



Addressing gender inequalities and strengthening women's agency to create more climate-resilient and sustainable food systems

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A B S T R A C T

Climate change affects every aspect of the food system, including all nodes along agri-food value chains from production to consumption, the food environments in which people live, and outcomes, such as diets and livelihoods. Men and women often have specific roles and responsibilities within food systems, yet structural inequalities (formal and informal) limit women's access to resources, services, and agency. These inequalities affect the ways in which men and women experience and are affected by climate change. In addition to gender, other social factors are at play, such as age, education, marital status, and health and economic conditions. To date, most climate change policies, investments, and interventions do not adequately integrate gender. If climate-smart and climate-resilient interventions do not adequately take gender differences into account, they might exacerbate gender inequalities in food systems by, for instance, increasing women's labor burden and time poverty, reducing their access to and control over income and assets, and reducing their decision-making power. At the same time, women's contributions are critical to make food systems more resilient to the negative impacts of climate change, given their specialized knowledge, skills and roles in agri-food systems, within the household, at work and in their communities. Increasing the resilience of food systems requires going beyond addressing gendered vulnerabilities to climate change to create an enabling environment that supports gender equality and women's empowerment, by removing structural barriers and rigid gender norms, and building equal power dynamics, as part of a process of gender transformative change. For this to happen, more research is needed to prioritize structural barriers that need to be removed and to identify effective gender transformative approaches.

1. Introduction: The case for gender equity in climate action

Climate change poses considerable risk to food systems in low- and middle-income countries (LMIC) and fragile contexts (IPCC, 2022, p. 9–10). The negative impacts span beyond production to other aspects of the food system, including along agri-food value chains from production to consumption, the food environments in which people live, and outcomes such as diets and livelihoods (Fanzo et al., 2018). Climate change threatens food and nutrition security, compounding multiple threats already faced by marginalized communities in LMICs, including the COVID-19 pandemic, civil wars and the global food crisis exacerbated by war in Ukraine (Bryan et al. 2022; FAO, IFAD, UNICEF, WFP, WHO, 2021; Scheffran et al., 2012). Long-term projections suggest climate change will further jeopardize progress towards eliminating hunger by 2050, particularly in sub-Saharan Africa, unless significant additional investments are made in international agricultural research (Sulser et al., 2021).

Systemic inequalities at multiple scales exacerbate climate change challenges for the most vulnerable and marginalized countries, social groups and communities (Schipper et al., 2022). Threats are largest in

climate-dependent economic sectors, such as agriculture, and in LMICs with limited adaptive capacity. Within countries and communities, there is considerable heterogeneity in vulnerability to shocks and stressors, and in preferences and needs when choosing how to respond. Social inequalities based on unjust social norms and unequal power dynamics within households, communities and food systems influence the distribution of the negative impacts of climate change, exacerbating vulnerability for the most marginalized and limiting options and scope for climate actions (ibid.). As a result, the outcomes of climate change differ by gender and other intersectional identities, such as ethnic group, age and wealth (Bryan et al., 2017; Djoudi et al., 2016; Huyer 2016; Jost et al., 2016; Kristjanson et al., 2017; Tandale 2019).

The literature documenting gender-related inequalities in exposure and sensitivity to climate disturbances, adaptive capacity, participation in climate responses at multiple scales and welfare outcomes has grown considerably in the last decade. These inequalities are driven by gender-differentiated roles and responsibilities, differential access to resources, technologies and services (e.g., financial and information), and are underpinned by patriarchal norms (Huyer and Partey 2020; Eastin 2018).

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There is also emerging evidence that addressing gender inequality and supporting women's empowerment builds climate resilience and reduces the negative effects of climate change on outcomes such as hunger and food security. Women play critical roles in agrifood systems and have distinct livelihood roles and responsibilities (FAO 2023). Thus, if they are provided with greater resources and agency, and when the enabling conditions are in place, women can contribute more effectively to achieve the goals of climate-smart agriculture—enhancing productivity, increasing resilience, and mitigating GHG emissions (Huyer et al., 2021). While some tradeoffs among these goals should be acknowledged (for example between profitability on the one hand and gender equality on the other) there are also many potential synergies where reducing inequality has instrumental value. For example, women often manage certain livelihood activities, such as rearing local or smaller livestock that are more resilient to the negative impacts of climate change, and are, thus, fundamental to climate resilience and nutrition security (Kristjanson et al., 2014; Chanamoto and Hall, 2015). Evidence shows that women can leverage their social networks for greater climate resilience (Tadesse et al., 2017; Violon et al. 2016), to share and access information, such as on seed varieties (Otieno et al. 2018, 2021; Ravera et al., 2019; Marimo et al., 2021), and negotiate for access to resources and formal institutions (Smucker and Wangui 2016). Women's climate response choices also reflect their preferences and specialized knowledge. Case studies show that when women are empowered to make decisions, they often show greater adoption of climate-resilient strategies leading to welfare improvements, such as drought-preparedness measures (Grillos 2018) and crop and livelihood diversification strategies leading to better household diets (De Pinto et al., 2020; Gumucio et al. 2017; Mersha and Van Laerhoven 2016; Smucker and Wangui 2016).

This review identifies gender inequalities in experiences with, responses to and outcomes of climate change, and points to emerging evidence on promising approaches to reach, benefit and empower women through climate action. The paper concludes with some observations on areas where more research and evidence are needed to achieve the twin goals of more resilient food systems and social transformation.

2. Methods for review

We used several approaches to identify literature for the review including systematic, snowballing, and narrative techniques (Sutton et al., 2019). We drew on a recent systematic review on gender and climate-smart agriculture that covered the literature from January 2010 to June 2021 (Chanana 2021). Articles not related to agriculture or food security and those with limited climate change or gender focus were excluded. The final set of articles were qualitatively ranked in terms of their relevance to these themes as low, medium, and high (ibid). From an original 414 papers 165 were considered relevant for inclusion; among these 111 articles were tagged as having a high or medium focus on the intersection of gender, climate change, and agriculture/food security and were included in this analysis (ibid).

We then added several articles from late 2021/early 2022 and supplementary search terms related to climate shocks and disasters, food systems and food security to broaden the analysis to beyond agriculture and to consider climate extreme events. The final set of search terms fell under 3 dimensions: 1) climate change, shocks, disasters, and resilience 2) gender/women, and 3) agriculture, food systems and food security. Keywords under each of these categories included: climate change, shocks, stressors, disasters, climate-smart agriculture, climate-resilient agriculture, resilience, mitigation, adaptation, gender, gendered, women, agriculture, food systems, and food security. Priority for inclusion was given to studies published after 2010, peer-reviewed publications, and papers from prominent working paper series and reports (especially CGIAR Working Papers and UN agency publications). Both qualitative and quantitative studies were included, while grey literature

was largely excluded from the review.

We also relied on several purposively selected review papers on gender and climate change, many of which provide conceptual framing, to organize the literature using a narrative approach. These studies include Bryan et al. (2017), Call and Sellers (2019), Huyer et al. (2021a, b), Kristjanson et al. (2017), Rao et al. (2019, 2019b) and Schipper et al. (2022). Additional studies were identified from the reference lists of these reviews using a snowballing approach and more studies were added to cover key topics, such as gender transformative approaches, migration, and payment for ecosystem services, at the suggestion of the reviewers.

3. Gender inequalities and climate change: Defining the relationships

Recent conceptual frameworks of the linkages between gender and climate change highlight how climate change has differential impacts on men and women—some of which are the direct result of exposure and sensitivity to climate shocks and stressors, and others are indirect or filtered through the institutional environment and by actions taken to ameliorate negative impacts (Bryan et al., 2017; Kristjanson et al., 2017; Theis et al. 2019). Other frameworks focus on action areas for facilitating women's empowerment and gender-transformative change through climate-smart agriculture (CSA) (Huyer et al., 2019; Huyer and Chanana 2021; Huyer et al., 2021), and inclusive climate policy (Huyer et al., 2020). Several recent studies have emphasized the need to understand the gender dimensions of food system transformation with increasing women's resilience to climate change being one key element (Njuki et al., 2022; Bryan et al. 2023).

Drawing on these conceptual foundations, it is possible to identify several dimensions in which gender inequalities interact with climate risks and disturbances to produce gender-differentiated well-being outcomes. These elements include: (1) gender differences in exposure and sensitivity to shocks and stressors; (2) differential resilience and adaptive capacities of men and women; (3) gendered preferences for and uptake of climate change responses (broadly defined to include climate-smart practices, adaptation strategies, mitigation strategies and climate-resilient agriculture); (4) the level of gender integration in the design and implementation of policies, investments and interventions, and participation in decision-making and leadership; and (5) differential outcomes of climate change as a result of climate disturbances and the chosen responses at multiple scales (Dankelman 2010).

3.1 Gender differences in exposure and sensitivity to climate shocks and stressors.

Identifying areas where vulnerability to climate change¹ is particularly high is important to target resources and design strategies to address the confluence of challenges for the most vulnerable people (Chanana-Nag and Aggarwal 2020; Koo et al., 2022). Recent studies have used mapping approaches to identify hotspots where women are particularly vulnerable to climate shocks and stressors (ibid.), while others use indices to compare the vulnerability of different populations along different dimensions (Magassa et al., 2020).

Vulnerability assessments tend to find that women have higher vulnerability to climate shocks and stressors. However, narratives that only describe women as victims of climate change ignore women's agency in addressing climate change or dimensions of men's vulnerability (Huyer et al., 2021; Rao et al., 2019; Arora-Jonsson, 2011). Moreover, such narratives miss important nuances about how vulnerability also varies by age, class, ethnicity and other intersectional identities (Djoudi et al., 2016).

Much of the literature focuses on vulnerability that is based on

¹ Vulnerability is defined based on the level of exposure and sensitivity to climate hazards and the degree of adaptive capacity (Adger 2006; IPCC 2018; Smit and Wandel 2006).

gender differences in adaptive or resilience capacities (e.g., [Yadav and Lal 2018](#)). Although this is a critical dimension of vulnerability and one where the largest gender gaps exist, it is also important to highlight how women and men are differently exposed to climate hazards and may experience the same climate shocks and stressors differently due to their gendered livelihood roles and responsibilities, and the livelihood assets on which they rely. For example, a case study from a peri-urban area in Magdalena, Mexico, shows that women were more affected by the negative impacts of climate change and associated water scarcity because they rely on fruit and vegetable processing for their livelihoods, for food security, and to maintain social ties ([Buechler 2009](#)). In other cases, women's roles may be less vulnerable to shocks and stressors. For instance, women are more likely to raise local livestock breeds and smaller animals, which tend to be more resilient to the negative impacts of climate change ([Köhler-Rollefson, 2012](#); [Chanamoto and Hall, 2015](#)).

Because gender roles vary in different contexts (e.g., rural and urban food environments) the nature of gender differences in exposure will also vary. In rural settings, where women spend considerable time collecting water for domestic use, their work burden may increase when climate change exacerbates water scarcity ([Rao et al., 2019](#); [Nkengla-asi et al., 2017](#)). Vulnerable urban households may experience more harm from flooding and associated health-related risks, like cholera, due to poor water infrastructure and crowded conditions, with disproportionate impacts on urban women ([Grasham, Korzenevica, and Charles, 2019](#)).

Differential exposure is also evidenced by gendered outcomes of climate disasters. Several global reviews have found that women tend to have higher morbidity and reduced life expectancy compared to men following droughts, storms, earthquakes and fires, especially where women have lower socioeconomic status, less access to information and limited agency to make strategic life choices ([Neumayer and Plümper 2007](#); [Doocy et al., 2013](#); [Erman et al., 2021](#)). Yet, women are not always more exposed to climate disasters. Some case studies found that men die at higher rates following climate disasters, such as Hurricane Mitch in 1998, because they are overrepresented in high-risk occupations like construction ([Delaney and Shrader 2000](#); [Zagheni et al. 2015](#); [Erman et al., 2021](#)).

Men's and women's differential experience with climate shocks and stressors is reflected in the different ways in which they perceive and report the impacts of these disturbances, though patterns are not easily generalizable across contexts ([Oloukoi et al., 2014](#); [Twyman et al., 2014](#); [Kristjanson et al., 2017](#); [Rao et al., 2019](#)) and sometimes there are few gender-differentiated perceptions of climate change ([Assan et al., 2018](#); [Nkengla-asi et al., 2017](#); [Dah-gbeto and Villamor, 2016](#); [Partey et al., 2020](#)). These experiences also have implications for how men and women respond to climate disturbances and how interventions may be designed to address gender-specific concerns.

Gender differences in food security, nutrition and health can influence men's and women's sensitivity to climate shocks and stressors; and the gender gap in food insecurity has grown in recent years (FAO, IFAD, UNICEF, WFP, WHO, 2022). Where women and girls reduce consumption as a strategy to cope with climate shocks, this has negative implications for their physical capacity to withstand additional shocks and to engage in other coping and adaptive measures ([Alston and Akhter 2016](#); [Dalugoda et al., 2022](#); [Rylander et al., 2013](#); [Shankar et al., 2023](#)). Sensitivity to disturbances also varies across contexts and food environments. For instance, the negative effect of climate change on the nutritional content of staple crops such as wheat, rice, potatoes and soy are more likely to affect poor consumers in low-income countries given that these foods comprise a larger share of their diets ([Fanzo et al., 2018](#)).

Lastly, although it is not a direct impact of climate change, a common view in the development community is that climate change exacerbates other shocks, such as conflict and the incidence of violence against women. One recent cross-country comparative study found mixed evidence on the impacts of climate shocks, such as drought on intimate-

partner violence ([Cooper et al., 2021](#)). However, other reviews suggest that climate change and disasters trigger multiple forms of violence against women and girls and that, in many cases, existing data under-represent the extent of the problem, given that violence survivors are unlikely to report abuse or seek help when supporting services are inadequate ([Masson 2022](#)).

3.1. Gender inequality in adaptive capacities

There is now a large body of literature focused on gender differences in adaptive or resilience capacities, which conforms with broader literature on the factors shaping structural gender inequalities in agri-food systems ([Kosec et al., 2023](#); [Lecoutere et al., 2023](#)). This literature highlights how factors, including differences in access to resources and technologies, access to information and financial services, and social norms, limit the range of response options available to women, thereby reducing their ability to respond effectively to climate change. Building women's adaptive capacities, therefore, is a key entry point for reducing their vulnerability and increasing their contribution to climate action.

3.1.1. Gender differences in access to and control over resources

Women tend to have more limited access to the resources and productive assets needed to respond effectively to climate change. These include natural resources, such land and water, productive inputs, and technologies, assets, and human capital. In particular, lack of access to and control over land prevents women from investing in longer-term climate-resilient agriculture practices ([Jost et al., 2016](#); [Perez et al., 2015](#)) including soil and water conservation ([Meinzen-Dick et al., 2019](#)), agroforestry ([Quisumbing and Kumar 2014](#)) and small-scale irrigation ([Theis et al., 2018](#); [Bryan and Garner 2022](#)).

Access to and control over assets are also an important source of resilience because they act as a store of value that can be drawn upon to cope with climate and other types of shocks ([Theis et al. 2019](#); [Goh 2012](#)). Yet women tend to own, and have control over, fewer high-value or productive assets, like livestock ([Djoudi and Brockhaus 2011](#); [Tavener and Crane 2018](#)). While gendered asset dynamics following climate shocks are nuanced, in many cases, women's assets, such as jewelry, are less important for generating household income and more easily disposable when shocks occur ([Rakib and Matz, 2016](#); [Quisumbing et al. 2018](#)). While protection of productive assets is important to maintain livelihoods during times of crisis, the depletion of women's assets following shocks may increase inequality in men's and women's resilience capacities over the longer term.

Women also lack access to productive inputs and technologies needed to adapt to climate change and reduce gender gaps in agricultural productivity ([Puskur et al., 2023](#)). Labor-saving tools and inputs such as fertilizers and pesticides are particularly important to increase the productivity of plots managed by women and reduce their labor burden, which is increasing with climate change ([Jost et al., 2016](#); [Murray et al., 2016](#); [Perez et al., 2015](#)). Reducing the gender gap in fertilizer use also has the potential to contribute to reducing greenhouse gas (GHG) emissions from agriculture ([Farnworth, Cathy et al., 2017](#)). However, when technologies and inputs are adopted at the household level, and even when they are distributed to women directly, they are often still controlled by men ([Haapala 2019](#); [Bryan and Garner 2022](#); [Theis et al., 2018](#)). Thus, women's use of climate-smart technologies, such as irrigation or conservation agriculture, do not always confer direct benefits to women, especially when underlying unequal power dynamics are not addressed ([Tsige 2019](#)).

3.1.2. Gender differences in human and social capital

Gender differences in human and social capital also contribute to gender differences in adaptive capacities. Social networks and groups are especially important to access information, resources and economic opportunities needed to respond to climate change and they provide an important platform for women's capacity development and agency

(Huyer et al., 2021; Kumar et al., 2021; Falco and Bulte 2013). Women also have more limited voice and leadership opportunities in rural organizations in some contexts: a case study from Kenya shows that men and women participate in different types of groups and that men tend to have a wider social network, leading to greater participation in community decision-making and in influencing adaptive behavior (Ngigi et al. 2017).

Human capital is an important adaptive capacity: people with better education, knowledge and skills have more options to access services, adopt new technologies and diversify their livelihoods (Muttarak and Lutz 2014). However, the gender gap in educational attainment persists (Evans et al. 2020). There is, moreover, growing evidence that climate change negatively affects girls' education more than boys', and that promoting girls' reproductive rights, education and life skills would lead to greater climate resilience (Sims 2021; Chigwanda 2016; Muttarak and Lutz 2014). Countries where girls have higher levels of schooling also have lower climate change vulnerability scores (Kwauk and Braga 2017).

3.1.3. Access to services

Access to services, especially climate information, extension, and financial services, are essential for climate change adaptation. Research shows that climate information services are less likely to reach women (Bernier et al., 2015; Bryan et al. 2021; Carr and Onzere 2018; Diouf et al., 2020; Gumucio et al., 2020b; Jost et al., 2016; Partey et al., 2020; Tall et al., 2014) and there is a long literature documenting gender differences in access to different sources and types of information (Kosec et al., 2023). Moreover, women have different preferences for the services they receive—including different preferences for weather index insurance products (Akter et al., 2016) and climate information services (Henriksson et al., 2021; Twyman et al., 2014; Tall et al., 2014; Gumucio et al., 2020b). When services are not designed to take women's needs and preferences into consideration, they are less likely to increase women's knowledge or adoption of climate-smart practices, such as agroforestry practices (Duffy et al., 2021).

Recent research explores the potential to reduce information asymmetry with digital devices and services. For example, a case study from India shows that climate and agricultural information provided via mobile phones reduced information gaps between men and women farmers and increased women's knowledge of climate-smart technologies (Mittal 2016). However, a large gender digital divide remains. For example, there is a gender gap in mobile phone ownership, estimated at 13 percent in sub-Saharan Africa (Rowntree et al., 2019), which can limit women's access to climate and weather information disseminated through ICT (Gumucio et al., 2020b). A case study from Ghana shows that women have less access to climate information via mobile phones compared to men, and that even when women do receive climate information, other resource constraints still limit their ability to apply climate information to farming practices (Partey et al., 2020).

Given both demand and supply constraints, women are less likely to be reached by and benefit from financial services (Adegbite and Machethe 2020; Njuki et al. 2019; Timu and Kramer 2021) and this contributes to larger income and wealth inequality (Fouejieu et al., 2020). There is also growing interest in the potential for agricultural insurance to provide financial protection to poor rural households that are particularly vulnerable to climate shocks (Janzen et al. 2021), enabling them to make investments that increase agricultural productivity and incomes (Karlan et al., 2014; Jensen and Barrett 2017; Farrin and Miranda 2015). However, a review by Timu and Kramer (2021) finds strong evidence of gender gaps in access to, demand for and usage of agricultural insurance.

3.1.4. Patriarchal norms underpin gender inequalities in adaptive capacities

Patriarchal norms underpin all the above barriers to women's ability to respond to climate change. Women's roles in farming are often overlooked and undervalued due to perceptions about appropriate

gender roles. As a result, women tend to be excluded from decision-making spaces and spheres in farming households, limiting adoption of climate-smart practices (Sumner et al. 2017). In some contexts, certain technologies are not considered appropriate for women to use, such as small-scale irrigation using treadle pumps (Njuki et al., 2014). Patriarchal norms also limit women's access to land and tenure security, preventing them from adopting practices to respond to climate change or investing in plots (Nchu et al. 2019), including agroforestry practices (Kiptot and Franzel 2012). Sociocultural barriers also limit women's mobility, income-earning opportunities, and ability to participate in groups (Djoudi and Brockhaus 2011; Jost et al., 2016; Rao et al., 2019).

3.2. Gender differences in climate change response preferences and choices

Harmful social norms and gender inequalities in access to resources and services also limit women's bargaining power and agency at multiple scales and in different domains, including in agricultural production decisions, livelihood choices, income-earning opportunities, and in market transactions (e.g., trade) (Quisumbing et al., 2023b). Unequal power dynamics limit women's ability to negotiate for their preferred responses to climate disturbances within households, communities, groups and organizations, and in policy spheres (Steinfeld and Holt 2020), despite having different needs, preferences, and priorities for how to respond to the negative impacts of climate change (Bryan et al., 2017; Ngigi et al. 2017; Kristjanson et al., 2017).

Given generally lower resilience capacities, women often have fewer options to respond to climate disturbances and are more likely to adopt short-term coping measures than medium- to longer-term adaptive strategies, which further exacerbates their vulnerability to future shocks (Ahmad et al. 2021; Anugwa et al., 2020; Jost et al., 2016; Mersha and Van Laerhoven 2016; Bastakoti and Doney 2020). For example, a comparative analysis of women's agency and adaptive capacity across Asia and Africa found that women often resort to coping strategies that reduce their well-being and future resilience (Rao et al., 2019). Women also are less able to participate in mitigation activities. Early evidence from agricultural carbon-market projects suggests that women are less likely to participate in sustainable land management activities that lead to soil-carbon sequestration, have little input in the design of such activities, and, when involved, they see a large increase in their labor burden (Lee et al., 2015).

When women are involved in decisions about climate change adaptation, evidence suggests that they tend to make choices that often differ from those of their spouses. Evidence from Tanzania shows that women's agency in intrahousehold bargaining is associated with greater engagement in non-farm income-earning activities, and different crop choices on the farm (Van Aelst and Holvoet, 2016; 2020). Case study evidence suggests that these choices are often reflective of gendered livelihood roles and responsibilities (Bernier et al., 2015; Bryan et al. 2021; Ngigi et al. 2017; Twyman et al., 2014). In Bangladesh, women were found to be more likely than men to adopt practices that relate to their existing livelihood roles, such as improved livestock feeding and grain storage practices, when they were aware of these practices (Bryan et al. 2021). Women also tend to prefer practices that reduce their workloads (Arora et al., 2017; Farnworth, Cathy et al., 2017; Murray et al., 2016; Mutenje et al., 2019; Khatri-Chhetri et al., 2017), although women sometimes adopt low-risk, labor-intensive practices due to the high cost of some labor-saving technologies (Mutenje et al., 2019).

Intersectional identities also influence response choices. For example, a study from three climate-smart villages in Latin America, where multiple climate-smart interventions were implemented, found that gendered patterns of adoption and the use of climate forecast information also depended on women's level of education and age (Acosta et al., 2021). In another example, widows and divorced women in Tanzania faced greater agricultural production constraints and were more likely to seek off-farm opportunities for earning income (Van Aelst

and Holvoet, 2016). A study from Uganda found that women's age, wealth, and marital status also influenced the adoption of drought tolerant maize (Fisher and Carr 2015). In South Asia, socioeconomic status influenced migration decisions following adverse climate events: resource-rich households chose to migrate as an adaptive response while resource-poor households tended to migrate to cope with climate shocks. Women and children of all income levels were less able to migrate at all (Bhatta et al., 2015).

3.3. Lack of women's leadership and gender integration in policies, investments, and interventions

Another important gender gap relates the lack of gender-responsive policies, investments and interventions, and the lack of women's leadership in policy spheres. A growing literature provides strong evidence that climate policies and programs at multiple scales do not adequately integrate gender (and intersectional social identities) or budget for stated outcomes (Acosta et al., 2019, 2020; Ampaire et al., 2016; Ampaire et al., 2016; Huyer et al., 2020; Mersha and Van Laerhoven, 2016). In comparison to other environment-related processes, the integration of gender equality into climate policy has been slow at both global and national levels (Huyer et al., 2020). When gender is mentioned in policy, women tend to be framed as victims of climate change rather than as agents of change (Huyer and Partey 2020; Garcia et al. 2020). A policy analysis of the extent to which gender is integrated into agricultural and climate change policies in Nepal found that, although gender was acknowledged in most policies, the scope for intervention was mostly restricted to increasing participation of women farmers in policy implementation, with less focus on benefits for women (Paudyal et al., 2019).

Governments, parliamentarians, policymakers and implementing agencies often lack the capacity to integrate gender in climate adaptation efforts (Ampaire et al., 2016; Bryan et al., 2018; Ragasa et al., 2013) and to understand the interests of different stakeholders based on intersectional identities, such as ethnicity, class and caste (Resurreccion et al., 2019). Even less attention is paid to the gender equity implications of climate mitigation interventions (Lee et al., 2015). Integrating gender into climate change policies also must consider how local gender norms limit women's ability to participate in and benefit from the implementation of climate interventions, and take steps to enhance the transformative potential of policy action (Acosta et al., 2019). This is not always easy as demonstrated by a case study from Uganda, which showed that although local policymakers often adhere to global discourses about gender inequality, there is limited interest in adopting local solutions that actually challenge the underlying social norms that drive gender inequalities (Acosta et al., 2021). Ampaire et al. (2016) also found that climate change, natural resource, and agriculture policies in East Africa tended not to address structural inequalities and that instruments for implementing and monitoring gender-related goals were missing.

There is also considerable gender inequality in climate investments (Faucherre 2016; Schalatek 2022). The amount of official development assistance dedicated to gender and climate change adaptation and/or mitigation is inadequate, at only 8.6% of all official development assistance (Schalatek 2021). Global financing mechanisms that fund adaptation and mitigation policies and programs, particularly the private sector mechanisms such as carbon and biodiversity offsets, often pay less attention to gender and equity concerns (ibid). Greater scrutiny of how financial mechanisms are deployed and what their distributional impacts are is, therefore, needed (Glemarec et al., 2016). For example, a review as well as several case studies from the literature on gender and

REDD+² found the subordination of women (particularly indigenous women) in decision-making in the forestry sector and, hence, in national REDD + regimes (Pham et al., 2016), as well as marginalization in the design and implementation of REDD + policies (Arwida et al., 2017), hindering effective forest protection, fair resource allocation, gender equality and social justice (Löw 2020). Expanding access to climate finance to reduce gender inequalities depends also on building capacities and institutions to challenge social structural constraints that limit women's ability to engage in CSA, forest sequestration, and disaster management (Wong 2016).

3.4. Gender inequality in outcomes of climate change responses

Climate change and the choice of climate-smart practices, technologies or adaptation strategies have important implications for women's empowerment and gender equality outcomes through changes in labor allocation, control over income and assets, and livelihood choices, among other pathways (Bryan et al., 2017). Every response option carries some degree of trade-off among people and across outcomes and spatial and temporal scales (ibid.). Thus, interventions aimed at increasing resilience to climate change are not gender neutral. Most climate interventions have been implemented without an explicit focus on women's empowerment or the use of gender-transformative approaches (GTAs). Given this shortcoming, such interventions may not address—and may, in fact, perpetuate or even worsen—structural inequalities that limit women's contribution to addressing the harmful impacts of climate change (Huyer and Partey 2020).

In particular, short-term coping strategies, such as drawing down assets, keeping girls home from school or reducing consumption have short- and long-term negative welfare implications for all family members but may be especially detrimental to women and girls. For example, although women are generally in charge of food preparation and cooking, in some cases they eat last (Hathi et al., 2021) and may be more likely to reduce how much they eat in response to shocks (Algur et al. 2021). Reducing consumption in the short-term can have long-term, even intergenerational, implications for nutritional outcomes of women, their children, and their families (Martorell and Zongrone 2012).

Climate shocks can also shift household expenditure away from investments in girls, toward immediate household needs, causing deficits in girls' long-term health and human capital outcomes (Feeny et al., 2021; Staffieri et al. 2022). Evidence from several contexts suggests that older girls are especially likely to be pulled from school following climate shocks, when the demand for family labor increases (Staffieri et al. 2022; Agamile and Lawson 2021; Björkman-Nyqvist 2013). A study in Vietnam showed long-term effects of rainfall shocks on gender gaps in employment and suggested that these operate through differential effects on educational attainment (Feeny et al., 2021).

The outcomes of response choices are often nuanced, as demonstrated by several case studies on the gendered impacts of climate-induced migration. In some contexts, male outmigration increases women's decision-making authority at home (Rajkarnikar 2020; Simelton et al. 2021). In other cases, women left behind due to men's outmigration face additional hardship, including increased work burden (Lei and Desai 2021), loss of identity, marital separation, increased health burden (Sznajder et al., 2022) and mortality risk (Agadjanian et al. 2021). Often, women migrants face sexual exploitation and human trafficking (Eldidi et al., 2022), in addition to social costs and stigma (Evertsen and van der Geest, 2020). Evidence from the Philippines suggests that climate shocks in conflict-prone areas exacerbate negative impacts on women, including forced migration, increased

² REDD + stands for Reducing Emissions from Deforestation and Forest Degradation plus conservation, sustainable management of forests and enhancement of forest carbon stocks.

discrimination, loss of customary rights to land, resource poverty and food insecurity (Chandra et al., 2017).

The case of conservation agriculture (CA) shows similar tradeoffs. A systematic review in sub-Saharan Africa showed that CA is associated with women's greater participation in agricultural decisions, increased income and better household food security. However, it is also associated with increased workloads and health risks (Wekesah et al. 2019). Other studies have similarly documented the negative implications of CA for women's time burden (Beuchelt and Badstue 2013; Farnworth, Cathy et al., 2016), which has resulted in many women abandoning the practice (Hove and Gweme 2018).

Another review found that women's participation in sustainable livelihood interventions leads to increased income, better food security and improvement in short-term environmental outcomes (Call and Sellers 2019). However, these benefits may come at a cost to women—namely, an increase in women's labor burden without corresponding gains in women's income (Beuchelt and Badstue 2013; Call and Sellers 2019). Similarly, in Ethiopia, adoption of multiple climate-smart practices was associated with higher dietary diversity and greater calorie and micronutrient intake, especially among female-headed households (Teklewold et al. 2019).

A growing number of studies examine how households reallocate labor in response to climate shocks and stressors and the adoption of specific climate-smart practices. A study on the impacts of climate extreme events (e.g. heatwaves and droughts) on labor force participation in agriculture across 30 countries in Africa, found that while heatwaves and droughts reduce individual effort intensity in agriculture considerably, the work intensity of women farmers increased relative to men (Nico and Azzarri 2022). A case study from Tanzania supports these overall findings: heat stress was shown to reduce total male family labor in agricultural production, while female family labor remained unchanged, or even increased in the case of female-headed households (Lee et al., 2021). These results highlight the importance of women farmers' contributions to agricultural production under a changing climate; however, they also raise concerns regarding the working conditions of women under a more hazardous production environment.

Some climate-smart technologies have the potential to reduce women's labor burden, while also contributing to higher productivity, incomes and, in some cases, positive environmental outcomes (Khatr-Chhetri et al., 2017). For example, the rice drum seeder was found to reduce women's time burden while mitigating GHG emissions in India (Gartaula et al., 2020; Joshi et al. 2019), although in other cases it was found to reduce employment for women (Paris and Chi, 2005). In some cases, the introduction of labor-saving technologies, like pumps for small-scale irrigation, may not reduce women's overall work burden but may rather enable them to allocate time to more-preferred livelihood activities (Bryan and Garner 2022).

Some have argued that CSA interventions in practice focus largely on technical solutions, are driven by entrenched global interests and emphasize market-oriented approaches that address the productivity and profitability objectives (Clay and Zimmerer 2020; Collins 2018; Haapala 2019; Karlsson et al., 2018). Shifting smallholder production toward a more commercial orientation has considerable equity implications (Karlsson et al., 2018). The literature suggests that women and other disadvantaged groups often face constraints to participating in value chains, markets and business activities (Farnworth, Cathy, 2011; Fischer and Qaim 2012; Waithanji et al. 2013; Dalaa et al., 2021) and that these constraints vary for different groups of women (Andersson Djurfeldt, 2018) and across value chains (Rubin et al. 2019). Thus, while commercial-oriented CSA may provide benefits in terms of productivity and profitability, it may involve a loss of women's agency—including their control over income, assets and decision-making authority (Tavener et al., 2019).

4. Reducing gender inequality through climate action: What strategies are effective?

Although much of the research on gender and climate change has focused on identifying differences in the ways in which men and women perceive climate shocks and changes, differential capacity needs and response-choice preferences, recent research has focused on applying this understanding to the development of gender-smart climate investments and interventions that reach, benefit and empower women for climate action and that transform the structures and barriers that drive gender inequality (Huyer and Chanana 2021). Increasingly research on the effectiveness of gender-focused interventions emphasizes the importance of designing programs that go beyond reaching women with agricultural innovations and technologies to ones that provide direct benefits to women, facilitate women's empowerment, and address the root causes of gender inequality through gender-transformative approaches (GTAs) (Quisumbing et al., 2023a). Scaling climate innovations or technologies that increase women's empowerment, along with complementary activities designed to address inequalities in food systems can create the conditions for more transformative change (see Huyer, 2023).

A set of promising approaches that have the potential to move along the reach, benefit, empower and transform continuum towards more gender transformative outcomes of climate actions at multiple scales is beginning to emerge. It centers around policies, investments, and interventions aimed at increasing women's access to productive resources (including labor-saving technologies), providing inclusive climate finance, expanding access to climate information services, and promoting group-based approaches (Huyer et al., 2021). The extent to which any climate-smart interventions can reach, benefit, and empower women depends on the design and implementation approach (Johnson et al., 2018; Quisumbing et al., 2023a). Most efforts concentrate on increasing women's access to and control over resources needed for responding effectively to climate change, while less effort has been made to address structural inequalities and institutional barriers through gender-transformative approaches at multiple scales. While there is growing acknowledgment that climate interventions should be accompanied by specific activities aimed at facilitating women's empowerment and gender-transformative change (Huyer and Partey 2020), more research is needed to understand which approaches are most effective.

4.1. Gender- and environment-sensitive social protection

Several studies have demonstrated that social protection programs provide a buffer against climate shocks by facilitating adaptation, speeding recovery from shocks and improving welfare outcomes in risk-prone contexts (Premand and Stoeffler 2020; Knippenberg and Hoddinnott 2017; Macours et al. 2012; Tenzing 2020). There is also evidence that social protection must go beyond targeting women in their capacity as mothers in order to promote women's empowerment and gender equality (Molyneux and Thomson 2011; Holmes and Jones 2013; Jones et al., 2017). However, few "shock-sensitive" social protection programs are gender-responsive, and there is little research at the intersection of social protection, gender, and climate change (Holmes 2019), although it is a promising area deserving of further study (Tschakert and Machado 2012) and some case studies are beginning to emerge. For instance, a school feeding program in Malawi was shown to increase school enrollment for older girls, who are more likely to be withdrawn from school following climate shocks (Staffieri et al. 2022).

Social protection programs are also being linked with payment for ecosystem services (PES) schemes to support broader environmental conservation and natural climate solutions through the protection, management, and restoration of ecosystems. Evidence suggests that such programs are synergistic, contributing to sustainable development and climate change adaptation and mitigation (Griscom et al., 2020). PES schemes, including REDD + programs, that include gender and social

equality objectives and requirements, such as including women in resource governance decisions and advancing women's land tenure security, have the potential to contribute to both gender equality, by ensuring more benefits accrue to women, and climate action, by providing greater incentives for environmental management (Elias et al., 2021). These schemes are particularly effective where they are aimed at diversifying rural incomes or fostering a shift to more regenerative and sustainable practices in food systems (Schwarzer et al. 2016). Some social protection programs—such as, Bolsa Verde, a cash transfer program with natural resource conservation conditions in Brazil—are beginning to integrate gender and environmental objectives with promising outcomes in both areas (de Brauw et al., 2014; Schwarzer et al. 2016). Gender- and climate-responsive social protection programs will require proper targeting to women, identification of appropriate communication channels, selection of gender-appropriate work opportunities, increasing women's financial inclusion, and sex-disaggregated monitoring and evaluation (Holmes 2019).

4.2. Collective climate action through group-based approaches

There is strong evidence that group-based, collective approaches support women's climate actions by increasing their access to information, shared resources, finance, and collective agency (Cabot Venton, Prillaman, and Kim, 2021; Huyer et al., 2021). Several studies demonstrate that women's groups and networks increase women's access to climate change and weather information (Rengalakshmi et al. 2018) leading to increased knowledge and adoption of climate-resilient practices (Dey et al. 2018; Farnworth, Cathy et al., 2017; Ngigi et al. 2017). A recent study in India and Nepal found that women were more reliant on social networks and groups as sources of agricultural information, particularly during crises, suggesting the need leverage social networks and farmer peers to improve women's information access (Alvi et al., 2021), to involve women in the design of ICT systems, and to ensure that the information provided responds to women's preferences (Gumucio et al., 2020b). Groups also provide resources, such as micro-credit, and training (Caretta 2014), which enable women to increase productivity and income (Huyer et al., 2021; Simelton et al., 2021).

Beyond increasing access to information and resources leading to the adoption of climate-smart practices, groups also provide a vehicle to increase women's agency. Women members of self-help groups in India were more politically engaged, more aware of public entitlements, and more likely to benefit from public entitlement schemes than non-members (Kumar et al., 2021). In Senegal, a women's committee participated in local environmental management, while also developing an income stream from baobab fruit powder (Huyer et al., 2021). The JP RWEE program, which was implemented by several UN Agencies across multiple countries, relied on group-based platforms to expand economic and livelihood opportunities for women, increase women's agency, and engage men to promote changes in gender relations and norms (Quisumbing et al., 2023a).

4.3. Gender-sensitive design and dissemination of climate information services.

There is considerable evidence that well-designed climate information services that reach women increase adoption of CSA in ways that benefit women and their communities. For example, women's access to climate information was found to be a key determinant of awareness and adoption of climate-smart practices in Kenya (Bernier et al., 2015) and Bangladesh (Bryan et al. 2021), reducing gender gaps in the adoption of key practices. Furthermore, a study using panel data from the Living Standards and Measurement Study in four countries in sub-Saharan Africa found that, when extension and information services reach women farmers, agricultural performance improves and the negative impacts of weather variability and climate shocks on agricultural income are reduced (Azzarri and Nico 2022). An evaluation of climate information service interventions in Rwanda suggests that interventions targeted to women fill a critical information gap leading to improved

agricultural management decisions that increase resilience to climate change: women participants were found to apply the climate knowledge received through these interventions to their agricultural decisions, while there were no differences in decision-making behavior of men in the intervention and control groups (Gumucio et al., 2020a).

Well-designed and targeted gender training was also shown to increase women's adoption of resilient seeds in India (Dar et al., 2020). Addressing the gendered information gap in knowledge of climate-smart practices was also shown to increase adoption of climate-smart practices in India, leading to further benefits in terms of reduced male out-migration and better food and nutrition security (Agarwal et al., 2022). Reducing information gaps may also increase women's agency. A study from India found that women with access to agricultural information were more involved in agricultural decision-making (Mittal 2016). Another study found that mobile phone usage among women in Uganda was associated with women's empowerment as well as increased income, food security and better diets (Sekabira and Qaim 2017). More research is needed on the benefits of closing the gender information and digital divide and the potential for such interventions to contribute to women's empowerment and gender equality.

4.3. Design and dissemination of inclusive financial products

Financial inclusion supports women's climate action by enhancing women's productive capacity within agriculture and small-businesses along agricultural value chains, potentially improving women's intra-household bargaining power leading to more equitable and efficient allocation of resources (Fletschner and Kenney 2014; Njuki et al., 2019). However, financial services, like insurance products, must be designed in a gender-sensitive way to reach, benefit, and empower women.

Evidence suggests that financial products, such as crop insurance programs, can be successfully tailored to support gender equality, provide welfare benefits to both men and women, and increase opportunities for women's empowerment (Timu and Kramer 2021). In particular, bundled weather index insurance products seem particularly effective at reaching women and other marginalized farmers (Timu and Kramer 2021; Aheeyar et al. 2021). In the case of South Africa, the lack of access women have to land, resources, and extension services may affect their interest in this form of insurance (Born et al. 2019). Thus, efforts to reach and benefit women with index insurance products should also include disseminating information and technology, building trust in financial institutions, and linking to existing institutions. Mobile money accounts also offer a promising way to increase women's financial inclusion in some contexts (Demirgüç-Kunt et al., 2022).

4.4. Gender-responsive climate policies and investments at multiple scales

Policies, interventions, investments, infrastructure, and institutions all play a role in creating an enabling environment for resilience and reducing gender inequalities in food systems. Mechanisms used to structure national planning and commitments relating to climate adaptation and mitigation, including national adaptation plans, (NAPs), nationally appropriate mitigation actions (NAMA), REDD+ and nationally determined contributions (NDCs), tend to not adequately integrate gender dimensions. Global climate financing mechanisms only recently began to integrate a gender lens, and then only the more prominent public multilateral mechanisms seem to have consistent frameworks, approaches and safeguards to ensure that gender and equity considerations are incorporated into their design, operation and evaluation (Schalatek 2021).

However, some progress is evident. While climate financing mechanisms, such as the Global Environment Facility, the Green Climate Fund, the Adaptation Fund, and the Climate Investment Funds started out as largely gender-blind, there has been substantial effort to retroactively incorporate gender considerations into funding programs and structures (Schalatek 2022). At the national level, a review of NDCs

found a significant increase in the content and number of references to gender since 2019 (Huyer 2022). To be effective, NDCs, NAPs and sectoral policies should include specific and concrete actions in climate-related sectors that have gender equality objectives, articulate gender-specific targets and develop gender-responsive monitoring frameworks (Acosta et al., 2019; Paudyal et al., 2019; Samboko and Dlamini 2016). Gender budgeting and other strategies are needed to ensure the integration of women and youth into climate action, and consultative multi-stakeholder approaches need to be central to climate policy processes.

Improving the representation of women's voices and women's leadership, as well as the collaboration of women's ministries with other climate-related ministries in policy processes, can support the design of policies and programs that support women's meaningful engagement in climate action (UNDP 2016). Truly gender-responsive global climate funds would have to go beyond retrofitting gender to fundamentally alter the focus of funding operations to be more inclusive, including by prioritizing climate investments that disproportionately benefit women, bringing in more gender experts and leaders from women's organizations to the design of interventions, and monitoring and evaluating gender equality results (Schalatek 2022).

4.5. Large integrated programs that create an enabling environment for women's empowerment and gender equality

While the literature is still scant, there is emerging evidence that large cross-sectoral, multi-pronged, and locally-adapted programs that integrate activities aimed at increasing women's empowerment and gender equality have the potential to improve outcomes for women beyond reaching and benefiting them. For example, a community-based adaptation program by CARE International that aimed to achieve social inclusion through focusing on building agency, changing relations and transforming structures, found positive shifts in women's empowerment (i.e., in terms of self-esteem and confidence to participate) and some initial signs of transformative social change, including shifting community attitudes regarding women's role in adaptation (Clarke et al., 2019).

Similarly, the multi-sectoral, climate-smart village approach, which uses participatory methods to test and apply a set of technological and institutional climate-smart practices in local contexts, was shown to increase gender equality across two dimensions, namely increasing women's access to and control over resources and women's collective action. In some regions, gender parity in the household increased as a result of participation in climate-smart villages, but impacts on women's workloads are less clear (Beal et al., 2021; Hariharan et al., 2020; Tesfaye et al., 2022). Thus, reaching, benefiting and empowering women (and other marginalized groups such as youth) through large, integrative programs or bundles of technologies and complementary social innovations requires careful planning and project design before scaling context-appropriate climate solutions (Huyer et al., 2021). More research is needed on how to tailor integrated approaches or social-technical bundles of innovations to maximize the effectiveness of these programs across different socioeconomic, cultural, geographic, and environmental contexts, and livelihood systems.

Moreover, there is growing recognition that integrated climate programs should include GTAs to remove structural barriers to gender equality (FAO, IFAD, 2018; Badstue et al., 2020; Moser 2017). A report by the Joint Programme on Gender Transformative Approaches led by several UN agencies highlights 15 GTAs that address underlying norms, attitudes and behaviors that perpetuate gender inequalities. These GTAs use participatory approaches, require deep reflection to raise critical consciousness, alter gendered power relations, promote equal governing structures and policies, and engage men and boys as partners for gender equality (FAO, IFAD, 2018). Specifically, GTAs may promote the agency of individuals and collective groups; increase access to and promote rights over resources; address imbalances in care and productive work;

redress practices that constrain women's autonomy, voice and leadership; reduce gender-based violence, and increase knowledge and skills (Badstue et al., 2020; FAO, IFAD, 2018; IFAD 2018; Resurrecion et al., 2019).

There is limited experience in applying GTAs in climate interventions and limited interest and action among local policymakers in tackling normative constraints (Acosta et al., 2021; Ampaire et al., 2016). However, some efforts are being made to tackle harmful norms, attitudes and behaviors through facilitated household and community dialogues as part of climate change interventions, including the use of International Fund for Agricultural Development's (IFAD) Gender Action Learning System (GALS) and FAO's community discussion clubs (Dimitria Clubs). These dialogues bring men and women together at the household and community levels to work together to solve local challenges, providing a platform for trained facilitators to raise awareness of harmful gender norms, attitudes, and beliefs and to challenge unequal structures (such as local rules governing resource access) (Quisumbing et al., 2023a).

Further efforts to increase the voice and influence of feminist movements in local development discourses may accelerate critical consciousness raising and normative change (Acosta et al., 2021; Ampaire et al., 2016). More testing and evaluation of the effectiveness of GTAs in addressing the root causes of gender inequality in climate change responses is needed. New measurement tools should enable an assessment of the effectiveness of these integrated programs to promote more transformative change (FAO, IFAD, WFP & CGIAR GENDER Impact Platform, 2023).

5. Conclusions

This review found very strong evidence of gender inequalities in climate change vulnerabilities and climate actions at multiple scales, including in policies, investments, and interventions. There is also strong evidence that climate change interventions and climate-smart practices and technologies have differential impacts on men and women, and that these outcomes vary across contexts and by other social characteristics. There may be key tradeoffs between productivity, on the one hand, and gender equality and women's empowerment goals on the other. The lack of gender responsiveness of interventions that specifically acknowledge and aim to address such tradeoffs can exacerbate gender inequalities (Eriksen et al., 2021). At the same time, focusing on gender equality objectives may come at a cost to other program objectives, at least in the short term. Considering the full set of outcomes of interventions—going beyond the 3 pillars of CSA to include gender equality and other well-being outcomes—is important to fully evaluate the value of alternative approaches.

Although some promising approaches emerged from this review, the evidence on effective approaches to reducing gender inequality through climate action remains limited (see also Call and Sellers 2019). Thus, there is a need for more research on the effectiveness of the approaches identified here to go beyond reaching and benefiting women to contributing to women's empowerment and reducing gender inequalities. There is also the need for more evidence on the extent to which reducing gender inequality in climate action leads to greater climate change and food system resilience. Furthermore, how gender intersects with other identities, such as age, ethnicity, and social identity, to influence vulnerability to climate change and needs for effective climate action has not been systematically explored. Moreover, most case studies come from sub-Saharan Africa or South Asia, with fewer studies from Southeast Asia, Latin America, North Africa, and the Middle East. Case studies from the global North may also provide insights on effective strategies for addressing climate change and gender inequality simultaneously.

In general, this review found few studies on gendered outcomes of climate change interventions. The literature that does exist is patchy, for example, focused only on a small set of climate-resilient practices and

approaches (e.g., conservation agriculture) or contexts. Clearly the status quo of promoting climate-smart technologies and innovations is not working, on its own, to advance social transformation. At the same time, implementing partners are applying more innovative approaches to facilitate women's empowerment and promote gender equality, such as facilitated household and community dialogues and engagement with community opinion leaders to shift patriarchal norms, attitudes, and behaviors. As these approaches are beginning to be applied as complementary activities to climate adaptation and mitigation programs (e.g. social-technical bundles of innovations) in ways that provide an enabling environment for more transformative change, implementing partners need to strengthen partnership with research organizations to evaluate gender-related outcomes. Large, complex, integrated programs that are adapted to different local contexts may be more effective but also more difficult to evaluate. Building the evidence base to guide the design of interventions to maximize benefits for women and other marginalized groups will require close coordination with researchers at the design stage to determine appropriate assessment approaches.

This research would benefit from the application of standardized tools, indicators, and approaches to measuring these outcomes, in order to build evidence on which approaches work, under which conditions, and in which contexts. There are some available gender indicators for measuring the effect of CSA practices, services and technologies, including indicators on equity in decision-making, women's empowerment, intrahousehold food security and dietary diversity, and equity in the ownership of productive resources (Gutierrez-Montes et al., 2020). Various versions of the Women's Empowerment in Agriculture Index may be used to evaluate changes in women's agency as a result of climate change interventions (Alkire et al., 2013; Malapit et al., 2019). There are other tools that measure perceived empowerment outcomes (for women and men) of climate-smart interventions across political, social, economic and agricultural domains (Hariharan et al., 2020). Guidelines for measuring gender transformative change could also be applied to evaluate the effectiveness of climate interventions (FAO, IFAD, WFP & CGIAR GENDER Impact Platform, 2023). New methods are being developed and tested to more easily collect data from rural women and explore their experiences with CSA, including data collection through mobile phones (Eitzinger et al., 2022). Furthermore, Duffy et al. (2017) propose a set of national-level indicators for measuring gender, poverty, food security, nutrition, and health status connected to CSA objectives.

While new tools are emerging to explore the gendered outcomes of climate interventions, few use intersectional approaches or include indicators of transformative change, such as changing gender attitudes (e.g., masculinities). Beyond measuring outcomes, policymakers, project implementers and other stakeholders need capacity building to implement climate actions in a gender-responsive way. A review of knowledge, attitudes and practices of climate change adaptation programming implemented in Bangladesh, Ethiopia, Kenya and Mali noted that measurable targets and monitoring of implementation as well as ex-post evaluation of program outcomes were lacking, and called for more capacity in these areas (Ragasa et al., 2013).

Despite more recent emphasis on the importance of transforming food systems under climate change (Steiner et al., 2020), understanding how gender inequalities drive food system outcomes (Njuki et al., 2022) and examining climate change impacts along agricultural value chains (Fanzo et al., 2018), this review found almost no literature on the intersection of gender, food systems, and climate change. Most of the evidence on gender, climate change, and food security in LMICs is focused on agricultural production. More evidence is needed to document gender differences in exposure to climate shocks and stressors along agricultural value chains and in different food environments, and how these overlap with existing inequalities, such as women's more limited opportunities to engage in higher-value production or high-value nodes of agricultural value chains (Coles and Mitchell 2010; Masamha et al. 2018). Better understanding of how climate change will

affect men's and women's livelihood strategies and opportunities along agricultural value chains would help devise gender-responsive strategies and interventions to increase men's and women's resilience, including through greater livelihood diversification and entrepreneurship.

Disclaimer

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

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