

Mirzabaev, Alisher et al.

Working Paper

Land, climate, energy, agriculture and development in the Sahel:
Synthesis paper of case studies under the Sudano-Sahelian
initiative for regional development, jobs, and food security

ZEF Working Paper Series, No. 204

Provided in Cooperation with:

Zentrum für Entwicklungsforschung / Center for Development Research (ZEF), University of
Bonn

Suggested Citation: Mirzabaev, Alisher et al. (2021) : Land, climate, energy, agriculture and
development in the Sahel: Synthesis paper of case studies under the Sudano-Sahelian
initiative for regional development, jobs, and food security, ZEF Working Paper Series, No. 204,
University of Bonn, Center for Development Research (ZEF), Bonn

This Version is available at:

<https://hdl.handle.net/10419/246473>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen
Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle
Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich
machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen
(insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten,
gelten abweichend von diesen Nutzungsbedingungen die in der dort
genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

*Documents in EconStor may be saved and copied for your
personal and scholarly purposes.*

*You are not to copy documents for public or commercial
purposes, to exhibit the documents publicly, to make them
publicly available on the internet, or to distribute or otherwise
use the documents in public.*

*If the documents have been made available under an Open
Content Licence (especially Creative Commons Licences), you
may exercise further usage rights as specified in the indicated
licence.*



zef
Center for
Development Research
University of Bonn



Working Paper 204

MIRZABAEV A, SAKKETA TG, SYLLA MB, DIMOBE K, SANFO S, ADMASSIE A, ABEBAW D, COULIBALY O, RABANI A, IBRAHIM B, BOKANEY AL, SEYNI AA, IDRISSE M, OLAYIDE OE, FAYE A, DIÈYE M, DIAKHATÉ PB, BÈYE A, SALL M, DIOP M, OSMAN AK, ALI AM, GARBA I, BAUMÜLLER H, OUEDRAOGO S, VON BRAUN J

Land, Climate, Energy, Agriculture and Development in the Sahel
Synthesis paper of case studies under the Sudano-Sahelian Initiative
for Regional Development, Jobs, and Food Security



ZEF Working Paper Series, ISSN 1864-6638
Center for Development Research, University of Bonn
Editors: Christian Borgemeister, Joachim von Braun, Manfred Denich, Till Stellmacher
and Eva Youkhana

Authors' addresses

Alisher Mirzabaev (corresponding author)
Center for Development Research (ZEF)
University of Bonn
Genscherallee 3, 53113 Bonn
+49-228-73-1915
almir@uni-bonn.de

Tekalign Gutu Sakketa
Center for Development Research (ZEF)
University of Bonn
Genscherallee 3, 53113 Bonn
tsak@uni-bonn.de

Mouhamadou Bamba Sylla
African Institute for Mathematical Sciences (AIMS)
AIMS Rwanda, Kigali, Rwanda
syllabamba@yahoo.fr

Kangbéni Dimobe
Université de Dédougou, Institut des Sciences de l'Environnement et du Développement
Rural (ISED), B.P. 176 Dédougou, Burkina Faso
kangbenidimobe@yahoo.fr

Safietou Sanfo
West African Science Service Center on Climate Change and Adapted Landuse (WASCAL)
WASCAL Competence Centre, Ouagadougou, Burkina Faso
sanfo.safy@gmail.com

Assefa Admassie
Addis Ababa University
College of Business and Economics
Addis Ababa, Ethiopia
aadmassie@yahoo.com

Degnet Abebaw
Independent Researcher
Addis Ababa, Ethiopia
degnet06@yahoo.com

Ousmane Nafolo Coulibaly
Consultant
Bamako, Mali
o.coulibaly1995@gmail.com

Adamou Rabani
Faculté des Sciences et Techniques
Université Abdou Moumouni, Niamey, Niger
adamrabani@yahoo.fr

Boubacar Ibrahim
Faculté des Sciences et Techniques
Université Abdou Moumouni, Niamey, Niger
ibraboub@yahoo.fr

Abdou Latif Bokaney
WASCAL Research Program Climate Change and Energy
University Abdou Moumouni, Niamey, Niger
babdoulatif@yahoo.fr

Abdoul Aziz Seyni
Ministère de l'environnement, de la Salubrité Urbaine et du Développement Durable
Niamey, Niger
golokoye@yahoo.fr

Mamoudou Idrissa
Conseil National de l'Environnement pour un Développement Durable (CNEDD)
Cabinet du Premier Ministre,
Niamey, Niger
mamoudou27@yahoo.fr

Olawale Emmanuel Olayide
Centre for Sustainable Development
Faculty of Multidisciplinary Studies
University of Ibadan, Ibadan, Nigeria
waleolayide@yahoo.com

Amy Faye
Senegalese Institute of Agricultural Research
Route des hydrocarbures, BP 3120
Dakar-Senegal
amy.faye1@gmail.com

Mohamadou Dièye
Senegalese Institute of Agricultural Research
Route des hydrocarbures, BP 3120
Dakar-Senegal
dieyemohamadou@gmail.com

Pape Bilal Diakhaté
Senegalese Institute of Agricultural Research
Route des hydrocarbures, BP 3120
Dakar-Senegal
dpapebilal@hotmail.fr

Assane Bèye
University Cheikh Anta Diop of Dakar
Dakar-Senegal
assane1.beye@ucad.edu.sn

Moussa Sall
Senegalese Institute of Agricultural Research
Route des hydrocarbures, BP 3120
Dakar-Senegal
gabkolda@gmail.com

Mbaye Diop
Senegalese Institute of Agricultural Research
Route des hydrocarbures, BP 3120
Dakar-Senegal
mbdiop@gmail.com

Abdelrahman Khidir Osman
Sudanese Environment Conservation Society
Khartoum, Sudan
arkosman@hotmail.com

Adil M. Ali
Sudanese Environment Conservation Society
Khartoum, Sudan
sanjak1956@gmail.com

Issa Garba
Agrhymet Regional Centre
Permanent Interstate Committee
for drought control in the Sahel
Boulevard de l'Université – BP 11011
Niamey, Niger
issa.garba@cilss.int

Heike Baumüller
Center for Development Research (ZEF)
University of Bonn
Genscherallee 3, 53113 Bonn
hbaumueller@uni-bonn.de

Souleymane Ouedraogo
Agrhymet Regional Centre
Permanent Interstate Committee for drought control in the Sahel
Boulevard de l'Universite – BP 11011
Niamey, Niger
drsouleymane.ouedraogo@cilss.int

Joachim von Braun
Center for Development Research (ZEF)
University of Bonn
Genscherallee 3, 53113 Bonn
jvonbraun@uni-bonn.de

Land, Climate, Energy, Agriculture and Development in the Sahel

Synthesis paper of case studies under the Sudano-Sahelian Initiative for Regional Development, Jobs, and Food Security

Alisher Mirzabaev, Tekalign Gutu Sakketa, Mouhamadou Bamba Sylla, Kangbéni Dimobe, Safietou Sanfo, Assefa Admassie, Degnet Abebaw, Ousmane Nafolo Coulibaly, Adamou Rabani, Boubacar Ibrahim, Abdou Latif Bonkaney, Abdoul Aziz Seyni, Mamoudou Idrissa, Olawale Emmanuel Olayide, Amy Faye, Mohamadou Dièye, Pape Bilal Diakhaté, Assane Bèye, Moussa Sall, Mbaye Diop, Abdelrahman Khidir Osman, Adil M. Ali, Issa Garba, Heike Baumüller, Souleymane Ouedraogo, and Joachim von Braun

Abstract

This paper synthesizes a set of national case studies conducted in the Sahelian countries during 2019-2020 as a collaboration between national universities and research institutes, and the Center for Development Research (ZEF), University of Bonn, with contributions from the Agrhymet Regional Centre, Permanent Interstate Committee for Drought Control in the Sahel (CILSS). These case studies provide up-to-date knowledge and critical insights on the nexus of land degradation, climate change and energy in the Sahel. The current synthesis paper highlights their major findings and provides cross-cutting and cross-regional analytical conclusions. First, the synthesis paper explores current trends in the Sahel region on land use and land degradation, energy use and supply, climate change projections and impacts, as well as their interactions and links to agricultural growth, food security, poverty reduction, and peace in the region. Second, technological, socio-economic and policy solutions at the nexus of land, water, energy and climate challenges that enable environmentally sustainable and socially inclusive rural development in the Sahel are discussed, including their interactions and implications for peace and stability in the region. The findings show that such socio-economic solutions as improving access to markets, strengthening social safety nets, increasing investments to transport and energy infrastructures, promoting land tenure security, expanding off-farm employment opportunities can greatly contribute to rural development in the Sahel, particularly by aiding climate change resilience and sustainable land management. Key technological innovations highlighted across the case studies include expanding irrigation and adopting water use efficient irrigation techniques, crop diversification, expanding agricultural mechanization, investing into restoring and rehabilitating degraded lands through reforestation, afforestation and agroforestry practices. The key lessons learnt from ongoing national policy initiatives for sustainable development highlight the importance of active stakeholder consultation and participation in policy formulation, institution of effective policy monitoring and assessment mechanisms, and avoiding of excessive reliance on external sources of funding for the successful implementation of sustainable development policies and programs. Based on these findings, the synthesis paper proposes an agenda for applied research to provide guidance to and accompany promising development strategies in and for the region.

Keywords: Sahel, water-energy-food security nexus, food insecurity, land degradation, climate change adaptation, development policies, job creation, infrastructure, conflicts, future research agenda

JEL codes: O1, O2, O3, Q1, Q2, Q4, Q5, J43

Acknowledgments

This synthesis paper and the underlying country case studies from the Sahel region were supported by the German Federal Ministry for Development Cooperation (BMZ) under the Program of Accompanying Research for Agricultural Innovation (PARI), which is gratefully acknowledged.

The authors express their deep appreciation and thanks to the participants of the virtual workshop on “Rural Development, Agricultural Livelihoods and Job Creation in the Sahel Region”, conducted jointly by the Center for Development Research (ZEF), University of Bonn, and the Agrhymet Regional Center of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) from 22-26 June 2020, for their valuable feedback, comments and suggestions to this paper and the underlying case studies.

We also would like to express our gratitude to Katharina Gallant, Niklas Müller, and Amy Newsom for their outstanding editorial assistance.

Table of contents

1	BACKGROUND AND PROBLEM DEFINITION	1
2	CONCEPTUAL UNDERPINNINGS	5
3	LAND USE AND LAND DEGRADATION	6
4	ENERGY SUPPLY AND USE	11
5	CLIMATE CHANGE	14
6	SOLUTIONS: TECHNOLOGIES, INFRASTRUCTURES, INSTITUTIONS AND POLICIES	16
6.1	Socio-economic, infrastructural and policy solutions	16
6.2	Technological solutions	18
6.3	Evaluation of existing major policies and investments	21
7	CONCLUSIONS	23
8	AGENDA FOR APPLIED RESEARCH	24
9	REFERENCES	26

1 Background and problem definition

The Sahel region, as defined here, is home to a half billion people. It stretches through the heart of Africa, from the Atlantic Ocean on the western coast to the Red Sea on the eastern coast. This economically and culturally diverse semi-arid region separates the hyper-arid Sahara, the largest desert in the world, to its North, from lush savannas and tropical forests to its South. The Sahel region is spread over 11 countries: Senegal, Mauritania, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, South Sudan, Eritrea, and Ethiopia (from west to east) (Figure 1).

Figure 1: The Sahel region



Source: Deutsche Welle (2019).

Poverty has been declining in the Sahelian countries over the last two decades due to rapid economic growth exceeding 6% annually. Nevertheless, about 42% of the population in the region are still below the international poverty line and the Sahelian countries are classified by the World Bank as low-income countries (Table 1).

Low agricultural productivity, vulnerability to extreme weather, income inequality and conflicts/insecurity are major causes of poverty in the region (Olayide, 2020: Nigeria case study; Sylla et al., 2020: Burkina Faso case study; Admassie and Abebaw, 2020: Ethiopia case study). Unemployment and under-employment levels are high, particularly among the younger generation. Although the share of agriculture in the Sahelian gross domestic products is declining, it still represents one third of the aggregate regional product and continues to play a major role in employment (40-80% of the active labor force), making the regional economies and livelihoods very vulnerable to climate change. Furthermore, most of crop production area in the Sahel is rainfed (> 85%), with limited irrigated agriculture. Biomass remains the major source of household energy across the region (Adamou et al., 2020: Niger case study; Coulibaly, 2020: Mali case study). This high dependency on biomass for energy has led to massive deforestation, loss of soil nutrients and organic matter. Most of the countries in the region are in the bottom ranks of the Human Development Index (HDI) (UNDP, 2019). The most recent FAO assessment under the Global Information and Early Warning System included all the Sahelian countries among those facing critical food insecurity problems, with some facing widespread lack of access to food, while some others are confronted with severe localized food insecurity. The key causes behind this food insecurity situation in the region are droughts and civil

conflicts.¹ The major drivers of conflicts across the region are competition for land and water resources, as well as political, religious and ethnical differences (Figure 2) (Olayide et al., 2020: Nigeria case study; Osman and Mohamed, 2020: Sudan case study).

Tab 1: Key socio-economic characteristics of the Sahelian countries

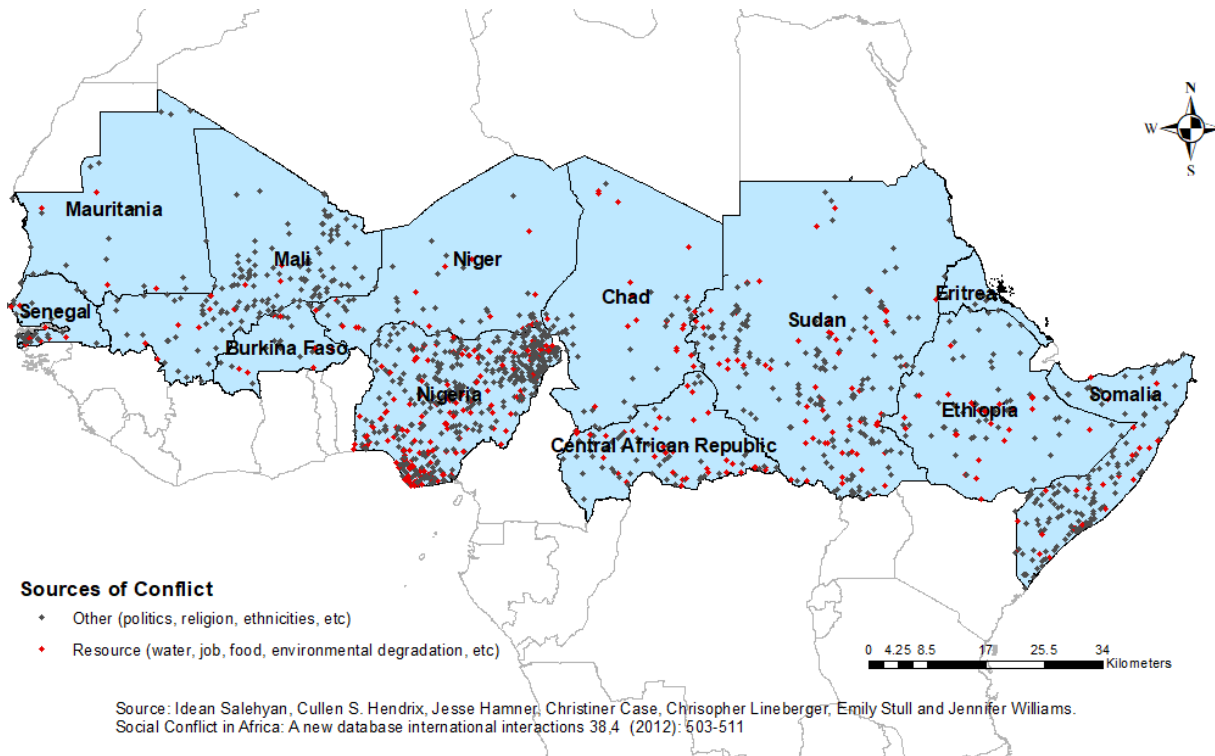
Country	Population (2018, in millions)	GDP per capita (2018, current USD)	Poverty headcount ratio at 1.90 USD a day (% of population, various years ²)	Share of agriculture, forestry, and fishing in GDP (% , 2018)	Main exports
Senegal	16	1522	38	17	fish, groundnuts, petroleum products, phosphates, cotton
Mauritania	4	1189	6	26	iron ore, petroleum, gold, copper, gypsum, fish
Mali	19	900	41	39	gold, cotton
Burkina Faso	20	715	38	28	gold, cotton, livestock, sesame
Niger	23	414	45	39	uranium ore, livestock, cowpeas, onions
Nigeria	196	2028	54	21	petroleum and petroleum products, cocoa, timber
Chad	15	728	38	45	petroleum, cattle, cotton, gum arabic
Sudan	42	977	13	32	gold; petroleum and its products; cotton, sesame, livestock
South Sudan	11	1120	43	10	petroleum
Eritrea	4	396	53	14	zinc, copper, precious metal ore
Ethiopia	109	772	24	31	coffee, qat, gold, leather products, livestock, oilseeds
The Sahel region	459	1345	42	31	petroleum, metals and agricultural products

(World Bank Open Data, <https://data.worldbank.org/>, accessed on 10.06.2020; the national case studies cited in Box 1.)

¹ <http://www.fao.org/giews/country-analysis/external-assistance/en/>

² Based on latest available data, mostly between 2009-2018.

Figure 2: Major sources of conflicts across the Sahel region



The Sahel is among the regions of the world confronted with the most severe problems of land degradation. Unsustainable cropping practices, grassland degradation, conversion of grasslands to croplands and deforestation were identified as the major forms of land degradation in the region (Nkonya et al., 2016). Climate change is projected to amplify these degradation processes (Mirzabaev et al., 2019). Land degradation, climate variability and change represent major underlying threats to rural livelihoods in the Sahel (Nkonya et al., 2016). Sustainable and peaceful development of the region critically depends on finding solutions to advance economic growth, human development, and food security. In this regard, sustainable land management, climate change adaptation, expanding access to clean, modern, and renewable energy sources, and investments into human capital in the Sahel are essential entry points for achieving these objectives, including peace and security, through their acceleration of agricultural growth rates. Agricultural growth is the most effective source of poverty reduction in the Sahel due to the concentration of unskilled and low-income labor in agriculture. The Sahelian countries have designed a big number of policies and strategies, such as the African Union (AU) program on Comprehensive Africa Agriculture Development (CAADP), the Great Green Wall (GGW) initiative, Silencing the Guns in Africa, the Malabo Declaration on Accelerated Agricultural Growth, Agenda 2063, and many others, to address land degradation, enhance agricultural productivity, adapt to changing climate, and to sustain peace processes and critical peace operations. However, the overall investments in sustainable land management, land restoration activities and agricultural productivity growth remain low. Therefore, it is particularly important not to lose sight of these fundamental challenges defining the future of the region in the post-COVID world.

Box 1: The National Case studies and other key publications

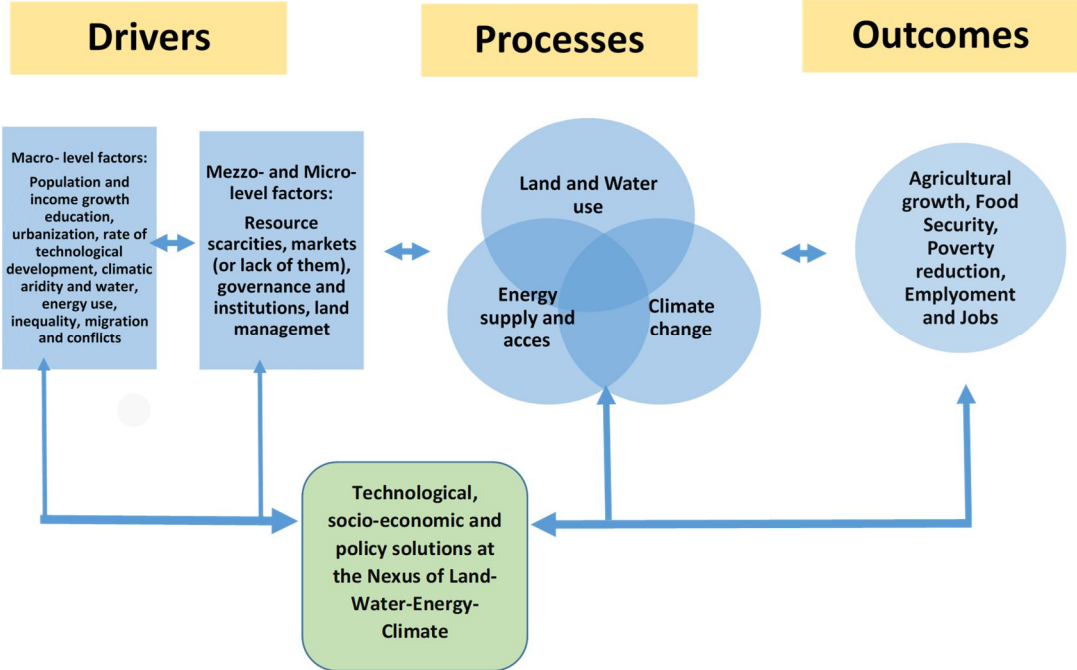
- Mouhamadou Bamba Sylla, Kangbéni Dimobe, Safietou Sanfo (2020) Burkina Faso - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 197 (Sylla et al., 2020).
- Assefa Admassie, Degnet Abebaw (2020) Ethiopia - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 198 (Admassie and Abebaw, 2020).
- Ousmane Coulibaly (2020) Mali - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 199 (Coulibaly, 2020).
- Rabani Adamou, Boubacar Ibrahim, Abdou Latif Bonkaney, Abdoul Aziz Seyni, Mamoudou Idrissa, Nassourou Bello (2020) Niger - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 200 (Adamou, 2020).
- Olawale Emmanuel Olayide (2020) Nigeria - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 201 (Olayide, 2020).
- Amy Faye, Mohamadou Dièye, Pape Bilal Diakhaté, Assane Bèye, Moussa Sall, Mbaye Diop (2020) Senegal - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 202 (Faye et al., 2020).
- Abdelrahman Khidir Osman, Adil Mohamed (2020) Sudan - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 203 (Osman and Mohamad, 2020).
- Malabo-Montpellier Panel (2018a). WATER-WISE: Smart Irrigation Strategies for Africa.
- Malabo-Montpellier Panel (2018b). MECHANIZED: Transforming Africa's Agriculture Value Chains.
- Malabo-Montpellier Panel (2019). ENERGIZED: Policy innovations to power the transformation of Africa's agriculture and food system.
- CILSS (2016). Landscapes of West Africa – A Window on a Changing World. U.S. Geological Survey EROS, 47914 252nd St, Garretson, SD 57030, UNITED STATES.
- United Nations Convention to Combat Desertification (UNCCD). 2019. The Global Land Outlook, West Africa Thematic Report, Bonn, Germany.

The main objective of this paper is to synthesize a set of accompanying national case studies conducted in the Sahelian countries during 2019-2020 as a collaboration between national universities and research institutes and the Center for Development Research (ZEF), University of Bonn (Box 1), with contributions from the Agrhymet Regional Centre, Permanent Interstate Committee for Drought Control in the Sahel (CILSS). The case studies reviewed existing scientific literature, government documents such as policy and administrative reports, as well as project documents. These case studies provide up-to-date knowledge and critical insights on the nexus of land degradation, climate change and energy in the Sahel region. They also identify policy entry points and investment opportunities that will help in advancing economic growth, food security, and job creation in the region. The current synthesis paper highlights their major findings and provides cross-cutting and cross-regional analytical conclusions. Based on these case studies and the discussions during the virtual workshop on “Rural Development, Agricultural Livelihoods and Job Creation in the Sahel Region”, conducted jointly by the Center for Development Research (ZEF), University of Bonn, and the Agrhymet Regional Center (CILSS) from 22-26 June 2020, this synthesis paper proposes an applied research agenda to provide guidance to and accompany promising development strategies in and for the region.

2 Conceptual underpinnings

The conceptual framework in Figure 3 depicts the interactions highlighted in the case studies and this synthesis paper. It shows that various drivers at macro-, mezzo- and micro-levels affect the interlinked processes of climate change, energy supply and access, and land and water use. On the positive side, there are many technological, socio-economic and policy solutions which can operate at the nexus of these overlapping challenges strengthening the resilience and adaptive capacities of rural communities against climate change, while simultaneously contributing to climate change mitigation, and facilitating the attainment of other sustainable development goals (SDGs), particularly addressing land degradation and expanding access to clean energy (Mirzabaev et al., 2019).

Figure 3: The conceptual framework



Source: The authors.

Certainly, land-climate interactions may also have trade-offs and negative externalities on various facets of sustainable development, e.g. large-scale bioenergy development and resulting food insecurity (Smith et al., 2019), or competition for resources leading to conflicts. Similarly, strengthening human capital building and higher education, including tertiary education, is key for boosting job creation, particularly in the non-farm sector, in this resource-constrained region. The role of research is to identify such synergies and trade-offs and assist the creation of enabling policy environments.

Following this conceptual framework, the case studies and the synthesis paper first explore current trends in the Sahel region on land use and land degradation, energy use and supply, climate change projections and impacts, as well as their interactions and links to agricultural growth, food security, poverty reduction, and peace in the region. Second, technological, socio-economic and policy solutions at the nexus of land, water, energy and climate that enable environmentally sustainable and socially inclusive rural development in the Sahel are discussed, including their interactions and implications for peace and stability in the region. Next, key lessons learnt from ongoing national policy initiatives for sustainable development are highlighted. Finally, based on the insights from these three sections as well as stakeholder consultations during the virtual workshop described in the introduction, an agenda for applied research is proposed.

3 Land use and land degradation

Land degradation is defined across the case studies as “a negative trend in land condition, caused by direct or indirect human-induced processes, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity or value to humans” (Olsson et al., 2019: 349-350). The Sahel region experienced a series of widespread droughts and resulting desertification during the 1970s, however, wetter climate and ensuing greening conditions have been observed in the Sahel since 1990s (Brandt et al., 2015; Leroux et al., 2017; Sylla et al., 2020: Burkina Faso case study; Adamou et al., 2020: Niger case study).

At the same time, greening does not necessarily mean land improvement, as it can be caused by invasive plants encroachment and accompanying decreases in species richness and biodiversity (Admassie and Abebaw, 2020: Ethiopia case study). Major land use changes in the region since the 1970s included the rapid expansion of cropland areas and population settlements, and decreases in forests, grasslands, and water bodies (Hiernaux et al., 2009; Aladejana et al., 2018). Although there is considerable debate about the expansion of the Sahara Desert based on annual rainfall, Thomas and Nigam (2018) indicated that the Sahara expanded by 10% over the 20th century (e.g., Osman and Mohamad, 2020: Sudan case study).

More recent land use and land cover changes between 2001 and 2018 based on remotely sensed data corroborate the findings on greening across the Sahel (Table 3). During this period, grasslands expanded in the region by 13 million ha, whereas the barren areas, i.e. those areas with no more than 10% vegetative cover and the remainder being bare soil, sand and rock, declined by 8.6 million ha. Another major difference between 2001 and 2018 across the region is the reduction of cropped areas, in total by 0.7 million hectares for the entire region. Cropland decline occurred in most countries, except for Nigeria and Senegal, and to a lesser extent Niger and Mauritania, where cropped areas increased between these years. This is contradictory to the impression that cropped areas have been constantly increasing in the region. At the same time, an important caveat to bear in mind is that the MODIS dataset does not include fallowed land under croplands, but summarizes these under other land uses, e.g. grasslands. Even as such, this is an important indicator for the changes of actually cropped areas between 2001 and 2018. More detailed studies are needed to identify the reasons behind these cropland changes, whether they are due to intensification of agricultural production or land degradation. However, indirect evidence indicates that unsustainable land management practices may be playing an important role (Nkonya et al., 2016). These land use and land cover changes are at the regional level, with specific regions of the Sahelian countries often experiencing divergent trends. In Burkina Faso, for example, although overall cropped areas declined, the area under croplands strongly increased in the central and southern parts of the country (Sylla et al., 2020: Burkina Faso case study). The year-to-year variations in the extent of biomes is given in Figure 4. Figure 4 shows that the changes between 2001 and 2018 represented in Table 2 are part of a broadly consistent pattern of annual changes between these years, and not some odd product of selecting these years as the baseline and end-line for comparison.

Tab 2: Changes in land use and land cover between 2001 and 2018

Land use and land cover in 2001, in thousand ha	Land use and land cover in 2018, in thousand ha								Total
	Forest	Shrubland	Woodland	Grassland	Wetland	Cropland	Settlement	Barren lands	
Forest	4,607	1	778	1,394	87	98	4	0	6,969
Shrubland	6	17,783	3	7,631	3	11	3	380	25,819
Woodland	173	0	1,725	434	5	190	5	0	2,531
Grassland	1,392	2,535	845	365,000	228	16,710	111	1,914	388,735
Wetland	33	0	3	186	1,636	10	6	4	1,879
Cropland	105	2	115	17,384	12	67,268	149	7	85,041
Settlements	0	0	0	0	0	0	1,255	0	1,255
Barren lands	0	1,017	0	9,853	47	4	5	465,000	475,927
Total	6,315	21,338	3,469	401,882	2,018	84,292	1,537	467,306	
Net gain/loss	-654	-4,481	937	13,147	139	-749	282	-8,621	

Notes: See Box 2 for the definition of these biomes. Despite high resolution of pixel size (25 hectares), this MODIS LUC database underrepresents cropped areas due to usually small farm sizes across the Sahel and frequent interspersion of cropped areas within larger biomes. (MODIS LUC database (at 500 meters' resolution)³; Friedl et al. 2019)

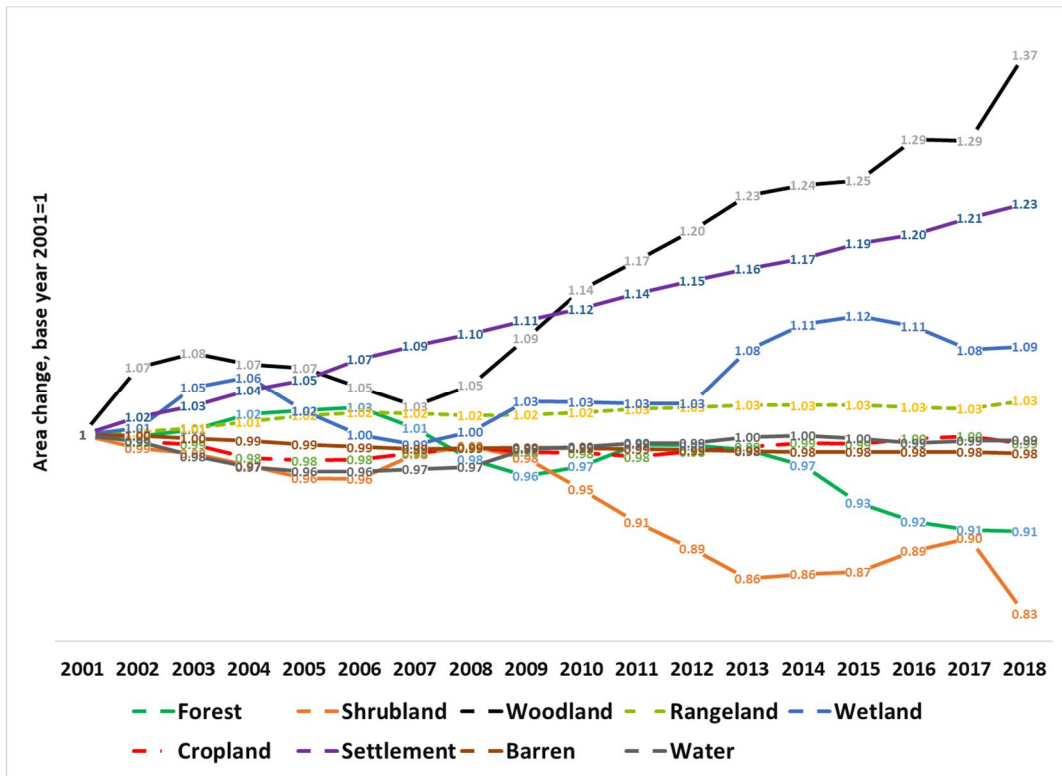
Box 2: Definition of biomes used in the study

Biome	International Geosphere-Biosphere Program (IGBP) definition
Forests	Woody vegetation with height >2m & covering at least 60% of land area.
Shrubland	Vegetation with mainly shrubs or short trees (shrubs) of less than 2m. Canopy of shrublands is fairly open and allows grasses and other short plants to grow between the shrubs.
Woodland	Biome with tree cover of 5-10%, with trees reaching a height of 5m at maturity.
Grassland	Lands with herbaceous types of cover. Tree and shrub cover is less than 10%.
Cropland	Lands covered with temporary crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems). Note that perennial woody crops are classified as forest or shrubland.
Barren lands	Barren or sparsely vegetated (bare soil and rocks) are lands with exposed soil, sand or rocks, with less than 10% vegetation cover throughout the year.
Settlements	Land covered by buildings and other man-made structures.
Wetland	Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present either in salt, brackish, or fresh water.

Note: For more definitions, please see <http://earthobservatory.nasa.gov/Experiments/Biome/vocabulary.php>.

³ <https://lpdaac.usgs.gov/products/mcd12q1v006/>, accessed on 05.06.2020.

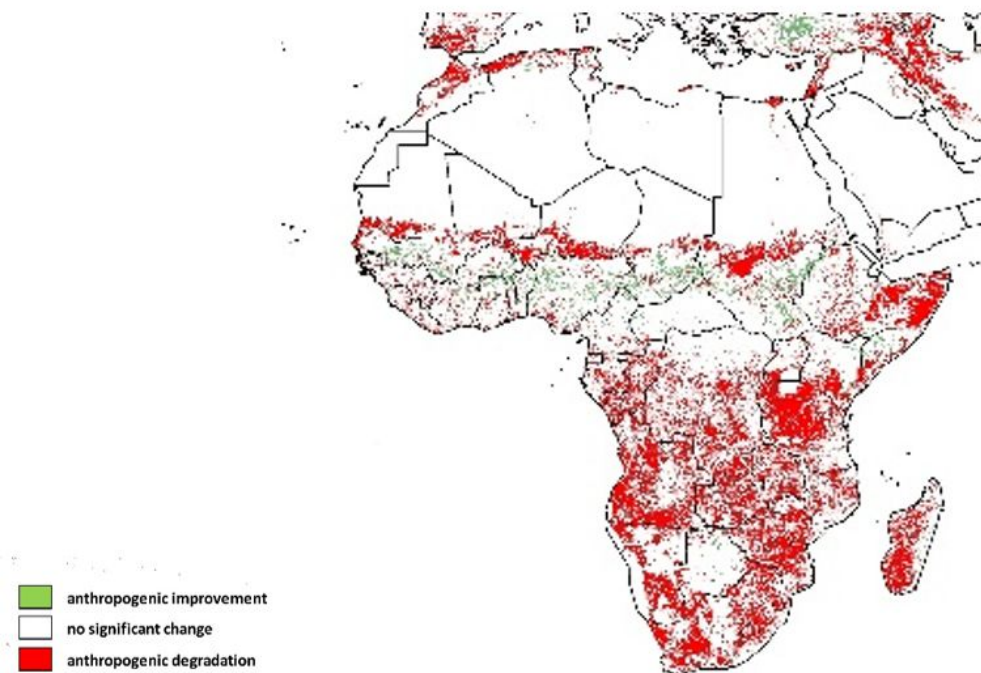
Figure 4: Annual changes in land use and land cover in the Sahel region (base year is 2001 = 1)



Notes: See Box 2 for the definition of these biomes. Despite high resolution of pixel size (25 hectares), this MODIS LUC database underrepresents cropped areas due to usually small farm sizes across the Sahel and frequent interspersions of cropped areas within larger biomes.

Source: based on MODIS LUC database (at 500 meters' resolution); Friedl et al. (2019).

Figure 5: The extent of land degradation and improvement in Africa and the Sahel



Source: Le et al. (2016).

The analysis done by Le et al. (2016) identified a mixture of land degradation and land improvement over the Sahel region with a clear pattern of land degradation at the edges of the Sahara Desert (the Sahelian bioclimatic zone) and more spread out land improvement in the southern parts of the region (Sudanian bioclimatic zone) (Figure 5). Analysis of land degradation, based on vegetation trends, showed that highest levels of land degradation occurred over grasslands (Table 4). On aggregate, the annual costs of land degradation in the Sahel region are estimated to be close to an equivalent of 20 billion USD annually in terms of lost ecosystem services from land. On the positive side, each dollar invested into land restoration and rehabilitation in the region was estimated to yield, on average, about 5 dollars of returns within a 30-year period (Nkonya et al., 2016).

Loss of vegetative cover due to land degradation, particularly in the northern parts of the Sahel region, is intensifying dust storms with considerable negative impacts on human health (Adamou et al., 2020: Niger case study). Although the origin of dust and sandstorms in the region is predominantly natural (coming from the Sahara Desert), assessments show that human activities are further amplifying these dust and sandstorms (Mirzabaev et al., 2019).

Tab 3: Area of vegetation-based land degradation by land use and land cover (km²) between 1980s and early 2000s, and annual cost of land degradation (billion USD 2007)

Country	Cropland	Mosaic vegetation-crop	Forested land	Mosaic forest-shrub/Grass	Shrub land	Grassland	Sparse vegetation	Annual cost of land degradation
Senegal	9280 (13%)	9216 (20%)	1920 (8%)	1088 (12%)	1344 (3%)	2112 (20%)	1408 (36%)	0.4
Mauritania	768 (13%)	7872 (39%)	N/A	11648 (46%)	0 (0%)	56960 (52%)	8832 (32%)	0.3
Mali	5824 (5%)	9152 (12%)	192 (2%)	8832 (19%)	3648 (4%)	48192 (34%)	7872 (22%)	2.2
Burkina Faso	7104 (6%)	4544 (7%)	128 (5%)	2176 (11%)	2496 (6%)	3200 (19%)	1216 (13%)	1.8
Niger	3328 (21%)	12800 (49%)	64 (100%)	8000 (49%)	0 (0%)	138176 (55%)	4992 (17%)	0.8
Nigeria	12160 (4%)	14784 (10%)	20736 (11%)	1728 (7%)	9984 (5%)	9216 (18%)	640 (21%)	5.2
Chad	5440 (5%)	3840 (5%)	3392 (6%)	5504 (8%)	4992 (4%)	41920 (33%)	2688 (13%)	2.4
Sudan	26624 (17%)	41472 (26%)	5696 (4%)	49664 (16%)	17344 (6%)	108608 (43%)	25408 (23%)	1.7
Eritrea	320 (7%)	448 (5%)	N/A	2304 (18%)	192 (25%)	1216 (6%)	3264 (12%)	0.2
Ethiopia	35904 (18%)	30976 (19%)	9984 (16%)	59776 (27%)	37824 (20%)	7808 (14%)	45888 (32%)	4.3

(Le et al., 2016; Gebreselassie et al., 2016; Mussa et al., 2016; Sow et al., 2016; Nkonya et al., 2016)

The key drivers of land degradation are population growth leading to increased demand for food and fuelwood (cf. all the case studies indicated in Box 1). Poor agro-sylvo-pastoral practices, such as the slash-and-burn system, land tenure insecurity, as well as lack of access to markets, extension services, and credit are also important drivers of land degradation in diverse settings across the region (Moussa et al., 2016; Sow et al., 2016; Gebreselassie et al., 2016; Nkonya et al., 2016). Mono-cropping of cash crops (especially cotton) in several Western African countries has led to depletion of soil fertility and secondary soil salinization (Sylla et al., 2020: Burkina Faso case study; Coulibaly, 2020: Mali case study).

Low productivity associated with subsistence farming has led to soil fertility mining and soil degradation in many parts of the Sahel. This has also brought about a more rapid expansion of cropping to marginal lands with fragile soils (Ogunlela and Ogunbile, 2006), leading to new cycles of land degradation, exacerbating conflict dynamics such as intense competition over land and water resources between pastoralists and sedentary farmers (Olayide, 2020: Nigeria case study; Admassie and Abebaw, 2020: Ethiopia case study).

4 Energy supply and use

Populations in the Sahel region use a wide range of energy sources including fuelwood, charcoal, liquefied petroleum gas (LPG), electricity generated using both fossil fuels and modern renewable energy sources, primarily hydro- and solar power. However, fuelwood represents a predominant share of the total energy use across the region (Table 4) (cf. all the case studies indicated in Box 1). The energy transition trajectories in the Sahel are closely following the “energy stacking” paradigm, where traditional biomass is heavily relied on even when access to other sources of energy is slowly expanding. The access to electricity in the region varies substantially, but remains low overall (Table 4). Extensive use of traditional biomass for cooking is resulting in major health issues through indoor air pollution, particularly for women and children. Growing use of fossil fuels is also rapidly increasing the air pollution in the Sahel’s major cities.

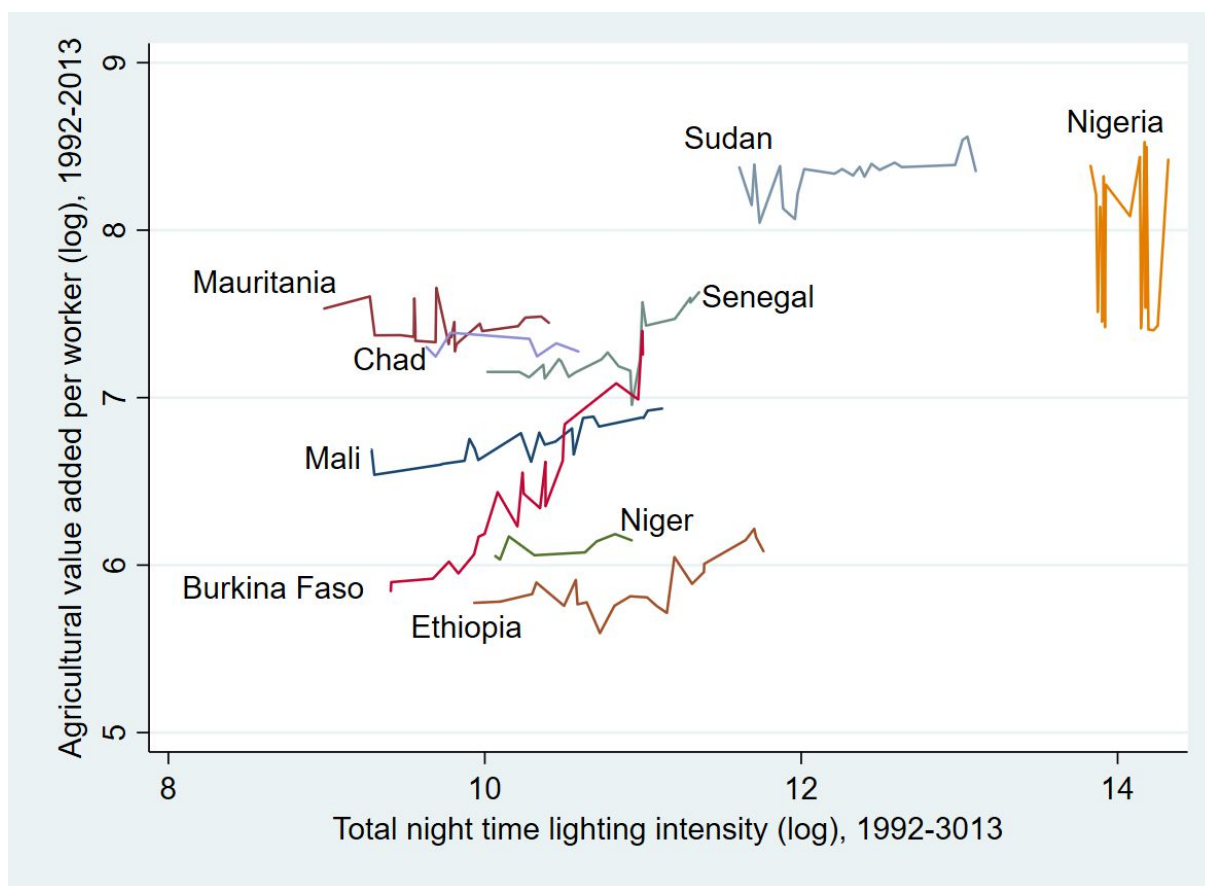
Tab 4: Energy profile of the Sahel region

Country	Share of biomass in energy supply (%)	Access to electricity (% of the population, 2018)	Access to electricity in rural areas (% of the rural population, 2018)	Share of population with access to clean cooking (%)
Senegal	57	67	44	31
Mauritania	60	45	1	50
Mali	76	51	25	<5
Burkina Faso	80	14	5	15
Niger	78	18	12	9
Nigeria	82	57	31	9
Chad	93	12	3	6
Sudan	78	60	47	45
South Sudan	>95	28	24	<5
Eritrea	80	50	35	<5

(World Bank Open Data, <https://data.worldbank.org/>, accessed on 10.06.2020)

Remotely sensed satellite data on night-time lighting intensity, which is a good proxy for electricity access, shows substantial improvements across the region since the 1990s (Figure 6). Particularly high rates of electricity expansion are observed in Ethiopia, Mali, Senegal and Sudan. However, growing electricity access rates were not always accompanied by a similarly fast growth in agricultural labor productivity. Only in Burkina Faso, Mali and Ethiopia agricultural labor productivity grew in tandem with expanding access to electricity. One reason for this is that despite of the expansion of electricity access, there is still a considerable gap in electricity access in rural areas (Table 4).

Figure 6: Dynamics of access to electricity (horizontal, with night-time lighting intensity as proxy) and agricultural value added per worker (vertical)



S

Source: NOAA - Version 4 DMS-OLS Nighttime Lights Time Series⁴, FAOSTAT⁵.

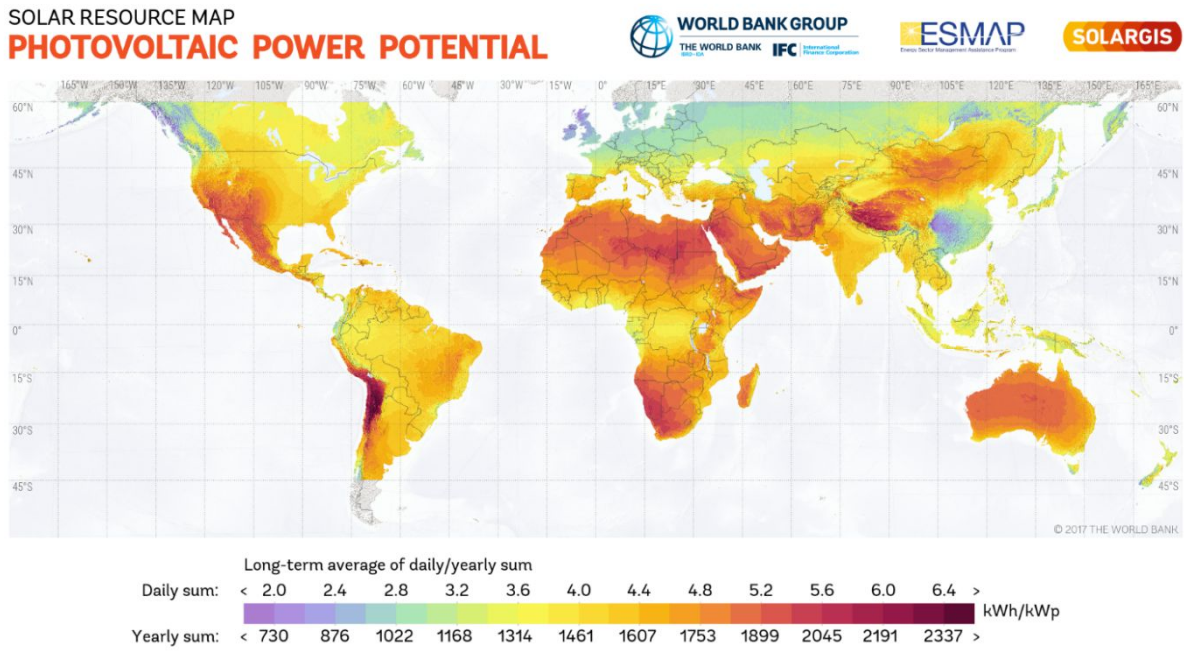
Most of the electricity access is concentrated in capital cities and other urban areas, hence, the access rates to electricity in rural areas are significantly lower. Often the quality of electricity access in many of those areas with grid connection is highly unreliable. Many electricity utilities in the region are not viable without heavy government subsidies despite growing electricity prices charged to consumers (Sylla et al., 2020: Burkina Faso case study; Adamou et al., 2020: Niger case study). This is due to losses in transmission, distribution and bill collection, as well as overstaffing of public electricity utilities (Trimble et al., 2016).

The Sahel region has substantial potential for renewable energy production, particularly through harvesting solar energy (Figure 6). In many locations across the region, the use of renewable energy sources as part of decentralized local grids can be less costly than electricity-generation using fossil fuels. Moreover, a large-scale installation of wind and solar farms in the Sahara Desert was even projected to create a positive climate feedback through increased surface friction and reduced albedo, doubling precipitation over the neighbouring Sahel region with resulting increases in vegetation (Li et al., 2018). Renewable energy development can also create substantial employment generation opportunities in the Sahel region. In fact, many governments across Africa identify the renewable energy sector as the major action area for creating “green jobs”. This particularly concerns year-round employment generation for young people in the agricultural sector (Malabo-Montpellier Panel, 2019).

⁴ <https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html>, accessed on 01.02.2020

⁵ <http://www.fao.org/faostat/en/>, accessed on 01.02.2020

Figure 7: Solar power potential across the world and the Sahel region



This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit <http://globalsolaratlas.info>.

Source: World Bank, ESMAP, Solargis, <https://globalsolaratlas.info>, accessed on 04.05.2020.

The expansion of decentralized mini-grid installations based on renewable energy sources could be a cost-effective solution for providing access to clean energy for remote communities. Despite this potential, current levels of use of clean renewable energy in the region are very low. The adoption of renewable energy-based technologies by people suffering from poverty is particularly low due to their limited financial resources. Indeed, wealthier households use more modern and cleaner appliances such as improved stoves for cooking needs. In contrast, poor and rural households use more biomass (wood and charcoal) to meet their cooking needs. Other factors include the lack of a financial framework to promote access to renewable energy, and the poor access to information on credit to access renewable energy (Faye et al., 2020: Senegal case study; Sylla et al., 2020: Burkina Faso case study; Ali and Mohamad, 2020: Sudan case study). As indicated earlier, insecurity in the region is one of the key development challenges hampering long-term planning and progress on essential development, including climate action.

In the recent past, there were also high hopes regarding the expansion of cultivation of energy crops for biofuels (e.g. jatropha). However, biofuel production in many countries of the region did not develop successfully because of the vulnerability to fluctuating oil prices as well as low yields of grains which have compromised the cost effectiveness of entire value chains (Mirzabaev et al., 2015).

5 Climate change

Climate change has become one of the major development challenges in the Sahel region. The effects of climate change are highly pronounced in the Sahelian countries due to their high vulnerability and low adaptive capacities. Even in terms of the exposure to climate change, the Sahel region has an inherently variable climate with long cyclical periods of wet and dry weather. In the past, a wet period was identified between 1940-1970 and a dry period between 1971-2000 (Lebel and Ali, 2009; Lodoun et al., 2013). Consequently, the 1970s and 1980s were marked as the now infamous drought episodes in the Sahel, which claimed the lives of millions of people through hunger and malnutrition (Mahoo et al., 2013).

In more recent years, most of the region has recorded precipitation recovery. However, these precipitation amounts are lower than during the previous wet period (Sylla et al., 2016). In addition, precipitation has intensified and led to extreme precipitation events frequently causing floods (Nka et al., 2015; Panthou et al., 2018; Tazen et al., 2018). The increase in surface flow despite the relative drop in precipitation (Mahé et al., 2005), called the 'Sahelian paradox', is a phenomenon that has been observed in many watersheds in the region (Sylla et al., 2020: Burkina Faso case study; Adamou et al., 2020: Niger case study). To illustrate, Burkina Faso experienced three flooding events per year during the period of 1986-2016, increasing to five flooding events per year since 2000 (Tazen et al., 2018). Flooding also contributed to soil erosion as well as to the loss of human and animal life. In Niger, flooding affected 1.7 million people between 1999 and 2015 (Fiorillo et al., 2018). These climatic changes caused crop yield and production losses of about 10–20% for millet and 5–15% for sorghum in West Africa (Sultan et al., 2019).

Even during the current relatively wet period across the Sahel, short-term drought spells are frequent. Rainfall is also increasingly becoming erratic compared to past long-term averages. In Ethiopia, rainy seasons are contracting, reducing the amount of seasonal rain available for crop production (Funk et al., 2012). Droughts, coupled with irregular and unreliable rainfall, have significant impacts on food security through their effects on crop yields and livestock productivity as well as their indirect effects on food prices, asset depletions, malnutrition and migration (Admassie and Abebaw, 2020: Ethiopia case study). Even today, drought, along with conflicts, remains a key driver of food insecurity across the Sahel region. Droughts are frequently accompanied by other hazards. For example, in 2009, the drought in Niger was compounded by locust infestation, leading to approximately 805 million USD of losses, which corresponded to 30% of the GDP of Niger (World Bank, 2017).

The vulnerability to climate change is also reflected in migration in West Africa. Water stress often leads to internal migration and conflict between farmers and pastoralists (Olayide, 2020: Niger case study). Conflicts constrain pastoralists' mobility and affect agricultural production and market access by disrupting supply routes. Droughts in Nigeria were shown to have triggered conflicts over the distribution of water and posed major challenges for water handling and management (Olayemi, 2016). Anyadike (2009) also reported that drought related conflicts resulted in the death of over 200,000 people and the displacement of more than two million people in Nigeria. In addition, recent scientific studies are pointing out several other related scenarios, including how climate change or climate variability and development challenges amplify the risks to a country's peacefulness by acting as a threat multiplier. These empirical findings suggest that climate change can induce adverse impact on resource availability (i.e. natural resources) and resource governance mechanisms, especially by exacerbating competition over resources (Diffenbaugh & Burke, 2019). Poverty and economic shocks, which are the main drivers of conflicts, are also climate change sensitive (Oppenheimer et al., 2015).

Projected climatic changes for the Sahel point at the intensification of warming all over the region and substantial increases in dry spell length and more frequent intense precipitation events (Sylla et al., 2016). In many northern sections of the Sahel, precipitation is projected to decrease, while some increases are projected for the southern parts of the Sahel. Droughts and floods are forecast to increase in intensity and frequency. Heatwaves and heat stress are projected to substantially increase

in future climates to reach dangerous risk levels for human health but also for agriculture and water resources (Russo et al., 2016; Sylla et al., 2018). As a consequence, substantial yield losses in maize, millet and sorghum are projected in 1.5°C and 2°C global warming scenarios even under higher fertilizer use (Faye et al., 2019). Tesfaye et al. (2015) showed that the number of food insecure people in Ethiopia alone could increase by up to 2.4 million people by 2050 as a result of the impact of climate change. The climate change effects on human health are manifested through climate-sensitive diseases, food and waterborne illnesses. The diarrheal disease rate is high across the Sahel region due to lack of improved sanitation facilities and related hygiene measures. Higher temperatures and elevated flood risks under climate change may enhance pathogen transmission and increase waterborne diseases (Mellor et al., 2016). In terms of water resources under future climates, projections reveal an increased risk of water deficit (10%-40% of decrease of water availability) in most river basins, and particularly in the Volta river basin (30%-60% of decrease) under 1.5°C and 2°C global warming scenarios (Sylla et al., 2018) and will amplify insecurity and competition in the region. Land fisheries are affected by increasing temperatures, more saline water and deoxygenation of lakes, harming fish reproduction, survivability, and virility.

6 Solutions: technologies, infrastructures, institutions and policies

There are a considerable number of technologies and practices that can be used for the sustainable intensification of agricultural productivity in the Sahel region. Major socioeconomic solutions, policy options, and sustainable land and water management technologies consistently highlighted in all of the case studies, are discussed below. A key aspect of these response options is their cross-cutting impacts affecting sustainable land management (SLM) and climate change adaptation simultaneously, often also with strong implications for energy supply and use. At the beginning of this paper, it was highlighted that SLM and climate change adaptation can serve as guiding frameworks for regional development, agricultural growth and employment creation in the Sahel. These response options discussed below embody concrete entry points of action to promote SLM, climate change adaptation and improved supply and access to energy.

6.1 Socio-economic, infrastructural and policy solutions

There are many socio-economic, institutional, and policy solutions, such as livelihood diversification, securing land tenure, improving access to credit and markets, community collective action, and infrastructure development, etc. that could promote SLM and facilitate climate change adaptation in dryland areas around the world, including in the Sahel region (Mirzabaev et al., 2019).

Access to markets, including input, output, and credit markets, was found to increase the income and consumption of households suffering from poverty (McDemott et al., 2015). In a similar vein, Grosh et al. (2008) highlighted the role of **social safety nets** in increasing the livelihoods of households, who in addition to suffering from poverty are exposed to climate shocks. Their study showed that income redistribution policies in favor of households suffering from poverty increase their investment capacity and enable them to cope with unexpected shocks. Particularly, well designed public works programs promote environmental conservation while at the same time creating jobs, improving infrastructure, and empowering people suffering from poverty, including women and youth (Sakketa and von Braun, 2019). According to Yang (2006), Yang and Choi (2007) and Arezki and Bruckner (2012), **remittances** provide private insurance against negative shocks for households in developing countries. Remittances complement households' income deficit when the domestic financial sector is inefficient (Admassie and Abebaw, 2020: Ethiopia case study) and also play an important role for intra-seasonal consumption smoothing (Adamou et al., 2020: Niger case study). **Improved access to crop and livestock insurance** could help smoothen risks and shocks from extreme weather events (Olayide, 2020: Nigeria case study).

Infrastructure development. Expanding access to energy in the Sahel region does not need to exclusively come from extending centralized electricity grids. The use of decentralized mini-grids, based on solar, wind and mini-hydropower could provide an alternative and viable option for providing access to electricity in remote rural areas of the region (Malabo-Montpellier, Panel 2019; Coulibaly, 2020: Mali case study). Policy options and instruments to facilitate the expansion of access to electricity and other sources of clean energy, such as biogas, which were successfully implemented in several countries in Africa are: setting energy sector development targets and providing targeted programmatic support to achieve those objectives (e.g. in Ethiopia), and the liberalization of the energy sector combined with incentives for private power producers (e.g. in Senegal) (Malabo-Montpellier Panel, 2019). Improving market access would require **investments into transportation infrastructures** (roads, railroads, ports, etc.). Such investments into transportation infrastructures may have significant multiplier effects for job creation, rural development and reducing poverty. Most of the countries of the Sahel are affected by economic water scarcity, despite sufficient physical availability of water resources. Hence, overcoming this economic water scarcity requires **investments**

into water infrastructures (not only for irrigation, but also for safe potable water access and sanitation in rural areas) (Sylla et al., 2020: Burkina Faso case study).

Promoting land tenure security. Land tenure insecurity is a major hindrance for investments into sustainable land management in the Sahel (e.g. Adamou et al., 2020: Niger case study). The Sahelian countries have diverse land tenure regimes with frequently overlapping or conflicting tenure rights. For example, in Senegal, access to land in rural areas is governed by the law on the National Domain (1964). Under this law, farmers are not owners of their land (Faye et al., 2020: Senegal case study). Nkonya et al. (2016) point out that when farmers do not own the land they cultivate; they have no incentive to safeguard its quality.

Off-farm job creation. Off-farm livelihood diversification strategies increase the resilience of rural households against land degradation and extreme weather events, such as droughts (Admassie and Abebaw, 2020: Ethiopia case study). Moreover, it can provide the funds to invest into SLM (Mirzabaev et al 2019). Access to non-agricultural employment is especially important for poorer pastoral households as their small herd sizes make them less resilient to droughts (Lybbert et al., 2004). Government action is needed to increase access to off-farm jobs especially for women and marginalized social groups who often lack education and social networks.

Collective action at the village level strengthens the resilience strategies of members and reduces their level of vulnerability (Diop et al., 2010; Diouf, 2014). The work of Diop et al. (2010) highlighted the various initiatives of local communities for the diversification of agricultural practices and sources of income. Thus, they have shown that collective action can facilitate crop diversification with the introduction of new crops. Community led actions in the region also include household drinking water supply (Sylla et al., 2020: Burkina Faso case study), building farm ponds for supplemental irrigation and livestock, crops diversification, development of soil and water conservation techniques (Coulibaly, 2020: Mali case study), cereal banks, delimitation and development of pastoral areas (e.g. see Admassie and Abebaw, 2020: Ethiopia case study), control of bush fires and uncontrolled logging; delimitation and monitoring of village forests (cf. the case studies). Resorting to the social capital embedded in centuries-old social, religious and cultural links between neighbouring countries (such as transhumant herders) in the region is also vital for both the sustainable use of natural resources and the restoring of peace in conflict zones. For instance, the populations from the border areas of Mali and Mauritania have maintained strong political, religious, economic and social ties (such as blood ties and marital alliances) which enabled both to utilize border areas for trade, and provided access to fodder and water for livestock herding by the nomadic Mauritanian herders on the Mali side. However, the outbreak of the Mali crisis has changed this situation making transhumant routes in the region more difficult. As a result, border trade has weakened and conflicts are occurring more frequently between the two countries (Bodian et al., 2020).

Carbon trading refers to the selling and buying of reductions in greenhouse gas emissions, called carbon credits (Gueye, 2019). The mechanism allows developed countries to buy emission reduction from developing countries or invest in emissions reduction projects in those countries (Gueye, 2019). It constitutes the main channel through which developing countries such as those in the Sahel region participate in the international carbon markets. Nevertheless, carbon trading approaches remain extremely underutilized in the region (Admassie and Abebaw, 2020: Ethiopia case study; Faye et al., 2020: Senegal case study). The cooperative approaches under Articles 6.2-6.3 of the Paris Agreement as well as the sustainable development mechanism under Articles 6.4-6.7 could be employed by the Sahelian countries for participating in the international carbon trading. The additional revenues earned could thus be spent for promoting sustainable development of the region (Faye et al., 2020: Senegal case study). However, this requires adjusting the national legislation and regulations in order to create adequate conditions for potential investors.

Promoting regional collaboration is needed to enhance broad-based solutions to ensure sustainable peace in the region. The drivers and consequences of conflicts in the region are complex and interconnected, which is why regional collaboration and innovative solutions are needed to address

these multifaceted challenges while balancing security and development priorities. This in turn depends on the strength of state institutions and governance structures, which are often weak in the region. Therefore, addressing the problems of structural governance is key in aligning and reorienting international interventions for development, jobs and food security. This would be effective by involving a variety of actors and sectors in meeting the needs and aligning with the priorities of local communities. This also suggests that addressing the insecurity in the region and advancing development outcomes require integrated development interventions and regional solutions in a coordinated manner among governments, international development partners and other actors. In addition, responses to climate change and land degradation restoration measures need to be “conflict-sensitive” and should not result in generating new tensions (Olayide, 2020: Nigeria case study).

6.2 Technological solutions

Expanding irrigation is an essential climate change and climate variability adaptation strategy to secure farmers’ livelihoods and their food security in semi-arid zones of the Sahel region (van Wesenbeeck et al., 2014; Sanfo et al., 2017). The extent of irrigated areas in the region is expanding, but nevertheless remains limited. Irrigation extension potential is sensitive to irrigation costs and crop prices (Xie et al., 2014). The growth of irrigation investments needs to be considered in the wider context of productivity increases (Coulibaly, 2020: Mali case study), rural development (Xie et al., 2017), and urbanization (Barbier et al., 2011). Expanding irrigation in the Sahel region requires close collaboration between farmers, the private sector and governments, with support measures ranging from tax cuts for importing irrigation equipment and technologies to capacity building and extension for farmers (Malabo-Montpellier Panel, 2018a; Admassie and Abebaw, 2020: Ethiopia case study). Needless to say, regulations for water use in agriculture are needed to avoid negative ecological consequences, such as overuse of water (Malabo-Montpellier Panel, 2018a). Surface irrigation is the most widespread form of irrigation in the region, with low but slowly growing levels of more water-efficient irrigation applications such as sprinkle and drip irrigation. Sprinkler and drip irrigation are more water-efficient and also frequently lead to higher crop yields than surface irrigation (Diouf et al., 2018). Key barriers for wider adoption of sprinkler and drip irrigation technologies are high upfront costs, skill requirements and in certain locations low water quality. Often, irrigation is made possible in the Sahel by **rainwater harvesting** in impluviums, ponds, sand dams, micro-catchments, and underground tanks (Fox et al., 2005; Sanfo et al., 2017; Adamou et al., 2020: Niger case study). Depending on topography, the main techniques of rainwater harvesting are: trays arrangement (Half-moons, Nardi Trenches, Benches), slope arrangement (Manual trenches, Filtering dykes), landscaping of glacis (Stony cords, Filtering dykes, Zaï), and development of the lowlands (Thresholds for water spreading, Micro-dams) (Sylla et al., 2020: Burkina Faso case study). **Sustainable use of groundwaters for irrigation** is a hitherto under-tapped source for irrigation expansion in the Sahel. For improved synergies, groundwater use for irrigation can be combined with the deployment of solar panels which could provide electricity for both groundwater pumping and for other rural household and business needs (Faye et al., 2020: Senegal case study).

Crop diversification is a wide-spread strategy used by smallholder farmers to mitigate agricultural risks at farm level (Sylla et al., 2020: Burkina Faso case study; Admassie and Abebaw, 2020: Ethiopia case study). Poverty and lack of financial resources often prevent Sahelian farmers from subscribing to crop insurance schemes. To cope with climate hazards, farmers have developed various crop diversification strategies (Lawin and Tamini, 2017), such as intercropping, catch crops, relay cropping, diversified crop rotations and improved fallow (Pereira, 2017; Tittonell and Giller, 2013). Catch cropping consist of the cultivation between two main annual crops while relay cropping consists of growing two crops of different species on the same plot, the second crop being planted just before the harvest of the first crop. Crop diversification is often combined with expanding irrigation, allowing to grow vegetables, irrigated rice and other commercial crops (Faye et al., 2020: Senegal case study). Mono-cropping of cotton practiced in several countries in the region is falling short of enhancing the well-being of smallholder farmers (Coulibali, 2020: Mali case study). In addition, mono-cropping’s contribution to

rural livelihoods is hampered by high per unit costs of production (FAO, 2014; Gautam and Andersen, 2016). The poor access to agricultural inputs, credit and equipment are important obstacles to crop diversification in those countries with strong mono-cropping legacies, such as Mali. Mono-cropping results in soil degradation and causes declines in production of the main cash and food crops (cotton, maize, millet, sorghum) and livestock (Sylla et al., 2020: Burkina Faso case study). The outcomes are often lower income, food insecurity and poverty among smallholder farmers and herders.

Agricultural mechanization has important potential to increase output and improve agricultural incomes and thus contribute to sustainable economic growth and transformation (Malabo-Montpellier, Panel 2018b). Its relationship with land degradation and agricultural mechanization is complex. On the one hand, the use of heavy agricultural machinery can lead to soil compaction. Excessive tillage, particularly in such dryland environments, often results in soil erosion. On the other hand, improved agricultural productivity and profitability can allow to invest more funds in sustainable land management measures. Currently, access to agricultural machinery in the Sahel remains very low. Less than 5% of the households in the region have access to tractors, while the major types of farm implements remain light tools such as cutlasses, hoes, and axes. Moreover, not all farming households use farm animal power (Kirui, 2019). Although individual ownership of agricultural machinery is currently prevalent across the Sahel countries, mainly among large-scale farmers, there are important opportunities in developing leasing services and setting up rural business for providing mechanization services (ploughing, land levelling). The potential for mechanization is not just limited to tractors (Malabo-Montpellier Panel, 2018b). Entire agricultural value chains across the Sahel region will benefit from mechanization, with more emphasis on post-harvest and processing technologies helping to reduce significant shares of food loss occurring due to a lack of processing and post-harvest management (Malabo-Montpellier Panel, 2018b). Thus, mechanization of the food sector in the Sahel can be a source of job creation and not necessarily come at the cost of job losses. The impact of agricultural mechanization also varies depending on the local context. Higher agricultural mechanization rates were associated with higher agricultural growth rates in Ethiopia, Mali, and Niger, while they did not lead to higher agricultural growth in Burkina Faso, Senegal, and Sudan (Malabo-Montpellier Panel, 2018b).

Adoption of drought resistant crop cultivars is another climate change adaptation strategy with low but slowly increasing adoption rates in the region. Research and crop breeding organizations across the Sahelian countries regularly churn out an impressive array of drought-resistant and early maturing varieties of crop cultivars. However, many factors such as a lack of farmer participation in breeding, high costs, and elevated demands for fertilizers are impeding wider adoption of drought-resistant varieties in many areas in the Sahel (Adamou et al., 2020: Niger case study).

Conservation agriculture involving minimum tillage, maintenance of crop residues and appropriate crop rotations is a drought-smart sustainable land management (D-SLM) technology with important potential in the region. Competition with livestock feeding for crop residues, a lack of direct seeding machinery, and also a lack of knowledge about conservation agriculture benefits are major obstacles for the adoption of conservation agriculture practices. In many other settings across the world, a key advantage of conservation agriculture were fuel savings. Low levels of mechanization in the region often make conservation agriculture a profitable proposition mostly for large-scale farms. Moreover, weed management requirements under conservation agriculture relying on chemical herbicides further limit the immediate spread of this technology in the region. Still, in some parts of the region, e.g. Burkina Faso, farmers have a long history of practicing conservation agriculture-based technologies under rainfed conditions (e.g. reduced tillage, soil cover by crops or residues, crop diversification) (Sop et al., 2012; Zougmore et al., 2000; Sylla et al., 2020: Burkina Faso case study). Kassie et al. (2009) have shown that the adoption of conservation agriculture practices increased crop productivity in Tigray, Ethiopia (Admassie and Abebaw, 2020: Ethiopia case study). Despite its economic and environmental benefits, the number of analyses of farmer-level costs and benefits of conservation agriculture in the Sahel region is still limited.

Agroforestry is the integration of trees in agriculture systems (Bayala et al., 2002). It is an approach that aims to achieve high levels of productivity by harnessing ecosystem services provided by trees (Kuyah et al., 2019), while at the same time contributing to climate change adaptation and mitigation. Agroforestry is one of the examples of technologies that have been successfully used for soil and water conservation across the Sahel region. It can improve yield depending on the tree species (Sawadogo, 2011). In the northern part of Burkina Faso, farmers manage (protect and regenerate) trees on their farms as a source of food, fuelwood and traditional medicine (Sawadogo et al., 2001). Trees in agroforestry parklands enhance soil fertility as greater yields have been observed around trees like *Faidherbia albida*. As a form of agroforestry, defensive living hedges are used to fight against cattle wandering and human incursions into fields and market gardens but also to delimit plots to avoid land conflicts (Sylla et al., 2020: Burkina Faso case study). Assisted natural regeneration initiatives were promoted in many countries in the Sahel with mixed results. Although preserved trees play important roles in agricultural systems, they can also exert a competition for growth resources on associated staple food crops in the Sahelian zone where the quality of soils is poor and rainfall is low. Studies have been conducted on the interactions between the agroforestry of fruit trees and crops in Burkina Faso. For instance, studies by Bayala et al. (2002) in the country showed that under the canopies of Shea butter tree (*Vitellaria paradoxa*) and African locust bean (*Parkia biglobosa*) the productivity of local sorghum (in terms of grain yield) was reduced by 50 to 70%, respectively, compared to the farms where there were no trees. This result indicates that the practice of agroforestry can have a negative effect on the productivity of some crops depending on the tree species and their management.

Rotational grazing in rangelands contributes to their sustainable use and helps to avoid overgrazing. According to Kagone (2001), the use of rotational grazing could increase the carrying capacity during the rainy season maintaining a high quality of re-growths. Rotational grazing is also practiced through distant transhumant pastoralism in the region, but often only when nearby pastures are already overgrazed (Olayide, 2020: Nigeria case study). However, tensions are becoming more frequent due to an imbalance between agricultural and pastoral areas, semi-subsistence livestock raising and larger-scale commercial livestock fattening operations, and often result in deadly conflicts. Other practices for sustainable rangeland and livestock management include the **supplementary feeding of breeding ewes, mineral supplementation, lamb and kid fattening and the seeding of pastures with forage legumes and grasses to improve their botanical composition and condition.**

Addressing invasive bush encroachment involves actions that help prevent the encroachment of invasive tree and shrub species in savannas, which suppress palatable plant species (e.g herbaceous plants) (Ward, 2005). Bush encroachment control consists of shifting plant communities dominated by trees species (e.g. woodland, tree savanna) by herbaceous vegetation to create a favorable habitat for grazers (Angassa and Oba, 2008). In the savanna ecosystems of Burkina Faso, different bush control methods such as hand removal of trees, use of fire (Zida et al., 2007), tree harvesting coupled with fire and grazing (Sawadogo et al., 2005, 2002), and fire combined with grazing (Sawadogo et al., 2005) are often used to increase the production of herbaceous species and their diversity. Several other bush encroachment control techniques were also identified, such as tree cutting, staining and uprooting (MEECC, 2014).

Afforestation and reforestation activities are not new in the Sahel region, but in fact were carried out at various scales since the 1930s. In the past, afforestation and reforestation actions were primarily done through government forestry departments. Over time they have become increasingly carried out in a more "participatory" way involving local communities. For this reason, the Sahelian countries have designed a large number of policies and strategies, particularly the African Union (AU) strategy on the Great Green Wall (GGW), to address land degradation, enhance agricultural productivity, and adapt to the changing climate. The GGW is a colossal flagship effort that aims to restore degraded ecosystems by planting locally suitable native trees and grasses stretching coast to coast across the Sahel. The total length of the GGW was estimated to reach 8,000 km from West Africa to the Horn of Africa and the planned width varies between 100 and 200 km. Originally a tree planting initiative, the program has

evolved into Africa's response to climate change and a broader development programming tool (Sacande, 2008).

6.3 Evaluation of existing major policies and investments

The Sahelian countries have a wide range of national programs and policies aimed at increasing agricultural growth and environmental sustainability in order to achieve the SDGs (cf. all the case studies indicated in Box 1). Some of these national strategies are outcomes of international processes and are hence applied in all countries of the region. This specifically concerns national climate change adaptation plans (NAP), the Intended Nationally Determined Contribution to climate change mitigation (INDC), and action programs to combat desertification and safeguard biodiversity, i.e. under the three so called Rio Conventions of the United Nations. Moreover, the Comprehensive Africa Agriculture Development Program (CAADP) under the auspices of the African Union is another initiative adhered to and applied by all countries of the region, which commits the individual countries to increasing government spending on agriculture to match 10% of their GDP by 2020. Most countries of the region also have poverty reduction strategies to guide their national activities and their collaboration with the World Bank and International Monetary Fund. National drought preparedness policies are also found in most countries of the region and frequently frame the countries' collaborations with UNCCD and WMO.

Each country also has more specific sectoral strategies, particularly on agriculture (crop and livestock), energy, and forestry. The major purpose of the national policies in the agricultural sector is to enhance production, productivity and competitiveness of food and cash crops. This often involves providing access to markets, agricultural services and inputs, improving value chains and post-harvest processing, as well as capacity building and development (cf. all the case studies indicated in Box 1). To illustrate, the Agricultural Growth Program in Ethiopia pursues strategies to raise agricultural productivity and production by enhancing market performance and aiding value addition. The implementation of the two phases of this program in Ethiopia highlighted the key role played by the activities on linking farmers to markets and farmer training centers. At the same time, the program faced considerable challenges in terms of poor quality of market infrastructures and a lack of locally suited agricultural technologies (Admassie and Abebaw, 2020: Ethiopia case study). Similarly, Burkina Faso's National Program for Land Management had the objective of reducing poverty and boosting agricultural growth through sustainable land and water management. However, the success of this program was considerably limited due to difficulties related to resolving issues of land tenure insecurity (Sylla et al., 2020: Burkina Faso).

There are several cross-cutting lessons coming from the diverse experiences of policy formulation and implementation in the Sahel. For country after country, the lack of access to credit and capital is emerging as one of the key hindrances to agricultural development in the region. Agricultural development programs require increased and more effective public and private partnerships as well as the active participation of a wide range of stakeholders. Lack of engagement of all relevant stakeholders early on in the designing process of many programs was found to be a limiting factor in the implementation of many programs in the region, for example the Climate Resilient Green Economy Strategy in Ethiopia (Admassie and Abebaw, 2020: Ethiopia case study). To be successful, these programs need to be conceived and driven by stakeholder interactions. The predominance of national funding for the core elements of these programs is critical for their sustainability. Currently, many national strategies are underfunded and lack in implementation. Often, this is an outcome of over-ambitious planning which is intrinsically linked to a high reliance on uncertain development funding by the international community.

Many conflicts across the region are also hindering the successful implementation of these programs and preventing long-term investments into rural development. Addressing these conflicts and their root causes is a critical element for the success of development policies (e.g. see Olayide, 2020: Nigeria case study). There are many interconnections, i.e. synergies and trade-offs, between policies on

climate change, land, water and energy. Available synergies across these sectors need to be used to reduce investment costs. Lower investment costs will increase the chances of successful implementation of the programs. Many national policies set out with hugely ambitious scopes and timelines. Often, they fail to achieve their purposes because the intended funding for these programs does not fully materialize (e.g. see Faye et al., 2020: Senegal case study). A lack of monitoring and evaluation systems was suggested to be a major hindrance to the full implementation of the Niger's Socio-economic Development Policy (2012-2015). Finally, improving political stability, investing in monitoring and evaluation, and increasing government effectiveness are found to be other prerequisites for improving policy implementation in the region (cf. all the case studies indicated in Box 1).

7 Conclusions

Climate variability and change, land degradation, lack of access to energy, instability and associated challenges continue to hinder sustainable development in the Sahel region, including efforts to reduce poverty and ensure food security. Thus, most immediate action needs to involve measures to address conflicts and enhance drought preparedness and resilience. Efforts to address development challenges such as climate change and land degradation need to be “conflict-sensitive” and should not result in generating new tensions. There is a need for locally driven recommendations which provide a basis for engaging in evidence-based actions for SLM, climate change adaptation, peace and development in the region. This includes promoting numerous regionally tested climate change adaptation and SLM technologies and practices, creating enabling institutional and policy environments for their adoption, as well as making use of indigenous conflict resolution mechanisms and supporting the participation of women and youth in key economic activities. SLM, climate change adaptation, and renewable energy expansion are the highest return areas for investments toward achieving SDGs. Investments into soft and hard infrastructures can provide substantial multiplicative effects for job creation and economic growth in the region. Improving policy formulation and implementation can be achieved by setting achievable objectives with guaranteed (mostly own) funding and accompanying the policy implementation with strong monitoring and evaluation. It is important not to lose sight of these critical issues for regional development in the post-COVID world, since investments into these areas may be undermined by the COVID-19 pandemic, as resources and priorities may be shifted away from these crucial development arenas in the Sahel region.

8 Agenda for applied research

The national case studies, regional cross-cutting analysis and stakeholder consultations during the virtual workshop highlighted that for attaining **the overall goal of prosperous, food and nutrition secure and peaceful Sahel**, policy and action-oriented research is needed on the **following specific objectives**:

- 1) Identifying and harnessing the synergies across the land-water-energy-food security nexus in order to promote agricultural growth, rural development and job creation, particularly for youth and women;
- 2) Accelerating climate change adaptation and building resilience against extreme weather events, particularly droughts. Developing mechanisms for the use of climate change mitigation measures to generate revenues through tapping into international carbon trading;
- 3) Examining how conflict risks are affected and exacerbated by human and environmental stressors (and vice-versa) and understanding the strengths and weaknesses of the current, including indigenous, conflict resolution mechanisms;
- 4) Exploring the impacts of investing into soft and hard infrastructures on economic growth and employment generation;
- 5) Improving policy formulation, monitoring and implementation.

Realizing these objectives requires investments into accompanying research and technical support, as well as into improving human and institutional capacities in the region. There are five key strategic areas where development investments could generate substantial multiplicative effects and high returns for achieving the objectives stated above. These areas and the more specific actions they include are summarized below in the form of five work packages.

Work package 1. Harnessing the synergies of the land-water-energy-food nexus

- 1.1. Assessment of synergies and trade-offs across the land-water-energy-food nexus in the Sahel region for agricultural intensification and rural development;
- 1.2. Integrated water-land-energy use modelling for optimal spatial allocation of investments in sustainable agricultural intensification;
- 1.3. Evaluation of decentralized energy solutions and centralized grid access for post-harvest processing and rural employment;
- 1.4. Spatially explicit modelling of land restoration impacts on sustainable development and their distributional effects on different socio-economic groups;
- 1.5. Analysis of the impacts of improved adoption of agricultural innovations, including potential trade-offs, synergies and impacts on agricultural labor markets, poverty reduction and food security.

Work package 2. Climate change adaptation and carbon trading

- 2.1. Analysis of observed impacts of climate change and extreme weather events and assessment of their economic and social costs in the Sahel region;
- 2.2. Creation of a toolbox of climate-smart technological, institutional and policy solutions;
- 2.3. Foresight modelling of future climate risks as an interaction of hazards, exposure and vulnerability in the Sahel;

- 2.4. Investments into drought risk mitigation: Modelling of drought risk reduction and adaptation using the options from the solutions toolbox under 2.2.;
- 2.5. Elaboration of effective mechanisms for carbon trading through land restoration and rehabilitation activities.

Work package 3. Conflicts and insecurity

- 3.1. Collate data on ecological, economic and political stresses on peace in the Sahel region;
- 3.2. Analyse drivers and impacts of conflicts in the Sahel region;
- 3.3. Analyse the strengths and weaknesses of the current, including indigenous, conflict resolution mechanisms;
- 3.4. Test alternative conflict resolution mechanisms through field experiments and focus group discussions.

Work package 4. Generating jobs and green growth by investing in soft and hard infrastructures

- 4.1. Ex post and ex ante assessments of the impact of infrastructural investments on economic growth and job creation in the Sahel region:
 - Soft infrastructure (vocational training, health care, and other public services),
 - Hard infrastructure (roads, railways, mobile phone and internet networks);
- 4.2. Support the design of national schemes to strengthen the symbiotic linkages between rural areas and secondary towns through investments into infrastructure and public services. Secondary towns are increasing rapidly in the region and represent a considerable potential for local employment to the rural youth.

Work package 5. Enhancing policy implementation

- 5.1. Policy implementation research: evaluating barriers and opportunities for enhancing policy formulation, implementation and monitoring;
- 5.2. Development of effective analytical and monitoring tools that countries can use for improved policy implementation.

9 References

- Admassie, A., & Abebaw, D. (2020). Ethiopia – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 198.
- Aladejana, O.O., Salami, A.T., & Adetoro, O.O. (2018). Hydrological responses to land degradation in the Northwest Benin Owena River Basin, Nigeria. *J. Environ. Manage.*, 225, 300–312, <https://doi.org/10.1016/j.jenvman.2018.07.095>.
- Angassa, A., & Oba, G. (2008). Effects of management and time on mechanisms of bush encroachment in southern Ethiopia. *African J Ecol*, 46, 186–196. <https://doi.org/10.1111/j.1365-2028.2007.00832.x>.
- Anyadike, R.N.C. (2009). Climate Change and Sustainable Development in Nigeria: Conceptual and Empirical Issues. African Institute for Applied Economics, Enugu Forum Policy Paper 10. (Accessed on January 21, 2020). Available at: <https://media.africaportal.org/documents/Polycypaper10.pdf>
- Arezki, R., & Brückner, M. (2012). Commodity Windfalls, Democracy and External Debt. *The Economic Journal*, 122(561), 848–66.
- Barbier, B., Ouedraogo, H., Dembélé, Y., Yacouba, H., Barry, B., & Jamin, J.Y. (2011). L'agriculture irriguée dans le Sahel ouest-africain. *Cah Agric*, 20(8), 1-2.
- Bayala, J.; Teklehaimanot, Z., & Ouedraogo, S.J. (2002). Millet production under pruned tree crowns in a parkland system in Burkina Faso. *Agroforestry Systems*, 54, 203–214. <https://doi.org/10.1023/A:1016058906682>.
- Bodian M., Tobie, A., & Marending, M. (2020). The Challenges of Governance, Development and Security in the Central Regions of Mali. SIPRI Insights on Peace and Security, No. 2020/4.
- Brandt, M., Mbow, C., Diouf, A.A., Verger, A., Samimi, C., & Fensholt, R. (2015). Ground- and satellite-based evidence of the biophysical mechanisms behind the greening Sahel. *Glob. Chang. Biol.*, 21, 1610-1620. <https://doi.org/10.1111/gcb.12807>.
- CILSS (2016). Landscapes of West Africa – A Window on a Changing World. U.S. Geological Survey EROS, Sioux Falls, United States.
- Coulibaly, O. (2020). Mali – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 199.
- Deutsche Welle (2019). Germany ponders bigger troop mandate in Africa's Sahel. (Accessed on January 6, 2021). Available at: <https://www.dw.com/en/germany-ponders-bigger-troop-mandate-in-africas-sahel/a-51828723>
- Diffenbaugh, N.S., & Burke, M. (2019). Global warming has increased global economic inequality. *Proceedings of the National Academy of Sciences*, 116(20), 9808-9813.
- Diop, M., Diop, N., & Diouf, B.L. (2010). Savoirs Endogènes et Changements Climatiques Chez Les Communautés de Pêche Du Sénégal. IDCR.
- Diouf, B., Lo, H.M., Dieye, B., Sane, O., & Sarr, O.F. (2014). Pour Une Agriculture Intelligente Face Au Changement Climatique Au Sénégal: Recueil de Bonnes Pratiques d'adaptation et d'atténuation. Program de Recherche Du CGIAR Sur Le Changement Climatique, l'Agriculture et La Sécurité Alimentaire.
- Diouf, M., Ndiaye, S., Diedhiou, I., & Diaw, E.H. (2018). Comparing Methods of Water Use by Irrigation in the Horticultural Hydro System of the Niayes, Senegal. *Journal of Chemical, Biological and Physical Sciences*, 8(4).
- FAO (2014). The State of Food and Agriculture. Innovation in Family Farming. Food Agriculture Organization of the United Nations, Rome.

- Faye A., Dièye, M., Diakhaté, P.B., Bèye, A., Sall, M., Diop, M. (2020). Senegal - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 202.
- Faye, A., Noblet, M., Camara, I., & Mboup, S.D. (2019). Evaluation de La Vulnérabilité Du Secteur Agricole à La Variabilité et Aux Changements Climatiques Dans La Région de Fatick (Sénégal). Senegal.
- Fiorillo, E., Crisci, A., Issa, H., Maracchi, G., Morabito, M., & Tarchiani, V. (2018). Recent Changes of Floods and Related Impacts in Niger Based on the ANADIA Niger Flood Database. *Climate*, 6, 59.
- Friedl, M., & Sulla-Menashe, D. (2019). MCD12Q1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V006 [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2020-11-06 from <https://doi.org/10.5067/MODIS/MCD12Q1.006>
- Funk, C., Rowland, J., Eilerts, G., Kebebe, E., Biru, N., White, L., & Galu, G. (2012). A climate trend analysis of Ethiopia. U.S. Geological Survey Fact Sheet, 2012-3053, p 6.
- Gautam, Y., & Andersen, P. (2016). Rural livelihood diversification and household well-being: Insights from Humla, Nepal. *Journal of Rural Studies*, 44, 239–249. <http://doi.org/10.1016/j.jrurstud.2016.02.001>
- Gebreselassie, S., Kirui, O.K., & Mirzabaev, A. (2016). Economics of Land Degradation and Improvement in Ethiopia. In: Nkonya, E., Mirzabaev, A., & von Braun, J. (eds). *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*. Springer, Cham. https://doi.org/10.1007/978-3-319-19168-3_14.
- Grosh, M., del Ninno, C., Tesliuc, E., & Ouerghi, A. (2008). For Protection and Promotion: The Design and Implementation of Effective Safety Nets. The International Bank for Reconstruction and Development. World Bank, Washington, D.C.
- Gueye, F. (2019). Carbon Market in West Africa Economic and Monetary (Waemu) Countries.
- Hiernaux, P., Ayantundeb, A., Kalilou, A., Mougina, E., Gérarde, B., Baupa, F., Grippaa, M., & Djabyf, B. (2009). Trends in productivity of crops, fallow and rangelands in Southwest Niger: Impact of land use, management and variable rainfall. *J. Hydrol.*, 375, 65–77. <https://doi.org/10.1016/j.jhydrol.2009.01.032>.
- Kagone, H. (2001). Sustainable management of grazed ecosystem in the North-Sudanian zone of Burkina Faso [WWW Document]. (Accessed on July 12, 2019). Available at: <http://agris.fao.org/agris-search/search.do?recordID=BE2001000713>
- Kassie, M., Zikhali, P., Manjur, K., & Edwards, S. (2009). Adoption of sustainable agricultural practices: Evidence from a semi-arid region of Ethiopia. *Natural Resources Forum*, 33, 189-198.
- Kirui, O. (2019). The Agricultural Mechanization in Africa: Micro-Level Analysis of State Drivers and Effects. ZEF-Discussion Papers on Development Policy, 272. <http://dx.doi.org/10.2139/ssrn.3368103>.
- Kuyah, S., Whitney, C.W., Jonsson, M., Sileshi, G.W., Öborn, I., Muthuri, C.W., & Luedeling, E. (2019). Agroforestry delivers a win-win solution for ecosystem services in sub-Saharan Africa. A meta-analysis. *Agron. Sustain. Dev.*, 39, 47. <https://doi.org/10.1007/s13593-019-0589-8>.
- Lawin, K.G., & Tamini, L.D. (2017). Risk preferences and crop diversification amongst smallholder farmers in Burkina Faso Paper prepared for presentation at the 2017 Canadian Agricultural Economics Society (CAES) Annual meeting - Montreal, 18-21 June, 2017 2, 18–21.
- Le, Q.B., Nkonya, E., & Mirzabaev, A. (2016). Biomass productivity-based mapping of global land degradation hotspots. In: Nkonya, E., Mirzabaev, A., & von Braun, J. (eds.). *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*. Springer International Publishing, Cham, Switzerland, pp. 55–84.
- Lebel, T., & Ali, A. (2009). Recent Trends in the Central and Western Sahel Rainfall Regime (1990-2007). *Journal of Hydrology*, 375, 52-64.

- Leroux, L., Bégué, A., Lo Seen, D., Jolivot, A., & Kayitakire, F. (2017). Driving forces of recent vegetation changes in the Sahel: Lessons learned from regional and local level analyses. *Remote Sens. Environ.*, 191, 38–54. <https://doi.org/10.1016/j.rse.2017.01.014>.
- Li, Y., Kalnay, E., Motescharrei, S., Rivas, J., Kucharski, F., & Kirk-Davidoff, D. (2018). Climate model shows large-scale wind and solar farms in the Sahara increase rain and vegetation. *Science*, 361, 1019-1022. <https://doi.org/10.1126/science.aar5629>.
- Lodoun, T., Giannini, A., Traore, P.S., Some, L., Sanon, M., Vaksman, M., & Rasolodimby, J.M. (2013). Changes in seasonal descriptors of precipitation in Burkina Faso associated with late 20th century drought and recovery in West Africa. *Environ. Dev.*, 5, 96–108.
- Lybbert, T.J., Barrett, C.B., Desta, S., & Layne Coppock, D. (2004). Stochastic wealth dynamics and risk management among a poor population. *Econ. J.*, 114, 750-777. <https://doi.org/10.1111/j.1468-0297.2004.00242.x>.
- Mahé, G., Patuel, J., Servat, E., Conway, D., & Dezetter, A. (2005). The impact of land use change on soil water holding capacity and river flow modelling in the Nakambe River, Burkina-Faso, *Journal of Hydrology*, 300(1-4), 33-43.
- Mahoo, H., Radeny, M., Kinyangi, J., & Cramer, L. (2013). Climate change vulnerability and risk assessment of agriculture and food security in Ethiopia: Which way forward? CCAFS Working Paper, 59. CGIAR Research Program on Climate Change, Agriculture and Food Security (CAAFS). Copenhagen, Denmark. (Accessed on January 6, 2021). Available at: www.ccafs.cgiar.org.
- Malabo-Montpellier Panel (2018a). WATER-WISE: Smart Irrigation Strategies for Africa. https://www.mamopanel.org/media/uploads/files/Irrigation_report_FINAL_ONLINE.pdf.
- Malabo-Montpellier Panel (2018b). MECHANIZED: Transforming Africa's Agriculture Value Chains. https://www.mamopanel.org/media/uploads/files/full_report.pdf.
- Malabo-Montpellier Panel (2019). ENERGIZED: Policy innovations to power the transformation of Africa's agriculture and food system. https://www.mamopanel.org/media/uploads/files/ENERGIZED_Report.pdf.
- McDemott, T., Lopez-Urbe, M.P., & Castells-Quintane, D. (2015). Coping with Climate Risk: The Role of Institutions, Governance and Finance in Private Adaptation Decisions of the Poor. *Knowledge Hub*, 52.
- MEECC (2015). Cinquieme rapport national du Burkina Faso, à la conférence des parties à la convention sur la diversité biologique.
- Mellor, J.E., Levy, K., Zimmerman, J., Elliott, M., Bartram, J., Carlton, E., Clasen, T., Dillingham, R., Eisenberg, J., Guerrant, R., Lantagne, D., Mihelcic, J., & Nelson, K. (2016). Planning for climate change: the need for mechanistic systems-based approaches to study climate change impacts on diarrheal diseases. *Science of the Total Environment*, 548-549(Suppl. C), 82–90. <https://doi.org/10.1016/j.scitotenv.2015.12.087>.
- Mirzabaev, A., Guta, D., Goedecke, J., Gaur, V., Börner, J., Virchow, D., Denich, M., & von Braun, J. (2015). Bioenergy, food security and poverty reduction: trade-offs and synergies along the water–energy–food security nexus. *Water International*, 40(5-6), 772-790.
- Mirzabaev, A., Wu, J., Evans, J., García-Oliva, F., Hussein, I.A.G., Iqbal, M.H., Kimutai, J., Knowles, T., Meza, F., Nedjraoui, D., Tena, F., Türkeş, M., Vázquez, R.J., & Weltz, M. (2019). Desertification. In: Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., & Malley, J. (eds.). *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. In press
- Moussa, B., Nkonya, E., Meyer, S., Kato, E., Johnson, T., & Hawkins, J. (2016). Economics of Land Degradation and Improvement in Niger. In: Nkonya, E., Mirzabaev, A., & von Braun, J. (eds).

- Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer, Cham. https://doi.org/10.1007/978-3-319-19168-3_17.
- Nka, B.N., Oudin, L., Karambiri, H., Paturel, J.E., & Ribstein, P. (2015). Trends in floods in West Africa: analysis based on 11 catchments in the region, *Hydrol. Earth Syst. Sci.*, 19, 4707–4719. <https://doi.org/10.5194/hess-19-4707-2015>.
- Nkonya, E., Johnson, T., Kwon, H.Y., & Kato, E. (2016). Economics of Land Degradation in Sub-Saharan Africa. In: Nkonya, E., Mirzabaev, A., & von Braun, J. (eds). Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer, Cham. https://doi.org/10.1007/978-3-319-19168-3_9
- Ogunlela, V., & Ogunbile, A.O. (2006). Alleviating rural poverty in Nigeria: A challenge for National agricultural research system. *Journal of Food Agriculture and Environment*, 6, 3-4.
- Olayemi, S.O. (2016). Challenges of a Changing Climate and the Industrial Sector Experience: A Review of Evidence in Nigeria. *Global Journal of Arts, Humanities and Social Sciences*, 4(11), 1-11.
- Olayide, O.E. (2020). Nigeria - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 201.
- Olsson, L., Barbosa, H., Bhadwal, S., Cowie, A., Delusca, K., Flores-Renteria, D., Hermans, K., Jobbagy, E., Kurz, W., Li, D., Sonwa, D.J., & Stringer, L. (2019). Land Degradation. In: Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., & Malley, J. (eds.). *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. In press
- Oppenheimer, M., Campos, M., Warren, R., Birkmann, J., Luber, G., O'Neill, B., & Hsiang, S. (2015). Emergent risks and key vulnerabilities. In *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects*, 1039-1100. Cambridge University Press.
- Osman, A.K., & Mohamed, A. (2020). Sudan - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 203.
- Panthou, G., Lebel, T., Viscel, T., Quantin, G., Sane, Y., Ba, A., Ndiaye, O. Diongue-Niang, A., & Diopkane, M. (2018). Rainfall intensification in tropical semi-arid regions: the Sahelian case. *Environ. Res. Lett.* 13(6). <https://doi.org/10.1088/1748-9326/aac334>.
- Pereira, L. (2017). Climate Change Impacts on Agriculture across Africa. <https://doi.org/10.1093/acrefore/9780199389414.013.292>.
- Rabani, A., Boubacar, I., Bonkaney, A.L., Seyni, A., Mamoudou, I., & Nassourou, B. (2020). Niger – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 200.
- Russo, S., Marchese, A.F., Sillmann, J., & Immé, G. (2016). When will unusual heat waves become normal in a warming Africa? *Environ. Res. Lett.* 11(5). <http://dx.doi.org/10.1088/1748-9326/11/5/054016>.
- Sacande, M. (2018). Action Against Desertification, Land Restoration. Food and Agriculture Organization of the United Nations, Rome, Italy.
- Sakketa, T.G., & von Braun, J. (2019). Labor-intensive public works programs in sub-Saharan Africa: Experiences and implications for employment policies. ZEF Working Paper 180.
- Salehyan, I., Hendrix, C.S., Hamner, J., Case, C., Linebarger, C., Stull, E., & Williams, J. (2012). Social Conflict in Africa: A New Database, *International Interactions*, 38(4), 503-511. <https://doi.org/10.1080/03050629.2012.697426>
- Sanfo, S., Barbier, B., Dabiré, I.W.P., Vlek, P.L.G., Fonta, W.M., Ibrahim, B., & Barry, B. (2017). Rainfall variability adaptation strategies: An ex-ante assessment of supplemental irrigation from farm

- ponds in southern Burkina Faso. *Agricultural Systems*, 152, 80-89.
<https://doi.org/10.1016/j.agsy.2016.12.011>.
- Sawadogo, H. (2011). Using soil and water conservation techniques to rehabilitate degraded lands in north-western Burkina Faso. *International Journal of Agricultural Sustainability*, 9, 120-128.
<https://doi.org/10.3763/ijas.2010.0552>
- Sawadogo, H., Hien, F., Sohero, A., & Kambou, F. (2001). Pits for trees: how farmers in semi-arid Burkina Faso increase and diversify plant biomass. In: Reij, C., & Waters-Bayer, A. (eds). *Farmer Innovators in Africa*, Earthscan Publications Ltd, 35-46.
- Sawadogo, L., Nygard, R., & Pallo, F. (2002). Effects of livestock and prescribed fire on coppice growth after selective cutting of Sudanian savannah in Burkina Faso. *Ann. For. Sci.* 59, 185-195.
<https://doi.org/10.1051/forest:2002005>.
- Sawadogo, L., Tiveau, D., & Nygard, R. (2005). Influence of selective tree cutting, livestock and prescribed fire on herbaceous biomass in the savannah woodlands of Burkina Faso, West Africa. *Agriculture, Ecosystems & Environment*, 105, 335-345.
- Smith, P., Nkem, J., Calvin, K., Campbell, D., Cherubini, F., Grassi, G., Korotkov, V., Hoang, A.L., Lwasa, S., McElwee, P., Nkonya, E., Saigusa, N., Soussana, J.F., & Taboada, M.A. (2019). Interlinkages Between Desertification, Land Degradation, Food Security and Greenhouse Gas Fluxes: Synergies, Trade-offs and Integrated Response Options. In: Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., & Malley, J. (eds.). *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. In press.
- Sop, T.K., Kagambèga, F.W., Bellefontaine, R., Schmiedel, U., & Thiombiano, A. (2012). Effects of organic amendment on early growth performance of *Jatropha curcas* L. on a severely degraded site in the Sub-Sahel of Burkina Faso. *Agroforestry Systems*, 86, 387-399.
<https://doi.org/10.1007/s10457-011-9421-4>.
- Sow, S., Nkonya E., Meyer, S., & Kato, E. (2016). Cost, Drivers and Action Against Land Degradation in Senegal. In: Nkonya, E., Mirzabaev, A., & von Braun, J. (eds). *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*. Springer, Cham.
https://doi.org/10.1007/978-3-319-19168-3_19
- Sultan, B., Defrance, D., & Iizumi, T. (2019). Evidence of crop production losses in West Africa due to historical global warming in two crop models. *Sci Rep*, 9. <https://doi.org/10.1038/s41598-019-49167-0>.
- Sylla, M.B., Faye, A., Giorgi, F., Diedhiou, A., & Kunstmann, H. (2018). Projected heat stress under 1.5°C and 2°C global warming scenarios creates unprecedented discomfort for humans in West Africa. *Earth's Future*, 6, 1029-1044. <https://doi.org/10.1029/2018EF000873>.
- Sylla M.B.; Elguindi, N.; Giorgi, F. and Wissler, D. (2016). Projected Robust Shift of Climate Zones over West Africa in Response to Anthropogenic Climate Change for the Late 21st Century. *Climatic Change*, 134, 241-253. <https://doi.org/10.1007/s10584-015-1522-z>.
- Sylla, M.B., Dimobe, K., & Sanfo, S. (2020). Burkina Faso - Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security. ZEF Working Paper 197.
- Tazen, F., Diarra, A., Kabore, R.F.W., Ibrahim, B., Traoré, M.B., Traoré, K., & Karambiri, H. (2019). Trends in flood events and their relationship to extreme rainfall in an urban area of Sahelian West Africa: The case study of Ouagadougou, Burkina Faso. *Journal of Flood Risk Management*, 12.
<https://doi.org/10.1111/jfr3.12507>.
- Tesfaye, Y., Roos, A., Campbell, B.J., & Bohlin, F. (2012). Factors associated with the performance of user groups in a participatory forest management around Dodola forest in the Bale Mountains, Southern Ethiopia. *Journal of Development Studies*, 48(11), 1665-1682.

- Thomas, N., & Nigam, S. (2018). 20th century climate change over Africa: Seasonal hydroclimate trends and Sahara Desert expansion. *J. Clim.*, 31, 3349–3370. <https://doi.org/10.1175/JCLI-D-17-0187.1>.
- Tittonell, P., & Giller, K.E. (2013). When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*, 143, 76–90. <https://doi.org/10.1016/j.fcr.2012.10.007>.
- Trimble, C., Kojima, M., Perez Arroyo, I., & Mohammadzadeh, F. (2016). Financial Viability of Electricity Sectors in Sub-Saharan Africa: Quasi-Fiscal Deficits and Hidden Costs. Policy Research Working Paper, 7788. World Bank, Washington, DC. United States. <https://openknowledge.worldbank.org/handle/10986/24869> License: CC BY 3.0 IGO
- UNDP. (2019). Human Development Report 2019: Human Development for Everyone. New York: UNDP.
- United Nations Convention to Combat Desertification (UNCCD). (2019). The Global Land Outlook, West Africa Thematic Report. Bonn, Germany.
- Van Wesenbeeck, C.F.A., Venus, V., Keyzer, M.A., Wesselman, B., & Asare Kye, D. (2014). Development of a horticulture production chain in Western Africa: a case study of tomatoes in Burkina Faso and Ghana.
- Ward, D. (2005). Do we understand the causes of bush encroachment in African savannas? *African Journal of Range and Forage Science*, 22, 101-105.
- World Bank (2017). Republic of Niger, Priorities for ending poverty and boosting shared prosperity: systematic country diagnostic. 115661-NE, 126.
- Xie, H., You, L., & Takeshima, H. (2017). Invest in small-scale irrigated agriculture: A national assessment on potential to expand small-scale irrigation in Nigeria. *Agricultural Water Management*, 193, 251-264.
- Xie, H., You, L., Wielgosz, B., & Ringler, C. (2014). Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. *Agric. Water Manag*, 131, 183-193.
- Yang, D. (2006). Coping with Disaster: The Impact of Hurricanes on International Financial Flows, 1970-2002. *The B.E. Journal of Economic Analysis & Policy*, De Gruyter, 8(1), 1-45.
- Yang, D., & Choi, H. (2007). Are Remittances Insurance? Evidence from Rainfall Shocks in the Philippines. *The World Bank Economic Review*, 21(2), 219-48.
- Zida, D., Sawadogo, L., Tigabu, M., Tiveau, D., & Oden, P-C. (2007). Dynamics of sapling population in savanna woodlands of Burkina Faso subjected to grazing, early fire and selective tree cutting for a decade. *Forest Ecology and Management*, 243, 102–115. <https://doi.org/10.1016/j.foreco.2007.02.013>.
- Zougmore, R., Guillobez, S., Kambou, N.F., & Son, G. (2000). Runoff and sorghum performance as affected by the spacing of stone lines in the semiarid Sahelian zone. *Soil and Tillage Research*, 56, 175–183. [https://doi.org/10.1016/S0167-1987\(00\)00137-9](https://doi.org/10.1016/S0167-1987(00)00137-9).

1. Evers, Hans-Dieter and Solvay Gerke (2005). Closing the Digital Divide: Southeast Asia's Path Towards a Knowledge Society.
2. Bhuiyan, Shajahan and Hans-Dieter Evers (2005). Social Capital and Sustainable Development: Theories and Concepts.
3. Schetter, Conrad (2005). Ethnicity and the Political Reconstruction of Afghanistan.
4. Kassahun, Samson (2005). Social Capital and Community Efficacy. In Poor Localities of Addis Ababa Ethiopia.
5. Fuest, Veronika (2005). Policies, Practices and Outcomes of Demand-oriented Community Water Supply in Ghana: The National Community Water and Sanitation Programme 1994 – 2004.
6. Menkhoff, Thomas and Hans-Dieter Evers (2005). Strategic Groups in a Knowledge Society: Knowledge Elites as Drivers of Biotechnology Development in Singapore.
7. Mollinga, Peter P. (2005). The Water Resources Policy Process in India: Centralisation, Polarisation and New Demands on Governance.
8. Evers, Hans-Dieter (2005). Wissen ist Macht: Experten als Strategische Gruppe.
- 8.a Evers, Hans-Dieter and Solvay Gerke (2005). Knowledge is Power: Experts as Strategic Group.
9. Fuest, Veronika (2005). Partnerschaft, Patronage oder Paternalismus? Eine empirische Analyse der Praxis universitärer Forschungsk Kooperation mit Entwicklungsländern.
10. Laube, Wolfram (2005). Promise and Perils of Water Reform: Perspectives from Northern Ghana.
11. Mollinga, Peter P. (2004). Sleeping with the Enemy: Dichotomies and Polarisation in Indian Policy Debates on the Environmental and Social Effects of Irrigation.
12. Wall, Caleb (2006). Knowledge for Development: Local and External Knowledge in Development Research.
13. Laube, Wolfram and Eva Youkhana (2006). Cultural, Socio-Economic and Political Constraints for Virtual Water Trade: Perspectives from the Volta Basin, West Africa.
14. Hornidge, Anna-Katharina (2006). Singapore: The Knowledge-Hub in the Straits of Malacca.
15. Evers, Hans-Dieter and Caleb Wall (2006). Knowledge Loss: Managing Local Knowledge in Rural Uzbekistan.
16. Youkhana, Eva; Lautze, J. and B. Barry (2006). Changing Interfaces in Volta Basin Water Management: Customary, National and Transboundary.
17. Evers, Hans-Dieter and Solvay Gerke (2006). The Strategic Importance of the Straits of Malacca for World Trade and Regional Development.
18. Hornidge, Anna-Katharina (2006). Defining Knowledge in Germany and Singapore: Do the Country-Specific Definitions of Knowledge Converge?
19. Mollinga, Peter M. (2007). Water Policy – Water Politics: Social Engineering and Strategic Action in Water Sector Reform.
20. Evers, Hans-Dieter and Anna-Katharina Hornidge (2007). Knowledge Hubs Along the Straits of Malacca.
21. Sultana, Nayeem (2007). Trans-National Identities, Modes of Networking and Integration in a Multi-Cultural Society. A Study of Migrant Bangladeshis in Peninsular Malaysia.
22. Yalcin, Resul and Peter M. Mollinga (2007). Institutional Transformation in Uzbekistan's Agricultural and Water Resources Administration: The Creation of a New Bureaucracy.
23. Menkhoff, T.; Loh, P. H. M.; Chua, S. B.; Evers, H.-D. and Chay Yue Wah (2007). Riau Vegetables for Singapore Consumers: A Collaborative Knowledge-Transfer Project Across the Straits of Malacca.
24. Evers, Hans-Dieter and Solvay Gerke (2007). Social and Cultural Dimensions of Market Expansion.
25. Obeng, G. Y.; Evers, H.-D.; Akuffo, F. O., Braimah, I. and A. Brew-Hammond (2007). Solar PV Rural Electrification and Energy-Poverty Assessment in Ghana: A Principal Component Analysis.

26. Eguavoen, Irit; E. Youkhana (2008). Small Towns Face Big Challenge. The Management of Piped Systems after the Water Sector Reform in Ghana.
27. Evers, Hans-Dieter (2008). Knowledge Hubs and Knowledge Clusters: Designing a Knowledge Architecture for Development
28. Ampomah, Ben Y.; Adjei, B. and E. Youkhana (2008). The Transboundary Water Resources Management Regime of the Volta Basin.
29. Saravanan.V.S.; McDonald, Geoffrey T. and Peter P. Mollinga (2008). Critical Review of Integrated Water Resources Management: Moving Beyond Polarised Discourse.
30. Laube, Wolfram; Awo, Martha and Benjamin Schraven (2008). Erratic Rains and Erratic Markets: Environmental change, economic globalisation and the expansion of shallow groundwater irrigation in West Africa.
31. Mollinga, Peter P. (2008). For a Political Sociology of Water Resources Management.
32. Hauck, Jennifer; Youkhana, Eva (2008). Histories of water and fisheries management in Northern Ghana.
33. Mollinga, Peter P. (2008). The Rational Organisation of Dissent. Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management.
34. Evers, Hans-Dieter; Gerke, Solvay (2009). Strategic Group Analysis.
35. Evers, Hans-Dieter; Benedikter, Simon (2009). Strategic Group Formation in the Mekong Delta - The Development of a Modern Hydraulic Society.
36. Obeng, George Yaw; Evers, Hans-Dieter (2009). Solar PV Rural Electrification and Energy-Poverty: A Review and Conceptual Framework With Reference to Ghana.
37. Scholtes, Fabian (2009). Analysing and explaining power in a capability perspective.
38. Eguavoen, Irit (2009). The Acquisition of Water Storage Facilities in the Abay River Basin, Ethiopia.
39. Hornidge, Anna-Katharina; Mehmood Ul Hassan; Mollinga, Peter P. (2009). 'Follow the Innovation' – A joint experimentation and learning approach to transdisciplinary innovation research.
40. Scholtes, Fabian (2009). How does moral knowledge matter in development practice, and how can it be researched?
41. Laube, Wolfram (2009). Creative Bureaucracy: Balancing power in irrigation administration in northern Ghana.
42. Laube, Wolfram (2009). Changing the Course of History? Implementing water reforms in Ghana and South Africa.
43. Scholtes, Fabian (2009). Status quo and prospects of smallholders in the Brazilian sugarcane and ethanol sector: Lessons for development and poverty reduction.
44. Evers, Hans-Dieter; Genschick, Sven; Schraven, Benjamin (2009). Constructing Epistemic Landscapes: Methods of GIS-Based Mapping.
45. Saravanan V.S. (2009). Integration of Policies in Framing Water Management Problem: Analysing Policy Processes using a Bayesian Network.
46. Saravanan V.S. (2009). Dancing to the Tune of Democracy: Agents Negotiating Power to Decentralise Water Management.
47. Huu, Pham Cong; Rhlrs, Eckart; Saravanan, V. Subramanian (2009). Dyke System Planing: Theory and Practice in Can Tho City, Vietnam.
48. Evers, Hans-Dieter; Bauer, Tatjana (2009). Emerging Epistemic Landscapes: Knowledge Clusters in Ho Chi Minh City and the Mekong Delta.
49. Reis, Nadine; Mollinga, Peter P. (2009). Microcredit for Rural Water Supply and Sanitation in the Mekong Delta. Policy implementation between the needs for clean water and 'beautiful latrines'.
50. Gerke, Solvay; Ehlert, Judith (2009). Local Knowledge as Strategic Resource: Fishery in the Seasonal Floodplains of the Mekong Delta, Vietnam
51. Schraven, Benjamin; Eguavoen, Irit; Manske, Günther (2009). Doctoral degrees for capacity development: Results from a survey among African BiGS-DR alumni.

52. Nguyen, Loan (2010). Legal Framework of the Water Sector in Vietnam.
53. Nguyen, Loan (2010). Problems of Law Enforcement in Vietnam. The Case of Wastewater Management in Can Tho City.
54. Oberkircher, Lisa et al. (2010). Rethinking Water Management in Khorezm, Uzbekistan. Concepts and Recommendations.
55. Waibel, Gabi (2010). State Management in Transition: Understanding Water Resources Management in Vietnam.
56. Saravanan V.S.; Mollinga, Peter P. (2010). Water Pollution and Human Health. Transdisciplinary Research on Risk Governance in a Complex Society.
57. Vormoor, Klaus (2010). Water Engineering, Agricultural Development and Socio-Economic Trends in the Mekong Delta, Vietnam.
58. Hornidge, Anna-Katharina; Kurfürst, Sandra (2010). Envisioning the Future, Conceptualising Public Space. Hanoi and Singapore Negotiating Spaces for Negotiation.
59. Mollinga, Peter P. (2010). Transdisciplinary Method for Water Pollution and Human Health Research.
60. Youkhana, Eva (2010). Gender and the development of handicraft production in rural Yucatán/Mexico.
61. Naz, Farhat; Saravanan V. Subramanian (2010). Water Management across Space and Time in India.
62. Evers, Hans-Dieter; Nordin, Ramli, Nienkemoer, Pamela (2010). Knowledge Cluster Formation in Peninsular Malaysia: The Emergence of an Epistemic Landscape.
63. Mehmood Ul Hassan; Hornidge, Anna-Katharina (2010). 'Follow the Innovation' – The second year of a joint experimentation and learning approach to transdisciplinary research in Uzbekistan.
64. Mollinga, Peter P. (2010). Boundary concepts for interdisciplinary analysis of irrigation water management in South Asia.
65. Noelle-Karimi, Christine (2006). Village Institutions in the Perception of National and International Actors in Afghanistan. **(Amu Darya Project Working Paper No. 1)**
66. Kuzmits, Bernd (2006). Cross-bordering Water Management in Central Asia. **(Amu Darya Project Working Paper No. 2)**
67. Schetter, Conrad; Glassner, Rainer; Karokhail, Masood (2006). Understanding Local Violence. Security Arrangements in Kandahar, Kunduz and Paktia. **(Amu Darya Project Working Paper No. 3)**
68. Shah, Usman (2007). Livelihoods in the Asqalan and Sufi-Qarayateem Canal Irrigation Systems in the Kunduz River Basin. **(Amu Darya Project Working Paper No. 4)**
69. ter Steege, Bernie (2007). Infrastructure and Water Distribution in the Asqalan and Sufi-Qarayateem Canal Irrigation Systems in the Kunduz River Basin. **(Amu Darya Project Working Paper No. 5)**
70. Mielke, Katja (2007). On The Concept of 'Village' in Northeastern Afghanistan. Explorations from Kunduz Province. **(Amu Darya Project Working Paper No. 6)**
71. Mielke, Katja; Glassner, Rainer; Schetter, Conrad; Yarash, Nasratullah (2007). Local Governance in Warsaj and Farkhar Districts. **(Amu Darya Project Working Paper No. 7)**
72. Meininghaus, Esther (2007). Legal Pluralism in Afghanistan. **(Amu Darya Project Working Paper No. 8)**
73. Yarash, Nasratullah; Smith, Paul; Mielke, Katja (2010). The fuel economy of mountain villages in Ishkamish and Burka (Northeast Afghanistan). Rural subsistence and urban marketing patterns. **(Amu Darya Project Working Paper No. 9)**
74. Oberkircher, Lisa (2011). 'Stay – We Will Serve You Plov!'. Puzzles and pitfalls of water research in rural Uzbekistan.
75. Shtaltovna, Anastasiya; Hornidge, Anna-Katharina; Mollinga, Peter P. (2011). The Reinvention of Agricultural Service Organisations in Uzbekistan – a Machine-Tractor Park in the Khorezm Region.
76. Stellmacher, Till; Grote, Ulrike (2011). Forest Coffee Certification in Ethiopia: Economic Boon or Ecological Bane?

77. Gatzweiler, Franz W.; Baumüller, Heike; Ladenburger, Christine; von Braun, Joachim (2011). Marginality. Addressing the roots causes of extreme poverty.
78. Mielke, Katja; Schetter, Conrad; Wilde, Andreas (2011). Dimensions of Social Order: Empirical Fact, Analytical Framework and Boundary Concept.
79. Yarash, Nasratullah; Mielke, Katja (2011). The Social Order of the Bazaar: Socio-economic embedding of Retail and Trade in Kunduz and Imam Sahib
80. Baumüller, Heike; Ladenburger, Christine; von Braun, Joachim (2011). Innovative business approaches for the reduction of extreme poverty and marginality?
81. Ziai, Aram (2011). Some reflections on the concept of 'development'.
82. Saravanan V.S., Mollinga, Peter P. (2011). The Environment and Human Health - An Agenda for Research.
83. Eguavoen, Irit; Tesfai, Weyni (2011). Rebuilding livelihoods after dam-induced relocation in Koga, Blue Nile basin, Ethiopia.
84. Eguavoen, I., Sisay Demeku Derib et al. (2011). Digging, damming or diverting? Small-scale irrigation in the Blue Nile basin, Ethiopia.
85. Genschick, Sven (2011). Pangasius at risk - Governance in farming and processing, and the role of different capital.
86. Quy-Hanh Nguyen, Hans-Dieter Evers (2011). Farmers as knowledge brokers: Analysing three cases from Vietnam's Mekong Delta.
87. Poos, Wolf Henrik (2011). The local governance of social security in rural Surkhondarya, Uzbekistan. Post-Soviet community, state and social order.
88. Graw, Valerie; Ladenburger, Christine (2012). Mapping Marginality Hotspots. Geographical Targeting for Poverty Reduction.
89. Gerke, Solvay; Evers, Hans-Dieter (2012). Looking East, looking West: Penang as a Knowledge Hub.
90. Turaeva, Rano (2012). Innovation policies in Uzbekistan: Path taken by ZEFa project on innovations in the sphere of agriculture.
91. Gleisberg-Gerber, Katrin (2012). Livelihoods and land management in the Ioba Province in south-western Burkina Faso.
92. Hiemenz, Ulrich (2012). The Politics of the Fight Against Food Price Volatility – Where do we stand and where are we heading?
93. Baumüller, Heike (2012). Facilitating agricultural technology adoption among the poor: The role of service delivery through mobile phones.
94. Akpabio, Emmanuel M.; Saravanan V.S. (2012). Water Supply and Sanitation Practices in Nigeria: Applying Local Ecological Knowledge to Understand Complexity.
95. Evers, Hans-Dieter; Nordin, Ramli (2012). The Symbolic Universe of Cyberjaya, Malaysia.
96. Akpabio, Emmanuel M. (2012). Water Supply and Sanitation Services Sector in Nigeria: The Policy Trend and Practice Constraints.
97. Boboyorov, Hafiz (2012). Masters and Networks of Knowledge Production and Transfer in the Cotton Sector of Southern Tajikistan.
98. Van Assche, Kristof; Hornidge, Anna-Katharina (2012). Knowledge in rural transitions - formal and informal underpinnings of land governance in Khorezm.
99. Eguavoen, Irit (2012). Blessing and destruction. Climate change and trajectories of blame in Northern Ghana.
100. Callo-Concha, Daniel; Gaiser, Thomas and Ewert, Frank (2012). Farming and cropping systems in the West African Sudanian Savanna. WASCAL research area: Northern Ghana, Southwest Burkina Faso and Northern Benin.
101. Sow, Papa (2012). Uncertainties and conflicting environmental adaptation strategies in the region of the Pink Lake, Senegal.

102. Tan, Siwei (2012). Reconsidering the Vietnamese development vision of “industrialisation and modernisation by 2020”.
103. Ziai, Aram (2012). Postcolonial perspectives on ‘development’.
104. Kelboro, Girma; Stellmacher, Till (2012). Contesting the National Park theorem? Governance and land use in Nech Sar National Park, Ethiopia.
105. Kotsila, Panagiota (2012). “Health is gold”: Institutional structures and the realities of health access in the Mekong Delta, Vietnam.
106. Mandler, Andreas (2013). Knowledge and Governance Arrangements in Agricultural Production: Negotiating Access to Arable Land in Zarafshan Valley, Tajikistan.
107. Tsegai, Daniel; McBain, Florence; Tischbein, Bernhard (2013). Water, sanitation and hygiene: the missing link with agriculture.
108. Pangaribowo, Evita Hanie; Gerber, Nicolas; Torero, Maximo (2013). Food and Nutrition Security Indicators: A Review.
109. von Braun, Joachim; Gerber, Nicolas; Mirzabaev, Alisher; Nkonya Ephraim (2013). The Economics of Land Degradation.
110. Stellmacher, Till (2013). Local forest governance in Ethiopia: Between legal pluralism and livelihood realities.
111. Evers, Hans-Dieter; Purwaningrum, Farah (2013). Japanese Automobile Conglomerates in Indonesia: Knowledge Transfer within an Industrial Cluster in the Jakarta Metropolitan Area.
112. Waibel, Gabi; Benedikter, Simon (2013). The formation water user groups in a nexus of central directives and local administration in the Mekong Delta, Vietnam.
113. Ayaribilla Akudugu, Jonas; Laube, Wolfram (2013). Implementing Local Economic Development in Ghana: Multiple Actors and Rationalities.
114. Malek, Mohammad Abdul; Hossain, Md. Amzad; Saha, Ratnajit; Gatzweiler, Franz W. (2013). Mapping marginality hotspots and agricultural potentials in Bangladesh.
115. Siriwardane, Rapti; Winands, Sarah (2013). Between hope and hype: Traditional knowledge(s) held by marginal communities.
116. Nguyen, Thi Phuong Loan (2013). The Legal Framework of Vietnam’s Water Sector: Update 2013.
117. Shtaltovna, Anastasiya (2013). Knowledge gaps and rural development in Tajikistan. Agricultural advisory services as a panacea?
118. Van Assche, Kristof; Hornidge, Anna-Katharina; Shtaltovna, Anastasiya; Boboyorov, Hafiz (2013). Epistemic cultures, knowledge cultures and the transition of agricultural expertise. Rural development in Tajikistan, Uzbekistan and Georgia.
119. Schädler, Manuel; Gatzweiler, Franz W. (2013). Institutional Environments for Enabling Agricultural Technology Innovations: The role of Land Rights in Ethiopia, Ghana, India and Bangladesh.
120. Eguavo, Irit; Schulz, Karsten; de Wit, Sara; Weisser, Florian; Müller-Mahn, Detlef (2013). Political dimensions of climate change adaptation. Conceptual reflections and African examples.
121. Feuer, Hart Nadav; Hornidge, Anna-Katharina; Schetter, Conrad (2013). Rebuilding Knowledge. Opportunities and risks for higher education in post-conflict regions.
122. Dörendahl, Esther I. (2013). Boundary work and water resources. Towards improved management and research practice?
123. Baumüller, Heike (2013). Mobile Technology Trends and their Potential for Agricultural Development
124. Saravanan, V.S. (2013). “Blame it on the community, immunize the state and the international agencies.” An assessment of water supply and sanitation programs in India.
125. Ariff, Syamimi; Evers, Hans-Dieter; Ndah, Anthony Banyouko; Purwaningrum, Farah (2014). Governing Knowledge for Development: Knowledge Clusters in Brunei Darussalam and Malaysia.
126. Bao, Chao; Jia, Lili (2014). Residential fresh water demand in China. A panel data analysis.

127. Siriwardane, Rapti (2014). War, Migration and Modernity: The Micro-politics of the Hijab in Northeastern Sri Lanka.
128. Kirui, Oliver Kiptoo; Mirzabaev, Alisher (2014). Economics of Land Degradation in Eastern Africa.
129. Evers, Hans-Dieter (2014). Governing Maritime Space: The South China Sea as a Mediterranean Cultural Area.
130. Saravanan, V. S.; Mavalankar, D.; Kulkarni, S.; Nussbaum, S.; Weigelt, M. (2014). Metabolized-water breeding diseases in urban India: Socio-spatiality of water problems and health burden in Ahmedabad.
131. Zulfiqar, Ali; Mujeri, Mustafa K.; Badrun Nessa, Ahmed (2014). Extreme Poverty and Marginality in Bangladesh: Review of Extreme Poverty Focused Innovative Programmes.
132. Schwachula, Anna; Vila Seoane, Maximiliano; Hornidge, Anna-Katharina (2014). Science, technology and innovation in the context of development. An overview of concepts and corresponding policies recommended by international organizations.
133. Callo-Concha, Daniel (2014). Approaches to managing disturbance and change: Resilience, vulnerability and adaptability.
134. Mc Bain, Florence (2014). Health insurance and health environment: India's subsidized health insurance in a context of limited water and sanitation services.
135. Mirzabaev, Alisher; Guta, Dawit; Goedecke, Jann; Gaur, Varun; Börner, Jan; Virchow, Detlef; Denich, Manfred; von Braun, Joachim (2014). Bioenergy, Food Security and Poverty Reduction: Mitigating tradeoffs and promoting synergies along the Water-Energy-Food Security Nexus.
136. Iskandar, Deden Dinar; Gatzweiler, Franz (2014). An optimization model for technology adoption of marginalized smallholders: Theoretical support for matching technological and institutional innovations.
137. Bühler, Dorothee; Grote, Ulrike; Hartje, Rebecca; Ker, Bopha; Lam, Do Truong; Nguyen, Loc Duc; Nguyen, Trung Thanh; Tong, Kimsun (2015). Rural Livelihood Strategies in Cambodia: Evidence from a household survey in Stung Treng.
138. Amankwah, Kwadwo; Shtaltovna, Anastasiya; Kelboro, Girma; Hornidge, Anna-Katharina (2015). A Critical Review of the Follow-the-Innovation Approach: Stakeholder collaboration and agricultural innovation development.
139. Wiesmann, Doris; Biesalski, Hans Konrad; von Grebmer, Klaus; Bernstein, Jill (2015). Methodological review and revision of the Global Hunger Index.
140. Eguavoen, Irit; Wahren, Julia (2015). Climate change adaptation in Burkina Faso: aid dependency and obstacles to political participation. Adaptation au changement climatique au Burkina Faso: la dépendance à l'aide et les obstacles à la participation politique.
141. Youkhana, Eva. Postponed to 2016 (147).
142. Von Braun, Joachim; Kalkuhl, Matthias (2015). International Science and Policy Interaction for Improved Food and Nutrition Security: toward an International Panel on Food and Nutrition (IPFN).
143. Mohr, Anna; Beuchelt, Tina; Schneider, Rafaël; Virchow, Detlef (2015). A rights-based food security principle for biomass sustainability standards and certification systems.
144. Husmann, Christine; von Braun, Joachim; Badiane, Ousmane; Akinbamijo, Yemi; Fatunbi, Oluwole Abiodun; Virchow, Detlef (2015). Tapping Potentials of Innovation for Food Security and Sustainable Agricultural Growth: An Africa-Wide Perspective.
145. Laube, Wolfram (2015). Changing Aspirations, Cultural Models of Success, and Social Mobility in Northern Ghana.
146. Narayanan, Sudha; Gerber, Nicolas (2016). Social Safety Nets for Food and Nutritional Security in India.
147. Youkhana, Eva (2016). Migrants' religious spaces and the power of Christian Saints – the Latin American Virgin of Cisne in Spain.
148. Grote, Ulrike; Neubacher, Frank (2016). Rural Crime in Developing Countries: Theoretical Framework, Empirical Findings, Research Needs.

149. Sharma, Rasadhika; Nguyen, Thanh Tung; Grote, Ulrike; Nguyen, Trung Thanh. Changing Livelihoods in Rural Cambodia: Evidence from panel household data in Stung Treng.
150. Kavegue, Afi; Eguavoen, Irit (2016). The experience and impact of urban floods and pollution in Ebo Town, Greater Banjul Area, in The Gambia.
151. Mbaye, Linguère Mously; Zimmermann, Klaus F. (2016). Natural Disasters and Human Mobility.
152. Gulati, Ashok; Manchanda, Stuti; Kacker, Rakesh (2016). Harvesting Solar Power in India.
153. Laube, Wolfram; Awo, Martha; Derbile, Emmanuel (2017). Smallholder Integration into the Global Shea Nut Commodity Chain in Northern Ghana. Promoting poverty reduction or continuing exploitation?
154. Attemene, Pauline; Eguavoen, Irit (2017). Effects of sustainability communication on environments and rural livelihoods.
155. Von Braun, Joachim; Kofol, Chiara (2017). Expanding Youth Employment in the Arab Region and Africa.
156. Beuchelt, Tina (2017). Buying green and social from abroad: Are biomass-focused voluntary sustainability standards useful for European public procurement?
157. Bekchanov, Maksud (2017). Potentials of Waste and Wastewater Resources Recovery and Re-use (RRR) Options for Improving Water, Energy and Nutrition Security.
158. Leta, Gerba; Kelboro, Girma; Stellmacher, Till; Hornidge, Anna-Katharina (2017). The agricultural extension system in Ethiopia: operational setup, challenges and opportunities.
159. Ganguly, Kavery; Gulati, Ashok; von Braun, Joachim (2017). Innovations spearheading the next transformations in India's agriculture.
160. Gebreselassie, Samuel; Haile Mekbib G.; Kalkuhl, Matthias (2017). The Wheat Sector in Ethiopia: Current Status and Key Challenges for Future Value Chain Development.
161. Jemal, Omarsherif Mohammed, Callo-Concha, Daniel (2017). Potential of Agroforestry for Food and Nutrition Security of Small-scale Farming Households.
162. Berga, Helen; Ringler, Claudia; Bryan, Elizabeth; El Didi, Hagar; Elnasikh Sara (2017). Addressing Transboundary Cooperation in the Eastern Nile through the Water-Energy-Food Nexus. Insights from an E-survey and Key Informant Interviews.
163. Bekchanov, Maksud (2017). Enabling Environment for Waste and Wastewater Recycling and Reuse Options in South Asia: the case of Sri Lanka.
164. Kirui, Oliver Kiptoo; Kozicka, Martha (2018). Vocational Education and Training for Farmers and Other Actors in the Agri-Food Value Chain in Africa.
165. Christinck, Anja; Rattunde, Fred; Kergna, Alpha; Mulinge, Wellington; Weltzien, Eva (2018). Identifying Options for the Development of Sustainable Seed Systems - Insights from Kenya and Mali.
166. Tambo, Justice A. (2018). Recognizing and rewarding farmers' creativity through contests: experiences and insights from four African countries.
167. von Braun, Joachim (2018). Innovations to Overcome the Increasingly Complex Problems of Hunger.
168. Bechanov, Maksud; Evia, Pablo (2018). Resources Recovery and Reuse in Sanitation and Wastewater Systems: Options and Investment Climate in South and Southeast Asian Countries.
169. Kirui, Oliver K.; von Braun, Joachim (2018). Mechanization in African Agriculture: A Continental Overview on Patterns and Dynamics.
170. Beuchelt, Tina; Sarah Nischalke (2018). Adding a gender lens in quantitative development research on food and non-food biomass production: A guide for sex-disaggregated data collection
171. Daum, Thomas (2018). Of Bulls and Bulbs: Aspirations and perceptions of rural youth in Zambia.
172. Salvatierra-Rojas, Ana; Torres-Toledo, Victor; Mrabet, Farah; Müller, Joachim (2018). Improving milk value chains through solar milk cooling.
173. Desalegn, Gashaw; Ali, Seid Nuru (2018). Review of the Impact of Productive Safety Net Program (PSNP) on Rural Welfare in Ethiopia.

174. Muli, Celestine; Gerber, Nicolas; Sakketa, Tekalign Gutu; Mirzabaev, Alisher (2018). Ecosystem tipping points due to variable water availability and cascading effects on food security in Sub-Saharan Africa.
175. Njiraini, Georgina; Ngigi, Marther; Baraké, Evelyn (2018). Women in African Agriculture: Integrating Women into Value Chains to Build a Stronger Sector.
176. Bekchanov, Maksud; Evia, Pablo; Hasan, Mohammad Monirul; Adhikari, Narayan; Gondhalekar, Daphne (2018). Institutional framework and financial arrangements for supporting the adoption of Resource Recovery Reuse technologies in South Asia.
177. Mirzabaev, Alisher; Njiraini, Georgina Wambui; Gebremariam, Gebrelibanos; Jourdain, Damien; Magaia, Emílio; Julio, Felita; Mosse, Gerivásia; Mutondo, João; Mungatana, Eric (2019). Transboundary Water Resources for People and Nature: Challenges and Opportunities in the Olifants River Basin.
178. Gupta, Anil; Shinde, Chintan; Dey, Anamika; Patel, Ramesh; Patel, Chetan; Kumar, Vipin; Patel, Mahesh (2019). Honey Bee Network in Africa: Co-creating a Grassroots Innovation Ecosystem in Africa.
179. Kabran, Estelle Gnankon; Eguavoen, Irit (2019). Ferry transportation in Abidjan: Establishment, operation and sustainability of a paratransit system.
180. Sakketa, Tekalign Gutu; von Braun, Joachim (2019). Labor-intensive public works programs in sub-Saharan Africa: Experiences and implications for employment policies.
181. Legesse, Ermias Engida; Srivastava, Amit; Kuhn, Arnim; Gaiser, Thomas (2019). Household income implications of improved fertilizer accessibility and lower use inefficiency: Long-term scenarios for Ethiopia.
182. Daum, Thomas; Capezzone, Filippo; Birner, Regina (2019). The forgotten agriculture-nutrition link: Estimating the energy requirements of different farming technologies in rural Zambia with time-use data.
183. Ganguly, Kavery; Gulati, Ashok; von Braun, Joachim (2019). Making Skill Development Aspirational: Indian Agriculture and Food Sector.
184. Gulati, Ashok; Juneja, Ritika (2019). Agricultural Credit System in India: Evolution, Effectiveness and Innovations.
185. Chaudhry, Rabia (2019). "An island of excellence?" How the Pakistan military reflects on its presence in the development sector.
186. Mai Le, Quyen; Kelboro, Girma (2019). When heritage goes ways apart: Heritagization and local involvement at the Complex of Monuments in Hue, Vietnam.
187. Eguavoen, Irit; Attemene, Pauline; Kouame, Fulgence; Konan, Eugène Kouadio; Madhy, Chérif Aidara; Gleisberg-Gerber, Katrin (2019). Dernier refuge ou presque d'opportunités? Démographie et conditions de vie à Adjahui-Coubé, une habitation spontanée à Abidjan.
188. Von Braun, Joachim (2019). AI and Robotics Implications for the Poor.
189. Daum, Thomas; Birner, Regina (2019). African agricultural mechanization Myths, realities and an emerging research agenda.
190. Wortmann-Kolundžija, Eli (2019). Empowering smallholder farmers through farmer organizations: Insights from Kenya and Burkina Faso.
191. Youkhana, Eva (2020). Actors networks in critical urban studies – protest against the subprime crisis in Madrid.
192. Tegegne, Azage; Feye, Getachew Legese (2020). Study of selected livestock innovations in Ethiopia.
193. Purwaningrum, Farah; Tayeb, Azmil; Rahmat, Siti Rahyla; Hornidge, Anna-Katharina (2020). Orientation shift? Understanding the 'Third Mission' of the University in Malaysia's Science System.
194. Seré, Carlos (2020). Investing Sustainably in African Livestock Development: Opportunities and Trade-Offs.
195. Gulati, Ashok; Das, Sandip (2020). India-Africa Partnership in Trade and Investment: With Focus on the Agriculture and Food Sector.
196. Scheiterle, Lilli; Birner, Regina (2020). Considerations on the role of institutions and networks in the bioeconomy: three case studies from Ghana and Brazil.

- 197. Sylla, Mouhamadou Bamba; Dimobe, Kangbéni; Sanfo, Safietou (2021). Burkina Faso – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.**
- 198. Admassie, Assefa; Abebaw, Degnet (2021). Ethiopia – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.**
- 199. Coulibaly, Ousmane (2021). Mali – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.**
- 200. Adamou, Rabani; Ibrahim, Boubacar; Bonkaney, Abdou Latif; Seyni, Abdoul Aziz; Idrissa, Mamoudou; Bello, Nassourou (2021). Niger – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.**
- 201. Olayide, Olawale Emmanuel (2021). Nigeria – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.**
- 202. Faye, Amy; Dièye, Mohamadou; Diakhaté, Pape Bilal; Bèye, Assane; Sall, Moussa; Diop, Mbaye (2021). Senegal – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.**
- 203. Osman, Abdelrahman Khidir; Mohamed, Adil (2021). Sudan – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.**
- 204. Mirzabaev, Alisher; Sakketa, Tekalign Gutu; Sylla, Mouhamadou Bamba; Dimobe, Kangbéni; Sanfo, Safietou; Admassie, Assefa; Abebaw, Degnet; Coulibaly, Ousmane Nafolo; Rabani, Adamou; Ibrahim, Boubacar; Bonkaney, Abdou Latif; Seyni, Abdoul Aziz; Idrissa, Mamoudou; Bello, Nassourou; Olayide, Olawale Emmanuel; Faye, Amy; Dièye, Mohamadou; Diakhaté, Pape Bilal; Bèye, Assane; Sall, Moussa; Diop, Mbaye; Osman, Abdelrahman Khidir; Ali, Adil M.; Garba, Issa; Baumüller, Heike; Ouedraogo, Souleymane; von Braun, Joachim (2021). Land, Climate, Energy, Agriculture and Development in the Sahel: Synthesis paper of case studies under the Sudano-Sahelian Initiative for Regional Development, Jobs, and Food Security.**

ZEF Development Studies

edited by
Solvay Gerke and Hans-Dieter Evers

Center for Development Research (ZEF),
University of Bonn

Shahjahan H. Bhuiyan
Benefits of Social Capital. Urban Solid Waste Management in Bangladesh
Vol. 1, 2005, 288 p., 19.90 EUR, br. ISBN 3-8258-8382-5

Veronika Fuest
Demand-oriented Community Water Supply in Ghana. Policies, Practices and Outcomes
Vol. 2, 2006, 160 p., 19.90 EUR, br. ISBN 3-8258-9669-2

Anna-Katharina Hornidge
Knowledge Society. Vision and Social Construction of Reality in Germany and Singapore
Vol. 3, 2007, 200 p., 19.90 EUR, br. ISBN 978-3-8258-0701-6

Wolfram Laube
Changing Natural Resource Regimes in Northern Ghana. Actors, Structures and Institutions
Vol. 4, 2007, 392 p., 34.90 EUR, br. ISBN 978-3-8258-0641-5

Lirong Liu
Wirtschaftliche Freiheit und Wachstum. Eine internationale vergleichende Studie
Vol. 5, 2007, 200 p., 19.90 EUR, br. ISBN 978-3-8258-0701-6

Phuc Xuan To
Forest Property in the Vietnamese Uplands. An Ethnography of Forest Relations in Three Dao Villages
Vol. 6, 2007, 296 p., 29.90 EUR, br. ISBN 978-3-8258-0773-3

Caleb R.L. Wall, Peter P. Mollinga (Eds.)
Fieldwork in Difficult Environments. Methodology as Boundary Work in Development Research
Vol. 7, 2008, 192 p., 19.90 EUR, br. ISBN 978-3-8258-1383-3

Solvay Gerke, Hans-Dieter Evers, Anna-K. Hornidge (Eds.)
The Straits of Malacca. Knowledge and Diversity
Vol. 8, 2008, 240 p., 29.90 EUR, br. ISBN 978-3-8258-1383-3

Caleb Wall
Argorods of Western Uzbekistan. Knowledge Control and Agriculture in Khorezm
Vol. 9, 2008, 384 p., 29.90 EUR, br. ISBN 978-3-8258-1426-7

Irit Eguavoen
The Political Ecology of Household Water in Northern Ghana
Vol. 10, 2008, 328 p., 34.90 EUR, br. ISBN 978-3-8258-1613-1

Charlotte van der Schaaf
Institutional Change and Irrigation Management in Burkina Faso. Flowing Structures and Concrete Struggles
Vol. 11, 2009, 344 p., 34.90 EUR, br. ISBN 978-3-8258-1624-7

Nayeem Sultana
The Bangladeshi Diaspora in Peninsular Malaysia. Organizational Structure, Survival Strategies and Networks
Vol. 12, 2009, 368 p., 34.90 EUR, br. ISBN 978-3-8258-1629-2

Peter P. Mollinga, Anjali Bhat, Saravanan V.S. (Eds.)
When Policy Meets Reality. Political Dynamics and the Practice of Integration in Water Resources Management Reform
Vol. 13, 2010, 216 p., 29.90 EUR, br., ISBN 978-3-643-10672-8

Irit Eguavoen, Wolfram Laube (Eds.)
Negotiating Local Governance. Natural Resources Management at the Interface of Communities and the State
Vol. 14, 2010, 248 p., 29.90 EUR, br., ISBN 978-3-643-10673-5

William Tsuma
Gold Mining in Ghana. Actors, Alliances and Power
Vol. 15, 2010, 256 p., 29.90 EUR, br., ISBN 978-3-643-10811-1

Thim Ly
Planning the Lower Mekong Basin: Social Intervention in the Se San River
Vol. 16, 2010, 240 p., 29.90 EUR, br., ISBN 978-3-643-10834-0

Tatjana Bauer
The Challenge of Knowledge Sharing - Practices of the Vietnamese Science Community in Ho Chi Minh City and the Mekong Delta
Vol. 17, 2011, 304 p., 29.90 EUR, br., ISBN 978-3-643-90121-7

Pham Cong Huu
Floods and Farmers - Politics, Economics and Environmental Impacts of Dyke Construction in the Mekong Delta / Vietnam
Vol. 18, 2012, 200 p., 29.90 EUR, br., ISBN 978-3-643-90167-5

Judith Ehlert
Beautiful Floods - Environmental Knowledge and Agrarian Change in the Mekong Delta, Vietnam
Vol. 19, 2012, 256 S., 29,90 EUR, br, ISBN 978-3-643-90195-8

Nadine Reis
Tracing and Making the State - Policy practices and domestic water supply in the Mekong Delta, Vietnam
Vol. 20, 2012, 272 S., 29.90 EUR, br., ISBN 978-3-643-90196-5

Martha A. Awo
Marketing and Market Queens - A study of tomato farmers in the Upper East region of Ghana
Vol. 21, 2012, 192 S., 29.90 EUR, br., ISBN 978-3-643-90234-4

Asghar Tahmasebi
Pastoral Vulnerability to Socio-political and Climate Stresses - The Shahsevan of North Iran
Vol. 22, 2013, 192 S., 29.90 EUR, br., ISBN 978-3-643-90357-0

Anastasiya Shtaltovna
Servicing Transformation - Agricultural Service Organisations and Agrarian Change in Post-Soviet Uzbekistan
Vol. 23, 2013, 216 S., 29.90 EUR, br., ISBN 978-3-643-90358-7

Hafiz Boboyorov
Collective Identities and Patronage Networks in Southern Tajikistan
Vol. 24, 2013, 304 S., 34.90 EUR, br., ISBN 978-3-643-90382-2

Simon Benedikter
The Vietnamese Hydrocracy and the Mekong Delta. Water Resources Development from State Socialism to Bureaucratic Capitalism
Vol. 25, 2014, 330 S., 39.90 EUR, br., ISBN 978-3-643-90437-9

Sven Genschick
Aqua-`culture´. Socio-cultural peculiarities, practical senses, and missing sustainability in Pangasius aquaculture in the Mekong Delta, Vietnam.
Vol. 26, 2014, 262 S., 29.90 EUR, br., ISBN 978-3-643-90485-0

Farah Purwaningrum
Knowledge Governance in an Industrial Cluster. The Collaboration between Academia-Industry-Government in Indonesia.
Vol. 27, 2014, 296 S., 39.90 EUR, br., ISBN 978-3-643-90508-6

Panagiota Kotsila
*Socio-political and Cultural Determinants of
Diarrheal Disease in the Mekong Delta.
From Discourse to Incidence*
Vol. 28, 2014, 376 S., 39.90 EUR, br., ISBN 978-
3-643-90562-8

Huynh Thi Phuong Linh
*State-Society Interaction in Vietnam.
The Everyday Dialogue of Local Irrigation
Management in the Mekong Delta*
Vol. 29, 2016, 304 S., 39.90 EUR, br., ISBN 978-
3-643-90719-6

Siwei Tan
*Space and Environment in the Industrialising
Mekong Delta.
A socio-spatial analysis of wastewater
management in Vietnam*
Vol. 30, 2016, 240 S., 29.90 EUR, br., ISBN 978-
3-643-90746-2

<http://www.lit-verlag.de/reihe/zef>



zef

Center for
Development Research
University of Bonn

Working Paper Series

Authors: Mirzabaev A, Sakketa TG, Sylla MB, Dimobe K, Sanfo S, Admassie A, Abebaw D, Coulibaly O, Rabani A, Ibrahim B, Bokaney AL, Seyni AA, Idrissa M, Olayide OE, Faye A, Dièye M, Diakhaté PB, Bèye A, Sall M, Diop M, Osman AK, Ali AM, Garba I, Baumüller H, Ouedraogo S, von Braun J

Photo: Sarah Verleysdonk (left), CC (right)

Published by:
Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Genscherallee 3
D – 53113 Bonn
Germany

Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: presse.zef@uni-bonn.de

www.zef.de