

Egamberdiev, Bekhzod; Djuraeva, Mukhayo; Primov, Abdulla

Article — Published Version

Women's empowerment for farm resilience in Ethiopia: A three-step approach for latent class analysis

Review of Agricultural, Food and Environmental Studies

Provided in Cooperation with:

Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Halle (Saale)

Suggested Citation: Egamberdiev, Bekhzod; Djuraeva, Mukhayo; Primov, Abdulla (2026) : Women's empowerment for farm resilience in Ethiopia: A three-step approach for latent class analysis, Review of Agricultural, Food and Environmental Studies, ISSN 2425-6897, Springer, Berlin, Vol. 107, Iss. 1, pp. 61-83,
<https://doi.org/10.1007/s41130-025-00243-2> ,
<https://link.springer.com/article/10.1007/s41130-025-00243-2>

This Version is available at:

<https://hdl.handle.net/10419/340823>

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.



<https://creativecommons.org/licenses/by/4.0>



Women’s empowerment for farm resilience in Ethiopia: a three-step approach for latent class analysis

Bekhzod Egamberdiev^{1,2} · Mukhayo Djuraeva¹ · Abdulla Primov³

Received: 5 January 2025 / Accepted: 8 October 2025 / Published online: 6 November 2025
© The Author(s) 2025

Abstract

Farm resilience to withstand shocks and stresses has become a key topic in research and policy debates. However, disproportionate behavior toward women’s empowerment may underestimate farm resilience capacity. We examine the effects of gender equality on farm resilience capacity, with a focus on land ownership and decision-making processes. By using the Living Standard Measurement Survey–Plus by the World Bank, we construct the farm’s robust capacity (RC), adaptive capacity (AC), and transition capacity (TC) in the first stage and farm resilience capacity (FRC) in the second stage of factor analysis. We also apply a latent class approach to identify homogenous households representing “low gender equality” and “high gender equality” topologies. We apply a three-step approach to identify the relationship between latent classes and resilience. The findings reveal a positive and significant relationship between the “high gender equality” class and AC or FRC compared to those households representing “low gender equality.” In conclusion, it is imperative to strengthen women’s empowerment through ownership and decision-making to enhance farm resilience capacity. A key contribution of this study was to understand the importance of access to resources and the decision-making of women to improve farm resilience in Ethiopia.

✉ Bekhzod Egamberdiev
egamberdiev@iamo.de

Mukhayo Djuraeva
djuraeva@iamo.de

Abdulla Primov
abdulla.primov@iau.uz

¹ Department Agricultural Market, Marketing and World Agricultural Trade, Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Theodor Lieser Street 2, 06120 Halle (Saale), Germany

² Center for Policy Research & Outreach (CPRO), Westminster International University in Tashkent (WIUT), 12 Istiqbol Street, Tashkent 100047, Uzbekistan

³ German-Uzbek Chair on Central Asian Agricultural Economics (GUCAE), International Agriculture University (IAU), Tashkent, Uzbekistan

Keywords Farm resilience · Capacity · Gender equality · Ethiopia

JEL classification J16 · Q10 · Q12 · N57

Introduction

A closer examination of the gendering of socioeconomic life and environment reveals distinct challenges to achieving the Sustainable Development Goals (SDGs). An actual situation is that the increasing role of women in agriculture, food security, and climate change mitigation, combined with limited access to resources and decision-making, increases the tendency to focus on women rather than feminist justice. For example, the gendered face of climate change mitigation indicates that women are disproportionately affected by climate change (de Wit, 2021). However, the condition for dealing with climate change has been exacerbated due to missing points for the intersection between gender, climate change, and other factors. In this case, a *feminization of responsibilities* poses a challenge that puts extra pressure on women to contribute to household chores and deal with the consequences of the environment (Dzialo, 2017; Southard & Randell, 2022). In addition to the restrictions on access to resources, women suffer more from food insecurity compared to household partners, thereby raising the term *feminization of food security* (Ake et al., 2020). A plethora of evidence suggests that addressing environmental problems and challenges requires connecting feminism and environmentalism, referred to as *ecofeminism* (Gonda, 2019). In the current unprecedented climate change scenarios, enhancing resilience has become analogous to building climate-adaptive capacity, particularly at the farm level. This also requires the further integration of gender elements into the resilience approach. This approach has been extended to *gendered farm resilience*, particularly by empowering women's capabilities in farm households (Huyer & Partey, 2020; Ravera et al., 2016a, 2016b).

Resilience in the literature implies the ability to remain in equilibrium when shocks intensify within an ecological system (Holling, 1973). The definition of resilience in socioeconomic science is “the ability of people, households, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth” (USAID, 2022). From this context, resilience is a multifaceted concept that encompasses different socioeconomic elements of the environment (Stotten, 2024). Therefore, the term resilience is highly context-specific, giving prominence to the socioeconomic conditions and social norms of the environment. Acknowledging the needs and differences among people, particularly women's capacities, is vital to building resilience (McNamara et al., 2021), requiring a gendered and power-sensitive approach in resilience thinking (Jordan, 2019). In the face of increasingly severe climate change scenarios, resilience-building strategies have already gained prominence as a potential solution to mitigate the consequences of climate change.

While academics and policymakers use the concept of resilience as a “mobilizing metaphor” for initiating actions to mitigate climate change, the concept still

suffers from its inability to capture agency and power. In this case, gender-neutral approaches to resilience thinking are pervasive in farm resilience studies. Although integrating gender elements into the resilience approach creates an additional layer of complexity, gender mainstreaming in resilience recognizes women's access to resources and decision-making (Smith et al., 2023). One of the direct methods to control for gender assumptions is to include a gender dummy variable without providing any remark on intrahousehold decision-making and resource ownership. Ignoring women's contributions to building household adaptation strategies may lead to biased assumptions due to the missing points in the distribution of responsibilities and power within households (Andersen et al., 2017). Such gender-blind social research omits critical aspects of dynamic perspectives on intrahousehold decision-making that should form the basis of climate change discussions (Pearse, 2017).

In this manuscript, we draw on gendered resilience perspectives to understand the role of women's empowerment in strengthening farm resilience. For the conceptualization, we use the concept of resilience in farm households to frame the analysis. We conceptually apply capacity-based operationalization to quantify or construct farm resilience capacity. The complementary use of capacity lens measurement employs robustness, adaptivity, and transition capacities to construct overall farm resilience capacity (van der Lee et al., 2022). For the gendered perspectives of resilience, we particularly use access to agricultural land, ownership, and decision-making to understand how women's empowerment improves farm resilience capacity. In the empirical analysis, we investigate how gender equality toward access to land and decision-making affects farm resilience capacity. The conclusion of the findings explains how household resilience dynamics are shaped by women's access to resources and their roles in decision-making. To investigate the relationship between women's access to resources/decision-making and resilience, we use sex-disaggregated data from the Living Standards Measurement Study-Plus (LSMS+) for Ethiopia, provided by the World Bank.

Ethiopia is one of the most vulnerable countries in Africa, experiencing the devastating impacts of climate change (Gezie, 2019). It requires special attention to household resilience under climate stress in Ethiopia (Habte et al., 2022; Sertse et al., 2021; Tesfaye et al., 2019; Thiede, 2016) for establishing a climate-robust and resilient agriculture (Senbeta et al., 2022; Tesfaye et al., 2019). Women in Ethiopia minimally contribute to the development of the country (Bayeh, 2016; Bayissa et al., 2018), and this situation is further exacerbated due to limited access to control the resource (Alemu et al., 2018; Teshome et al., 2012) and decision-making (Geleta et al., 2017). The situation is even more severe in farm operations, where women often face limited access to resources, land, and decision-making authority regarding agricultural practices (Petros et al., 2018; Tsige et al., 2020). In this case, findings from the Ethiopian context confirm that adaptation strategies and practices are highly gender-biased (Cholo et al., 2020). This is particularly true for women farmers, who often experience limited access to resources and decision-making (Assefa & Gebrehiwot, 2023; Mekonnen, 2022; Tsige et al., 2020).

The manuscript is structured into five main sections: "Introduction," Literature review on resilience and gender perspectives in resilience," "Data and methodology,"

“Results,” and “Conclusions with discussions.” To ensure methodological transparency and provide detailed information, six further sections are located in the Online Supplementary Material. The findings in this manuscript are important in supporting a gender-sensitive approach, especially in terms of prioritizing women’s access to resources and decision-making. Gender mainstreaming in the Ethiopian context should be based on empirical findings at the local level, thereby increasing the importance of studies on the relationship between gender equality, women’s empowerment, and farm resilience capacity.

Resilience and gender

Farm resilience capacity

A resilience conceptualization, emerging from engineering and ecology (Folke et al., 2010; Gunderson, 2000; Holling, 1973), as well as later from social systems (Ansah et al., 2019), provides a necessary foundation for the evolution of farm resilience. Further studies provided explicit directions to conceptualize farm resilience by reconciling different aspects of farm operations (Darnhofer et al., 2016; Meuwissen et al., 2019). Similarly, methodologies and frameworks are offered to evaluate farm operations, ascertaining a multidimensional adaptive system in farming (Constas et al., 2022). From concepts to assessment, Urruty et al. (2016) explicated a conceptual framework of farm resilience by differentiating stability, robustness, vulnerability, and resilience in agricultural systems. Theoretical notes indisputably viewed farm resilience through traditional, vulnerability, agroecology, and capacity lenses (van der Lee et al., 2022), out of which capacity-based measurement of resilience has become one of the prominent approaches in the framework.

Resilience is multidimensional and unobservable (Chamdimba et al., 2021), and its determinants entail several indicators that show general or specific patterns of farm resilience (Meuwissen et al., 2019). For the farming system, some authors methodologically proposed three resilience capacities with related attributes (Meuwissen et al., 2019; Nicholas-Davies et al., 2021; Slijper et al., 2022): robustness, adaptability, and transformability. According to the authors, resilience is amorphous, including different attributes of a farming system. Within the three capacities, farm households can differentiate resilience strategies and coping mechanisms. Since the framework is based on capacity pillars, it can be used for *ex post* farming systems and *ex ante* resilience strategies. The definition of farm resilience in this manuscript is based on the assessment framework proposed by Meuwissen et al. (2019). The assumptions of the framework depend on five questions that specify farm resilience: *resilience of what, resilience to what, resilience for what purpose, what resilience capacities, and what enhances resilience* (Nicholas-Davies et al., 2021). Detailed discussions of the framework are available in Section A1 and Table A1 of the Online Supplementary Material.

According to the measurement approach, *robustness* implies the capacity to withstand shocks and stresses without having a functional change in the farm operations (Slijper et al., 2022). *Adaptive* capacity indicates that households may experience

marginal changes to adapt; however, the existing function of the farm operation should be maintained (van der Lee et al., 2022). A *transformation* refers to the capacity of farm households to change the structure to cope with climate change issues (Meuwissen et al., 2019). In essence, transformative capacity may require transitions in farm operations that should not be susceptible to shocks and stresses (Ansah et al., 2019). This capacity is of the utmost importance in transforming farming operations or systems when positive progress is not being realized. The system or farm operations may undergo minor and incremental changes, which are inherent in their overall transformative capacity (Termeer et al., 2017). In line with the capacity approach, reflections on the narrative approach enhanced the understanding of the farm's strategic response through three interdependent capacities (Nicholas-Davies et al., 2021). Therefore, Daniele et al. (2022) concluded that the effectiveness of farm resilience in the face of shocks and pressures is inextricably linked to the synergy between the three pillars. For instance, the authors found that socioeconomic challenges require commensurate attention to the combination of adaptability and transformability. At the same time, the robustness of farm resilience is effective against economic and environmental challenges. Of course, there are trade-offs between capacities, as improving one capacity might be at the cost of another one (Béné et al., 2012; Egamberdiev et al., 2023). However, it does not mean that the measurement technique should be based on an "either-or" approach, excluding any pillar from the estimation.

Gender perspectives in resilience

Women exercise agency if they have the power to make strategic decisions. Perhaps the most conspicuous is women's empowerment through agency, resources, participation, and decision-making. Therefore, a conceptualization of women's empowerment is defined as "*the process by which those who have been denied the ability to make strategic life choices acquire such an ability*" (Kabeer, 1999). From this perspective, it becomes conceivable that the process, which changes from disempowerment to empowerment, enables women to make decisions that lead to desired outcomes. At the same time, it is indispensable that the ability to make strategic choices incorporates *agency*, *resource*, and *achievement* dimensions of empowerment. In this case, the conceptualization of three dimensions endeavored to demonstrate how women, as agents, control resources to achieve their goals. Further attempts to explain empowerment have brought practically fruitful concepts in agricultural development and food security (Alkire et al., 2013).

Gender perspectives that refer to a gendered view of resilience recognize unequal power relations and inequality within the household (Smyth & Sweetman, 2015). In this case, feminist scholarship on environmental problems has analyzed the significance of gendered responses to climate change by defining a "strange resilience" in relation to environmental changes (Lever-Tracy, 2008; MacGregor, 2009). In other words, a strong adaptation of climate-resilient agriculture is observed if the gender gap is addressed by supporting access to resources and decision-making. For example, a comprehensive study by Ravera et al. (2016a, 2016b) confirmed that gender

makes a significant contribution to improving resilience. While the intricacies of gender patterns in building resilience are complex, Slavchevska et al. (2024) found that women enhance their resilience through employment, time use, income, and access to resources. For gender-sensitive analysis in resilience thinking, it is imperative to analyze the economic status of women through their access to resources, particularly land and assets (Menon & Rustagi, 2020; Najjar et al., 2020). In addition, women's decision-making power is another effective proxy indicator of the role of women in households (Alwang et al., 2017; Fingleton-Smith, 2018), which can ultimately mobilize efforts to enhance climate change resilience (Misra, 2024). Similarly, Djoudi et al. (2016) analyzed different articles studying the relationship between gender and adaptation strategies in the context of environmental changes. Although incorporating gender into the discourse creates additional challenges in the conceptualization, gender-based perspective studies confirm that women controlling resources are more responsible for building or strengthening resilience (Perez et al., 2015; Terry, 2009; Tschakert & Machado, 2012). This is especially true for women's decisional empowerment in agriculture, which improves adaptive capacity (Shahbaz et al., 2022) and farm efficiency (Czyżewski et al., 2024). However, ensuring gender perspectives in resilience thinking is happening piecemeal, implying the existence of inequalities in *resource ownership* and *decision-making*.

There are a few studies analyzing farm resilience in Ethiopia. For example, the findings have endeavored to examine climate change resilience in farm households (Atara et al., 2020; Dawid et al., 2023; Ghebreyohannes et al., 2022; Negera et al., 2025b; Quinlan et al., 2015; Teklu et al., 2023; Temesgen Gelata et al., 2024; Tofu et al., 2023a, 2023b; Williams et al., 2020). The studies analyzing farm resilience included a female gender variable (dummy) in socioeconomic characteristics (Ali et al., 2023; Asmamaw et al., 2019; Bekele, 2024; Dawid Mume et al., 2023; Gugissa et al., 2022; Melketo et al., 2021; Tofu et al., 2023a, 2023b; Weldegebriel & Amphune, 2017). The findings confirmed that female-headed households are less vulnerable due to limited ownership, access to, and control over assets. In addition to this, the results concluded that the difference might be due to limited access to information, land, and other resources (Debela et al., 2025; Demie & Lojka, 2025; Demisse et al., 2024; Mekuyie et al., 2018; Negera et al., 2025a). By generalizing the prevalence of limited access to resources and decision-making in agriculture, the review study by Asefa et al. (2025) confirmed that gender mainstreaming in the resilience approach is of particular importance.

By examining gender equality in terms of access to land, ownership, and decision-making, we analyze the impact of women's empowerment on farm resilience. Due to the dynamic nature of the resilience concept, we explore the complexities of the relationship between women's empowerment and dynamic resilience determinants (e.g., crop or livestock resistance and changes in farm type). In addition, the measurement of women's empowerment utilizes different dimensional determinants (e.g., the right to improve land, use the parcel, ownership of use or sale, documented ownership, and decision-making on the parcel). An important step in linking women's empowerment to farm resilience is establishing a causal relationship. Therefore, the results are built upon the causal claims, making the conclusions more direct and purposeful for policy interventions in Ethiopia.

Data and methodology

Data and descriptive statistics

The data used for this study are from the Ethiopian Panel Survey (ESPS), supported by the Living Standard Measurement Survey–Plus (LSMS+) of the World Bank. The ESPS includes socioeconomic, agricultural, and gender-related modules for each household member aged 18 and above (WB, 2024). The current study includes ESPS-4 for 2018/2019 and ESPS-5 for 2021/2022, designed to focus on data differences across men and women in asset ownership, decision-making, and labor market outcomes (Hasanbasri et al., 2021). Both waves, obtained from the two-stage stratified probability sample, are nationally representative, allowing for the provision of regional estimates for both rural and urban areas (WB, 2024). The survey encompasses 10 regions, including both rural and urban areas, and covers households across the regions. Due to security reasons, the northern parts of the country, specifically in Tigray, were not included in ESPS-5. The scope of the survey encompasses households, communities, postharvest activities, postplanting operations, and livestock production. As for the sample size, ESPS-5 uses the households, precipitated in the fourth wave of ESPS (ESPS-4).

Table A2 shows the dependent and independent variables used in the estimation. Among resilience pillars, the mean values of resistance capacity and transition capacity are more than 0.400. Adaptive capacity has the lowest mean value at 0.382. Resilience capacity or FRC represents more than 0.550 at its mean level. Concerning individual controlling variables of women respondents, the average age of the respondents is approximately 34 years old. Approximately one-third of the respondents have a higher education level. Officially employed respondents account for close to 1%. The variables explaining household characteristics indicate that the number of financial assets is less than 1, indicating that households are highly dependent on agricultural assets. The number of people residing in the household is close to 6. The average expenditure on non-food items accounts for around 625 ETB. Households, on average, experienced 14 types of idiosyncratic and exogenous shocks over the last 12 months. The regional distribution of farm households in the sample reveals that more than 10% of these households are located in SNNPR, Amhara, Addis Ababa, Oromia, Somali, and Dire Dawa. The remaining Benishangul-Gumuz, Gambela, Harari, and Afar regions have less than 10% farm households in the sample.

Conceptual framework for women's empowerment

It is essential to incorporate sex-disaggregated land indicators for conceptualizing access to and ownership of land. We construct latent-based variables for women's land ownership and decision-making variables through three measures: reported ownership, document ownership, and effective ownership through decision-making. Considering data availability and challenges in modeling, we employ a total

of 10 variables, mostly related to women's access to land, ownership, right to use, and decision-making. In this perspective, we use five observables and one constructed variable to cluster households for gender equality. For reported ownership, two variables represent whether women own and use the right to agricultural land. For documented ownership, we include the variable that defines whether a woman has her name on the certified documentation indicating that she owns the land. The importance of this variable lies in the fact that an ownership document is one of the key indicators for women, demonstrating tenure security in Africa (Doss et al., 2015). The conceptualization and measurement include a constructed variable, which entails the right to bequeath, use the land as collateral, rent the land, and make improvements or investments in the land. Finally, decision-making on the parcel is included for the latent classes. Summary statistics of observed variables are provided in Table A1 of the Online Supplementary Material.

We employ latent class analysis (LCA) to identify patterns of gender roles by clustering households based on their access to resources and the decision-making of women. LCA has become one of the prominent models used to construct a typology through a set of observed variables. Therefore, the model allows identifying unobserved subgroups of respondents within a population (Collier & Leite, 2017). Technically speaking, the model represents a mixture modeling approach that successfully deals with heterogeneous samples by obtaining homogenous clusters (Collins & Lanza, 2009). The application of LCA has been explored in the field of gender studies. Detailed discussions explaining women's empowerment through LCA are available in Section A2 of the Online Supplementary Material.

The measurement strategy of latent analysis primarily aims to associate the created typology (clustered latent class or profile) with other variables (Collins & Lanza, 2009). In this case, the latent class variable may be either an independent or dependent variable, as it can be investigated through the associations between typology and other variables. Latent class models with covariates facilitate the identification of the relationship between the characteristics of other variables and latent classes (Collier & Leite, 2017). From this perspective, there are two extensions of latent class models: *one-step* and *three-step approaches*. We employ a three-step approach, and further detailed discussions are available in Section A3 of the Online Supplementary Material.

In the estimation, a causal relationship between latent women's empowerment and resilience outcomes is established through a three-step approach. LCA is modeled through two parameters: *class prevalence (class membership)* and *item-response probabilities* (Collins & Lanza, 2009). The estimation of parameters is based on maximum likelihood (ML) estimates. To obtain ML estimates, the maximum number of iterations and the maximum absolute deviation (MAD) are used to stop the ML procedure. A detailed explanation of model parameters is available in Section A4 of the Online Supplementary Appendix. To obtain the best-fit models, we utilize the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) (Collins & Lanza, 2009).

Conceptual framework for farm resilience

Since resilience is a latent phenomenon, it is challenging to construct indicators that accurately reflect the levels of farm resilience. A two-stage factor analysis methodology is used to measure the farm resilience capacity (FRC) (Section A5 in the Online Supplementary Material). In the first stage, the constructed variables for robustness capacity (RC), adaptive capacity (AC), and transformation capacity (TC) are measured. As for the farm resilience capacity (FRC) construction, the index is obtained from using PCA on three RC, AC, and TC pillars. For the construction of pillars and farm resilience, we use principal component analysis (PCA) (d'Errico et al., 2018). To obtain the estimation value for the resilience pillars and resilience itself, we use Bartlett's scoring method (Bartlett, 1937):

$$\Gamma^{-1}\Lambda'\Psi^{-1}\chi \quad (1)$$

in which $\Gamma = \Lambda'\Psi^{-1}\Lambda$ is the unrotated loading matrix. The diagonal matrix of uniqueness is defined by Ψ , while the vector of observed variables is χ . Λ is the factor loading, and it is used together with Ψ for obtaining the weight of observed data. For the factorability analysis, we apply the Bartlett test, the Kaiser–Meyer–Olkin (KMO) test, and the determinant of the R -matrix (Acock, 2013). Factorability findings for each pillar and FRI are provided in Table A4 of the Online Supplementary Material. The *min–max scaling* technique for the pillars and resilience capacity is applied (d'Errico et al., 2018):

$$x_{scaled} = \frac{x - x_{min}}{x_{max} - x_{min}} \quad (2)$$

We use a variety of variables to measure the farm resilience capacity levels. The choice of the selected variables is explained by the context in Africa and the availability of data. Section A6 and Tables A5–A7 in the Online Supplementary Material provide detailed information on the selected variables with related sources. For robustness (RC), we employ related variables that describe how farms are resilient to changing environments. It captures the dynamic changes in four variables: *crop diversification*, *the number of livestock*, *crop damage*, and *the number of negative consequences experienced due to the shock (rescaled to show the resistance)*. Regarding the AC pillar, we use various variables that reflect how farm households adapt to a changing environment. For example, the estimation incorporates the *extension service* because it represents one of the most prevalent strategies to strengthen farm resilience (Antwi-Agyei & Stringer, 2021). Moreover, techniques such as *crop rotation*, *improved fertilizer*, and *seed assistance* are of particular importance in strengthening farm resilience in Sub-Saharan Africa (Acevedo-Siaca & Goldsmith, 2020; Holden, 2018). Since cropping plans and crop rotation decisions are dynamic processes (Dury et al., 2012), the estimation strategy for the TC pillar includes changes in parcel rent, mixed cropping, and farm type. We also include dummy variables for changes in *farm type*, *mixed cropping practices*, and *renting the land*, as practiced by the farmers over the 2018 and 2021 waves.

Estimation strategy

As for latent class literature, the literature proposed the relationship between latent class variables (class membership) and covariates using a three-step approach. For the general finite mixture model, $f(x)$ is the composite density function of x observed variable for all $k = 1, \dots, K$:

$$f(x) = \pi_1 f_1(x, \theta_1) + \dots + \pi_k f_k(x, \theta_k) \quad (3)$$

where a single density function $f_k(x, \theta_k)$ is the component for component-specific parameter vector θ_k . The mixing proportions equal to one are defined by π_1, \dots, π_k (McLachlan & Peel, 2004).

As for LCA, the density function of a single x in class k is given below:

$$f(x|k) \sim \prod_{j=1}^n p_{jk}^{1\{x=j\}} \quad (4)$$

where $1\{x=j\}$ as the indicator function is 1 for each observed variable taking the value of j . Otherwise, it is equal to 0. The probability of j value in the class k is denoted by p_{jk} . The variable taking the number of possible categories is defined by n .

For the latent class variable denoted by η , the posterior distribution of latent classes is used below:

$$p(\eta|x) = \frac{p(x|\eta) \cdot p(\eta)}{\sum_{\eta=1}^K p(x|\eta) \cdot p(\eta)} \quad (5)$$

In the third stage, a latent categorical variable (class membership) can be used as one of the predictor auxiliary variables (Collier & Leite, 2017). For the given relationship between resilience variables and gender equality class membership, independent sample *t-test* and *multinomial logistic regression* are used:

$$\text{Resilience or Pillar}_{it} = \beta_0 + \beta_1 \text{Gender Equality}_{it-1} + \beta_2 Z_{it} + \varepsilon_{it} \quad (6)$$

where $\text{Resilience or Pillar}_{it}$ is for woman i in the household at time t . $\text{Gender Equality}_{it-1}$ is a lagged latent variable to capture gender equality dynamics in the past. The vector Z_{it} denotes other socioeconomic characteristics of women (age, higher education, employed over the last 12 months, and holding the number of financial assets) and households (household size, non-food expenditure, the number of shocks experienced, and related geographical locations). ε_{it} is the unobservable error term. Summary statistics for the variables are provided in Table A2 of the Online Supplementary Material.

Table 1 Fit information of latent models

No	LL	df	AIC	BIC
1	-1694.284	6	3400.568	3427.908
2	11,582.643	13	3191.286	3250.524

LL log-likelihood, *df* number of free parameters, *AIC* Akaike information criterion, *BIC* Bayesian information criterion

Results

Topologies for gender equality

Summary statistics for the variables used to construct gender empowerment latent classes in Table 1 show that the right to use the parcel is relatively high at 79%. However, parcel ownership is low, suggesting that 52% of women own parcels. Regarding documented ownership, 90% of women reported that their names are listed on the ownership document. Other variables for the effective ownership imply that the ownership to sell/rent the parcel is high (87%); however, the constructed variable (right to bequeath, use the land as collateral, rent the land, and make improvements or investments in the land) has a mean value of 26%. Land use decision-making implies that 90% of women are capable of making decisions.

Table 1 shows the AIC and BIC criteria for the two-class model. Although we do not have any convergence in the third model, a two-class model has a better fit compared to the one expressed with a one-class model.

As for a two-class model, 19% of the sample falls into Class 1. The remaining 81% of the sample represents Class 2 in the latent analysis. To interpret the classes, we estimate the item response probability using the statements that characterized women's access to resources and decision-making in the household.

Based on the item response probabilities in Fig. 1, we label the classes through distinct differences across classes. For example, a key feature of Class 1 is that a substantial proportion of women have a scale for statements 3–6 that is less than the predicted mean. They, however, have a higher predicted mean scale score for the constructed variables. We label Class 1 as “low equality.” Accordingly, Class 2 exhibits the highest item response probabilities for all statements except the first indicator, indicating higher gender equality within the household. This nature in Class 2 implies that women have higher resource ownership and decision-making, although they do not fully control the land regarding the constructed variable. We label this class as a “high equality” class.

Relationship between gender equality and resilience

This section presents the results obtained from the relationship between resilience and gender equality classes, considering whether the difference is statistically significant. The findings from the *t-test* analysis confirm that adaptation capacity, as a condition for anticipating and responding to change in farm operations, directly



Fig. 1 Latent class for gender equality. Note: 1—constructed variable (right bequeath, use the land as collateral, rent the land, and the make the improvement or investment in the land); 2—right to use the parcel; 3—parcel ownership; 4—available name on the ownership document; 5—decision-maker on the parcel; 6—ownership to sell/rent the parcel

Table 2 Across class differences

	Low equality	High equality	<i>p</i> value
Robustness capacity	0.445	0.431	0.645
Adaptive capacity	0.372	0.452	0.020
Transition capacity	0.493	0.442	0.146
Farm resilience capacity	0.497	0.586	0.000

refers to women’s abilities to navigate inevitable change (Table 2). The contribution of women certainly depends on access to ownership and decision-making, which is inherent in women’s capacity to adapt in the first instance. A positive and significant relationship between adaptive capacity and gender equality recognizes that gender role dynamics, particularly in relation to asset ownership and decision-making, shape farm adaptive capacity in farm households.

Regarding the outcomes obtained from the *multinomial logistic regression*, a positive and significant relationship is observed between gender equality and adaptive capacity (Table 3). In this case, contemporary literature also accentuates the significance of gender role dynamics in the household, contributing to farm adaptive capacity (Cohen et al., 2016). The capacity building of women further explains this

Table 3 Gender equality and resilience pillars

	AC	TC	RC
High equality	0.080*** (0.032)	-0.034 (0.037)	-0.015 (0.032)
Age	-0.001 (0.001)	0.001 (0.001)	-0.001 (0.001)
Higher education	-0.042 (0.029)	-0.011 (0.034)	0.020 (0.032)
Employed last 12 months	-0.062 (0.049)	0.080 (0.059)	0.016 (0.056)
Financial assets	0.035** (0.016)	-0.001 (0.019)	0.010 (0.018)
HH size	0.021*** (0.005)	-0.009 (0.006)	-0.011** (0.005)
Nonfood expenditure	0.001 (0.001)	0.001 (0.001)	0.001** (0.001)
Total shock	0.003 (0.003)	-0.001** (0.001)	-0.009** (0.003)
Addis Ababa and Oromia	0.635*** (0.232)	-0.073 (0.298)	-0.094 (0.224)
Somali	0.222 (0.281)	-0.352 (0.342)	0.008 (0.256)
Amhara	0.703*** (0.233)	-0.114 (0.299)	-0.001 (0.225)
Benishangul-Gumuz	0.728*** (0.240)	-0.194 (0.307)	-0.029 (0.234)
SNNPR	0.601*** (0.232)	-0.087 (0.297)	0.001 (0.224)
Gambela	0.251 (0.237)	0.024 (0.303)	0.051 (0.229)
Harari	0.387 (0.234)	-0.114 (0.300)	-0.170 (0.227)
Observation	405	471	321

* $p < 0.10$; ** $p < 0.05$; *** $P < 0.001$

Standard errors in parentheses; a "Low equality" profile is a reference group for latent profile variable. Afar is a reference group for regional variables. SNNPR is Southern Nations, Nationalities and Peoples Region

apparent relationship through control over assets and the decision-making process, intermingled with farm adaptability and resilience (Dev & Manalo, 2023). In the context of Ethiopian farmers, women can engage in building adaptation strategies through their actions to strengthen farm resilience (Aryal et al., 2022).

As for the relationship between gender equality and farm resilience in Table 4, households characterized by "high equality" are positively and significantly associated with farm resilience capacity compared to the base class, "low equality" class. There is sufficient evidence to suggest that gender equality dimensions in the household are one of the particular determinants of Ethiopian farm resilience (Chanamuto

Table 4 Gender equality and resilience pillars

	FRC
High equality	0.071*** (0.029)
Age	-0.001 (0.001)
Higher education	-0.008 (0.028)
Employed last 12 months	-0.069 (0.047)
Financial assets	0.042*** (0.015)
HH size	0.004 (0.005)
Nonfood expenditure	0.001 (0.001)
Total shock	-0.001 (0.003)
Addis Ababa and Oromia	0.253 (0.173)
Somali	0.182 (0.209)
Amhara	0.324* (0.175)
Benishangul-Gumuz	0.374** (0.182)
SNNPR	0.283 (0.173)
Gambela	0.095 (0.179)
Harari	0.121 (0.176)
Observation	267

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.001$

Standard errors in parentheses; a “Low equality” profile is a reference group for latent profile variable. Afar is a reference group for regional variables. *SNNPR* is Southern Nations, Nationalities and Peoples Region

& Hall, 2015), facilitating gender-responsive adaptation (Devonald et al., 2024). From this perspective, enhancing resource ownership and decision-making to empower Ethiopian women within the household is locally relevant for strengthening resilience (Balehey et al., 2018).

The findings confirm a positive relationship between financial assets and adaptability (AC) or farm resilience (FRC). Since financial capital increases the liquidity of farm households, the findings underscore the importance of financial assets (Chepkoech et al., 2020). In this case, the availability of financial assets facilitates the establishment of flexible and adaptive measures. The methodological assumptions

for measuring farm resilience, as proposed by Meuwissen et al. (2019), confirm that farm size is one of the main determinants of characterizing farming systems. A negative relationship between household size and robustness can be explained by the fact that household size does not reflect the growth of farm size. Otherwise, the findings confirm a positive relationship between farm size and robustness, primarily through productivity (Sheng et al., 2015). As expected, a positive relationship exists between shocks and resilience pillars. The extent of the association is statistically significant in the outcomes of TC and RC. However, the relationship between shocks and AC or FRC is not significant, which may be due to coping strategies being activated relatively in the short term (Egamberdiev et al., 2024). Although some regions exhibit statistically significant results, insignificant findings may be attributed to sociocultural context, institutional support, or sample size. In this case, gender empowerment should be tailored to the regional context, capturing better dynamics between regions and changes in resilience capacity.

Discussion and conclusion

Climate change exacerbates gender inequality and injustice, particularly in farm households (Eastin, 2018; Rather & Mahalik, 2025). In this case, women suffer more in the context of climate vulnerabilities. Climate-induced losses in farm households increase the burden of work on women due to high male migration in rural areas (Mayer et al., 2023). In the context of the feminization of agriculture and the feminization of responsibilities, women are at the forefront of building farm resilience to respond to climate change consequences. Therefore, it necessitates gender-responsive approaches to support women who build climate-resilient agriculture. In other words, incorporating gender-based approaches into household resilience in Ethiopia allows for gender-transformative climate change resilience in the long term. In this circumstance, resilience enhancement policy should recognize women as more than objects of discussion. In other words, interventions should involve adaptation practices that facilitate access to resources and promote informed decision-making. In practice, the situation in many African countries garnered more attention such that women's access to resources and decision-making is barely audible in sustaining farm resilience. Instead, the efforts are given to the model, indicating "one-size-fits-all," in which gender-specific constraints are less accentuated.

Societies have already changed their behavior, undeniably presenting changes in the perception of gender roles in the presence of climate change. Our direct contribution in this manuscript is analyzing building farm resilience through a gender lens. In other words, recognizing gender equality in the household is found to be promising in strengthening and building farm resilience capacity. It is particularly true for the adaptive capacity of farm households. Therefore, neglecting women's access to resources and decision-making exacerbates the negative consequences of climate change, rigidly constraining farm resilience to climate change. A unique methodology for gender analysis in this manuscript is based on the mixture modeling approach, employing LCA applications. LCA is considered

a “person-centered” approach because it focuses on the patterns of behavior rather than variables proposed by the “variable-centered approach”.

The feminization of responsibility and the feminine task stereotype for housework hinder progress toward gender equality. Although the current situation in Ethiopia is tied to gender social roles and cultural norms, feminization of environmental responsibilities should not be allowed without supporting women’s access to resources. Therefore, a key contribution of this study was to understand the importance of access to resources and the decision-making process of women in improving farm resilience in Ethiopia. Previous work analyzing the resilience phenomenon used a dummy gender variable without accounting for dynamic gender relations in the household. By controlling access and agency domains in gender roles, we provided important results for integrating gender relations into resilience thinking. Methodologically, applying latent analysis for clustering households toward resources and agency of women has promise as a novel approach for empirical analysis and is readily applicable to policy recommendations. Although there are comprehensive methods to analyze women’s empowerment in agriculture, the methodological aspect provides new insight into dealing with the multidimensionality and heterogeneity issues in the estimation of gender roles in the household. The integration of latent analysis can be a useful method for researchers to categorize gender-related patterns in the household that can be useful for gender intervention programs and policies.

Resilience-building activities in the context of the feminization of agriculture should be based on linking the assessment to the vulnerability context. For example, future studies should also focus on how women can use resources innovatively, as findings by Loarne-Lemaire et al. (2021) indicate that women’s innovation in climate change is particularly important in mitigating the negative consequences. Moreover, the gendered-resilience approach should be shock-specific. In this case, Knippenberg et al. (2019) suggested that resilience-building activities are highly sensitive to the type of shocks, requiring an understanding of resilience to “what.” Further research on the relationship between gender and resilience should consider the intersectionality of demographic characteristics. For example, Quandt (2019) argues that the intersection of gender and ethnicity may provide more robust results for gendered approaches in resilience thinking. In addition to this, there is a need to go beyond technical explanations of farm resilience to climate change; instead, the efforts should consider social capital (Egamberdiev et al., 2024), social learning (Ross et al., 2024), and women’s agency of the households to unveil implicit and explicit factors to improve farm resilience (Bullock & Tegbaru, 2019). Further research studies should consider other aspects of women’s empowerment. For example, the integration of the Women’s Empowerment in Agricultural Index (WEAI) by Malapit et al. (2019) might provide new insight into farm resilience modeling.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s41130-025-00243-2>.

Author contribution All authors equally contributed to the conceptual and design writing. BE wrote the first draft by including the framework, data analysis, and concluding remarks. MD contributed to

finalizing the literature review part. AP contributed to data management and descriptive studies. All authors read and confirmed the final manuscript.

Funding Open Access funding enabled and organized by Projekt DEAL. This manuscript is written within the project An Innovative Pilot Program on the Re-Integration of Scientists to Central Asia: Research and Capacity Building on Food Chains under Climate Change (IPReS) supported by the Volkswagen Foundation (VolkswagenStiftung) and implemented by the Leibniz Institute for Agricultural Development in Transformation Economies (IAMO).

Data availability Data is available from the World Bank or <https://www.worldbank.org/en/programs/lsm/initiatives/lsm-plus>.

Code availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Consent to participate Not applicable.

Conflict of interest The authors declare no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Acevedo-Siaca, L., & Goldsmith, P. D. (2020). Soy-maize crop rotations in sub-Saharan Africa: A literature review. *International Journal of Agronomy*, 2020, Article 8833872. <https://doi.org/10.1155/2020/8833872>
- Acock, A. C. (2013). *Discovering structural equation modeling using Stata*. Stata Press Books.
- Ake, M., Rasak, B., Igbokwu, C., Ogunlade, P., & Nwozo, A. (2020). Feminization, food security, and hunger eradication: A case of Omu-Aran community in Kwara State, Nigeria. *IOP Conference Series: Earth and Environmental Science*, 445(1), Article 012047. <https://doi.org/10.1088/1755-1315/445/1/012047>
- Alemu, S. H., Van Kempen, L., & Ruben, R. (2018). Women empowerment through self-help groups: The bittersweet fruits of collective apple cultivation in highland Ethiopia. *Journal of Human Development and Capabilities*, 19(3), 308–330. <https://doi.org/10.1080/19452829.2018.1454407>
- Ali, H., Menza, M., Hagos, F., & Hailelassie, A. (2023). Impact of climate smart agriculture on households' resilience and vulnerability: An example from Central Rift Valley, Ethiopia. *Climate Resilience and Sustainability*, 2(2), Article e254. <https://doi.org/10.1002/cli2.54>
- Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A., Seymour, G., & Vaz, A. (2013). The women's empowerment in agriculture index. *World Development*, 52, 71–91. <https://doi.org/10.1016/j.worlddev.2013.06.007>
- Alwang, J., Larochelle, C., & Barrera, V. (2017). Farm decision making and gender: Results from a randomized experiment in Ecuador. *World Development*, 92, 117–129. <https://doi.org/10.1016/j.worlddev.2016.11.015>

- Andersen, L. E., Verner, D., & Wiebelt, M. (2017). Gender and climate change in Latin America: An analysis of vulnerability, adaptation and resilience based on household surveys. *Journal of International Development*, 29(7), 857–876. <https://doi.org/10.1002/jid.3259>
- Ansah, I. G. K., Gardebroeck, C., & Ihle, R. (2019). Resilience and household food security: A review of concepts, methodological approaches and empirical evidence. *Food Security*, 11(6), 1187–1203. <https://doi.org/10.1007/s12571-019-00968-1>
- Antwi-Agyei, P., & Stringer, L. C. (2021). Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from Northeastern Ghana. *Climate Risk Management*, 32, Article 100304. <https://doi.org/10.1016/j.crm.2021.100304>
- Aryal, J. P., Sapkota, T. B., Rahut, D. B., Gartaula, H. N., & Stirling, C. (2022). Gender and climate change adaptation: A case of Ethiopian farmers. *Natural Resources Forum*, 46(3), 263–288. <https://doi.org/10.1111/1477-8947.12259>
- Asefa, A., Haile, M., Berhe, M., & Zenebe, A. (2025). Climate smart land management practices for livelihood resilience in Ethiopia: A systematic review. *Heliyon*. <https://doi.org/10.1016/j.heliyon.2025.e42950>
- Asmamaw, M., Mereta, S. T., & Ambelu, A. (2019). Exploring households' resilience to climate change-induced shocks using climate resilience index in Dinki watershed, central highlands of Ethiopia. *PLoS ONE*, 14(7), Article e0219393. <https://doi.org/10.1371/journal.pone.0219393>
- Assefa, E., & Gebrehiwot, G. (2023). Gender dimensions of climate change adaptation in Tigray, Ethiopia. *Global Environmental Change*, 82, Article 102737. <https://doi.org/10.1016/j.gloenvcha.2023.102737>
- Atara, A., Tolossa, D., & Denu, B. (2020). Analysis of rural households' resilience to food insecurity: Does livelihood systems/choice/ matter? The case of Boricha woreda of Sidama zone in Southern Ethiopia. *Environmental Development*, 35, Article 100530. <https://doi.org/10.1016/j.envdev.2020.100530>
- Balehey, S., Tesfay, G., & Balehegn, M. (2018). Traditional gender inequalities limit pastoral women's opportunities for adaptation to climate change: Evidence from the Afar pastoralists of Ethiopia. *Pastoralism*, 8(1), 23. <https://doi.org/10.1186/s13570-018-0129-1>
- Bartlett, M. S. (1937). The statistical conception of mental factors. *British Journal of Psychology. General Section*, 28(1), 97–104.
- Bayeh, E. (2016). The role of empowering women and achieving gender equality to the sustainable development of Ethiopia. *Pacific Science Review B, Humanities and Social Sciences*, 2(1), 37–42. <https://doi.org/10.1016/j.psrb.2016.09.013>
- Bayissa, F. W., Smits, J., & Ruben, R. (2018). The multidimensional nature of women's empowerment: Beyond the economic approach. *Journal of International Development*, 30(4), 661–690. <https://doi.org/10.1002/jid.3268>
- Bekele, W. D. (2024). Enhancing farmers' resilience to climate change-induced impacts through financial inclusion in Sidama region, southern Ethiopia. *Climate and Development*, 16(2), 149–160. <https://doi.org/10.1080/17565529.2023.2203675>
- Béné, C., Wood, R. G., Newsham, A., & Davies, M. (2012). Resilience: New utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. *IDS Working Papers*, 2012(405), 1–61. <https://doi.org/10.1111/j.2040-0209.2012.00405.x>
- Bullock, R., & Tegbaru, A. (2019). Women's agency in changing contexts: A case study of innovation processes in Western Kenya. *Geoforum*, 105, 78–88. <https://doi.org/10.1016/j.geoforum.2019.07.007>
- Chandimba, O. Y., Ortmann, G. F., & Wale, E. (2021). Resilience to shocks and food insecurity: Determinants, and the impact of smallholder *jatropha curcas* cultivation in Southern Malawi. *African Journal of Science, Technology, Innovation and Development*, 13(5), 619–633. <https://doi.org/10.1080/20421338.2020.1774962>
- Chanamuto, N. J. C., & Hall, S. J. G. (2015). Gender equality, resilience to climate change, and the design of livestock projects for rural livelihoods. *Gender & Development*, 23(3), 515–530. <https://doi.org/10.1080/13552074.2015.1096041>
- Chepkoech, W., Mungai, N. W., Stöber, S., & Lotze-Campen, H. (2020). Understanding adaptive capacity of smallholder African indigenous vegetable farmers to climate change in Kenya. *Climate Risk Management*, 27, Article 100204. <https://doi.org/10.1016/j.crm.2019.100204>

- Cholo, T. C., Peerlings, J., & Fleskens, L. (2020). Gendered climate change adaptation practices in fragmented farm fields of Gamo Highlands, Ethiopia. *Climate and Development*, 12(4), 323–331. <https://doi.org/10.1080/17565529.2019.1618234>
- Cohen, P. J., Lawless, S., Dyer, M., Morgan, M., Saeni, E., Teioli, H., & Kantor, P. (2016). Understanding adaptive capacity and capacity to innovate in social–ecological systems: Applying a gender lens. *Ambio*, 45(3), 309–321. <https://doi.org/10.1007/s13280-016-0831-4>
- Collier, Z. K., & Leite, W. L. (2017). A comparison of three-step approaches for auxiliary variables in latent class and latent profile analysis. *Structural Equation Modeling: A Multidisciplinary Journal*, 24(6), 819–830. <https://doi.org/10.1080/10705511.2017.1365304>
- Collins, L. M., & Lanza, S. T. (2009). *Latent class and latent transition analysis: With applications in the social, behavioral, and health sciences* (Vol. 718). John Wiley and Sons.
- Constas, M. A., d'Errico, M., & Pietrelli, R. (2022). Toward core indicators for resilience analysis: A framework to promote harmonized metrics and empirical coherence. *Global Food Security*, 35, Article 100655. <https://doi.org/10.1016/j.gfs.2022.100655>
- Czyżewski, B., Prędko, A., & Brelik, A. (2024). Importance of women empowerment for eco-efficiency of small farms in the context of other social factors: Building sustainable agriculture in Central and Eastern European countries. *Sustainable Development*, 32(5), 5550–5566. <https://doi.org/10.1002/sd.2989>
- d'Errico, M., Romano, D., & Pietrelli, R. (2018). Household resilience to food insecurity: Evidence from Tanzania and Uganda. *Food Security*, 10(4), 1033–1054. <https://doi.org/10.1007/s12571-018-0820-5>
- Daniele, B.-C., Barbara, S., Isabel, B., & Alberto, G. (2022). Analysis of perceived robustness, adaptability and transformability of Spanish extensive livestock farms under alternative challenging scenarios. *Agricultural Systems*, 202, Article 103487. <https://doi.org/10.1016/j.agsy.2022.103487>
- Darnhofer, I., Lamine, C., Strauss, A., & Navarrete, M. (2016). The resilience of family farms: Towards a relational approach. *Journal of Rural Studies*, 44, 111–122. <https://doi.org/10.1016/j.jrurstud.2016.01.013>
- Dawid, I., Haji, J., & Aman, M. (2023). Evaluating farm household resilience and perceptions of the role of small-scale irrigation in improving adaptability to climate change stress: Evidence from eastern Ethiopia. *Frontiers in Climate*, 5, Article 1193910.
- Dawid Mume, I., Haji Mohammed, J., & Aman Ogeto, M. (2023). Impact of small-scale irrigation on the livelihood and resilience of smallholder farmers against climate change stresses: Evidence from Kersa district, eastern Oromia, Ethiopia. *Heliyon*. <https://doi.org/10.1016/j.heliyon.2023.e18976>
- de Wit, S. (2021). Gender and climate change as new development tropes of vulnerability for the Global South: Essentializing gender discourses in Maasailand, Tanzania. *Tapuya: Latin American Science, Technology and Society*, 4(1), Article 1984638. <https://doi.org/10.1080/25729861.2021.1984638>
- Debelo, C. M., Aweke, C. S., & Tefera, T. L. (2025). Farmers resilience to climate variability and perceptions towards adoption of climate smart agricultural practices: Evidence from Kersa district, East Hararghe of Ethiopia. *Environment, Development and Sustainability*, 27(8), 19611–19629. <https://doi.org/10.1007/s10668-024-04723-1>
- Demie, G., & Lojka, B. (2025). Agroforestry systems as livelihood resilience to climate change and variability: Evidence from central escarpment of Ethiopia. *Agroforestry Systems*, 99(6), 143. <https://doi.org/10.1007/s10457-025-01240-6>
- Demisse, U., Bazezew, A., & Bantigegen, S. (2024). Rural households' resilience to the adverse impacts of climate variability and food insecurity in the North-eastern highlands of Ethiopia. *Heliyon*. <https://doi.org/10.1016/j.heliyon.2024.e32960>
- Dev, D. S., & Manalo, J. A. (2023). Gender and adaptive capacity in climate change scholarship of developing countries: A systematic review of literature. *Climate and Development*, 15(10), 829–840. <https://doi.org/10.1080/17565529.2023.2166781>
- Devonald, M., Jones, N., Iyasu Gebru, A., & Yadete, W. (2024). Rethinking climate change through a gender and adolescent lens in Ethiopia. *Climate and Development*, 16(3), 176–186. <https://doi.org/10.1080/17565529.2022.2032568>
- Djoudi, H., Locatelli, B., Vaast, C., Asher, K., Brockhaus, M., & Basnett Sijapati, B. (2016). Beyond dichotomies: Gender and intersecting inequalities in climate change studies. *Ambio*, 45(3), 248–262. <https://doi.org/10.1007/s13280-016-0825-2>
- Doss, C., Kovarik, C., Peterman, A., Quisumbing, A., & van den Bold, M. (2015). Gender inequalities in ownership and control of land in Africa: Myth and reality. *Agricultural Economics*, 46(3), 403–434. <https://doi.org/10.1111/agec.12171>

- Dury, J., Schaller, N., Garcia, F., Reynaud, A., & Bergez, J. E. (2012). Models to support cropping plan and crop rotation decisions. A review. *Agronomy for Sustainable Development*, 32(2), 567–580. <https://doi.org/10.1007/s13593-011-0037-x>
- Dzialo, L. (2017). The feminization of environmental responsibility: A quantitative, cross-national analysis. *Environmental Sociology*, 3(4), 427–437. <https://doi.org/10.1080/23251042.2017.1327924>
- Eastin, J. (2018). Climate change and gender equality in developing states. *World Development*, 107, 289–305. <https://doi.org/10.1016/j.worlddev.2018.02.021>
- Egamberdiev, B., Bobojonov, I., Kuhn, L., & Glauben, T. (2023). Household resilience capacity and food security: Evidence from Kyrgyzstan. *Food Security*, 15(4), 967–988. <https://doi.org/10.1007/s12571-023-01369-1>
- Egamberdiev, B., Bobojonov, I., Kuhn, L., Glauben, T., & Akramov, K. (2024). Household resilience and coping strategies to food insecurity: An empirical analysis from Tajikistan. *Applied Economic Perspectives and Policy*, 46(4), 1646–1661. <https://doi.org/10.1002/aep.13422>
- Fingleton-Smith, E. (2018). The lights are on but no (men) are home. The effect of traditional gender roles on perceptions of energy in Kenya. *Energy Research & Social Science*, 40, 211–219. <https://doi.org/10.1016/j.erss.2018.01.006>
- Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*. <https://doi.org/10.5751/ES-03610-150420>
- Geleta, E. B., Elabor-Idemudia, P., & Henry, C. (2017). Scaling-up: Gender integration and women's empowerment in southern Ethiopia. *Cogent Food & Agriculture*, 3(1), Article 1415100. <https://doi.org/10.1080/23311932.2017.1415100>
- Gezie, M. (2019). Farmer's response to climate change and variability in Ethiopia: A review. *Cogent Food & Agriculture*, 5(1), Article 1613770. <https://doi.org/10.1080/23311932.2019.1613770>
- Ghebreyohannes, T., Nyssen, J., Negash, E., Meaza, H., Tesfamariam, Z., Frankl, A., Demissie, B., Van Schayebroeck, B., Redda, A., Annys, S., & Abay, F. (2022). Challenges and resilience of an indigenous farming system during wartime (Tigray, North Ethiopia). *Agronomy for Sustainable Development*, 42(6), Article 116. <https://doi.org/10.1007/s13593-022-00812-5>
- Gonda, N. (2019). Re-politicizing the gender and climate change debate: The potential of feminist political ecology to engage with power in action in adaptation policies and projects in Nicaragua. *Geoforum*, 106, 87–96. <https://doi.org/10.1016/j.geoforum.2019.07.020>
- Gugissa, D. A., Abro, Z., & Tefera, T. (2022). Achieving a climate-change resilient farming system through push-pull technology: Evidence from maize farming systems in Ethiopia. *Sustainability*. <https://doi.org/10.3390/su14052648>
- Gunderson, L. H. (2000). Ecological resilience—In theory and application. *Annual Review of Ecology and Systematics*, 31(1), 425–439. <https://doi.org/10.1146/annurev.ecolsys.31.1.425>
- Habte, M., Eshetu, M., Maryo, M., Andualem, D., & Legesse, A. (2022). Effects of climate variability on livestock productivity and pastoralists perception: The case of drought resilience in Southeastern Ethiopia. *Veterinary and Animal Science*, 16, Article 100240. <https://doi.org/10.1016/j.vas.2022.100240>
- Hasanbasri, A., Kilic, T., Koolwal, G., & Moylan, H. (2021). *LSMS+ program in Cambodia: Findings from individual-level data collection on labor and asset ownership*. Retrieved from <https://documents.worldbank.org/en/publication/documents-reports/documentdetail/240461620192973394/lsm-program-in-sub-saharan-africa-findings-from-individual-level-data-collection-on-labor-and-asset-ownership>. Accessed 11.03.2024.
- Holden, S. T. (2018). Fertilizer and sustainable intensification in sub-Saharan Africa. *Global Food Security*, 18, 20–26. <https://doi.org/10.1016/j.gfs.2018.07.001>
- Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4, 1–23. <https://doi.org/10.1146/annurev.es.04.110173.000245>
- Huyer, S., & Partey, S. (2020). Weathering the storm or storming the norms? Moving gender equality forward in climate-resilient agriculture. *Climatic Change*, 158(1), 1–12. <https://doi.org/10.1007/s10584-019-02612-5>
- Jordan, J. C. (2019). Deconstructing resilience: Why gender and power matter in responding to climate stress in Bangladesh. *Climate and Development*, 11(2), 167–179. <https://doi.org/10.1080/17565529.2018.1442790>
- Kabeer, N. (1999). Resources, agency, achievements: Reflections on the measurement of women's empowerment. *Development and Change*, 30(3), 435–464. <https://doi.org/10.1111/1467-7660.00125>

- Knippenberg, E., Jensen, N., & Constan, M. (2019). Quantifying household resilience with high frequency data: Temporal dynamics and methodological options. *World Development*, *121*, 1–15. <https://doi.org/10.1016/j.worlddev.2019.04.010>
- Lever-Tracy, C. (2008). Global warming and sociology. *Current Sociology*, *56*(3), 445–466. <https://doi.org/10.1177/0011392107088238>
- Loarne-Lemaire, S. L., Bertrand, G., Razgallah, M., Maalaoui, A., & Kallmuenzer, A. (2021). Women in innovation processes as a solution to climate change: A systematic literature review and an agenda for future research. *Technological Forecasting and Social Change*, *164*, Article 120440. <https://doi.org/10.1016/j.techfore.2020.120440>
- MacGregor, S. (2009). A stranger silence still: The need for feminist social research on climate change. *The Sociological Review*, *57*(s2), 124–140. <https://doi.org/10.1111/j.1467-954X.2010.01889.x>
- Malapit, H., Quisumbing, A., Meinzen-Dick, R., Seymour, G., Martinez, E. M., Heckert, J., Rubin, D., Vaz, A., & Yount, K. M. (2019). Development of the project-level women's empowerment in agriculture index (pro-WEAI). *World Development*, *122*, 675–692. <https://doi.org/10.1016/j.worlddev.2019.06.018>
- Mayer, N., Darebo, T. D., Fourie, E., & Bosse, G. (2023). Climate variability and development interventions influence migration aspirations and capabilities of project beneficiaries in Southern Ethiopia. *Migration and Development*, *12*(1), 68–90. <https://doi.org/10.1177/21632324231194762>
- McLachlan, G. J., & Peel, D. (2004). *Finite mixture models*. Wiley.
- McNamara, K. E., Clissold, R., & Westoby, R. (2021). Women's capabilities in disaster recovery and resilience must be acknowledged, utilized and supported. *Journal of Gender Studies*, *30*(1), 119–125. <https://doi.org/10.1080/09589236.2020.1801397>
- Mekonnen, Z. (2022). Intra-household gender disparity: Effects on climate change adaptation in Arsi Negele district, Ethiopia. *Heliyon*, *8*(2), Article e08908. <https://doi.org/10.1016/j.heliyon.2022.e08908>
- Mekuyie, M., Jordaan, A., & Melka, Y. (2018). Understanding resilience of pastoralists to climate change and variability in the Southern Afar Region, Ethiopia. *Climate Risk Management*, *20*, 64–77. <https://doi.org/10.1016/j.crm.2018.02.004>
- Melketo, T., Schmidt, M., Bonatti, M., Sieber, S., Müller, K., & Lana, M. (2021). Determinants of pastoral household resilience to food insecurity in Afar region, Northeast Ethiopia. *Journal of Arid Environments*, *188*, Article 104454. <https://doi.org/10.1016/j.jaridenv.2021.104454>
- Menon, R., & Rustagi, P. (2020). Gender asset gaps and land rights in the context of the Asia-Pacific region. In *Women, Land and Power in Asia* (pp. 37–59). Routledge.
- Meuwissen, M. P. M., Feindt, P. H., Spiegel, A., Termeer, C. J. A. M., Mathijs, E., Mey, Yd., Finger, R., Balmann, A., Wauters, E., Urquhart, J., Viganì, M., Zawalińska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroege, W., ... Reidsma, P. (2019). A framework to assess the resilience of farming systems. *Agricultural Systems*, *176*, Article 102656. <https://doi.org/10.1016/j.agsy.2019.102656>
- Misra, D. (2024). Gendered perspectives on climate change resilience: Exploring women's leadership and the power of collectives in community management of commons in India. In P. Singh & N. Yadav (Eds.), *The climate-health-sustainability nexus: Understanding the interconnected impact on populations and the environment* (pp. 443–481). Springer.
- Najjar, D., Baruah, B., & El Garhi, A. (2020). Gender and asset ownership in the old and new lands of Egypt. *Feminist Economics*, *26*(3), 119–143. <https://doi.org/10.1080/13545701.2020.1743877>
- Negera, M., Alemu, T., Hagos, F., & Hailelassie, A. (2025). Does financial inclusion enhance farmers' resilience to climate change? Evidence from rural Ethiopia. *Sustainable Development*, *33*(2), 3008–3022. <https://doi.org/10.1002/sd.3277>
- Negera, M., Alemu, T., Hagos, F., & Hailelassie, A. (2025). Impacts of climate-smart agricultural practices on farm households' climate resilience and vulnerability in Bale-Eco Region, Ethiopia. *Environment, Development and Sustainability*, *27*(1), 2187–2216. <https://doi.org/10.1007/s10668-023-03962-y>
- Nicholas-Davies, P., Fowler, S., Midmore, P., Coopmans, I., Draganova, M., Pettitt, A., & Senni, S. (2021). Evidence of resilience capacity in farmers' narratives: Accounts of robustness, adaptability and transformability across five different European farming systems. *Journal of Rural Studies*, *88*, 388–399. <https://doi.org/10.1016/j.jrurstud.2021.07.027>

- Pearse, R. (2017). Gender and climate change. *Wires Climate Change*, 8(2), Article e451. <https://doi.org/10.1002/wcc.451>
- Perez, C., Jones, E. M., Kristjansson, P., Cramer, L., Thornton, P. K., Förch, W., & Barahona, C. (2015). How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective. *Global Environmental Change*, 34, 95–107. <https://doi.org/10.1016/j.gloenvcha.2015.06.003>
- Petros, S., Abay, F., Desta, G., & O'Brien, C. (2018). Women farmers' (dis)empowerment compared to men farmers in Ethiopia. *World Medical & Health Policy*, 10(3), 220–245. <https://doi.org/10.1002/wmh3.280>
- Quandt, A. (2019). Variability in perceptions of household livelihood resilience and drought at the intersection of gender and ethnicity. *Climatic Change*, 152(1), 1–15. <https://doi.org/10.1007/s10584-018-2343-7>
- Quinlan, R. J., Quinlan, M. B., Dira, S., Caudell, M., Sooge, A., & Assoma, A. A. (2015). Vulnerability and resilience of Sidama Enset and Maize farms in Southwestern Ethiopia. *Journal of Ethnobiology*, 35(2), 314–336. <https://doi.org/10.2993/etbi-35-02-314-336.1>
- Rather, K. N., & Mahalik, M. K. (2025). Do climate change and world uncertainty exacerbate gender inequality? Global evidence. *Population and Environment*, 47(1), Article 5. <https://doi.org/10.1007/s11111-025-00479-6>
- Ravera, F., Iniesta-Arandia, I., Martín-López, B., Pascual, U., & Bose, P. (2016). Gender perspectives in resilience, vulnerability and adaptation to global environmental change. *Ambio*, 45(3), 235–247. <https://doi.org/10.1007/s13280-016-0842-1>
- Ravera, F., Martín-López, B., Pascual, U., & Drucker, A. (2016). The diversity of gendered adaptation strategies to climate change of Indian farmers: A feminist intersectional approach. *Ambio*, 45(3), 335–351. <https://doi.org/10.1007/s13280-016-0833-2>
- Ross, H., Haque, C. E., & Berkes, F. (2024). Transmission of knowledge and social learning for disaster risk reduction and building resilience: A Delphi study. *Sustainable Development*, 32(2), 1525–1537. <https://doi.org/10.1002/sd.2685>
- Senbeta, A. F., Sime, G., & Struik, P. (2022). Enset farming system – A resilient, climate-robust production system in South and South-Western Ethiopia. *Cogent Food & Agriculture*, 8(1), Article 2074626. <https://doi.org/10.1080/23311932.2022.2074626>
- Sertse, S. F., Khan, N. A., Shah, A. A., Liu, Y., & Naqvi, S. A. A. (2021). Farm households' perceptions and adaptation strategies to climate change risks and their determinants: Evidence from Raya Azebo district, Ethiopia. *International Journal of Disaster Risk Reduction*, 60, Article 102255. <https://doi.org/10.1016/j.ijdr.2021.102255>
- Shahbaz, P., ul Haq, S., Abbas, A., Batool, Z., Alotaibi, B. A., & Nayak, R. K. (2022). Adoption of climate smart agricultural practices through women involvement in decision making process: Exploring the role of empowerment and innovativeness. *Agriculture*, 12(8), Article 1161.
- Sheng, Y., Zhao, S., Nossal, K., & Zhang, D. (2015). Productivity and farm size in Australian agriculture: Reinvestigating the returns to scale. *Australian Journal of Agricultural and Resource Economics*, 59(1), 16–38. <https://doi.org/10.1111/1467-8489.12063>
- Slavchevska, V., Acosta, M., Ndiaye, T., & Park, C. M. Y. (2024). Gendered pathways for resilient and inclusive rural transformation. *Global Food Security*, 43, Article 100818. <https://doi.org/10.1016/j.gfs.2024.100818>
- Slijper, T., de Mey, Y., Poortvliet, P. M., & Meuwissen, M. P. M. (2022). Quantifying the resilience of European farms using FADN. *European Review of Agricultural Economics*, 49(1), 121–150. <https://doi.org/10.1093/erae/jbab042>
- Smith, R., Mdee, A., & Sallu, S. (2023). How gender mainstreaming plays out in Tanzania's climate-smart agricultural policy: Isomorphic mimicry of international discourse. *Development Policy Review*, 41(6), Article e12718. <https://doi.org/10.1111/dpr.12718>
- Smyth, I., & Sweetman, C. (2015). Introduction: Gender and resilience. *Gender & Development*, 23(3), 405–414. <https://doi.org/10.1080/13552074.2015.1113769>
- Southard, E. M. L., & Randell, H. (2022). Climate change, agrarian distress, and the feminization of agriculture in South Asia*. *Rural Sociology*, 87(3), 873–900. <https://doi.org/10.1111/ruso.12439>
- Stotten, R. (2024). The natural domain and its social representation in the community resilience concept. *Sustainable Development*, 32(2), 1458–1470. <https://doi.org/10.1002/sd.2681>
- Teklu, A., Simane, B., & Bezabih, M. (2023). Effect of climate smart agriculture innovations on climate resilience among smallholder farmers: Empirical evidence from the Choke Mountain watershed of the Blue Nile Highlands of Ethiopia. *Sustainability*, 15(5), 4331.

- Temesgen Gelata, F., Han, J., & Kipkogei Limo, S. (2024). Impact of dairy contract farming adoption on household resilience to food insecurity evidence from Ethiopia. *World Development Perspectives*, 33, Article 100560. <https://doi.org/10.1016/j.wdp.2023.100560>
- Termeer, C. J. A. M., Dewulf, A., & Biesbroek, G. R. (2017). Transformational change: Governance interventions for climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and Management*, 60(4), 558–576. <https://doi.org/10.1080/09640568.2016.1168288>
- Terry, G. (2009). No climate justice without gender justice: An overview of the issues. *Gender & Development*, 17(1), 5–18. <https://doi.org/10.1080/13552070802696839>
- Tesfaye, A., Hansen, J., Kassie, G. T., Radeny, M., & Solomon, D. (2019). Estimating the economic value of climate services for strengthening resilience of smallholder farmers to climate risks in Ethiopia: A choice experiment approach. *Ecological Economics*, 162, 157–168. <https://doi.org/10.1016/j.ecolecon.2019.04.019>
- Teshome, E., Zenebe, M., Metaferia, H., & Biadgilign, S. (2012). The role of self-help voluntary associations for women empowerment and social capital: The experience of women's Iddirs (burial societies) in Ethiopia. *Journal of Community Health*, 37(3), 706–714. <https://doi.org/10.1007/s10900-011-9503-2>
- Thiede, B. (2016). Resilience and development among ultra-poor households in rural Ethiopia. *Resilience*, 4(1), 1–13. <https://doi.org/10.1080/21693293.2015.1094166>
- Tofu, D. A., Fana, C., Dilbato, T., Dirbaba, N. B., & Tesso, G. (2023). Pastoralists' and agro-pastoralists' livelihood resilience to climate change-induced risks in the Borana zone, south Ethiopia: Using resilience index measurement approach. *Pastoralism*, 13(1), 4. <https://doi.org/10.1186/s13570-022-00263-3>
- Tofu, D. A., Mekuria, M. M., & Ogato, G. S. (2023). Climatic extremes' resilient livelihoods of rural households in the Eastern Ethiopia. *Agriculture & Food Security*, 12(1), 42. <https://doi.org/10.1186/s40066-023-00446-0>
- Tschakert, P., & Machado, M. (2012). Gender justice and rights in climate change adaptation: Opportunities and pitfalls. *Ethics and Social Welfare*, 6(3), 275–289. <https://doi.org/10.1080/17496535.2012.704929>
- Tsige, M., Synnevåg, G., & Aune, J. B. (2020). Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers. *Scientific African*, 7, Article e00250. <https://doi.org/10.1016/j.sciaf.2019.e00250>
- Urruty, N., Tailliez-Lefebvre, D., & Huyghe, C. (2016). Stability, robustness, vulnerability and resilience of agricultural systems. A review. *Agronomy for Sustainable Development*, 36(1), Article 15. <https://doi.org/10.1007/s13593-015-0347-5>
- USAID. (2022). *Resilience policy revision*. Retrieved from Washington: <https://www.usaid.gov/sites/default/files/2022-12/Resilience-Policy-Revision-Jan-2023.pdf>. Accessed 3 Feb 2024.
- van der Lee, J., Kangogo, D., Gülzari, ŞÖ., Dentoni, D., Oosting, S., Bijman, J., & Klerkx, L. (2022). Theoretical positions and approaches to resilience assessment in farming systems. A review. *Agronomy for Sustainable Development*, 42(2), Article 27. <https://doi.org/10.1007/s13593-022-00755-x>
- WB. (2024). Living standards measurement study - plus (LSMS+). Retrieved from <https://www.worldbank.org/en/programs/lsm/initiatives/lsm-plus>. Accessed 10 Feb 2024.
- Weldegebriel, Z. B., & Amphune, B. E. (2017). Livelihood resilience in the face of recurring floods: An empirical evidence from Northwest Ethiopia. *Geoenvironmental Disasters*, 4(1), 10. <https://doi.org/10.1186/s40677-017-0074-0>
- Williams, T. G., Guikema, S. D., Brown, D. G., & Agrawal, A. (2020). Resilience and equity: Quantifying the distributional effects of resilience-enhancing strategies in a smallholder agricultural system. *Agricultural Systems*, 182, Article 102832. <https://doi.org/10.1016/j.agsy.2020.102832>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.