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REVIEW

Unveiling gendered perspectives on farmers' climate risk perception and adaptation strategies

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Abstract

Climate change poses a significant challenge to farmers worldwide. It affects men and women differently due to their diverse roles, responsibilities, resource access, and socio-cultural norms. Understanding gender perspective would help policymakers to develop evidence-based strategies that address unique vulnerabilities, promoting equitable, inclusive adaptation, and resilience policies to climate risk. This systematic review utilizes the PRISMA technique using three databases: Web of Science, PubMed, and CABI Reviews, and analyzes 162 studies from 32 countries, unveiling nuanced gender perspectives and evidence gaps on farmers' climate risk perceptions and adaptation strategies. These gender variations are primarily driven by four interrelated levers: knowledge and experience, resource availability (including land and finance), socio-cultural norms and mobility, and economic and institutional constraints. The insights from the study show notable variations among men and women farmers in their perceptions of climate risk attributes in agriculture. For instance, men's perception of temperature predominantly revolves around its immediate consequences on crop growth and farm management, while women farmers consider broader implications on household food security and community resilience. These varied gendered perceptions arise from divergent roles, responsibilities, and social and economic status. Adaptation strategies also differed, for example, with men adopting modern approaches while women often relied on traditional knowledge as their primary means of adaptation. This study not only identifies the critical literature gap on climate change impacts and adaptation with a gender lens but also highlights the need for recognizing and incorporating gender-responsive climate adaptation strategies into policy and practices towards climate-resilient agri-food systems and sustainable livelihoods.

Keywords Climate risk · Climate adaptation · Farmers' perception · Gender · Agri-food system

Introduction

Climate change poses significant challenges to agriculture systems worldwide (Shah et al. 2008; Trenberth and Fasullo, 2007; Djoudi and Brockhaus, 2011; Das et al. 2025), affecting the livelihoods of millions of farmers. Recognizing the need for effective adaptation strategies, researchers and policymakers have increasingly emphasized the importance of understanding farmers' perceptions of climate risks and their access to relevant information. Women and men may have distinct perceptions of climate risks due to their different roles, responsibilities, and access to resources (Pearse 2017; Opare and Wrigley-Asante, 2008). These diverse perspectives can result in varying priorities, strategies, and coping mechanisms when they are faced with climate-related challenges. Therefore, gender plays an important role in shaping farmers' vulnerability and capacity to respond to climate change impacts. Hence, it is crucial to consider the gender dimensions within this context, as gender roles and inequalities can shape how farmers experience and respond to climate change (Jost et al. 2016; Kang et al. 2009; Phiri et al. 2013; Lambrou and Piana, 2006). The reality of climate change requires adaptation actions and helps the farmers respond to the changes (Pedercini et al., 2012; Speranza et al. 2010; Olabode 2014; Solomon et al. 2007; Mugambiwa and Tirivangasi, 2017). Therefore, exploring gendered perspectives will contribute to a more comprehensive

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understanding of farmers' experiences and enable the design of gender-responsive climate policies.

While there have been numerous studies to understand the impacts of climate change on agriculture, as well as assessment of potential adaptation strategies (Issa et al. 2015; Smale et al. 2008; Alhassan et al. 2019; Assan et al. 2018; Thornton et al. 2018). However, there is a limited understanding of the gender perspective of farmers' climate risk perception, access to climate information, and adaptation strategies needed to build climate resilience. Although women play an increasingly dominant role in managing agriculture and farming systems, especially in the Global South, women farmers are known to be the most vulnerable to climate risk because of their poor access to resources and preclusion in decision-making, resulting in a low ability to adapt (McKune et al. 2015; Owusu and Yiridomoh, 2021; Carr et al. 2016). Thus, the absence of a gender lens in planning and development actions is likely to result in suboptimal outcomes (Abid et al. 2016). Therefore, research is needed to determine how gender groups, particularly women, can successfully adapt to climate change (Carr and Thompson, 2014). Research on gender inclusion is much needed to better target climate information services and to implement direct action towards gender-responsive climate adaptation (Bryant et al. 2000; Roehr et al. 2009). Gender analysis in climate change research draws conceptually on feminist political ecology and intersectionality theory, which emphasize how power, knowledge, and access to resources shape differentiated experiences of environmental risk. These perspectives highlight that women's and men's adaptive capacities are structured by overlapping social positions, such as class, age, ethnicity, and livelihood roles, rather than by gender alone. Integrating these insights provides a stronger analytical foundation for examining how gender mediates farmers' responses to climate stress. Hence, this study aims to provide a comprehensive analysis of existing literature, offering insights into the patterns and gaps in knowledge regarding gender-specific climate risk perceptions and adaptation responses by focusing on the intersection of gender and climate change in the agricultural context.

It sheds light on the challenges faced by women and men and explores how these challenges influence their decision-making processes. Moreover, by examining how women adapt to climate risks, we can identify effective gender-responsive adaptation practices and policies that enhance resilience and sustainability in agricultural systems. Through synthesizing existing research and analyzing empirical evidence, this paper can contribute to the growing body of literature on gender and climate change and inform policy discussions and interventions that promote gender equality and enhance climate resilience in agriculture.

Following this introduction, the next section outlines the study's methodology, detailing the search strategy, eligibility criteria, and study selection process. The subsequent section presents the study's characteristics, including a breakdown by country, year, and distribution of selected studies. The results are then analyzed under three key themes: gender-differentiated farmers' perceptions of climate risk, factors influencing gender differences in risk perception, and gender-differentiated adaptation strategies. The discussion contextualizes these findings, examining the socio-economic, cultural, and institutional factors shaping gender disparities. Finally, the study concludes with key insights and policy recommendations aimed at promoting gender-responsive climate adaptation strategies.

Protocol

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for conducting the study (Moher et al. 2010).

Search strategy

This study includes the three search databases, PubMed, CABI, and Web of Science, to run the systematic review. We have categorized our research into three main themes: farmers' perceptions, factors affecting gender differences, and adaptation strategies. These three themes consist of 16 subthemes. Within these subthemes, we have utilized a total of 90 different search keywords (details of keywords are in the ESM). We have employed different keywords for the themes, subthemes, "OR" and "AND" operators to capture all relevant results both within and across subthemes. To provide a comprehensive overview, we have compiled all relevant themes, subthemes, and queries. Furthermore, two filters, one about the timeline, the publication period from 1991 until 2022, and the articles published in English, are used to get more relevant results.

Eligibility criteria and study selection

Our primary goal was to comprehend the perception of climate risk, factors affecting perception, and adaptation strategies among farmers, considering gender differences (Table 1).

Final consideration

Upon implementing all the filters and criteria, we narrowed down the initial pool of 2899 studies to a more relevant selection of 162. The search process is visually depicted in the following PRISMA figure (Fig. 1).

Table 1 The screening process of inclusion and exclusion criteria for the systematic review study

Screening phase	Criteria	Inclusion	Exclusion	Rationale
Title screening	Topic related to gender-differentiated farmers and climate change	Issues related to gender, farmers, and climate change	Irrelevant issues not about gender-differentiated farmers	Relevance
Title and abstract	Publication type	Peer-reviewed articles, discussion papers, and significant grey literature from reputed international bodies like FAO, USDA	Only abstracts, partial text available, meta-analyses and opinion papers, editorials, conference abstracts	Peer-reviewed articles with solid quality content and methodology and studies without are excluded
Abstract and full text	Interventions	Studies interventions related to gender focus on farmers' perception, access to information, and adaptation to climate risk	Exclude the articles that could not provide sufficient details for data extraction	Included studies that are relevant to gender-differentiated farmers to climate risk
Full text	Inclusion analysis	Studies reporting the outcomes of climate risk based on gender-related	Studies reporting gender differences in farmers and climate change	Descriptive analysis of understanding the results of farmers' perception and adaptation based on gender

Study characteristic

In our systematic review, we meticulously organized the literature survey by categorizing it into three primary themes and fourteen subthemes. Following a thorough screening process, out of the initial 2899 articles, a total of 162 articles were selected for analysis. The PRISMA flow diagram depicted in Fig. 1 visually presents the sequential search terms employed for the review conducted in this study.

Country-wise distribution

The relevant literature reviewed was related to 32 countries to analyze the gender-differentiated farmers' perception of climate risk, factors affecting perception, and adaptation strategies. We found that the highest number of studies was in Africa in Ghana ($n=26$), Uganda ($n=12$), and Nigeria and Kenya ($n=10$). Study-wise detailed map for the selected studies is shown in Fig. 2.

Year-wise distribution

In the early years of 1991–2009, no literature reviews related to the study were found. However, the assessment is based on the analysis observed from 2010 onwards. Figure 3 shows the details of the year-wise publications, where the highest study was found in the year 2021 ($n=25$), followed by 2020 ($n=20$), 2019 ($n=17$), and 2022 ($n=17$), respectively.

Results

Gender-differentiated farmers' perception of climate risk

Both women and men farmers perceive climate change differently, and this variation is influenced by their level of engagement in agricultural activities and other factors. The literature identifies six climatic aspects in which men and women exhibit distinct perceptions: temperature, rainfall, floods, droughts, seasonal variations, and strong winds.

Perception of temperature

Both men and women farmers acknowledged rising temperatures and related agricultural challenges but differed in concerns. Men focused on direct impacts on crop growth and farm management, especially during the growing season (Lambrou et al., 2010; Assan et al. 2020; Lambrou and Piana, 2006). Women emphasized broader effects on household welfare, food security, nutrition, and community resilience (Su et al. 2017; Diarra et al. 2021; Mafongoya and Ajayi, 2017; Duyen et al. 2021; Kumar et al., 2022). These differences stem from distinct farming and household roles.

Perception of rainfall

Men and women farmers largely agreed on rainfall changes, relying on observations and local meteorological data

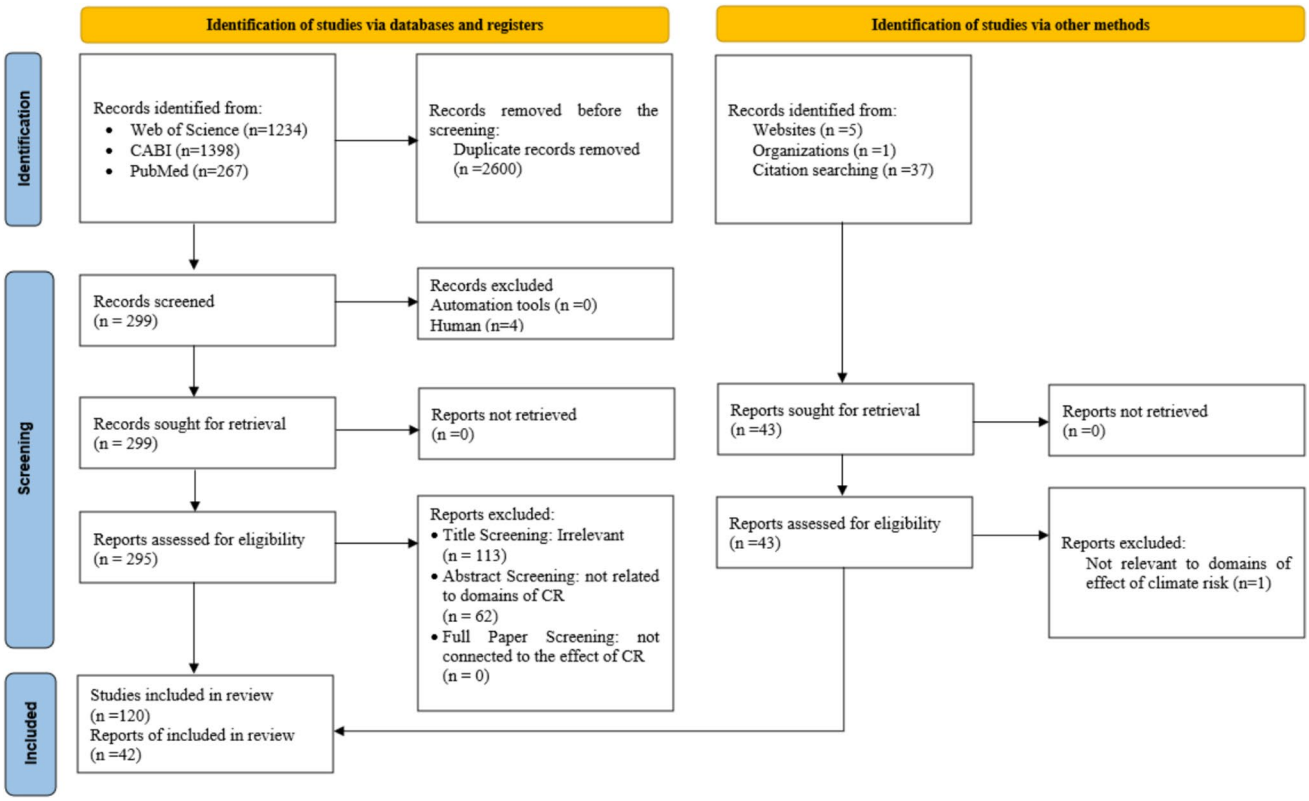


Fig. 1 PRISMA 2020 flow diagram (Page et al., 2020) for new systematic reviews, which included searches of databases, registers, and other sources

(McKinley et al. 2016; Lambrou and Nelson, 2010). Both expressed concerns over increasing rainfall unreliability, experiencing extremes of excess or insufficiency. They noted that late onset and frequent interruptions during critical farming periods reduced crop yields (McKinley et al. 2016; Bessah et al. 2021; Othniel Yila and Resurreccion, 2014; Rao et al. 2011; Othniel Yila and Resurreccion, 2013). Men, like women, observed shifts in the rainy season, with early cessation causing crop failures and production challenges. They also recognized a shorter cropping season due to delayed spring rains (Bessah et al. 2021; Mishra and Pede, 2017).

Women farmers were more observant of rainfall timing and rainy days than men (McKinley et al. 2016; Adzawla and Kane, 2018; Diiro et al. 2016; Ngigi et al., 2022). They relied on extensive farming experience to interpret forecasts, especially rainfall onset and duration (Su et al. 2017; Radeny et al. 2019). Women predicted rainfall cessation earlier, while men focused on the delayed onset and decreasing rainfall. These differences stemmed from gender roles—men handled land preparation, while women maintained the crops until harvest (Wrigley-Asante et al., 2019; Mafongoya and Ajayi, 2017).

Perception of floods

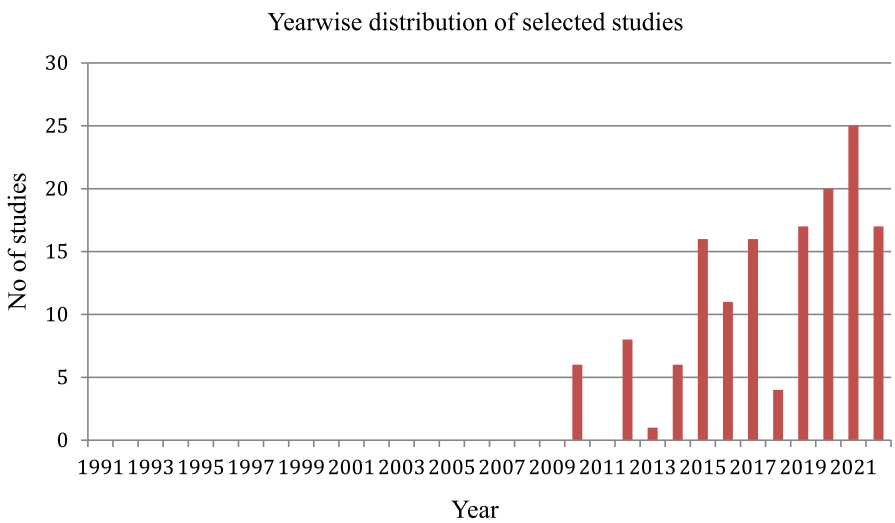
Men and women farmers share concerns about frequent floods but emphasize different impacts. Men focus on physical damages and economic losses, while women highlight social and household effects (Wrigley-Asante et al., 2019; Achandi et al. 2018; Mulenga et al. 2017; Armah et al. 2010).

Men recognize floods' negative effects on farming, citing crop destruction, soil erosion, and asset loss (Bessah et al. 2021; Naz et al. 2018; Rufat et al. 2015; Mafongoya and Ajayi, 2017; Duyen et al. 2021; Nyantakyi-Frimpong, 2019; Nyadzi et al. 2018). Their concerns align with broader agricultural challenges. Women, however, stress floods' impact on food security, water access, and vulnerability, linking them to increased workload, infrastructure damage, and daily disruptions (Mafongoya and Ajayi, 2017; Adzawla et al. 2019; Nyantakyi-Frimpong and Bezner Kerr, 2017; Antwi-Agyei et al., 2021; Speranza et al. 2010; Duyen et al. 2021).

Women's close ties to households and land give them detailed knowledge of local flood patterns and long-term climate trends (Jost et al. 2016; Mersha and

Fig. 2 Distribution of relevant studies across the world

Fig. 3 Year-wise distribution of selected studies



Laerhoven, 2016; FAO, 2015). They observe subtle variations in flood frequency, intensity, and duration, while men focus more on practical flood management and recovery (Mensah et al. 2022; Ahmad et al. 2021; Joshua et al. 2016).

Perception of droughts

Men and women farmers perceive drought as the most severe and recurrent climatic stressor affecting crops, livestock, and water resources. Both identify drought through delayed

rainfall, prolonged dry spells, and reduced water availability; however, their interpretations and experiences differ by gendered roles and access to productive assets. In Makueni, Kenya, men link drought mainly to losses in crop yield, fodder, and income, while women associate it with water scarcity, household food insecurity, and increased labor demands (Kiumbuku et al. 2020; Habiba et al. 2012).

Women's greater responsibility for water collection, household food preparation, and care work makes drought's social and nutritional consequences more visible to them. They report walking longer distances for water, prioritizing children's consumption, and shifting to less preferred foods during prolonged dryness (Habiba et al. 2014; Ferdous and Mallick 2019). Men, conversely, perceive drought primarily as a production crisis that threatens livestock and income stability. They respond through herd destocking, switching livestock breeds, or migrating for employment (Kiumbuku et al. 2020).

Differences in control over resources reinforce these divergent perceptions. Men's control of land, livestock, and irrigation infrastructure allows them to view drought in terms of economic risk and asset management. Women, constrained by limited access to credit and formal markets, perceive drought as a household survival challenge, relying on low-cost coping strategies such as small-scale irrigation, kitchen gardening, and informal social networks for mutual aid (Mersha and Van Laerhoven 2016).

Perception of seasonal variations in rainfall

The majority of both men and women farmers indicated that there were more occurrences of seasonal variations as compared to their past experiences, and they also had similar views about the change in the length of growing seasons (Eastin 2018; Armah et al. 2010). However, men were less likely to perceive the change in the season compared to women, mainly due to their gender roles and activities; however, they agreed that the length of the growing season had changed recently (Eastin 2018; Armah et al. 2010).

Perception of strong winds

Both men and women farmers noted an increase in strong winds (Olabode 2014; Björnberg and Hansson, 2013; Othniel Yila and Resurreccion, 2014) but differed in concerns. Men focused on rising wind speeds in both dry and wet seasons (Singh et al. 2017; Le Dang et al. 2014; Moyo et al. 2012; Kichamu et al. 2018) and reported stronger winds, especially during dry and rainy seasons (Rondhi et al. 2019). They observed winds had intensified compared to the past (Björnberg and Hansson, 2013) and linked them to increased bushfire damage in the dry season (Rondhi et al. 2019). Women recognized stronger, more frequent winds carrying dust, which reduced crop yields (Tambo and Abdoulaye, 2013). They also highlighted household risks, particularly hazardous cooking conditions due to fire dangers (Rondhi et al. 2019; Eastin 2018).

These perception differences are rooted in the everyday gendered division of labor. Women's routine responsibilities, such as collecting water, preparing daily meals, managing household food stocks, caring for dependents, and running small household enterprises, expose them directly to water scarcity, food shortages, and sanitation problems. Consequently, changes in rainfall, flooding, or water availability become immediate and personal climate concerns. Men's labor roles, such as land preparation, mechanized operations, market-oriented decisions, and larger-scale livestock management, focus their attention on crop productivity, input costs, market risks, and household income. Several reviewed studies explicitly link these task-based exposures to perception: for example, women's higher time burden for water collection is associated with stronger concern about drought and water stress (Kristjanson et al. 2017; Lambrou and Nelson, 2010), while men's market responsibilities relate to reporting yield and price impacts (Deressa et al. 2009; Bryan et al. 2009). Framing perception through the lens of everyday tasks clarifies the proximate mechanisms that translate broader structural constraints, such as limited land, credit, and mobility, into distinct climate concerns and adaptation choices. The specific socio-economic, cultural, and institutional factors shaping these patterns are discussed in detail in section "Factors affecting gender differences in perception of climate risk." These differentiated perceptions also shape actual adaptation decisions: women, prioritizing household food and water security, adopt measures such as home gardening, food preservation, and water storage, whereas men's yield- and income-focused perceptions drive investment in irrigation, seed selection, and other input-intensive technologies. Hence, perception differences act as both a reflection of gendered roles and a driver of gender-specific adaptation behavior.

Factors affecting gender differences in perception of climate risk

Climate change affects everyone but unevenly (Wheeler and Braun, 2013; Tall et al. 2014). Social, economic, and cultural factors shape how men and women experience and perceive climate risks.

Examining these factors reveals how gender norms, roles, and inequalities intersect with environmental challenges. This understanding helps address specific gender-based vulnerabilities to climate change (Issa et al. 2015; Carr et al. 2016; Kristjanson et al., 2015c; Tall et al. 2014; Mosso et al. 2022; Kyazze et al. 2012). Effective policies must consider these diverse needs and perspectives.

The literature identifies four key factors influencing gender differences in climate risk perception: knowledge and experience, access to information and resources, socio-cultural influences, and economic factors. These factors often interact rather than act independently. Several studies indicate that vulnerabilities emerge from their convergence. For example, limited education opportunities, social and economic marginalization, and restricted land rights can jointly constrain women's access to adaptive technologies, finance, and decision-making spaces, producing compounded vulnerabilities. Where study evidence permitted, we noted these interacting drivers to provide a partial intersectional reading of gendered adaptation processes. Table 2 provides an overview.

Knowledge and experience

Knowledge and experience play a key role in gender differences in climate risk perception. The literature highlights several sub-factors:

- *Access to formal education*: Limited education access can reduce women's climate change knowledge, especially in rural areas, affecting their risk perception compared to educated men (Diiro et al. 2016; Ngigi et al. 2016, 2022; Partey et al. 2020; Khoza et al. 2019).
- *Exposure to climate hazards*: Women, due to roles in crop and livestock management, often have more direct exposure to climate events like floods and droughts, heightening their risk perception (Perez et al. 2015; McKune et al. 2015; Bessah et al. 2021; Rahman 2013).
- *Previous disaster experience:* Women who have witnessed severe climate events may perceive risks as more imminent and severe than men with fewer encounters (Bryant et al. 2000; Chandra et al. 2017).
- *Roles in farming households*: Women's responsibilities in crop, livestock, and water resource management deepen their understanding of climate risks (Adzawla et al. 2019; Elum et al. 2017; Lawson et al. 2020; Morton, 2007).
- *Experience and knowledge in agriculture*: Women's farming expertise, including knowledge of local crop varieties and adaptive strategies, shapes their climate risk perception differently from men (Jost et al. 2016; Singh et al. 2022; Friedman et al. 2019; Mertz et al. 2009).

Access to information and resources

Access to information and resources is key to gender differences in climate risk perception. The literature highlights several sub-factors:

- *Climate knowledge*: Unequal access to climate information, scientific literature, education, mobile phones, and the internet limits women's understanding of climate risks (Pearse 2017; Zoundji et al. 2018). In rural Ghana, women lacked climate information, making them less informed than men (Issa et al. 2015; Owusu et al. 2020; Nyantakyi-Frimpong 2020).

Table 2 Factors affecting gender difference climate risk perception

Attributes	Factors
Knowledge and experience	• Access to formal education • Exposure to climate hazards such as floods, droughts, and heatwaves • Previous experience with climate-related disasters • Roles and responsibilities in farming households • Experience and knowledge related to crop and livestock management, non-farm income-generating activities, and resource management
Access to information and resources	• Access to information and knowledge about climate change • Access to weather forecasting and early warning systems • Access to technological innovations and new agricultural practices • Access to extension services and technical assistance related to climate change • Access to training, government policies, and programs for climate change adaptation • Access to social networks and community organizations
Socio-cultural factors	• Exposure to conflicts and social instability • Social and economic marginalization • Gender roles in different farming activities • Access to legal protections and rights related to land and natural resources • Exposed to discrimination based on gender
Economic factors	• Decision-making power and influence in farming households • Access to productive resources such as land, water, and seeds • Access to credit, insurance, and financial risk management tools • Access to markets for agricultural products

- *Weather forecasting*: Women, especially in remote areas, have limited access to weather forecasts, hindering their ability to anticipate and respond to climate hazards (Mishra and Pede, 2017; Adzawla et al. 2019). Since most climate information programs target men, women struggle with decisions on planting and livestock protection (Bryan et al. 2013; Issa et al. 2015; Thomas et al. 2007; Vincent, 2007).
- *Technology and innovation*: Social, economic, and cultural barriers restrict women's access to climate-smart technologies like drought-resistant seeds and efficient tools, affecting their perception of risks and adaptive capacity (Naz et al. 2018; Naab and Koranteng, 2012; Huyer 2016; Acosta et al. 2021).
- *Extension services*: Women face challenges in accessing climate-related extension services due to gender norms, mobility restrictions, and exclusion from decision-making, limiting their exposure to training and assistance (Nnadi et al. 2019; Fosu-Mensah et al., 2012; Perez et al. 2015; Bryan et al. 2013).
- *Training and policies*: Gender biases and limited access to training and policy processes hinder women's adaptation efforts and shape their climate risk perception (Ngigi et al. 2016; Tanjeela and Rutherford, 2018; Ampaire et al. 2020).
- *Social networks*: Cultural norms restricting women's participation in community networks reduce their access to climate-related information, shaping their risk perception compared to men with broader networks (Jost et al. 2016; Gumucio et al. 2020; McOmber et al. 2013).

Socio-cultural factors

Socio-cultural factors significantly shape gender disparities in climate risk perception. Key sub-factors include:

- *Exposure to conflicts and social instability*: Women, disproportionately affected by conflicts, directly witness the intersection of social, political, and environmental challenges. Those in conflict-affected regions often perceive climate risks as more severe due to experiences of displacement and vulnerability (Mishra and Pede, 2017; Nyantakyi-Frimpong, 2019; Nyadzi et al. 2018).
- *Social and economic marginalization*: Limited access to resources and decision-making power affects women's ability to address climate risks. Marginalized women in rural areas may perceive risks differently from men in positions of authority (Figueiredo and Perkins, 2013; Arora-Jonsson, 2011; Jost et al. 2016; McKune et al. 2018; Nyantakyi-Frimpong and Bezner Kerr, 2017).
- *Access to legal protections and land rights*: Restricted access to land and natural resource rights limits women's ability to invest in climate-resilient practices, shaping their risk perception (Naz et al. 2018; Naab and Koranteng, 2012; Othniel Yila and Resurreccion, 2013).
- *Gender-based discrimination*: Discrimination, gender-based violence, and unequal power dynamics heighten women's exposure to climate risks and hinder their adaptive capacity (Djoudi and Brockhaus, 2011; Kristjanson et al. 2017).

Economic factors

Economic factors shape gender differences in climate risk perception through several key sub-factors:

- *Decision-making power in farming households*: Women's limited role in agricultural decisions, resource management, and climate adaptation results in their perspectives being underrepresented, influencing their risk perception (Van Aelst and Holvoet, 2018; Phiri et al. 2022; Achandi et al. 2018; Mersha and Laerhoven, 2016; FAO, 2015; Kiewisch 2015).
- *Access to productive resources*: Barriers in accessing land, water, and seeds limit women's ability to adopt climate-resilient practices, increasing vulnerability and shaping risk perception (Singh et al. 2022; Mensah et al. 2022; Carranza and Niles, 2019).
- *Access to financial tools*: Limited access to credit, insurance, and financial risk management tools restricts women's ability to invest in climate-smart practices and cope with climate shocks, affecting their risk perception (Elum et al. 2017; Resurrección et al. 2019; Bryan et al. 2013; Batung 2021).
- *Access to agricultural markets*: Transportation barriers, lack of market information, and gender biases hinder women's market access, affecting their income and ability to adapt. Those unable to access competitive markets may perceive climate risks differently as they struggle to secure fair returns (Nnadi et al. 2019; Achandi et al. 2018; Mersha and Laerhoven, 2016).

Gender-differentiated farmers' adaptation strategies

Understanding adaptation strategies is vital for both men and women farmers (Alhassan et al. 2019; Edvardsson Björnberg and Hansson, 2013); Twyman et al. 2014; Tall et al. 2015; Mitchell and Tanner, 2006; Alston 2013). Table 3 highlights key strategies, including sustainable resource management, pest and disease control, water stress management, income diversification, climate information use, extension services, crop diversification, community seed banks, crop preferences, livestock production, and financial activities in post-harvest processes. While the review identifies a clear gender divide between modern, capital-intensive strategies adopted mainly by men and low-cost, labor-intensive approaches adopted by women,

Table 3 Adaptation strategies based on gender differences

Adaptation strategies	Women	Men
Sustainable resource management	• Planting of trees for long-term • DSR- direct seeding of rice • Zero-till planting of crops	• Planting of trees for short term • Use of soil moisture retention techniques such as mulching and reducing tillage • Crop diversification • Rainwater harvesting • DSR and zero-till planting
Pest and disease management	• Use of traditional knowledge • Intercropping • IPM	• Use of modern technology, such as weather-monitoring equipment • Optimal scheduling of pesticide application
Managing water stress under rainfed and irrigated systems	• Rainwater harvesting techniques for domestic and agricultural use (supplemental irrigation)	• Use of modern irrigation technologies such as drip irrigation (micro-irrigation) • Use of small-scale irrigation systems
Income diversification through off-farm activities	• Engage more in off-farm activities within the area they are living • Maintenance of small business, e.g., value addition, marketing	• Temporary migration
Use of climate information and extension services	• Training conducted by NGOs	• Training and workshops by the government and other organizations
Cropping/farming system diversification	• Home gardening • Community-managed nurseries	• Integration of perennial component- horti-culture • Crop-rotation
Community seed bank	• Creation of a seed bank to ensure access to diverse seed varieties in case of crop failure	• Selection of crop varieties that have high yields, better resistance to pests and diseases, and drought-resistant characteristics
Crop preferences	• Cultivation of drought-tolerant crop varie-ties	• Cultivation of crops that have high higher yield and market value
Adaptation strategies for livestock production	• Engage in livestock maintenance especially small ruminants as adaptation strategy	• Fodder production for livestock during drought periods • Livestock as a diversification strategy • Fodder trees • Fodder market development- surplus areas to deficit areas
Post-harvest and other financial activities	• Establishment of women's group for collec-tive action and support	• Investment in post-harvest facilities, such as drying facilities, to reduce crop loss • Use of market information systems to identify profitable crops and prices

these choices should not be read as simple opposites of progress and backwardness. Women's reliance on traditional or small-scale methods, such as manual irrigation, intercropping, or income diversification, often represents rational, context-appropriate responses to limited access to land, credit, and technology. These approaches reflect both creativity and constraint: they enable short-term coping within existing resource limits but rarely secure long-term resilience without broader institutional support.

Sustainable natural resource management

Gender differences in access to productive resources strongly shape how men and women manage soil, water, and vegetation. Women's limited access to land, machinery, and hired labor lead them to prioritize low-cost, labor-based conservation practices that can be implemented within household resource constraints. Sustainable natural resource management includes various adaptation strategies, such as tree planting for soil conservation. Women were more engaged in tree planting and committed to long-term growth, while men focused on selling trees for financial gain (Amin et al. 2019; Naab and Koranteng, 2012; Buechler 2016; Sanogo et al. 2016; Thorlakson and Neufeldt, 2012; Antwi-Agyei et al. 2021; Goh 2012).

For soil moisture retention, both genders use compost, with men preparing it and women applying it on farms (Antwi-Agyei et al. 2021; Murray et al. 2016). Women adapt to drought by adjusting planting dates and constructing drains, as they face higher climate vulnerability (Lambrou and Nelson, 2010; Ncube and Shikwambana, 2016; Alhassan et al. 2019). While both men and women adopt soil conservation techniques, adoption rates vary (Nyantakyi-Frimpong and Bezner Kerr, 2017).

Gender disparities exist in agricultural technology adoption, with more women favoring the System of Rice Intensification (SRI) and fertilizer use (Duyen et al. 2021). Men prioritize soil fertility through organic management, intercropping, crop rotation, and short-cycle crops, while women prefer traditional flood- or drought-tolerant varieties and organic soil fertility management (Ravera et al. 2016; Manda et al. 2016). Both genders engage in mulching and water catchment, though men practice these more due to better financial access (Chinasho et al. 2022; Naab and Koranteng, 2012). Taken together, women's strategies demonstrate adaptation through efficiency and persistence rather than capital investment, illustrating how resource constraints shape practical but labor-intensive environmental management.

Pest and disease management

Differences in access to tools, inputs, and extension information also determine how men and women manage agricultural pests and diseases. Women's limited access to chemical inputs, knapsack sprayers, and formal pest-control training forces them to depend on locally available and labor-based techniques, whereas men, with greater access to technology, rely more on chemical control and machinery. Men show higher awareness of pest and disease management, while women report a greater increase in pest occurrences (Roehr et al. 2009; Mwadzingeni et al. 2022; Sanogo et al. 2016; Kawarazuka et al. 2020). Women face challenges in pest control due to limited access to modern technology like knapsack sprayers, mostly owned by men (Twyman et al. 2014). However, in some regions, women lead in using mechanical traps for banana plantations (Naab and Koranteng, 2012).

Gender disparities exist in planting date adjustments to erratic rainfall in Ghana. More men change planting dates, while women adapt due to higher climate vulnerability (Tambo 2016; Alhassan et al. 2019; Arku 2013). Women adopt zero tillage and intercropping, often due to limited tractor access, unlike men (Adzawla et al. 2019; Chaudhury et al. 2012). In Ha Tinh and Thai Binh provinces, women benefit more from integrated pest management (IPM) for agricultural sustainability (Duyen et al. 2021). These examples highlight that women's adaptive pest management practices arise not from preference alone but from constrained access to technology, illustrating how gendered resource gaps influence adaptation choices.

Managing water stress under rainfed and irrigated systems

Access to irrigation facilities remains highly gendered. Because irrigation infrastructure, credit, and water-user networks are largely controlled by men, women rely on traditional, small-scale, and labor-intensive water-harvesting systems that fit within their limited financial and social resources. Men have greater access to irrigation water, benefiting from modern technologies and support, enhancing productivity (Diiro et al. 2016; Deressa et al. 2009; Chaudhury et al. 2012). Women, facing water challenges worsened by droughts, rely on small-scale irrigation and traditional water harvesting (Kristjanson et al. 2017). Gender disparities exist in irrigation use, with men controlling irrigation but acknowledging water-saving techniques as suitable for women (Duyen et al. 2021; Le Dang et al. 2014).

Men dominate labor-intensive water harvesting techniques, while women's participation is limited by access to labor and financial resources (Naab and Koranteng, 2012). Trenching and mulching are more common among men, as are micro-irrigation and water harvesting, due to high costs and labor demands (Kawarazuka et al. 2020; Jost et al. 2016). Men also favor zero grazing and small-scale irrigation for high-value crops. Consequently, women's strategies emphasize water efficiency and household-scale resilience more than productivity gains, revealing how inequitable resource control defines adaptation pathways.

Income diversification through off-farm activities

Gender-based constraints on land ownership, market access, and financial capital strongly influence income diversification choices. Women diversify livelihoods through non-farm and home-based enterprises as a rational response to limited agricultural assets and growing climate uncertainty. Women farmers are more inclined towards off-farm activities, engaging in trading and basketry during droughts to boost household income, reflecting their diverse cultural and gender roles (Kristjanson et al. 2015c; Björnberg and Hansson, 2013). They expand income through non-farm activities more than men (Achandi et al. 2018; Mersha and Laerhoven, 2016); Deressa et al. 2009). As temperatures rise, female-headed households reduce farm size to mitigate income loss and show greater financial risk aversion by making smaller farming investments while diversifying livelihoods (Kristjanson et al. 2015a).

Women participate in income maintenance programs like sewing and use micro-businesses with government or non-institutional loans to counter climate impacts (Ahmad et al. 2021). Compared to men, more women diversify household income by securing credit loans for small businesses or livestock farming (Assan et al. 2018; Kumasi et al. 2019) and transition to non-farm jobs as an adaptation strategy (Antwi-Agyei et al. 2021). This shift is driven by men's temporary migration during hot spells, increasing women's responsibilities (Vinke et al. 2022; Ekpo and Agu, 2014). Women also take on sowing, weeding, watering, harvesting,

post-harvest activities, and animal husbandry due to male outmigration (Onta and Resurreccion, 2011). Evidence on income diversification thus reflects women's constrained but adaptive agency—balancing risk under unequal access to land and finance.

Usage of climatic information and extension services

Information asymmetry and institutional bias limit women's participation in climate-related training. Lower literacy levels, restricted mobility, and the need for male permission reduce women's ability to engage in extension programs, pushing them towards informal learning networks and NGO-supported initiatives. Training is crucial for women's climate adaptation, with many participating in NGO-led sessions (Kristjanson et al. 2015a; Enid et al. 2008; Orlove et al. 2010). However, time constraints and the need for husbands' permission limit their application of knowledge. NGOs addressing gender inequality are more accessible to women (Antwi-Agyei et al. 2021; Kyazze et al. 2012; Kisauzi et al. 2012). A gender gap exists in extension service use, as men benefit more due to higher literacy and resource control. Enhancing women's access to technical resources and recruiting more women extension officers can help bridge this gap (Diiro et al. 2016). Training from local organizations and NGOs promotes strategies like crop replacement and resilient varieties for flood risk mitigation (Anik et al. 2021; Aryal et al. 2020). Organizations must strengthen gender-responsive support, addressing social and cultural barriers (Acosta et al. 2021; Kumar et al. 2022). Societal norms often require women to seek husbands' permission before joining training programs (Acosta et al. 2021).

In rice production, men make input and investment decisions, while women focus on livestock and off-farm activities. Their limited role in rice farming stems from restricted access to technical knowledge and exclusion from training and extension services (Duyen et al. 2021). Men tend to adopt new practices earlier, with women learning from husbands or NGOs about improved crop varieties, fertilizers, agrochemicals, and composting (Jost et al. 2016). Women also gain agricultural knowledge from friends and neighbors and manage tree nurseries through training in vermiculture, composting, vegetable gardening, and income-generating activities (Jost et al. 2016). Women's adaptive learning largely occurs through community sharing and experiential practice, showing how knowledge gaps reinforce dependence on informal institutions.

Cropping/farming system diversification

Patterns of diversification reflect differences in resource ownership and decision power. Women's limited control over land, credit, and farm inputs encourages emphasis on small-scale, low-input diversification practices that secure food rather than maximizing yield. Men adapted better through crop diversification, mixed cropping, and improved varieties (Fadina and Barjolle, 2018). Women excelled in adjusting planting dates, delaying the season, widening the gender gap (Ubisi et al. 2017). Men practiced adaptation strategies like planting fruit trees, intercropping, crop rotation, composting, using manure, avoiding burning, incorporating crop residues, leaving fields fallow, and cultivating in lowlands. Women planted dry-season vegetables for consumption and sale and showed interest in tree nurseries but cited limited land ownership as a barrier to long-term investments (Chaudhury et al. 2012; Jost et al. 2016). Women farmers also stored food from home gardens to sustain during extreme floods (Khoza et al. 2019; Umar 2021; Dhanya and Ramachandran, 2016; Singh et al. 2017; Singh et al. 2011; Buechler 2016). Their focus on household-level resilience demonstrates adaptive pragmatism shaped by systemic inequality in asset control.

Community seed bank

Seed access illustrates how community-based initiatives offset institutional exclusion. Women's restricted access to formal seed markets and improved inputs makes community seed banks vital for maintaining local genetic diversity and resilience. These banks provide locally adapted varieties and social mechanisms for sharing resources. In Ghana, men adopted early maturing seeds more than women due to women's limited access to inputs (Alhassan et al. 2019; Naab and Koranteng, 2012). Drought-tolerant varieties were also more common among men (Wrigley-Asante et al. 2019). Men and women adopted different crop varieties in response to erratic, short rains (Adzawla et al. 2019). Another study found gender differences in adopting stress-tolerant cultivars, leading to shifts in crop choices to reduce failure (McKinley et al. 2016; Mishra and Pede, 2017). Thus, community seed systems act as an equalizing mechanism where formal channels fail to reach women farmers.

Crop preferences

Crop-choice decisions also reveal gendered trade-offs between labor, land, and market participation. With less access to land, machinery, and input credit, women select crops that are labor-manageable and nutritionally important, while men focus on yield-maximizing, market-oriented varieties. Both men and women plant early and use machinery, but more women practice late sowing due to constraints on new crops' adoption (Lawson et al. 2020). Men plant in rows and benefit from higher yields, reflecting access to labor (Björnberg and Hansson, 2013).

Gender gaps exist in crop technology adoption. Despite widespread awareness of productivity information, fewer women access it because extension programs favor large, male landholders (Abid et al. 2016). More women adopt drought-tolerant crops to adapt to climate change (Antwi-Agyei et al., 2021; Laube et al. 2012), while men implement broader changes, including new crop varieties, tree crops (mango, cashew, citrus, papaya), and livestock (pigs, rabbits). Men use more inorganic fertilizers and agrochemicals, whereas women adopt vegetable crops (moringa, spinach, cabbage), composting, and row planting for better rainwater retention. These changes increase workloads and disease risks (Chaudhury et al. 2012; Jost et al. 2016). These patterns highlight that women's crop decisions are guided by necessity, balancing household nutrition and manageable workloads more than market returns.

Adaptation strategies for livestock production

Livestock ownership mirrors the broader gender asset gap. Men's greater access to capital allows investment in large ruminants and market-oriented herds, while women, constrained by smaller assets and care responsibilities, focus on small livestock for immediate income and household nutrition. Both men and women adopted livestock farming as a climate adaptation strategy. Men reported a decline in local livestock production over five decades, as they owned more animals (Bryan et al. 2009). Women reared goats, chickens, rabbits, and poultry to supplement household income, especially during the rainy season when farmlands were flooded (Kristjanson et al. 2015a).

Farmers expanded livestock holdings in response to rainfall variability, noting higher prices during droughts (Mosso et al. 2022). To reduce crop failure risks, both men and women sometimes decreased livestock numbers (Carranza and Niles, 2019).

Tree plantations integrated with livestock farming were common, with women contributing more to maintenance. Fruits were used for household consumption during crises, and tree branches served as fuelwood (Kyazze et al. 2012; Chaudhury et al. 2012). Women maintained livestock, while men managed and marketed livestock products (Chaudhury et al. 2012; Jost et al. 201). Such division of labor highlights complementary adaptation roles shaped by ownership patterns and intra-household bargaining power.

Post-harvest and other financial activities

Financial access and market interaction remain among the most entrenched gender barriers. Women's limited mobility, lack of collateral, and exclusion from formal credit systems confine them to low-risk, post-harvest, and small-scale financial activities that nonetheless sustain household adaptation. Access to financial resources is key to tackling climate challenges, yet women farmers struggle with limited access to financial institutions and markets due to restricted family interactions (Rao et al. 2019; Osbahr et al. 2010). Their reliance on family and friends for forming groups and businesses further limits involvement (Huyer 2016).

While eager to diversify livelihoods (Kristjanson et al. 2015a; Stathers et al. 2013), women's lack of credit access hinders farm control and climate adaptation efforts, increasing vulnerability (Kristjanson, 2015c). Cultural norms restrict women's interactions with development professionals, limiting access to market information and agricultural supplies, whereas men benefit from greater financial control (Bryan et al. 2009; Kristjanson, 2015c).

Men are more likely to travel for marketing, purchase improved seeds, and attend development training, while women focus on post-harvest work (Chaudhury et al. 2012; Jost et al. 2016; Ahmed & Kiester, 2021). Women's reliance on collective savings and small-enterprise initiatives illustrates adaptive resilience within constrained financial systems.

Overall, linking specific constraints to the strategies used clarifies that adaptation behavior reflects structural inequality as much as individual choice. Low-cost and decentralized methods developed or maintained by women cannot be dismissed as inferior, but their long-term viability depends on whether policies expand access to productive assets and services. Conversely, the adoption of "modern" technologies by better-resourced male farmers is not automatically a measure of success, as high-input methods may be financially or ecologically unsustainable. Recognizing these trade-offs underscores the need for policies that support diverse, equitable, and locally grounded adaptation pathways.

Discussion

This study highlights significant gender disparities in climate risk perception and adaptation strategies, shaped by socio-economic, cultural, and institutional factors. These disparities stem from gender roles that influence access to resources, decision-making power, and livelihood responsibilities.

Gendered differences in climate risk perception are shaped by distinct roles in agriculture and household activities. Men, responsible for land preparation, crop production, and market-related decisions, focus on direct agricultural impacts such as declining yields and economic losses. Women, managing food security and household well-being, perceive climate risks through the lens of food availability, water access, and household resilience. These perspectives reflect the different ways climate stressors affect their daily responsibilities.

Another key driver of gendered risk perception is access to knowledge and technology. Men, with greater access to formal education and extension services, rely more on scientific data and climate forecasts. Women, often excluded from these resources, depend on experiential knowledge and traditional forecasting methods. Limited access to information makes women more risk-averse, as uncertainty about climate risks leads them to prefer low-risk, traditional farming methods over adopting new technologies. This lack of information prevents them from making fully informed decisions, reinforcing their vulnerability.

Social networks and mobility also contribute to these differences. Men are more likely to participate in farmers' associations, cooperatives, and policy discussions, where climate-related information is shared. Women, due to cultural and mobility restrictions, often have fewer opportunities to engage in these platforms. As a result, their risk perception is shaped more by immediate household experiences than broader climate trends discussed in agricultural forums.

The adaptation strategies employed by men and women reflect differences in resource access, decision-making power, and economic constraints. Men, who control land, finances, and agricultural inputs, are more likely to adopt capital-intensive adaptation measures such as irrigation, mechanization, and improved seed varieties. These strategies require substantial investment and technical knowledge, which men are better positioned to access.

On the other hand, women often work with lower-quality land, have less access to improved seeds and fertilizers, lack financial resources to invest in new technologies, and have low access to the market. These constraints make them more cautious when adopting unfamiliar climate adaptation strategies, as they cannot afford the risks associated with high-cost investments and rely on low-cost, labor-intensive adaptation methods. Adjusting planting dates, intercropping, using traditional soil conservation techniques, and engaging in small-scale irrigation are common strategies. However, these approaches demand significant time and effort, increasing women's workload while offering limited protection against extreme climate events. The lack of secure land tenure also discourages women from adopting long-term adaptation measures, as they cannot invest in practices that require land ownership.

Women are also more likely to engage in livelihood diversification, such as small businesses, handicrafts, and trading, to compensate for climate-related income losses. Unlike men, who focus on intensifying agricultural production, women seek alternative income sources to reduce economic dependence on farming. However, financial constraints, restricted market access, and cultural barriers often limit the effectiveness of these strategies.

Another key challenge is access to technology. Women's limited exposure to new agricultural innovations reinforces their reliance on traditional methods, making them hesitant to adopt modern climate adaptation strategies. Without adequate training, financial support, and information, women are less likely to experiment with new techniques, further widening the gender gap in climate adaptation.

Institutional barriers play a major role in reinforcing gender disparities in climate adaptation. Policies and agricultural programs often fail to consider the unique needs and constraints of women farmers. Extension services, for instance, tend to target male farmers, assuming they are the primary decision-makers in agriculture. This exclusion leaves women with limited access to training, climate-smart technologies, and financial support.

Cultural norms further restrict women's participation in climate adaptation initiatives. In many communities, women require permission from male family members to attend training programs or access financial services. These restrictions not only limit their adaptive capacity but also reinforce their dependence on male counterparts for climate-related decision-making.

Additionally, financial institutions often favor male farmers when providing credit and insurance, as men are more likely to own land and assets that can be used as collateral. Women, with little or no land ownership, struggle to secure loans for climate adaptation investments, further widening the gap in resilience-building measures.

To synthesize how these constraints combine to shape gendered perceptions and adaptation choices, we present a simple conceptual model (Fig. 4). Structural constraints such as limited formal education, restricted mobility, insecure land tenure, and exclusion from extension services operate together to reduce access to timely climate information, adaptive inputs, and decision-making authority. These proximate mediators (knowledge, resource access, and agency) in turn shape how women and men perceive climate risk and select adaptation strategies (low-cost, labor-intensive vs. capital-intensive approaches). Contextual modifiers such as poverty, social norms, market access, and policy environment both shape and are shaped by these pathways, creating feedback that can entrench vulnerability or enable resilience. The model clarifies why single-factor interventions are often insufficient and highlights leverage points for policy (education and extension reform, secure tenure, inclusive finance).

Despite growing attention to gender and climate change, several gaps remain. First, while many studies examine gender differences in risk perception and adaptation strategies, few explore the long-term socio-economic impacts of these disparities. Future research should assess how gendered adaptation strategies influence food security, income stability, and overall resilience over time. A deeper understanding of how these disparities evolve across generations and within different farming systems is also needed.

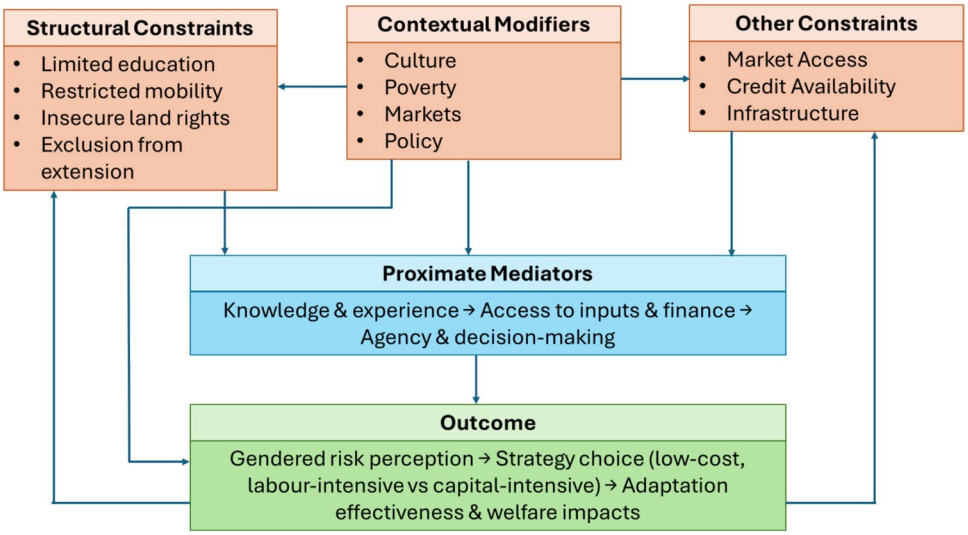


Fig. 4 Conceptual model linking structural constraints, mediating factors, and gender-differentiated adaptation outcomes

Second, there is limited empirical data on the effectiveness of women's adaptation strategies. While it is acknowledged that women adopt different approaches to climate resilience, little is known about their long-term sustainability. Research should focus on evaluating how well women-led strategies perform under varying climate conditions and how they can be enhanced through policy and technological support. Additionally, studies should examine how knowledge-sharing among women farmers influences adaptation outcomes and whether local innovations can be scaled up to improve resilience.

Third, existing climate policies often lack a gender-sensitive approach. While there is growing emphasis on gender mainstreaming, many adaptation programs fail to address women's specific barriers, such as restricted land rights, financial exclusion, and limited access to training. Future research should explore how policies can be tailored to bridge these gaps and ensure equitable climate adaptation. More studies should also analyze how existing policy frameworks impact women's climate resilience at local, national, and global levels.

Fourth, the role of financial mechanisms in women's climate adaptation remains underexplored. Women face significant barriers in accessing credit, insurance, and financial incentives for climate-resilient farming. Research is needed on how inclusive financial tools, such as gender-sensitive microfinance models, can improve women's ability to invest in climate-smart technologies and practices.

Fifth, the gender gap in access to agricultural extension services and climate information requires further investigation. While it is known that men benefit more from formal extension services, little research has been conducted on how to design extension programs that effectively reach women farmers. Studies should examine the effectiveness of community-based training, peer learning, and digital platforms in overcoming these barriers.

Sixth, more research is needed on the adoption of agricultural technologies by women farmers. While men tend to adopt modern tools and mechanized farming methods, women often rely on traditional, low-cost strategies. Future studies should assess the factors influencing women's adoption of new technologies, including cultural norms, affordability, and institutional innovation and training needs, and explore ways to promote gender-equitable access to climate-smart innovations. While intersectional patterns were noted, most primary studies did not provide disaggregated data to test compounding effects formally. Future research should examine how overlapping constraints—such as low education, poverty, and insecure land tenure—create distinct barriers to adaptation.

Lastly, an intersectional approach is needed to understand how factors such as age, ethnicity, and socio-economic status influence climate adaptation. Women are not a homogenous group, and their experiences vary widely based on multiple social and economic factors. Future studies should incorporate an intersectional lens to develop more inclusive and targeted adaptation strategies. Additionally, research should explore how intra-household dynamics, such as decision-making power and resource control, affect women's ability to adapt to climate risks.

Addressing these interlinked gaps requires study designs that can capture compounding effects and causal pathways. We recommend (1) longitudinal panel studies to trace how perceptions and strategies evolve and influence welfare over time; (2) mixed-methods research combining gender-disaggregated surveys with in-depth qualitative case studies and life histories to uncover mechanisms; (3) participatory action research to evaluate women-led strategies and co-develop

context-specific solutions; (4) quasi-experimental or impact-evaluation designs (e.g., difference-in-differences, propensity score matching) to test the effects of gender-targeted interventions; (5) social network analysis to map information diffusion and extension reach; and (6) ethnographic and feminist political ecology approaches to reveal intra-household norms and intersectional constraints. Each method contributes uniquely: longitudinal designs show trajectories, mixed methods explain mechanisms, experimental designs test causality, and participatory approaches center women's knowledge and priorities.

Conclusions and recommendations

This study highlights significant gender disparities in climate risk perception and adaptation strategies among farmers due to various socio-economic, cultural, and institutional factors. Institutional and policy barriers further exacerbate these disparities, with agricultural extension services and climate policies often failing to incorporate gender-sensitive approaches. Women form a majority of the farmers and farm workers in smallholder agriculture. Poor access to climate-resilient agriculture technologies, infrastructure, and resources for farm women not only creates serious inequities but also results in underperforming and risky agri-food systems.

Addressing these inequalities is critical for enhancing climate resilience in farming communities. The findings emphasize the need for targeted, gender-responsive policies and interventions that ensure equitable access to resources, training, and decision-making opportunities for both men and women farmers.

Accordingly, the recommendations are organized into two categories: programmatic recommendations that outline actionable interventions at the project and community levels, and policy recommendations that propose systemic, institutional, and governance-level reforms.

Programmatic recommendations

Enhancing women's access to climate-smart technologies

Closing the gender gap in climate adaptation requires targeted efforts to improve women's access to climate-smart technologies. Gender-responsive agricultural training programs should actively involve women in learning and adopting modern techniques. It is essential to make climate-smart innovations such as drought-resistant crops, micro-irrigation systems, and mechanized farming tools affordable and accessible to women farmers. Establishing technology-sharing platforms where women can access demonstrations and hands-on experience with new agricultural practices will further support their ability to adopt modern techniques.

Improving access to financial resources and market participation

Strengthening women's access to credit, insurance, and financial services through gender-sensitive microfinance programs and tailored loan schemes is crucial for climate adaptation. Supporting women-led cooperatives and farmer organizations can contribute to their empowerment, enhance collective bargaining power, and improve access to markets. Providing training in financial literacy and market linkages will enable women to participate more effectively in commercial agriculture, ultimately reducing gender disparities in economic opportunities.

Strengthening gender-inclusive agricultural extension services

Bridging the knowledge gap in climate adaptation requires gender-inclusive agricultural extension services. Increasing the number of female extension officers will improve outreach to women farmers. Implementing mobile-based and community-driven extension programs can help overcome women's mobility constraints. Furthermore, integrating gender-sensitive approaches in agricultural policies will ensure the equitable dissemination of climate information and advisory services.

Supporting sustainable and inclusive livelihood diversification

Reducing women's vulnerability to climate change requires sustainable and inclusive livelihood diversification strategies. Promoting alternative income-generating activities such as agro-processing, artisanal crafts, and small-scale trading will provide additional sources of income. Facilitating skill development programs will help women transition into climate-resilient economic sectors. Strengthening rural infrastructure, including transportation and storage facilities, will enhance women's market participation and value-chain engagement.

Policy recommendations

Securing land rights and strengthening legal protections

Providing women with secure land rights is critical for long-term climate adaptation. Policies that promote women's land tenure security should be prioritized, allowing them to own, lease, or co-manage agricultural land. Implementing land reform initiatives will further support women's agricultural productivity. Raising awareness among women farmers about their legal rights to land and resource ownership will empower them to make informed decisions regarding climate adaptation.

Bridging the gender gap in climate information and decision-making

Ensuring equitable access to climate information requires the development of inclusive climate information services tailored to the specific needs of women farmers. Weather-based agro-advisors also need to target the women-led activities such as small-scale vegetable production, small ruminants, and small-scale agro-processing. Providing accessibility through radio, mobile applications, and community networks will improve their ability to respond to climate risks. Establishing women-focused climate advisory groups that contribute to policy discussions and local adaptation planning will strengthen their role in decision-making. Encouraging participatory decision-making at local, regional, and national levels will ensure that women's perspectives shape climate resilience strategies.

Addressing institutional and policy barriers

Creating an enabling environment for gender-inclusive climate adaptation requires addressing institutional and policy barriers. Integrating gender considerations into national climate adaptation policies and agricultural development plans will help ensure equal opportunities for men and women. Climate finance mechanisms should prioritize women's participation and benefit-sharing. Collaboration between government agencies, NGOs, and private sector actors should be fostered to design and implement gender-responsive climate policies that effectively support both men and women farmers.

However, implementing gender-transformative policies is rarely straightforward. Efforts to reform land rights, expand women's access to credit, or promote their leadership in agricultural institutions often face practical and political obstacles. Social resistance to changing norms, inconsistent policy support, and limited financial or institutional capacity can slow or undermine progress. Recognizing these realities is critical for designing feasible, context-sensitive reforms and maintaining long-term commitment to gender equality within agricultural and climate governance frameworks.

Implementing these recommendations will likely help bridge the gender gap in climate adaptation, ensuring that both men and women farmers are equally equipped to mitigate risks and enhance agricultural resilience. A gender-inclusive approach to climate adaptation will ultimately lead to more sustainable and equitable food systems, benefiting entire farming communities and contributing to broader climate resilience goals.

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