2021).

With Germany poised for substantial regulatory shifts and potential legalization, it's prudent for forthcoming studies to integrate longitudinal surveillance. This would enable tracking changes in consumption patterns, motivations, and the interplay between wine and cannabis as substitutes or complements. Analyzing alterations in attitudes and perceived benefits regarding cannabis and wine post-legalization can offer insights into behavioural shifts and associated health outcomes. Such insights can inform public health initiatives to mitigate harm in the post-legalization landscape (TURNA et al., 2022).

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SOCIETAL CHANGE IN NUTRITION – WISHFUL THINKING OR REALITY?

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Abstract

This paper examines the question of whether the transformation towards a more sustainable nutrition is a reversible fashion or a permanent process. The presented study, with a sample of 2000 people, largely representative of the German population, addresses the self-assessment of citizens with regard to their compassion for food producing animals; satisfaction with current animal welfare legislation; awareness of negative externalities of livestock farming; willingness to change nutrition; future protection of natural resources and climate. As a result, the widespread prevalence of cross-species empathy, moral obligation to improve farm animal welfare and approval of stricter animal protection laws suggest that a violation of the sense of morality and justice can be assumed in large parts of the population. If this assumption is correct, it can be concluded that the increasingly larger and more attractive range of milk and meat substitutes is perceived as morally relieving. This in turn indicates a lasting change in eating habits, which is ultimately due to the prevailing moral attitudes in society. However, the figures also indicate that around one quarter of the German population is excluded from this development because they are unable or only partially able to develop empathy for animals. The situation is similar when it comes to agreeing to improve climate and resource protection. As changing eating habits require corresponding changes in food production, consumer studies can improve political and economic planning security for agriculture and the food sector, especially if they are designed for the long term.

Keywords

animal welfare, public concern, morally motivated commitment, nutrition, climate protection, cognitive dissonance

1 Introduction

The welfare of farm animals, such as pigs, cattle, poultry, etc., plays a major role for Europeans. In 2023, more than 90% of the citizens in the European Union (EU) considered the issue to be very important or fairly important; in Germany, the figure was 92% (SPECIAL EUROBAROMETER 533). At that time, 84% of EU citizens expressed the opinion that the welfare of farm animals in their respective countries should generally be better than it currently is; in Germany, 90% of respondents were of this opinion (ibid.). Eight years earlier (2015), 82% of EU citizens surveyed stated that the welfare of farm animals in their respective countries should generally be better than it currently is; in Germany, the figure was 83% (Special Eurobarometer 442). The current figures for Germany were confirmed in a survey conducted also in 2023 on behalf of the Federal Ministry of Food and Agriculture (BMEL). As many as 94% of respondents in Germany stated that they thought it was very important or important for politicians to ensure better animal husbandry conditions with fewer animals in stables (BMEL NUTRITION REPORT 2023).

In line with this trend, fewer and fewer people in Germany are eating meat and sausage products every day. In Germany, the proportion is currently at 20%. At the beginning of the surveys (by

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the BMEL) in 2015, it was 34%. At the same time, the share of people who choose vegetarian and vegan alternatives to animal products every day is steadily increasing. In 2020 it was five percent, now it is ten percent (BMEL NUTRITION REPORT 2023). It is known that in Western industrialized economies, personal health and animal and environmental protection are the three main reasons for a vegetarian or vegan diet (HOPWOOD ET AL. 2020; LUY 2018). But are these more likely to be reversible fads or a permanent change in diet?

It is in the nature of things that these questions cannot be answered with absolute certainty, as they relate to the future. In economic terms, but also from a political perspective, it is, however, particularly relevant how stable the attitudes and changes in consumer behaviour are. The emerging societal changes in expectations towards food production, food consumption and nutrition habits require corresponding changes in food production. Consumer studies, especially long-term oriented, can help to improve political and economic planning security for farmers and the food sector. The here presented data is based on a project funded by the BMEL, carried out by an interdisciplinary consortium. Based on a synergetic structure of work packages, the project involves various scientific disciplines, a wide range of methods, numerous surveys and the participation of various interest groups.

The study presented here builds on the ethical hypothesis of LUY (2018), according to which the need for fair treatment of all sentient beings is at the centre of the human sense of morality. The selected statements from the analysed representative online survey of German citizens can be grouped to the following topics: compassion for food producing animals; satisfaction with current animal welfare legislation; awareness of negative externalities of livestock farming; willingness to change nutrition; future protection of natural resources and climate.

2 Method and Data

The data collection took place in Germany between March and May 2023. With the help of a market research institute, 2000 data sets on citizens assessment of items related to the mentioned six topics were collected via an online survey.

The selection of the here analysed statements was based on an exploratory approach looking at the complete dataset. With the selected topics it is possible to shade some light in the actually intensely discussed question whether there is a change in food nutrition towards more plant-based diets or not and whether this change is based on societal changes. Table 1 presents the tested topics / constructs, the respective statements and in which sub sample the questions occurred.

Table 1: Overview about tested topics, statements and sub samples

Topic / Construct	Statement	Sub sample
Perceived moral obligation to improve farm animal welfare	As a consumer, I feel that I have an obligation to influence the conditions in which animals are kept through the choices that I make when purchasing products.	n 1
	I am completely satisfied with my own commitment as a consumer to improving the welfare of animals in agriculture.	n 1
	I am completely satisfied with my fellow citizens' consumer commitment to improving the welfare of animals in agriculture.	n 1
	When I voluntarily buy products at a higher price that have been produced in a more animal-friendly or environmentally friendly way, it annoys me that some consumers do not make this commitment.	n 1
Compassion for food producing animals	I can feel compassion for chickens kept in cages	n 2
	I can feel compassion for those pigs that are not completely stunned at the slaughterhouse	n 3
	I can feel compassion for pigs in intensive livestock farming.	n 4
	I can feel compassion for those chickens that are not completely stunned at the slaughterhouse	n 4
Satisfaction with current animal welfare legislation	The legislation on the welfare of animals kept for farming purposes should be strengthened.	n 2
	I support the constitutional goal of improving farm animal welfare.	n 4
Awareness of negative externalities of livestock farming	Livestock farming causes emissions that are hazardous to health.	n 2
	The use of animals for food production is associated with adverse effects on animal welfare.	n 3
	Livestock farming produces greenhouse gases that are harmful to the climate	n 4
Willingness to change nutrition	Halving the number of animals on farms is an effective way to protect the climate and the environment. However, it also means that we would have to consume half as much food of animal origin. Do you agree with the idea of halving your own consumption of these foods in the long term?	n 2
	The range of food products in the stores I visit is diverse enough to provide me with food that is in line with my expectations of how food should be produced.	n 3
Future protection of natural resources and climate	In the future, drinking water should be protected (better than today / just like today / less than today) from nitrate pollution caused by livestock farming.	n 5
	In the future, the climate should be protected (better than today / just like today / less than today) from greenhouse gases caused by livestock farming.	n 6

The statements used in this paper were measured on six sub-samples with each at least 500 data sets (Table 2). The sample and sub-samples are approximately representative of the German population in terms of gender, age, region, net household income, education, employment and dietary habits. Omnivores as well as vegetarians and vegans were included in the survey according to their proportion in the German population.

Five-point Likert scales were used as selection options (strongly agree – tend to agree - partly agree/partly disagree – tend to disagree – strongly disagree). For a clearer presentation of the results, the options "strongly agree" and "tend to agree" were combined to "agree" and the options "strongly disagree" and "tend to disagree" were combined to "disagree". For three statements, an additional answer option "I cannot judge / have not yet bought the product" was included. For two questions on future protection, respondents could choose between "better than today", "just like today" and "less than today".

The data was analyzed using SPSS software and Excel. The univariate data analyses are shown in Figure 1.

Table 2: Characteristics of the sample

Sample Size	N = 2000	n ¹ = 1000 (%)	n ² = 999 (%)	n ³ = 1000 (%)	n ⁴ = 1001 (%)	n ⁵ = 500 (%)	n ⁶ = 500 (%)	DE ^a (%)
Gender								
Female	51.2	51.6	50.3	52.0	50.7	52.0	48.8	49.3
Male	48.6	48.1	49.3	47.9	48.9	47.6	51.0	50.7
Diverse	0.2	0.3	0.4	0.1	0.4	0.4	0.2	-
Age								
18-29	12.0	10.6	9.5	9.8	9.5	10.0	10.2	16.3
30-39	23.5	23.0	23.1	24.2	23.7	25.4	23.4	15.5
40-49	16.5	16.7	18.6	15.9	17.0	18.0	13.2	14.7
50-59	23.4	23.0	21.1	22.5	23.0	18.2	26.2	19.4
60 und +	24.6	26.7	27.6	27.6	26.9	28.4	27.0	34.2
Region								
North ¹	16.2	17.0	16.7	15.8	15.1	14.4	16.8	16.1
South ²	24.8	24.2	26.2	24.1	24.5	25.6	24.0	29.4
West ³	37.3	37.0	37.2	38.4	36.8	35.8	39.4	35.4
East ⁴	21.7	21.8	19.8	21.7	23.7	24.2	19.8	19.2
Net Household In- come (Euro)								
1,499 and less	21.5	20.6	22.2	20.5	22.7	22.4	22.0	25.7
1,500 – 2,599	23.9	23.0	23.2	24.9	24.5	22.0	25.4	31.1
2,600 – 3,199	16.4	17.5	16.3	15.0	16.8	16.2	14.2	11.7
3,200 – 4,499	18.7	20.3	17.7	19.9	16.9	17.8	19.0	16.6
4,500 and more	19.5	18.6	20.5	19.7	19.2	21.6	19.4	14.9
Education								
Low ⁵	14.6	14.5	15.1	14.5	14.1	13.2	16.4	26 – 37 ⁸
Middle ⁶	37.3	37.6	36.0	35.9	39.5	37.0	34.0	29 – 34 ⁸
High ⁷	48.2	47.9	48.8	49.6	46.5	49.8	49.6	32 – 40 ⁸
Employment								
Employed	66.9	66.1	67.9	67.6	65.8	68.2	66.4	59 – 70 ⁸
Not Employed	33.1	33.9	32.1	32.4	34.2	31.8	33.6	29 – 35 ⁸
Diet								
Vegetarian / Vegan	10.4	8.8	12.3	10.1	10.4	10.8	10.4	10
Omnivore	89.6	91.2	87.7	89.9	89.6	89.2	89.6	90

Notes:

N: total sample

n¹ to n⁶: sub-samples

DE = Germany

¹Bremen, Hamburg, Lower-Saxony, Schleswig-Holstein²Bavaria, Baden-Wuerttemberg³Hessia, North Rhine-Westphalia, Rhineland-Palatinate, Saarland⁴Brandenburg, Berlin, Saxony, Saxony-Anhalt, Thuringa, Mecklenburg-Western Pomerania⁵No secondary education completed (yet); graduated from general or lower-level secondary school (German: Hauptschul-/Volksschulabschluss)⁶Graduated from a polytechnical college or middle-level secondary school (German: Polytechnische Oberschule; Realschulabschluss/Mittlere Reife)⁷Graduated from higher-level secondary school (German: Abitur)⁸As we do not have official population data for the age range included in our study for this criterion, intervals for the quotas were estimated^a Statistisches Bundesamt, GENESIS-Datenbank 2019

3 Results

Figure 1 shows the results of the survey questions analysed, which summarize approval, differentiated consideration and rejection in an overall overview.

Three quarters of the population believe that they have cross-species empathy (73-76%). The greater kinship between humans and other mammals compared to birds does not appear to affect the ability to empathize with suffering animals. Around one in twelve respondents (7-9%) admitted that they cannot empathize with farm animals, while one in six respondents (15-20%) answered the question about compassion only partially in the affirmative.

This high level of empathy with farm animals, particularly in relation to their welfare, is linked to the finding that 61% of respondents believe that the current use of animals for food production is generally associated with negative impacts on animal welfare. 29% distinguish between different forms of animal use, some of which they perceive as detrimental to animal welfare and others not. Only 10% do not believe that current livestock farming has a negative impact on animal welfare.

More than two thirds of respondents call for stricter animal welfare regulations for livestock farming. Only a very small proportion of the population is against this. Around 74% of respondents support the goal of improving animal welfare in agriculture, which is enshrined in the German constitution. A further 20% differentiate between areas of livestock farming that could be improved and those that are acceptable. 6% are explicitly against improving animal welfare in agriculture. 69% of respondents believe that minimum animal welfare legislation should be strengthened to improve animal welfare in agriculture. 24% differentiate between areas of livestock farming in which the legal framework should or should not be tightened. 7% are against tightening the regulations for the protection of farm animals.

66% of respondents say they feel morally obliged to influence the conditions in which farm animals are kept through their purchasing decisions. A further 23% occasionally feel obliged to do so and occasionally do not. 9% have no such sense of obligation when buying food.

When it comes to paying more for products that have been produced in a more animal or environmentally friendly way, 42% of respondents are annoyed by consumers who do not make this commitment. 26% say they are sometimes annoyed and sometimes not, while 27% do not feel annoyed by other consumers who do not make this commitment.

48% of respondents state that they are generally satisfied with their own commitment as consumers to greater animal welfare in agriculture. 36% are sometimes satisfied with themselves and sometimes not. 12% are dissatisfied with themselves when it comes to influencing the conditions in which farm animals are kept through their own purchasing decisions.

In contrast, only 33% of respondents agree with their fellow citizens' commitment to better animal welfare in agriculture. A further 36% are satisfied with some of their fellow citizens and not with others. 23% state that they are generally dissatisfied with the consumer behaviour of their fellow citizens with regard to farm animal welfare.

In addition to animal welfare concerns caused by livestock farming, other ethical considerations are also important to respondents, focusing primarily on climate impact. 54% of respondents are generally of the opinion that livestock farming causes climate-damaging greenhouse gases. A further 30% differentiate between climate-damaging and climate-neutral forms of livestock farming. 16% do not believe that livestock farming contributes to the climate crisis.

44% of respondents assume that livestock farming generally causes emissions that are harmful to health. 36% differentiate between livestock farming with and without harmful emissions. 20% do not believe that agricultural livestock farming releases emissions that are harmful to health.

About 70% agree that resources like drinking water and the climate should be better protected from livestock farming emissions in the future.

The generally rather critical perception of livestock farming corresponds with the willingness to change one's own eating habits. Halving animal husbandry on farms is an effective measure for climate and environmental protection. However, it presupposes that only half as much food of animal origin is consumed. When asked whether they agree with the idea of halving their own consumption of these foods in the long term, 53% of respondents answered yes. 29% are undecided. 18% reject this idea.

Around one in three respondents have experienced that, at least in some product categories, they cannot easily obtain food that exactly meets their expectations of how food should be produced. 68% of respondents stated that the range of food available in the stores they visit is diverse enough to meet their farm animal welfare and environmental protection requirements. For 25% of respondents, the range is sufficient for some foods, but not for others. 7% of respondents stated that in general they cannot easily get the food they want.

Figure 1: Evaluation and self-assessment of citizens on tested statements



For the complete texts of the tested statements please see Table 1

4 Discussion

The results of the survey show that a large majority of respondents would like to see stricter animal welfare legislation for food-producing animals (69%). In quantitative terms, this demand is about as widespread as a sense of a moral obligation toward these animals (66%). At least 73 to 76% of the respondents are convinced that they have the ability to empathise across species themselves. In contrast, about 7 to 9% of respondents explicitly state that they are not capable of developing empathy for suffering animals. This figure corresponds to the 10% who assume that the raising of animals for food production is not associated with negative effects for these animals.

We interpret this finding as empirical support for the assumption that the ability to empathise across species is a prerequisite for feeling morally obligated toward animals. On the other hand, those who are unable to empathise with suffering animals will find it more difficult to imagine that some practices involving food-producing animals are widely perceived as harmful.

Regarding the questions of whether the current trends in dietary change are reversible fads or a permanent phenomenon, the widespread prevalence of cross-species empathy, perceived moral obligation and support of stricter animal welfare legislation suggest that the sense of morality and justice of large segments of the population is being violated by today's food production. Similar conclusions are also found by SCHULZE ET AL. 2023. If this assumption is correct, it can be assumed that the ever broader and more attractive range of milk and meat substitutes is recognized as a moral relief (BRYANT 2022; DHONT AND IOANNIDOU 2024). This in turn suggests that we can assume that this is a permanent phenomenon for a large part of the population. Conversely, however, the figures also indicate that about a quarter of the population is excluded from this development because they are unable or only partially able to develop empathy for animals.

Similarly, the widespread support for improving climate and resource protection (68% and 69%, respectively) and the respondents' admitted annoyance at fellow citizens who do not commit themselves to climate and resource protection in their consumer behaviour, suggest that two-thirds of the population also perceive the supply of climate and resource-friendly products as a moral relief. The figures for climate and resource protection therefore also point to a lasting phenomenon.

When confronted with the statement that halving the number of farmed animals would be an effective measure to protect the climate and resources, a small majority of respondents (53%) said they could agree with the idea of halving their consumption of animal products in the long term. However, we interpret this finding very cautiously. We believe that a much lower level of agreement would have been observed if we had asked about immediate changes in diet. The reason why it makes a difference whether we ask about the long-term or the immediate change in diet is seen in the fact that although agreement in both cases has a morally relieving effect, this relief is much more strongly neutralized by the idea of having to give up attractive foods immediately than by the idea of only taking this step at some point in the future.

One psychological explanation for this phenomenon is based on the assumption of a perceived uncomfortable "cognitive dissonance" between individual ethical convictions and one's own interests, the mostly unconscious reduction of which is associated with a distorted perception of reality. In the context of animal welfare, the dissonance arises from the logical incompatibility between the belief that animals should not be subjected to pain, suffering or harm and the simultaneous desire to eat them - tastily prepared - at the next available opportunity (ROTHGERBER AND ROSENFELD 2021). While a small proportion of the population overcomes the dissonance by abstaining from meat, meat eaters reduce the dissonance through a number of mostly unconscious strategies. These strategies include, for example, the mental separation of animal and food, wilful ignorance of food production processes, denial of problematic issues and/or animal suffering, self-deception about one's own behaviour, denigration of vegetarians, and

indignation and blaming others (ibid.). If the unpleasant cognitive dissonance is not reminded from the outside, it may be completely suppressed from consciousness after some time. In order to reduce the unpleasant burden, the strategies work with a somewhat distorted perception. As a result, the unconscious denial mechanism can be expected to reduce commitment to the dietary change.

In our results, such an unconscious dissonance reduction mechanism is probably behind the different values of satisfaction with one's own commitment to more animal welfare (48%) and the corresponding commitment of fellow citizens (33%). In an objective evaluation (e.g. with information on age or height), the information on satisfaction with oneself and the information on satisfaction of others with this person should result in the same value. Since the survey is roughly representative of the German population, one would therefore expect almost identical values. Apparently, however, there is a double standard between one's own commitment and that of one's fellow citizens, as the overall picture shows that the average self-satisfaction is significantly higher than the average satisfaction with one's fellow citizens. If our assumption that the discrepancy between the two satisfaction values is due to the relieving effect of indignation and blame is correct, then the undistorted (actual) satisfaction of respondents with their own involvement is likely to be lower than the 48% reported.

5 Conclusion

The results show that there is widespread public concern about the production of food from animals, both in terms of animal welfare and climate, environmental and resource protection. The results suggest that a violation of the sense of morality and justice can be assumed. If this conclusion is correct, it is a lasting motivation to change to a more plant-based diet. It is difficult to assess the feeling of wanting to preserve eating habits and the predominantly unconscious strategies for reducing dissonance that hinder the realization of the need for change. In this respect, the political commitment to sustainable nutrition (e.g. the German government's 2024 nutrition strategy) faces a challenge.

Looking to the future, it can be said that society, agriculture, the food industry, supermarkets and policymakers must work together to transform the animal-based food sector. This means not only responding to the needs and demands of citizens for sustainable change, but also enabling a change in consumer behaviour. This might be difficult to achieve due to strong cultural roots, but with a broad mix of efforts there could be a new impetus for sustainable change, especially in the face of a growing market for plant-based alternatives.

It is important to be able to scientifically monitor social developments and changes in consumer behaviour in the long term. The study presented here presents a promising foundation for possible long-term monitoring. Politicians are asked to continue to support such research infrastructure in order to provide all actors affected by the transformation of the agricultural and food industry with fact-based decision-making aids in a timely manner.

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BRIDGING GAPS: LINKING SECTORAL MODELS AND INDIVIDUAL DIETARY BEHAVIOR

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Abstract

Bridging the gaps between sectoral models and individual dietary behavior allows for integrated analyses of health and sustainability policies. Linking market balance data and food intake surveys, our tool translates raw primary commodities into food intake and vice versa. Consolidating seven datasets, we establish a consistent quantity flow capturing the agri-food chain. The data consolidation confirms that individuals underreport energy, sugar, and dairy intake, whereas they overreport fruit intake. This consolidated dataset provides a more reliable grasp of current diets, which is essential as a precise starting point for dietary recommendations. The food-based dietary guidelines by the German Nutrition Society (DGE) are analyzed. We take up the shortcomings that the DGE formulated regarding their recommendations: Instead of only considering direct intake of foods, we also include indirect consumption of foods as ingredients in composite foods. We then formulate more accurate recommendations based on our improved database. This study is a valuable building block for interdisciplinarity between nutrition scientists and agricultural economists using sectoral models. It provides a foundation for future analyses of food processors and consumer behavior. The tool uses freely available and public data and is designed as an easily adaptable extension to pre-existing models like the CAPRI model.

Keywords

equilibrium models, DNLP models, food consumption, food-based dietary guidelines

1 Introduction

1.1 Relevance

What we eat affects our health and the planet. The production of meat and animal products in the excessive quantities demanded by consumers in high-income countries leads to the transgression of numerous planetary boundaries. Large areas of land and high amounts of water are needed to produce animal feed. Animal production is linked to high greenhouse gas emissions. This way, Western, resource-intensive diets are associated with negative impacts on global biodiversity and climate change (CAMPBELL et al., 2017; KEHOE et al., 2017; CRIPPA et al., 2021). While other sectors of the economy can be fully decarbonized through technological changes, this is not possible in agriculture (GRETHE et al., 2021). Furthermore, many non-communicable diseases could be avoided through healthier diets, leading to increased years of healthy life (GBD 2017 DIET COLLABORATORS, 2019). Western diets are often associated with micronutrient deficiencies and overnutrition (ADOLPH and TILG, 2024). The imperative for diet transformation for health and environmental sustainability is essentially a consensus among the research community (WILLETT et al., 2019). Policy interventions targeting diet transformation must consider both the health and ecological aspects. However, both require different approaches. While the environmental impact is a challenge on a societal level and only total consumption quantities matter on a national or international level, health issues must be addressed

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on the individual level. The extent and direction of necessary change depend on the personal status quo consumption.

1.2 Research Gap

The balance between societal and individual levels is not only a challenge in policy-making but also in research. The entanglements between the different goals underscore the need to link the respective methods and approaches. Nutrition scientists implicitly define environmentally sustainable diets as diets that, when adopted by everyone, would lead to agrifood systems that stay within the planetary boundaries. However, when deducting from the individual to the system level, they do not consider that a society-wide adoption can change the conditions in the agricultural sector (e.g., CLARK et al., 2022). A significant increase in the demand for one type of food will increase prices and set incentives for farmers to expand production, possibly onto soils that are less suited and yield smaller harvests. This would mean an increased average land use per ton of this food and a more negative environmental footprint. Such dynamics are not accounted for if fixed greenhouse gas emissions per ton are used to assess the environmental impact of diets (CLARK et al., 2022). Therefore, exciting work on how diet shifts can be achieved (STYLIANOU et al., 2021; e.g., GRUMMON et al., 2023; SCARBOROUGH et al., 2023) cannot be applied accurately to the sectoral level. Conversely, agricultural economists' models typically do not depict consumption patterns in detail. They usually depict raw primary commodities (RPC), like wheat or meat, instead of the foods consumers eat (RIEGER et al., 2023). While this is a sufficient approach for assessing impacts on the sectoral level, it lacks complexity for answering questions on how to achieve dietary shifts and what these new diets would look like on peoples' plates. Combining the individual and sector-level approaches can potentially build a more reliable data basis. Both food intake surveys and market balance have shortcomings but are logically connected. Hence, combining survey answers, market balance quantities, and other data reduces the impact of these weaknesses. Prior reconciliation efforts in the literature restrained themselves to selected parts of the value chain or did not use the array of information to validate data (ARNOULT et al., 2010; GRÜNBERGER, 2014; CALDEIRA et al., 2019; DE LAURENTIIS et al., 2021). Against the background of the prior research, we conclude that too little focus has been placed on databases and the disaggregation of value chains and household types in simulation models to adequately depict the sectoral effects of dietary change.

1.3 Objective

We combine the advantages of individual, detailed survey data on the consumption of specific food items with the systemic perspective of economic simulation models of the agrifood sector dealing with RPC. This combination allows for more holistic analyses. We consolidate seven datasets to capture the complete agrifood value chain from the RPC reported by market balances to the intake of final food products, including data on meat partitioning, waste, processing, and recipes. We develop a structure that translates scenarios of individual dietary behavior onto the sectoral level and vice versa. The resulting integrated database can be directly linked to sectoral models. It can, therefore, be used to analyze the impact of policies incentivizing dietary change and to get a more detailed understanding of what such a change can look like on peoples' plates.

2 Method and Research Design

2.1 Term Definition

In this publication, we differentiate between raw primary commodities (RPC) (e.g., apples, wheat), their derivatives after processing (e.g., apple compote, white wheat flour) and food items (e.g., apple strudel, mixed rye and wheat bread and rolls). Many RPC and RPC derivatives (e.g., apples and apple compote) can also be directly consumed and are food items. We use the FoodEx2 classification to describe and group food items (EFSA, 2015). At the most detailed level, level 7, there are around 1,700 food items, of which consumers mention 906 in the German food intake survey. Each level aggregates the items into broader categories (e.g., the level 7 food items "apple strudel" and "mixed rye and

wheat bread and rolls” are aggregated into the level 3 categories “pastry based on laminated dough”, respectively “leavened bread and similar” and into the level 1 category “grains and grain-based products”). Further, we differentiate between quantities available to human consumption according to the market balance, from which the inedible parts like vegetable peels, weight changes after processing, and waste have not yet been subtracted, and intake quantities, which describe only the quantities of food items or RPC that the consumers actually take in.

2.2 Data

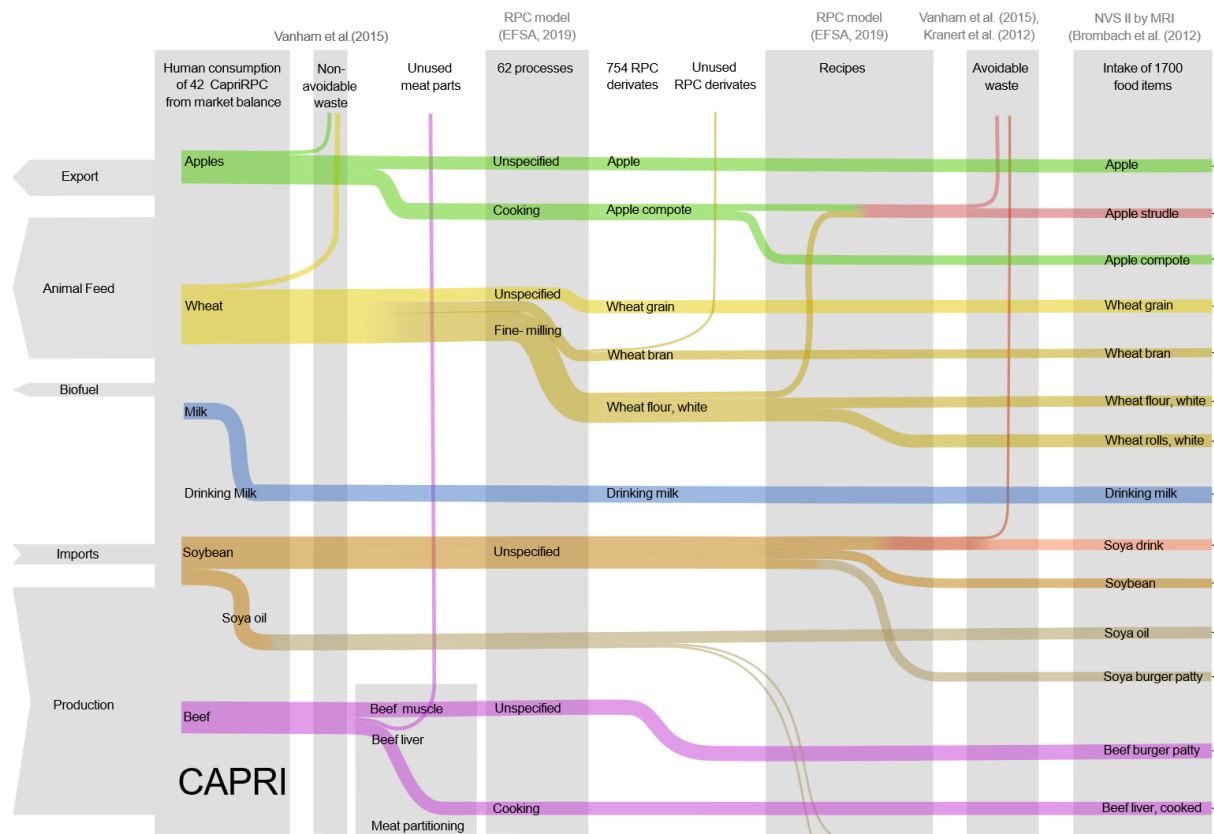
Seven databases are integrated:

1. **Market balances:** Quantities of RPC available for human consumption in Germany (CAPRI CONSORTIUM, 2022; BMEL, 2023). Human consumption quantities are calculated as the residual of the directly recorded production, net trade, and other uses. We use the same RPC aggregates as the equilibrium model CAPRI to allow for a direct connection of our tool.
2. Proportions for **meat partitioning** (HÖRETH, 1995; PAPSTEIN et al., 1995; RISTIC et al., 1995; ENDER and AUGUSTINI, 1998; PINGEL et al., 1998; VON Lengerken et al., 1998)
3. **Processing** yields (EFSA et al., 2019)
4. **Recipes** (EFSA et al., 2019; FSANZ, 2020)
5. **Non-avoidable waste** (VANHAM et al., 2015)
6. **Avoidable waste** (KRANERT et al., 2012; VANHAM et al., 2015)
7. **Food intake survey:** Average per capita intake quantities per food item from the German National Nutrition Survey II (NVSII) from 2006, with 13,926 randomly selected participants, representative of the German-speaking population, between the ages of 14 and 80, questioned in 24-hour recalls about their intake of food and beverages (BROMBACH et al., 2006; KREMS et al., 2006; EFSA, 2023).

2.3 Data Consolidation

The physical relationships between the different steps of the value chain, as visualized in Figure 26, are defined as equations. Figure 26 is a schematic visualization that only includes a few exemplary RPCs, their derivatives, and food products. For a better overview, not all quantity flows are depicted (e.g., avoidable waste is included for all food items in the tool even though it is not shown). The value chain starts with the RPC quantities that go into human consumption according to the market balance (left-hand side of Figure 26) and can be categorized according to the aggregates used in the desired model (here: CAPRI). Non-avoidable and avoidable waste, unused meat parts, and unused RPC derivatives leave the food value chain. Non-avoidable waste is included as shares of the RPC (e.g., the apple pit), whereas avoidable waste regards the final food item. However, if RPC derivatives are products of coupled processes (e.g., fine milling of wheat into white flour, bran, and germ) where one derivative is more demanded (i.e., white flour) than the others (bran and germ), the later is depicted as non-food RPC derivatives that are used for purposes other than human food (e.g., for feeding animals or in the bioeconomy). Meat partitioning is modeled similarly to the coupled processing but is treated separately as the data on proportions within the animals comes from a different source.

Figure 1: Schematic visualization. Source: own compilation.



To estimate a mass flow that is both consistent and as close as possible to the original datasets, the information from each dataset is entered as expected values. The consolidation is formulated as a nonlinear programming problem with discontinuous derivatives. The objective function minimizes deviations from expected values (e.g., due to underreporting in intake data or oversimplifying waste assumptions). Also, bounds are set on how much a variable may deviate from its expected value.² They may reflect the trustworthiness of the data points or just follow from a logical condition.³

2.4 Simulations

The tool allows for analyzing scenarios regarding the society-wide adoption of different dietary recommendations, building on the consolidated data. Logical linkages between datasets remain the same as in the consolidation process. Processing yields, recipes, shares of avoidable and non-avoidable waste, and meat partitioning are fixed to the consolidated values.

Scenario “DGE_FoodItem”. The food-based dietary guidelines (FBDG) published by the German Nutrition Society (DGE) recommend intake quantities for food categories (SCHÄFER et al., 2024). In the simulation, the intake quantities of the food items are fixed to this value⁴. With the consistent quantity flow, the intake quantities can be unambiguously translated into the RPC quantities at the market balance level, which would supply these intake quantities and allow for a society-wide adoption of the DGE recommendations. The resulting RPC quantities

² For all datasets reporting shares or coefficients (i.e., avoidable and non-avoidable waste, meat partitioning, processing, recipes) the bounds are generally set to $\pm 20\%$.

³ A share cannot be larger than 1. Quantities cannot be negative. If the expected value of a processing yield indicates a weight loss, the weight loss can be larger or smaller, but it cannot become a weight gain.

⁴ The DGE recommendations are for the most aggregate FoodEx2-categories (level 1, e.g., “grains and grain-based products”). In the simulation “DGE_FoodItem” we assume that the proportions of the food items (e.g., “mixed rye and wheat bread and rolls”) within the categories do not change. Therefore, we calculate the percentage difference between the consolidated and the recommended intake quantities for each category. Then we apply this percentage difference to the consolidated intake quantity of each food item in this category and fix the intake quantity of the food item to the resulting value.

at the market balance level can serve as input for simulations of such a dietary change with a sectoral model like CAPRI.

Scenario “DGE_RPCIntake” aims to improve the accuracy of the DGE recommendations. In the “DGE_FoodItem” scenario, the daily intake goal, e.g., nuts and seeds, was modeled by increasing the intake of all food items in the FoodEx2 category “nuts and oilseeds”, missing nuts and seeds that may be consumed via bread. The DGE has identified this shortcoming (BREIDENASSEL et al., 2022). We take this up; therefore, in “DGE_RPCIntake”, we fix the intake quantities of RPC equivalents instead of the food items to the DGE recommendations. The combination of intake quantities of the 900 food items that supply these RPC quantities directly and indirectly and that is associated with the least adjustment efforts by the consumers is determined by minimizing the deviation from the intake habits as defined by the consolidated intake quantities (Equation 1). These are unambiguously translated into the RPC quantities at the market balance level. This way, the accuracy of the DGE recommendations can be assessed to determine whether they meet their own intake goals on the level of RPC equivalents.

Equation 1: Objective function for simulations. Deviations in food intake.

$$vDevIntake = pWeight^{intake} * corr^{term}^{intake}$$

$$* \sum_{FoodItem} \left[\left(\frac{vFoodIntake_{FoodItem} - consoldFoodIntake_{FoodItem}}{StdDev^{intake, FoodItem}} \right)^2 + \left(\frac{(penalty * bound^{intake} * consoldFoodIntake_{FoodItem}) - vFoodIntake_{FoodItem}}{consoldFoodIntake_{FoodItem}} \right) - \frac{(0.001 * consoldFoodIntake_{FoodItem}) * \ln \left(1 + e^{\frac{(penalty * bound^{intake} * consoldFoodIntake_{FoodItem}) - vFoodIntake_{FoodItem}}{0.001 * consoldFoodIntake_{FoodItem}}} \right)}{consoldFoodIntake_{FoodItem}} + \left(\frac{vFoodIntake_{FoodItem} - \left(\frac{1}{penalty * bound^{intake}} * consoldFoodIntake_{FoodItem} \right)}{consoldFoodIntake_{FoodItem}} \right) - \frac{(0.001 * consoldFoodIntake_{FoodItem}) * \ln \left(1 + e^{\frac{vFoodIntake_{FoodItem} - \left(\frac{1}{penalty * bound^{intake}} * consoldFoodIntake_{FoodItem} \right)}{0.001 * consoldFoodIntake_{FoodItem}}} \right)}{consoldFoodIntake_{FoodItem}} \right]^2$$

3 Results

3.1 Food intake according to the original survey answers and consolidated data.

The consolidation process leads to adjustments in all seven datasets. The Pearson correlation coefficient for each dataset between the original and the consolidated data is above 0.95. The market balance data is considered the most accurate dataset when consolidating the seven data sets. The tool found consistent quantity flows to match almost all the original market balance quantities by adjusting the other data points within the allowed bounds. However, our consolidation procedure shows that the market balance quantities of dairy powders⁵ and palm oil are too high to match the food intake data even when considering error margins for all other data

⁵ whey powder, skimmed milk powder and whole milk powder

points. These RPC may be underrepresented as ingredients in the recipe data as they are typically used in industrial food processing but less in home cooking, and the recipe data is biased towards the latter.

There is a visible bias toward increasing rather than decreasing the waste shares and the intake quantities. This leads to the conclusion that the original intake data is too low to fit the market balance data for most food items. When data consolidation finds food intake quantities higher than the starting values, the avoidable waste shares are usually also higher than the starting values suggested by the literature. This was expected as increasing the wasted share of this food item and increasing its intake both work towards matching initial intake levels too low to fit the available RPC quantities. The positive correlation between the deviations from initial values for non-avoidable waste shares and processing yields further confirms the functionality of the consolidation tool. RPCs that are too abundantly available for the reported intake of food items that use them as ingredients are (usually) estimated to have higher non-avoidable waste shares and higher processing coefficients⁶ than in the initial data.

For food items in the categories “Fruit and fruit products” and “Fruit and vegetable juices and nectars (including concentrates),” the consolidated intake quantities are significantly smaller than the original data suggests⁷. This suggests that survey participants could have overreported their intake of fruit and juices. The opposite is true for “Sugar and similar, confectionery and water-based desserts” and “Fish, seafood, amphibians, reptiles and invertebrates” which are the categories with the largest positive deviations from the starting values in relative terms (+116% for both). In absolute terms, the largest deviations can be found for “Grains and grain-based products”, “Milk and dairy products”, and “Alcoholic beverages”⁸. Here, the reported intake quantities are too small to match the RPC quantities needed for producing the food items of this category. Such positive deviations suggest that consumers may have underreported their intake quantities. The overreporting for the category “Fruit and fruit products” and the underreporting of the intake of “Sugar and similar, confectionery and water-based desserts” and “Alcoholic beverages” can be explained by survey participants adjusting their answers consciously or unconsciously to what they believe is socially desirable. This supports existing analyses of the NVSII (EISINGER-WATZL et al., 2015; HEUER et al., 2015).

3.2 Food intake in the context of dietary recommendations

3.2.1 Status quo consumption as the starting point for dietary recommendations.

The DGE formulates desirable diets with absolute intake quantities (e.g., 300 g of fruit per day), but for communication, the difference between the current and the recommended diet matters (i.e., “eat more/less of...”). Hence, an accurate grasp of the status quo food intake is crucial as it is the starting point of any dietary recommendation. However, definitions of status quo consumption differ. The DGE considers direct intake quantities of the FoodEx2 categories that best fit the recommended food groups. For example, the DGE reports the intake of eggs as the total intake of food items belonging to the FoodEx2-category “Eggs and egg products”⁹ and the intake of plant oils for food items of the FoodEx2-category “Vegetable fats and oils, edible” (SCHÄFER et al., 2024). In Figure 27, the direct intake defined by the DGE is shown in the far left column “direct intake”. This definition, however, does not accurately capture the actual intake as a) food items in the respective category do not consist exclusively of eggs (e.g., fried eggs consist of 8% oils) and b) a relevant

⁶ The higher the processing coefficient is, the more RPC (e.g., wheat grain) is needed to produce a unit of RPC derivative (e.g., flour).

⁷ “Fruit and fruit products”: -2.076 Mio tons or -43% and “Fruit and vegetable juices and nectars (including concentrates)”: -4.223 Mio tons or -69%.

⁸ “Grains and grain-based products”: +3.944 Mio tons, “Milk and dairy products”: +2.370 Mio tons, and “Alcoholic beverages”: +2.221 Mio tons.

⁹ E.g., boiled eggs, fried eggs, poached eggs.

share of eggs and plant oils are consumed indirectly through other products (e.g., eggs and oils in cakes and biscuits, oils in salad dressing or for frying). When calculating the intake quantities, considering both direct and indirect consumption leads to significantly different values for many foods, as shown in the columns “startVal” in Figure 27. The intake of eggs is 18 g per capita and day and, therefore, 50% higher than the intake reported by the DGE (11 g). The intake of plant oils is 16 g per day when the intake, primarily via grain products, sauces, and condiments, is included. This is more than 500% of DGE’s reported daily 3 g. This gap is even more exacerbated when calculating direct and indirect intake with the consolidated data, thus accounting for under-/overreporting, inconsistent data, etc. As shown in column “consol” of Figure 27, the consolidated data suggests the daily intake of eggs is 27 g (more than double the direct intake) and 31 g for oils (10 fold of the direct intake). Acknowledging these vast discrepancies is essential for contextualizing dietary recommendations. The definition of status quo consumption determines the direction and extent of the diet changes necessary to meet the recommended intake quantities.

Figure 7: Daily intake quantities per capita in grams. Different definitions of status quo intake (“direct intake”, “startVal”, “consol”) and intake quantities in the scenarios (“DGE_FoodIntake” and “DGE_RPCIntake”)



3.2.2 Dietary recommendations are more meaningful at the level of raw primary commodities.

Considering both the direct and indirect consumption of RPC allows us to analyze the accuracy of the scenario formulations and assess whether the scenarios meet their own recommendations. We interpret the published recommendations by the DGE (SCHÄFER et al., 2024) to target both direct and indirect intake of the RPCs, as we assume that it does not matter neither for health or environment whether, e.g., eggs or plant oils are consumed directly or indirectly as ingredients in other foods (lines “DGEgoal” in Figure 27). Then, we calculate the total intake (direct and indirect intake) of these RPCs for the scenario (columns “DGE_FoodItem” in Figure 27) and compare it to the goals as formulated. For RPC primarily consumed as ingredients of other food items (e.g., plant oils), the RPC intake in the “DGE_FoodItem” scenario is much higher than recommended by the DGE’s FBDG. This discrepancy occurs because the DGE ignored important consumption sources when formulating their recommendations. For example, to meet the recommended intake of plant oils of 12 g, the DGE suggests increasing the intake of all food items from the FoodEx2 category “Vegetable fats and oils, edible”. However, food items like “salad dressing” or “fries (finger chips)” are listed in other categories and are not considered by the DGE even though they contribute significantly to the overall intake of plant oils. Therefore, if the recommendations of the DGE are taken literally for the FoodEx2-categories (“DGE_FoodItem”), much more plant oils are consumed than the interpretation of the recommendations on RPC-level suggests (“DGEgoal”). The same applies to spreadable fats, eggs, red meat, and potatoes, and to a lesser extent to dairy and poultry. Wholegrain, however, is much less consumed than recommended.

In the “DGE_RPCIntake” scenario, the intake of sauces and vegetable oils is drastically reduced compared to “DGE_FoodItem”. Composite dishes with a high vegetable content substitute for those containing lots of plant oil and potatoes. To meet the intake goals for red meat, less unprocessed mammal meat, composite dishes, and other sources are consumed. Processed meat appears to be more challenging for consumers to let go of. The necessary decrease in eggs is mainly accomplished by the reduced intake of egg products. From the consumers’ perspective, it appears easier to cut those than the grain products made with eggs. The standard deviation for the intake of egg-containing grain products is smaller than for egg products; hence, consumers’ willingness to adjust intake quantities is considered more rigid. Similarly, the intake of spreadable fats is lowered by reduced intake of butter and other fat emulsions, but the intake of spreadable fats through grain-based products stays almost constant. The differences in standard deviations also lead to the high intake of canned legumes and nut paste (instead of legumes and nuts like in “DGE_FoodItem”). This concentration makes the diet of “DGE_RPCIntake” appear somewhat monotonous. However, this is the easiest to adopt among many other options.

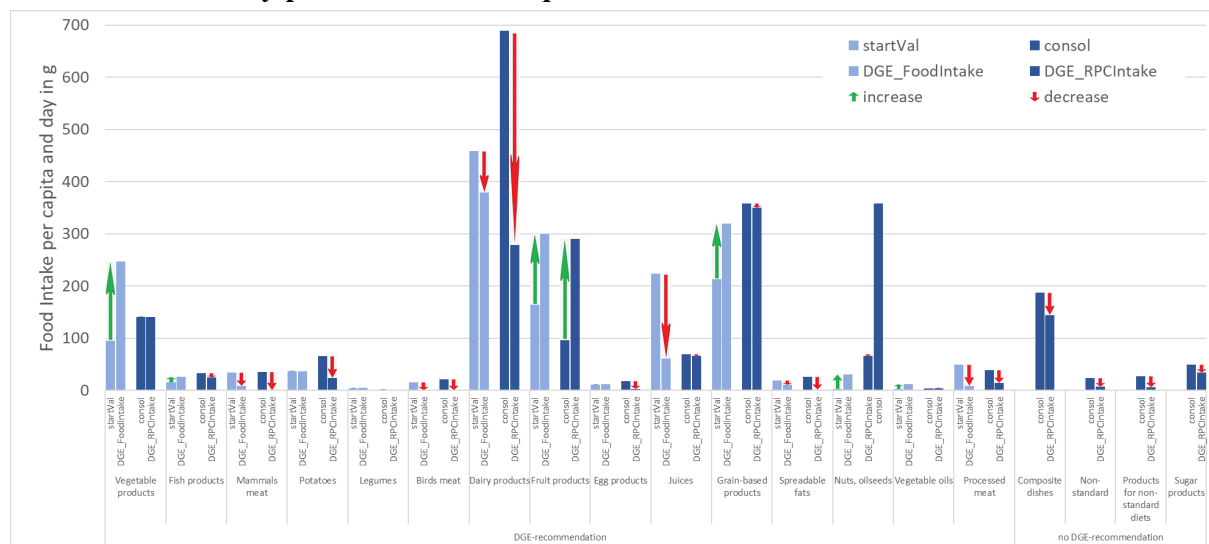
3.2.3 Recommended adjustments depend on the definition of status quo and intake

Against the background of the presented analysis of different definitions of status quo consumption and varying interpretation of recommended intake quantities, the FBDG by the DGE are compared to the recommendations that can be derived with our tool (Figure 3). The first two columns (light blue) for each food category reflect the recommendations from the DGE’s publications on FBDG, with “startVal” describing the reported intake quantity and “DGE_FoodItem” describing the recommended quantity from the original FBDG. The arrows indicate the extent of the increase (green) or decrease (red) required to meet the target. The second pair of columns (dark blue) depict the recommendations derived by the authors. The column “consol” gives the food intake quantities derived from the data consolidation, accounting for potential data problems or inaccurate reporting. The column “DGE_RPCIntake” describes the food intake quantity that allows to meet the requirements of the FBDG but on the RPC level (i.e., eggs consumed directly or indirectly as an ingredient via other products), not on the food item level (i.e., only foods that are classified in the category “eggs and egg products”).

These two approaches imply different adjustments in consumer behavior – both in direction and extent. As the data consolidation suggests that the intake of fruit and fruit products is lower than reported in the survey, the actual increase to meet the recommended intake levels is higher than the DGE suggests. For “vegetables and vegetable products” and “grains and grain-based products”, data consolidation finds that the status quo intake is likely higher than reported, meaning that smaller adjustments have to be made by consumers to meet the target. Also, data consolidation suggests that the actual intake is higher than reported for “milk and dairy products” and “eggs and egg products”. Additionally, the DGE’s FBDG disregard the indirect intake of dairy and eggs via other food products, leading to a target for the categories “milk and dairy products” and “eggs and egg products” that is too high. Hence, the recommended intake for this category is smaller when considering the overall intake of dairy products, leading to a larger required adjustment in intake quantities.

In direct comparison to the communication by the DGE, the presented result translates as follows¹⁰: Instead of reducing the daily consumption of milk products by the equivalent of 80 g, the average consumer needs to reduce it by 411 g of milk equivalents, which is, e.g., almost two portions of yogurt or two slices of cheese. Instead of eating one more portion of fruit a day, it should be nearly two. Instead of eating two more portions of cereal products (e.g., two slices of bread or two portions of cereal flakes), the consumption should be kept stable. To accommodate the indirect consumption of eggs via processed foods, the direct intake of eggs would have to be reduced to close to zero to meet the recommended egg intake. In contrast, the original recommendation by the DGE suggests keeping the direct consumption of eggs constant. For plant oils, the directions change from a recommended increase of 400% (from 3 to 12 g per day and per capita) to a significant decrease in oil-containing sauces and grain-based products and a slight decrease in the direct intake of vegetable oils.

Figure 3: Comparison of the FBDG by DGE and own derived recommendations. Food Intake per capita per day in g, and per FoodEx2-category at level 1. Dairy products in milk equivalents.



4 Conclusion

4.1 Recap on results and strengths

This study establishes a foundation for linking sectoral equilibrium models with data from a food intake survey while considering losses and food processing.

¹⁰ A portion of dairy products is the equivalent of 250 g fresh milk, one portion of fruit is 110 g, one portion of cereal is 60 g. See Schäfer et al. (2024) for complete original DGE recommendations and portion sizes.

Linking food intake quantities with recipe composition and processing yields allows us to quantify both direct and indirect intake of raw primary commodities. We build a more reliable data basis for diet analyses by combining several datasets depicting the whole value chain, including food losses, waste, and weight changes from processing. We consolidate this data into a consistent quantity flow. These steps allowed us to critically assess the accuracy of the utilized food intake survey as a starting point for dietary recommendations and implied adjustments. The linkage of food intake quantities with recipe and processing data also allowed us to check whether formulations of dietary recommendations like the FBDG by the DGE are accurate in reaching their own goals in terms of RPC intake and quantify the shortcomings as voiced in Breidenassel et al. (2022). Consequently, with the tool, we review recommendations on necessary adjustment of consumer behavior by the DGE and formulate new adjustment recommendations based on our improved database and understanding of direct and indirect consumption ways.

By depicting the complete value chain between market balance and food intake and then calculating a consistent quantity flow, we can translate scenarios on the level of food items (like the adoption of FBDG) into market balance shocks for simulations in sectoral models. Vice versa, we can now translate results from such models into likely ways of adoption for consumers at the level of food items. Hence, this study is a valuable building block for interdisciplinarity between nutrition scientists and agricultural economists using sectoral models such as CAPRI. The tool uses freely available and public data and is designed as an easily adaptable extension to pre-existing models like the freely available CAPRI model. FoodEx2 was used as the product categorization and, therefore, fits the latest version of the Comprehensive Food Consumption Database. Hence, the tool can be adapted to work with other surveys from this database.

4.2 Implications of the Results for the Research Community and Policy Makers

When assessing dietary recommendations, two aspects are important. Firstly, they should be accurate in that they are suitable to meet their declared goals regarding the food intake in terms of RPC and nutrients and the environmental impact. Secondly, dietary recommendations should be easy to understand and adopt by consumers, as well as policymakers and institutions providing communal catering. We believe that our tool helps to decrease the extent of the trade-off between them. By consolidating seven different data sources, we provide a better idea of the German status quo diet, offering a better starting point for recommended diet changes. Further, the tool allows the accuracy of dietary recommendations regarding the associated intake of RPC equivalents to be checked. Therefore, this study contributes to a research gap that the DGE has already identified as a limitation to their recommendations (BREIDENASSEL et al., 2022). Furthermore, with the help of our tool, diets that are precise at the intake of RPC equivalents are accurately translated into total quantities available for human consumption at the market level. Accurate numbers for these improve the assessment of the effect of dietary changes on the agricultural sector and the environment.

Our work accounts for the fact that dietary recommendations cannot be viewed as a collection of independent recommendations for separate food items or RPC but that each recommended intake quantity is linked to others. We consider that many RPCs are consumed directly and indirectly as ingredients in food items and in combination with other RPCs. From a communication perspective, this adds complexity and may make it harder to convey recommendations in an easily understandable way. However, it also shows consumers' flexibility in adopting dietary recommendations according to their preferences. One option for communicating this flexibility is to clearly state that, e.g., the quantity of boiled or fried eggs one can eat within the framework of the DGE recommendations depends on the quantity one eats of egg-containing cookies and cakes. Accompanying such formulations with the average diet we present in this

work (e.g., that on average, 40% of eggs are eaten in bakery products, and only 60% are consumed as egg products) can help raise awareness in consumers for indirect intake and serve as a point of orientation for their eating behavior and potential for adjustment.

4.3 Outlook

The tool can also be used to analyze dietary recommendations for the intake of RPC, like the Planetary Health Diet (PHD) (as opposed to recommendations regarding food items like the DGE's FBDG). The PHD recommendations are given as intake quantities per capita and day (WILLETT et al., 2019) and are translated into national, annual market balance quantities. In this format, the PHD is modeled in simulation models like CAPRI (RIEGER et al., 2023). To depict how consumers can adopt the PHD, the RPC quantities in the market balance are fixed to the amounts recommended. Minimizing the deviation from the intake habits as defined by the consolidated intake quantities (equation 1) finds the combination of intake quantities of the 900 food items that match this shock and are associated with the smallest possible adjustment effort by the consumers. These results offer hints for policymakers, food processors, and organizers of institutional catering on how diet transformation can be made accessible for consumers. Also, the translation of daily per capita intake into market balance quantities is not trivial, as the latter also includes losses and processing weight changes. Therefore, checking whether this translation was conducted correctly and whether the recommended intake quantities were met in terms of RPC equivalents is a valuable contribution to improving the modeling of the dietary recommendations.

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RESIDUE USAGE AND CIRCULAR ECONOMY

CIRCULAR ECONOMY IN DER AGRAR- UND ERNÄHRUNGSWIRTSCHAFT? EINE VERGLEICHENDE ANALYSE VON DREI KREISLAUFBASIERTEN INNOVATIONEN IN DEUTSCHLAND

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Zusammenfassung

In diesem Beitrag wird das Potenzial von drei entstehenden missionsorientierten Innovationssystemen (MIS) analysiert: SUSKULT, RUN und CUBES Circle. Es wird untersucht, inwiefern sie zur Mission einer Kreislaufwirtschaft (Circular Economy) im deutschen Agrar- und Ernährungssektor beitragen können. Die drei MIS stehen für Forschungs-, Entwicklungs- und Innovationsaktivitäten, die neue Wege der zirkulären Agrar- und Lebensmittelproduktion durch Materialkreislaufschließung, Ressourcenrückgewinnung mittels Nährstoffrecycling und innovative Produktionsansätze erschließen. Der Beitrag untersucht anhand vergleichender Fallstudienforschung und eines Multimethoden-Forschungsdesigns die Faktoren, die die Implementierung der drei MIS unterstützen oder behindern. Die empirischen Ergebnisse zeigen, dass die drei untersuchten MIS trotz unterschiedlicher technologischer Ansätze ähnlichen systemischen Barrieren gegenüberstehen. Es ist offensichtlich, dass missionsorientierte Politiken erforderlich sind, um Innovationsnischen zu schaffen, den sektorübergreifenden Austausch zu fördern und regulatorische Anpassungen vorzunehmen.

Keywords

Agri-food Innovationen; Circular Economy; missionsorientiertes Innovationssystem; Nährstoffrecycling

1 Einleitung

Die Verringerung des Ressourcenverbrauchs und der Abfälle bei Produktion und Konsum in allen Sektoren wird seit langem als eine der wesentlichen Herausforderungen für die wirtschaftliche Entwicklung auf einem begrenzten Planeten angesehen (Vereinte Nationen, 1973; Vereinte Nationen, 1992). Obwohl Ideen und Praktiken zur Wiederverwendung von Produkten und zum Recycling von Materialien bereits seit den 1970er Jahren verbreitet sind, wurde das Konzept der Circular Economy bzw. der Kreislaufwirtschaft erst in den frühen 1990er Jahren vollständig formuliert (Pearce & Turner, 1990; Ekins et al., 1992) und gewann mit dem Setzen der Agenda durch die Ellen Mac Arthur Foundation (EMF, 2013) weiter an Bedeutung. In seiner ambitioniertesten Form beinhaltet Circular Economy eine umfassende Vision eines technisch-wirtschaftlichen Systems, das seine Umweltauswirkungen minimiert, indem es die Ressourcengewinnung durch die Wiederverwendung und das Recycling von Materialströmen ersetzt, die derzeit als Abfall behandelt werden (Stahel, 2016). Verschiedene Foren, wie die OECD (McCarthy et al., 2018) oder das IISD SDG Knowledge Hub (2018), haben versucht, das Konzept der Circular Economy zu operationalisieren. Kirchherr et al. (2017) zeigen jedoch, dass es nicht weniger als 114 Definitionen von Circular Economy gibt, die sich in ihrer Spezifität und

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in dem Ausmaß unterscheiden, wie sie Circular Economy als ein industrielles oder wirtschaftliches Konzept behandeln (Ekins et al., 2020). Circular Economy kann daher am besten als ein „übergreifendes“ Konzept verstanden werden, das in der Sorge um Ressourcenknappheit und Toxizität verwurzelt ist (Blomsma & Brennan, 2017) und sich auf eine Reihe von Kreislaufwirtschaftsstrategien bezieht (Potting et al., 2017). Die zunehmenden Umweltprobleme im Agrar- und Ernährungssektor (Toreti et al., 2019; Willett et al., 2019) steigern die Bedeutung von Circular Economy als einen möglichen Weg, um zukünftige globale Herausforderungen und die Transformation zu einem resilienten, ressourcen-effizienten und nachhaltigen Ernährungssystem zu adressieren (Galli et al., 2020; Picchioni et al., 2021).

Die Verwirklichung der Circular Economy im Agrar- und Ernährungssektor ist daher sowohl auf EU- als auch auf nationaler Ebene eine wichtige Mission. Die Europäische Kommission hat im März 2020 einen neuen Aktionsplan für die Circular Economy verabschiedet, der als Hauptbestandteil des europäischen Green Deals eine neue Agenda für Europa auf dem Weg zu nachhaltigem Wachstum darstellt (Europäische Kommission, 2020b). Die Mission der Circular Economy besteht darin, den Druck auf natürliche Ressourcen zu verringern, Arbeitsplätze zu schaffen, Klimaneutralität bis 2050 zu erreichen und den Verlust der biologischen Vielfalt zu stoppen. Dies soll durch verschiedene Maßnahmen entlang des gesamten Lebenszyklus von Produkten erreicht werden. Diese Maßnahmen zielen darauf ab, Produkte nachhaltig zu erzeugen, Prozesse der Circular Economy zu fördern, einen nachhaltigen Konsum zu unterstützen und sicherzustellen, dass Abfälle vermieden werden und die verwendeten Ressourcen so lange wie möglich in der EU-Wirtschaft gehalten werden (Europäische Kommission, 2020b). In Deutschland wurde eine Nationale Kreislaufwirtschaftsstrategie als Rahmenstrategie erarbeitet. Diese enthält Ziele und Maßnahmen für eine zirkuläre Wirtschaft und zur Schonung der Ressourcen. Die Rahmenstrategie soll einen Beitrag zur Senkung der Umweltbelastung, zum Biodiversitätsschutz und zum Klimaschutz leisten. Bis 2030 sollen nachhaltige Konsum- und Produktionsmuster erreicht werden, indem die natürlichen Ressourcen nachhaltig bewirtschaftet und effizient genutzt werden (BMUV, 2023b).

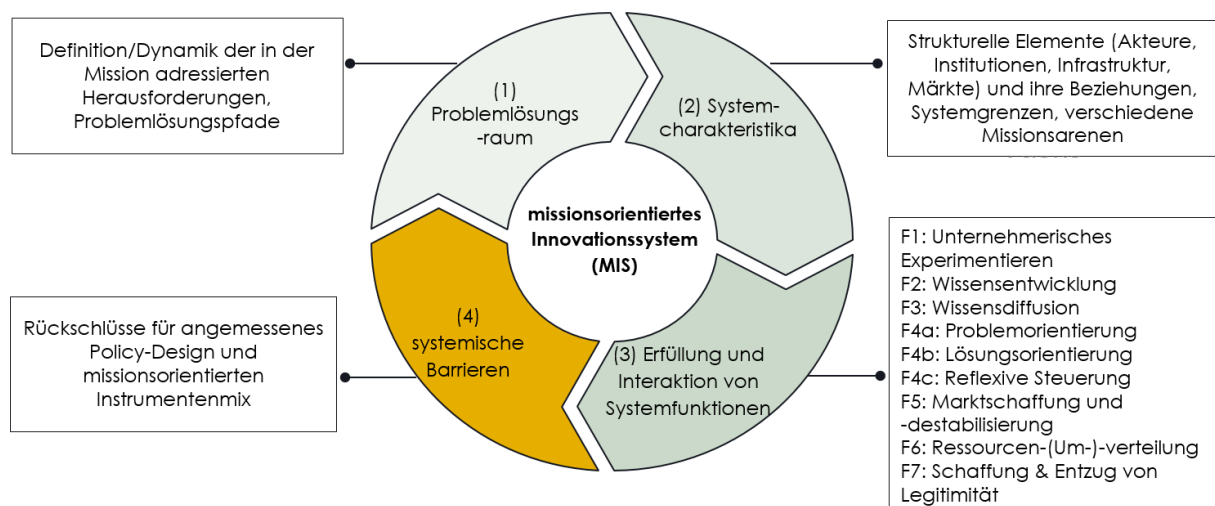
Im Einklang mit Transformationsstudien, die nahelegen, dass die Circular Economy nicht nur neue Technologien und nichtlineare Veränderungsdynamiken erfordert, sondern auch eine nachhaltige Transformation bestehender sozio-technischer Systeme (Köhler, 2019; Singh et al., 2021), müssen die Rahmenbedingungen im jeweiligen spezifischen Kontext mit den neuen Technologien harmonisiert werden. Jedoch ist dies bei Technologien, die Circular Economy einbeziehen, schwierig zu bewerkstelligen, da gegenwärtig noch viele Rahmenbedingungen eine lineare Ökonomie bevorzugen (BMUV, 2023b). Trotz umfangreicher Forschung zur Circular Economy (u.a. Chiaraluce et al., 2021; Zhang et al., 2022; Scandurra et al., 2023) ist das Verständnis der institutionellen Beziehungen und Praktiken in Transformationsprozessen hin zur Circular Economy noch begrenzt. Die vorliegende Studie zielt darauf ab, zur Schließung dieser Forschungslücke beizutragen, indem drei vom Bundesministerium für Bildung und Forschung (BMBF) im Rahmen des Programms „Agrarsysteme der Zukunft“ (BMBF, 2022) geförderte und auf Circular Economy ausgerichtete Innovationssysteme mit Hilfe des Forschungsansatzes des missionsorientierten Innovationssystems (MIS) vergleichend analysiert werden. Der MIS-Ansatz ermöglicht eine umfassende Sicht auf Innovationen und die Transformation in Richtung einer bestimmten gewünschten gesellschaftlichen Mission (Schot & Steinmueller, 2018a; Wanzenböck et al., 2020). Der Beitrag fragt: *Wie gut sind die drei MIS in der Lage, Circular Economy-Innovationen zu ermöglichen? Welche Barrieren beeinträchtigen die Etablierung von Circular Economy-Innovationen sowie die Transformation zu zirkulären Agrar- und Lebensmittelproduktionssystemen?* Basierend auf den identifizierten Barrieren können missionsorientierte Innovationspolitiken formuliert werden, die darauf abzielen, die Performance der MIS zu stärken, um die Mission einer Circular Economy zu erreichen. Der Beitrag stellt zunächst den konzeptionellen Analyserahmen in Kapitel 2 vor. Kapitel 3 erläutert die

Fallstudien und das methodische Vorgehen. Kapitel 4 präsentiert die empirischen Ergebnisse. Der Beitrag schließt mit einer Diskussion und Schlussfolgerungen in Kapitel 5.

2 Das missionsorientierte Innovationssystem

Der MIS-Ansatz (siehe Abbildung 1) dient als konzeptioneller Rahmen für die Bewertung einer Transformation hin zur Circular Economy durch kreislaforientierte Ansätze im Agrar- und Ernährungssektor. Er ermöglicht in besonderer Weise die Analyse von Systemen, die sich auf Innovation und Veränderungen in Bezug auf vordefinierte Missionen konzentrieren (Hekkert et al., 2020). Der MIS-Ansatz wurde eingeführt, um sicherzustellen, dass Innovationspolitiken nicht nur auf Wirtschaftswachstum ausgerichtet sind, sondern auch dazu beitragen, aktuelle gesellschaftliche Herausforderungen zu bewältigen und mehr oder weniger genau spezifizierte Missionen zu erreichen (Hekkert et al., 2020). Der MIS-Ansatz basiert auf dem Konzept der Innovationssysteme (Freeman, 1987), welche die strukturellen Elemente und deren Aktivitäten beschreiben, die an der Innovationsentwicklung innerhalb verschiedener Systemgrenzen (z.B. national, regional oder technologisch) beteiligt sind (Lundvall, 1992; Malerba, 2004; Hekkert et al., 2007). Die Aktivitäten innerhalb eines Innovationssystems werden als Funktionen beschrieben (Johnson, 2001; Hekkert et al., 2007), mit deren Hilfe Barrieren und Herausforderungen, welche die Erfüllung der Mission beeinträchtigen können, analysiert werden (Coenen et al., 2023).

Abbildung 1: Das missionsorientierte Innovationssystem als konzeptioneller Rahmen



Quelle: Eigene Darstellung (2023) basierend auf Wesseling & Meijerhof (2021) und COENEN et al. (2023)

Die Analyse innerhalb des MIS-Rahmens erfolgt in vier Schritten. Zunächst wird der *Problemlösungsraum* (1) betrachtet, welcher die sozialen Herausforderungen definiert, die von der formulierten Mission mittels verschiedener potenzieller Lösungswege adressiert werden sollen (Wanzenböck et al., 2020). Im zweiten Schritt erfolgt die Analyse der *Systemcharakteristika* (2) innerhalb definierter Systemgrenzen. Dabei werden strukturelle Elemente und deren Beziehungen sowie vorhandene Missionsarenen und involvierte Akteure identifiziert (Wesseling & Meijerhof, 2021). Der dritte Schritt umfasst die Bewertung der fördernden und hemmenden Aktivitäten im Innovationsprozess, die das Erreichen der Mission beeinflussen (Bergek, 2019). Dabei werden die *Erfüllung und Interaktion von Systemfunktionen* (3) innerhalb des MIS beurteilt (Raven & Walrave, 2020). Es lassen sich sieben Funktionen unterscheiden: unternehmerisches Experimentieren (F1), Wissensentwicklung (F2), Wissensdiffusion (F3), Problemorientierung (F4a), Lösungsorientierung (F4b) und reflexive Steuerung (F4c), Marktschaffung für neue Lösungen und Marktdestabilisierung für alte Lösungen (F5), Ressourcen-(Um-)verteilung (F6) sowie Schaffung und Entzug von Legitimität (F7) (Hekkert et al., 2020; Coenen et al., 2023). Eine detaillierte Beschreibung der Funktionen findet sich im Anhang I.

Während die Funktionen F1 bis F4c weitgehend aus dem MIS selbst heraus generiert werden können, sind die Funktionen F5 bis F7 von weiteren strukturellen, wirtschaftlichen, politischen und sozialen Faktoren abhängig (Coenen et al., 2023). Die Funktionen innerhalb eines MIS stehen in Wechselwirkung zueinander, sodass die Erfüllung einer Funktion die Leistung einer anderen beeinflussen kann. Eine fehlende Legitimität kann beispielsweise die Mobilisierung von Ressourcen oder unternehmerisches Experimentieren innerhalb des MIS einschränken (Hekkert et al., 2007). Durch die Identifizierung gesellschaftlicher Herausforderungen und die Analyse der strukturellen und funktionalen Aspekte des MIS können im vierten Schritt *systemische Barrieren* (4) für das Erreichen einer Mission ermittelt (Wesseling & Meijerhof, 2021; Coenen et al., 2023) und auf dieser Grundlage missionsorientierte Politiken entwickelt werden. Diese haben das Ziel, schwache oder fehlgeleitete Funktionen zu stärken und zu korrigieren (Wanzenböck et al., 2020; Janssen et al., 2021), um die formulierte Mission zu erreichen (Schot & Steinmueller, 2018a; Wanzenböck et al., 2020).

3 Empirische Methoden und Analyserahmen

3.1 Die Fallstudien

In diesem Beitrag werden die Innovationssysteme für drei sich noch in der Entwicklung befindliche Nischeninnovationen – SUSKULT, RUN und CUBES Circle – näher betrachtet, um Unterschiede und Gemeinsamkeiten verschiedener technologischer Innovationen auf unterschiedlichen räumlichen Skalen hinsichtlich des Erreichens einer Circular Economy-Mission zu untersuchen (Yin, 2003; Baxter & Jack, 2008; Goodrick, 2014). Die Analyse verfolgt dabei einen vergleichenden Fallstudienansatz, um ein tieferes Verständnis eines zuvor noch nicht erforschten Phänomens zu erlangen, das für einen größeren Kontext repräsentativ sein kann (Flyvbjerg, 2006; Baxter & Jack, 2008; Yin, 2017).

3.1.1 SUSKULT

Die SUSKULT-Innovation entwickelt sich im Kontext des transdisziplinären Verbundforschungsprojekts „SUSKULT – Entwicklung eines nachhaltigen Kultivierungssystems für Nahrungsmittel resilienter Metropolregionen“ (FKZ 031B0423). Sie zielt auf die Transformation einer konventionellen Kläranlage in ein 'NEWtrient®-Center', in dem die wesentlichen Ressourcen für den urbanen hydroponischen Pflanzenbau aus kommunalem Abwasser zurückgewonnen werden (Keuter et al., 2021). Die Pilotanlage für die Umsetzung des Vorhabens wird seit September 2022 auf der Kläranlage 'Emschermündung' in Nordrhein-Westfalen betrieben. Die Kreislaufvision von SUSKULT fußt auf der wichtigen Rolle von Kläranlagen für die Erhaltung der Gesundheit und des Wohlbefindens von Mensch und Umwelt weltweit. Kläranlagen verhindern durch die Behandlung und Reinigung von Abwasser, dass Schadstoffe und Verunreinigungen in die Gewässer und Ökosysteme gelangen. Dies umfasst den Abbau oder die Entfernung von Schadstoffen sowie die Reinigung des Abwassers während des Klärprozesses. Die vorhandenen Behandlungsschritte sind darauf ausgelegt, verbindliche Grenzwerte einzuhalten, beispielsweise für organische Einträge oder Phosphor. Die SUSKULT-Innovation nutzt die im Abwasser vorhandenen Nährstoffe Stickstoff, Phosphor und Kalium und extrahiert eine kombinierte Flüssigdüngerlösung, die unmittelbar für die urbane Nahrungsmittelproduktion eingesetzt werden soll. Die SUSKULT-Innovation bietet in Städten mit hoher Bevölkerungsdichte einen flächeneffizienten Ansatz. Der Pflanzenanbau erfolgt in vertikalen hydroponischen (erdlosen) Kultivierungssystemen. Diese ermöglichen eine kontrollierte Atmosphäre, eine effiziente Ressourcennutzung und eine bedarfsgerechte und pflanzenspezifische Nährstoffversorgung. Der Fokus liegt auf dem Anbau von kohlenhydrat-, vitamin- und proteinreichen Pflanzen, wie Süßkartoffeln, Moringa und Wasserlinsen. Dadurch wird eine stabile und saisonunabhängige lokale Versorgung mit frischen und gesunden Lebensmitteln gewährleistet, die auch unter

den Ansatz einer 'Controlled-Environment Agriculture' (CEA) kategorisiert werden kann. Damit wird den Herausforderungen der unvorhersehbaren Anbaubedingungen aufgrund der negativen Auswirkungen des Klimawandels begegnet und eine kurze und nachhaltige Lebensmittelwertschöpfungskette in der Stadt gefördert (Keuter et al., 2021).

3.1.2 RUN

Die RUN-Innovation, die im Verbundprojekt „RUN – RURAL URBAN NUTRIENT PARTNERSHIP. Nährstoffgemeinschaften für eine zukunftsfähige Landwirtschaft“ (FKZ: 031B0732B) entwickelt wird, hat zum Ziel, regionale Nährstoff- und Ressourcenkreisläufe zu schließen, indem Bioabfälle und Abwässer aus städtischen Siedlungen in sichere Düngemittel (Nährstoffe), Pflanzenkohle und Kunststofffolien (Kohlehydrate) für die Landwirtschaft verarbeitet und umgewandelt werden. Dazu werden städtebauliche und Logistik-Strukturen entwickelt, welche die Trennung, Verarbeitung, Umwandlung und das Recycling von Nährstoffen auf mehreren Ebenen integrieren. Die RUN-Innovation verfolgt einen Ansatz, der sich von der End-of-Pipe-Abwasserbehandlung entfernt, bei der der kombinierte Abwasserstrom aus Haushalten und Betrieben behandelt wird, der sich aus Schwarzwasser, Grauwasser sowie industriellen Fremdstoffen zusammensetzt. Im RUN-Verfahren werden die Abwässer aus Küchen (angereichert mit organischen Abfällen, die dem Abwasser über einen Zerkleinerer zugesetzt werden) und Toiletten getrennt gesammelt und in kleineren siedlungsnahen Anlagen aufbereitet. Letzteres wird in einer Pilotanlage am Umweltcampus Birkenfeld erforscht, wo Schwarzwasser und organische Abfälle aus einem Studentenwohnheim in Rheinland-Pfalz verarbeitet werden. Das Ziel besteht darin, die Nährstoffe zu recyceln und die Kohlenstofffraktionen im Restschlamm zu Biopolymeren zu verarbeiten, um Biokunststoffe herzustellen. Damit soll verhindert werden, dass in einem linearen Produktionssystem in der Landwirtschaft wertvolle Stoffe verloren gehen, die stattdessen in die Betriebe zurückgeführt werden (Fendel et al., 2022; Steinmetz et al., 2023).

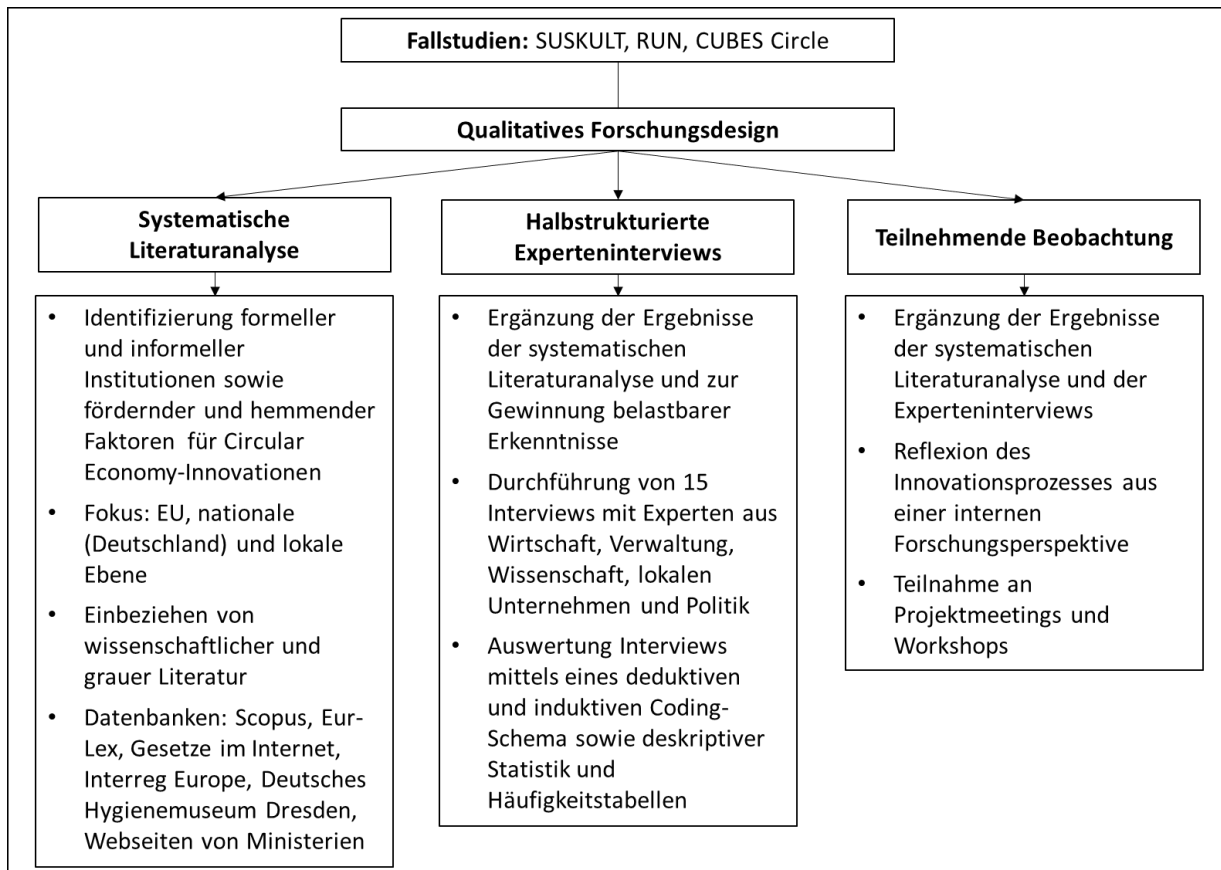
3.1.3 CUBES Circle

Die CUBES Circle-Innovation wird innerhalb des inter- und transdisziplinären Verbundforschungsprojekts „CUBES Circle – Future Food Production“ (FKZ 031B0733A) entwickelt. Die Innovation sieht die Integration von drei verschiedenen Produktionszyklen – Fisch, Pflanzen und Insekten – in einem modularen, containerbasierten System vor, das eine ressourcen-effiziente und zirkuläre Lebensmittelproduktion ermöglichen soll (Ulrichs et al., 2017; CUBES Circle, n.d.). Dabei werden die Rückstände aus einem Produktionszyklus für einen anderen verwendet. Das Fischwasser wird beispielsweise zur Düngung der Pflanzen genutzt, während das Transpirationswasser aus dem Pflanzencontainer wieder in den Fischtank zurückgeführt wird. Die Insekten dienen als Fischfutter, während gleichzeitig die Sedimente aus den Fischtanks und die Pflanzenreste zur Fütterung der Insekten genutzt werden (Ulrichs et al., 2017; CUBES Circle, n.d.). Eine Pilotanlage befindet sich auf dem Campus Dahlem der Humboldt-Universität zu Berlin. Das CUBES Circle-System verspricht die Produktion von frischen, hochwertigen und sicheren Lebensmitteln unter nahezu vollständig kontrollierten Umweltbedingungen ohne äußere Umwelteinflüsse wie Dürreperioden oder Jahreszeiten. Dadurch soll eine kontinuierliche und ganzjährige Produktion von Lebensmitteln gewährleistet werden, die zur lokalen Ernährungssicherheit beitragen kann. Aufgrund dieser Eigenschaften kann CUBES Circle als CEA-Ansatz eingestuft werden, die für den Einsatz auf brachliegenden und versiegelten Flächen in städtischen oder stadtnahen Gebieten geeignet ist. Dies bietet das Potenzial, Abfall- und Materialströme aus der externen Umwelt in das Produktionssystem zu integrieren, was zur Abfallreduzierung und Ressourceneffizienz beiträgt und Kosten und Emissionen im Zusammenhang mit dem Lebensmitteltransport verringert (Ulrichs et al., 2017; CUBES Circle, n.d.).

3.2 Datensammlung und -auswertung

Um die Faktoren zu untersuchen, die die Umsetzung der drei entstehenden Circular Economy-MIS unterstützen oder behindern, wurde ein qualitatives Multimethoden-Forschungsdesign verwendet (Creswell, 2014; Kalu & Bwalya, 2017), das systematische Literaturanalyse, Interviewforschung und teilnehmende Beobachtung kombiniert (siehe Abbildung 2).

Abbildung 2: Methodisches Vorgehen der Datensammlung und -auswertung



Quelle: Eigene Darstellung (2023)

3.2.1 Systematische Literaturanalyse

Das Ziel der systematischen Literaturrecherche war es, wissenschaftliche Arbeiten zu identifizieren und auszuwerten, die sich explizit mit formellen und informellen Institutionen sowie den fördernden und hemmenden Faktoren für die Entwicklung von Circular Economy-Innovationen auf EU-, nationaler (Deutschland) und lokaler Ebene beschäftigen. Die systematische Durchsicht der wissenschaftlichen Literatur folgte dem PRISMA-Statement, das vier Phasen umfasst: (1) Suchstrategie, (2) manuelle Sichtung, (3) Extraktion von Datensätzen und (4) Darstellung der Ergebnisse (Snyder, 2019). Die wissenschaftliche Literatur wurde in Scopus recherchiert, der größten und meistgenutzten Datenbank für akademische Forschung (Baas et al., 2020) unter Verwendung der Suchbegriffe: ('Urban Food Production' OR 'Controlled-Environment Food Production' OR 'CEA' OR 'Controlled-Environment Agriculture' OR 'Aquaponics' OR 'Vertical Farming' OR 'Insect Feed' OR 'Insect Food', 'Container Farming') AND ('Institutional Framework' OR 'Informal Institutions' OR 'Formal Institutions' OR 'Acceptance' OR 'Cultural Aspects' OR 'Taboos' OR 'Habits' OR 'Laws' OR 'Regulations' OR 'EU Policy' OR 'German Policy').

Die Literatursuche wurde am 09.01.2024 durchgeführt und beschränkte sich auf Literatur, die zwischen 2013 und 2024 veröffentlicht wurde. Insgesamt wurden 2.179 Publikationen gefunden. Nach manueller Sichtung von Titeln, Abstracts und Keywords wurden Publikationen aus-

geschlossen, die für das Forschungsthema nicht relevant waren oder einen naturwissenschaftlich-experimentellen Fokus hatten. Dadurch reduzierte sich der Textkorpus auf 67 Publikationen. Anschließend wurden diese Publikationen gelesen und diejenigen aussortiert, die sich nicht mit dem institutionellen Rahmen beschäftigten oder die einen räumlichen Schwerpunkt außerhalb der EU hatten. Dadurch reduzierte sich die Stichprobe auf 41 Publikationen. Nach dem Schneeballprinzip wurde der Textkorpus um weitere fünf wissenschaftliche Publikationen ergänzt, die von Kolleginnen und Kollegen empfohlen wurden, was letztlich zu einem Korpus von 46 Publikationen führte. Für die Analyse der Publikationen wurde eine deduktive Kodierungsstrategie angewandt, die sich aus dem Forschungsschwerpunkt ableitete.

Zusätzlich wurde nach grauer Literatur, wie Regularien, politischen Strategien, Aktionsplänen oder Handbüchern in den Datenbanken Eur-Lex (<https://eur-lex.europa.eu/homepage.html?locale=de>), “Gesetze im Internet” (<https://www.gesetze-im-internet.de/>), Interreg Europe (<https://www.interregeurope.eu/>), Deutsches Hygiene-Museum Dresden (<https://www.dhmd.de/sammlung/publikationen>) und auf den Webseiten von Ministerien recherchiert. Durch die Analyse der grauen Literatur konnten verschiedene Regelungsbereiche identifiziert werden, die die Aspekte der Circular Economy-Innovationen betreffen.

3.2.2 Interviews mit Expertinnen und Experten

Um die Ergebnisse der systematischen Literaturrecherche zu ergänzen und belastbare Erkenntnisse zu gewinnen, wurden halbstrukturierte Experteninterviews durchgeführt. Die Expertinnen und Experten wurden nach den Grundsätzen des Purposive Sampling (Rapley, 2014) auf der Grundlage vorab definierter Merkmale wie Fachwissen im Abwasser- und Lebensmittelsektor oder Kompetenzen bei der Entwicklung von Circular Economy-Innovationen ausgewählt. Weitere relevante Expertinnen und Experten wurden durch das Schneeballsystem während der Interviews ermittelt (Rapley, 2014). Die Interviewpartnerinnen und Interviewpartner stammten aus den Bereichen Wissenschaft, Verwaltung, Wirtschaft, lokale Unternehmen und Politik. Es wurden zwei halbstrukturierte Interviewleitfäden entwickelt, die sowohl offene als auch geschlossene Fragen enthielten. Der erste halbstrukturierte Interviewleitfaden befasste sich mit der Bewertung der Meinungen der Interessenvertreter zu SUSKULT. Dabei wurden die Vorschriften, die Akzeptanz, die Vermarktung und das Potenzial für die Nutzung von SUSKULT-Produkten berücksichtigt. Der zweite Interviewleitfaden thematisierte relevante Strukturelemente wie Akteure, Infrastruktur, Interaktion und Institutionen sowie Hindernisse und Erleichterungen bei der Konzeption und Entwicklung der CUBES Circle-Innovation.

Insgesamt wurden zwischen 2019 und 2021 15 Interviews per Videokonferenz und persönlich geführt. Nach dieser Anzahl wurde eine theoretische Sättigung im Sinne der Grounded Theory erreicht (Baur & Blasius, 2014). Die Interviews dauerten im Durchschnitt 60 bis 90 Minuten und wurden aufgezeichnet, manuell transkribiert und mittels qualitativer Inhaltsanalyse ausgewertet (Mayring, 2019). Hierfür wurde ein Kategoriensystem entwickelt, das auf deduktiven und induktiven Codes basierte. Die deduktiven Codes wurden aus der Literaturauswertung abgeleitet, während die induktiven Codes auf Basis der Erkenntnisse aus den Interviews und deren Auswertung gebildet wurden (Bortz & Döring, 2015). Die geschlossenen Fragen wurden mithilfe von deskriptiven Statistiken und Häufigkeitstabellen analysiert⁶.

3.2.3 Teilnehmende Beobachtung

Die Ergebnisse der systematischen Literaturanalyse und der Experteninterviews wurden durch Einblicke aus teilnehmender Beobachtung ergänzt (Walsh, 2009). Die Autorinnen und Autoren dieses Beitrags hatten als Mitglieder der Forschungsprojekte Zugang zu Projektmeetings und

⁶ Die quantitative Erhebung diente nicht zur Gewährleistung der Repräsentativität der erhobenen Daten, sondern lediglich dazu, einen Einblick in die Einstellungstendenzen der Befragten zu erhalten.

anderen Ereignissen des Forschungsprozesses, bei denen sie Feldnotizen anfertigten. Dadurch konnten sie den Innovationsprozess aus einer internen Perspektive verstehen. Die Reflexion des Innovationsprozesses war eine Aufgabe, die allen Autorinnen und Autoren innerhalb ihres jeweiligen Forschungsprojekts zugeordnet war. Um die Integrität und Vertraulichkeit von Forschung und beteiligten Personen zu wahren, wurden die Beobachtungen vorsichtig genutzt und in allgemeiner Form wiedergegeben. Die Feldnotizen und präsentierten Ergebnisse beziehen sich nicht auf substantielle Forschungs- und Entwicklungsinhalte, sondern ausschließlich auf die Akteure im Innovationsprozess und den Verlauf der Technologieentwicklung.

4 Ergebnisse

4.1 Problemlösungsraum

Die drei MIS verfolgen die transformativen Ziele der Circular Economy-Mission. Sie sollen die nachhaltige Nutzung und das Recycling von zurückgewonnenen Nährstoffen fördern (vgl. Europäische Kommission, 2020a; Europäische Kommission, 2020b). Die MIS adressieren mehrere Herausforderungen in der Agrar- und Ernährungswirtschaft, die mit der Umsetzung der Circular Economy-Mission verbunden sind. Zu den Herausforderungen gehören Umweltprobleme wie Nährstoffverluste aus offenen Ressourcenkreisläufen sowie der hohe CO₂-Fußabdruck langer Lebensmittelwertschöpfungsketten, aber auch wirtschaftliche Herausforderungen wie Unterbrechungen der Lieferketten aufgrund geopolitischer Konflikte und steigende Kosten für Lebensmittel und Düngemittel. Obwohl die drei MIS auf dieselben Herausforderungen reagieren, verfolgen sie unterschiedliche Transformationspfade, die auf die Circular Economy-Mission ausgerichtet sind (siehe Abschnitt 3.1).

4.2 Charakteristika der missionsorientierten Innovationssysteme

4.2.1 SUSKULT

Im MIS der SUSKULT-Innovation sind die Interaktionen zwischen den *Akteuren* und die Systemgrenzen aufgrund eines sich entwickelnden Umfelds dynamisch. Am Forschungs- und Entwicklungsprozess sind politische, gesellschaftliche und wirtschaftliche Akteure beteiligt, die sich für die transformativen Ziele und Initiativen der Circular Economy einsetzen. Die Beteiligung der Abwasserverbände Emschergenossenschaft und Ruhrverband ist besonders wichtig für den Innovationsprozess. Durch ihre Einbindung werden die Perspektiven der Kläranlagenbetreiber berücksichtigt, was für eine erfolgreiche Umsetzung unerlässlich ist. In Deutschland forschen Kläranlagenbetreiber verstärkt an der Rückgewinnung von Nährstoffen, insbesondere von Phosphor (LAGA Ad-hoc-AG, 2019), die der Gesetzgeber mit der Novellierung der Klärschlammverordnung (AbfKlärV) ab 2029 vorschreibt. Auch Unternehmen des Düngemittel- und Lebensmittelsektors leisten einen wichtigen Beitrag. Die führenden Unternehmen Yara, Rewe und Metro haben erkannt, dass die Verwendung von recycelten Nährstoffen für die Düngemittelproduktion und ihre Anwendung in der städtischen hydroponischen Lebensmittelproduktion Vorteile bietet. Als Projektpartner bringen sie Erkenntnisse über Markt- und Verbrauchertrends sowie Kundenbedürfnisse und -anforderungen ein.

Der SUSKULT-Innovationsprozess ist mit einem komplexen institutionellen Rahmen konfrontiert, an dem eine Vielzahl *formeller Institutionen* auf verschiedenen Ebenen beteiligt ist. Die EU-Düngeprodukteverordnung ((EU) 2019/1009) beispielsweise zielt darauf ab, die Rolle von zurückgewonnenen Nährstoffen zu stärken und abfallbasierte Düngemittel zu fördern. Die deutsche Klärschlammverordnung (Bundesamt für Justiz, 2017) verpflichtet Kläranlagenbetreibende gesetzlich zum Phosphorrecycling. Dies wird durch die Nationale Wasserstrategie unterstützt, die betont, dass Phosphor und Stickstoff aus Abwasser zur Herstellung von Düngemitteln genutzt werden sollen (BMUV, 2023a). Darüber hinaus ist der SUSKULT-Innovationsprozess

mit *informellen Institutionen* konfrontiert, wie vorherrschenden kulturell-religiösen Ernährungsgewohnheiten und der Nachhaltigkeitskultur in der Stadt.

4.2.2 RUN

Die Entwicklung der RUN-Innovation erfordert Beiträge von verschiedenen *Akteursgruppen*. Wissensakteure sind hauptsächlich für die Technologieentwicklung, Informationsbeschaffung und Wissensproduktion verantwortlich. Anschließend investieren Hauseigentümer in diese neuen Technologien und betreiben sie. Auch die Bürgerinnen und Bürger spielen eine entscheidende Rolle, indem sie die Rohstoffe für die Produktion des Designdüngers bereitstellen. Gemeinden organisieren sich häufig in spezialisierten Zweckverbänden, um Abwasser zu sammeln und zu behandeln. Der zugelassene Designdünger wird dann von Düngemittelherstellern produziert und an landwirtschaftliche Betriebe verteilt, die ihn für die Lebensmittelproduktion verwenden. Die produzierten Lebensmittel werden vom Lebensmitteleinzelhandel an Konsumentinnen und Konsumenten verkauft. Einige der genannten Akteure sind mehr oder weniger formell in Netzwerken organisiert, zum Beispiel verschiedene Bauernverbände, Verbraucherschutzorganisationen, Vermarktungsorganisationen für landwirtschaftliche Produkte und Genossenschaften, die mit Düngemitteln und Saatgut handeln und teilweise als Zwischenhändler für den Lebensmitteleinzelhandel fungieren.

Die RUN-Innovation ist mit zahlreichen *formellen Institutionen* konfrontiert, insbesondere mit Gesetzen und Vorschriften aus verschiedenen Rechtsbereichen auf EU-, nationaler und lokaler Ebene. In diesem Zusammenhang ist die EU-Abfallrahmenrichtlinie (2008/98/EG) von Bedeutung, da sie Materialien, die aus Abwasser stammen, als Abfall einstuft. Die EU-Richtlinie 91/271/EWG regelt die Verantwortung von Abwasserentsorgungsunternehmen für die Reinigung von kommunalem Abwasser, um dessen sichere Einleitung in Gewässer zu gewährleisten. Wie auch bei SUSKULT stellt die Klärschlammverordnung (AbfKlärV) eine weitere relevante Rechtsvorschrift für die RUN Innovation dar (Bundesamt für Justiz, 2017). Neben formellen Institutionen muss sich die RUN-Innovation auch mit *informellen Institutionen* befassen. Insbesondere bei kulturellen Aspekten, die möglicherweise Hindernisse auf dem Weg zur Schließung der Nährstoffkreisläufe darstellen könnten, müssen Bedenken hinsichtlich der Lebensmittelsicherheit berücksichtigt werden. Diese ergeben sich aus der Verwendung von Nährstoffen, die aus Küchenabwässern, Fäkalien und Urin zurückgewonnen und als Dünger in der Lebensmittelproduktion eingesetzt werden.

4.2.3 CUBES Circle

Das MIS der CUBES Circle-Innovation umfasst verschiedene *Akteursgruppen*, wie zum Beispiel Wissensakteure oder Akteure in der Wertschöpfungskette, die an der Entwicklung der Circular Economy-Innovation beteiligt sind. Diese Akteure nehmen verschiedene Rollen wahr, wie beispielsweise Wissensgenerierung, Bereitstellung von Software, Hardware und anderen Inputs wie Saatgut, den Bau und Betrieb der Demonstrationsanlage, Kommerzialisierung oder die finanzielle Unterstützung. Diese Akteursgruppen sind hauptsächlich durch informelle Beziehungen verbunden (Dietze & Feindt, 2023). Sie haben durch jahrelange Zusammenarbeit eine starke Netzwerkbeziehung aufgebaut (C01-03, Ulrichs et al., 2017).

Der institutionelle Rahmen, der die Entwicklung und Umsetzung der CUBES Circle-Innovation beeinflusst, umfasst vielfältige *formelle Institutionen* wie Gesetze und Verordnungen, Förderinstitutionen sowie gesetzliche Vorgaben (Dietze & Feindt, 2023). Zum Beispiel regelt die EU-Verordnung Nr. 305/2011 das Inverkehrbringen von Bauprodukten, was in Deutschland im Baurecht in nationales Recht umgesetzt wird (Europäische Kommission, 2011). Gemäß dem deutschen Pflanzenschutzgesetz müssen primär natürliche Lösungen zur Schädlingsbekämpfung vor dem Einsatz von Pestiziden genutzt werden (Reinhardt et al., 2019). Zusätzlich beeinflussen *informelle Institutionen* wie vorherrschende Werte, kulturelle und religiöse Faktoren

den Innovationsprozess. Diese Faktoren haben Einfluss auf die Art und Weise der produzierten Lebensmittel im CUBES Circle (Dietze & Feindt, 2023).

4.2 Erfüllung und Zusammenspiel der Funktionen innerhalb der Missionsorientierten Innovationssysteme

Dieser Abschnitt gibt einen Einblick in die Erfüllung und das Zusammenspiel der Funktionen der MIS von SUSKULT, RUN und CUBES Circle (siehe Anhang II).

4.2.1 Funktion 1: Unternehmerisches Experimentieren

In den drei Innovationsprojekten werden Experimente durchgeführt, um die Machbarkeit und die technischen Aspekte der Innovationen zu untersuchen. Die MIS unterscheiden sich jedoch hinsichtlich der Art der Experimente. Im Rahmen der SUSKULT-Innovation werden Anbauversuche mit Pflanzen durchgeführt und Qualitätsprüfungen vorgenommen. Es wird sichergestellt, dass die SUSKULT-Nährlösung die Grenzwerte der Düngemittelverordnung für Schwermetalle erfüllt und organische Spurenstoffe um mehr als 90% reduziert werden (Genz & Reemtsma, 2022). Die Sicherheit von SUSKULT-Lebensmitteln wurde durch die toxikologische Unbedenklichkeitsschwelle der EFSA bestätigt. Der Ansatz wurde durch den Dauerbetrieb der Pilotanlage validiert. Im Rahmen von Projekttreffen, Stakeholder-Diskussionen und Workshops werden Rückmeldungen aus der Praxis gesammelt und zur Anpassung des Forschungs- und Entwicklungsprozesses an aktuelle Bedürfnisse und Anforderungen genutzt. Zur öffentlichen Bewertung der Experimente des SUSKULT-Innovationslabors werden partizipative Forschung (Schwindenhammer & Gonglach, 2022) und Szenariostudien (Steines et al., 2022) durchgeführt. Die Experimente, die im Rahmen des MIS der CUBES Circle-Innovation durchgeführt wurden, weisen Ähnlichkeiten zu den Experimenten in SUSKULT auf. Der Fokus liegt jedoch stärker auf dem integrierten Kreislauf dreier Produktionssysteme: Fische, Pflanzen und Insekten sowie deren Nährstoffflüsse (C01-09, CUBES Circle, o.J.). Zusätzlich werden Versuche durchgeführt, um verschiedene Futtermittel für die Produktion von Fischen und Insekten zu erforschen (Shaw et al., 2022). Wie bei der SUSKULT-Innovation ist auch bei der CUBES Circle-Innovation die sozialwissenschaftliche Perspektive entscheidend, um hemmende und unterstützende Faktoren für die Implementierung in städtischen Gebieten sowie die damit verbundenen sozialen Akzeptanzfragen zu identifizieren (Ulrichs et al., 2017). Demgegenüber führt die RUN-Innovation Anbauexperimente durch, um den von ihnen produzierten Design-Dünger zu testen. Auch hier spielen sozialwissenschaftliche Methoden eine wichtige Rolle. Es werden ebenfalls Szenariostudien durchgeführt, um Fragen der Lebensmittelsicherheit, Verfahrenstechnik und Nachhaltigkeit unter Verwendung verschiedener wirtschaftlicher und sozialer Rahmenbedingungen zu erörtern. Darüber hinaus werden quantitative und qualitative methodische Ansätze angewandt, um die Perspektiven von Landwirtinnen und Landwirten sowie Bürgerinnen und Bürgern zu analysieren. Im Gegensatz zu den beiden anderen Innovationen wird bei der RUN-Innovation auch bereits die wirtschaftliche Effizienz und Nachhaltigkeit bewertet.

4.2.2 Funktion 2: Wissensentwicklung

Die experimentellen Aktivitäten im Labor in Kombination mit einem qualitativen sozialwissenschaftlichen Ansatz dienen der Generierung von neuem Wissen. Dies wird durch die Vergabe öffentlicher Mittel in allen drei MIS ermöglicht (BMBF, 2022). Die Innovationen zeichnen sich durch trans- und interdisziplinäre Projektkonsortien aus, die Wissen aus verschiedenen Disziplinen integrieren. Im CUBES Circle MIS tragen acht Forschungseinrichtungen zum Wissensaufbau bei (CUBES Circle, n.d.). Externe Partnerinnen und Partner mit einschlägiger Expertise werden in den Entwicklungsprozess eingebunden, falls die beteiligten Akteure nicht über die entsprechenden Kompetenzen verfügen (C01-C09). Die SUSKULT-Innovation hat seit 2019 die Wissensentwicklung in über 450 Arbeitsgruppensitzungen vorangetrieben.

Die Entwicklungsprozesse der SUSKULT- und CUBES Circle-Innovationen werden jeweils von einem wissenschaftlichen Beirat begleitet, der die Innovation kritisch bewertet und Empfehlungen für die weitere Forschungsrichtung gibt (SUSKULT, 2024; CUBES Circle, n.d.). Die RUN-Innovation wird von einem transdisziplinären Beirat unterstützt, welcher sich aus Wissenschaftlerinnen und Wissenschaftlern, Praktikerinnen und Praktikern, Mitgliedern von Dachverbänden und Verwaltungsmitarbeiterinnen und -mitarbeitern zusammensetzt.

4.2.3 Funktion 3: Wissensdiffusion

Das gewonnene Wissen wird über verschiedene Kanäle an ein breites öffentliches und wissenschaftliches Publikum weitergegeben. Dazu gehören traditionelle Methoden wie Konferenzbeiträge, Veröffentlichungen und Medienbeiträge sowie neuere Formen der Informationsverbreitung. Beispiele hierfür sind der Podcast über die SUSKULT-Innovation "Aufn Käffken zur ..." (SUSKULT, 2023) oder Radiobeiträge über die CUBES-Circle-Innovation (Hannover, 2019; Becker, 2023). Die Ideen der RUN-Innovation wurden in einem Comic (Grund & Stelzer, 2022) und in YouTube-Clips (Universität Hohenheim, 2021) präsentiert. Die SUSKULT Innovation hat über 150 Medienbeiträge generiert, darunter Videos, Artikel und Interviews. Außerdem haben alle drei Innovationen an Ausstellungen und wissenschaftlichen Konferenzen teilgenommen, Grundsatzpapiere erstellt und wissenschaftliche Artikel veröffentlicht. Im Rahmen des MIS der CUBES Circle-Innovation finden regelmäßig interne Teamsitzungen statt, um die neuesten Ergebnisse der einzelnen Teilprojekte unter den Teammitgliedern auszutauschen (CO1-CO9). Um die Akteure innerhalb der Wissenschaft im Bereich CEA stärker zu vernetzen, hat die Deutsche Agrarforschungsallianz (DAFA) eine Plattform geschaffen, auf der die CEA-Akteure ihr Wissen und ihre Expertise austauschen können (DAFA, 2022). Außerdem nehmen die drei Innovationsprojekte am jährlichen Statusseminar des Programms „Agrarsysteme der Zukunft“ teil, um die neuesten Ergebnisse und Fortschritte in der Innovationsentwicklung zu präsentieren.

4.2.4 Funktion 4: Herstellung von Richtungssicherheit und Reflexivität

Die drei Innovationen haben mehrere drängende Probleme im Lebensmittelsektor aufgezeigt. Dazu gehören die Verschwendung von Ressourcen, die negativen Umweltauswirkungen der derzeitigen landwirtschaftlichen Praktiken sowie die hohen Nährstoffverluste. Die vorgeschlagenen Lösungen der drei Innovationen zielen darauf ab, diese Probleme anzugehen und gleichzeitig mit der Mission einer Circular Economy und der Schließung von Nährstoffkreisläufen in städtischen Gebieten sowie zwischen städtischen und ländlichen Gebieten zu verbinden. Die Ansätze fördern die städtische Lebensmittelproduktion, kürzere Lieferketten und Nachhaltigkeit. Es geht um die Klimaanfälligkeit, die CO₂-Neutralität, die Widerstandsfähigkeit von Städten und die Abschwächung von Unterbrechungen in der Versorgungskette sowie die Resilienz gegenüber steigenden Lebensmittel- und Düngemittelpreisen. Die drei Innovationen konzentrieren sich auf technologische Fortschritte und Prozesse, die soziale und politische Veränderungen zum Erreichen der Mission einer Circular Economy fördern. Zur Steuerung und Lenkung der Mission setzen die drei Projekte reflexive Steuerungsmaßnahmen ein. Dazu gehören der Einsatz von wissenschaftlichen und transdisziplinären Beiräten, die Durchführung von Folgenabschätzungen, der Einsatz von KI für das Wissensmanagement sowie die kritische Selbstüberprüfung des transdisziplinären Forschungsansatzes (Graf et al., 2023).

4.2.5 Funktion 5: Marktschaffung und -destabilisierung

Für SUSKULT- und CUBES-Circle-Produkte besteht noch kein kommerzieller Markt. Die expandierende vertikale Landwirtschaft in Europa bietet jedoch Potenzial für beide Innovationen aufgrund von wachsenden Investitionen, Start-ups und dem Interesse der traditionellen Agrarindustrie (S04, Butturini & Marcelis, 2020). Der EU-Ansatz einer Circular Economy priorisiert

das Nährstoffrecycling durch die Nutzung von Sekundärrohstoffen für Düngemittel (Europäische Kommission, 2015) und die Schaffung von Märkten für zurückgewonnene Nährstoffe (Europäische Kommission, 2020b). Jedoch ist das Potenzial zur Neugestaltung der wirtschaftlichen Bedingungen für die Nährstoffrückgewinnung und -verwertung in städtischen Lebensmittelsystemen begrenzt. Ebenso sind CEA-Anlagen von aktuellen agrarpolitischen Förderprogrammen ausgeschlossen. Insbesondere ist die Einkommensunterstützung im Rahmen der Gemeinsamen Agrarpolitik (GAP) auf landwirtschaftliche Flächen ausgerichtet, was hydroponische und aquaponische Produktionssysteme ausschließt (Curry et al., 2014). Außerdem sind die bestehenden öffentlichen Kennzeichnungssysteme nicht für die SUSKULT- und die CUBES Circle-Innovationen geeignet. So können Produkte, die aus Fischen und Pflanzen in aquaponischen und hydroponischen Systemen gewonnen werden, gemäß der EU-Öko-Verordnung (EU 2018/848) nicht als ökologisch eingestuft werden und daher keine Bio-Zertifizierung erhalten, da diese voraussetzt, dass Pflanzen im Bodenökosystem angebaut werden. Gemäß der EU-Öko-Zertifizierungsregelung ist die Integration des Systems von rezirkulierenden Aquakultursystemen ebenfalls verboten, bei denen Fischabfälle als natürlicher Dünger für Pflanzen verwendet werden (Cammies et al., 2021; Fruscella et al., 2021). Die EU-Düngemittelverordnung (FPR) ((EU) 2019/1009) unterstützt zwar die Verwendung von Sekundärrohstoffen und die Herstellung von Düngemitteln auf Abfallbasis (Europäische Union, 2019). Allerdings ist die SUSKULT-Nährlösung derzeit nicht in den Materialkategorien der FPR enthalten, die festlegen, aus welchen Komponenten ein Düngemittel bestehen muss, um eine Conformité Européenne-Zertifizierung zu erhalten und auf den europäischen Düngemittelmarkt zugelassen zu werden. Der ökologische Landbau ist ein aufstrebendes Marktsegment in der EU und seit 2023 sind hier zurückgewonnene Struvit- und Phosphatsalze als Düngemittel zugelassen (Europäische Kommission, 2023a). Im Gegensatz dazu sind die großen ökologischen Zertifizierungssysteme wie Demeter, Bioland und Naturland für die RUN-Innovation von besonderem Interesse. Diese Systeme verbieten generell den Einsatz von Mineraldüngern, erlauben jedoch den Einsatz von Düngemitteln, die nach dem Prinzip der Circular Economy hergestellt wurden (Bioland, n.d.).

4.2.6 Funktion 6: Ressourcen(um)verteilung

Nährstoffrückgewinnung und -recycling sind zentrale Themen der Forschungsförderung. Die drei genannten Forschungsprojekte werden vom BMBF unterstützt, welches u.a. Forschung, Entwicklung und Wissenstransfer im Förderschwerpunkt „Agrarsysteme der Zukunft“ im Rahmen der Nationalen Forschungsstrategie BioÖkonomie 2030 fördert (BMBF, 2016). Allerdings zeigt eine Analyse der EU einen Mangel an Forschungsmitteln für Innovationen im Bereich der Lebensmittelsysteme auf. Dies deutet darauf hin, dass die Forschungsfinanzierung gegenüber der Kommerzialisierung priorisiert wird und dass es auf nationaler und EU-Ebene nur begrenzte Unterstützung für die Marktumstellung gibt (Europäische Kommission, 2023b). Daher sind zusätzliche öffentliche und private Mittel erforderlich, um die Kommerzialisierung dieser Innovationen zu erreichen und administrative Prozesse sowie Öffentlichkeitsarbeit abzudecken. Alle drei Innovationen sind technologiebasiert und erfordern erhebliche Ressourceninvestitionen, da sie sich noch in einem frühen Entwicklungsstadium befinden (Mankins, 1995; Parkes et al., 2022). Um einen erfolgreichen Markteintritt zu gewährleisten, sind zusätzliche wirtschaftliche Ressourcen, wie etwa private Investitionen, erforderlich. Potenziellen privaten Investoren sollten daher auch die ökologischen Vorteile der drei Innovationen präsentiert werden (Europäische Kommission, 2011; Sippel & Dolinga, 2023). Damit die Anlagen operieren können, braucht es zudem den Einsatz von speziell geschultem Personal. Jedoch mangelt es aufgrund fehlender Aus- und Weiterbildungsprogramme an Fachkräften in diesen Bereichen (Villarroel et al., 2016; König et al., 2018).

4.2.7 Funktion 7: Schaffung und Entzug von Legitimität

Bei allen drei Innovationen gibt es offene Fragen hinsichtlich der gesellschaftlichen Akzeptanz der Produktionssysteme und der Lebensmittelsicherheit (Milicic et al., 2016; Specht et al., 2016a). Die SUSKULT-Innovation erfüllt die Nachfrage der Verbraucherinnen und Verbraucher nach nachhaltig produzierten Lebensmitteln (S04). Die drei Innovationen sind jedoch mit einem komplexen, teilweise restriktiven und widersprüchlichen rechtlichen Rahmen konfrontiert. Der bestehende Rechtsrahmen steht teilweise den innovativen Merkmalen von SUSKULT, RUN und CUBES Circle entgegen. So schränkt beispielsweise das Planungsrecht die Integration von Lebensmittelproduktion in städtischen Flächennutzungsplänen ein (Cammies et al., 2021). Obwohl sich die Wasserpolitik in Richtung einer stärkeren Wasserwiederverwendung und Nährstoffrückgewinnung bewegt, berücksichtigt sie die Düngemittelproduktion für die Pflanzenernährung nicht angemessen und räumt dem Schutz der Gewässer weiterhin Vorrang ein. Die EU-Verordnung zur Wasserwiederverwendung ((EU) 2020/741) konzentriert sich auf die Bewässerung für die bodengebundene Landwirtschaft und vernachlässigt das Nährstoffrecycling und die Hydrokulturen. Die deutsche Klärschlammverordnung (Bundesamt für Justiz, 2017) schreibt vor, dass Phosphor von Kläranlagenbetreibenden zurückgewonnen werden muss. Derzeit liegt der Fokus dabei auf Klärschlamm und Asche. Andere interne Stoffströme, wie das nach der Entwässerung des ausgefaulten Schlammes verbleibende Wasser, werden oft vernachlässigt (Genz & Reemtsma, 2022). Die nationale Wasserstrategie identifiziert rechtliche Lücken, insbesondere bei der Rückgewinnung von Nährstoffen aus der flüssigen Phase und der Verwendung von zurückgewonnenem Phosphor und Stickstoff aus Abwasser für Düngemittel (BMUV, 2023a). Einer verbesserten Legitimitätsposition der drei Innovationen steht dabei entgegen, dass Interessengruppen fehlen, die ihre Ziele in der öffentlichen und politischen Arena unterstützen, während Lobbyaktivitäten der konventionellen Landwirtschaft auf die Erhaltung des Status Quo ausgerichtet sind.

5 Diskussion und Schlussfolgerung

Das MIS-Konzept hat sich als nützlicher analytischer Rahmen für die Ermittlung von Faktoren erwiesen, die die Entwicklung und Implementierung der in dieser Studie untersuchten kreislauforientierten Innovationssysteme beeinflussen. Die Analyse zeigt, dass die drei MIS sowohl ähnliche als auch unterschiedliche Leistungen hinsichtlich ihrer Funktionen aufweisen. So ist die Leistung der Funktionen F1 bis F4 in allen drei MIS gegeben. Alle drei MIS treiben im Forschungs- und Entwicklungsprozess transdisziplinäres Wissen voran, verbreiten es weiter und ermöglichen unternehmerisches Engagement in der Entwicklung technologischer Innovationen, die auf die Mission einer Circular Economy ausgerichtet sind. Allerdings stoßen die drei MIS auf systemische Barrieren im ökonomischen, rechtlichen und gesellschaftlichen Umfeld, die eine Umsetzung der CE-Mission beeinträchtigen und daher unterstützende missionsorientierte Politiken erfordern.

Eine große Herausforderung besteht darin, dass gegenwärtig allenfalls Nischenmärkte für Circular Economy-Lösungen und CEA-Produkte existieren und unpassende rechtliche Regelungen sowie fehlender Zugang zu Fördermöglichkeiten zugleich deren Wettbewerbsfähigkeit beschränken. Ein Ansatz förderlicher missionsorientierter Politiken könnte die Ausweitung der EU-Öko-Zertifizierung auf Lebensmittelprodukte aus hydroponischen Kultivierungssystemen umfassen. Zudem könnte die Erweiterung der Komponentenmaterialkategorien der EU-Düngemittelverordnung den Vertrieb von in kreislauforientierten Innovationssystemen hergestellten Düngemitteln mit einer Conformité Européenne Zertifizierung stärken. Ein möglicher Weg für alle drei MIS könnte darin bestehen, sich für die weitere Skalierung der Systeme auf spezielle Siedlungsstrukturen oder stadtnahe Gebiete zu konzentrieren. Allerdings ist hier die Stärkung von Fördermöglichkeiten erforderlich, die den Sprung der MIS aus dem Forschungsstadium in die Kommerzialisierung unterstützen. Hierfür sind sowohl private Kapitalgeber als

auch öffentliche Fördermittel zielführend, wobei letztere durch die Erweiterung der Förderfähigkeit kreislaforientierter Nahrungsmittelproduktionssysteme im Rahmen der GAP mobilisiert werden könnten. Da die drei MIS mit hohen Investitionskosten und einer ungewissen Kapitalrendite verbunden sind, sind auch gezielte Strategien erforderlich, um das Interesse privater Investoren an der Kommerzialisierung zu steigern und die Rentabilität zu fördern. Dies umfasst die Umsetzung innovativer Geschäftsmodelle, beispielsweise die Integration von Produktionsanlagen mit Tourismus und Gastgewerbe oder die Etablierung lokaler Nährstoffgemeinschaften. Allerdings stehen die drei MIS auch vor der Herausforderung, dass für ihren Betrieb spezifisches Fachwissen und geschulte Arbeitskräfte benötigt werden. Noch stellt die fehlende Ausbildung von Fachkräften eine Hürde dar, die durch neue Ausbildungsprogramme überwunden werden könnte, beispielsweise durch die Verschränkung der Berufszweige Gartenbau und Abwassertechnik.

Die Akzeptanz kreislaufbasierter Innovationssysteme bei Verbraucherinnen und Verbrauchern hängt von der Legitimität der Systeme und den Kosten der Endprodukte ab. Die Schaffung von politischer und rechtlicher Legitimität ist derzeit inkohärent. Trotz der europäischen und nationalen Initiativen, die Mission einer Circular Economy zu etablieren, stehen zirkuläre Innovationssysteme vor besonderen regulatorischen Hürden. Wie die vorliegende Studie zeigt, werden zirkuläre Innovationssysteme im Bereich der Lebensmittelproduktion durch verschiedene Regularien wie das Düngemittel- und das Lebensmittelrecht erheblich behindert. Der regulatorische Rahmen ist stark auf eine lineare Ökonomie ausgerichtet (BMUV, 2023b). Dadurch entstehen Wettbewerbsnachteile gegenüber etablierten Systemen. Um kreislaforientierte MIS im Agrar- und Ernährungssektor politisch zu stärken, ist es notwendig, die Auswirkungen etablierter und neuer Agrar- und Ernährungssysteme in einer transparenten und kritischen Weise vergleichend zu betrachten. Dabei sollten die tatsächlichen Umwelt-, Gesundheits- und sozialen Kosten inklusive externer Kosten (*true costs*) zukünftig stärker im Fokus stehen (FAO, 2023) und in marktpolitische und regulatorische Rahmensetzungsprozesse einbezogen werden. Insgesamt betrachtet sind missionsorientierte Politiken erforderlich, die Innovationsnischen schaffen, den sektorübergreifenden Austausch fördern und regulatorische Anpassungen vornehmen, die sowohl neue Marktchancen schaffen als auch die Bereitstellung öffentlicher Güter unterstützen. Darauf bezogen sollte sich die weitere Forschung darauf konzentrieren, die Instrumente der bestehenden Politik auf verschiedenen Regulierungsebenen, von der EU bis zur lokalen Ebene, weiterzuentwickeln und zu klären, unter welchen Bedingungen ein kohärenter, konsistenter und kongruenter Policy-Mix (Howlett & Rayner, 2018) für die Unterstützung der Mission einer Circular Economy im Agrar- und Ernährungsbereich realisiert werden kann.

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Anhang

Anhang I

Tabelle 1: Funktionen innerhalb des MIS Rahmens

Funktionen	Beschreibung
F1: Unternehmerisches Experimentieren	Alle Aktivitäten, Experimente, Markteinführungen, Pilotprojekte und Geschäftsmodelle, die neue Lösungen zur Erfüllung der Mission darstellen.
F2: Wissensentwicklung	Wissen über Probleme und Lösungen wird durch Forschung und Maßnahmen generiert, wie zum Beispiel prospektive Studien, Feldstudien, Arbeitsgruppen oder Laborarbeit.
F3: Wissensdiffusion	Die Verbreitung und Übernahme von Wissen über das Problem und seine Lösungen erfolgt durch die Medien, Netzwerktreffen, Regierungsstrukturen, Veröffentlichungen und Interaktionen.
F4a: Problemorientierung	Formulierung und Ausrichtung des sozialen Problems werden unter Berücksichtigung des Auftrags und seiner Priorität sowie der Wechselwirkung mit anderen sozialen Problemen und Aufträgen beschrieben.
F4b: Lösungsorientierung	Die Anstrengungen, die im Hinblick auf mögliche Lösungen und deren Prioritäten unternommen wurden, um die Ziele der Mission zu erreichen.
F4c: reflexive Steuerung	Aktivitäten der Überwachung, des aktiven Lernens, der Folgenabschätzung, der Wissenssicherung und der Antizipation von Fortschritten, um die Erfüllung der Mission zu lenken und zu steuern.
F5: Markterschaffung und –destabilisierung	Schaffung von Bedingungen, die es innovativen Lösungen ermöglichen, sich zu entwickeln und mit bestehenden Praktiken zu konkurrieren, z. B. Schaffung von Arenen, Preisbildungsmechanismen, Auslaufen und Destabilisierung unerwünschter Märkte.
F6: Ressourcen(um)verteilung	Mobilisierung finanzieller, personeller und materieller Ressourcen, um die Erfüllung anderer Systemfunktionen zu ermöglichen, und Beseitigung von Ressourcen, die unerwünschte Aktivitäten im Zusammenhang mit der Mission unterstützen.
F7: Schaffung und Entzug von Legitimität	Bewusstseinsbildung, verstärkte Einbindung von Interessengruppen, Lobbyarbeit, Normung oder Vorschriften zur Schaffung und Beseitigung von Legitimität und gesellschaftlicher Akzeptanz für die Lösung von Problemen im Zusammenhang mit der Mission.

Quelle: Eigene Darstellung der Autorinnen und Autoren basierend auf Wesseling & Meijerhof (2021) und COENEN et al. (2023)

Anhang II

Tabelle 2: Übersicht über die Funktionserfüllung im MIS von SUSKULT, RUN und CUBES Circle

Funktionen	SUSKULT	RUN	CUBES Circle
F1: Unternehmerisches Experimentieren	Versuchsanlage/ NEWtrient®-Center Laborforschung und hydroponische Anbauversuche Entwicklung einer Düngerlösung, die den Qualitätsstandards entspricht Evaluierung möglicher Verwertungspfade mit Unternehmen Identifizierung von Verbraucherwünschen	Pilotanlage Kultivierungsversuche Sekundäranalyse von Studien zur Lebensmittelsicherheit, Verfahrenstechnik und Nachhaltigkeit Erstellung von Szenarien zur Untersuchung von Optionen und Folgen der Umsetzung Nachhaltigkeitsanalyse der neuen Lösung	Pilotanlage Experimentelle Aktivitäten und Datenerfassung Entwicklung von Hard- und Software Durchführung von Interviews zur Ermittlung der Anforderungen an die Entwicklung und Implementierung des CUBES Circle in städtischen Gebieten Identifizierung von Verbraucherwünschen durch Workshops
F2: Wissensentwicklung	Transdisziplinärer und partizipativer Forschungsansatz (Integration von Laborforschung, Felduntersuchungen, Szenariostudien, Stakeholder-Workshops und Umfragen) Projektbeirat, der den Entwicklungsfortschritt beobachtet und berät	„Klassischer“ ingenieurwissenschaftlicher Ansatz zur Entwicklung und Erprobung von Technologien Transdisziplinärer und partizipativer Ansatz mit Nutzerperspektive (Haushalte und Landwirte)	Transdisziplinärer und partizipatorischer Forschungsansatz, einschließlich Laborforschung, Erhebungen bei Interessengruppen und Expertenbefragungen Wissenschaftlicher Beirat, der den Entwicklungsfortschritt beobachtet und berät Schaffung von Wissen durch acht Forschungseinrichtungen
F3: Wissensdiffusion	Medienbeiträge Podcast-Reihe Teilnahme an Konferenzen und Ausstellungen Policy-Papers Wissenschaftliche Veröffentlichungen	Medienbeiträge Komik Teilnahme an Konferenzen und Ausstellungen Wissenschaftliche Veröffentlichungen Veröffentlichungen in Fachzeitschriften Erlebnisraum	Medienbeiträge Wissenschaftliche Veröffentlichungen Teilnahme an Konferenzen und Ausstellungen Radiobeitrag Regelmäßige interne Projekttreffen DAFA-Plattform Unzureichende Zusammenarbeit zwischen relevanten Akteuren und lokalen Unternehmen im Bereich der Nahrungsmittelproduktion unter kontrollierten Bedingungen
F4: Herstellen von Richtungssicherheit F4a Problemorientierung F4b Lösungsorientierung F4c reflexive Steuerung	Nutzung von Abwassernährstoffen im städtischen hydroponischen Anbau Ausrichtung auf die Mission einer Circular Economy zur Schließung von Nährstoffkreisläufen	Problem der Nährstoffverluste im aktuellen Abwassersystem	Identifizierung der Herausforderungen des Lebensmittelsektors (z.B. hohe Ressourcenverschwendung, Umweltverschmutzung) Ausrichtung auf die Mission einer Circular Economy zur Schließung von Nährstoffkreisläufen

	Förderung der städtischen Lebensmittelproduktion zur Bewältigung von Klima- und Lieferkettenproblemen Innovative Technologie für Circular Economy-Veränderungen Sicherstellung von Transparenz, Rückverfolgbarkeit und Nachhaltigkeit durch KI/Blockchain und Folgenabschätzungen Kritische Selbstüberprüfung des transdisziplinären Forschungsansatzes	Anpassung an die Mission einer Circular Economy zur Schließung von Nährstoffkreisläufen zwischen städtischen und ländlichen Gebieten Bereitstellung von Düngemitteln für den ökologischen Landbau Analyse der Nachhaltigkeit der neuen Lösung im Vergleich zum etablierten System	Bereitstellung einer innovativen Technologie zur Verbesserung der lokalen Ernährungssicherheit und zur Stärkung der lokalen Lebensmittelversorgungsketten gegen Störungen von außen Kritische Selbstüberprüfung des transdisziplinären Forschungsansatzes
F5: Marktschaffung und -destabilisierung	Herausforderungen durch nachteilige Subventionen für die konventionelle Landwirtschaft und Hindernisse bei der Zertifizierung der Confor-mité Européenne für recycelte Nährstoffe Chancen durch das Wachstum der vertikalen Landwirtschaft; Fokus auf Nährstoffrecycling; neue Marktsegmente (EU-Ökolandbau)	Normative und ökonomische Herausforderungen für den konventionellen Düngemittelmarkt RUN-Dünger aufgrund hoher Investitionskosten zunächst nicht wettbewerbsfähig Zertifizierungssysteme für den ökologischen Landbau potenziell interessant	Eingeschränkte Kennzeichnungssysteme für CEA Fehlende institutionelle Anreize für die Schaffung eines Marktes für CEA Fehlen von Marktstandards für CEA
F6: Ressourcen-(Neu-)Zuteilung	Zuschuss vom BMBF für F&E Fehlende finanzielle Unterstützung für den Sprung zur Kommerzialisierung Mangel an privaten Investitionen und speziell ausgebildetem Personal	Zuschuss des BMBF für F&E Fehlende finanzielle Unterstützung für den Sprung zur Kommerzialisierung Mangelnde Berücksichtigung des RUN-Systems bei Investitionen in Abwassersysteme	Förderung durch das BMBF für F&E Die finanziellen Mittel sind begrenzt und decken nur einen Teil des Innovationsprozesses ab, nicht aber die Kosten für Verwaltung, Öffentlichkeitsarbeit und Umsetzung Fehlen von Fachkräften zur Bedienung der Systeme aufgrund fehlender Ausbildungsprogramme
F7: Schaffung und Entzug von Legitimität	Ressourcenverschwendende Agrar- und Lebensmittelproduktionssysteme Unzureichende Berücksichtigung in der Düngemittel- und Lebensmittelpolitik Abhängigkeit von der Akzeptanz der Verwendung recycelter Nährstoffe aus Abwasser in der städtischen Lebensmittelproduktion durch Markt, Politik und Gesellschaft Potenzial zur Anregung des politischen Diskurses und der sektorübergreifenden Integration von Maßnahmen Anpassung an die Nachfrage der Verbraucher nach nachhaltig erzeugten Lebensmitteln	Bestehendes Abwassersystem ist sehr gut etabliert Das Abwassersystem ist Teil der öffentlichen Infrastruktur. Alle Änderungen müssen politisch beschlossen werden Vertrauen auf die Akzeptanz von recycelten Nährstoffen als Düngemittel durch die Landwirte	Mangelnde Berücksichtigung in politischen Strategien und Vorschriften Komplexer rechtlicher Rahmen für die Lebensmittelproduktion in städtischen Gebieten Fehlen einer Lobby für CEA Ablehnung der Verbraucher gegenüber der Art und Weise, wie Lebensmittel produziert werden

Quelle: Eigene Darstellung der Autorinnen und Autoren.

POSTER SESSION 1:
INTERNATIONAL AGRICULTURE AND FOOD MARKETS

EXPLORING THE INTERPLAY OF ATTITUDES TOWARDS NOVEL FOOD TECHNOLOGIES AND ANIMAL ETHICS ORIENTATION ON CONSUMER ACCEPTANCE OF CULTURED MEAT: INSIGHTS FROM A CROATIAN STUDY

Faletar, Ivica¹; Cerjak, Marija¹

Abstract

This study investigated the influence of attitudes towards novel food technologies and animal ethics orientation on the willingness to consume cultured meat (WTC). The results showed that attitudes measured with the Food Technology Neophobia Scale have a significant influence on WTC. The more positive the attitude towards the benefits of novel food technologies, the greater the willingness to consume cultured meat. In contrast, the more pronounced the attitude towards the risks and dangers of new food technologies, the less willing consumers are to consume cultured meat. The consumers for whom the positive aspects of new food technologies predominate tend to be those who have a more liberal worldview than the others. The animal ethics orientation had no significant influence on the WTC. The results obtained can be used to develop a communication policy to promote cultured meat in the market studied.

Keywords

Food Technology Neophobia Scale, Animal Ethics Orientation, Willingness to consume cultured meat

1 Introduction

Although cultured meat is not yet widely available on the market, numerous studies have been conducted on potential consumers of this type of meat. A review of the literature (PAKSERESHT et al., 2022) showed that the acceptance of cultured meat is influenced by the following factors: public awareness, perceived naturalness, perceived food-related risks, food neophobia, perceived uncertainty regarding safety and health, price and sensory appearance, and some socio-demographic characteristics of respondents. In addition, willingness/reluctance to consume cultured meat is influenced by presence of allergies, concern about food technologies, curiosity about food, importance of meat, and perceptions of cultured meat (ROMBACH et al., 2022). Despite numerous studies on potential consumers of cultured meat at a global level, many aspects of the willingness to buy and consume this meat are still unexplored at many national levels. Since research on potential consumers of cultured meat in Croatia has so far mainly focused on consumer perceptions (e.g., FRANCEKOVIĆ et al., 2021; FALETAR AND CERJAK, 2022), the aim of this study is to investigate the influence of attitudes towards novel food technologies as well as animal ethics orientation on the willingness to consume cultured meat. The aim of the paper is to be achieved by answering the following research questions:

RQ1: Do attitudes towards novel food technologies influence willingness to consume cultured meat and if so, do consumers differ in these attitudes?

RQ2: Does the animal ethics orientation influence the willingness to consume cultured meat and if so, do consumers differ in animal ethics orientation?

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2 Material and Methods

An online survey was conducted in Croatia in summer 2021. With the help of social networks and personal contacts, 402 completed surveys were collected. In addition to other questions on cultured meat and demographics, the questionnaire also included the Food Technology Neophobia Scale (FTNS), the Animal Ethics Orientation Scale (AEOS) and a question on willingness to consume cultured meat (WTC). FTNS, AEOS and WTC were measured on a 5-point Likert scale. Several statistical methods were used to answer the research questions. First, two separate exploratory factor analyzes were conducted for the FTNS statements and the AEOS statements. The factors identified were used as independent variables in a multiple regression analysis in which their influence on the willingness to consume cultured meat was examined. A two-step cluster analysis was then performed with the previously identified factors for those variables that were found to be statistically significant determinants of willingness to consume cultured meat. The resulting clusters were described in a binary logistic regression analysis with socio-demographic characteristics.

3 Results

The results show that attitudes towards new food technologies influence the willingness to consume cultured meat. The more positive the attitude towards aspects that emphasize the benefits of new food technologies, the greater the willingness to consume cultured meat. On the other hand, the stronger the attitude towards aspects that emphasize risks, caution and restraint, the lower the willingness to consume. Consumers with a predominantly positive attitude towards novel food technologies are more likely to be less religious, their political orientation is between centre-left and centre-right, and they are more likely to live in a city compared to consumers with a negative attitude towards new food technologies (RQ1). Obviously, consumers with positive attitudes are more willing to consume cultured meat compared to the other once. Animal ethics orientation had no significant influence on the willingness to consume cultured meat (RQ2).

4 Conclusions

On the basis of the research results, recommendations can be made for communication policy aimed at improving the image and consequently increasing the willingness to consume cultured meat. Given consumers' lack of familiarity with this type of meat, it is clear that worldview plays an important role in their willingness to consume cultured meat. For this reason, it is necessary to educate consumers and show them the advantages and disadvantages of this meat so that they can make their assessment of lab-grown meat production based on objective facts. This study represents a valuable contribution to the already rich body of research related to the acceptance of cultured meat, as it is, to our knowledge, one of the first studies to introduce the Animal Ethics Orientation Scale in this context, using it together with the Food Technology Neophobia Scale.

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GEOPOLITICAL TENSIONS AND FOOD SECURITY - POLICY NARRATIVE IN THE EU AND UK –

Kristina Mensah¹

Abstract

This study explores the extent to which the narrative of national food security has influenced agricultural policy since 2020, focusing on the European Union and the United Kingdom. Examining the interplay between recent geopolitical tensions and national food security concerns, this comparative qualitative analysis reviews policy developments from 2020 to 2023. The analysis categorises these policies into three key areas within a geostrategic context: domestic agricultural policies, trade measures, and crisis response strategies. The findings reveal a renewed and intensified emphasis on food security, highlighting a deliberate and strategic shift towards incorporating food security into broader economic and geopolitical considerations, signalling a reorientation of priorities.

Keywords

geopolitics, food security, agricultural policy, trade policy.

1 Introduction

Major global events such as COVID-19, the Russian invasion of Ukraine and climate change, also referred to as “the three Cs” – COVID-19, conflict and climate change – have underscored the resilience of global food supply chains. However, these events have also exacerbated the food security situation in some countries due to previous destabilisation of the food market, such as the food price crises of 2008 and 2011 (BENTON et al. 2022; HENDRIKS et al. 2022). COVID-19 and the Russian invasion of Ukraine have sparked a broad debate about the direction of national economic policy, mainly related to “economic security”, which includes re-evaluating trade practices (IOANNIDES, 2022). The decision of the United Kingdom (UK) to leave the European Union (EU) is a prominent example of a change in the priority of cooperative and regionalised trade. Here, national sovereignty is valued over regional integration, at least when linked to deep political integration (ANTRÀS, 2020). Defining applicable economic security strategies for decision-makers revolves around how best to combine different approaches and to what extent. Policymakers are increasingly concerned about food security within a geopolitical context. Recent literature on geopolitical aspects of economic policy has increasingly addressed food security as part of economic security. While acute food security concerns have not been an issue for the EU or the UK, since 2020, the concept of food security has been invoked more often in political debates (RUDLOFF et al., 2024). This has raised the question of to what extent the use of the narrative of national food security has influenced agricultural policy decisions since 2020. This contribution will take a closer look at this question.

2 Methodology

This study employs a comparative qualitative research design to explore policy developments in the EU and the UK between 2020 and 2023. The rationale for choosing the EU and the UK lies in their distinct geopolitical context and the divergent policy trajectories post-Brexit. The study is based on a literature review of academic and policy papers, government reports, and

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official communications. The policy in each region will be analysed across three categories: (1) domestic food policy includes the examination of national agricultural policies that have been implemented or reformed in response to recent geopolitical tensions; (2) trade policy on both trade liberalisation and protectionist measures, with particular attention to how these policies reflect national sovereignty and geopolitical strategies; and (3) crisis and emergency examining the alert and monitoring mechanisms developed or activated in response to crises. The analysis will assess how these mechanisms are integrated into broader policy frameworks. Each category will be examined through a structured analytical framework that compares the historical evolution of food security policies with the recent shifts observed since 2020. The analysis will involve coding policy documents and reports to identify key themes and patterns. These themes will be cross-referenced between the EU and UK cases to highlight both convergences and divergences in their policy approaches. In a final step, it will be determined whether the observed policy changes indicate a strategic shift towards integrating food security as a narrative within broader geopolitical and economic strategies.

The advantage of this comparative qualitative research design is that it provides an overview and allows for the identification of patterns. However, it has to be noted that observational studies have a potential for bias since policy papers that are not publicly available could not be considered. Expert judgement was used to identify relevant policy developments through consultation with a range of experts in the field to reduce bias in the research design.

3 Results

The EU has re-emphasised food security by adopting e.g. a food-first strategy in response to the Russian invasion (EUROPEAN PARLIAMENT, 2023: 26). This has led to the postponement of environmental reforms to prioritise food security. Approaches to monitor and support the single market are less interventionist than in other sectors, which focus on setting specific targets for self-sufficiency in raw materials. In addition, trade policy-related aspects have evolved to balance sustainability with trade attractiveness (RUDLOFF et al. 2024). The potential accession of Ukraine, accelerated by the war, is also geostrategically crucial for food security. It will affect the EU's single food market and member competition while supporting the EU's role as a globally dominant agricultural power. The UK had started to highlight national food security with the publication of its first status report on food security in 2021. The UK's approach emphasises the importance of both affordability and accessibility of food, highlighting the challenges that have arisen in the aftermath of COVID-19 and during an ongoing cost-of-living crisis. The latter can be partly attributed to the impact of Brexit, which also initiated the geostrategic slogan "Global Britain" as an important focal point for policy decisions (COLE and PETRIKOVA, 2024). This was further underscored by the UK government's announcement to introduce an annual food security index for the UK (GOV.UK, 2024). This could be considered a response to growing tensions surrounding the criticism by UK farmers in light of the post-Brexit trade deals and the new agricultural policy schemes that put a higher emphasis on ecology than production. Recent trade agreements have underscored the geographical shift towards the Indo-Pacific region. Domestic agricultural interests have played a less prominent role, as evidenced by the extensive market opening of the UK's agricultural sector in the Australia-UK trade agreement (Smith, 2023).

Overall, food security has become more prominent as a narrative for defining policy strategies, even in countries without observable food security problems, at least regarding availability. The findings underscore the increased strategic use of food security narratives within policy debates in the EU and the UK. These narratives are reactive and increasingly framed within broader geopolitical and economic strategies.

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MOVING AWAY FROM ILLICIT CROPS FOR PROMOTING SUSTAINABLE AGRICULTURE: UNVEILING THE DRIVERS OF DECISION TO CULTIVATE AND THE INTENSITY OF POPPY CULTIVATION AMONG FARMERS NARCOTICS-OPIMUM IN AFGHANISTAN

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Abstract

Afghan farmers grow more than 90% of the world's poppy. The income from drugs is about 40% of Afghanistan's GDP. The waste of scarce production resources, especially land, water, and capital in poppy cultivation in Afghanistan, on the one hand, and the increasing consumption of drugs around the world and the resulting losses, not only in Afghanistan but in other countries of the world; Including the financing of terrorism and on the other hand, the ineffectiveness of the policies adopted to fight against poppy cultivation and the more or less upward trend of this crop cultivation in Afghanistan reveal the need to identify the factors influencing the decision to cultivate and the intensity of poppy cultivation by farmers. Based on this regard, the main goal of the present study is to determine the factors affecting the cultivation and intensity of poppy cultivation in Afghanistan so that by taking advantage of it, we can take action towards the complete elimination of this crop. Therefore, to isolate the influencing factors on the decision to cultivate poppy and the intensity of poppy cultivation by farmers, the Tobit model was estimated by Heckman's two-stage method using the information obtained from sampling and face-to-face interviews with 350 Afghan farmers in the most important provinces. The results of the Tobit model estimation also show that the factors influencing the farmer's decision to cultivate poppy are not the same as the factors influencing the intensity of cultivated area. Also, the level of influence is not the same at the level of regions. Farmers' decision-making is influenced by individual variables such as experience, number of family members, and the farmer's housing situation and addiction, economic variables such as the ratio of profitability of the poppy crop to other agricultural products, the ratio of farm income to the total income and the amount of debt of the farmer, social variables such as the experience of violence, Farmers' access to government services and local councils and policies to combat poppy cultivation. The intensity of cultivated area is driven by factors such as access to agricultural tools and production inputs, diversity of production, access to irrigated land, and demand and purchase conditions. Finally, the results obtained in this research by accurately evaluating the value of final effects, can be used as a guide for the policymakers in this field to eliminate the cultivation of this product reduce the problems caused by its consumption in the world, and be a step towards the sustainable prosperity of agriculture and the economy of Afghanistan.

Keywords

Poppy cultivation, Farmer's decision, Heckman's two-stage model, Afghanistan.

1 Introduction

Agriculture in Afghanistan has contributed substantially to the GDP due to the lack of growth in other economic sectors such as industry and services. Currently, about 75% of the people of Afghanistan are farmers and make a living through agriculture. About 80% of Afghan people, who live mainly in rural areas, are directly or indirectly engaged in agriculture and animal hus-

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bandry (SAFI, 2023). Therefore, the sustainable development of the agricultural sector is necessary to ensure the economic development of the country. Afghanistan's agricultural sector has advantages such as the existence of rich unused resources of water and arable soil, young and cheap human resources, climatic diversity, and large consumption markets in the neighborhood of this country (PAIN, 2002). The lack of proper strategy; has caused the agricultural sector in this country not only to not grow much but also to spread the cultivation of drugs (as seen in graphs 1&2) and destroy its resources. Extensive national and international expenses are spent every year to implement policies to combat drug cultivation (such as destroying cultivated land, livelihood and alternative cultivation, extension training, etc.), which have not had acceptable results (MANSFIELD, 2020). Also, every year, part of the security forces is killed in the fight against drug cultivation and transit in Afghanistan and the region. The causes of extensive drug cultivation in the country are various social, political, security, and economic factors, which in the studies of WARD AND BYRD (2004), MANSFIELD (2005, 2020), and SIMON (2015) have also mentioned some of them. But so far, there has been no comprehensive study based on economic principles to evaluate the main and multidimensional factors. Therefore, the main goal of this study is to determine the factors affecting farmers' decision to cultivate and the intensity of cultivation. So that by evaluating and understanding all the effective dimensions and factors, the national and international policies that have not been fruitful so far can be properly formulated and implemented to eradicate drug cultivation.

2 Empirical Methods and Analytical Frameworks

In the models that determine the factors affecting the decision to cultivate and the intensity of cultivation separately, in the first stage, the allocation or non-allocation of land to crop cultivation is discussed, and in the second stage, the intensity of cultivated area. Assuming these two groups to be the same may cause failure to obtain the real behavior of producers to draw incorrect conclusions and lead to incorrect policy recommendations. This issue was first raised by TOBIN (1958) and later emphasized by HECKMAN (1979). Therefore, in this study, Heckman's two-stage model including Tobit and linear models has been used. The models encompass a combination of quantitative and qualitative (dummy) variables, which are designed to accommodate variations across 3 different cultivation Regions and 9 provinces. Additionally, the model specification and adequacy have been assessed through rigorous econometric diagnostics. The decision to cultivate or not to cultivate a crop as well as the intensity of the cultivated area for each crop depends on different factors, including economic and technical factors, social factors, individual characteristics, political factors, and environmental factors (Graphs 3&4). The sampling method in this study is a two-stage cluster sampling considering the scope of the research, the economic savings of the sampling cost, and on the other hand, the security and life risks especially in the drug growing areas. The total sample volume was determined based on COCHRAN'S (1963) formula of 350 samples (Table 1). This data was collected from the level of 9 main drug-growing provinces in Afghanistan as seen in the map (1) including Helmand, Kandahar, Farah, Uruzgan, Nangarhar, Badakhshan, Badghis, Daikundi, and Nimruz (UNODC, 2021).

The set of studied variables has been collected and compiled from field surveys, face-to-face interviews with officials and government departments, and international organizations such as UNODC, USAD, WB, and FAO, as well as reports and other articles. In Heckman's method, to determine the effective factors in each of the above-mentioned two sets of variables, the Tobit model is broken into two Probit models and a linear regression model.

$$\begin{aligned}
 (1) \quad & Z_i = B'X_i + V_i & i=1, 2, \dots, n \\
 & Z_i = 1 & \text{if } Y_i^* > 0 \\
 & Z_i = 0 & \text{if } Y_i^* \leq 0 \\
 (2) \quad & Y_i = B'X_i + \sigma \lambda_i + e_i & i=1, 2, \dots, n
 \end{aligned}$$

In the above models, B and σ are the parameters of the model. λ_i is also the inverse Mills ratio. ei and vi are error parts. In the first step of Heckman's two-step method, the Probit model is estimated using the MLE2 method (GREENE, 2005). At this stage, the role of factors influencing the farmer's decision to grow poppy crops and the degree of influence of each is determined by calculating the change in the probability of entering the activity. In addition to this, the inverse Mills ratio (Heckman's Lambda) is expressed as:

$$(3) \quad \lambda_i = \frac{\phi(\beta'x_i/\sigma)}{\Phi(\beta'x_i/\sigma)}$$

Using the obtained parameters, the Probit model is built for all observations $Y_i > 0$ (HOFFMANN & KASSOUF, 2005). In the second step of Heckman's two-step method, the linear regression model is estimated for the observations for which Y_i is greater than zero. In this step, the inverse Mills ratio λ_i is added to the set of independent variables in the regression model. The coefficient of this variable tells the error caused by the selection of the sample (HECKMAN, 1979) and as a result, the role and the degree of influence of each variable in the two groups can be better defined.

3 Conclusion

3.1 The Results of Estimating the First Stage of the Tobit Model by Heckman's Two-Stage Method (Tabel 2)

According to the results obtained from the first stage of the Heckman method in the form of a Probit model, the effect of relative profitability variables, the share of farm income from the total income, the number of family members, poppy cultivation experience, addiction, and personal consumption, fear of imprisonment and the destruction of the following lands Cultivation, the experience of violence and problems, the amount of debt and loans, as well as virtual variables including the variable of the southern region (Helmand, Kandahar and Uruzgan) and the variable of the western region (Farah, Nimruz and Nangarhar), have a positive and significant effect on the decision to cultivate poppy. The results show the decision to plant more in the south and west fields. Also, the results show that the variables of access to the market for the sale of other agricultural products, housing conditions, access to schools and medical and health clinics, the number of meetings attended in councils and rural-agricultural cooperatives, the number of hours spent in class agricultural and public consultations, opinions of religious leaders and council elders, fear of imprisonment and destruction of cultivated lands, a set of projects and policies to combat poppy cultivation in the region have a negative and significant relationship with the decision Farmers. However, the variables of the total value of the aid received and the virtual variable of the north and east regions (Badakhshan, Badghis, and Daikundi) have positive but insignificant effects in this model. This issue shows the failure of executive policies in the region and their inadequacy with the needs of farmers. Also, the probabilities of the decision to cultivate poppy and the computational marginal effect of virtual variables at the levels of the three regions determined in the model have been calculated separately as well as in the best and worst possible scenarios. Here, only a part of the tables for the provinces of the North and East regions are presented (Table 3). This part of the results can specify the importance and expected results of the implementation of each policy by region for the policymaker and provide the basis for the optimal allocation of budget and policy facilities.

3.2 The Results of Estimating the Second Stage of the Tobit Model by Heckman's Two-Stage Method (Table 5)

In estimating the second stage, first, the significance test of the effect of the regions was performed through the likelihood ratio. Then the final model was estimated with virtual variables

² Maximum Likelihood Estimate

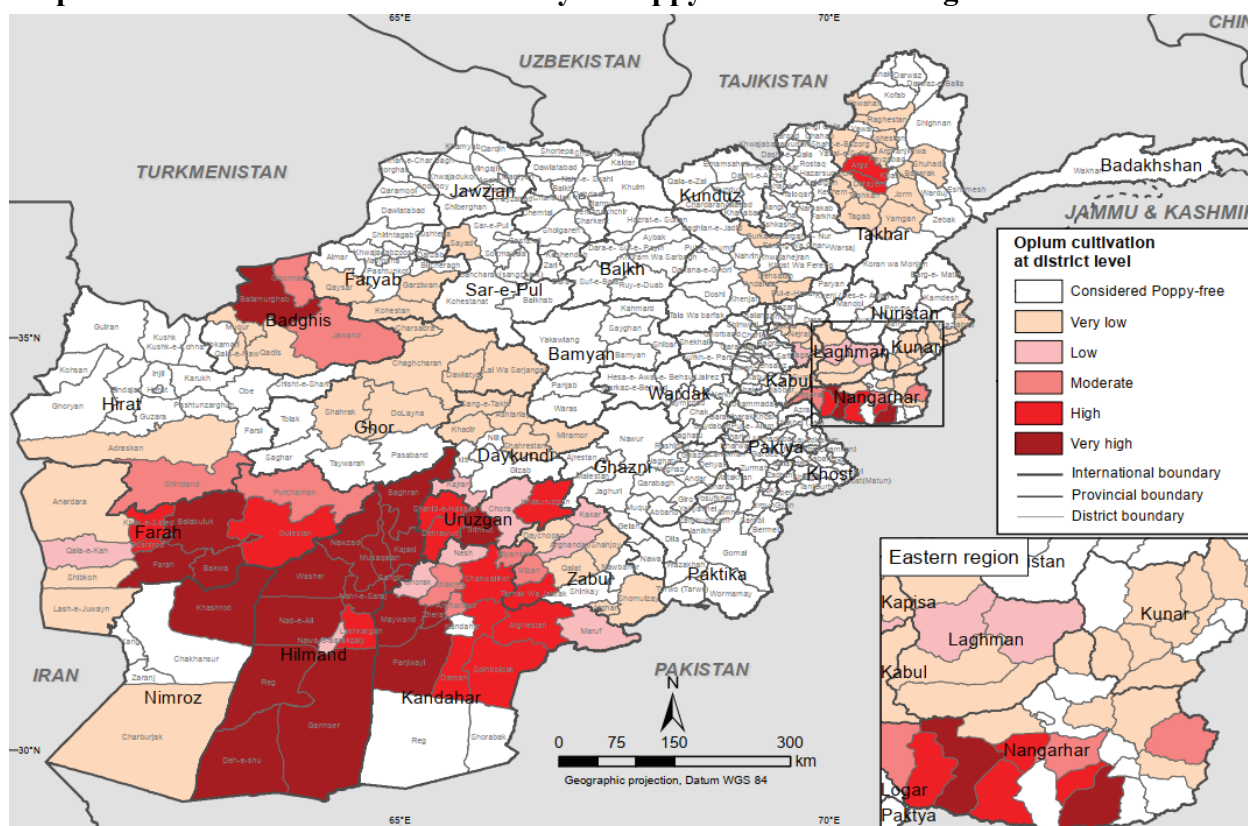
for the provinces that had a significant difference in the intensity of poppy cultivation (Tabel 4). Variables of relative profitability, the share of irrigated land from the whole farm, the amount of cultivation last year, having tools and livestock for agricultural affairs, the number of family members, access to water sources, the demand situation and purchase conditions, the amount of debt and loans, the experience of violence, policy set the combat against poppy cultivation in the region, show a positive and significant relationship in the model. Also, the results show the intensity of poppy cultivation in Helmand and Kandahar provinces compared to other provinces. Moreover, the variables of variety of productions, fear of imprisonment, and destruction of cultivated lands show a negative and significant effect on the intensity of poppy cultivation in the investigated provinces in this research. It should be noted that in this model, the effect of the variables of the set of projects and policies to combat poppy cultivation in the region and access to other inputs including fertilizer and labor were negative and positive respectively, but due to the lack of proper implementation, it still has non-significant effects.

These insights provide valuable guidance for policymakers seeking to eradicate poppy cultivation, mitigate its global repercussions, and foster agricultural and economic sustainable prosperity in Afghanistan.

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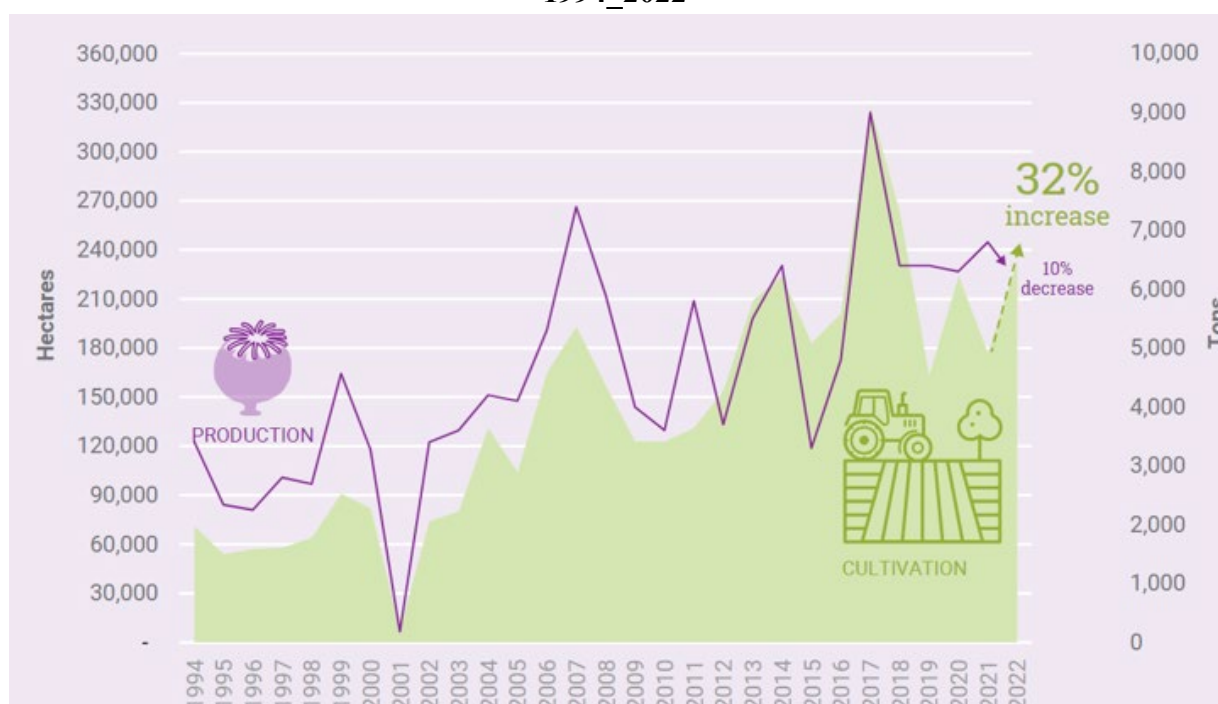
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Map 1: Distribution and Intensity of Poppy Cultivation in Afghanistan



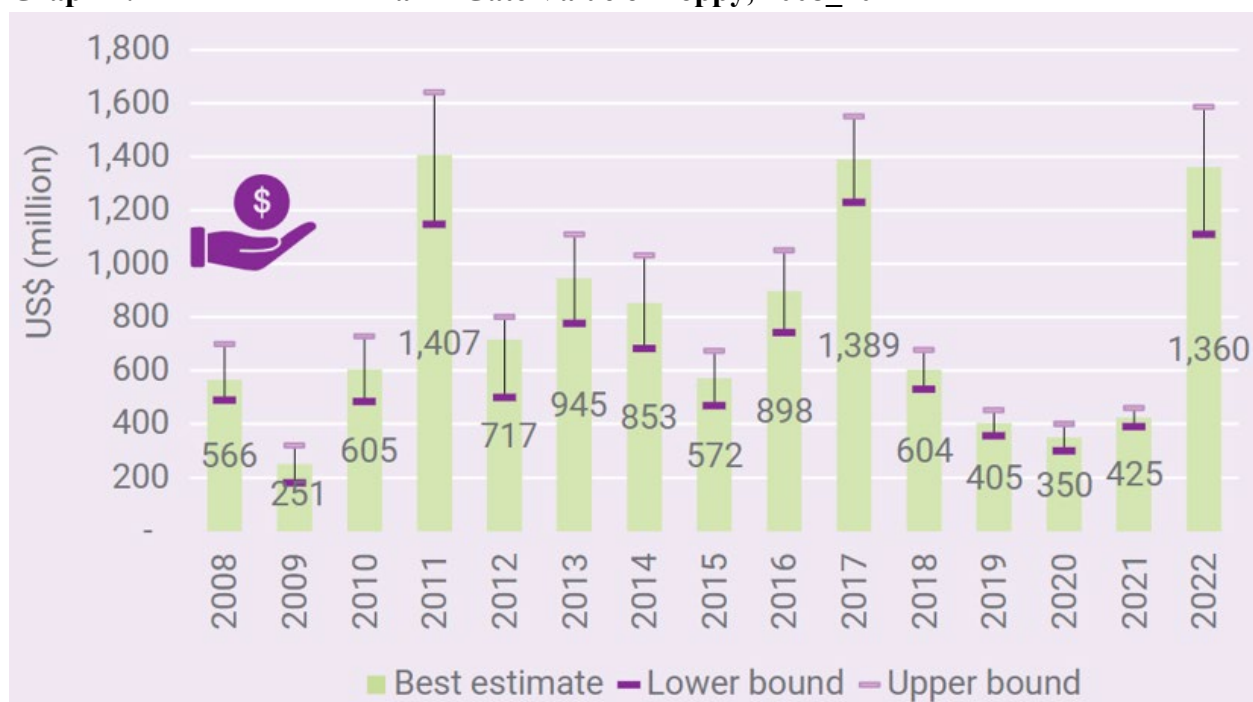
Source: Afghanistan opium survey-Cultivation and Production (UNOCD, 2021)

Graph 1: Area under Poppy Cultivation and Opium Production in Afghanistan, 1994_2022



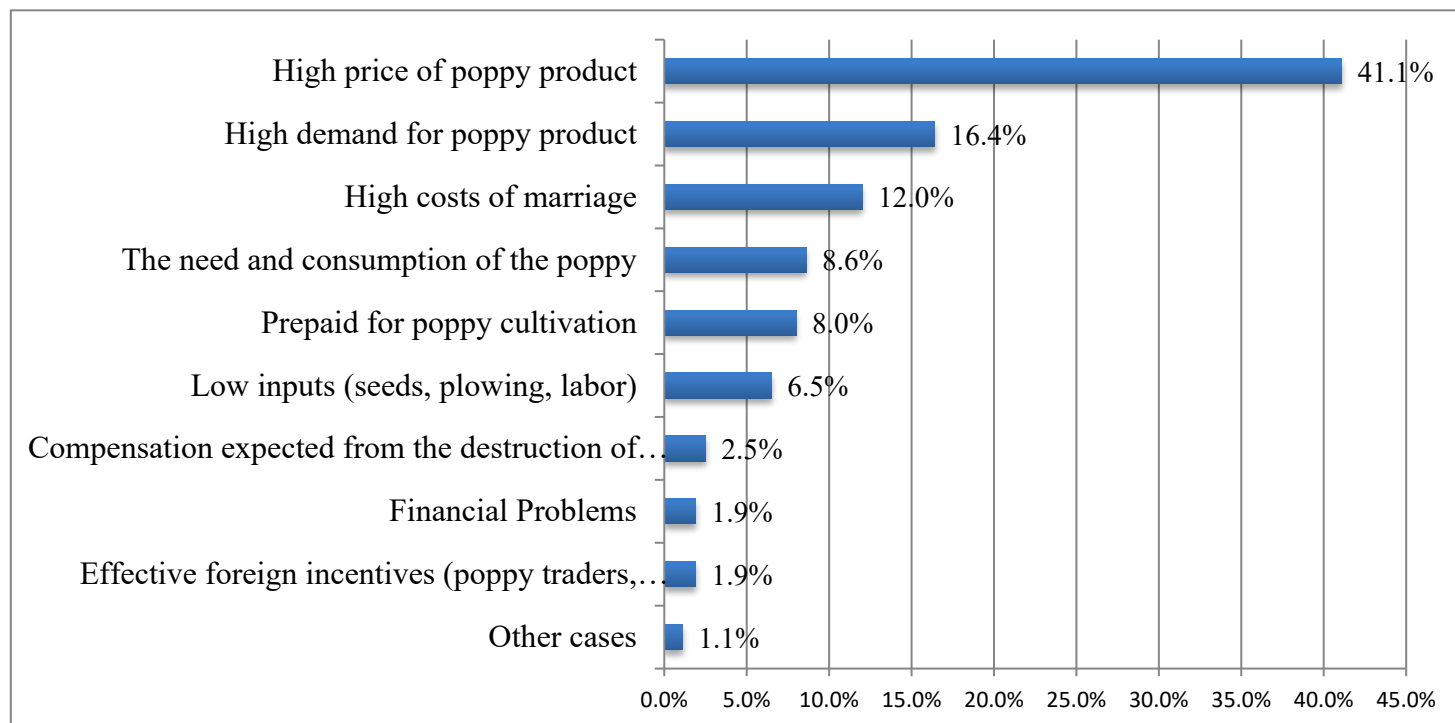
Source: Opium Cultivation in Afghanistan (UNOCD, 2022)

Graph 2: Farm-Gate Value of Poppy, 2008_2022



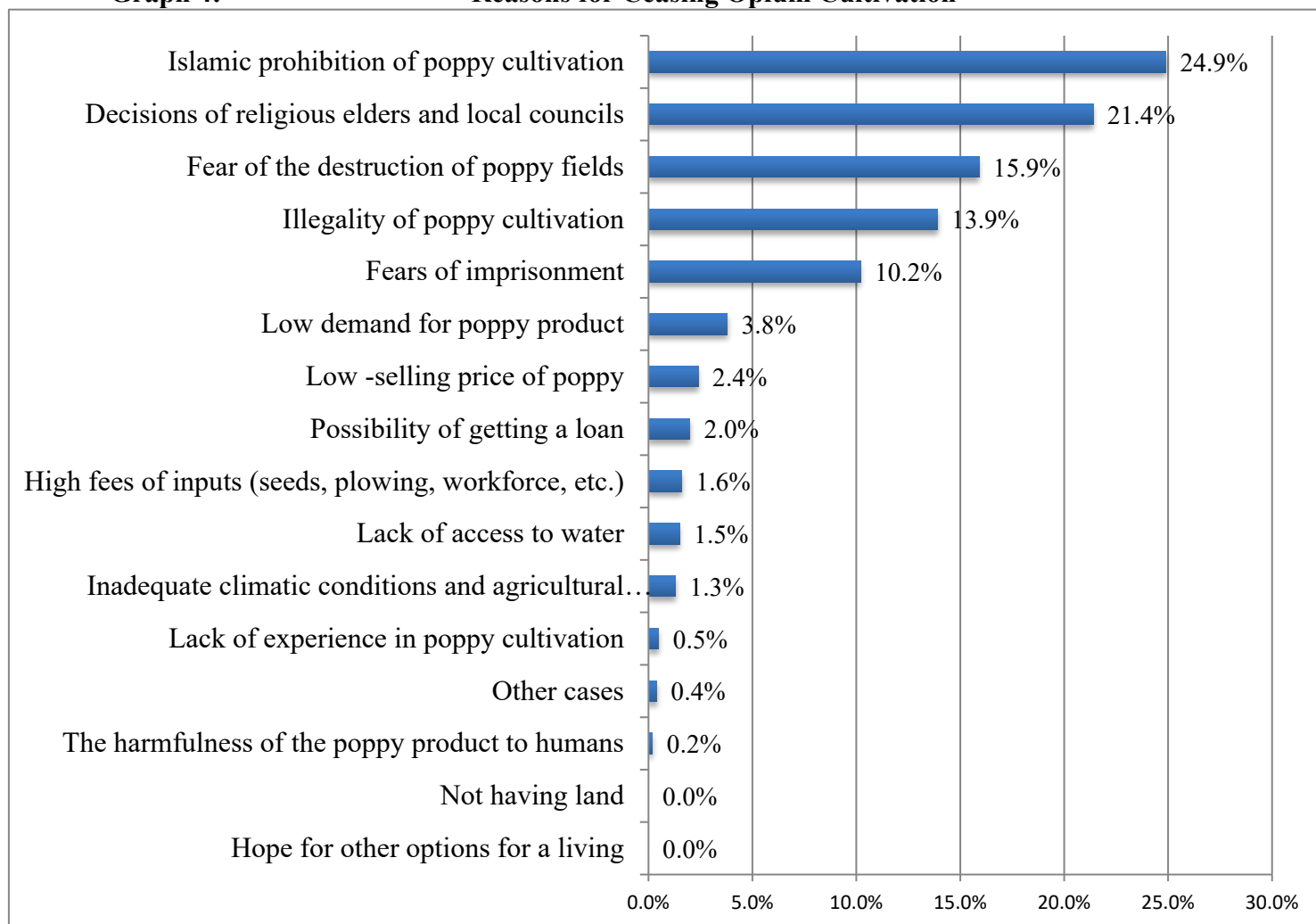
Source: Opium Cultivation in Afghanistan (UNOCD, 2022)

Graph 3: Reasons for Cultivating Poppy



Source: Research Findings and Interviews

Graph 4: Reasons for Ceasing Opium Cultivation



Source: Research Findings and Interviews

Table 1: Sampling Areas and Number of Samples from each Province

Row	Geographical Region	Province	Center	Area (Km2)	Number of Dis-tricts	Number of Villa-ges	Population	Number of Samp-les
1	Southwest	Helmand	Lashkargah	58305/07	14	607	879500	42
2	Southwest	Kandahar	Kandahar	54844/50	18	3160	1151100	55
3	the West	Farah	Farah	49339/11	11	1239	482400	23
4	Southwest	Uruzgan	Tarinkot	11473/67	6	412	333500	16
5	East	Nangarhar	Jalal Abad	7641/05	22	907	1436000	69
6	northeast	Badakhshan	Fayzabad	44835/91	28	1500	904700	43
7	the West	Badghis	Qala naw	20794/01	7	1270	471900	23
8	Southwest	Daykundi	Nili	17501/36	9	1537	438500	21
9	Southwest	Nimruz	Zaranj	42409/53	6	805	156600	8
10		SUM		307144/21	121	11437	6254200	300

Source: Statistical Yearbook of the Islamic Republic of Afghanistan 2021 and Research Findings

Table 2: Estimation of the First Stage of the Tobit Model by Heckman's Two-Stage Method (Probit Model)

Row	variable	Definition	coefficient value	standard deviation	t statistic	1. Weight ed Aggregate Elasticities	2. Mar- ginal Effects
1	(BN)	Relative profitability	1/32**	0/69	1/88	0/26	-
2	(INCOM)	The share of farm income from the total income	0/11*	0/06	1/83	0/05	-
4	(NF)	Number of family members	0/14***	0/03	4/56	0/20	-
5	(T)	The experience of poppy cultivation	0/09**	0/04	1/84	0/10	-
6	(TN)	Access to the market for the sale of other agricultural products	-1/87***	0/30	-4/79	-0/17	-0/38
7	(HP)	The total value of the donations received	-0/97	0/0001	-0/77	-0/62	-
8	(HM)	Housing situation	-0/71*	0/36	-1/41	-0/01	-0/03
9	(KM)	Access to schools and health clinics	-0/01*	0/007	-1/72	-0/06	-
10	(ST)	The number of meetings attended in councils and rural-agricultural cooperatives	-0/64*	0/004	-1/37	-0/05	-
11	(CT)	The number of hours of using extension classes and agricultural and general consultations	-1/12**	0/51	-2/17	-0/24	-
12	(LD)	The opinion of religious leaders and council elders	-0/65**	0/13	-1/92	-0/02	-0/22
13	(AD)	Addiction and personal consumption	0/72*	0/43	1/67	0/003	0/008
14	(ZN)	Fear of imprisonment and destruction of cultivated lands	-0/91**	0/11	-3/15	-0/04	-0/05
15	(KH)	Experience violence and problems	0/02**	0/01	1/42	0/08	-
16	(DN)	Amount of debt and loan	0/05*	0/002	1/99	0/06	-
17	(PJ)	A collection of projects and policies to combat poppy cultivation in the region	-0/08*	0/04	-1/80	-0/03	-
18	(HNO)	southern region virtual variable (Helmand-Kandahar-Uruzgan)	0/72**	0/41	1/73	0/01	0/13
19	(FNN)	The virtual variable of the western region (Farah, Nimruz, Nangarhar)	0/52**	0/27	1/90	0/03	0/03
20	(C)	intercept	3/49***	1/43	2/44	-	-
LIKELIHOOD RATIO TEST					158/792***		
The coefficients of determination	(ESTRELLA R-SQUARE)				0/48		
	(MADDALA R-SQUARE)				0/51		
	(CRAGG-UHLER R-SQUARE)				0/63		
	(MCFADDEN R-SQUARE)				0/62		
	(PERCENTAGE OF RIGHT PREDICTIONS)				0/89		
Heterogeneity of variance test (LM2)					1/540		

Source: Research Findings

*** and ** and * are significant at the level of 1%, 5% and 10%, respectively.

Table 3: The calculated probabilities of the decision to cultivate poppy and the Computational marginal effect of virtual variables in the provinces of the North and East region (Badakhshan-Badghis- Daykundi)

Best Case	(ZN)	(AD)	(LD)	(HM)	(TN)	Worst Case	Coefficient Value	Variable
0/99	1/20	1/20	1/20	1/20	1/20	1/20	1/32	(BN)
2/15	2/35	2/35	2/35	2/35	2/35	2/35	0/11	(INCOM)
8/51	9/66	9/66	9/66	9/66	9/66	9/66	0/14	(NF)
5/91	6/40	6/40	6/40	6/40	6/40	6/40	0/09	(T)
1	1	1	1	1	1	0	-1/87	(TN)
311/85	309/85	309/85	309/85	309/85	309/85	309/85	-0/97	(HP)
1	1	1	1	1	0	0	-0/71	(HM)
27/71	26/03	26/03	26/03	26/03	26/03	26/03	-0/01	(KM)

47/93	47/57	47/57	47/57	47/57	47/57	47/57	-0/64	(ST)
12/05	10/50	10/50	10/50	10/50	10/50	10/50	-1/12	(CT)
1	1	1	1	0	0	0	-0/65	(LD)
0	0	1	1	1	1	1	0/72	(AD)
1	1	1	0	0	0	0	-0/91	(ZN)
13/92	15/47	15/47	15/47	15/47	15/47	15/47	0/02	(KH)
6844	6812	6812	6812	6812	6812	6812	0/05	(DN)
2/79	2/18	2/18	2/18	2/18	2/18	2/18	-0/08	(PJ)
0	0	0	0	0	0	0	0/72	(HNO)
0	0	0	0	0	0	0	0/52	(FNN)
1	1	1	1	1	1	1	3/49	(C)
-2/06	1/1851	1/9051	2/8151	3/4651	4/1751	6/0451	-	Predicted Value
0/1144	0/7644	0/8690	0/9424	0/9689	0/9844	0/9975	-	Probability (percentage)
0/65	0/1045	0/0734	0/0265	0/0154	0/0131		-	Computational Marginal Effect

Source: Research Findings

*Tables related to the southern region (Helmand-Kandahar-Uruzgan) and western region (Farah, Nimruz, Nangarhar) have been omitted due to the extensiveness of the article.

Table 4: Results of the Test for the Influence of Provinces on the Area under Poppy Cultivation

Title		Diagnosis statistics	
Model		without considering the virtual variable of provinces	Considering the virtual variable of provinces
Row	statistics		
1	R-Square	0/49	0/61
2	Jarque-Bera	3/94	4/32
3	Log of the Likelihood Function	-906/75	-889/17
	LR	(DOP=8) 35/17***	

Source: Research Findings

*** is significant at the level of 1% respectively.

Table 5: Estimation of the Second Stage of the Tobit Model by Heckman's Two-Stage Method (Linear Model)

Row	Variable	Definition	Coefficient Value	Standard Deviation	T Statistic	Significance
1	(BN)	Relative profitability	1/17	0/50	2/32	**
2	(ZA)	The share of irrigated land from the whole farm	2/01	0/57	3/48	***
3	(Y1)	Amount of cultivation last year	1/03	0/28	3/60	***
4	(AH)	Having tools and livestock for agricultural purposes	0/25	0/11	2/11	**
5	(NF)	Number of family members	0/57	0/40	1/42	*
6	(AB)	Access to water sources	0/09	0/04	2/17	**
7	(NH)	Access to other inputs including fertilizer and labor	0/81	2/18	0/37	-
8	(D)	Demand status and purchase conditions	0/05	0/01	3/14	***
9	(DN)	Amount of debt and loan	0/07	0/01	3/67	***
10	(PN)	Variety of products	-0/03	0/01	-2/93	***
11	(ZN)	Fear of imprisonment and destruction of cultivated lands	-0/40	0/20	-1/93	**
12	(KH)	Experience violence and problems	0/26	0/13	1/92	**
13	(PJ)	A collection of projects and policies to combat poppy cultivation in the region	-0/01	0/008	-1/23	-
14	(H)	Virtual variable of Helmand province	0/76	0/28	2/63	**
15	(GH)	Virtual variable of Kandahar province	0/31	0/14	2/07	**
16	(D)	Virtual variable of Daykundi province	-0/08	0/05	-1/45	*
17	(IMR)	inverse Mills ratio	-0/67	0/34	-1/97	**
18	(C)	intercept	-2/54	0/95	-2/67	***

R ² statistic	0/67
adjusted R ² statistic	0/61
Jarek–Bra test	3/27
Durbin Watson (DW) statistic	1/92
White's heterogeneity test (TR)	1/92
F Test	5/80***

Source: Research Findings

*** and ** and * are significant at the level of 1%, 5% and 10%, respectively.

ECONOMY-WIDE IMPACTS OF CLIMATE-INDUCED CROP YIELD CHANGES IN KENYA: EXPLORING THE IMPLEMENTATION OF PRODUCTIVITY SHOCKS IN CGE MODELING

Peter Mwangi¹, Zuhail Elnour¹ and Harald Grethe¹

Abstract

Understanding how projected changes in climatic variables affect the Kenyan economy is important as it strongly depends on agriculture. Using a Computable General Equilibrium (CGE) model, this paper examines the economy-wide impact of climate change and presents systematic ways of exploring how to differently implement productivity changes at various levels of the production function. In the first option, yield changes are implemented as changes in total factor productivity. In the second option, these changes are implemented at the value-added level. Lastly, changes are applied only to land productivity. Results indicate significant effects on agricultural sectors compared to non-agricultural sectors, with shock implementation at lower levels having greater impacts. Highly factor-intensive sectors are severely impacted by shocks; for example, a shock to land productivity significantly impacts sectors that heavily depend on land. Household income declines are observed, driven by differences in factor ownership and consumption patterns. The study underscores the importance of understanding production systems to address climate-induced yield changes effectively.

Keywords

Climate change, Kenya, agricultural yield, CGE model

1 Introduction

Climate change poses a substantial global concern, with harmful impacts on agricultural production, particularly in the global South (IPCC, 2021). Studies indicate the likelihood of increased land suitability for crops in the high-altitude regions and decreased suitability in the tropics, with respective changes in agricultural yields (HADDAD et al., 2021). Kenya's economy is highly dominated by climate-sensitive sectors such as agriculture (OJARA et al., 2021). Agriculture represents about 20% of the entire landmass with 3% of land being irrigated and 17% rain-fed (MULWA et al., 2016). With a projected 1.7°C temperature increase by 2050 and rainfall distribution changes (WORLD BANK, 2021), agricultural productivity is expected to decline and yield uncertainty to increase. In most economy-wide simulation studies, climate change-induced crop yield changes are implemented as changes in total factor productivity (eg., SIDDIG et al., 2020). Few studies implement these changes at the level of value-added (eg. MANUEL et al., 2021) or specific factors, such as land-use efficiency (eg., WANG et al., 2021). A systematic analysis of different approaches helps to understand how productivity changes at different levels impact the production system and the whole economy. This study addresses this gap by exploring different implementation options.

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2 Research methods

2.1 STAGE model

We use a comparative static applied general equilibrium (STAGE) model to quantify the economy-wide impact of climate change on agricultural yields. Modelling is based on microeconomic theory depicting economic agents' behaviour where firms maximize their profits subject to production technology while households (consumers) maximize their utility subject to budget constraints. Production is modelled as a nested Constant Elasticity of Substitution (CES) production function combined with a Leontief production function. At the top level, aggregate value-added and intermediate inputs are combined using a CES function. Production factors are aggregated using CES functions, and the intermediate input component uses a Leontief production function. Consumers' demand for domestic goods and imports is determined by a CES function. Producers' supply of products to domestic or foreign markets is determined by a Constant Elasticity of Transformation (CET) function. Households supply production factors to productive activities through factor markets in exchange for income. Consumption of goods is based on utility maximization subject to prices, preferences, and income constraints.

To assess climate-induced yield changes, crop yield data from the Potsdam Institute for Climate Impact Research (PIK) are used. These data are produced using the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b) under two climatic scenarios, consistent with Shared Socioeconomic Pathways (SSP) 126 (optimistic), and 585 (pessimistic) for the period 2019 to 2100. Global temperatures are projected to increase under these scenarios by 1.8°C and by 4.3°C, respectively, by 2100. Using the data, we calculate the annual yield growth rate per sector for the two scenarios. Then, we calculate the growth difference between the two scenarios up to the year 2050, with the SSP 126 scenario as the reference scenario. Finally, we calculate the compounded growth rate difference by exponentiating the growth difference to the number of years from 2015 to 2050. These growth rate differentials enter the production functions in the CGE model as productivity changes.

Together with a base SAM, three counterfactual options representing productivity changes are developed and implemented in three different ways. In the first option (TFP), these differentials affect total factor productivity (top-level nesting). In the second option (VAD), they influence the efficiency parameter in the value-added demand function (second level). In the third option (LAND), they impact the efficiency parameter in the land demand function (third level). Model closure rules include savings-driven investments, fixed government consumption expenditure and savings, full employment and mobility of production factors, the small country assumption, and the Consumer Price Index (CPI) applies as numéraire.

2.2 Data

A 2019 Social Accounting Matrix (SAM) for Kenya is used (ELNOUR, SIDDIG AND GRETHE, 2023). This SAM is aggregated to include 22 activities (agricultural, industrial, and service) producing 22 different commodities. Five factors of production are considered: land, capital disaggregated as agricultural and non-agricultural, and labour as skilled and non-skilled. Households are categorized as rural and urban, based on region and as poor and non-poor based on income level. Other accounts include enterprises, government, capital, and the rest of the world.

3 Preliminary results

Climate change has a detrimental impact on production and economic performance. Across all implementation options, the production of the agricultural sector drops substantially compared to non-agricultural sectors, attributed to the negative yield shock. Within the agricultural sector, commercial crops and poultry are the hardest hit, driven by rising costs associated with reduced demand and increasing prices of cereals, respectively.

Despite non-agricultural sectors also experiencing a falling output due to reduced demand, some sectors such as mining and other manufacturing are positively affected, benefiting from falling factor prices. The price of all factors falls substantially except for agricultural-specific factors such as agricultural capital and land, which experience a small reduction. Increased demand for capital by the livestock sector, which is highly capital-intensive, drives up its price, while the scarcity of productive land raises land rents leading to a small decline in these prices. In terms of welfare, all household groups experience losses, with poor households living in urban areas being the most affected. These households are more reliant on income from skilled labour and non-agricultural capital, whose prices decrease the most, and have a higher expenditure share on agricultural products, thus suffering from increasing food prices. Consequently, all macroeconomic indicators fall, with exports and imports declining sharply due to reduced demand.

When comparing the three options (TFP, VAD and LAND), LAND depicts the most pronounced effect, primarily due to a higher productivity shock. Scaling up the shock to a lower level (nest) of the production function magnifies the overall impact, as production activities have limited options to escape the high productivity shocks on specific factors. For example, production in the crop sector drops by 9% under TFP, by 11% under VAD and by 18% under LAND. Land productivity significantly affects production especially in land-intensive sectors, implying that the magnitude of impact is highly sector-specific.

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ANALYZING WHEAT PRODUCTION COST STRUCTURE IN IRAN: IMPLICATIONS FOR INNOVATIONS IN SUSTAINABLE OPTIMIZATION IN AGRI-FOOD SYSTEMS

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Abstract

Wheat is considered a strategic product all over the world because of the important role it plays in the field of political and economic competition as well as the food security of countries, especially developing countries. Therefore, it is very important to find ways to benefit from the available facilities to achieve more yield in this product and evaluate the technology governing the wheat production process to achieve sustainable production in agri-food systems and ensure food security. So, employing econometric techniques such as the Translog cost function, demand functions, and seemingly unrelated regression equations, we analyze the role of production inputs and technology in wheat cultivation. After the statistical tests of different functional forms, from the Translog cost function and the demand functions derived from it in the form of a system of equations Seemingly unrelated repetitions were used which were estimated simultaneously. This function was estimated from the constrained non-linear maximum likelihood method, using the time series data of 1990-2023. The results of the first part have been used to calculate Asymmetrical Morishima Elasticity of Substitution (MES), self-price, and cross elasticity, Allen-Uzawa partial elasticities of substitution, function coefficients, and Returns to Scale in the Production of Wheat. According to the results, the numerical values related to self-price elasticities and cross-Allen's elasticities show the inelasticity of the demand for machinery and labor in wheat production. Also, inputs of chemical fertilizers- seeds and machinery water are complementary to each other. Morishima Substitution Elasticity (MSE) values show that the elasticity of the ratio of water-labor and water-poison factors as well as labor-machinery is greater than one and there is a strong substitution between them. Also, the return to scale in this production of this product is upward, Therefore, it is suggested to pay attention to the optimal production scales and the price and relationship sensitivities of the production inputs to always be considered in the policies and planning of wheat production. This study contributes to the discourse on innovative optimized approaches to enhance wheat production efficiency and sustainability in the Agri-Food systems.

Keywords

Cost function, Cost Elasticities and Returns to Scale, Maximum Likelihood Method, Wheat Cultivation

1 Introduction

Wheat, a staple crop globally, holds paramount importance in ensuring food security and economic stability, particularly in regions like Iran. As a strategic commodity, understanding the dynamics of wheat production is crucial for effective agricultural policymaking and sustainable development (SENDHIL et al., 2022). This necessitates a comprehensive analysis of the cost structure and production technology governing wheat cultivation, as it directly influences resource allocation, productivity, and environmental sustainability (KOUNDOURI et al., 2013). Despite Iran's potential, a substantial proportion of its wheat needs are imported, highlighting underlying challenges in domestic wheat production (AMIRTEIMOORI & DAVOUDI, 2015). Factors

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such as low productivity, inefficiencies in production units, and inadequate management contribute to this dependency (AMIRTEIMOORI & DAVOUDI, 2015). Moreover, a lack of adherence to economic principles and limited adoption of advanced technology further hinder progress (AMIRTEIMOORI & DAVOUDI, 2015). Econometric methods such as the Translog cost function provide a robust framework for assessing input-output relationships and production efficiency in agriculture (GREENE, 2012). By examining the elasticities of production inputs and returns to scale, insights can be gleaned into the optimal allocation of resources and the potential for innovation-driven improvements in wheat production systems (FÄRE et al., 2005). This study aims to fill this gap by employing advanced econometric techniques to evaluate the cost structure of wheat production in Iran and elucidate its implications for sustainable agri-food systems.

2 Materials and Methods

Using the cost function instead of the production function to estimate the production parameters can provide a richer framework for the analysis of production relations (WALTERS, 1963). The study utilizes econometric techniques including the Translog cost function and seemingly unrelated regression equations to analyze the cost structure of wheat production in Iran (GREENE, 2012). Of course, based on econometric statistics and the significance of coefficients, the best functional form was determined. Time series data from 1990 to 2023 is employed for constrained non-linear maximum likelihood estimation (KOUNDOURI et al., 2013). Asymmetrical Morishima Elasticity of Substitution (MES), self-price, and cross elasticity, Allen-Uzawa partial elasticities of substitution, Returns to Scale in the Production of Wheat, and function coefficients are calculated to assess input-output relationships and production efficiency (FÄRE et al., 2005). This rigorous approach enables the examination of the optimal allocation of resources and the potential for innovation-driven improvements in wheat production systems. statistical tests have been checked to ensure the absence of econometric problems and the robustness of the model. The data utilized in this study encompassed time series information spanning the entirety of Iran, collected in collaboration with the Production Cost Information Department of the Ministry of Agriculture.

3 Conclusion and Recommendations

The analysis of the cost structure of irrigated wheat in Iran reveals substitution relationships between labor, seed, and water inputs, along with complementary relationships between machinery, fertilizer, and water. This substitution in the cost function may be due to the farmer's budget constraints. In other words, due to the limited budget, more use of labor led to less use of fertilizer, seeds, and water. In addition, based on agricultural science, with the increase of the labor force, and precision in the consumption of the mentioned inputs in the stages of planting and planting, their consumption will increase and decrease. Optimal pricing strategies for chemical fertilizer and water are crucial for sustainable development and environmental protection. Mechanization policies can enhance employment and production, necessitating support through facilities and bank credits. Machines act as substitutes for fertilizers, poisons, and water, promoting efficient input management and reducing production costs. Promotional services can enhance input efficiency and guide users toward optimal input utilization. The study highlights inefficiencies in current production structures, emphasizing the need to address factors hindering unit efficiency for improved economic outcomes in larger units.

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IMPLICATIONS OF INCREASING SCHOOLING ENROLMENT IN DEVELOPING COUNTRIES: AN ECONOMY-WIDE ANALYSIS

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Summary

The high number of out-of-school children in developing countries constitutes a pressing challenge with profound implications for attaining sustainable development. Sudan, for example, has the fourth-highest number globally while struggling with sluggish economic growth and high youth unemployment. In this study, taking Sudan as a case study, we assess the potential economy-wide implications of options to enhance enrollment among children by lowering private household spending on education and training services using a recursive-dynamic single-country Computable General Equilibrium model (STAGE-Edu). Cost reduction is considered for: a) primary education, b) secondary education, c) primary and secondary education, and d) all acknowledged educational cycles and vocational training. The findings suggest that cost reduction in primary education significantly reduces out-of-school children and enhances long-term economic growth. However, it increases dropouts from post-primary education and vocational training. In contrast, cost reduction for both primary and secondary education improves enrollment in the tertiary education cycle and promotes the overall skill composition. Funding such cost reductions from foreign development aid and grants yields higher economic benefits than increasing domestic taxes.

Keywords

Modelling education and training, Economic growth, School dropout, CGE models, Developing countries

1 Introduction

The high number of out-of-school children in developing countries is a significant barrier to sustainable development. Sudan is grappling with the highest number of out-of-school children in the Middle East and North Africa region and the fifth-highest number globally (UIS - UNESCO, 2023), a situation that not only hampers its economic growth but also poses a significant obstacle to achieving Sustainable Development Goals. This dropout crisis in Sudan is exacerbated by inadequate government spending on education and training services (FMOGE, 2019), which is lower compared to the average global level relative to its Gross Domestic Product and total public expenditure (ADAM, 2013; UNICEF, 2019; WORLD BANK, 2012). Sudanese households cover about 16% of primary and secondary education costs to compensate for these gaps (FMOGE, 2019), which are primarily for tuition fees set by parent-teacher associations, and are used for daily school operations (UNESCO, 2018; WORLD BANK, 2012). Such pressures compel families, especially the poorest and those with multiple children, to prioritise immediate needs over education and training, exacerbating the out-of-school children issue (WORLD BANK, 2012; ADAM, 2013; FINCHAM, 2018; WORLD BANK, 2021a). External factors such as the COVID-19 pandemic, the Russia-Ukraine conflict, and Sudan's military coup have further complicated matters, causing school closures, interruptions in learning, and inequalities in digital education access (WORLD BANK, 2021b). Additionally, the April 2023 conflict aftermath inflicted severe

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damage on Sudan's education and training system (ABUSHAMA *et al.*, 2023). This paper analyzes the potential economy-wide implications of enhancing school enrolment in Sudan by decreasing private household spending on education and training services.

2 Methods

2.1 Data

STAGE-Edu is calibrated to a 2019 Social Accounting Matrix (SAM) for Sudan, containing detailed data about the educational and training system in the country. This SAM is constructed using official statistical data collected from various domestic institutions, e.g., the Central Bank of Sudan and the Central Bureau of Statistics in Sudan. These data are complemented by information from a 2012 SAM for Sudan (SIDDIG *et al.*, 2018).

a. Model

We developed a novel recursive-dynamic single-country Computable General Equilibrium (STAGE-Edu) model that captures secondary education by type (vocational and non-vocational), vocational training, and education and training choices at different levels with broad coverage of existing bridges between education and training. STAGE-Edu also establishes endogenous and consistent linkages between the educational and training system (graduates and dropouts) and the skill levels of the labour force through six-stage nested production functions.

b. Simulation Design

The baseline scenario develops a trajectory for the Sudanese economy between 2019 and 2055, using recent projections (e.g., gross domestic product and population) from the International Monetary Fund and the World Bank. Under this scenario, no specific changes are implemented concerning education and training policies.

We use STAGE-Edu to assess the economy-wide effects of four policies in Sudan aimed at increasing school enrolment by reducing private household spending on education and training. These policies target different education cycles: primary, secondary (vocational and non-vocational), primary and secondary combined, and all cycles.

3 Results and Policy Implications

Results suggest that reducing private household costs in primary education significantly lowers the number of out-of-school youth and enhances long-term economic growth. However, it drives up dropouts from post-primary education and vocational training. Conversely, reducing private household costs for both primary and secondary education improves tertiary education enrollment and enhances the labour force's overall skill composition. Besides, results indicate that funding these cost reductions through foreign development aid and grants yields higher economic benefits than increasing domestic taxes.

This research offers policymakers insights into the immediate and long-term impacts of reducing private household spending on education and training. These insights aid in formulating policies that reduce out-of-school children and promote economic growth and poverty alleviation, considering the dynamic interplay between education, training, labour markets, and economic outcomes.

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**POSTER SESSION 2:
SUSTAINABILITY AND AGRICULTURAL PRODUCTION**

ASSESSING ECONOMIC AND DISTRIBUTIONAL IMPACTS OF RESTORING DEGRADED RANGELANDS IN JORDAN

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Abstract

This paper evaluates the potential impacts and trade-offs from sustainable management of Jordan's rangelands. These rangelands, serving as significant economic, environmental, and cultural resources in the country, have faced severe degradation due to many external and internal factors, including climate change and overgrazing, negatively impacting natural pasture provision. These pastures are critical for sustaining pastoralist livestock production—vital to Jordan's economy, contributing significantly to small ruminants production and exports, and serving as a primary income source for rural households (ABU-ZANAT et al., 2010).

Keywords

Rangelands, livestock production, ecosystem services

1 Background

In Jordan, rangelands are primarily recognized as government-owned common land. Traditionally, the oversight of grazing and cultivation activities within these expansive areas was governed by a tribal tenure system. This system achieved a balance between the conservation of the rangeland ecosystem and the sustainable extraction of resources. However, in the face of substantial development in Jordan and the surrounding region, the management of rangeland resources weakened, leading to a notable decline in forage production in the rangelands. This drop has been particularly attributed to overgrazing, and it is impacting pastoralist production, specifically within the small ruminant production system that is most prevalent in Jordanian rangelands (MINISTRY OF AGRICULTURE, 2013).

Several interventions have been implemented to rehabilitate and restore the degraded rangeland ecosystem in Jordan, aiming to foster benefits such as increased forage production. Most economic valuations of these interventions focus on specific locations and markets. A more comprehensive analysis is needed, taking into account the economy-environment nexus in Jordan to evaluate the impact of these interventions (MINISTRY OF AGRICULTURE & INTERNATIONAL UNION FOR CONSERVATION OF NATURE, 2015).

2 Methods

To achieve this, we assess the economy-wide and distributional effects of improvements in the supply of natural fodder, building on a general equilibrium model developed by McDONALD (2015). We modify the model by adding a production structure for ruminants, allowing for the substitution between fodder from rangelands and other feed types such as barley, which is mostly imported and subsidized for and a subject of policy debate, currently constitutes most of the livestock production costs in Jordan (DoS, 2018).

Furthermore, we distinguish between two pastoralist production systems—extensive, intensive. This differentiation is crucial in evaluating the distributional impacts of restoration projects, as

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these systems exhibit diverse dependencies on rangelands and possess distinct factor endowments. Given these specific characteristics, it becomes challenging to shift from one system to another.

Our model is calibrated to an extended version of the social accounting matrix developed by RAOUF et al.(2021) for Jordan. This extension includes a rangeland account reflecting the value of natural pasture, as well as three distinct pastoralist livestock activities and corresponding households, which are linked through specific factor accounts (e.g., herder labor, livestock capital). The restoration initiatives led by the Jordanian government and various national and international partners encompass a diverse range of approaches. In this study, we will focus on a specific example—the establishment of contour ridges, a rainwater harvesting system designed to counteract the degradation of vegetation in the rangelands by addressing soil erosion. The extent of improvement in fodder production resulting from implementing such water harvesting projects will be assessed based monetary evaluation of the biomass produced by the rangelands.

3 Expected Results

We expect the results to indicate the importance of including non-market environmental services in economic analysis, as restoring rangelands is expected to exert a positive multiplier effect throughout the economy. Extensive livestock production heavily relies on purchased domestic and imported fodder, accounting for 75% of the total feeding requirement. By increasing the availability of natural pasture, the cost of livestock production decreases as it substitutes for purchased feed. This, in turn, can lead to an increase in livestock production and a decrease in meat and dairy prices. Rural poor households, most involved in livestock production, are expected to experience welfare gains due to the increased demand for livestock. Additionally, the reduction in subsidized barley feed imports is anticipated to improve the fiscal deficit substantially.

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IDENTIFYING THE FUNDAMENTAL ELEMENTS FOR SETTING UP A BUSINESS MODEL FOR ECOSYSTEM SERVICES VALORISATION IN MOUNTAIN REGIONS

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Summary

Alpine grasslands, which are rich in biodiversity, are crucial for ecosystem services (ES) and local economies. However, in order to maintain alpine management and the delivery of ES, it is necessary to provide incentives to farmers that cover the costs involved. Private business models, which are based on the valorisation of ES, could open up new opportunities in this context (e.g. through EU's Green Deal). The objective of this study is to identify the fundamental supply and demand side elements required for the establishment of new ES business models for mountain agriculture. To this end, we apply an inter- and transdisciplinary three-step approach, where we map and test the ES delivered by mountain farming, include farmers' opinions by using farm survey and workshops as well as interview managers and consultants. It can be observed that, on the supply side, both suitable indicators and measures for the delivery of ES already exist, particularly in the case of biodiversity. Furthermore, a significant proportion of farmers is willing to collaborate with companies in order to sell the services provided. On the demand side, there is an increasing need for biodiversity compensation, while the quantities of additional biodiversity must be measurable.

Keywords

Biodiversity, ecosystem service valorisation, mountain farming, Green Deal

1 Introduction

Close-to-nature, small structured alpine grasslands are biodiversity hotspots (SCHIRPKE et al. 2022), providing a range of ES to various economic sectors and the society (e.g. recreation, genetic resources, habitats for biodiversity) (BRUNNER und GRÊT-REGAMEY, 2016). For farmers in mountain regions, grassland-based milk and beef production is an important source of income, but at the same time faced by low yields and high production costs, jeopardising this form of farming. National and global market competition exacerbates the strong decline in (small) mountain farms (HINOJOSA et al., 2016), reducing ES delivery. However, keeping up alpine management and ES delivery demands cost-covering incentives to farmers. Here, private business models, building on the valorisation of ES, could open up new opportunities, especially as the EU's Green Deal and its strategies, directives and regulations require companies to reorganise their sustainability efforts. This study's aim is therefore to identify fundamental supply and demand side elements required for the establishment of new ES business models for mountain agriculture.

2 Methodological approach and results

We apply an inter- and transdisciplinary three-step approach. (1) We survey and assess the existing range of ES of mountain farming by developing both area and farm related indicators and measures, tested and mapped using IACS data and an in-depth farm survey on 29 farms, including farm visits and utilising the FarmLife Tool (<https://www.farmlife.at/>). (2) We identify farmers' opinions on the realisation of ES promoting measures and the application of different

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marketing schemes by analysing 144 online questionnaires of dairy, cattle sheep and goat farmers received through a quantitative farm survey, and by analysing the results of a farmers' workshop with 20 farmers participating. (3) We identify opportunities and needs of companies regarding their sustainability requirements by means of a literature research of relevant regulatory frameworks at the EU level and by 13 qualitative, guided interviews within intermediary organisations, the financial sector, corporate and sustainability consultancies and companies. As case-study region we use the "Nationalpark Kalkalpen Region" in Austria.

Our results on ES provided by mountain farms show that they offer more space for biodiversity, both on regional and on farm level. Applicable indicators such as the number of landscape elements and size of extensive fruit orchards reveal greater structural richness, while indicators like the extent of extensively managed grasslands and (alpine) pastures, reveal less intensive management. Also, mountain farms provide a higher level of livestock diversity, both in terms of animal species per farm and rare livestock breeds.

The quantitative survey on ES promoting measures shows that measures like the maintenance of extensive fruit orchards and the management of extensive grasslands are often realised - particularly on farms managed by elder farmers and in part-time. Farmers reason the implementation of such measures primarily by the aims to protect species diversity and to preserve the attractiveness of the landscape. Only 35% of all farms stated that additional income is a reason for implementing the measures. However, 14% of farmers would be willing to adopt the above mentioned measures, when there is an additional payment. As regards the promotion of biodiversity via future business models, about 40% of surveyed farms would be in favour of offering services to partner companies, while for about 30% this would not be an option. When implementing contract based business models, for farmers the dependence on contractual partners is seen as a risk and additional bureaucracy is seen as a burden.

Our results on opportunities and needs perceived by companies to meet future sustainability requirements reveal that compensation measures for biodiversity loss will play an increasing role. However, sustainability activities affected by the new regulations are moving away from project- or marketing-related measures and become data-driven. This means that on the one hand, there is a demand for offers that include measures whose impact can be measured - particularly in the area of compensation measures. On the other hand, the new requirements reduce the interest of companies in entering into project partnerships with agricultural operations that do not contribute added value to their mandatory reporting.

3 Conclusions

By identifying fundamental elements of ES business models in mountain farming, we find, that on the supply side both suited indicators as well as measures for ES delivery already exist - particularly for the provision of biodiversity. Furthermore, a great share of farmers is willing to team up with companies to sell services provided. On the demand side, we find an increasing need for biodiversity compensation, while the quantities of additional biodiversity need to be measurable. Measurability particularly challenges the development of business models for mountain farms, as most existing indicators are management related while not revealing ES quantities. New indicators and new data collection are needed, while such data collection can't add much bureaucracy to the farmers. Future research on indicators is therefore needed as well as research on prices for services provided, by means of e.g. calculating provisioning costs or applying stated-preference methods to assess willingness-to-pay of company managers.

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NUTRIENT MANAGEMENT PRACTICES CONTRIBUTION TRANSFORMATION TOWARDS CIRCULARITY IN THE AGRICULTURAL PRODUCTION

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Abstract

This paper explores the role of nutrient management practices in facilitating transformation towards circularity in agriculture. The circular economy concept has gained significant attention in recent decades and is increasingly applied to diverse sectors, including the food and agriculture systems. In this context, we assessed the transformative potential of various innovation cases on nutrient management. Thereby, we found that including actors impacted by the innovation from an early stage will increase other characteristics of the transformative potential of the innovations. These results underscore the importance of actively engaging and creating value for all actors involved in innovation for circularity transformation.

Keywords

Circularity, Transformation, nutrient management practices, innovation.

1 Introduction

The global food system faces profound challenges, including heavy reliance on synthetic fertilisers, fragmented farming systems leading to localised nutrient imbalances, and substantial waste of resources, contributing to environmental degradation (SCHULTE-UEBBING ET AL., 2022; JURGILEVICH ET AL., 2016). Circular agriculture emerged as a promising paradigm shift, advocating for a sustainable alternative where nutrients and materials are continuously cycled, waste is minimised, and resources are utilised efficiently (JURGILEVICH ET AL., 2016). Scholars underscore the necessity of a transformative approach to address these environmental challenges, characterising transformation as a profound and irreversible alteration of fundamental system attributes, encompassing structural and agency changes (BRAND ET AL., 2013; FEOLA, 2015). Various innovative approaches, such as aquaponic systems, urban farming, and recovered traditional farming methods, have emerged as promising strategies to enhance nutrient circularity and sustainable food production (DONNER & VRIES, 2021) (ALEKSIĆ & ŠUŠTERŠIČ, 2020) (SCHNEIDER ET AL., 2021). Their variety also raises the question of how differences in innovations can contribute to the circular nutrient management transformation.

Building on the concept of circular agriculture, which seeks to safeguard agroecosystem health, minimise waste, and optimise resource use (KIRCHHERR ET AL., 2017; MUSCAT ET AL., 2021), we aim to elucidate the transformative potential of nutrient management practices within this framework. Therefore, we take examples from the research project trans4num, which develops and implements tailored nutrient management solutions within diverse contexts in Europe, to illustrate how a range of context-specific innovations in nutrient management can contribute to advancing circularity in practice.

2 Methodology

The study adopts a qualitative research approach, drawing on secondary literature and empirical insights from the trans4num project. The practical cases are part of the trans4num project with

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sites in Denmark, Hungary, the Netherlands and the United Kingdom (Figure 1). Every site aims to find regional solutions for circular nutrient management, particularly for Nitrogen and Phosphorus. To delve deeper into the transformative potential of these practices, we applied the principles of circular agriculture (MUSCAT ET AL., 2021) and characteristics that determine the transformative potential of circular agriculture initiatives (SILVIUS ET AL., 2023). This heuristic builds on the small wins theory, which posits that transformative change often emerges through accumulating small, impactful innovations in an incremental but continuous way (LINDBLOEM, 1979; WEICK & QUINN, 1999).

Figure 1: Nutrient management innovation cases of the trans4num project



3 Results and Implications

The cases deal with several circular agriculture principles, most of which deal with safeguarding watershed, groundwater, and surrounding ecosystems, mostly avoiding synthetic fertilisers and recycling by-products as a nutrient source. Entropy is primarily relevant for more technical solutions, such as in the case of a biorefinery for grass-clover and phosphor fertiliser from abattoir waste. The cases were mainly in the experiment stage, while only one case in the Netherlands is already a well-established initiative with several actors included. Cases in the experiment stage had to deal with barriers regarding the trials and the inclusion of actors such as farmers or politicians in the development and implementation process. The more well-established the initiative is, or if actors were included in establishing communication between actor groups, barriers would be identified early and could be easily overcome. As mentioned earlier, the synergy between social and technological change was visible in all cases. However, cases with strongly involved actors other than research had an impact on an increased transformative potential. Therefore, including diverse societal actor groups possibly impacted by the innovation plays an essential role in the transformative potential of circular nutrient management innovations.

The characteristics for determining the transformative potential of circular agriculture initiatives by SILVIUS ET AL. (2023) have shown to be a valuable heuristic to identify the current state of transformativity of the analysed cases and their future potential. Integrating affected actors of the innovations from an early stage to develop the innovation further, establish the initiative well, and overcome regulative or social barriers was a key factor. The results can help the innovations further develop and reflect upon their transformativity.

Though the cases differ in their aim and practices, their overall understanding is going in a similar direction to working with so-called nature-based solutions, which allow for technical support but mimic natural processes as much as possible. Therefore, highly technical solutions are not considered in this study since this would come with the question of which transformed circular nutrient management future is desired. Nevertheless, the cases provide concrete examples of how innovations in nutrient management practices contribute to the transformation of

circular agriculture, generating insights into the conditions that determine their transformative potential.

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FALLOW LAND IN THE EU – HOW ARE AGRICULTURAL REVENUES AND MARKETS AFFECTED?

Verena Laquai¹, Max Zirngibl, Marlen Haß

Summary

This contribution shows different projections and their effect on agricultural markets and revenues regarding requirements to set-aside land in the European Union (EU). The policies concerning fallow land have frequently been eased in the past and are subject to change in the future. The analysis gives insights per EU Member State on changes in fallow land and the resulting changes in agricultural revenue. For this purpose, the partial equilibrium model AG-MEMOD is applied which projects price and production changes due to policy-driven changes in fallow land. The effects in the EU Member States are very heterogenous and can range from losses to gains depending on the initial level of fallow land and the detailed national policy design.

Keywords

Common Agricultural Policy, partial equilibrium analysis, non-productive areas, EU Member States.

1 Introduction

The conditionality and eco-schemes of the Common Agricultural Policy of the EU (CAP) in the current period (2023-2027) are the successors of the greening in the previous CAP period (2015-2022). Within this framework, the good agricultural and environmental conditions 8 (GAEC8), which specifies requirements for non-productive areas, has been subject to changes: exemptions from the rules have been made in 2023 due to the invasion of Russia into Ukraine and in 2024 due to farmer protests in the EU. The farmer protests have also led to the suspension of GAEC8 for 2025 to 2027. In contrast to this development, the biodiversity strategy of the EU has the aim to put “at least 10% of agricultural area under high-diversity landscape features” by 2030 (EUROPEAN COMMISSION, 2020).

These various changes and different options have not been researched in a comprehensive way and at EU Member State level. The paper aims to close this research gap by explicitly modelling the effects of the CAP policies with respect to providing non-productive areas at the EU Member State level. For this purpose, the partial equilibrium model AGMEMOD (CHANTREUIL et al., 2012) was extended and applied. Specifically, the paper addresses the following research questions : What quantity of fallow land and resulting agricultural arable land can be expected under different policy options? What effects does this have on agricultural markets, especially revenue, production, and prices?

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2 Data and method

To answer our research questions, the dynamic, multi-country, multi-market, econometrically estimated, partial equilibrium model AGMEMOD (CHANTREUIL et al., 2012) has been extended to simulate various shares of fallow land in arable land, i.e., non-productive areas. In AGMEMOD, the land use is determined by estimating shares of land use via a nested top-down structure. Arable land is distributed between the land use categories “fallow land”, “fodder” and “land other than fodder”. The equation for the share of fallow land determines the amount of land that will be fallow and covers the policy schemes of the previous and current CAP period. Additionally, fallow land is not allowed to fall below the lowest historically observed value of fallow land between 2010 and 2022.

A baseline and three scenarios are simulated with AGMEMOD to answer the research questions of this paper. Table 1 shows the differences between the simulations, i.e., the specifications regarding fallow land.

Table 2: Scenarios in AGMEMOD

Scenario name	Fallow land representation in the scenarios
Baseline	Non-productive areas of 3% or 4% (GAEC 8) and planned amounts of eco-schemes based on the national strategic plan of each EU Member State for the period from 2025 onwards
Fallow10	Minimum of 10% of fallow land in arable land in each EU Member State and elimination of eco-schemes from 2028 onwards
OldGreening	Ecological focus areas of 5% for each EU country with adjusted factors to determine the share of fallow land to other option to fulfil the requirement according to Greening rules in the period 2015-2022 for whole simulation period
NoReqFallow	Elimination of GAEC 8 from 2025 onwards but keeping the eco-schemes

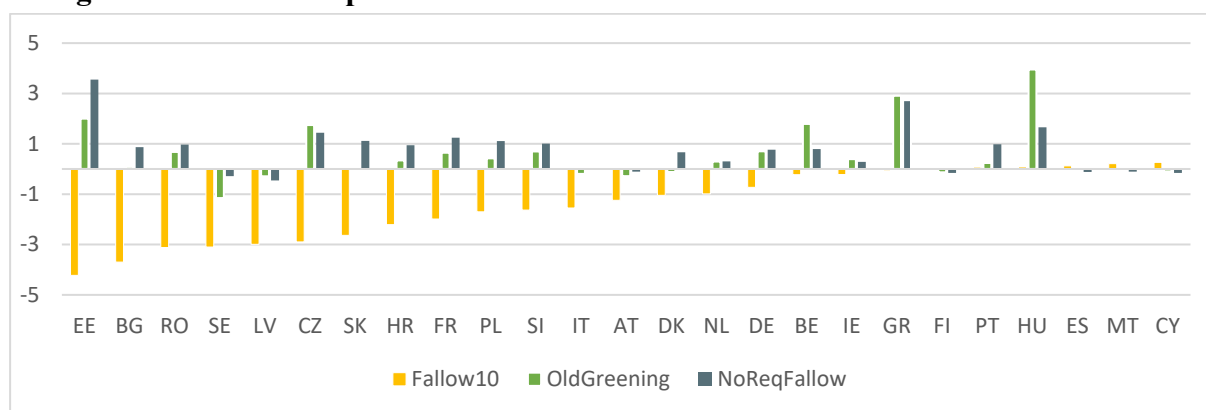
Quelle: own compilation 2024.

The resulting changes of fallow land are very heterogenous across the different EU Member States depending on their original share of fallow land. In the Fallow10 scenario, this ranges from no changes in Spain, Portugal and Cyprus (because fallow land is already above 10% of arable land) to more than a triplication of fallow land in the Netherlands, Poland and Austria compared to the baseline.

3 Results

Results are shown for the year 2030, i.e., the target year of the biodiversity strategy. Figure 1 shows the percentage change of revenue in total primary agricultural production per EU Member State. The changes of revenue are a result of changes in production and prices. Estonia is most responsive to changes in fallow land. Applying the old greening rules would benefit farmers in the Netherlands, Hungary and Greece the most. Price increases triggered by lower production (in the Fallow land scenario) result in some EU Member States in increased revenues.

Figure 3: Change in revenue of total primary agricultural production, percentage change of Scenarios compared to Baseline in 2030



Quelle: own simulations with AGMEMOD 2024.

4 Discussion and conclusion

The analysis shows the heterogeneity across the different EU Member States in their application of the policies and the results on farm revenue and agricultural markets. Overall, the changes in farm revenue between the different analyzed options would not exceed 5%, except for Estonia.

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**POSTER SESSION 3:
MARKETING, ENTREPRENEURSHIP AND
RENEWABLE RESOURCES**

ATTACHED TO SE(A)E?

CONSUMER PREFERENCES FOR NORTH SEA BROWN SHRIMP: THE EFFECT OF TOURISTIC EXPERIENCE ON FOOD CHOICE

Brianne A. Altmann¹, Thiemo Wolgast, Charlotte Bühner, Antje Risius

Abstract

The largest commercial fishery in Germany takes place in the biggest natural resorts. Understanding consumer preferences for its main produce, North Sea brown shrimp, can help to understand connection, preference and exposure to the value and conflict of transforming food value chains. Using a discrete choice experiment, we estimate consumer preferences for innovative marketing strategies of North Sea brown shrimp. Respondents were selectively grouped by personal exposure to the area to understand the effect of personal experience to the area. Respondents who vacationed at the North Sea exhibit higher willingness-to-pay, especially for the local produce innovation strategy.

Keywords

regional products, geographical indication, short supply chains, tourism

1 Introduction

North Sea brown shrimp, locally referred to as *Nordseekrabben*, is the single most important

Table 3: Discrete choice experiment attributes

Attribute	Levels (reference in bold)	Variable
Price (€ / 100g)	3.99, 4.99, 5.99, 6.99, 7.99	PRICE
Peeling Method	“peeled” “hand-peeled” “machine-peeled”	HAND MACHINE
Peeling Region	no claim “onsite” “in Germany” “in Poland” “in Morocco”	ONSITE DE PL MAR
Sustainability Label	no label Marine Stewardship Council Geographical Indication National Park Wadden Sea Protected designated origin	MSC GI WADD PDO

commercial German fishery product. North Sea brown shrimp also plays an important role in regional cuisine and could be considered a cultural heritage food in a region popular with tourists. Yet, most North Sea brown shrimp is transported by wholesalers in Europe to Morocco for hand-peeling. Due to the extensive transport of this geographic product, it is critically viewed by restaurateurs and consumers. Machine peeling may lead to higher amounts of regional processing, playing into German consumer preferences for sustainably produced seafood (ZANDER and

FEUCHT, 2017). We use discrete choice analysis to test the hypothesis: personal experience to the produce (e.g. through tourism) positively influences preferences for North Sea brown shrimp attributes.

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2 Methodology

This research focuses discrete choice analysis data from a larger online consumer survey (n = 2343) conducted December 2023 in Germany on fishery knowledge and consumption behaviour. Consumers who had never purchased North Sea brown shrimp (n = 704) and those who opted-out of all choice sets (n = 91) were excluded from analysis for this paper. The total sample (n = 1548) was split based on response to the question “have you ever vacationed at the North Sea in the last 15 years?”

Discrete choice analysis applies utility theory, where utility is a summation of a product’s intrinsic attributes (LANCASTER, 1966). Our choice experiment included attributes price, peeling method, peeling region, and sustainability label (Table 1) and was created using a *d*-efficient design using prior estimates from a pre-test resulting in 9 choice sets. A package of North Sea brown shrimp photo was edited to include a sales tag with price per package (100g), peeling method and region, and a sustainability label. Prices were chosen based on a retail inventory conducted in 2022. A status quo product (with reference levels and lowest price level) and opt-out option were included in each choice set. Panel-data mixed logit choice models were run for each sample using the Stata command “cmxtmixlogit” default settings (STATA CORP, 2021), with the opt-out alternative as the base alternative. The model was specified as follows:

$$U_{ijt} = ASC + \beta_{ijt}PRICE + \beta_{ijt}ONSITE + \beta_{ijt}DE + \beta_{ijt}PL + \beta_{ijt}MAR + \beta_{ijt}HAND + \beta_{ijt}MACHINE + \beta_{ijt}MSC + \beta_{ijt}GI + \beta_{ijt}WADD + \beta_{ijt}PDO + \varepsilon_{ijt}$$

where variable (refer to Table 1) coefficient β_{ijt} is the marginal utility derived from alternative *j* for individual *i* in choice set *t*, *ASC* is the alternative specific constant and ε_{ijt} is an error term.

Willingness-to-pay (*WTP*) was calculated according to HENSCHER ET AL. (2005):

$$WTP = -\frac{\beta_{variable}}{\beta_{PRICE}}$$

3 Results & Discussion

Compared to no indication of region, respondents who had vacationed at the North Sea (i.e. tourists) show a high *WTP* for domestic peeling (*DE*), whereas no preference is observed for non-tourists. This is unusual considering consumers typically prefer domestic origin (THØGERSEN, 2023). Explicitly indicating a non-domestic peeling leads to a negative *WTP* for both tourists and non-tourists, consistent with literature (THØGERSEN, 2023). This finding supports current marketing of peeling in Morocco without disclosing peeling region. Yet, consumers with exposure to the region should be considered for marketing domestically peeled brown shrimp. Surprisingly, *WTP*

Table 2: *WTP* for attributes

Variable	Total (n=1548)	Tourists (n=936)	Non-Tourists (n=612)
ONSITE	<i>n.s.</i>	<i>n.s.</i>	-0.33**
DE	0.47***	0.71***	<i>n.s.</i>
PL	-2.32***	-2.27***	-2.23***
MAR	-2.94***	-3.02***	-2.74***
HAND	0.35***	0.31**	0.34**
MACHINE	-1.38***	-1.37***	-1.33***
MSC	0.66***	0.91***	<i>n.s.</i>
GI	0.50***	0.58***	0.33 **
WADD	<i>n.s.</i>	<i>n.s.</i>	-0.33**
PDO	-0.70***	-0.68***	-0.68***

n.s., $p > 0.10$, ** $p < 0.05$, *** $p < 0.001$

for machine- (*MACHINE*) was penalized; hand-peeling (*HAND*) increases *WTP* which could be linked to “handwork” associated with higher end product quality. Tourists strongly prefer the *MSC* label, perhaps further underlining a connection and felt responsibility to the region. Similarly, tourists did not reject the National Park Wadden Sea (*WADD*) label in association with an economic natural resource, whereas non-tourists penalized the label. Both groups showed homogenous choice preferences and negative *WTP* for the *PDO* label, while positive *WTP* for the *GI* label. This is interesting because the *PDO* label indicates regional production

and processing and adherence to such a label standard could silence current criticisms regarding the current supply chain. Overall, we recommend marketing alternatively peeled brown shrimp in tourist regions as well as regions where tourists reside. Marking products as “peeled in Germany” with an MSC label is sufficient for domestically machine peeled products. Tourism is an important activity for enhancing the marketability of geographic products within and outside their region.

Acknowledgement

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REDISCOVERING ENTREPRENEURSHIP IN COOPERATIVES: IMPLICATIONS FOR ORGANIZATION AND MANAGEMENT IN THE CONTEXT OF THE GERMAN WINE INDUSTRY

Frederik Nikolai Schulz¹, Jon H. Hanf

Summary

Entrepreneurship in cooperatives is closely linked to the two-layered organizational structure with member-owners on one side and the cooperative firm on the other. With increasing market orientation, the entrepreneurial function has increasingly shifted towards the cooperative management in the last decades. However, several developments point to a rediscovery of entrepreneurial attitudes on member-level. For instance, winegrowers' cooperatives in Germany deal with concepts such as "partial delivery". This article therefore aims to draw implications for the organisation and management of cooperatives when members become more entrepreneurial again, considering traditional theoretical approaches to cooperative organization. It can be shown that the rediscovery of entrepreneurship on member-level is associated with a wide-ranging field of tension. In the sense of an interdependent approach to cooperative organisation, the foundation for *collective entrepreneurship* as an important contribution to the overall development of agricultural cooperatives is illustrated.

Keywords

Cooperatives, Entrepreneurship, Wine Industry, Cooperative Management

1 Introduction

Cooperatives in the agricultural sector were originally founded as an association of entrepreneurs aiming to optimise their own operations through the establishment of a jointly-owned business. Over time, decision-making competences in cooperatives have increasingly been transferred from members to the cooperative's management. An illustrative example is the wine industry, where cooperatives often rely on employed managers. As a result, the entrepreneurial role of members has increasingly changed towards more discretion (HANF and SCHWEICKERT, 2014). However, concepts such as the so-called "partial delivery" illustrate a growing demand for entrepreneurial decision making on member-level in winegrowers' cooperatives (BITSCH and HANF, 2023). What are the implications for the organization and management of cooperatives if members become more entrepreneurial again? This article aims to analyse this question from the perspective of classic theoretic approaches to the cooperative and uses the wine sector as an example.

2 Distribution of Entrepreneurship in Cooperatives – A Theoretical Approach

The analysis draws on the functional approach to entrepreneurship (KLEIN, 2008). In this sense, entrepreneurship describes the decision-making process regarding the employment of firm resources within new and established companies (FOSS and LYNGSIE, 2014). In cooperatives, entrepreneurship is linked to the two-layered organisational structure, with members as owners on one side and the cooperative firm on the other (COOK et al., 2004). This setting ultimately raises the question of how the two layers interact. Traditionally, cooperatives have been viewed as an extension of the farm, representing a form of vertical integration (PHILLIPS, 1953). In this

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perspective, the jointly-owned cooperative primarily serves the purpose of joint production and marketing. Consequently, entrepreneurial decisions hold significant weight for member-owners. As the interests of cooperative members may diverge over time, decision-making costs increase simultaneously. In this approach, the cooperative entity is seen as an independent firm with an emphasis on centralized, hierarchical decision-making processes (HELMBERGER and HOOS, 1962). Here, entrepreneurial competences on member-level may increasingly be marginalized. Finally, a third theoretical perspective characterizes the cooperative as a coalition, placing the network concept at its core (COOK et al., 2004). In this view, the significance of members is increasingly emphasized, without diminishing the cooperative's importance as a collective entity. From an entrepreneurial perspective, this approach seems to be particularly relevant, as it considers entrepreneurial action as interdependent across both layers rather than favouring one over the other (BIJMAN and DOORNEWEERT, 2011).

3 Developments fostering entrepreneurship in winegrowers' cooperatives

In Germany, 144 cooperatives are responsible for approximately one third of the country's wine production, with more than 35,000 grape growers across 13 wine-growing regions (STAPPEL, 2023). With 28,000 hectares, the vineyard area managed by cooperatives represented roughly 28 percent of Germany's total winegrowing area in 2016 (DRV, 2017). In winegrowers' cooperatives, increasing entrepreneurial attitudes on member-level are reflected in the context of "partial delivery", a concept which is also found in other areas of agribusiness such as the dairy sector (HESS et al., 2017). "Partial delivery" is characterised by members of the cooperative officially and unofficially delivering only part of the grapes grown to the cooperative and market the rest independently either in own wineries or to other market participants such as private wineries and cellars. Overall, the example illustrates that entrepreneurial action is not only demanded by cooperative members, but also practised despite formal regulations that actually restrict such behaviour.

4 Implications: Collective Entrepreneurship or Collective of Entrepreneurs?

The example of partial delivery highlights the tension that arises in the interaction of market orientation and the demand for more entrepreneurial decision-making at member-level. Viewing the development of winegrowers' cooperatives as a spectrum between member-focused cooperation and hierarchical operating firms yields two significant implications regarding the rediscovery of entrepreneurship at member-level: Firstly, it is debatable to what extent entrepreneurship can thrive at member-level without compromising necessary market orientation in a highly competitive landscape. This individual approach rather leads to an understanding of the cooperative as a *collective of entrepreneurs*. Secondly, these considerations raise doubts about the cooperative's mission to enhance its members' economic conditions, as alternative options are perceived as more advantageous. Consequently, diminished performance and member engagement are expected to impact the contribution of entrepreneurial activities to the cooperative. However, entrepreneurial attitude on member-level can be crucial to the cooperative's value creation, underscoring the importance of the interplay between the two organizational layers and an efficient management of member-entrepreneurs. The optimal balance between member and market orientation would therefore be attained when members are granted increased entrepreneurial decision-making authority, supported and encouraged by cooperative management. This equilibrium can ultimately be linked to the concept of *collective entrepreneurship* and draws strongly on the theoretical approach of the cooperative as a coalition. With the rediscovery of entrepreneurial qualities on part of the cooperative members, the fundamental concept of promoting otherwise independent farms could ultimately be revitalized. In this regard, cooperatives may serve as engines and platforms for entrepreneurs, thus driving innovation in the agricultural sector.

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EINE WEINREGION ALS MARKE: NUTZUNG DES MARKENSTEUERRADES ZUM VERGLEICH VON MARKENIDENTITÄT UND MARKENIMAGE DER WEINREGION SÜDTIROL

Lea Pircher, Katharina Mybes¹, Jon H. Hanf

Zusammenfassung:

Besonders in wettbewerbsintensiven Branchen sind starke Marken zunehmend entscheidend für den Unternehmenserfolg (ESCH et al. 2005a). Die Branche der Weinwirtschaft ist mit weltweiter Überproduktion bei gleichzeitigem Konsumrückgang solch eine wettbewerbsintensive Branche, in der Differenzierung für das Überleben bzw. den Unternehmenserfolg unerlässlich ist. Somit ist ein gutes Verständnis von Marken und Wahrnehmung für die Weinwirtschaft unerlässlich. Dies wird mithilfe des Markensteuerrades nach Esch (ESCH et al. 2005b, ESCH & FISCHER 2009) exemplarisch angewendet. Ziel ist die Nutzung des Markensteuerrades zur Identifizierung von Markenidentität und -image von Südtiroler Weinen.

Keywords

Weinvermarktung, Markenidentität, Markenimage, Südtirol

1 Ziel und theoretischer Hintergrund

Ziel dieser Arbeit ist die Anwendung des Markensteuerrades (ESCH et al. 2005) auf eine Weinregion als Marke. Dies erlaubt eine strukturierte Erhebung und Überprüfung des Status Quo von Markenidentität & Markenimage von Südtiroler Weinen. Nachfolgend lassen sich Handlungsempfehlungen ableiten.

Den theoretischen Rahmen dieser Arbeit bildet die Betrachtung der Rolle von Marken sowie das Markensteuerrad. Der Begriff "Marke" hat sich von einem Mittelalterlichen Eigentumsnachweis zu einem umfassenden Konzept entwickelt, das zur Identifikation und Differenzierung gegenüber dem Wettbewerb (BRUHN 2004; ESCH et al. 2005a). Dem Konsumenten erleichtern Marken Kaufentscheidungen und fördern die Gewohnheitsbildung. Emotionale Bindung und Vertrauen können zu Markenbindung und -loyalität führen (FOURNIER 2005; FLEUCHAUS 2011). Für Unternehmen bieten starke Marken somit nicht nur einen wirtschaftlichen Wert, sondern bieten darüber hinaus Sicherheit, fördern Innovationen und schützen Produkte in Krisenzeiten. Sie können somit für Konsumenten und für Unternehmen relevante Wertschöpfung darstellen (JOHNSON & BRUWER 2007 in CHAMBERS et al. 2011; ESCH et al. 2005a). Marken sind in der Weinwirtschaft aktuell besonders relevant, da eine weltweite Überproduktion gepaart mit abnehmendem Konsum den Druck auf das Wettbewerbsumfeld verschärft (OIV 2023). Die Attribute einer Marke gelten auch für Herkunftsmarken und Terroir-geprägte Weine, wie an dem folgenden Beispiel der Region Südtirol verdeutlicht. **Die Marke „Südtirol Wein“** ist Teil der Dachmarke Südtirol und zielt darauf ab, die Region als Qualitäts- und Innovationsstandort zu positionieren (AUTONOME PROVINZ BOZEN – SÜDTIROL, o.J.a). Der Erfolg in Süddeutschland, einem wichtigen Exportmarkt, zeigt den Einfluss der geografischen Nähe und der Markenwahrnehmung auf den Absatz (HANF & GIERING 2014).

Zum Verständnis des Markensteuerrades wird der **Gesamtaufbau der Marke** betrachtet. Dieser führt von der Markenidentität über die Positionierung hin zum Markenimage. Die Markenidentität, das vom Unternehmen gestaltbare Selbstbild, und die Positionierung bilden die

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Aktionsebene, während das Markenimage als Fremdbild aus der Zielgruppensicht resultiert. Das Fremdbild wird durch die Stärke von Markenassoziationen beeinflusst, die das Unternehmen nicht direkt steuern kann, was die Bedeutung der Eigenbildanalyse für die Markenpositionierung unterstreicht (ESCH 2004, KAPFERER 1992, MEFFERT & BURMANN 2002, MEFFERT & KOERS 2001, ROSSITER & BELLMAN 2005, UPSHAW 1995, VAN REKOM 1998 In ESCH et al. 2005b). Markenassoziationen stehen in enger Verbindung mit dem Aufbau von Markenwissen und Konsumentenbildern, die durch Schemata im Gedächtnis repräsentiert werden. Diese Strukturen entstehen durch Markenbeschäftigung und -kommunikation (DOMIZLAFF 1992 in ESCH et al. 2005a; ESCH & MÖLL 2005). Emotionale Erlebnisse während dieses Prozesses können die Stärke von Assoziationen und das Markenimage weiter beeinflussen.

Das **Markensteuerrad** dient der detaillierten Erfassung und Darstellung der Markenidentität. Es unterscheidet zwischen rationalen, funktionalen Aspekten (Markennutzen und -attribute) und emotionalen Aspekten (Markentonalität und -bild), die von unterschiedlichen Gehirnhälften wahrgenommen werden und gemeinsam ein einheitliches Bild formen (ESCH et al. 2006).

Ein einheitliches Bild führt zu einer Übereinstimmung zwischen Markenidentität und -image und kann die Glaubhaftigkeit und somit das Vertrauen des Konsumenten fördern. Eine Diskrepanz zwischen Markenidentität und -image kann zu einem negativen Markenimage führen.

2 Material und Methode

Zur Erhebung und Analyse der Markenidentität und -image von Südtiroler Weinen wurden qualitative Interviews mit fünf lokalen Produzenten und fünf deutschen Fachhändlern durchgeführt (Rückmeldungsquote > 60%). Das Ergebnis spiegelt die Eigenwahrnehmung der Produzenten (Markenidentität) und die Fremdwahrnehmung durch Fachhändler (Markenimage) wider. Die Ergebnisse wurden mit der qualitativen Inhaltsanalyse nach Mayring ausgewertet und zur Qualifizierung anhand eines Kodierleitfadens auf die Kategorien des Markensteuerrades angewendet (MAYRING 2002; PFEIFFER 2021). Hierbei wurden weitere relevante Kategorien identifiziert, auf die im Rahmen dieser Zusammenfassung jedoch nicht weiter eingegangen wird.

3 Ergebnisse, Diskussion und Limitationen

Die Analyse der Wahrnehmung von Südtiroler Weinen in Deutschland und Italien offenbart Unterschiede, insbesondere im Hinblick auf das Ansehen und die Marktakzeptanz. Während Südtirol in Italien als führende Weißweinregion mit kostenintensiven, innovativen Prozessen etabliert ist, wird der Preis in Deutschland als Hindernis wahrgenommen. Deutsche Konsumenten, die einen persönlichen Bezug zur Region haben, bilden eine zentrale Zielgruppe. Tourismus spielt eine wichtige Rolle, doch gibt es lokale Bestrebungen, ihn zu begrenzen. Innerhalb Italiens unterstützen diverse Aktivitäten wie Fachmessen und Weinpräsentationen die Produzenten, während in Süddeutschland verstärkt Maßnahmen zur Steigerung der Sichtbarkeit der Weinregion Südtirol gefordert werden. Es besteht eine Divergenz zwischen dem Eigenbild und der Wahrnehmung der süddeutschen Fachhändler.

Im Rahmen des Markensteuerrads fokussiert sich die rationale Seite auf den DOC-Status und autochthone Rebsorten wie Lagrein und Vernatsch, während emotional Tradition und familiäre Werte betont werden. Deutsche Fachhändler heben die Sortenvielfalt hervor, Südtiroler Experten hingegen die Persönlichkeiten hinter den Weinen. Den Markennutzen sehen Südtiroler Experten bei hoher Qualität und einzigartigem Stil für, während für deutsche Befragte Emotionalität und persönliche Erlebnisse vorrangig sind. Die Marke wird als traditionell und familiär wahrgenommen, wobei deutsche Experten sie als weniger innovativ empfinden.

Die Studie zeigt eine teilweise Übereinstimmung zwischen Markenidentität und Markenimage, jedoch auch Divergenzen, insbesondere zwischen traditioneller und moderner Wahrnehmung. Eine einheitliche Positionierung und Kommunikation sind entscheidend, um Glaubwürdigkeit,

höhere Preisakzeptanz oder Kundenbindung zu sichern. Die Studie bietet auch anderen Weinregionen wertvolle Ansätze zur Prüfung und Optimierung.

Durch das Ziel der Arbeit ergeben sich einige Limitationen. Die exemplarische Anwendung ist inhaltlich nicht auf andere Weinbauregionen übertragbar, sondern zeigt vielmehr ein Vorgehen, das auch von anderen Weinbauregionen nutzbar ist, um ihre Markenidentität und -Image zu überprüfen. Weiterführend sollten die qualitativ generierten Ergebnisse im Folgeschritt vertieft, quantifiziert und mit weiteren Interessensgruppen überprüft werden.

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WER BESUCHT EINE EVENTMARKETING-VERANSTALTUNG FÜR REGIONALE ÄPFEL UND WARUM?

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Zusammenfassung

Für viele landwirtschaftliche Betriebe und Erzeugergemeinschaften des Obst- und Gemüsesektors erscheint die Fokussierung auf regionale Absatzkanäle als vielversprechende Strategie, um sich von Konkurrenzprodukten abzuheben. Exemplarisch wird daher die Wirksamkeit einer Eventmarketing-Veranstaltung für regionale Äpfel untersucht. Die Ergebnisse zeigen, dass lokale Veranstaltungen eine positive Wirkung auf die Kaufbereitschaft für regionale Produkte haben. Je weiter Besucher zu der Veranstaltung angereist waren, umso höher ist dabei ihre Affinität zu dem regionalen Produkt. Die Kaufbereitschaft für regionale Äpfel kann somit gestärkt werden, indem Veranstaltungen auch über größere Entfernung bekannt gemacht und beworben werden.

Keywords

Regionale Vermarktung, Verkaufsförderung, Probitmodell, Elaboration Likelihood Modell.

1 Einleitung

Der Absatz über Erzeugerorganisationen ist für deutsche Obst- und Gemüseproduzenten von hoher Bedeutung. Erzeugerorganisationen erfüllen die Aufgabe der Bündelung von Produkten, ihre Verarbeitung und vor allem die anschließende Vermarktung. Erzeugerorganisationen stehen für eine relativ große Gruppe von Obst- und Gemüseerzeugern, die sich auf die Vermarktung im Lebensmitteleinzelhandel (LEH) und Discount spezialisiert haben. Auf Märkten, die durch einen starken Verdrängungswettbewerb gekennzeichnet sind, erscheint es sinnvoll, dass Vermarktungsstrategien die Präferenzen der Konsument*innen zielgerichtet ansprechen und auch Kommunikationsinstrumente strategisch eingesetzt werden, um sich hinreichend gegenüber Mitbewerbern differenzieren zu können (BENNER und KLIEBISCH, 2004; ZÜHLSDORF und SPILLER, 2012). Der folgende Beitrag untersucht eine solche Maßnahme, um zu klären, inwiefern eine regional etablierte Veranstaltung mit Volksfestcharakter (hier am Beispiel des „Apfelwandertages Ettenkirch“) Elemente des Eventmarketings für regionales Obst transportieren kann.

2 Methodik und Daten

Das Elaboration Likelihood Modell (ELM) (PETTY et al., 1983) wird in der gegenwärtigen Untersuchung als theoretischer Rahmen gewählt, um herauszufinden, wie Besucher*innen einer regionalen Veranstaltung angesprochen werden können, um den Absatz von regionalem Obst und Gemüse zu stimulieren. Hierbei liegt die Annahme zugrunde, dass eine Ansprache der Konsument*innen abhängig vom Motiv ihrer Teilnahme an der Veranstaltung gestaltet werden muss, um den erwünschten Effekt zu erzielen. Zur Differenzierung verschiedener Konsument*innengruppen werden mögliche Faktoren auf ihren Einfluss zur Motivation des Veranstaltungsbesuchs hin untersucht. In diesem Rahmen soll insbesondere der Zusammenhang der Anreisedistanz und der Motivation, die Veranstaltung zu besuchen, geprüft werden, da gemäß des Reisekostenansatzes (*Travel Cost Method*, TCM) von Hotelling (1947) davon ausgegangen

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wird, dass die Kosten, welche für eine Anreise zu einer Veranstaltung in Kauf genommen werden, indirekt den Nutzen bzw. Wert widerspiegeln, den die Konsument*innen einer Veranstaltung zuschreiben (HOTELLING, 1949).

In einem ersten Untersuchungsschritt bildet der regional erzeugte Apfel als Grund der Teilnahme an der Veranstaltung (1 = Apfel, 0 = anderer Grund) die abhängige Variable y_i eines erweiterten Probitmodells. Es soll geprüft werden, welche Faktoren (x_i) Einfluss auf den Grund der Teilnahme der Besucher*innen i nehmen. Die potenziell endogene Variable, die Distanz zum Veranstaltungsort, $w_{Distanz}$, wird im Rahmen der ökonometrischen Schätzung auf Endogenität geprüft und mit einer Hilfsgleichung instrumentiert. Als Instrumente dienen hierbei die Angabe der Geselligkeit als Grund der Teilnahme und die Anzahl der Teilnahmen an vergangenen Apfelwandertagen. Die Schätzgleichung nimmt in diesem Zusammenhang folgende Form an:

$$(1) \quad y_i = \alpha_0 + \beta_i x_i + \beta_i w_{Distanz} + \varepsilon_i$$

Im zweiten Untersuchungsschritt sollen in einem geordneten Probitmodell Einflussfaktoren auf die abhängige Variable der Zustimmung der Aussage, dass die Veranstaltungsteilnahme die Kaufbereitschaft für regionale Äpfel erhöht hat, geprüft werden. Als Regressoren dienen erklärende Variablen, die Aufschluss über die Verbundenheit der Befragten mit regionalen Produkten geben. Hierzu zählen i) die üblich genutzte Einkaufsstätte, ii) weitere Faktoren, die das allgemeine Kaufverhalten von Äpfeln beeinflussen, iii) das Informationsverhalten der Befragten sowie iv) soziodemographische Faktoren. Zur Ergebnisinterpretation wurden marginale Effekte der erklärenden Variablen auf Basis der zuvor geschätzten Probit Modelle berechnet.

Als Datengrundlage der Untersuchung dient eine Befragung von 201 Besucher*innen einer lokalen Veranstaltung, dem sog. Apfelwandertag in Ettenkirch, die thematisch auf die regionale Apfelerzeugung ausgelegt war und im Jahr 2023 in Baden-Württemberg im Bodenseekreis stattfand.

3 Ergebnisse und Fazit

Die Ergebnisse der Hilfsregression zur Instrumentierung der endogenen Variable zeigen, dass Besucher*innen des Apfelwandertags, die aus weiterer Entfernung kommen, weniger wahrscheinlich auf Grund der sozialen Komponente anreisen. Für sie liegt der Wert der Veranstaltungen eher im Erlebnis rund um das Thema Apfel. Dies zeigt, dass Personen, die höhere Reisekosten auf sich nehmen, auch eine stärkere Teilnahmemotivation in dem produktbezogenen Anlass der Veranstaltung sehen und weniger in begleitenden sozialen Gründen. Hingegen sehen Personen, die aus dem direkten Umfeld der Veranstaltung kommen, den Wert der Veranstaltung vorrangig in der Geselligkeit, die von der Veranstaltung ausgeht. Haben die Besucher*innen die Erwartung, einen großen Informationsgewinn zum regionalen Anbau von Äpfeln durch die Veranstaltung zu erlangen, so ist es gemäß dem geschätzten marginalen Effekt 19,5 % wahrscheinlicher, dass sie auch auf Grund des Apfels die Veranstaltung besuchen. Diese Besucher*innen lassen sich auf der Veranstaltung erfolgreich durch Informationsstände, -grafiken und -flyer oder Fachvorträge ansprechen, da sie, dem ELM folgend, insbesondere für Marketing-Instrumente mit hohem Informationsgehalt empfänglich sind und dem *zentralen Pfad der Überzeugung* folgen. Hingegen lassen sich Personen, die nicht auf Grund des Apfels an der Veranstaltung teilnehmen, gemäß ELM erfolgreicher über niederschwellige Informationsangebote ansprechen, da sie dem sog. *peripheren Pfad der Überzeugung* folgen. Diese Konsument*innengruppe kann durch Probierstationen, die Präsentation des Apfels durch Produktbotschafter*innen oder Gewinnspiele angesprochen werden (PETTY et al., 1983). Auf Personen, die vom Apfelwandertag einen Informationsgewinn erwarten, hat die Veranstaltung einen statistisch signifikant positiven Einfluss, der die Wahrscheinlichkeit eines Anstiegs der Kaufbereitschaft um 11,8 % steigert. Für die Personengruppe, die offen für einen Informationsgewinn

ist, wurde das Ziel der Veranstaltung somit erreicht. Sie konnten durch die bereitgestellten Informationen aktiviert werden. Da die Gruppe der Besucher*innen mit hohem Interesse an Produktinformationen auch am stärksten in der Steigerung ihrer Kaufbereitschaft beeinflusst werden können, sollten Veranstaltungen zur Verkaufsförderung regionaler Lebensmittel in Zukunft über die Landkreisgrenze der Veranstaltung hinweg bekanntgemacht werden. Auch wenn die vorliegende Untersuchung sich auf das Beispiel „regionales Obst“ beschränkt hat, könnten die Ergebnisse auch für Produkte mit ähnlicher Vermarktungsstruktur relevant sein.

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STAKEHOLDER INCLUSION IN THE GOVERNANCE OF INNOVATION: THE CASE OF BIOMETHANE PRODUCTION IN GERMANY

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Abstract

Innovative technologies for biomethane production that use agricultural residues and waste can contribute to methane emission reduction in agriculture and the expansion of renewable energies. Since the introduction of a greenhouse gas quota in Germany that requires mineral oil companies to reduce their greenhouse gas emission, biomethane produced from residues has received growing attention. Simultaneously, the planning and construction of biomethane projects have triggered resistance from the affected stakeholders such as residents and environmental groups. We analyzed local newspaper articles, policy documents, and statements from citizens' initiatives to identify the constraints to stakeholder inclusion in local biomethane governance. We employ a multiple case study approach, which deals with two biomethane plant projects in Brandenburg and Lower Saxony. The findings of the study show that climate, environmental, and energy regulations shape the economic and political interest of the powerful stakeholders and hinder the coordination of stakeholders, sectors, expectations, and interactions over temporal scales, which resulted in compromised inclusion of local stakeholders and their concerns.

Keywords

Biomethane, inclusive governance, networks of action situations, network analysis, biogas

1 Introduction

Biomethane, methane generated from biomass, can be produced by purifying biogas (ABDALLA et al., 2022). With the strengthening of the greenhouse gas quota on transport fuel in Germany, demand for biomethane produced from manure, which has a favorable greenhouse gas value, has been steadily increasing. Furthermore, since the gas crisis induced by Russia's attack on Ukraine, the contribution of biomethane to energy security has been highlighted. Since a few years ago, there have been several biogas plants and biogas upgraders to biomethane in the planning and construction phase in Germany and the EU, which aim to produce biomethane for transport fuel purposes. Although there are opportunities for public participation in the decision-making process of an energy project in Germany that are legally guaranteed, stakeholders' dissatisfaction with the local biomethane project governance has been evident. In the literature on biogas and biomethane projects, the barriers to inclusive governance have been mostly analyzed at the local level with a focus on the interactions between operating companies and residents only, although an energy project is governed by a diversity of institutions at multiple levels. In the energy transition literature, the focus is often on the points of exclusion, the effect of (different forms of) participation, and drivers of participation, but less often on the root causes of exclusion (SIMCOCK, 2016). We aim to close the research gap by studying the multi-level and polycentric governance arrangements in large-scale biomethane plants in Germany and identify constraints to inclusive governance of commercial biomethane project planning and implementation.

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2 Study design

2.1 Study case: two biomethane projects in Germany

This article is based on the investigation of two case studies of biomethane projects in Karstädt, federal state Brandenburg and Friesoythe, federal state Lower Saxony, in Germany. The two cases were carefully selected as they show similar results (i.e., dissatisfaction about the inclusion of stakeholders in the decision-making process) (YIN, 1989). They deal with a large-scale biomethane plant project, and the project developers and the authorities showed a high willingness to engage stakeholders.

2.2 NAS and inclusive governance

We draw on the concept of networks of action situations (ASs), which is the networks of “events, venues, or physically interdependent instances of decision-making” (KIMMICH, BALDWIN, et al., 2023, p. 11). The NAS approach is especially useful in our study context, as it can reveal the interdependency of multiple decision-making situations that shape interactions of actors and governance outcomes (KIMMICH, EHLERS, et al., 2023). We apply the lens of inclusive governance to the networks of ASs approach in order to identify how different decision-making situations shape the inclusivity of local-level biomethane project planning and implementation, which is the “focal” AS of the study. We consider the following working components of an AS: actors, rules, and outcomes. We identify a connection between ASs if an outcome of an AS influences another AS.

2.3 Data collection and analysis methods

We found regional newspaper articles, reports, and gray literature that dealt with biomethane projects at the local level with a keyword search. A total of 262 articles for the two cases were retrieved and analyzed. We identified ASs, their working components, and linkages to other ASs presented in the articles. The linkages recorded in a Microsoft Excel format were converted to network graphs by using the network analysis and visualization software *gephi*. The collected data was also qualitatively analyzed with ATLAS.ti to identify the constraints to inclusive governance, their causes, and strategies to address them. Statement of stakeholder groups, documents for project approvals, and public announcements complemented the qualitative analysis. In addition, the first author attended a conference in 2023 in Potsdam, Germany, where the Shell project was presented.

3 Data collection and analysis methods

We found that higher-level regulations such as energy, climate, and environmental regulations have an influence on the multiple ASs including approval decisions made by authorities, biomethane operators’ decisions as well as public participation process. High awareness of climate and environmental problems, corresponding to multiple policy targets, combined with technology-focused approaches in the regulations, compromises the inclusion of residents and their concerns about the biomethane projects. Next, the regulations do not sufficiently facilitate coordination between different sectors and stakeholders such as livestock holders, existing biogas producers and users of agricultural residues. Furthermore, the regulations do not ensure the interaction between key ASs such as biomethane project implementation and public participation after the approval process is concluded. The results point towards several coordination gaps to be filled: (i) coordination between the authority and citizens’ initiatives and NGOs (ii) coordination between current and future users of feedstock, (iii) coordination of the interactions across temporal scales and (iv) coordination of expectations about biomethane project and public participation process.

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PORTFOLIOEFFEKT BEI INVESTITIONEN IN BIOGASANLAGEN: WIEVIEL RISIKO LÄSST SICH DIVERSIFIZIEREN?

Isatu Waag¹

1 Problemstellung

In Deutschland gibt es einen Bestand von rund 10.000 Biogasanlagen mit einer installierten elektrischen Leistung von ca. 6.000 Megawatt (FACHVERBAND BIOGAS E.V., 2023). Ausgehend von stabilen Erträgen durch die gesetzlich garantierte Einspeisevergütung über 20 Jahre und Wirtschaftlichkeitsberechnungen, die Gesamtkapitalrenditen von bis zu 16% in Aussicht stellen (DÖHLER et al., 2016: 163), sind Biogasanlagen für institutionelle und private Investoren zu einer attraktiven Anlagemöglichkeit geworden. Während in verschiedenen Arbeiten insbesondere der Portfolioeffekt bei fluktuierenden Energieträgern wie Wind und Photovoltaik bereits umfassend untersucht wurde (z.B. DUNLOP, 2004; BORCHERT und SCHEMM, 2007; WIESE et al., 2008; RIESSEN, 2010; CHAVES-SCHWINTECK, 2013), fokussieren sich die agrarökonomischen Beiträge zur Risikoforschung bei Investitionen in Biogasanlagen auf Einzelanlagen und deren Risiken (z.B. RAUH, BERENZ und HEIßENHUBER, 2007; BERENZ, BOCHMANN und HEIßENHUBER, 2008; MÖLLER, 2008; RIESSEN, 2010; HILL 2012, BÖTTCHER, 2013; HERBES und SCHOLWIN, 2015) – und das obwohl auf dem Markt Konsolidierungstendenzen zu erkennen sind. Zunehmend betreiben Marktteilnehmer mehrere Biogasanlagen und bauen ihr Portfolio weiter aus. EnviTec zum Beispiel betreibt 89 Biogasanlagen (ENVITEC BIOGAS AG, 2023), BALANCE Erneuerbare Energien 40 Biogasanlagen (BALANCE ERNEUERBARE ENERGIEN GMBH, 2023) und die deutsche Agrarholding 22 Biogasanlagen (DAH GRUPPE, 2023). Es stellt sich die Frage, ob und wenn ja in welchem Umfang die Portfoliobildung bei Biogasanlagen für Investoren aus Risikosicht Vorteile gegenüber der Einzelinvestition bietet.

2 Datengrundlage und Methode

2.1 Datengrundlage

Die empirische Analyse des Portfolioeffekts bei Investitionen in Biogasanlagen basiert auf Bilanzdaten von 180 Biogas-Gesellschaften, die im Bundesanzeiger veröffentlicht wurden. Im Rahmen der Erhebung wurden Jahresabschlüsse im Zeitraum von 2005 bis 2019 berücksichtigt. Da nicht für alle Gesellschaften Daten über den gesamten Zeitraum zur Verfügung stehen, wurden Datensätze berücksichtigt, die mindestens fünf Beobachtungen im genannten Zeitraum aufweisen. Die Erwartungswerte der Netto-Gesamtkapitalrendite (vgl. SCHIERENBECK, 2000: 64f.) der untersuchten Biogasanlagen liegen zwischen -14,79% und 20,14% bei einem Mittelwert von 1,22%. Das erwartete Risiko der Stichprobenanlagen, gemessen als Standardabweichung, liegt zwischen 0,48% und 24,4%, bei einem Mittelwert von 6,58%.

2.2 Methode

HARRY M. MARKOWITZ (1952) gilt als (Mit-)Begründer der Portfoliotheorie und Pionier des quantitativen Portfoliomanagements. Er beschreibt, dass im Gegensatz zur Rendite das Risiko eines Portfolios nicht der gewichteten Summe der Risiken der Einzelanlagen entspricht, sondern vielmehr von deren Wechselwirkungen bzw. der Korrelation untereinander abhängt:

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$$\sigma_p^2 = \sum_{j=k}^n \sum_{k=1}^n x_i x_k \sigma_j \sigma_k \rho_{j,k}$$

Ist das Portfoliorisiko geringer als die Summe der mit ihren Portfolioanteilen gewichteten Risiken der Einzelwerte, spricht man vom Diversifikationseffekt (BRUNS und MEYER-BULLERDIEK, 2013: 78). Effiziente Portfolios sind dadurch gekennzeichnet, dass sie zu einer gegebenen erwarteten Rendite die geringste Varianz aufweisen (ERNST und SCHURER, 2015: 272 ff.). Unter der Nebenbedingung, dass sich die Portfolioanteile zu Eins aufsummieren und negative Anteile ausgeschlossen sind.

Darüber hinaus unterteilt die Portfoliotheorie bzw. das Capital Asset Pricing Model das Gesamtrisiko in einen unsystematischen Anteil, der durch die Aufnahme weiterer Anlagen in das Portfolio reduziert werden kann, und einen nicht diversifizierbaren, systematischen Anteil. Dieser entspricht dem Risiko, das dem Markt zugrunde liegt. Ein Maß für das systematische Risiko ist der Betafaktor (GARZ et al., 2006: 43):

$$\beta_i = \frac{\sigma_i \rho_{i,M}}{\sigma_M}$$

Der Betafaktor misst die Beziehung zwischen der Überrendite der Einzelanlage und dem Marktportfolio und damit, wie stark eine Einzelanlage auf die Einflussgröße „Markt“ reagiert. In der Praxis wird das Marktportfolio in der Regel mit einem Marktindex gleichgesetzt (SPREMANN, 2008: 302). Da für Biogasanlagen kein Marktindex existiert, wird dieser der Argumentation von DUNLOP (2004) folgend auf Basis der Stichprobendaten entwickelt. Die Gewichtung im Index erfolgt entsprechend der durchschnittlichen Bilanzsumme.

3 Ergebnisse

3.1 Portfolioeffekt bei Markowitz-Diversifikation

Über 70% der Korrelationskoeffizienten liegen zwischen -0,2 und 0,2. Ein Großteil der Biogasanlagen sind demnach unkorreliert. Rund 22% der Korrelationskoeffizienten sind positiv und liegen zwischen 0,2 und 0,6, während 0,29% der Korrelationskoeffizienten stark positiv sind und zwischen 0,6 und 1,0 liegen. Im Gegensatz dazu sind nur 7,5% der Korrelationskoeffizienten negativ und liegen zwischen -0,2 und -0,6. Stark negative Korrelationskoeffizienten zwischen -0,6 und -1,0 kommen mit nur 0,01% fast gar nicht vor. Basierend auf den Daten der 180 Biogasanlagen in der Stichprobe, welche das Anlageuniversum darstellen, konnten effiziente Portfolios ermittelt werden. Das varianzminimale Portfolio weist eine Standardabweichung von nur 0,32% auf, während es bei der Einzelanlage mit der geringsten Standardabweichung 0,48% sind und das Risiko im Durchschnitt bei einer Einzelanlage 6,59% beträgt. Durch mathematische Optimierung kann das Risiko der Einzelinvestition durch Portfoliobildung um 95% reduziert werden.

3.2 Systematisches und unsystematisches Risiko der Biogasanlageninvestition

Obwohl man innerhalb einer Assetklasse und Branche einen hohen Anteil des systematischen Risikofaktors erwartet, hat die Analyse gezeigt, dass der systematische Anteil bei Biogasanlagen sehr gering ist. Dieser liegt im Mittelwert bei 10% und im Maximum nicht über 45% des Gesamtrisikos einer Einzelanlage. Das bedeutet zum einen, dass der Umfang des diversifizierbaren Risikos zwischen 55% und 100% liegt. Zum anderen überwiegt das anlagenspezifische Risiko, was dafürspricht, dass die Leistung der Anlage weniger von externen Faktoren, sondern mehr von den handelnden Personen und dem Management der Anlage abhängt. Bereits ab einer Portfoliogröße von 15 Einzelanlagen wird das unsystematische Risiko fast vollständig eliminiert.

4 Schlussfolgerung

Der Umfang der Risikoreduktion bei optimierten Biogas-Portfolios größer als bei naiver Diversifikation. Gleichzeitig ist die mathematische Portfoliooptimierung bei Biogasanlagen in der Praxis eher unüblich. Da auch durch naive Diversifikation eine erhebliche Risikoreduktion erzielt werden kann, ist der Portfolioeffekt ein möglicher Erklärungsansatz für das zu beobachtende Markt- bzw. Konsolidierungsverhalten von Investoren.

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POSTER SESSION 4:
VERBRAUCHERVERHALTEN, SOZIOÖKONOMIE UND WISSENSTRANSFER

STRUKTUREN URBANER AGRAR- UND ERNÄHRUNGSWIRTSCHAFTLICHER CLUSTER IM REGIONALEN VERGLEICH – UNTERSUCHT ANHAND DER BEISPIELE BERLIN, FRANKFURT AM MAIN, HAMBURG, KÖLN UND MÜNCHEN

Johannes Harsche¹

Zusammenfassung

Den Gegenstand der Untersuchung bilden Branchen- und Größenstrukturen urbaner Cluster der Agrar- und Ernährungswirtschaft, und dies im Vergleich zwischen den Städten Berlin, Frankfurt am Main, Hamburg, Köln und München. Als Untersuchungsergebnis lässt sich u. a. festhalten, dass gemessen am branchenspezifischen Gesamtumsatz die strukturelle Bedeutung des Ernährungsgewerbes in Frankfurt am Main und Hamburg überproportional hoch ist. Bezüglich des Großhandels gilt dies für Hamburg und Köln. Darüber hinaus lässt sich hinsichtlich zurückgehender Unternehmenszahlen und zunehmender Ø-Unternehmensumsätze ein Strukturwandel erkennen.

Keywords

Empirische Regionalanalyse, Standortfaktoren, Clusterkonzept, Strukturwandel in der Agrar- und Ernährungswirtschaft

1 Einleitung

In städtischen Zentren existieren vielfältige Agglomerationseffekte, welche die Produktionsbedingungen der Agrar- und Ernährungswirtschaft beeinflussen. Positive Impulse gehen beispielsweise von einer Ballung der Kaufkraft und der Bevölkerung, eher niedrigen intraregionalen Transportkosten, Bildungsinstitutionen, Spillover-Effekten und der Diffusion von Informationen bzw. Innovationen aus. In negativer Hinsicht wirken sich z. B. vergleichsweise hohe Immobilienpreise und Arbeitskosten wie auch eine ausgeprägte Ballung von Umweltschädigungen aus.

Mit der vorliegenden vergleichenden Regionalanalyse anhand der Beispiele Berlin, Frankfurt am Main, Hamburg, Köln und München wird das Ziel verfolgt, in Anknüpfung an theoretische Überlegungen aus der Raumwirtschaftslehre standortspezifische Branchen- und Größenstrukturen agrar- und ernährungswirtschaftlicher Cluster aufzuzeigen. Dies erfolgt im Hinblick auf spezifische Wirtschaftszweige (WZ), die auf regionaler Ebene wie auch in zeitlicher Hinsicht untersucht werden. Es gibt Anhaltspunkte dafür, dass sich die gewonnenen Untersuchungsergebnisse in Teilen auch auf andere Ballungsräume mit vergleichbaren Standorteigenschaften übertragen lassen.

2 Regionalökonomische Überlegungen und methodische Vorgehensweise

Den Ausgangspunkt der vorliegenden Untersuchung bildet das Cluster-Konzept, das von PORTER (1998) wie folgt definiert wird: „Bei einem Cluster handelt es sich um eine geographische Konzentration von miteinander verbundenen Unternehmen und Institutionen in einem bestimmten Wirtschaftszweig. Er umfasst eine Reihe vernetzter Branchen und weitere für den Wettbewerb relevante Organisationseinheiten.“

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Dem Cluster der Agrar- und Ernährungswirtschaft werden die nachfolgend genannten Wirtschaftszweige zugeordnet (s. die WZ-Bezeichnungen in den Fußnoten zu Tab. 1): Landwirtschaft, Ernährungsgewerbe, Großhandel und Einzelhandel. Als Datengrundlage dient die amtliche Umsatzsteuerstatistik (basierend auf Voranmeldungen), in der u. a. die Anzahl der steuerpflichtigen Unternehmen und die steuerbaren Umsätze ausgewiesen sind.

Gemäß der Raumwirtschaftslehre lassen sich wesentliche Standortfaktoren für die Herausbildung regionalökonomischer Agglomerationen identifizieren. Unterscheiden lässt sich zwischen primären Standortfaktoren und sekundären Standortfaktoren. Erstere werden durch die natürliche Ausstattung einer Region geprägt (bspw. Klima, Verfügbarkeit von Wasser und Rohstoffen, Vorhandensein von fruchtbaren Ebenen bzw. Tälern, räumliche Lage, Barrieren durch Gebirgszüge und Nähe zu Flüssen). Zweitere resultieren aus der wirtschaftlichen Nutzung des Raumes (z. B. Verkehrsinfrastruktur, Technologien/ innovatives „Milieu“, Qualifikation der Erwerbstätigen, Lohnkosten und Bodenpreise). Wirksam ist nach KRUGMAN (1980) des Weiteren der sogenannte Home-Market-Effekt mit einer räumlichen Konzentration von Abnehmern, der sich näherungsweise über das regionale Bruttoinlandsprodukt (BIP) abbilden lässt; als Wohlstandsindikator eignet sich das BIP je Einw. (s. Tab. 1).

Tabelle 4: Regionale Strukturen der-Cluster der Agrar- und Ernährungswirtschaft

	Berlin		Frankfurt am Main		Hamburg		Köln		München	
Steuerpfl. Unternehmen										
2021	Anzahl	‰ ⁶⁾	Anzahl	‰ ⁶⁾	Anzahl	‰ ⁶⁾	Anzahl	‰ ⁶⁾	Anzahl	‰ ⁶⁾
Landwirtschaft ¹⁾	92	0,6	72	2,5	336	4,0	78	1,7	151	2,0
Ernährungsgewerbe ²⁾	661	3,9	186	5,0	345	4,4	201	4,1	316	4,3
Großhandel ³⁾	706	4,0	183	6,6	642	7,3	356	7,3	576	6,9
Einzelhandel ⁴⁾	2.147	12,4	473	14,3	1.130	13,3	490	11,0	1.072	13,2
Σ (Cluster)	3.606	20,9	914	28,4	2.453	29,0	1.125	24,0	2.115	26,5
2021 zu 2016	%	‰-Punkte	%	‰-Punkte	%	‰-Punkte	%	‰-Punkte	%	‰-Punkte
Landwirtschaft ¹⁾	n. V.	n. V.	9,7	0,4	0,9	0,3	-2,6	0,1	2,6	0,3
Ernährungsgewerbe ²⁾	-2,7	-0,4	-16,7	-0,4	8,7	0,6	-7,5	0,1	5,7	0,7
Großhandel ³⁾	-6,9	-0,6	12,0	1,3	-2,2	0,4	-7,0	0,2	-6,8	0,4
Einzelhandel ⁴⁾	-5,2	-1,7	-5,9	0,6	0,5	1,0	2,7	1,3	-4,4	1,0
sämtliche WZ	8,1		-9,6		-7,3		-9,8		-11,6	
Umsatz ⁵⁾ gesamt (1.000 Euro)										
2021	Σ	‰ ⁷⁾	Σ	‰ ⁷⁾	Σ	‰ ⁷⁾	Σ	‰ ⁷⁾	Σ	‰ ⁷⁾
Landwirtschaft ¹⁾	26.326	0,2	22.326	0,4	172.668	1,3	24.391	0,6	134.156	2,1
Ernährungsgewerbe ²⁾	4.098.454	30,5	6.237.102	88,5	8.499.156	63,4	2.826.831	49,2	894.166	9,2
Großhandel ³⁾	4.184.265	28,7	2.075.244	43,1	51.139.035	381,3	6.167.367	83,5	3.934.449	43,3
Einzelhandel ⁴⁾	1.098.939	8,7	600.568	3,4	1.907.392	14,2	358.377	6,9	798.429	7,3
BIP (Mio. Euro)	133.210		74.087		110.541		66.687		128.752	
BIP je Einw.	45.203		97.270		72.372		61.787		86.529	
2021 zu 2016	%	‰-Punkte	%	‰-Punkte	%	‰-Punkte	%	‰-Punkte	%	‰-Punkte
Landwirtschaft ¹⁾	n. V.	n. V.	25,7	0,05	51,4	0,3	71,7	0,2	104,1	0,9
Ernährungsgewerbe ²⁾	23,4	-0,3	5,1	-4,7	2,4	-11,7	16,1	4,7	32,6	1,1
Großhandel ³⁾	13,6	-2,8	53,9	12,1	20,3	-3,3	-9,7	-13,6	41,8	7,6
Einzelhandel ⁴⁾	31,8	0,5	-58,1	-5,6	50,9	2,8	27,5	1,2	17,9	0,1
BIP	24,2		10,7		18,4		5,1		16,9	
Umsatz ⁵⁾ je Unt. (1.000 Euro)	2021	Δ zu 2016	2021	Δ zu 2016	2021	Δ zu 2016	2021	Δ zu 2016	2021	Δ zu 2016
Landwirtschaft ¹⁾	353,4	n. V.	355,3	45,2	509,3	170,0	551,1	238,4	1.766,6	878,1
Ernährungsgewerbe ²⁾	7.863,2	1.662,9	42.307,0	8.774,2	22.664,4	-1.400,4	17.640,3	3.576,5	3.550,6	721,0
Großhandel ³⁾	7.235,8	1.309,1	15.582,0	4.241,8	81.431,6	15.214,1	16.830,0	-494,1	10.390,6	3.560,0
Einzelhandel ⁴⁾	711,5	199,7	565,0	-704,7	1.679,0	560,1	908,2	176,9	918,4	173,6
sämtliche WZ	1.827,6	478,4	11.701,0	8.898,5	5.170,2	844,6	4.904,3	1.620,5	5.470,5	2.073,6

¹⁾ Land- und Forstwirtschaft, Fischerei (WZ08-A); für Berlin in 2021 Landwi., Jagd u. verbundene Tätigkeiten (WZ08-01)

²⁾ Herstellung von Nahrungs- und Futtermitteln (WZ08-10)

³⁾ Großhandel mit Nahrungsmitteln, Genussmitteln, Getränken und Tabakwaren (WZ08-463)

⁴⁾ Einzelhandel mit Nahrungs- und Genussmitteln, Getränken u. Tabakwaren (in Verkaufsräumen; WZ-08- 47.2, WZ08-472)

⁵⁾ steuerbarer Umsatz aus Lieferungen und Leistungen

Quelle: Amt für Stadtentwicklung und Statistik der Stadt Köln, Hessisches Statistisches Landesamt (jeweils versch. Jahrg), Landesbetrieb IT.NRW - Statistik und IT-Dienstleistungen, Statistisches Amt München, Statistisches Bundesamt (jeweils 2024).

Von Bedeutung für die Regionalentwicklung und -struktur sind in Anlehnung an die Neue Ökonomische Geographie die Produktionskosten, die durch interne Ersparnisse (Economies of Scale) und externe Ersparnisse infolge einer räumlichen Ballung von Unternehmen derselben Branche (economies of localisation) oder unterschiedlicher Branchen (economies of urbanisation) beeinflusst werden, wie auch die Transportkosten.

3 Ausgewählte Ergebnisse der vergleichenden Regionalanalyse

Was die Struktur der agrar- und ernährungswirtschaftlichen Cluster betrifft, so fällt bezüglich des Jahres 2021 die Relation der Umsätze des Ernährungsgewerbes zum BIP für Frankfurt am Main und Hamburg mit 88,5 % bzw. 63,4 % erheblich größer aus als für Berlin (30,5 %) und München (9,2 %, s. Tab. 1). Zudem erzielten die Unternehmen in Hamburg und Frankfurt am Main einen Ø-Umsatz, der einem Mehrfachen der Vergleichswerte für die drei anderen Städte entspricht. Im Hinblick auf den Großhandel ragen Hamburg und Köln mit entsprechenden Relationen zum BIP von 381,3 % bzw. 83,5 % hervor (Berlin: 28,7%; Frankfurt am Main und München: jeweils rund 43%).

Für die hervorgehobene Position Hamburgs als Produktions- und Handelsstandort lässt sich als mögliche Ursache dessen hervorragende transportwirtschaftliche Anbindung mit einem besonders günstigen Zugang zu landwirtschaftlichen Rohstoffen und Halbwaren anführen. Im Vergleich zu 2016 (zur Zeit vor der Coronapandemie) lässt sich etwa feststellen, dass sich die Anzahl der Unternehmen des Ernährungsgewerbes bzw. des Einzelhandels in Berlin und Frankfurt am Main verringert hat, während beide Wirtschaftszweige in Hamburg eine Zunahme verzeichnet haben. Darüber hinaus hat sich in mehreren Fällen der Ø-Unternehmensumsatz erhöht.

4 Fazit

Die untersuchten Zweige der agrar- und ernährungswirtschaftlichen Cluster weisen gemessen insbesondere am Umsatz in Relation zum BIP je nach Standort eine unterschiedliche Bedeutung auf. Des Weiteren ist aus sinkenden Unternehmenszahlen und steigenden Ø-Unternehmensumsätzen ein Strukturwandel ersichtlich.

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VON VISION ZU AKTION: EINE ROADMAP ZU MEHR NACHHALTIGKEIT IN DER VOLLVERPFLEGUNG

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Zusammenfassung

Die Außer-Haus-Verpflegung (AHV) in Deutschland ist ein wichtiges Forschungsfeld hinsichtlich Nachhaltigkeit, insbesondere in Bezug auf die Mittagsverpflegung. Bisherige Forschungslücken sollen geschlossen werden, um eine umfassende Bewertung der Nachhaltigkeit zu ermöglichen, insbesondere in der bisher vernachlässigten Vollverpflegung und Verpflegungsgruppen wie Senioreneinrichtungen und Krankenhäusern. Diese Arbeit konzentriert sich auf Care-Einrichtungen (Krankenhäuser, Behinderten- und Senioreneinrichtungen) und untersucht ihre Verpflegung mittels Ökobilanzierung. Die Analyse der Wochenspeisepläne von den Akteuren der Außer-Haus-Verpflegung zielt darauf ab, Handlungsempfehlungen für eine umweltfreundlichere Speisenplanrotation abzuleiten. Hierfür werden in einer Status-Quo Analyse die Umweltauswirkungen der Vollverpflegung in Care-Einrichtungen der AHV (n=3) erhoben. Weiterhin erfolgt eine Einordnung der Verpflegung in Bezug auf die Planetary Health Diet (PHD). Im letzten Schritt erfolgt die Entwicklung eines Zielzustandes in Co-Creation mit den Praxispartnern mithilfe von Roadmapping.

Keywords

Außer-Haus-Verpflegung, Nachhaltige Ernährungssysteme, Gemeinschaftsverpflegung

1 Einleitung

Das globale Ernährungssystem hat einen entscheidenden Einfluss auf Ökosysteme und planetare Grenzen (ROCKSTRÖM et al. 2009). In Deutschland kann der Außer-Haus-Verpflegung (AHV) aufgrund der täglich an rund 16 Millionen Gäste ausgegebenen Essensmenge eine besondere Rolle zugeschrieben werden (PFEFFERLE et al., 2021). Die Akteure der AHV stellen zudem ein Bindeglied zwischen Produktion (Herstellung der Lebensmittel) und Konsum (Verzehr der Gäste) dar und sind somit ein wichtiges Forschungsfeld für die Reallaborforschung (SPECK et al. 2020). Zahlreiche Forschungsprojekte beschäftigen sich mit der Nachhaltigkeitsbewertung von Mittagsverpflegung, jedoch nur selten mit Kaltverpflegung / Vollverpflegung (LASSEN, A. D. et al., 2021; AYTEKIN-SAHIN, G. et al., 2023; BENVENUTI, L. UND DE SANTIS, A., 2020). Diese Forschungslücke soll geschlossen werden, um eine systemische Betrachtung der täglichen Vollverpflegung zu ermöglichen und verschiedene Verpflegungsgruppen des Care-Segments (z.B. Senioreneinrichtungen und Krankenhäuser) zu untersuchen, die bisher nicht im Fokus der Forschung stehen. Die Betrachtung einer gesamten Speiseplanrotation der Vollverpflegung kann im Vergleich zur Betrachtung einzelner Menüs einen besseren Einblick in die Umweltwirkungen der Vollverpflegung in der Gemeinschaftsverpflegung geben. Die vorliegende Studie quantifiziert die Umweltauswirkungen (THG) unter Berücksichtigung des gesamten Speisenplans der Vollverpflegung (Frühstück, Mittagessen, Abendessen, Zwischenmahlzeiten) in Einrichtungen (n=4) der Gemeinschaftsverpflegung (AHV). Zudem steht die Befähigung der Akteure in der AHV, nachhaltige Verpflegungskonzepte zu entwickeln und umzusetzen, im Vordergrund. Dies geschah durch Schulungen und den Austausch im Rahmen des Co-Creation Prozesses.

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2 Methodik

Die Status-Quo Analyse der Umweltwirkungen der Vollverpflegung wurde mittels LCA (LCI: Cradle to Gate, LCIA: ReCiPe 2016 Midpoint (H), Datenbank: Agribalyse, Ecoinvent 3.6) durchgeführt. Dabei wurde die Warmverpflegung (Mittagessen) und die Kaltverpflegung (Frühstück, Abendessen, Zwischenmahlzeit) betrachtet. Ziel war es, die Gesamtemissionen der Vollverpflegung zu quantifizieren und Potenziale zur Reduktion zu identifizieren. Dabei wurden die THG-Emissionen (THGE) innerhalb der Wertschöpfungsstufen sowie in Bezug auf die Rohstoffauswahl gewichtet. Zur Sammlung von Maßnahmen zur Verringerung der Umweltauswirkungen wurde eine Desk-Research durchgeführt. Diese flossen in die Zusammenarbeit mit den Einrichtungen (Meetings, Interviews) ein. Innerhalb dessen werden je Praxispartner umweltfreundliche Zielzustände mit zeitlichem Rahmen festgelegt.

3 Ergebnisse

Die Auswertungen hinsichtlich der THGE zeigen, dass die Warmverpflegung innerhalb der Vollverpflegung größeren Schwankungen unterliegt als die Kaltverpflegung. Insgesamt kann den Praxispartnern eine ökologische Wirkung von 2,8 kg CO₂e (Partner A), 3,9 kg CO₂e (Partner B) und 2,77 kg CO₂e (Partner C) pro verpflegter Person und Verpflegungstag zugeschrieben werden. Bei der Betrachtung der einzelnen Wertschöpfungsstufen wird deutlich, dass ein Großteil der Emissionen (über 90 %) auf die landwirtschaftliche Produktion entfällt. An zweiter Stelle folgt der Transport der Lebensmittel, während Lagerung, Garprozesse und Warmhalten keinen entscheidenden Einfluss haben. Die Höhe der THGE an den einzelnen Verpflegungstagen wird maßgeblich durch die Warmverpflegung bestimmt. Rindfleisch führt punktuell zu besonders hohen Emissionen, während Schweinefleisch über den gesamten Verpflegungszeitraum hinweg häufiger eingesetzt wird, wodurch die Emissionen in Summe ansteigen. Auf der Verpflegungsebene haben in der Kaltverpflegung Käse, Butter und Wurst einen großen Anteil an den Gesamtemissionen der Verpflegung. In der Warmverpflegung spielt insbesondere Rindfleisch eine entscheidende Rolle. Darüber hinaus führt die Verwendung von Hähnchen-, Fisch- und Schweinefleisch zu erhöhten Emissionen. Gerichte mit geringer ökologischer Belastung zeichnen sich dadurch aus, dass sie lediglich durch Fleischkomponenten ergänzt werden und Fleisch nicht als Hauptbestandteil verwendet wird. Beispiele hierfür sind Rezepturen für Hühnereintopf, Erbseneintopf oder Gemüsesuppe mit Fleischklößchen.

Darüber hinaus kann festgestellt werden, dass das Speisenangebot bei allen untersuchten Akteuren eingeschränkt ist. So wird im Vergleich zur Planetary Health Diet (PHD) im Durchschnitt zu viel Fleisch, Milch, Eier und nicht vollwertiges Getreide verzehrt. Dagegen ist das Angebot an Obst und Gemüse, Vollkorngetreide, Hülsenfrüchten und Nüssen im Vergleich zu den Empfehlungen der PHD zu gering.

4 Diskussion

Die langfristige Betrachtung der Vollverpflegung ist essenziell, um eine umfassende Bewertung der Zusammenhänge zu ermöglichen. Besonders die Auswahl tierischer Produkte, insbesondere Schweinefleisch in Wurstwaren und große Portionen (>140g), beeinflusst die Treibhausgasemissionen erheblich. Die Anpassung dieser Zutaten steht im Einklang mit wissenschaftlichen Empfehlungen zur THG-Reduktion. Um den Empfehlungen der Deutschen Gesellschaft für Ernährung (DGE) und der Planetary Health Diet (PHD) gerecht zu werden, ist eine Diversifizierung des Lebensmittelangebots notwendig, wodurch sowohl Nachhaltigkeit als auch eine ausgewogene Ernährung gefördert werden. Durch den Co-Creation-Ansatz mit Praxispartnern können innerbetriebliche Stärken und Schwächen identifiziert und Veränderungsprozesse strategisch umgesetzt werden. Hürden bestehen in unterschätzten Reduktionspotenzialen, interner Kommunikation und dem Konflikt zwischen Kundenwünschen und Nachhaltigkeitszielen.

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EXPRESS-LIEFERUNG VS. CLICK & COLLECT: EIN PREIS- UND SORTIMENTSVERGLEICH FÜR LEBENSMITTEL BEI FLINK UND REWE

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Zusammenfassung

Beschleunigt durch die Corona-Pandemie gewinnen Lebensmittel-Lieferunternehmen an Bedeutung, die Einkäufe innerhalb von Minuten zur Haustür liefern. Flink ist eines davon, welches in Großstädten in ganz Deutschland vertreten ist. Durch einen Vergleich mit dem Rewe-Abholservice wird exemplarisch für diese neue Form des Lebensmitteleinzelhandels untersucht, ob Unterschiede in der Sortiments- und Preisgestaltung auftreten. Dafür werden Daten aus den Webs-hops der beiden Anbieter für sechs deutsche Städte erhoben und mittels Panelregression analysiert. Neben einem geringeren Produktangebot, sind die Produkte bei Flink durchschnittlich rund 35 % teurer. Zudem ergeben sich Unterschiede zwischen den Städten sowie bei Handelsmarken und Sonderangeboten.

Keywords

Lebensmitteleinzelhandel, Lieferdienste, Web-Scraping, Preisunterschiede.

1 Einleitung

Lebensmittel können heute bequem und zeitnah per App nach Hause bestellt werden. Diese neue Form des Lebensmittel-E-Commerce etabliert sich auch in deutschen Großstädten, verstärkt durch die Corona-Pandemie (ARMELI et al., 2023; KRONMÜLLER et al., 2023). Einer der größten deutschen Anbieter im Bereich der Express-Lebensmittellieferungen (auch Quick-Commerce oder Flash-Lieferungen genannt) ist Flink. Flink und andere Anbieter erweitern das Angebot des etablierten Lebensmittel-E-Commerce, wie z.B. den Rewe-Abholservice, indem sie kleine Mengen innerhalb kürzester Zeit, oft unter 30 Minuten, an die Haustür liefern (NIERYNK, 2020; EDIGIN und FEND, 2023).

Flink SE ist ein im Jahr 2020 gegründetes Unternehmen, das Haushalte in den meisten deutschen Großstädten mit Produkten des täglichen Bedarfs beliefert. Durch zentral gelegene Depots, auch Dark Stores genannt, sind kurze Lieferzeiten möglich (EDIGIN und FEND, 2023; KRONMÜLLER et al., 2023; PACHÉ, 2022). Seit 2021 kooperiert das Unternehmen mit der Rewe Group, die Anteile an der Flink SE hält und Flink exklusiv beliefert (REWE GROUP, 4. Juni 2021). Durch Kooperationen mit etablierten Einzelhändlern sichern sich diese neuen Unternehmen den Zugang zu einem breiten Produktsortiment und günstigen Einkaufskonditionen (ARMELI et al., 2023; PACHÉ, 2022). Allerdings sind die mit Expresslieferungen verbundenen Kosten hoch (EDIGIN und FEND, 2023), was sich in der geringen Profitabilität der Branche widerspiegelt (ARMELI et al., 2023).

In diesem Beitrag wird untersucht, ob der Express-Service Flink im Vergleich zum Rewe-Abholservice höhere Produktpreise fordert und wenn ja, ob die Aufschläge in den Produktkategorien unterschiedlich sind.

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2 Daten und Methodik

Für die Analyse werden wöchentliche Produktpreise aus den Onlineshops von Flink und Rewe verwendet, die mittels Web-Scraping erhoben wurden. Durch die oben beschriebene unternehmerische Verbindung ähnelt sich das Produktangebot von Flink und Rewe. Bei Rewe stammen die gesammelten Beobachtungen aus dem Bereich "Abholservice". Die Produkte können online ausgewählt und zu einem gebuchten Zeitpunkt ohne zusätzliche Kosten im Geschäft vor Ort abgeholt werden. Die Untersuchung betrachtet einen Zeitraum von drei Wochen im März 2024 und berücksichtigt insgesamt sechs große Städte: Berlin, Frankfurt, Hamburg, Kiel, Köln und München. Zunächst wird für jede Stadt die Lieferadresse bei Flink und anschließend der nächstgelegene Rewe mit Abholservice ausgewählt. Es werden neun wichtige Lebensmittelkategorien für den Onlineshop von Rewe verwendet. Die Kategorien des Onlineshops von Flink wurden entsprechend angepasst.

Mit einer Random-Effects-Panel-Schätzung, die getrennt nach Kategorie durchgeführt wird, untersuchen wir die Preisunterschiede zwischen Flink und Rewe. Dabei dient der logarithmierte Produktpreis als abhängige Variable. Als unabhängige Variablen fließen neben Dummy-Variablen für Flink und die jeweiligen Städte auch Dummy-Variablen für Sonderangebote, Handelsmarken sowie Bioprodukte in das Modell ein.

3 Ergebnisse

Die Schätzungen ergeben für alle Kategorien einen signifikant positiven Preisunterschied für den Onlineshop von Flink. Die ermittelten prozentualen Preisunterschiede sind in Tabelle 2 dargestellt und variieren zwischen den Kategorien von +13 % (Süßes & Salziges) bis +68 % (Fertiggerichte & Konserven). Im Durchschnitt über alle Kategorien ergibt sich ein Preisaufschlag für Produkte von Flink von 34,7 %.

Tabelle 5: Durchschnittlicher Preisunterschied für Produktkategorien Flink und Rewe

Kategorie	Preisunterschied Flink	Kategorie	Preisunterschied Flink
Brot, Cerealien & Aufstriche	+39,5%	Kochen & Backen	+29,7%
Fertiggerichte & Konserven	+68,0%	Obst & Gemüse	+33,5%
Fleisch & Fisch	+32,4%	Süßes & Salziges	+13,0%
Kaffee, Tee & Kakao	+27,6%	Tiefkühlkost	+18,3%
Käse, Eier & Molkerei	+50,1%	Durchschnitt	+34,7%

Anmerkung: Werte repräsentieren den Koeffizienten der Dummy-Variable Flink aus den Random-Effects-Schätzungen und wurden in %-Preisunterschiede übersetzt. Quelle: Eigene Berechnungen.

Neben den Unterschieden zwischen Rewe und Flink lassen sich auch signifikante Unterschiede zwischen den betrachteten Städten feststellen. Produkte sind in München und Frankfurt im Vergleich zu Berlin tendenziell teurer, während sie in Kiel günstiger sind. Zudem ergeben sich signifikante Unterschiede beim Preiseinfluss von Sonderangeboten und Handelsmarken zwischen Flink und Rewe. Im Durchschnitt sind Sonderangebote bei Flink weniger tief, dafür sind Handelsmarken bei Flink günstiger.

4 Diskussion und Ausblick

Die Untersuchung ergibt einen durchschnittlichen Preisaufschlag von 34,7 % für Flink, alle untersuchten Kategorien sind im Durchschnitt teurer. Allerdings ist das Sortiment des Expresslieferanten Flink deutlich kleiner. Daher ist es interessant, im weiteren Verlauf der Studie zu untersuchen, ob die Preisunterschiede auf das unterschiedliche Sortiment zurückzuführen sind oder ob es Preisunterschiede zwischen den gleichen Produkten gibt.

Da Rabattgutscheine in der Untersuchung nicht berücksichtigt wurden, könnte es zu einer Überschätzung des Preisniveaus bei Flink kommen. Insbesondere für Neukunden gibt es immer wieder Aktionen, bei denen prozentuale Ersparnisse auf den Gesamteinkauf erzielt werden können

(EDIGIN und FEND, 2023). Zudem deuten die Bestimmtheitsmaße unserer Schätzungen von 10 bis 20 Prozent darauf hin, dass weitere Faktoren die Preisunterschiede erklären könnten.

Das Geschäftsmodell der Expresszustellung ist mit hohen Kosten verbunden (EDIGIN und FEND, 2023). Ein Großteil der Kunden ist jedoch nicht bereit, für eine schnelle Lieferung einen Aufpreis zu zahlen (BAHR, 2021). Eine Überwälzung der höheren Kosten auf den Produktpreis, wie es die Ergebnisse nahelegen, wäre daher eine denkbare Strategie. Da ein zu hohes Preisniveau zu Kundenverlusten führen kann, weil der Produktpreis eines der wichtigsten Kriterien für die Kaufentscheidung ist (ARMELI et al., 2023; BAHR, 2021), ist es interessant zu untersuchen, wie Flink mit dieser Herausforderung umgeht.

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GLEICHSTELLUNG AM ARBEITSMARKT? DIE PERSPEKTIVE FAMILIENFREMDER STÄNDIG ANGESTELLTER FRAUEN UND WEIBLICHER AUSZUBILDENDER IN DER LANDWIRTSCHAFT

Christine Niens¹

Zusammenfassung

In diesem Beitrag wird der Frage nachgegangen, inwieweit das Ziel der Geschlechtergleichheit (Deutsche Nachhaltigkeitsstrategie, SDG 5) unter familienfremden ständig angestellten Frauen und weiblichen Auszubildenden in der Landwirtschaft verwirklicht ist. Eine Onlinebefragung sowie narrative Einzelinterviews und Gruppendiskussionen deuten darauf hin, dass eine Gleichstellung der Geschlechter im landwirtschaftlichen Sektor noch nicht erreicht ist und die Potentiale, die Frauen als Arbeitnehmerinnen bieten, nicht hinreichend genutzt werden.

Keywords

Familienfremde Arbeitskräfte, Arbeitsbedingungen, Geschlechtergleichheit, Methodenmix

1 Einleitung

Die Deutsche Nachhaltigkeitsstrategie strebt zur Verwirklichung des Sustainable Development Goal 5 „Geschlechtergleichheit“ u.a. die Gleichstellung von Frauen am Arbeitsmarkt inklusive einer Lohngerechtigkeit und Entgelttransparenz, wie auch der Förderung einer geschlechtergerechten Berufsorientierung an. Die Landwirtschaft gilt indes nach wie vor als männlich dominierter Sektor. Zwar sind deutschlandweit ca. 32 % der familienfremden ständig Angestellten (DESTATIS, 2021: 40) und ca. 25 % der Auszubildenden in den Grünen Berufen (BZL, 2023) weiblich, jedoch konnte ein paritätisches Verhältnis unter den familienfremden Arbeitskräften bisher nicht erreicht werden. Gleichzeitig gelten Frauen als wichtige Ressource, um den Arbeits- und Fachkräftebedarf in der Landwirtschaft zu decken (GOTTER et al., 2018), sowie als Initiatorinnen für Diversifizierung und ökologische Bewirtschaftung (INHETVEEN et al., 2021). Trotzdem wurde der Arbeitssituation von Frauen in der Landwirtschaft in Deutschland lange wenig Aufmerksamkeit geschenkt. Diese Studie soll Barrieren für einen Berufseinstieg junger Frauen aufdecken und Einblicke in den Arbeitsalltag familienfremder weiblicher Angestellter, fokussiert auf die Gleichstellung am Arbeitsmarkt, geben.

2 Empirische Methoden und Analyserahmen

Im Jahr 2021 wurde eine deutschlandweite Onlinebefragung von 98 weiblichen Auszubildenden und 161 familienfremden ständig auf landwirtschaftlichen Betrieben angestellten Frauen ohne Leitungsfunktion durchgeführt. Darüber hinaus wurden 21 narrativ-biographische Interviews mit Angestellten (n = 16) und Auszubildenden (n = 5) aus Ost- und Westdeutschland und drei Gruppendiskussionen geführt. Unter den Angestellten befanden sich sowohl Frauen mit abgeschlossener landwirtschaftlicher Berufsausbildung, wie auch ungelernte Mitarbeiterinnen von ökologischen und konventionellen Betrieben.

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3 Ergebnisse und Diskussion

Gleichbehandlung: Ständig Angestellte und Auszubildende sind im Mittel der Auffassung, dass Männer und Frauen auf landwirtschaftlichen Betrieben manchmal gleichbehandelt werden ($md = 3$, $sd = 1,00$, fehlend $n = 33$, fünfstufige Skala). Weniger als ein Viertel der Befragten (22,1 %) gibt an, dass Männer und Frauen immer oder oft gleichbehandelt werden. Demgegenüber äußern 33,6 % der Frauen, dass eine Gleichbehandlung selten oder nie stattfände. Signifikante Unterschiede zwischen ökologischen und konventionellen Betrieben bestehen nicht. Eine langjährig angestellte Landwirtin erklärt: „Aber ich hatte immer das Gefühl, dass ich wesentlich mehr leisten muss und wesentlich mehr einbringen muss, um die gleiche Wertschätzung zu erhalten“. Die narrativen Interviews und die Gruppendiskussion verdeutlichen zudem, dass Vorurteile der Auszubildenden und Zeitmangel zentrale Gründe dafür sind, dass weibliche Auszubildende in vermeintlich männlichen Tätigkeitsbereichen, wie die Bedienung landwirtschaftlicher Maschinen, nur unzureichend geschult werden, so dass sich geschlechterunabhängig Qualifikationsprofile schwer entwickeln können. Zudem wird wiederholt von geschlechterbezogener Kompetenz- und Fehlerbeurteilung berichtet.

Lohntransparenz und Entgeltgerechtigkeit: Etwa ein Drittel (35,2 %) der ständig Angestellten und Auszubildenden glaubt, dass sie im gleichen Beruf weniger verdienen als ihre männlichen Kollegen. Dagegen meinen 42,0 %, dass dies nicht der Fall sei. Auffällig groß ist mit 22,8 % der Anteil derer, die dies nicht einschätzen können (fehlend $n = 40$). Eine Angestellte aus Ostdeutschland äußert sich wie folgt: „Aber wenn natürlich die Frauen hauptsächlich in der Tierproduktion sind und alle nur für 9,60 Euro beschäftigt werden und der Rest der Kollegen, der auf dem Traktor sitzt, für 11,50 Euro arbeitet, ist dann schon wieder eine Ungleichbehandlung. Weil, alle machen eine gleichwertige Arbeit hier“. Allerdings glauben Befragte von ökologischen Betrieben signifikant seltener als Frauen auf konventionellen Höfen, dass geschlechterabhängige Lohnunterschiede bestehen und geben zudem seltener an, dies nicht beurteilen zu können ($\chi^2(2) = 16,67$, $p < 0,001$, $\phi = 0,29$). Lohntransparenz und Entgeltgerechtigkeit erscheinen somit auf ökologischen Betrieben bereits besser umgesetzt.

Geschlechtergerechte Berufsorientierung und Barrieren: Mehrere Interviewte berichten davon, dass ihnen in der Berufsberatung empfohlen wurde, keine landwirtschaftliche Ausbildung zu beginnen, da Frauen (aus der Stadt) hierfür ungeeignet seien. Zudem legen die Gruppendiskussionen offen, dass landwirtschaftliche Ausbildungsberufe unter jungen Frauen wenig bekannt sind. Als weitere Barrieren für einen Ausbildungsbeginn werden das negative Image der Landwirtschaft und des Berufs der Landwirtin angeführt. So würde der Beruf als „dreckig“ angesehen, das negative Image wirke abschreckend und auf 51,3 % Befragten zudem belastend.

Insgesamt scheint das Ziel der Gleichstellung am landwirtschaftlichen Arbeitsmarkt noch nicht erreicht. Zwar erklären die Interviewten vereinzelt, auf ökologischen Betrieben sei die Gleichstellung besser verwirklicht, die quantitativen Daten bestätigen dies jedoch nur begrenzt. Um die Entfremdung von der Landwirtschaft zu reduzieren, empfehlen die Interviewten die Einführung eines Wahlpflichtfachs „Landwirtschaft“ an allgemeinbildenden Schulen. Zudem scheint eine umfassende Sensibilisierung der Berufsberatenden und Auszubildenden für einen geschlechterneutralen Umgang notwendig, auch angesichts des steigenden Bedarfs an familienfremden Arbeitskräften und des Potentials, dass Frauen für die Landwirtschaft bieten. Weiter untermauert die Studie wie wichtig es ist, landwirtschaftliche Produktion und Bevölkerungswünsche (wieder) in Einklang zu bringen, um die Attraktivität und das Ansehen des Berufs der Landwirtin zu steigern und den Arbeitskräftebedarf zu decken.

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GENERATION Z IN DER LANDWIRTSCHAFT: HERAUSFORDERUNG ODER CHANCE?

Lena Marie Meyer, Bernd Hübers¹, Nana Zubek

Zusammenfassung

Die Generation Z steht vor der Möglichkeit, aber auch Herausforderung, zukünftig als Mitarbeitende oder Hofnachfolgende auf landwirtschaftlichen Betrieben mitzuwirken. In der Arbeitswelt werden Auswirkungen von mit dieser Generation verbundenen typische Verhaltensmuster vielfach und kontrovers diskutiert. Fraglich ist, ob die Generation Z eine zusätzliche Herausforderung oder eine Chance für die Zukunft landwirtschaftlicher Betriebe darstellt. Zur Beantwortung wurden zehn Expert*inneninterviews mit aktuellen Betriebsleitenden durchgeführt. Die Ergebnisse zeigen, dass die Generation Z bereits in der Landwirtschaft vertreten ist und eine hohe Arbeitsbereitschaft zeigt. Die berufliche Weiterentwicklung, eine ausgeprägte Feedbackkultur und Flexibilität bzgl. Arbeitszeiten und Aufgaben sind wichtige Anliegen. Der Vergleich von Einstellungen, Motivationen und präferiertem Arbeitsumfeld zwischen der Generation Z in der Landwirtschaft und der aktuellen Führungsebene zeigt überwiegend Gemeinsamkeiten. Als herausfordernd wird die umfangreiche Nutzung neuer Medien durch die Generation Z hervorgehoben. Bezogen auf die Notwendigkeit landwirtschaftlicher Betriebe sich zukunftsfähig aufzustellen, wird auf das Transformationspotential, das in der Technikaffinität der Generation Z liegen kann, eingegangen.

Keywords

Generation Z, Landwirtschaft, Hofnachfolge, Transformation.

1 Einleitung

In den nächsten Jahren gehen etwa die Hälfte der aktuellen landwirtschaftlichen Betriebsleitende in den Ruhestand, sodass die Klärung der Hofnachfolge bei vielen landwirtschaftlichen Betrieben bevorsteht (HEMMERLING und PASCHER, 2022). Im Spiegel von Klimawandel und globalen Marktunsicherheiten wird die Herausforderung der Hofübergabe von diversen weiteren Herausforderungen umrahmt: um den Betrieb zukunftsfähig aufzustellen gilt es, diese für die landwirtschaftlichen Betriebe nicht nur adäquat zu adressieren, sondern bei deren Lösung umfangreiche betriebliche Veränderungen und einen Wandel bisheriger Landnutzungs- und Produktionsweisen anzugehen. Der Erfolg hierbei hängt neben Betriebs-, Umfeld-, und Umweltbedingungen, Managementfähigkeiten und fachlichen Know-Hows auch vom Engagement der Betriebsleitenden und Mitarbeitenden ab (HAUSER et al. 2022). Für dieses gibt es generationstypische, divergierende Antriebskräfte, sodass mögliche Generationsunterschiede bei der Betriebsübergabe ebenso wie bei der gemeinsamen Bewirtschaftung und Entscheidungsfindung zur zukunftsfähigen Aufstellung des landwirtschaftlichen Betriebs auftreten können. Dies erscheint umso relevanter, da für die anstehenden Hofübergaben sowie den gegebenen Fachkräftebedarf potenzielle Personen aus der Generation Z (Geburtsjahrgänge 1995-2011) bereitstehen, die oftmals als freizeitorientiert sowie technologieabhängig dargestellt werden und für die Leistung, Genuss und Entschleunigung im Arbeitsleben keine unvereinbaren Gegensätze, sondern Ausdruck einer postmodernen Wertesynthese und des Wunsches nach stärkerer Selbstbestimmung sind (KLAFFKE 2021). Hinsichtlich beschriebener Herausforderungen landwirtschaftlicher Betriebe stellt sich die Frage, ob diese Generation eine Chance oder

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eine weitere Herausforderung für die Zukunft der Landwirtschaft darstellt. Zur Beantwortung der Frage wird zunächst ermittelt, ob und in welchem Ausmaß die Generation Z gegenwärtig in der Landwirtschaft vertreten ist. Unter Rückbezug auf gegebene Literatur werden generelle Charakterisierungen der Generation Z zusammengetragen, Unterschiede zu den Vorgängergenerationen aufgezeigt und mögliche Konfliktpotenziale identifiziert. Diese Erkenntnisse bilden die Grundlage für zehn leitfadengestützte Expert*inneninterviews.

2 Empirische Methoden und Analyserahmen

Die Wahl der Expert*inneninterviews als qualitative Forschungsmethode ermöglicht detaillierte Einblicke in Erfahrungen und Einschätzungen von landwirtschaftlichen Betriebsleitenden mit der Generation Z. Für die Interviews ausgewählt wurden zehn Betriebsleitende. Die Auswahlkriterien beinhalteten langjährige Erfahrung, Ausbildungshintergrund und Führungserfahrung in tierhaltenden, familiengeführten Betrieben. Neun männliche und eine weibliche Person wurden interviewt, ihr Alter erstreckte sich von 31 bis 66 Jahren. Der Betriebsstandort lag überwiegend in Niedersachsen. Die Auswertung des Interviewmaterials erfolgte nach (MAYRING 2016). Die Interviews wurden transkribiert und paraphrasiert, um anschließend Gemeinsamkeiten und Differenzen bei den Themen Arbeitsmoral, Motivation und Nutzung neuer Medien sowie Technologien zu erfassen.

3 Ergebnisse und Diskussion

Im Vergleich zu den Ergebnissen der Literaturstudie zeigen die Auswertungen der Expert*inneninterviews gleichsam Parallelen als auch Unterschiede von Generation Z-lern in bzw. außerhalb der Landwirtschaft. Innerhalb der Landwirtschaft ist das Bild der Generation Z vielfältig. Sie ist hier bereits vertreten und zeigt eine hohe Arbeitsbereitschaft, Interesse an beruflicher Weiterentwicklung, fordert eine ausgeprägte Feedbackkultur und wünscht sich Flexibilität in Arbeitszeiten und -abläufen. Der Vergleich der Einstellungen, Motivationen und des präferierten Arbeitsumfelds zwischen der Generation Z und der aktuellen Führungsebene zeigt überwiegend Gemeinsamkeiten, sodass keine Beeinträchtigung der generationsübergreifenden Zusammenarbeit identifiziert werden konnte. Derzeitige Führungskräfte kritisieren die Generation Z für ihren starken Konsum digitaler Netzwerke und neuer Medien, da sie Ablenkungen und Informationsüberflutung mit sich bringen können. Die Expert*innen betonen die Bedeutung moderner Agrartechnik. Die Technikaffinität der Generation Z wird hierbei als große Chance für anstehende Transformationsprozesse gesehen. Dies steht im Einklang zur Literatur, die die Generation Z als eine, die in der Gesellschaft zu den Innovatoren bei Produkten und Trends gehören möchte, beschreibt (FROMM 2018). Zusammenfassend stellt die Generation Z für die generationsübergreifende Zusammenarbeit oder Hofübergabe keine Herausforderung in der Landwirtschaft dar. Unzufriedenheit ist zu erwarten, wenn der Wunsch nach ausreichenden Freiräumen aufgrund hoher Arbeitsbelastung nicht erfüllt werden kann. Hierbei kann es sich aber auch weniger um eine generations- denn vielmehr um eine lebensphasentypische Herausforderung handeln. Um dieser zu begegnen, sollte zukünftige Forschung unabhängig der Generationszugehörigkeit die spezifischen Bedürfnisse und Präferenzen junger bzw. zukünftiger Mitarbeitender oder Betriebsleitender in der Landwirtschaft untersuchen, um gezielte Maßnahmen zur Mitarbeitergewinnung, -bindung und -motivation zu entwickeln, die Effektivität von Schulungsprogrammen u.a. zur Nutzung neuer Technologien zu steigern und Möglichkeiten der Implementierung flexibler Arbeitsmodelle in landwirtschaftlichen Betrieben voranzutreiben.

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GRÜNE GENTECHNIK IN DEUTSCHEN AGRAR- UND MASSEN MEDIEN ALS TEILBEREICH MEDIALER WISSENSCHAFTSKOMMUNIKATION

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Zusammenfassung

Grüne Gentechnik ist ein umstrittenes Thema. Divergierende Standpunkte führen zu Kontroversen, die, zusammen mit bedeutsamen Entwicklungen, regelmäßig den Nachrichtenwert *Grüner Gentechnik* steigern. Um herauszufinden, welche Bedeutung dem Thema in Massen- und Fachmedien zugesprochen wird, welche thematischen Bezüge vorkommen, welchen Stellenwert wissenschaftliche Inhalte dort einnehmen, und wie sich diese Parameter im Zeitverlauf verändern, wurden 1.331 Artikel aus deutschen Tages- und Wochenzeitungen (stellvertretend für Massenmedien) und Agrarzeitschriften (stellvertretend für Fachmedien) von 2018 bis 2023 analysiert. Als signifikant ergeben sich eine höhere Thematisierung von *Grüner Gentechnik* in Agrarmedien sowie wie ein höherer Anteil an Wissenschaftskommunikation in den Zeitungen. Bezüglich der Akkuratessse der wissenschaftlichen Quellen bestehen moderate Abweichungen zwischen beiden Medienarten.

Keywords

Grüne Gentechnik, Agrarmedien, Wissenschaftskommunikation, Medienanalyse

1 Einleitung

Obwohl die Ergebnisse der Genom-Editierung, zu denen auch die mit dem Chemie-Nobelpreis 2020 ausgezeichnete Genschere CRISPR-Cas9 gehört, denen natürlicher Mutationen gleichen, unterliegen sie den seit über 30 Jahren bestehenden Gentechnik-Gesetzen (KEMPKEN, 2020; EuGH, 2018). Eine Neuregulierung, 2024 vom EU-Parlament beschlossen, befindet sich im Gesetzgebungsverfahren (EP, 2024). *Grüne Gentechnik*, die als eine mögliche Lösung für eine „nachhaltige Intensivierung“ der Landwirtschaft gilt (QAIM, 2020), wird in der Öffentlichkeit kontrovers diskutiert. Dabei stehen die Vorbehalte – zwei Drittel der Bevölkerung lehnen den Einsatz *Grüner Gentechnik* ab (BMUV, 2023) – im Gegensatz zu der vielfach von Wissenschaftler*innen öffentlich vertretenen Meinung (Leopoldina und DFG, 2023). Mediale Wissenschaftskommunikation, die sich als wichtige Funktion von Fachmedien, aber auch von Massenmedien etabliert hat (BLÖBAUM, 2017), umfasst die journalistische Vermittlung wissenschaftlicher Inhalte an die Öffentlichkeit. Fach- und Massenmedien gehören dabei zu den wichtigen Kanälen (BONFADELLI et al., 2017), wobei sich die Fachpresse als Informationsquelle für Landwirt*innen besonderer Beliebtheit erfreut: Agrarmedien gehören zu den meistgelesenen Fachzeitschriften in Deutschland (GÖRDES-GIESEN, 2018). Der vorliegende Beitrag untersucht die Berichterstattung über *Grüne Gentechnik* im bisher kaum erforschten Zeitraum ab 2018 und vergleicht erstmals die Inhalte deutscher *Zeitungen* mit denen deutscher *Agrarmedien*. Im Fokus der Untersuchung stand die Artikelfrequenz zum Thema *Grüne Gentechnik* im Allgemeinen sowie zu thematischen Schwerpunkten, die Quantität medialer Wissenschaftskommunikation sowie deren Akkuratessse. Dafür wurde überprüft, ob, und wenn ja, wie detailliert, wissenschaftliche Quellen angegeben wurden.

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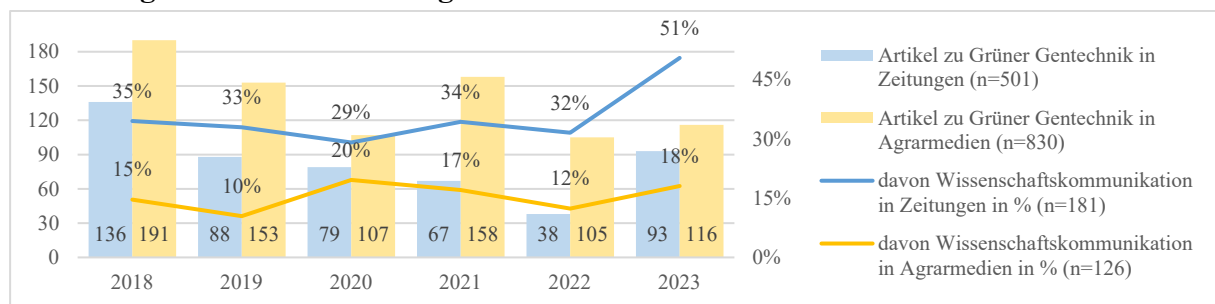
2 Empirische Methoden und Analyserahmen

Sieben *Zeitungen* und drei *Agrarmedien* der Jahrgänge 2018 bis 2023 wurden mit einer Kombination aus quantitativen und qualitativen Verfahren (SCHNEIJDERBERG et al., 2022) inhaltsanalytisch untersucht. Mittels Stichwortsuche nach „gentechn* UND landwirtschaft“ wurden 1.331 Artikel identifiziert; 501 in *Zeitungen* und 830 in *Agrarmedien*. Diese wurden in einem automatisierten Verfahren nach Stichwörtern durchsucht und in sechs Kategorien; *Biodiversität*, *Regulierung*, *Ernährungssicherheit*, *Klimawandel*, *Nachhaltigkeit* und *Gentechnikfreiheit*, eingeordnet. Zur qualitativen Auswertung der Wissenschaftskommunikation wurden Artikel mit Wissenschaftsbezügen zunächst automatisch selektiert und anschließend, gemäß der Akkurateesse der Quellenangaben, manuell in fünf Subkategorien codiert (s. Abb. 2) (KESSLER und WICKE, 2023).

3 Ergebnisse

Grüne Gentechnik wird in *Agrarmedien* mit durchschnittlich 1,2 Artikeln pro Ausgabe (120%) signifikant häufiger thematisiert als in *Zeitungen* (5%). Der Anteil an wissenschaftsbezogenen Artikeln unterliegt in beiden Medienarten moderaten Schwankungen, mit einem signifikanten Anstieg in den *Zeitungen* in 2023 (s. Abb.1).

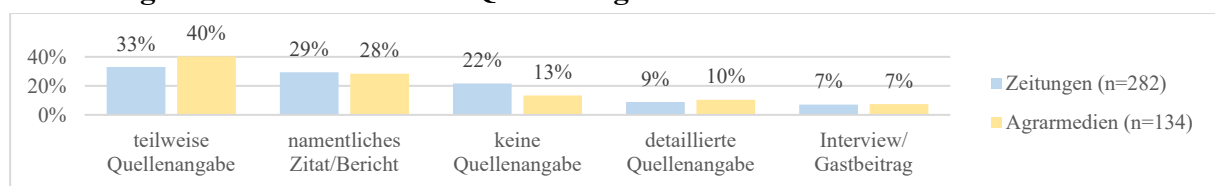
Abbildung 1: Thematisierung Grüner Gentechnik im Zeitverlauf



Quelle: Eigene Darstellung, 2024

Der Anteil an unterschiedlichen wissenschaftlichen Informationen pro Artikel liegt mit durchschnittlich 1,6 in den *Zeitungen* um 46% höher als in den *Agrarmedien*. Die Akkurateesse weicht zwischen beiden Medienarten moderat ab (s. Abb. 2).

Abbildung 2: Akkurateesse der Quellenangaben bei wissenschaftlichen Inhalten



Quelle: Eigene Darstellung, 2024

Die Analyse der Berichterstattungsthemen zeigt Abweichungen bei Bezügen zu *Biodiversität*, *Regulierung*, *Ernährungssicherheit* sowie *Klimawandel*. *Gentechnikfreiheit* wird in *Agrarmedien* signifikant häufiger als in *Zeitungen* thematisiert.

4 Fazit

Die Ergebnisse der Frequenzanalyse implizieren eine höhere Bedeutung des Themas *Grüne Gentechnik* für Zielgruppen der *Agrarmedien*. Inhaltlich ist die *Zeitungsberichterstattung* naturgemäß breiter gefächert, während das für Landwirt*innen wichtige Thema *Gentechnikfreiheit* in den *Agrarmedien* einen Schwerpunkt bildet. Die Auswertung der Wissenschaftskommunikation deutet darauf hin, dass Inhalte mit Wissenschaftsbezug in den *Zeitungen* einen höheren Stellenwert haben, während die Akkurateesse in den *Agrarmedien* höher zu sein scheint.

Ereignisse des Zeitgeschehens, wie das EuGH-Urteil von 2018 und die durch die EU-Kommission initiierte Neuregulierung, spiegeln sich in den Frequenzen beider Medienarten wider. Abweichungen im Zeitverlauf lassen eine höhere Sensibilität der *Agrarmedien* vermuten: Diese reagieren bereits auf den Start der Neuregulierungsinitiative im Jahr 2021, die *Zeitungen* hingegen erst auf den Gesetzesvorschlag im Jahr 2023, mit vermehrter Berichterstattung. Diese weist in den *Zeitungen* einen überproportional hohen Anteil an Wissenschaftskommunikation auf. Da Medien eine bedeutende Rolle für die Beeinflussung der öffentlichen Meinung zugeschrieben wird (MCCOMBS und SHAW, 1972), sollte diese Möglichkeit, den Wissensstand der Bevölkerung unabhängig ob mit oder ohne direkten Agrarbezug zum Thema *Grüne Gentechnik* zu erhöhen, stärker als bisher genutzt werden.

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STELLENWERT DER SUBSISTENZLANDWIRTSCHAFT IN KRISENZEITEN: EMPIRISCHE BELEGE AUS DER UKRAINE IM KRIEGSZUSTAND

Iryna Tröster¹, Michael Friedrich Tröster¹, Iryna Yakymchuk², Svitlana Samofalova³, Tatiana Tyshkovets⁴, Olha Orel⁵, Nataliia Smyslova⁴, Uliana Dudka⁶, Iryna Shapoval⁷

Zusammenfassung

Diese Studie widmet sich der Bedeutung der subsistenzorientierten Landwirtschaft (sL) in Krisenzeiten. Für die Analyse wird ein Datensatz verwendet, der Anfang 2024 in der Ukraine erhoben wurde. Die Ergebnisse zeigen einen Anstieg der Bedeutung der sL und stellen Einflussfaktoren heraus. Die Aussagen der Befragten deuten darauf hin, dass die sL relevant für die Ernährungssicherheit der Haushalte ist und daher auch künftig einen wichtigen Platz in der Agrar- und Ernährungswirtschaft beibehält.

Keywords

Subsistenzorientierte Landwirtschaft; Krieg; Ukraine; Ernährungssicherheit

1 Einführung

Die sL trägt in vielen Haushalten zur Versorgung mit Lebensmitteln bei (KAPLAN et al. 2016). In Industrieländern gilt diese Form der Landnutzung jedoch eher als rückständig (VARGA 2019; KOPSIDIS 2014). Diese Studie geht auf die Bedeutung der sL in Krisenzeiten ein und untersucht damit eine Wirtschaftsform, die gerade bei disruptiven Ereignissen zur Ernährungssicherheit beiträgt (MAMONOVA 2018, PALLOT und NEFEDOVA 2007). Wir stellen daher die These auf, dass sL in Krisenzeiten an Bedeutung zunimmt und parallel dazu, ein unterschätztes Risikomanagementinstrument ist. Die Relevanz der sL zeigt sich vor allem in folgenden Fällen:

- Geld ist knapp und muss primär für Güter ausgegeben werden, die nicht selbst hergestellt werden können wie Kleidung, Mobilität, Bildung.
- Das Angebot an Lebensmitteln ist quantitativ oder qualitativ nicht ausreichend.

In beiden Fällen wird die Problematik durch Krieg zusätzlich verschärft (KOVÁCS et al. 2022). Mit dem Überfall Russlands auf die Ukraine sind dort in vielen Regionen die Versorgungswege zusammengebrochen, Menschen haben Ihre Arbeit verloren oder mussten fliehen. Dennoch ist im Hinblick auf die Ernährungslage der ukrainischen Zivilgesellschaft eine hohe Resilienz, auch in den städtischen Gebieten, feststellbar (WORLD FOOD PROGRAMME, 2024).

Diese Arbeit untersucht, ob mit Ausbruch des Krieges in der Ukraine die sL für die Bevölkerung an Bedeutung gewonnen hat, welche Einflussfaktoren dabei eine Rolle spielen und welche Hemmnisse möglicherweise existieren.

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2 Methode

Für die Erhebung der Daten im Zeitraum von Januar bis Mai 2024 wurde ein Fragebogen erstellt. Die Datenerhebung fand aufgrund der aktuellen Situation durch lokale Interviewer statt, zumeist Lehrkräfte landwirtschaftlicher Bildungszentren. Zur Analyse der Daten wurden ge-läufige quantitative und qualitative Methoden verwendet.

3 Ergebnisse und Ausblick

Die Teilnehmer wurden gebeten die Bedeutung der sL für den eigenen Haushalt auf einer Skala von 1 (sehr gering) bis 10 (sehr hoch) zum Zeitpunkt vor dem Ausbruch des Krieges, und zum Zeitpunkt der Befragung einzuschätzen. Im Mittel wurde die Bedeutung der sL vor Kriegsausbruch mit 8.02 bewertet, und im Befragungszeitraum mit 8.83. Ein t-Test zeigt, dass der Anstieg der Bedeutung signifikant ist, was die aufgestellte Hypothese stützt. Das Regressionsmodell in Tabelle 1 zeigt, welche Variablen einen, bzw. keinen Einfluss auf die gestiegene Bedeutung der sL haben.

Tabelle 1: Regressionsmodell zur Bedeutung der sL im Umfragezeitraum

Aktuelle Bedeutung	[1=sehr gering, bis 10]	Koef.	SE	P> t
Vorherige Bedeutung	[1=sehr gering, bis 10]	0.2817	0.1183	0.024
Familienmitglied im Krieg	[binär]	1.4370	0.5621	0.016
Absatzmöglichkeiten	[1=sehr leicht, bis 4]	-0.7576	0.2545	0.006
Personen im Haushalt	[Anzahl]	0.0576	0.0933	0.542
Einkommenseffekt	[Gryvna, geschätzt]	0.1542	0.1828	0.406
Verwandte in der Stadt	[Anzahl]	0.0556	0.0542	0.313
Konstant		7.0580	1.4133	0.000

n= 36 | Prob > F = 0.005 | Adj. R-squared = 0.3372 | SE = Standard Fehler

Tabelle 1 zeigt, dass die aktuelle Bedeutung der sL durch drei Variablen beeinflusst wird:

- von der Grundeinstellung zur sL vor Kriegsbeginn „Vorherige Bedeutung“
- von der Frage, ob ein Familienmitglied in den Krieg musste „Familienmitglied im Krieg“
- von den Absatzmöglichkeiten für eigene Agrarprodukte „Absatzmöglichkeiten“

Dass die Variable „Einkommenseffekt“ keinen Einfluss haben soll, ist fragwürdig. Die Teilnehmer schätzten den Einkommenseffekt der sL je Monat zwischen 20000 und 55000 Gryvna (umgerechnet 500-1375 €). Eine weitere Regression prüft daher, welche Variablen Einfluss auf den „Einkommenseffekt“ haben. Dieses Modell stellt signifikant heraus, dass diejenigen, die angeben Probleme mit der Beschaffung von Betriebsmitteln zu haben, einen höheren Einkommenseffekt aus der sL erzielen. Damit stellt sich die Frage, ob Haushalte, die weniger produktiv sind, evtl. kaum Betriebsmittel einsetzen und hier deshalb keine Schwierigkeiten sehen. Zusätzliche Interviews sollen künftig Aufschluss über diese Vermutung geben.

Im qualitativen Teil der Auswertung zeigt sich, dass sich das Produktionsprogramm der Haushalte, kaum verändert hat. Die ersten fünf Plätze einer Top-Ten Liste belegen jeweils: Kartoffeln, Getreide, Gemüse gefolgt von Fleisch und Milch. Nur etwa ein Drittel der Befragten würde die sL aufgeben, wenn sie den Einkommenseffekt der sL anderweitig verdienen könnten. Begründet wird dies mit der persönlichen Risikoeinstellung, Tradition und den mutmaßlichen externen Arbeitsbedingungen. Abbildung 1 zeigt das Ergebnis der Frage: „Wofür würden Sie einen einmaligen Subventionsbetrag zur Förderung der sL in Höhe von 40000 Gryvna (umgerechnet rund 1000 €) verwenden?“

Abbildung 1: Wortwolke zur Verwendung von Subventionsmitteln in die sL



Abschließend bleibt festzuhalten, dass die sL in Krisenzeiten von besonderer Bedeutung ist. Die Politik sollte die sL in der Ukraine daher unterstützen, um Wertschöpfungsketten in ländlichen Räumen zu bilden, bzw. zu fördern und damit Zukunftsaussichten zu schaffen. Welche Aspekte hier eine Rolle spielen, z.B. Absatzmöglichkeiten, landwirtschaftliche Bildung oder Verfügbarkeit und Qualität von Betriebsmitteln, muss in weiterführenden Untersuchungen bewertet werden.

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POSTER SESSION 5:
NACHHALTIGKEITSTRANSFORMATIONEN

WER SOLLTE DIE RECHNUNG ZAHLEN? DIE SICHT DEUTSCHER LANDWIRTE AUF DIE BEREITSTELLUNG ÖFFENTLICHER GÜTER DER LANDWIRTSCHAFT

Nils L. Langanke¹, Marlene E. Noack, Michael H. Grunenberg, Uwe Latacz-Lohmann

Zusammenfassung

Nachhaltige Agrar- und Ernährungssysteme bieten neben landwirtschaftlicher Produktion auch Ökosystemleistungen wie Klimaschutz, Biodiversität und Tierwohl. Die entsprechende Transformation der Landwirtschaft und die Finanzierung der damit verbundenen Mehrkosten sind Teil des aktuellen politischen und gesellschaftlichen Diskurses. Die vorliegende Studie untersucht, wie die finanzielle Verantwortung aus Sicht der Landwirte verteilt werden sollte und ob sich diese Verteilung je nach Schutzgut unterscheidet. Die Ergebnisse zeigen, dass die Befragten die Finanzierung der Kosten als gesellschaftliche Aufgabe wahrnehmen und auch sich selbst einen Teil der Verantwortung zuweisen. Die weitestgehende Übereinstimmung mit den Ergebnissen aus Sicht der Konsumenten spricht für die Unterstützung der Anliegen der Landwirtschaft.

Keywords

Öffentliche Güter, Landwirtschaft, ANOVA, kompositionale Daten, Cluster-Analyse

1 Einleitung

Wertschöpfungsketten nachhaltiger Agrar- und Ernährungssysteme umfassen eine landwirtschaftliche Produktion, die neben Nahrungsmitteln und Rohstoffen auch Ökosystemleistungen wie Klimaschutz, den Erhalt der biologischen Vielfalt sowie Tierwohl bietet (LEBACQ et al., 2013). Die Bereitstellung dieser öffentlichen Güter erfordert jedoch Anpassungen der derzeitigen landwirtschaftlichen Praktiken, die zum Teil mit erheblichen Mehrkosten verbunden sind. Die Transformation der Landwirtschaft hin zu einer nachhaltigeren Produktion und die Finanzierung der damit verbundenen Mehrkosten sind Teil des aktuellen politischen und gesellschaftlichen Diskurses in Deutschland (LAMPKIN und SANDERS, 2009). Die Bereitstellung öffentlicher Güter ist mit einem Trittbrettfahrerproblem verbunden, was dazu führt, dass sie trotz hoher gesellschaftlicher Nachfrage in unzureichender Menge angeboten werden. Für die Auflösung dieser ineffizienten Marktallokation werden politische Interventionen notwendig (STERNER und CORIA, 2013). Je nach Interventionsmaßnahmen wird die finanzielle Verantwortung für die zusätzlichen Kosten in einem Spannungsdreieck (Simplex) auf die drei Akteure Staat, Konsument und die Landwirte selbst verteilt. Die vorliegende Studie untersucht, wie die finanzielle Verantwortung für die Erbringung von Ökosystemleistungen durch die Landwirtschaft aus Sicht der Primärproduzenten auf die beschriebenen Akteure verteilt werden sollte und ob sich diese Verteilung in Abhängigkeit vom betrachteten Schutzgut unterscheidet. Anschließend werden die Daten auf latente Gruppen untersucht und diese anhand der erhobenen Variablen charakterisiert.

2 Daten und Methoden

Zur Beantwortung der Forschungsfragen wurden 400 deutsche Landwirte zu ihren individuellen Präferenzen für die Verteilung der Kosten, als relative Werte auf einer Skala von 0 bis 100 in den beschriebenen Dimensionen, persönlich befragt. Die Kostenanteile spiegeln somit ihre Position innerhalb des Simplexes wider. Die erhobenen Daten sind multivariat, nicht-negativ

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und können zur gleichen Konstanten aufsummiert werden. Folglich liegen kompositionale Daten vor. Für die erste Analyse wurden multiple Mittelwertvergleiche durch Anwendung einer ANOVA durchgeführt. Durch die anschließende Cluster-Analyse können die Ergebnisse weiter differenziert werden.

3 Ergebnisse

Für die untersuchten Schutzgüter ergeben sich folgende Verteilung: 11% der Kosten für Klimaschutz muten sich die Landwirte selbst zu. Die verbleibende Last soll jeweils zur Hälfte durch Staat und Konsumenten getragen werden. Über die Hälfte der Kosten für die Bereitstellung von Biodiversität teilen die Landwirte den Konsumenten (52,8%) zu, sich selbst belasten sie deutlich geringer (8,7%). Die übrigen 38,5 % entfallen auf den Staat. Eine ähnliche Verteilung weist Tierwohl auf. Die ANOVA zeigt, dass sich die Verteilung der Kosten beim Tierwohl signifikant von denen des Schutzgutes Klima für den Anteil der Verbraucher unterscheidet. Die darauffolgende Cluster-Analyse unterteilt das Sample in 7 homogene Gruppen (Abbildung 1). Gruppe 3 und 7 weisen vor allem den Verbrauchern die finanzielle Verantwortung zu. Diese Gruppen zeichnen sich durch ihr geringes Nachhaltigkeitsbewusstsein, ein hohes Interesse an Agrar- und Umweltpolitik und einen hohen Bildungsgrad aus. Die Gruppen 2 und 6 hingegen sehen den Staat in der finanziellen Verantwortung und sind durch hohes Nachhaltigkeitsbewusstsein charakterisiert. Zudem konnte eine Gruppe identifiziert werden, die sich vor allem selbst belastet. In Gruppe 5 befinden sich verhältnismäßig viele ökologisch wirtschaftende Befragte, die ein geringes agrarpolitisches Interesse aufweisen. Die Gruppen und ihre charakterisierenden Variablen sind in Tabelle 1 aufgeführt.

Abbildung: Clusterzugehörigkeit

Quelle: eigene Darstellungen

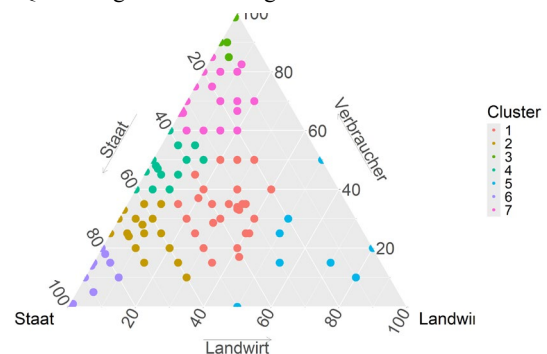


Tabelle 6: Darstellung der Cluster und ihrer charakterisierenden Variablen

Quelle: eigene Darstellungen

Cluster	Alter	Nachhaltigkeits-einstellung	Bil-dung	Agr.- & Umwelt-pol. Interesse	Acker-bau	Tierhal-tung	Ökologis-che Bewirtschaf-tung	CDU	FDP	GREEN	n
1	27 ^a	-0,10 ^{a,b}	4,23 ^{a,b}	0,06 ^{a,b}	0,83	0,68	0,16 ^{a,b}	0,37	0,20	0,05	93
2	26 ^a	-0,26 ^a	4,06 ^a	0,06 ^{a,b}	0,93	0,59	0,21 ^{a,b}	0,46	0,11	0,06	70
3	37 ^b	0,35 ^b	5,00 ^b	-0,23 ^a	0,93	0,67	0,07 ^a	0,47	0,16	0,02	55
4	29 ^a	0,10 ^{a,b}	4,32 ^{a,b}	0,03 ^{a,b}	0,89	0,70	0,10 ^a	0,52	0,19	0,02	90
5	33 ^{a,b,c}	-0,02 ^{a,b}	3,92 ^{a,b}	0,81 ^b	0,92	0,58	0,42 ^b	0,42	0,08	0,00	12
6	35 ^c	-0,17 ^{a,b}	4,14 ^{a,b}	0,17 ^{a,b}	0,73	0,65	0,16 ^{a,b}	0,30	0,03	0,11	37
7	32 ^{a,b,c}	0,06 ^{a,b}	4,90 ^b	-0,16 ^a	0,84	0,59	0,04 ^a	0,53	0,11	0,03	105

Wie aus den Ergebnissen hervorgeht, wird der größte Teil der zusätzlichen Kosten für öffentliche Güter den Verbrauchern und dem Staat zugewiesen, nicht aber den Landwirten. Diese Verteilung steht im Einklang mit der gängigen Wirtschaftstheorie, wonach der Staat für die Bereitstellung öffentlicher Güter verantwortlich ist. Interessanterweise belasten sich auch die Landwirte selbst und weisen sich so eine Mitverantwortlichkeit zu. Was die politische Unterstützung

angeht, so deuten diese Ergebnisse darauf hin, dass die Finanzierung öffentlicher Güter der Landwirtschaft als Aufgabe der gesamten Gesellschaft angesehen wird. Daher werden Instrumente zur Förderung öffentlicher Güter akzeptiert, wenn sie die Landwirte selbst nur gering belasten, sondern die übrige Gesellschaft für die zusätzlichen Kosten aufkommt. Auf Grundlage der Ergebnisse der Clusteranalyse kann weiter differenziert werden: Landwirte, die die zusätzlichen Regeln der ökologischen Produktionsverfahren bereits einhalten, trauen sich eine Mehrbelastung eher zu, wohingegen Befragte mit hohem agrar- und umweltpolitischem Interesse sowie Politikinteresse eher die Konsumenten in der Pflicht sehen. Ein Vergleich mit den Antworten aus Perspektive der Konsumenten (Parallelstudie) zeigt die weitestgehende Übereinstimmung der Verteilungen und weist so auf eine breite Unterstützung der Anliegen der Landwirtschaft im Transformationsprozess hin.

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BAULICHE UMSETZUNG VON PHOTOVOLTAIK-FREIFLÄCHENANLAGEN AUF WIEDERVERNÄSSTEN MOORSTANDORTEN

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Zusammenfassung

Photovoltaik-Freiflächenanlagen auf wiedervernässten Moorstandorten (Moor-PV) ermöglichen es, Flächen im Rahmen der Wiedervernässung zeitgleich für den Klimaschutz und die Stromproduktion aus erneuerbaren Energiequellen zu nutzen. Ein grundlegender rechtlicher Rahmen ergibt sich in Deutschland unter anderem durch die nationale Moorschutzstrategie und die Photovoltaikstrategie sowie das Erneuerbare-Energien-Gesetz (EEG) 2023. Praktische Erfahrungswerte im Bereich Moor-PV gibt es zum Zeitpunkt der Betrachtung nur in geringem Ausmaß. Um erste Erkenntnisse für eine praktische Realisierung zu gewinnen, wurden Experteninterviews durchgeführt. Der Fokus lag dabei auf allgemeinen Herausforderungen bei der baulichen Umsetzung von Moor-PV und potenziellen Gründungssystemen sowie deren Eignung für Moorstandorte. Als präferierte Lösung für niedermächtige Moorstandorte ergeben sich dabei vorwiegend gerammte Systeme, wobei mögliche Anpassungsoptionen diskutiert werden. Schwimmende Systeme ergeben sich als potenzielle Option für hochmächtige Standorte. Auch Sonderlösungen werden diskutiert. Schlussendlich wird besonders in dem Bereich der praktischen Umsetzung ein weiterer Forschungsbedarf aufgezeigt.

Keywords

Photovoltaik, Moor, Wiedervernässung, Gründungssysteme

1 Einleitung

Mit Blick auf das Pariser Abkommen und das Erreichen der Zielsetzungen für eine nachhaltige Entwicklung von Flächen zeigen sich entwässerte Moorstandorte als diffizil (ABEL, GAUDIG UND NORDT, 2017: 181). Um die Zielsetzung der Reduktion der Netto-Emissionen auf null zu erfüllen, ist eine Wiedervernässung der entwässerten Moorstandorte notwendig (REICHELT UND LECHTAPE, 2019: 18). Nahezu die Hälfte der europäischen Moorstandorte wurde für die land- oder forstwirtschaftliche Nutzung entwässert (ABEL, GAUDIG UND NORDT, 2017: 181). Eine potenzielle Nutzungsalternative für entwässerte, landwirtschaftlich genutzte Flächen besteht in der Kombination von Paludikulturen mit einer Teilvernässung oder einer vollständigen Wiedervernässung (EICKENSCHIEDT, KRIMMER UND DRÖSLER, 2023: 5). Neuartige Konzepte mit einer Kombination von Nutzungsarten werden bei der Beurteilung der aktuellen Situation im Rahmen der nationalen Moorschutzstrategie als ein Bereich mit Forschungsbedarf herausgestellt (BMUV, 2022: 42). Moor-PV bedeuten die parallele Nutzung der Flächen für die Stromproduktion durch Photovoltaik und für den Klimaschutz (Fraunhofer Institut für Solare Energiesysteme (FRAUNHOFER ISE), o.D.). Zielsetzung dieser Arbeit war es, zu untersuchen, wie sich eine praktische Umsetzung von Moor-PV darstellen kann. Dabei wurden insbesondere bauliche Herausforderungen im Bereich der Anlagengründung adressiert und potenzielle Systemansätze diskutiert.

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2 Methodisches Vorgehen

Es erfolgt eine Fokussierung auf die mit der Novellierung des EEG in dem Jahr 2023 und damit eine zu der Zeit der Durchführung der Datenerhebung von Juni bis Oktober 2023 erst kürzlich in Kraft getretene Gesetzesfassung. Aufgrund von nur geringfügig vorhandenen Praxiserfahrungen mit Photovoltaik-Freiflächenanlagen auf Moorstandorten wurde die Methode des Experteninterviews für die Datenerhebung gewählt. Die standardisierte Befragung nutzt einen Fragebogen mit geschlossenen Fragen und gibt Antwortmöglichkeiten vor (SCHOLL, 2018: 77). Um möglichst alle aus Sicht der befragten Personen realisierbaren Gründungsoptionen darzustellen, wurde eine solche Beschränkung der Auswahlmöglichkeiten auf zuvor festgelegte Gründungssysteme nicht vorgenommen. Ein Interviewleitfaden wurde als thematische Orientierung genutzt. Es konnten Interviews mit insgesamt 17 Expert*innen aus den Fachbereichen Natur- und Klimaschutz, Photovoltaik und Projektierung sowie dem Bereich der Geologie geführt werden. Eine Auswertung erfolgte unter Verwendung der Software MAXQDA in Anlehnung an das Vorgehen der fokussierten Inhaltsanalyse nach KUCKARTZ UND RÄDIKER (2020: 1ff) unter Ausarbeitung eines eigenen Kategoriensystems auf der Basis verschiedener Systemansätze für die Gründung. Zudem wurden allgemeine bauliche Herausforderungen aus den Ausführungen der Expert*innen zusammengestellt.

3 Ergebnisse

Ergebnis der Interviews ist eine Übersicht potenzieller Gründungssysteme für Moor-PV und ihrer Eignung sowie möglicher Formen der baulichen Ausgestaltung für die Anwendung auf Moorstandorten aus der Perspektive der befragten Expert*innen. Tabelle 1 stellt ausgewählte Anmerkungen zu den verschiedenen Systemansätzen bezüglich der Gründung von Moor-PV dar. Allgemeine Herausforderungen für die Realisierung von Moor-PV und Einflussfaktoren für die Gründungsauswahl bestehen zudem unter anderem in den Bereichen des Korrosionsschutzes, der Heterogenität innerhalb und zwischen Flächen und hinsichtlich der Moormächtigkeit der Standorte.

Tabelle 7: Systemansätze für die Gründung auf Moorstandorten

System	Systemeigenschaften
Beton- und Gabionenfundamente	• Ausführung z.B. Schwerkraftfundamente, Brunnenringe, insgesamt weniger geeignet • Hohes Gewicht= Gefahr des Einsinkens • Nur für geringmächtige Standorte bei Auflage auf festem Untergrund
Geschraubte Fundamente	• Schmales Gewinde= kaum Mehreffekt auf Lastübertragung • Tellerartiges System als potenzieller Ansatz (Lage des Tellers im Untergrund ist zu prüfen)
Einem Wurzelwerk nachempfundene Systeme	• Aufwändige Gründungsberechnung • Kein Preisvorteil angenommen
Rammpfosten	• Zumeist präferierte Lösung insbesondere für niedermächtige Standorte • Günstiger (Standardverfahren) • Technische Begrenzung der Rammtiefe (Rammgerät) • Verschiedene bauliche Anpassungsoptionen an Moorstandorte möglich, beispielsweise: • Stahlplatten (horizontal/ vertikal), Pfostenmaterial und Beschichtungen • Längere Pfosten und/ oder größere Pfostenanzahl, zwei Pfostenreihen
Schwimmende Systeme (Floating)	• Aufliegende Systeme als Option bei größeren Mächtigkeiten • Statische Herausforderung, Unsicherheiten bei Ausgestaltung und Montage • Teurer als Rammpfosten

Quelle: Eigene Darstellung auf Basis der durchgeführten Experteninterviews.

4 Fazit

Es bestehen verschiedene Gründungssysteme und Systemansätze für die Gründung von Moor-PV. Die Eignung dieser Systeme für die Gründung auf wiedervernässten Moorstandorten konnte mit Expert*innen in Hinblick auf die bauliche Umsetzung in der Praxis diskutiert werden. Ergebnis der Arbeit ist eine erste Einordnung verschiedener Gründungssysteme bezüglich der untersuchten Flächenkategorie in Abhängigkeit der Standorteigenschaften.

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DAUERGRÜNLANDUMWANDLUNG UND KLIMASCHUTZ: EINE ANALYSE FÜR MINERALISCHE GRÜNLANDSTANDORTE IN NORDWESTDEUTSCHLAND

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Zusammenfassung

Dieser Beitrag beleuchtet Folgen einer Dauergrünlandumwandlung in Ackerland in Verbindung mit einer verpflichtenden Aufgabe bzw. Reduktion der Milchviehhaltung für Klima und Betriebswirtschaft. Bei Berücksichtigung der Verkehrswertsteigerung einer Umwandlung ergeben sich auf extensiv über die Milchviehhaltung genutzten Standorten leichte wirtschaftliche Vorteile beim Übergang zum Ackerbau, während bei intensiver Nutzung mit Nachteilen zu rechnen ist. Das Klima profitiert in beiden Fällen – trotz reduzierter Bodenkohlenstoffvorräte.

Keywords

Grünlandumwandlung, Klimaschutz, Kohlenstoffvorräte, THG-Emissionen

1 Einleitung

Aktuell wird auf europäischer Ebene eine Lockerung des Dauergrünlandsschutzes im GLÖZ-Standard 1 diskutiert, um im Sinne der Marktumorientierung (reduzierte Nachfrage nach Milch und Fleisch) eine Dauergrünlandumwandlung in Ackerland bei Aufgabe der Tierhaltung zu ermöglichen (EUROPÄISCHE KOMMISSION, 2024). Durch eine Grünlandumwandlung in Ackerland nimmt der Bodenkohlenstoffvorrat auf mineralischen Standorten nach Berechnungen für Schleswig-Holstein von FEY und WIERMANN (2023) im Mittel um ca. 0,62 – 0,83 t C_{org}/ha und Jahr ab. Den daraus resultierenden THG-Emissionen steht die THG-Einsparung infolge der Aufgabe der Milchviehhaltung gegenüber. Somit eröffnet sich insbesondere vor dem Gesichtspunkt rückläufiger Rinderbestände die Forschungsfrage, ob eine Grünlandumwandlung in Ackerland bei einer verpflichtenden Aufgabe bzw. Reduktion der Milchviehhaltung aus Sicht des Klimaschutzes und der Betriebswirtschaft empfehlenswert sein kann.

2 Datengrundlage und Methoden

Eine Treibhausgasbilanzierung für die extensive und intensive Milchviehhaltung inklusive Grundfuttererzeugung erfolgte nach den Vorgaben des BEK-Ansatzes (ARBEITSGRUPPE BEK, 2021). Die Veränderung des Bodenkohlenstoffvorrates konnte durch eine stichometrische Umrechnung von C_{org} in CO₂ bewertet werden. Durch den Humusabbau bedingte Lachgasemissionen wurden ebenfalls erfasst. Die THG-Emissionen der ackerbaulichen Folgenutzung basierten auf einer dreigliedrigen Fruchtfolge eines Grenzstandorts mit niedrigem Ertragsniveau: Winterraps (30 dt/ha) – Winterroggen (70 dt/ha) – Wintergerste (70 dt/ha). Die betriebswirtschaftliche Bewertung erfolgte auf Ebene eines arbeitskorrigierten Deckungsbeitrages. Datengrundlage waren Richtwerte und Kalkulationsdaten der Landwirtschaftskammer Schleswig-Holstein (LKSH, 2024) für die Wirtschaftsjahre 2020/21 bis 2022/23. Der Lohnansatz betrug 20 €/AKh. Ebenfalls wurde eine Verkehrswertsteigerung der Dauergrünlandumwandlung in Ackerland über den Kauf- und Pachtpreisspiegel Schleswig-Holstein berücksichtigt.

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3 Ergebnisse

Tabelle 1 stellt die Folgen einer Dauergrünlandumwandlung bei Aufgabe oder Reduktion der Tierhaltung dar. Aus Sicht des Klimaschutzes ist mit Treibhausgaseinsparungen von ca. 6 bzw. 12 t CO₂-Äq/ha Dauergrünland und Jahr zu rechnen. Wird die potenzielle Steigerung des Verkehrswertes der Fläche mitbewertet, so ergibt sich für Standorte, auf denen Milchvieh extensiv gehalten wird, ein kleines Plus. Hier könnte auf pflugfähigen Standorten bei einer Lockerung des Dauergrünlandschutzes das Grünland umgebrochen werden. Werden hingegen die hohen Deckungsbeiträge der intensiven Milchviehhaltung erzielt, so ist ein Umbruch nicht wirtschaftlich. Hier würde es zusätzlicher Anreize bedürfen, z.B. über Förderprogramme.

Tabelle 8. Jährliche Effekte einer Dauergrünlandumwandlung in Verbindung mit einer Aufgabe oder Reduktion der Viehhaltung auf THG-Emissionen und Deckungsbeitrag

	Milchvieh extensiv (7.500 kg ECM/Kuh und Jahr, 0,8 ha LN /Kuh, 120 Tage Weide)		Milchvieh intensiv (10.500 kg ECM/Kuh und Jahr, 0,6 ha LN /Kuh, Stall)	
	THG-Emissionen (kg CO ₂ -Äq/ha*a)	Deckungsbeitrag ^a (€/ha*a)	THG-Emissionen (kg CO ₂ -Äq/ha*a)	Deckungsbeitrag ^a (€/ha und Jahr*a)
Viehhaltung	- 10.549 (1,13 kg CO ₂ -Äq/ kg ECM)	- 914 ^a (731 €/Kuh) ^a	- 16.751 (0,96 kg CO ₂ -Äq/ kg ECM)	- 2.502 ^a (1.501 €/Kuh) ^a
Grünlandumwandlung	+ 2.882	- 2 (+ 603 ^b)	+ 2.882	- 2 (+ 603 ^b)
ackerbauliche Folgenutzung	+ 1.858	+ 555	+ 1.858	+ 555
Saldo	-5.809	- 361 (+ 244^b)	-12.011	-1.949 (- 1.344^b)

^aabzüglich Lohnansatz

^binkl. durchschnittlicher Verkehrswertsteigerung (20.136 €/ha) bei 3 % Kalkulationszins

Quelle: eigene Darstellung

4 Diskussion und Schlussfolgerungen

Die Ergebnisse zeigen, dass aus Sicht des Klimaschutzes eine Umwandlung von Dauergrünland in Ackerland zu Treibhausgaseinsparungen führen kann, wenn die Milchviehhaltung auf diesen Standorten verpflichtend aufgegeben wird, der Futterbau nicht an anderen Standorten kompensiert wird und auf der Fläche künftig kein Futter erzeugt wird. Die rechtliche Absicherung dieser Nutzungsaufgabe stellt eine Herausforderung dar, insbesondere, wenn Schläge mit dieser Auflage weiter handelbar sein sollen. Eine Absicherung im Grundbuch bleibt höchstwahrscheinlich unumgänglich. Zudem vernachlässigt diese Betrachtung die Folgen einer Grünlandumwandlung für andere Schutzgüter (z. B. Biodiversität, Gewässerschutz, Bodenschutz etc.).

Für die Diskussion um GLÖZ-Standard 1 kann geschlussfolgert werden, dass eine Lockerung gerade auf eher extensiv genutzten, pflugfähigen Standorten zur Grünlandumwandlung führen kann. Überlegungen zur nutzungseinschränkungsabhängigen Verkehrswertsteigerung können dabei je nach betrieblicher Situation (Verkauf, Verpachtung oder Weiterbewirtschaftung der Fläche) eine entscheidende Rolle spielen. Auf intensiv genutzten Standorten ist zunächst von keinem Umbruch auszugehen. In beiden Fällen wäre mit THG-Einsparungen zu rechnen.

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WIRTSCHAFTLICHKEIT VON NITRIFIKATIONSINHIBITOREN IM WINTERWEIZEN

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Zusammenfassung

Unter Anwendung der stochastischen Simulation (Risikoanalyse) und auf Basis von Feldversuchen wird die Wirtschaftlichkeit des Einsatzes von Stickstoff-Düngemitteln (N-Düngemitteln) mit Nitrifikationsinhibitoren (NI) im Winterweizenanbau analysiert. Aus ökonomischer Perspektive ist nur eine bedingte Wirtschaftlichkeit des Einsatzes von NI abzuleiten, wenn Kosten für inhibierten N gering sind und zumindest geringe Ertragssteigerungen erreicht werden.

Keywords

Mineraldüngung, stochastische Simulation, Kostenanalyse, Feldversuche.

1 Einleitung

Durch Zugabe von NI bei der Düngung wird gedüngter N im Boden um 4 bis 8 Wochen stabilisiert und Verluste via Auswaschung und gasförmige Emission werden vermindert. Durch die Stabilisierung sind höhere N-Einzelgaben möglich sowie diese vorziehbar und zusammenlegbar. Die NI werden während der Produktion dem Düngerkorn zugefügt. Wissenschaftliche Studien zur NI-Wirkung auf Ertrag und Qualität beziehen sich bisher vermehrt auf Standorte in China, den USA oder Südeuropa, mit Versuchen im Mais-, Weizen- oder Reisanbau (LINQUIST et al., 2013; FOLINA et al., 2021), während ökonomische Studien selten sind. Im Nachfolgenden findet auf Basis von experimentellen Daten eine ökonomische Analyse der NI-Nutzung im Winterweizenanbau in Deutschland statt. Eine Risikoanalyse wird durchgeführt, um den Einfluss der Parameter zu bestimmen.

2 Untersuchungsrahmen und Methodik

Die ökonomischen Analysen sind Teil eines Verbundvorhabens zur standortdifferenzierten Evaluierung des Einsatzes von NI im Winterweizen- und Gemüseanbau in Deutschland. Auf sieben Versuchsstandorten werden von 2023 bis 2025 die Wirkungen von verschiedenen NI bei der Mineraldüngung auf unterschiedliche Pflanzenparameter untersucht. Angelegt werden die Versuche randomisiert, in vierfacher Wiederholung. Die nachfolgend dargestellte ökonomische Analyse fokussiert auf Ergebnisse des ersten Versuchsjahres 2023 am Standort Osnabrück in Winterweizen. Analysiert wurden die Prüfglieder basierend auf Ammonsulfatsalpeter (ASS), die mit den zwei NI-Produkten Dimethylpyrazolphosphat (DMPP) und Dicyandiamid mit Triazol (DCD+T) behandelt wurden. Zum Vergleich wurde ASS in zwei Gaben (50 % / 50 %) oder drei Gaben (35 % / 35 % / 30 %) ausgebracht.

Kalkuliert werden die Direkt- und arbeitserledigungskostenfreien Leistungen (DakfL) der Düngemaßnahmen. Hierbei sind von den Leistungen aus dem Verkauf des Korns die Düngungskosten (N-Düngung) abzurechnen. Die Düngungskosten bestehen aus den Direktkosten des Mineraldüngers und den Arbeitserledigungskosten für die Mineraldüngerapplikation. Kosten und Preise zum Maschinen- und Betriebsmitteleinsatz oder der Winterweizenpreis sind den Datenbanken des Kuratoriums für Technik und Bauwesen in der Landwirtschaft (KTBL 2024), der

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Agrarmarkt Informationsgesellschaft mbH (AMI 2024) und Landwirtschaftskammern dreier Bundesländer entnommen (LK 2024).

Zur Bewertung der Wirtschaftlichkeit von NI und des Einflusses der drei ausgewählten sensiblen Parameter „Weizenpreis“, „Kornertrag“ und „N-Kosten“ werden stochastische Simulationen durchgeführt. Für den Weizenpreis und die N-Kosten wurde eine 10-jährige Preisreihe verwendet. Die Kornerträge der Varianten sind dem Feldversuch im Jahr 2023 entnommen. Für alle Parameter wurde eine Normalverteilung angenommen.

3 Ergebnisse und Diskussion

Im Mittel ergibt sich bei den Varianten ohne NI eine leicht höhere Wirtschaftlichkeit gegenüber den Varianten mit NI (Tabelle 1). Hauptgrund sind die Unterschiede in den stark schwankenden Leistungs-Niveaus. Die durchgeführte Risikoanalyse zeigte, dass ein Großteil der Variabilität von DakfL durch die Variabilität des Weizenpreis bestimmt ist, als durch die Variabilität des Kornertrags oder die Düngungskosten. Im Vergleich zwischen Varianten ist dies aber unbedeutend, da der Weizenpreis für alle Varianten gleich ist, sofern durch NI nicht maßgeblich die Erntegutqualität (Proteingehalt) gesteigert wird. Die Düngungskosten haben einen geringeren Einfluss auf die Wirtschaftlichkeit der Varianten. Hierbei haben die N-Kosten einen höheren Einfluss auf die Düngungskosten als die Arbeitserledigungskosten.

Tabelle 9: Model In- und Outputparameter der ausgewählten Varianten (Weizenpreis 18,15 €/dt, $\pm 4,51$ €/dt)

Variante	Leistungen €/ha	N-Kosten €/kg N	N-Düngung €/ha	DakfL €/ha
ASS_DMPP	1.834 (± 459)	1,33 ($\pm 0,85$)	235 (± 144)	1.599 (± 483)
ASS_DCD+T	1.867 (± 469)	1,33 ($\pm 0,85$)	226 (± 144)	1.632 (± 492)
ASS_50/50	1.864 (± 465)	1,20 ($\pm 0,77$)	214 (± 130)	1.650 (± 484)
ASS_35/35/30	1.762 (± 444)	1,20 ($\pm 0,77$)	218 (± 130)	1.544 (± 462)

Die Kalkulationen zeigen, dass ökonomisch betrachtet die Bedeutung der Einsparungen von Überfahrten mit einem Mineraldüngerstreuer gering sind. Bei den Düngungskosten sind maßgeblich entscheidend die N-Kosten. Da zurzeit in öffentlichen Datenbanken die N-Kosten für inhibierte Düngemittel nur selten erfasst sind, besteht dahingehend ein größerer Bedarf nach Datenverfügbarkeit, um ökonomische Analyse exakter durchführen zu können. Ökonomisch entscheidend für NI sind mögliche Steigerungen beim Kornertrag - oder wie noch zu untersuchen - Steigerungen in der Produktqualität.

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LUZERNE ALS KRAFTFUTTERMITTELALTERNATIVE IN BRANDENBURGER MILCHVIEHBETRIEBEN

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Zusammenfassung

In diesem Beitrag wird eine ökonomische Bewertung des Luzerneanbau in Brandenburg im Kontext neuer Forschungsergebnisse dargestellt. Im Projekt FUFAPRO (Futter-Faser-Proteine) des Leibniz-Zentrums für Agrarlandschaftsforschung (ZALF) wurden Erkenntnisse zu Erntezeitpunkten und -methoden gewonnen, die eine hohe Futterqualität versprechen. Zur Bewertung der Wirtschaftlichkeit wird mit Hilfe des bioökonomischen Betriebsmodells FarmDyn ein konventioneller Brandenburger Milchviehbetrieb modelliert. Neben der Wirtschaftlichkeit liegt das Hauptaugenmerk auf der Substitution von Kraftfuttermitteln wie Raps- und Sojaextraktionsschrot durch innerbetrieblich produzierte, hochqualitative Luzerne.

Keywords

Luzerne, Milchproduktion, Kraftfutter, Bioökonomisches Betriebsmodell.

1 Einleitung

Dieser Beitrag betrachtet das Potenzial hochqualitativer Luzernesilage als ökonomisch sinnvolles Ersatzfutter für konventionelle Futtermittel in der Milchviehhaltung vor dem Hintergrund der landwirtschaftlichen Gegebenheiten in Brandenburg. Die im FUFAPRO-Projekt des ZALF entwickelte Erntemethode für Luzerne verspricht erhöhte Futterwerte mittels eines alternativen Mähwerks und der Anpassung des Erntezeitpunkts mit der Wuchshöhe als Indikator. Die Qualität der Luzerne zeigt sich in den erhöhten Futterwerten von bis zu 8,8 MJ NEL und 30,8% Rohprotein im 1. Schnitt. Die zentrale Fragestellung dieses Beitrags behandelt die Wirtschaftlichkeit der hochqualitativen Luzerne im gesamtbetrieblichen Kontext und ihre potenzielle Substitutionswirkung in Bezug auf konventionelle Kraftfuttermittel.

2 Methodik

Die Frage nach der Wirtschaftlichkeit des Anbaus der hochqualitativen Luzerne aus dem FUFAPRO-Projekt wird mittels FarmDyn (BRITZ et al., 2016), ein gemischt-ganzzahliges Betriebsmodell der Universität Bonn, untersucht. Die detaillierte Darstellung von Schnittzeitpunkten, Erntemengen und -qualitäten sowie Arbeits- und Maschinenkosten in FarmDyn erlauben eine realitätsnahe Optimierung der Futtergestehungskosten im Betrieb. Das integrierte Fütterungsmodul verknüpft Pflanzenbau und Milchproduktion mittels der Futterwerte, wobei wichtige Faktoren wie der Energie- und Proteinbedarf sowie die Trockensubstanzaufnahme in den einzelnen Laktationsphasen unter Einbeziehung der ruminalen Stickstoffbilanz berücksichtigt werden. Dadurch lassen sich im Modell Aussagen bezüglich der Substitution von Kraftfutter durch Luzerne aus gesamtbetrieblicher Sicht treffen.

Als Datengrundlage für die Anpassungen von FarmDyn an die Bedingungen Brandenburgs dienen die Veröffentlichungen des Ministeriums für Landwirtschaft, Umwelt und Klimaschutz in Brandenburg (MLUK, 2021a,b). Die erforderlichen Fütterungsparameter werden auf Basis der Gruber-Tabelle (LFL, 2021) ergänzt, während Arbeits- und Maschinenparameter auf KTBL-

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Daten (KTBL, 2024a,b,c) basieren. Die Kalibrierung des Modells erfolgt mittels der in FarmDyn integrierten Kalibrierungsfunktion (BRITZ, 2021). Die Berechnungen sind komparativ statisch angelegt, mit dem Ziel, den Gesamtdeckungsbeitrag für das Jahr 2021 zu maximieren. Auf Grundlage dieser Daten wird in FarmDyn ein Betriebsszenario SZ1 inklusive konventionell angebauter Luzerne (5,15 MJ NEL, 19% Rohprotein) berechnet. Im zweiten Betriebsszenario SZ2 wird die konventionelle Luzerne durch die hochqualitative Luzerne (8,0 MJ NEL, 24,3% Rohprotein) ersetzt.

Nach der Berechnung der Betriebsszenarien wird eine Sensitivitätsanalyse durchgeführt. Diese betrachtet die Auswirkung mehrerer linear ansteigender Gradienten auf die Wirtschaftlichkeit und Substitutionseffekte der Luzerne. So werden unter anderem die Milchleistung sowie schwankende Erträge untersucht.

3 Ergebnisse

Die in FarmDyn modellierten Betriebsszenarien SZ1 und SZ2 sind in Tabelle 1 einem durchschnittlichen konventionellen spezialisierten Milchviehbetrieb in Brandenburg gegenübergestellt.

Tabelle 10: Gegenüberstellung eines durchschnittlichen konventionellen Milchviehbetriebs in Brandenburg (F-MI) und den Betriebsszenarien SZ1 und SZ2

		F-MI	SZ1	SZ2
Ackerfläche	[ha]	222,2	222,0	222,0
Grünland	[ha]	82,1	82,0	82,0
Arbeitskräfte		4,9	6,0	6,0
Milchkühe		172	170	181
Milchleistung	[kg/Kuh/Jahr]	9.382	8.500	8.500
Milchpreis	[Ct/kg]	40,7	40,0	40,0
Anbaustruktur	[ha]			
	Getreide	43,0	66,9	63,1
	Hülsenfrüchte	0,5	-	-
	Ölfrüchte	4,4	5,6	5,7
	Kartoffeln	0,1	-	-
	Ackerfutter	47,4	27,5	31,2
	darunter Luzerne	-	3,6	1,6
	darunter Silomais	39,2	23,9	29,6
	Flächenstilllegung	2,3	-	-
Kosten Futtermittelzukauf	[€/Jahr]	149.872	80.462	68.888
Gewinn (vor Steuern)	[€]	169.984	179.098	190.357

Quelle: MLUK 2021b/Eigene Berechnung

In SZ1 wird konventionelle Luzerne auf einer Fläche von 7,9 ha (3,6% der Gesamtfläche) angebaut, während in SZ2 die hochqualitative Luzerne auf einer Fläche von 3,5 ha (1,6%) kultiviert wird. Der hohe Anbauanteil an Getreide in beiden Szenarien lässt sich durch die Fütterungsstrategien erklären, bei denen Gerste, Triticale und im Fall von SZ1 auch Weizen zum Einsatz kommen. Die Berechnungen zeigen, dass die Kosten für den Zukauf von Futtermitteln in beiden Szenarien deutlich niedriger ausfallen als in der Praxis. In SZ1 wird ausschließlich Kraftfutter zugekauft, wobei der Bedarf bei 278,6 t/Jahr liegt. In SZ2 wird hingegen nur 72,4 t/Jahr an Kraftfutter zugekauft, wobei der Großteil des zugekauften Futters aus Getreide besteht (245 t/Jahr).

Diese ersten Berechnungen verdeutlichen das Potenzial des Anbaus hochwertiger Luzerne und werden im nächsten Schritt mittels einer Sensitivitätsanalyse tiefergehend untersucht.

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EINSCHÄTZUNG MÖGLICHER MAßNAHMEN ZUR OPTIMIERUNG DES WISSENSTRANSFERS IM MILCHVIEHBEREICH AUS EXPERTINNENSICHT

Jasmin Godemann, Tamara Simonis¹

Zusammenfassung

In diesem Beitrag wird die Lücke zwischen Wissen und Handeln im Milchviehsektor basierend auf einer sozialwissenschaftlichen Mixed-Methods-Analyse im Rahmen des Verbundprojektes „MiKuWi“² dargestellt. Ziel des Gesamtprojektes ist die Erfassung von Hemmnissen bei der praktischen Umsetzung vorhandenen Wissens in der Milchviehhaltung unter Berücksichtigung der Quellen, aus denen LandwirtInnen ihr Fachwissen beziehen sowie die Klärung der Ursache, warum Fort- und Weiterbildungsveranstaltungen nicht ausreichend wahrgenommen werden, um schließlich ein betriebsindividuell anpassbares Wissenstransferkonzeptes zu erarbeiten. Der Fokus in diesem Beitrag liegt auf der ersten Phase des Projektes, d.h. den Einschätzungen der ExpertInnen aus dem Bereich der Beratung und Weiterbildung im Milchviehbereich hinsichtlich des Wissenstransfers. Aufbauend auf einer Literaturrecherche bezüglich möglicher Gründe der Nichtteilnahme an Veranstaltungen und Hemmnissen in der Umsetzung von Wissen wurden ExpertInnen interviewt. Aus den Ergebnissen dieser Interviews heraus wurde ein Fragebogen entwickelt, der deutschlandweit vor dem theoretischen Hintergrund des Use-and-Gratification-Ansatzes die Bedürfnisse der LandwirtInnen im Rahmen der Beratung und Weiterbildung wie auch der Informationsbeschaffung durch Mediennutzung erfasst. Im weiteren Verlauf der Projektarbeit werden thematisch zugespitzte Daten mittels qualitativer Interviews mit LandwirtInnen vertiefend erhoben sowie das finale Wissenstransferkonzept mit den Projektbeteiligten entwickelt, erprobt und in Gruppendiskussionen evaluiert.

Keywords

Wissenstransfer, Mixed-Methods, Use-and-Gratification-Ansatz, Beratung

1 Einleitung

Die Nutzungsdauer von Kühen und das Ausmaß der Kälbersterblichkeit in Milchviehherden können als Indikatoren für die Tiergesundheit und das Tierwohl herangezogen werden (AUF DER MAUER und WELLBROCK, 2023: 7). Es kann festgestellt werden, dass wirksame Maßnahmen in der täglichen Praxis bisher nicht umfassend umgesetzt werden, obwohl den handelnden Personen deren Wirksamkeit grundsätzlich bekannt ist (BLE und BMEL, 2020: 14). Als Gründe werden hierfür häufig finanzielle und zeitliche Hindernisse (BLE und BMEL, 2020: 13; RITTER et al., 2015: 7836 ff.), fehlendes Vertrauen in die Informationsquelle (GARFORTH, 2010: 64), mangelhaft umgesetzte Kommunikation im Rahmen der Wissensvermittlung (JANSEN und

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² Verbundprojektspartner: Thüringer Tierseuchenkasse (AdöR), Tierklinik Reproduktionsmedizin und Neugeborenenkunder der Justus-Liebig-Universität Gießen, Professur für Kommunikation und Beratung in den Agrar-, Ernährungs- und Umweltwissenschaften der Justus-Liebig-Universität Gießen, Zentrum für angewandte Forschung und Technologie e.V. an der Hochschule für Technik und Wirtschaft in Dresden. Das Projekt MiKuWi ist Teil der Modell- und Demonstrationsvorhaben (MuD) Tierschutz im Bundesprogramm Nutztierhaltung. Die Förderung erfolgt aus Mitteln des Bundesministeriums für Ernährung und Landwirtschaft (BMEL) aufgrund eines Beschlusses des deutschen Bundestages, Projektträger ist die Bundesanstalt für Landwirtschaft und Ernährung (BLE), Förderkennzeichen «28N421MB01»

LAM, 2012: 364ff.; RITTER et al., 2019: 4286 ff.), betriebspezifische Hindernisse sowie die zu Grunde liegende Motivation der LandwirtInnen (HOISCHEN-TAUBNER und SUNDRUM, 2018: 18f.) genannt. Die Literatur lässt außerdem darauf schließen, dass die Nutzung verschiedener Informationskanäle sowie auch die Teilnahme an Bildungsangeboten abhängig ist von Alter, Betriebsgröße und Grundbesitz (KIRNER et al., 2019: 91ff.). Die Analyse des derzeitigen Forschungsstands zum Wissenstransfer in der deutschen Milchviehwirtschaft hat gezeigt, dass bereits ein weitreichendes Angebot an Informationen existiert, diese medial unterschiedlich kommuniziert werden und über diverse Kanäle zu erreichen sind. Außerdem gibt es bereits zahlreiche Bildungsangebote und Vernetzungsmöglichkeiten für LandwirtInnen im Milchviehbereich, allerdings scheinen diese Informationen und Angebote bisher nicht anschlussfähig an die Akteure in der Milchviehwirtschaft zu sein.

2 Empirische Methoden und Analyserahmen

Für die Gesamtstudie wurde ein Mixed-Methods-Ansatz gewählt, der qualitative Interviews und eine standardisierte Online-Umfrage kombiniert. Auf Grundlage des Forschungsstands wurden Leitfragen für die Interviews mit ExpertInnen aus dem Bereich Beratung und Bildung abgeleitet. Die ExpertInnen wurden aufgrund ihres spezifischen Rollen- und Erfahrungswissen ausgewählt und die qualitativen Interviews nach dem Prinzip der theoretischen Sättigung durchgeführt. Das Ziel der explorativen ExpertInneninterviews ist eine Einschätzung seitens MultiplikatorInnen zur Akzeptanz bisheriger Weiterbildungsangebote sowie des Wissenstransfers in der Beratung und somit das Generieren von Fakten- und Erfahrungswissen. Aus den Ergebnissen der neun Interviews lassen sich sowohl inhaltliche (z.B. Sprachbarrieren beim Personal) als auch strukturelle Aspekte (z.B. Defizite in der Ausbildung) herausarbeiten. Auch die unzureichende Ansprache der jüngeren Generation wurde betont.

Um ein noch umfassenderes Verständnis des untersuchten Gegenstandes zu erhalten und aussagekräftigere, belastbare Erkenntnisse für das Wissenstransferkonzept zu generieren (KELLE, 2022: 173) wird aus den Einschätzungen der ExpertInnen sowie dem Forschungsstand ein Fragebogen konzipiert, der drei thematische Dimensionen umfasst. Dieser quantitative Teil der Analyse zielt auf die Beantwortung der Frage ab, welche Bedürfnisse bei der jeweiligen Form der Informationsbeschaffung im Wissenstransfer (Medien, Beratung, Weiterbildungsveranstaltungen) seitens der LandwirtInnen im Vordergrund stehen. Definiert wird Mediennutzung als eine Form der *indirekten* Kommunikation im Rahmen der Informationsbeschaffung. In der Beratung, wie aber auch bei der Teilnahme an Weiterbildungsveranstaltungen, steht die *direkte* Kommunikation in Präsenz der indirekten Kommunikation in Form von online-Formaten oder anderweitig technisch-gestützter Formate (z.B. App) gegenüber. Theoretische Grundlage bei der Erstellung dieses Fragebogens ist der Use-and-Gratification-Ansatz zur Einschätzung der unterschiedlichen Mediennutzungsbedürfnisse der LandwirtInnen sowie der Entstehung dieser Bedürfnisse in unterschiedlichen sozialen Situationen (KATZ et al. nach STARK und SCHNEIDERS, 2022: 51 ff.).

Basierend auf diesen Ergebnissen werden anschließend im weiteren Verlauf der Projektarbeit vertiefende leitfadengestützte Interviews zur Optimierung des Wissenstransfer LandwirtInnen durchgeführt und schließlich ein anschlussfähiges Wissenstransferkonzept erarbeitet, das betriebsindividuell anpassbar sein soll und letztendlich in der Branche verstetigt wird.

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(Stand: Januar 2025)

Jahr	Ort	Leitung	Thema
1960	Gießen	ROLFES	Das landwirtschaftliche Betriebsgrößenproblem im Westen und Osten
1961	Hohenheim	HANAU	Bedeutung und Anwendung ökonomischer Methoden
1962	Göttingen	BLOHM	Anpassung der Landwirtschaft an die veränderten ökonomischen Bedingungen
1963	Bonn	HERLEMANN	Grenzen und Möglichkeiten einzelstaatlicher Agrarpolitik
1964	Weihenstephan	RINTELEN	Konzentration und Spezialisierung in der Landwirtschaft
1965	München	KÖTTER	Landentwicklung - Soziologische und ökonomische Aspekte
1966	Kiel	REISCH	Quantitative Methoden in den Wirtschafts- und Sozialwissenschaften des Landbaues
1967	Bonn	SCHLOTTER	Landwirtschaft in der volks- und weltwirtschaftlichen Entwicklung
1968	Gießen	SCHMITT	Möglichkeiten und Grenzen der Agrarpolitik in der EWG
1969	Heidelberg	ZAPF	Entwicklungstendenzen in der Produktion und im Absatz tierischer Erzeugnisse
1970	Bonn	SCHLOTTER	Die Willensbildung in der Agrarpolitik
1971	Münster	SCHMITT	Mobilität der landwirtschaftlichen Produktionsfaktoren und regionale Wirtschaftspolitik
1972	Hohenheim	WEINSCHENCK	Die zukünftige Entwicklung der europäischen Landwirtschaft - Prognosen und Denkmodelle
1973	Braunschweig	BUCHHOLZ/ VON URFF	Agrarpolitik im Spannungsfeld der internationalen Entwicklungspolitik
1974	Göttingen	ALBRECHT/ SCHMITT	Forschung und Ausbildung im Bereich der Wirtschafts- und Sozialwissenschaften des Landbaues
1975	Kiel	LANGBEHN/ STAMER	Agrarwirtschaft und wirtschaftliche Instabilität
1976	Berlin	ANDREAE	Standortprobleme der Agrarproduktion

Jahr	Ort	Leitung	Thema
1977	Weihenstephan	SCHMITT/ STEINHAUSER	Planung, Durchführung und Kontrolle der Finanzierung von Landwirtschaft und Agrarpolitik
1978	Gießen	SEUSTER/ WÖHLKEN	Konzentration und Spezialisierung im Agrarbereich
1979	Bonn	HENRICHSMEYER	Prognose und Prognosekontrolle
1980	Hannover	von ALVENSLEBEN/ KOESTER/ STORCK	Agrarwirtschaft und Agrarpolitik in einer erweiterten Gemeinschaft
1981	Hohenheim	BÖCKENHOFF/ STEINHÄUSER/ VON URFF	Landwirtschaft unter veränderten Rahmenbedingungen
1982	Gießen	BESCH/ KUHLMANN/ LORENZL	Vermarktung und Beratung
1983	Hannover	GROSSKOPF/ KÖHNE	Einkommen in der Landwirtschaft - Entstehung, Verteilung, Verwendung und Beeinflussung
1984	Kiel	Teilnahme am 4 th European Congress of Agricultural Economists	
1985	Berlin	VON BLANCKENBURG/ DE HAEN	Bevölkerungsentwicklung, Agrarstruktur und ländlicher Raum
1986	Weihenstephan	VON URFF/ ZAPF	Landwirtschaft und Umwelt - Fragen und Antworten aus der Sicht der Wirtschafts- und Sozialwissenschaften des Landbaues
1987	Bonn	HENRICHSMEYER/ LANGBEHN	Wirtschaftliche und soziale Auswirkungen unterschiedlicher agrarpolitischer Konzepte
1988	Kiel	HANF/ SCHEPER	Neuere Forschungskonzepte und -methoden in den Wirtschafts- und Sozialwissenschaften des Landbaues
1989	Braunschweig	BUCHHOLZ/ NEANDER/ SCHRADER	Technischer Fortschritt in der Landwirtschaft - Tendenzen, Auswirkungen, Beeinflussung
1990	Frankfurt a.M.	SCHMITZ/ WEINDLMAIER	Land- und Ernährungswirtschaft im europäischen Binnenmarkt und in der internationalen Arbeitsteilung
1991	Göttingen	SCHMITT/ TANGERMANN	Internationale Agrarpolitik und Entwicklung der Weltwirtschaft
1992	Rostock	LANGBEHN/ VON ALVENSLEBEN/ SCHINKE	Strukturanpassungen der Land- und Ernährungswirtschaft in Mittel- und Osteuropa
1993	Halle	ISERMAYER/ HAGEDORN/ ROST/ WEBER	Gesellschaftliche Forderungen an die Landwirtschaft
1994	Hohenheim	ZEDIES/ GROSSKOPF/ HANF/ HEIDHUES	Die Landwirtschaft nach der EU-Agrarreform

Jahr	Ort	Leitung	Thema
1995	Berlin	KIRSCHKE/ ODENING/ SCHADE	Agrarstrukturentwicklung und Agrarpolitik
1996	Gießen	KUHLMANN/ HERMANN/ BAUER	Märkte der Agrar- und Ernährungswirtschaft
1997	Weihenstephan	VON URFF/ HEIßENHUBER	Land- und Ernährungswirtschaft in einer erweiterten EU
1998	Bonn	BERG/ HENRICHSMEYER/ SCHIEFER	Agrarwirtschaft in der Informationsgesellschaft
1999	Kiel	LANGBEHN/ von ALVENSLEBEN/ KOESTER	Wettbewerbsfähigkeit und Unternehmertum in der Agrar- und Ernährungswirtschaft
2000	Berlin	IAAE-Teilnahme	
2001	Braunschweig	BROCKMEYER/ ISERMAYER/ VON CRAMON-TAUBADEL	WTO-Strategien und Konzepte
2002	Halle	GRINGS/ AHRENS/ PETERSEN	Perspektiven der europäischen Agrarwirtschaft nach der Osterweiterung der EU
2003	Hohenheim	DABBERT/ GROSSKOPF/ HEIDHUES/ ZEDDIES	Perspektiven in der Landnutzung - Regionen, Landschaften, Betriebe - Entscheidungsträger und Instrumente
2004	Berlin	ODENING/ HAGEDORN/ NAGEL	Umwelt- und Produktqualität im Agrarbereich
2005	Göttingen	THEUVSEN/ SPILLER/ BAHRS/ VON CRAMON-TAUBADEL/ ZELLER	Unternehmen im Agrarbereich vor neuen Herausforderungen
2006	Gießen	KUHLMANN/ SCHMITZ	Good Governance in der Agrar- und Ernährungswirtschaft
2007	Weihenstephan	HEISSENHUBER/ KIRNER/ PÖCHGTRAGER/ SALHOFFER	Agrar- und Ernährungswirtschaft im Umbruch
2008	Bonn	BERG/ HARTMANN/ HECKELEI/ HOLM-MÜLLER/ SCHIEFER	Risiken in der Agrar- und Ernährungswirtschaft und ihre Bewältigung
2009	Kiel	LOY/ MÜLLER	Agrar- und Ernährungsmärkte nach dem Boom
2010	Braunschweig	BANSE/ GÖMANN/ ISERMAYER/ NIEBERG/ OFFERMANN/ WEINGARTEN/ WENDT	Möglichkeiten und Grenzen der wissenschaftlichen Politikanalyse
2011	Halle (Saale)	BALMANN/ GLAUBEN/ GRINGS/ HIRSCHAUER/ WAGNER	Unternehmerische Landwirtschaft zwischen Marktanforderungen und gesellschaftlichen Erwartungen

Jahr	Ort	Leitung	Thema
2012	Hohenheim	BAHRS/ BECKER/ BIRNER/ BROCKMEIER/ DABBERT/ DOLUSCHITZ/ GRETHE/ LIP- PERT/ THIELE	Herausforderungen des globalen Wandels für Agrarentwicklung und Welternährung
2013	Berlin	KIRSCHKE/ BOKELMANN/ HAGEDORN/ HÜTTEL	Wie viel Markt und wie viel Regulierung braucht eine nachhaltige Agrarentwicklung?
2014	Göttingen	MUßHOFF/ BRÜMMER/ HAMM/ MARGGRAF/ MÖL- LER/ QAIM/ SPILLER/ THEUVSEN/ VON CRAMON- TAUBADEL/ WOLLNI	Neuere Theorien und Methoden in den Wirt- schafts- und Sozialwissenschaften des Land- baus
2015	Gießen	KÜHL/ AURBACHER/ HERR- MANN/ NUPPENAU/ SCHMITZ	Perspektiven für die Agrar- und Ernährungs- wirtschaft nach der Liberalisierung
2016	Bonn	BRITZ/ BRÖRING / HART- MANN/ HECKELEI/ HOLM- MÜLLER	Agrar- und Ernährungswirtschaft – Regional vernetzt und global erfolgreich
2017	Weihenste- phan	SAUER/ KANTELHARDT/ BITSCH/ GLEBE/ OEDL- WIESER	Agrar- und Ernährungswirtschaft zwischen Res- sourceeffizienz und gesellschaftlichen Erwar- tungen
2018	Kiel	BRAATZ, HENNING, HESS, LATA CZ-LOHMANN, LOY, THIELE	Visionen für eine Agrar- und Ernährungspolitik nach 2020
2019	Braunschweig	BANSE, CHRISTOPH- SCHULZ, GOCHT, NIEBERG, PELIKAN, RÖDER, SALA- MON, THOBE, WEINGAR- TEN, ZANDER	Landwirtschaft und ländliche Räume im gesell- schaftlichen Wandel
2020	Halle (Saale)	GOTTER, GÖTZ, GRAUB- NER, HERZFELD, HIRSCH- AUER, KASHTANOVA, THEESFELD, WAGNER	Herausforderungen für die ländliche Entwick- lung - Wirtschafts- und sozialwissenschaftliche Perspektiven
2021	Berlin	GRETHE, FEINDT, HACKFORT, MITHÖFER, ODENING, RITTER, SIDDIG	Transformationsprozesse im Agrar- und Ernäh- rungssystem: Herausforderungen für die Wirtschafts- und So- zialwissenschaften
2022	Hohenheim	BAHRS, BIELING, BIRNER, BRAUN, HESS, HIRSCH, KNIERIM, LIPPERT, SCHÖN- LEBER, SCHÜLE, WEINRICH, WIECK	Resilienz von regionalen und globalen Wert- schöpfungsketten der Agrar- und Ernährungs- wirtschaft

Jahr	Ort	Leitung	Thema
2023	Göttingen	PLIENINGER, BRÜMMER, COLEN, ENNEKING, HÜT- TEL, KUSSIN, MÖLLER, MUßHOFF, RECKE, SPILLER, VON CRAMON-TAUBADEL, THIEL, WÄHRISCH, WOLLNI, YU, ZANDER, ZU- BEK	Nachhaltige Ernährungssysteme und Landnut- zungswandel
2024	Gießen	AURBACHER, BRÄUNIG, HANF, HERZIG, PETRICK, TEUBER	Innovative Konzepte für eine zukunftsfähige Agrar- und Ernährungswirtschaft

**ANSCHRIFTEN DER MITGLIEDER DES VORSTANDES
UND DER GESCHÄFTSSTELLE DER
GESELLSCHAFT FÜR WIRTSCHAFTS- UND
SOZIALWISSENSCHAFTEN DES LANDBAUES E.V.**

(Wahlperiode 01.01.2023 bis 31.12.2025)

Stand: April 2025

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EHRENMITGLIEDER DER GESELLSCHAFT FÜR WIRTSCHAFTS- UND SOZIALWISSENSCHAFTEN DES LANDBAUES E.V.

(Stand: Januar 2025)

Name	Ort	Ehrenmitglied seit
Prof. Dr. Dr. h.c. Georg Blohm (+)	Kiel	11.10.1977
Prof. Dr. Arthur Hanau (+)	Göttingen	11.10.1977
Prof. Dr. Dr. Paul Rintelen (+)	Weihenstephan	11.10.1977
Prof. Dr. Max Rolfes (+)	Gießen	11.10.1977
Prof. Dr. Emil Woermann (+)	Göttingen	11.10.1977
Prof. Dr. Roderich Plate (+)	Stuttgart-Hohenheim	08.10.1980
Prof. Dr. Herbert Kötter (+)	Lollar	07.10.1987
Prof. Dr. Hans-Heinrich Herlemann (+)	Weihenstephan	07.10.1987
Dr. Kurt Pfeleiderer (+)	Bonn	07.10.1987
Prof. Dr. Dr. h.c. Günther Schmitt (+)	Göttingen	06.10.1988
Dr. Edgar Lohmeyer (+)	Bonn	06.10.1988
Prof. Dr. Dr. h.c. Günther Steffen (+)	Bonn	05.10.1989
Prof. Dr. Günther Weinschenck (+)	Stuttgart	05.10.1989
Prof. Dr. Adolf Weber (+)	Kiel	02.10.1990
Prof. Dr. Egon Wöhlken (+)	Gießen	01.10.1992
Prof. Dr. Peter v. Blankenburg (+)	Berlin	06.10.1994
Prof. Dr. Hans Stamer (+)	Kiel	06.10.1994
Prof. Dr. Dr. h.c. Erwin Reisch (+)	Hohenheim	30.09.1996
Prof. Dr. Hugo Steinhauser	Weihenstephan	07.10.1997
Prof. Dr. Winfried v. Urff	Weihenstephan	05.10.1999
Prof. Dr. Wilhelm Henrichsmeyer (+)	Bonn	30.09.2002
Prof. Dr. Cay Langbehn	Kiel	30.09.2002
Dr. h.c. Uwe Zimpelmann	Frankfurt/M.	30.09.2002
Dr. Günther Fratzscher (+)	Rheinbreitbach	30.09.2003
Prof. Dr. Dr. h.c. Ulrich Koester	Kiel	28.09.2004
Dr. Wilhelm Schopen	Bonn	28.09.2004
Prof. Dr. Dr. h.c. Friedrich Kuhlmann	Gießen	05.10.2006
Prof. Dr. Dr. h.c. Jürgen Zeddies	Hohenheim	27.09.2007
Prof. Dr. Stefan Tangermann	Göttingen	01.10.2009
Prof. Dr. Wilhelm Brandes (+)	Göttingen	27.09.2012
Prof. Dr. Klaus Froberg	Bonn	18.09.2014

Name	Ort	Ehrenmitglied seit
Prof. Dr. Ernst Berg	Bonn	14.09.2017
Prof. Dr. Dr. h.c. Alois Heißenhuber	Weihenstephan	14.09.2017
Prof. Dr. Roland Herrmann	Gießen	13.09.2018
Prof. Dr. Dr. h.c. Dieter Kirschke	Berlin	13.09.2018
Prof. Dr. Peter Weingarten	Braunschweig	23.09.2020
Prof. Dr. Martina Brockmeier	Hohenheim	22.09.2021
Prof. Dr. Folhard Isermeyer (+)	Braunschweig	27.09.2024
Prof. Dr. Martin Odening	Berlin	27.09.2024