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Climate Change and Women – Impacts and Adaptation

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Abstract

This paper reviews literature on climate change impacts and adaptation in developing countries with a focus on women, their role in households, production and economic growth. Climate change impacts are a phenomenon channeled initially via the influence of changed climatic conditions on natural resources and their productivity. The consequences from these environmental shocks affect the whole economy and particularly vulnerable socio-economic groups such as women. Implementing adaptation measures requires an understanding of the climate change impacts on women in households, production and economic growth. The review indicates that climate change impacts are complex and highly dependent on region and socio-economic circumstances. Overall, women from developing countries are more vulnerable to climate change impacts than men and are, at the same time, less able to adapt to its effects, particularly in the agricultural sector. Further, the review suggests that since climate impacts affect growth, counteracting the effects of climate change on women has the potential to support growth. The compilation of findings from the reviewed studies assists by providing an overview on the current state of problems and the particular socio-economic conditions at play.

Keywords: Developing countries, macroeconomics, agriculture, production, gender

JEL Codes: E23, Q54, J45, J16

1 Introduction

Climate change is one of the greatest challenges of our time, largely affecting countries negatively, although by varying degrees and channels (Baez et al., 2010). Beyond the immediate human and material damage, climate change leads to a decrease in the yields of certain crops, which affects agricultural output and the food security of populations. Droughts reduce the availability of water, leading to reduced water supply (for nutrition and sanitary usage), factor productivity (Henseler and Schumacher, 2019; Letta and Tol, 2019) and economic growth (Dell et al., 2014). As a consequence, droughts drive population displacement and migration (Baez et al., 2017; Berlemann and Steinhardt, 2017). These impacts are felt by all countries, but the economies of poor countries are more affected (Dell et al., 2009, 2012; The Intergovernmental Panel on Climate Change (IPCC), 2014a, 2022; Tol, 2018). Within the developing countries, vulnerable groups are the most affected (IPCC, 2001, 2014a, 2022; Park et al., 2018) because they are more dependent on natural resources and lack the capacity to adapt to climate change (Fankhauser and McDermott, 2014; Hallegatte and Rozenberg, 2017; Stern, 2007).

Previous literature shows that the impacts of climate change are not gender-neutral (Adzawla et al., 2019; Andersen et al., 2017; Asfaw and Maggio, 2018; Cannon, 2002; Denton, 2002; Eastin, 2018; Goh, 2012; Nelson et al., 2009; Paudyal et al., 2019; Quisumbing et al., 2018; Rao et al., 2019). Women are more vulnerable than men to changes caused by globalization, economic crises, and environmental degradation (Denton, 2002). Among the poor social groups, women are particularly vulnerable to climate change for a variety of reasons. They have unequal access to productive resources such as land or other assets, and less access to economic opportunities (Mehar et al., 2016; Mersha and Van Laerhoven, 2016; Potsdam Institute for Climate Impact Research and Climate Analytics, 2013; SOFA Team and Doss, 2011). Moreover, as they have less access to financial services and credits, they have less capacity to cope with the effects of climate change (Deressa and Hassan, 2009; Eastin, 2018; Terry, 2009). Climate change, therefore, threatens to exacerbate women's precariousness and increase their vulnerability (Denton, 2002).

In developing countries, women mainly work in agricultural sectors. Indeed, the share of female labour is estimated at approximately 40% (in middle income countries) and 50% (in low income countries) (International Labour Organization 2019, Palacios-Lopez et al. 2017, World Bank, 2022). Yet, this sector is identified as the most impacted by climate change (Dell et al., 2012; FAO, 2019; Fischer et al., 2005; Hertel and Rosch, 2010; IPCC, 2014a, 2022). Working mainly in agriculture, which is highly affected by climate change, exposes women to income losses. A decline in agricultural yields or a reduction in the length of growing season affects the production of food that women provide for their families. At the national level, this may threaten the country's food security (IPCC, 2007, 2001, 2022). The decrease in production also leads to a drop in agricultural income. The drop in income thus further increases women's vulnerability and poverty.

Women are usually responsible for domestic tasks, including childcare, water and wood collection for the household (Wood and Salway, 2000). These unpaid domestic activities reduce the amount of time women can spend on paid work (Elson, 1999; Fontana and Van Der Meulen Rodgers, 2005). For example, after repeated droughts, clean water may become scarce and therefore the distance and collection time may increase. Consequently, women's available time for paid work reduces, and gender gaps in paid and unpaid work widen, to women's disadvantage. The social norms and women's social status within the society also determine

their resilience capacity, such as their marital status (married, divorced or widowed women) (Azong and Kelso, 2021; Wineman, 2019). Climate change events such as heat waves, droughts, and floods can increase women's vulnerability in society (e.g., to partner violence or early marriage) (Carrico et al., 2020).

Although there are many studies evaluating the impacts of climate change in developing countries (e.g., on the agricultural sector and productivity), there is a dearth of studies on distributional impacts of climate change between men and women. Indeed, including gender in such literature has only significantly increased since 2000, with a trend of moving from qualitative general assessments focused on women's vulnerability to more regional and quantitative assessments, including adaptation and economic growth.

In the early 2000s, the first studies pointed to the need to assess climate change from a gender perspective. These studies were mainly descriptive and were focusing on the channels of vulnerability of women, and the need to include a gender lens in the climate impact studies. For example, Denton (2002) explained that rural women are the most vulnerable to climate change but are absent from decision-making processes. The author calls for an inclusion of women in the different international organizations to make sure climate change does not hamper gender equality. Then, IPCC (2007) started to report gender differences of climate change in terms of vulnerabilities and how climate change would affect the achievement of the Millennium Development Goal 5 (gender equality). The report identified rural women as the most affected because they rely on natural resources for their livelihoods and are responsible for domestic chores such as collecting clean water and wood. Neumayer and Plümper (2007) found that more women were dying during and right after climatic events mainly due to harsher impacts brought about by their lower socio-economic status. Following Denton, (2002), Terry (2009) and Alston (2014) there has been a call to shape adaptation and mitigation strategies with a gender lens.

Since then, the number of articles, specifically empirical studies, including a gender lens has increased. Some studies were trying to identify the drivers of this gender inequality in given climate change. For instance, Dillon and Gill (2014) found that the unequal access to irrigation equipment and other agricultural capital in Mali would worsen gender differences in crop production during a climate shock. Flatø et al., (2017) showed that, domestic burdens on women keep them from adjusting to climate shocks, especially in terms of mobility. Eastin (2018), published one of the few macro studies that analyses the links between gender equality and climate change. He finds that climate change reinforces pre-existing gender inequality in developing countries and calls for studies that can address the compatibility of the different micro-studies. Previous literature reviews provide overviews on specific impacts of climate change: women's vulnerability (Pearse, 2017), and women and agriculture (Doss et al., 2018; SOFA Team and Doss, 2011). Since 2000, a large number of new literature reviews present the nexus of climate change and women, either with a focus on specific countries (e.g., Anugwa et al., 2022; Nakiyemba et al., 2022 for Nigeria and Uganda) or on specific aspects. Awiti (2022) presents different angles of women's vulnerability to agricultural production, food and nutrition security, health, water and energy, climate-related disaster, migration, and conflicts. Desai et al., (2021) and Pankhurst (2022) focus their review on the climate change-induced health impacts and on the education of girls and women. Jain et al. (2022) describes the climate change impacts on women on the agricultural labour market adaptation effects in rural areas. Gardezi et al., (2022) and Huyer and Partey (2020) review adaptation strategies differentiated by gender, especially initiatives on smart agriculture. Loarne-Lemaire et al., (2021) and Sprout (2022) review how technological progress, innovation and information can be used to adapt to climate

change and to mitigate gendered impacts. Mohammed et al., (2022) review women's participation in climate change policies, while, Lau et al., (2021) call for reviewing and revising the assumptions underlying some gendered climate policies.

Despite the large number of studies, there is still a gap in terms of macroeconomic studies, especially on the cost of adaptation measures and the trade-off governments may face to finance those policies. The present paper aims at partially filling this gap. The paper reviews findings of different studies on the impacts of climate change on women in developing countries through a macroeconomic lens. It analyses the recent literature through the framework of households, production and economic growth with respect to impacts and adaptation strategies. The paper derives insights into the complex nexus between climate change and women's vulnerabilities by reviewing a large number of studies. It systematically analyses and compares findings based on different research approaches and countries in Southern regions: Africa (e.g., South Africa, Ghana, Kenya), Asia (e.g., India, Bangladesh) and Latin America (i.e., Brazil, Peru). More concretely it reviews studies on climate change and women with respect to impacts and adaptation strategies. Specifically, the article:

- i- describes different findings on climate change impacts on aspects of households, production and economic growth.
- ii- discusses the impacts of climate change and adaptation strategies to mitigate those findings in (i).
- iii- identifies research gaps in the literature and suggests future research needs to support policy making.

This paper consists of five sections. Section 2 presents the findings of studies analysing the impacts on women as individuals or in households. Section 3 focuses on impact on production and adaptation in agricultural production. Section 4 switches focus to the impact of climate change on economic growth, considering the nexus between women in households, production and economic growth. Section 5 concludes the paper with possible future research directions.

2 Women in households

Within a household, women are represented as individual women and girls (i.e., as household members) and also as heads in female headed households. They have different tasks, responsibilities and decision powers than men and different physiological and social conditions. These differences result in different climate change impacts and adaptation options for them than for men.

2.1 Impacts

The literature describes many channels through which climate change impacts women in households. Climate change impacts women differently than men by impacting agricultural income, food security, food prices, health and mortality. Besides these different impacts, social norms and socio-economic status determine women's climate change resilience.

2.1.1 Income and poverty

Climate change resilience capacity is the ability to manage climate changes and counteract or adapt to their impacts. Literature differentiates three main forms of resilience capacities: absorptive capacity aims at preventing damaged resulting from shocks (e.g., to build dams against floods), adaptive capacity aims at increasing flexibility to adjust to changed conditions (e.g., climate smart agriculture technologies), transformative capacity aims at more structural

changes to reduce vulnerability (e.g., increase women's participation in decision processes and reduce norms which create gender bias) (Smith and Frankenberger, 2018). Women, like other vulnerable groups (the elderly, children, sick) have less resilience capacity, for instance, they are generally physically weaker and economically less empowered than men to pay for climate change resilience.

In developing countries, many households rely on rain-fed agriculture for food and income. Rising temperatures and insufficient rainfall will directly affect crop and livestock yields, and thus food security and household income will decrease. For instance, Kabubo-Mariara and Karanja (2007) showed the impact of climate change on crop revenue at the household level in Kenya. They found that high winter temperatures increase net crop revenue whereas increased summer temperatures decrease it. Increased precipitation was found to increase net crop revenue. Ochieng et al., (2016) also found that climate change has the potential to significantly affect the livelihoods of smallholder farmers by either increasing or decreasing crop revenues. Huong et al., (2019) showed that an increase in temperature and rainfall during the dry season decreases the net revenue of farm households in Northwest Vietnam. In addition, they estimated that net revenue should decrease by about 18 and 21% in 2050 and 2100 respectively, under projected future climate change scenarios and in the absence of adaptation measures. However, when farmers' adaptation measures are taken into account, the projected loss in net revenue should only be about 0.37% and 0.20% in 2050 and 2100 respectively (Huong et al., 2019).

The poverty implications of climate-induced crop yield losses depend on a household's source of income as well as whether it is a net food buyer or seller. For example, households who are net food sellers are likely to benefit if climate change causes food prices to rise, whereas net food buyer households are likely to be hurt by higher prices. Bandara and Cai (2014) demonstrated that climate-induced agricultural productivity loss adversely affects food production and prices in all South Asian countries with negative consequences on food security. Ahmed et al., (2009) found that extreme weather events could have an adverse effect on agricultural income and raise the prices of staple foods that are important to poor households in developing countries. Thus, urban wage earners are likely to be the most vulnerable to climate impacts by paying for increased food prices yet not benefiting from increased farm products.

2.1.2 Food security and mortality

Farmland, poverty, recurrent drought and climate change, shortage of rainfall, and land degradation are determinants of food security. The access to productive resources is critical to food security. Food security is higher with relatively bigger livestock herds and better access to credits. Gender inequalities in terms of access to resources create food and nutrition insecurity particularly for women and female-headed households (Agidew and Singh, 2018; Asare-Nuamah, 2021). Male household heads have more access to essential resources than female household heads. This, therefore, tends to imply more food security in male-headed households (Asare-Nuamah, 2021). It goes without saying that where female headed households have access to substantive remittances or income, they do not necessarily suffer these insecurities. The share of female labour is estimated at between 40 and 50 % (FAO, 2012, International Labour Organization 2019, Palacios-Lopez et al., 2017, World Bank, 2022). Thus, wealthier households and households headed by men are more food-secure than those headed by women (Ndiritu and Muricho, 2021).

Tibesigwa and Visser (2016) showed that male-headed households are more food secure compared to female-headed households in South Africa, because the latter depend more on agricultural activities to increase the household food levels. Thus, in rural areas the food security gap between households is bigger than in urban areas (Tibesigwa and Visser, 2016). Tibesigwa et al., (2015) found that although weather-related crop failure threatens food security

in both male- and female-headed households, households with female heads who are single, widowed, divorced, or separated, are more vulnerable. These groups of women are more dependent on subsistence agriculture and wild natural resources such as wild fruits and bush meat. Kairiza et al., (2021) found that, in Zimbabwe, female headed households establish better collaboration and bonding with family members and close friends (bonding social capital). This bonding social capital creates more food security for female-headed households than for male headed households at least in normal food availability situations. However, in extreme food security crisis when all households become food insecure, bonding and social capital might be limited (Kairiza et al., 2021). In Ethiopia, the gender of the household head and the resource endowments determines the household nutrition. Female heads were found to prioritize good nutrition more than male heads (Teklewold et al., 2019).

Disasters (e.g., floods and earthquakes) have bigger economic impact on women and female headed households than their male counterparts, particularly in developing countries. The situation of labour markets, society and domestic burden makes women more vulnerable than men and less resilient to disasters (Flatø et al., 2017; Ray-Bennett, 2018). Indeed, natural disasters, and their economic impacts, kill on average more women than men world-wide (Ray-Bennett, 2018). Women (like children, the elderly, and the sick) are at higher risk of mortality during disasters than men because of less physical strength (e.g., to climb and swim). Also, social and cultural norms contribute to an increased risk for women. In some countries, girls are less expected to learn swimming or climbing and the female dress codes (as saree or burqa) can reduce women's mobility. Additional to having fewer lifesaving skills, women have more responsibility to look after children, which puts them at additional risk (Ray-Bennett, 2018).

Sivadasan and Xu (2021) found that extreme rainfall events (too much or too little) result in a smaller female population. Thus, especially in regions with stronger male preference girls and women require more targeted aid for weather shocks (Sivadasan and Xu, 2021). However, regionally men and boys can also be at higher risk of natural disasters by flood or earthquakes. Male fishermen, quarry, workers, and labourers working in prawn rearing can be more exposed to floods than women. Thus, customized-programs are required to educate these groups at risk on early warning systems and the risks associated with different hazards (Ray-Bennett, 2018). While women are globally more vulnerable to disasters and their consequences, high temperature cause more male mortality, which depends on geographical and socio-economic factors and cultural and social norms. Women's traditional roles of staying at home for care work might protect them from being exposed to temperature extremes (Alahmad et al., 2020; Song et al., 2021).

2.1.3 Social norms and domestic chores

While the social norms influence women's vulnerability on the one hand, climate change can influence women's social status on the other hand. Thus, women's marital status determines their resilience capacity, e.g., by rights to inheriting land. Male inheritance of properties is predominant making widowed women more vulnerable than married women (Azong and Kelso, 2021). Women who exit marriage as widows or divorcees experience a reduction in land access, face the risk of poverty and depend more on off-farm employment (Wineman, 2019). In Bangladesh, in the years after extreme heat, girls and young women are at higher risk of being married into poorer households and to husbands with less education where there is more risk for intimate partner violence (Carrico et al., 2020).

Women's domestic responsibilities lead to lack of time resources available to them (time poverty as a result of domestic chores). It is important to note that while the time allocation and responsibilities are regionally differentiated (Bhadwal et al., 2019), women bear the disproportionate responsibilities of unpaid household reproductive work such as home maintenance, subsistence production, and caring for children and the elderly worldwide in

developing countries. These responsibilities influence their decisions to participate in or the time spent in remunerative activities (Akyeampong and Fofack, 2013; Kabeer and Natali, 2013; Seguino and Were, 2014). During disasters women are responsible for cooking, firewood, caring and livestock management (Abbasi et al., 2019). Division of labour limits women's time and ability to participate in formal political and planning activities (Khandekar et al., 2019). In Ghana, girls' education is impacted by the girl's domestic responsibility for water supply. Long trips to fetch and carry water reduce the girls' time to attend school (Nauges and Strand, 2017). In Zimbabwe, with increased drought incidents, there was noticeable increase in water point violence affecting women and girls (Chigusiwa et al., 2023).

2.2 Adaptation

The options for adaptive measures and their effectiveness in counteracting the impact of climate change on women and households depends on the individual contexts of the people involved. Implementing technical adaptation measures requires consideration of the socio-economic situation, the perception of climate change and the access to information, the gendered roles, and decision-making processes. Literature describes these aspects as relevant for applying effective adaptation measures.

2.2.1 Adaptation measures

Society, institutional barriers, and social norms and their roles in households, constrain women's resilience capacities as mentioned earlier. These constraints result in low adaptive capacity of women, which make them more vulnerable to hazards. Effectively closing the gender gaps in household food security and inequality requires targeted measures to increase women's resilience capacities. This can be done by focusing on empowerment and increasing access to credit, land, education and capacity building. Furthermore, agricultural development policies should be targeted to consider regional and socio-economic specific gender gaps to effectively reduce the vulnerability of women and female headed households (Tibesigwa and Visser, 2016). Women left behind by their job-seeking husbands, in particular, need to acquire capacities to adapt to climate change risks. Often the women of migrant-sending households are responsible for managing disaster risks and resources. Thus, tailor-made capacity building activities and peer-to-peer learning at a household-level, flood preparedness, precautionary savings and approaching financial institutions, would support women's adaptive capacities (Banerjee et al., 2019).

Beside instruments for financial support and capacity building, investments into technological support are considered as effective gendered adaptation measures. Crucial elements of such investments are the affordable supply of energy and water to households. Energy and women empowerment are linked. Access to clean, affordable energy is a gendered issue because it allows the reduction of women's time-poverty by changing the pattern and habits of wood collection for fuel and cooking. Thus, clean cooking can improve women's roles and socio-economic status (Mazorra et al., 2020; Ravindra et al., 2021). A similar impact can be expected from equipping households with water supply techniques (e.g., water pipes).

2.2.2 Perception and information

The perception of how climate change impacts livelihoods and preferences for specific adaptation measures differ between men and women. This difference informs and determines how decisions are made about adaptation strategies. These perceptions can be differentiated between household heads but also on an intra-household level (e.g., Mehar et al., 2016; Ngigi et al., 2017). Furthermore, the perception of climate change can differ by region. In Nigeria men and women farmers experience different impacts of climate variability and change in rainfall, with women perceiving stronger impacts in terms of food insecurity and water shortage (Nnadi et al., 2019). In Ghana, if farmers perceive improved rainfall they believe there is less

need to adapt to climate change. Thus, they perceive the need for adaptation only with declining rainfall and real water stress (Etwire et al., 2022). It is therefore critical that there be clear information systems that inform farmers, together with community-level awareness campaigns (e.g.: practical on-farm demonstrations, video shows and radio programs). In rural Amazonia, Funatsu et al., (2019) do not find gender differences for perception of climate change impacts. Yet, in general male farmers have better access to this information than female farmers (Etwire et al., 2022). This again underscores the importance of gender sensitive policies and approaches.

Information, communication and education on climate impact and adaptation strategy determine farmers decision for adaptation options and differ for men and women. In Kenya, men and women differ in their gender-specific climate information needs, trust in information and preferred channels of information dissemination (Ngigi et al., 2017). Women and men differ in the preference to specific sources of information. Women prefer information from neighbours, friends, and media while men prefer information exclusively from media. Women were better informed than men about climate smart agricultural practices (Waaswa et al., 2021). In Ghana, the awareness of climate change between men and women is comparable but men have more access to the financial capacity required to purchase and use mobile phones. This allows men to be more responsive in adapting to climate change information and climate risk mitigation (Partey et al., 2020). For Ghana, climate information accessibility and the willingness to pay for climate information is determined, for men, by drought experience, food insecurity and farming experience. For women it is determined by government subsidies, membership of a social group and training (Antwi-Agyei et al., 2021).

2.2.3 Gender roles and decision making

Different roles in agriculture and the household, different socio-economic and cultural statuses and social norms make men and women suffer differently under the impact of climate change. This results in different levels of resilience and adaptive capacities. Gender gaps, other barriers for women and current inequalities increase with climate change impacts (Huyer and Partey, 2020). Local social norms and institutions determine the power among men and women with different socio-economic characteristics, therefore the adaptation responses differ among groups (Ahmed et al., 2016). Women face disadvantages in participation in decisions and in terms of bargaining for wages. Women are also less capable of adapting to the labour market. Restricted mobility conditions do not allow job migration for women (Abbasi et al., 2019).

Like socio-economic status (e.g., assets and economic status) determines the impact of climate change on women, the division of labour and responsibilities impact upon women's adaptation options in a different way than for men (Hariharan et al., 2020; Khandekar et al., 2019; Van Aelst and Holvoet, 2016). In Tanzania, compared to other women, widows and divorced women face disadvantages in water management. On the other hand, divorced women show relatively more income-earning activities outside the farming sector than married women (Van Aelst and Holvoet, 2016). In coastal Tanzania, the social and religious norms even support women's adaptation. The predominantly Muslim women are not allowed to accept paid physical and labour-intensive jobs on large scale farms which take place under exploitative conditions. Thus, women focus their work on small scale farms where they avoid the exploitative labour conditions, and they might have more management decision power to produce for their own consumption and secure family nutrition. In this respect, women engage in more climate change adaptation strategies than men and suffer less vulnerabilities to food supply than men hired in large scale farms (Atuoye et al., 2021). In India, empowered women benefit more from climate smart agriculture measures in the context of a climate smart village approach than less empowered women (Hariharan et al., 2020).

3 Agricultural production

Agriculture is a key economic sector which links women with economic growth. In most developing countries, the agricultural sector –together with mining and tourism– contributes one of the largest shares to the gross domestic product (GDP). Many women work in agricultural production and thus contribute significantly to the GDP. Women predominantly work either as employees for the household income or they work as subsistence farmers for the households' food security. The situations of men and women in agricultural sector are different, which is why the impact of climate change and adaptation measures differ.

Agriculture is of considerable importance in the social, economic, and cultural lives of developing countries world-wide. In Sub-Sahara Africa (SSA), the sector contributes about 23% of total gross domestic product (GDP) on average and employs more than 50% of the labour force which is predominantly female (Goedde et al., 2019; OECD, 2016). Of the percentage involved in agriculture, the majority are small-scale farmers who live in rural areas and mainly engage in subsistence production. It is estimated that about 80% of farms in SSA are on small plots and directly employ about 175 million people (OECD, 2016). Similarly, in South Asia agriculture is one of the largest contributors to GDP – about 20% of total GDP on average – and provides employment for over 45% of the population with women being the majority (Jat et al., 2016). In both regions, however, climate change is in general projected to have negative impacts on the agricultural sector due to fragile agro-ecosystems and limited investment in agriculture (IPCC, 2014b, 2022; Jat et al., 2016; Jones and Thornton, 2003).

3.1 Impacts

Similar to women in households, the impact on women in agricultural production are driven by socio-economic conditions and social norms, which determine women's vulnerability and resilience in agricultural production. Literature identifies natural and financial resources endowment and gender roles/responsibilities as the drivers for the adaptation.

3.1.1 Natural resources

In many countries, women have limited access to land because landownership is restricted to men (Ahmed et al., 2016; Khandekar et al., 2019). Women's restricted property rights over land and limited access to credit set them at risk when exposed to climate stress and makes it difficult for women to implement climate adaptation practices (Antwi-Agyei et al., 2015). Decisions on resources are made by men, who own the resources on producing climate adapted varieties or changing herd size or livestock (Khandekar et al., 2019). In Ghana, Carr (2008) found that existing gender roles regarding access to land led some husbands to prohibit their wives from cultivating individual plots as a response to shifting precipitation patterns, thereby undermining both women's agency and household well-being.

Quisumbing et al., (2018) observed that the level of involvement in agricultural production and exposure to weather risk determines the impact of weather-related shocks on men's and women's assets in Bangladesh and Uganda. They found that because Bangladeshi women rarely cultivate land independently and have a low level of ownership and control of agricultural assets, they were less exposed to weather-related shocks compared to Bangladeshi men who bore the brunt of drought shocks. On the other hand, drought shocks only reduced the size of Ugandan women's non-land assets (mostly agricultural and consumer durables) because they manage land and grow their own crops whereas Ugandan men were able to increase their landholdings after floods. Water scarcity impacts women in two ways, first it means reduced resources for agricultural production and household use and, second, it increases their responsibilities for water supply. Collecting water from long distance sources with increased effort (e.g., use of hand pumps and carrying the water) results in physically exhaustive work and time cost for women. Time and physical strength are then reduced for carrying out other

activities (e.g., adaptation). The same applies for the collection of firewood as a traditional female responsibility (Khandekar et al., 2019).

Inasmuch as there are gender differences in the access to productive inputs such as credit, fertilizer, land title, and extension services, the impacts of climate change on the livelihoods of men and women will also be different (Alston and Whittenbury, 2013; Goldstein and Udry, 2008; Grantham et al., 2021; Seguino and Were, 2014). For example, Goldstein and Udry, (2008) found that because of weaker property rights, women do not fallow their land enough, leading to lower productivity. Thus, gender equality in the access to inputs such as access to credit (which is influenced by the right to land title) could increase yields on women's plots and hence food production. This implies that in the absence of gender equality in productive inputs, climate change-induced loss of agricultural productivity will impact more women than men due to existing gender and social norms.

The unequal access to production factors tends to be to the disadvantage of women in many developing countries. The extent of this inequality, however, is difficult to quantify, because regionally heterogeneous ownership constellations (individual ownership by men or women or by mixed groups) hamper the quantitative measurement on the gender differences (Doss et al., 2015). Quantitative information on these differences is needed to analyse the gendered differences in factor productivity. Quantitative information on the plot size farmed or owned by men, by women or in mixed groups (men and women) is required to measure the factor productivity and the difference between men and women. Furthermore, the labour allocation between men and women in agricultural and domestic work needs to be considered. Gendered programs on agricultural development require this information to be effective and efficient (Doss, 2018).

Women's labour participation is determined by norms on particular crops, animals or in case of forestry to certain production systems like fuel wood (De Giusti et al., 2019). Women rather work in farming and fishery, as well as transporting and selling products at markets. Women also carry water, fuel, wood, fodder on their heads, backs and shoulders, which exerts damaging physical pressure (Khandekar et al., 2019). Waldman and Richardson (2018) and De Pinto et al., (2020) argue on the other hand that women's smaller land endowment results in advantageous conditions for adaptation in terms of crop diversification. Women farm on smaller plots and thus time constraints for farming activities can be lower and sufficient labour is available. Therefore, female farmers are willing to farm more labour-intensive crops with higher nutritional value (vegetables, pulses, cash crops) for subsistence farming (De Pinto et al., 2020), or more climate resistant perennial variants (Waldman and Richardson, 2018).

3.1.2 Financial resources

Decisions on adaptation are determined by factors such as location, age, marital status, gender and education. Furthermore, decisions on adaptation depend directly on the financial resources accessible to farmers, while, on the contrary, climate change impacts influence the access to financial resources. For example, in South Africa, the experience of drought-affected the smallholder farmers' access to credit (Ojo et al., 2021). In terms of financial decisions, women often have less decision-making power than men (Bhadwal et al., 2019), because they have fewer financial assets and they normally have lower wages compared to men. A significant share of women even work without receiving a salary as, for example, unpaid family workers. The gender wage gap depends upon the gender roles underlying the technology of production. Lauria et al., (2018) described that Bangladesh fishery women earn 50% less wages than men (Lauria et al., 2018). Mahajan (2017) described that in India, decreasing rainfall, which reduced rainfed rice, creates a decrease in women's wage rate relative to men's wage rate. Thus, in years of low rainfall, female-headed households earn less income and suffer more stress, when they would need more financial means to adapt to climate stress. The reduced female wage rate in

the labour market relative to that of males can reduce the bargaining power of females within the household (Mahajan, 2017).

Besides being better endowed with natural resources men are also better endowed with financial resources and have more access to credit. Women are not involved in financial dealings or decision making and often only responsible for the cash flows, while larger financial decisions are made by men (Bhadwal et al., 2019; Chingala et al., 2017; Waldman and Richardson, 2018). In Malawi women have less capital for livestock farming (e.g., for disease and parasite control) therefore female cattle producers in smallholder farming systems have limited possibilities to control capital and to access veterinary information and technologies, and to purchase chemical products (e.g., antibiotics, anthelmintics,) against diseases and parasites (Chingala et al., 2017). In Malian households, the women have less access to money and assets than men. Women often manage smaller plots of land with fewer resources (Waldman and Richardson, 2018).

3.1.3 Gender roles and responsibilities

Decisions on farm management are directly impacted by the gender specific responsibilities. Different roles and responsibilities in farming activities, often mean men are market oriented to increase their income and aim at product characteristics such as yield appearance and market demand. Some farming activities are traditionally gendered (e.g., livestock and cropping). Also, within these subsectors allocation is also gendered (e.g., domestic livestock, pasture, certain crops traditionally produced by men or women). Women, who are often responsible for subsistence farming and the supply of food for the household, might rather target nutrient content, taste or cooking characteristics (De Pinto et al., 2020; Huyer and Partey, 2020). As mentioned, men often produce for the market in order to earn household income, and thus produce cash and export crops. Women have less access to information on climate risk mitigation, while men are responsive in adapting by using their telephone devices (e.g., on strategic farm decision-making concerning land preparation, planting and crop selection). Partey et al., (2020) showed that women have less access to cell phones. Financial resources to buy mobile phones are predominantly controlled by men, thus women access information and communication only through their husbands' mobile phones.

In intra-household decisions on farm management, women generally have less decision power than men (Waldman and Richardson, 2018). With progressing climate impacts, there tends to be increased inequality and women who suffer more of the impacts of climate change will have less influence on implementing adaptation measures (Khandekar et al., 2019). The marginalization of women in decision making processes on adaptation implies that societies are not taking advantage of women's knowledge and skills on adaptation (e.g., in agro-biodiversity management) (Khandekar et al., 2019). Increasing women's access to information, their bargaining power in household participation in production decisions can increase crop diversification, from male preferred cereals and cash crops to more labour intensive but nutrient vegetable, fruit and protein crops (De Pinto et al., 2020). Decision making does not only differ between male and female headed households. Also, the intra-household gender dynamics are of relevance for adaptation. The decision-making process to cope with drought and floods is attributed to men as they are often the most senior member of the household, who is actively involved in farming and who has access to resources (land, house) (Meher et al., 2016). Also, male and female household members who work in agriculture, show higher levels of adaptation than the household heads, who have less time for the implementation of adaptation strategies (Adzawla et al., 2019).

In the decision-making processes at community-level, women's participation is relevant for adaptation strategies. Here participation and decision power require women's recognition of their income generation, economic empowerment, social capital and networks (Patnaik, 2021). The decision dynamics and interference between community level and household level are

complex and dependent on the regional social norms in the communities. In northern Kenyan pastoral societies women are under-represented in formal decision-making processes on drought preparedness. The increase of empowerment does not result in a more active participation in decision-making processes at community level. At household level, however, the participation in decision-making increases with increased empowerment and results e.g., in pre-emptive livestock sales as drought preparation (Grillos, 2018). In Peru men as land-owners are more represented in the communal irrigation commission meetings, where women's decision power is marginalized. Women do not have the status to vote and cultural norms ensure that women do not feel comfortable to speak in public meetings (Erwin et al., 2021).

3.2 Adaptation

In agricultural production, adaptation requires the adjustments in the ecological, social, and economic systems in which women play a key role for specific responsibilities. The reviewed literature below analyses the gendered aspects of adaptation with respect to different agricultural adaptation measures, job diversification, gendered preferences, and decision making.

3.2.1 Adaptation measures

Climate smart agriculture comprises measures to adapt farming to climate change, to lower dependency on field labour, to manage risks and to increase productivity in a sustainable way.¹ Such measures can change crop varieties, soil and water conservation and crop diversification (Chanana-Nag and Aggarwal, 2020). The costs of implementing climate smart agriculture technologies are gender and household specific. They depend on resource and market access constraints, social capital and information access and agri-climate factors, as well as the investment incentive (Mutenje et al., 2019). Labour-saving climate smart agriculture technologies can lower women's labour burden and free up time in work intensive periods.² The suitable option to reduce female labour input depends on different conditions (regional agro-climate conditions, as well as socio-economic and traditional norms), (Chanana-Nag and Aggarwal, 2020; Khatri-Chhetri et al., 2020). Climate-smart village approaches orient the application of climate smart agricultural technologies according to the gendered farming requirements in order to reach more household members in male and female headed households (Hariharan et al., 2020).

Agrobiodiversity management and crop diversification are measures to reduce risk and to increase crop resilience and yield under climate variability. By increasing the number of different crops, the risk for pests is reduced (compared to monocropping), while the selection of crops/variants with more adapted factor demand can have more resilience (e.g., against drought). Gender is a key variable in agrobiodiversity adaptation processes to climate change (Bhattarai et al., 2015). Social norms influence the diversification of crops since in many countries male and female farmers traditionally produce different crops, e.g., men produce cash crops and export crops for household income, while women produce crops for family nutrition. While crop diversification plans might aim at diversifying within cereal crops (e.g., maize, wheat, rice), non-cereal crops (pulses, vegetable, fruit) contribute to increased agrobiodiversity

¹ Huyer and Partey (2020) reflect the current relevance of gendered agricultural adaptation in their special issue in "Climatic Change" collecting five articles on the "Gender Equality in Climate-Smart Agriculture: Approaches and Opportunities" (Huyer and Partey, 2020).

² Examples for labor saving technologies are: direct seeded rice, zero tillage machines, laser land leveling, and green manuring, crop harvesters, weeder, solar pump irrigation, and post-harvest management (Khatri-Chhetri et al., 2020).

and thus to climate change adaptation. Furthermore, non-cereal-crops improve the supply of nutrients and vitamins in diets and nutrition (De Pinto et al., 2020).

Genetically modified crops, hybrid crops, and perennial crops are technologies that adapt crops to variable climatic conditions, such as disease resistance, with regionally adapted and accepted plant morphology. All over Africa hybrid crops associated with genetic modification of crops create a negative perception. Farmers' decision making is relevant for considering these technologies for climate adaptation and can be different between men and women (Waldman and Richardson, 2018). Male farmers are indifferent to the use of hybrid sorghum over traditional but prefer annual crops. The advantages of labour and seed requirements are not as important to male farmers. Thus, hybrid crops will likely not be accepted because of the long tradition of saving and reusing seeds among traditional cultures in Mali, which also allows independence and flexibility of seed selection (Waldman and Richardson, 2018). Waldman and Richardson (2018) argued that women farmers show fewer barriers to the labour requirements for perennial crops and the ability to reuse hybrid seeds. However, traditionally in Mali, women do not crop sorghum for income generation, rather doing so for domestic use and then only on small plots.

Implementing technologies for cropping can contribute to reduction of labour time, and water and energy demand while increasing crop yields. In rice production, machine transplanting and direct-seeded rice practices save labour and time compared to conventional rice cultivation. Time saving aspects are advantageous for women in situations with scarcity of labour time. Irrigation is used to counter crop losses through evapotranspiration and achieve maximum production in a particular growing environment. Different water-smart technologies and water supply systems can provide water for irrigation³ (Chanana-Nag and Aggarwal, 2020; Leal Filho et al., 2022). Such technologies can also reduce the burden of physical labour for women. However, for poor households and for women working as unpaid family labourers purchasing or renting such machinery might not be affordable. Thus, they cannot benefit from technological progress (Gartaula et al., 2020). Furthermore, one problem of male migration from water-scarce regions is that often women are left behind without sufficient infrastructure to implement the technological adaptation needed for necessary water supply (Leal Filho et al., 2022).

3.2.2 Job diversification

Farming is often rain-fed and dependent on women's activity. The outcome of agriculture depends on natural factors. Poor connections to the market to sell products often require long distance carrying of produce by women. Men's work is often limited to land preparation activities and their income earning activities include also non-agricultural work (e.g., tourism, construction, and manufacturing) (Khandekar et al., 2019). In India, Lambrou and Nelson, (2013) found that more women, particularly of lower castes, than men, work as wage labourers to compensate for weather-related crop losses. For rural unskilled women the labour diversification is limited to day-labour in agriculture (Erwin et al., 2021). Knowledge outside farming and cropping can be very different between men and women. In Nepal's mountain regions for instance, men's knowledge about grazing lands and weather conditions, trekking routes etc., is more advanced than for women (Bhadwal et al., 2019).

Migration from the rural to the urban areas is more often used by men than by women, mainly because of mobility constraints for women. Although women also show intention to migrate,

³ Water-smart technologies are for example: weather-smart and knowledge-smart interventions, agro-advisory services, climate information. Water supply systems are for example: rain water harvest, collection, groundwater extraction, water reuse and recycling, and desalination (Chanana-Nag and Aggarwal, 2020; Leal Filho et al., 2022).

they often stay left behind in the climate impacted region to continue agricultural and household activities (Codjoe et al., 2012; Cundill et al., 2021; Khandekar et al., 2019; Lauria et al., 2018; Leal Filho et al., 2022; Zander et al., 2019). In male out migrated families the reduced fodder availability hits harder and causes a reduction of domesticated animals, which is the source of income for these families. Male out migration and reduced yields increase the stress and the workload among women (Khandekar et al., 2019). However, high rates of men's outmigration can increase women's ability to participate in farming management decision and thus increase women driven agrobiodiversity management (Bhattarai et al., 2015).

3.2.3 Preferences and decision making

Gendered adaptation strategies are determined by the preferences of men and women. These preferences are determined by gender specific roles in farming and production objectives (market or subsistence), their access to productive resources and their availability (Codjoe et al., 2012).⁴ The preferences are also regionally different. In Ghana male farmers, as they are producing for the market demand, tend to adopt the climate adaptation strategies more than their female counterparts if adaptation strategies are promising improved crop yields (Adzawla et al., 2019). In India male farmers prefer adaptation strategies similar to the generic indicators proposed by IPCC (borrowing or using past savings, eating less, or taking an additional job) compared to specific indicator-based strategies according to adaptation to sustainable agricultural practices (e.g., climate smart strategies) (Meher et al., 2016). In Kenya, women tend to adapt by crop related strategies, while men prefer livestock- and agro-forestry related strategies (Ngigi et al., 2017). In Philippines, female farmers show diversification preference toward crops such as vegetable and fruit compared to men (De Pinto et al., 2020).

Increasing women's decision power in agri-diversity management can result in a higher share of land allocation for vegetable and fruit production, which provides food supply with higher nutritional value. Both, non-cereals production and prioritizing of subsistence supply by women result in higher household nutritional security (De Pinto et al., 2020; Teklewold et al., 2019). When women have more decision power on household budget, a higher share is allocated to children's education and health. Adaptation measures which contribute to increasing women's health and empowerment also increase children's health and access to education. This contributes to long term economic growth and to building transformative resilience.

Women's ability to participate in decision making processes and social power need to be enforced or increased (Grillos, 2018; Mutenje et al., 2019; Nnadi et al., 2019; Patnaik, 2021). At community level, group-based decision-making processes can support women organize and aim collectively at empowerment and reducing gender (Ngigi et al., 2017; Udas et al., 2019). At household level, men need to be involved while women's wellbeing must be prioritised (Udas et al., 2019). In developing adaptation programs, the gendered decision-making processes need to be understood at the household and community levels (Mutenje et al., 2019).

4 Economic growth

Women's traditional roles in the household and in agricultural production are their main links to contributing to economic growth. Since climate change impacts women in households and in agricultural production, it thus also indirectly impacts economic growth. The changes of economic growth, caused by climate change or other drivers, spill-over to the household and to the economic sectors and thus there is a vicious cycle among women, agricultural production and economic growth.

⁴ Codjoe et al., (2012) analyses the preferences of male and female farmers for different adaptation strategies in farming, fishing and charcoal production.

4.1 Impacts

The impacts of climate change can be differentiated between women in households and economic growth, between production and economic growth and by considering the full nexus between women, production and growth. Often, literature provides descriptions of multiple aspects from a partial perspective. These aspects range from impacts on women's income, education and health to the impact on factor productivity and crop yields.

4.1.1 Women and growth

To the extent that crop growth and yield are largely influenced by weather during the growing season, climate change-induced shocks significantly impact the livelihoods of people living in tropical developing countries such as those who rely on rain-fed subsistence agriculture, those who live in rural areas and urban slums and vulnerable groups like women. This has dire consequences for food insecurity, poverty, and gender inequality. In that respect, some studies evaluate the impacts of climate change on factor incomes and the cost of living. Hertel et al., (2010) found that higher global agricultural prices due to lower global productivity can enhance factor returns in agriculture in regions where the majority of the poor are self-employed in agriculture thereby reducing overall poverty. However, the opposite is true in regions where poverty is dominated by wage earners and urban dwellers.

The stage of economic development of a country and hence the structure of production influences the degree of gendered job segregation by occupation and sector and thereby determines the value and recognition given to women's contributions to economic growth (Grantham et al., 2021). Historical development of agricultural production has driven women's labour participation and social role. While in hunting and gathering economies, women's participation of outside work is high in economies based on cereal farming, labour is divided between men and women with women spending more time on processing cereals rather than on field work with the men (Alesina et al., 2013; Hansen et al., 2015). Technological progress in domestic work can improve girls' education, demographic transition and economic growth. Technological progress (e.g.: electrification, water pipes, cooking facilities) reduces the time women spend on domestic work and frees time for childrearing (and thus increases fertility) and labour-force participation. Less demand for domestic labour increases the willingness to invest in the education of girls, whose labour is less demanded for domestic activities. As educated adults, the women have higher opportunity cost for childrearing, which decreases fertility. The higher investment into girls' education decreases the education gender gap and fertility but increases average human capital and economic growth (Dao et al., 2021).

The root cause of failing to translate female labour and human capital into the productive formal economy is poor institutional arrangements that undervalue the roles women play in the informal and reproductive sectors of the economy (Grantham et al., 2021; IMF, 2019). Addressing these root causes preventing full translation of female labour to human capital necessary for economic growth is central when informing future policy-making that enhances women's resilience to climate change impacts. In many developing economies, women are over-represented in the informal economy where wages are low, jobs are insecure, working conditions are poor, and career prospects are limited (Grantham et al., 2021). For the most part, this is due to cultural and institutional barriers that prevent women from actively and freely participating in certain economic activities thereby underutilizing their full potential and contribution to the formal economy (Akyaempong and Fofack, 2013; Kabeer and Natali, 2013). In SSA countries, women are mostly concentrated in the informal and reproductive sectors mainly due to lower educational attainment as well as institutional and cultural barriers that define where and what type of work is suitable for a woman (Grantham et al., 2021).

In 18 SSA countries during the 12 months after the occurrence of above-average temperatures and precipitation anomalies it was observed that there was, on average, a lower ideal family

size and reduced probability of desiring a first or additional child. After a period of 60 months after above-average precipitation the ideal family size increased in size (Eissler et al., 2019). This provides evidence that climate change effects extend to affecting the population. The ideal population is an important determinant of growth in any economy. Importantly, male and female health capital is relevant for economic growth (Hassan et al., 2017). Improving women's health positively impacts their participation in the labour market and improves the level of childcare and investment in education. Therefore, women's health contributes to demographic transition and long-term economic growth (Bloom et al., 2021). Climate change can impact human fertility (Sellers and Gray, 2019). For 19 countries in sub-Saharan Africa drought conditions during their early childhood reduce women health status as adults. Thus, the drought experienced in early childhood negatively impact upon women's long-term health and empowerment. These impacts can be transmitted to the next generation when women bear children with a low birth weight (Hyland and Russ, 2019). In South-East Asia precipitation extremes during the first year result into reduced height-for-age of children. This observation increases with lower educational and socio-economic status of the mothers. Temperature extremes reduce the nutritional health in children's first two years of life (McMahon and Gray, 2021).

4.1.2 Agricultural production and economic growth

In developing countries, the strongest impacts of climate change on economic growth results from the impact on the agricultural sector. Thus, the impact of climate change on agriculture and other climate-sensitive sectors has consequences on job losses and poverty reduction efforts. Also, compared to advanced economies, developing countries have limited capacity in terms of the know-how and financial resources to appropriately adapt to the vagaries and perils of extreme weather conditions.

Several studies have analysed the impacts of climate change on economic growth at a macro-economic level. These studies provide empirical evidence that climate change impacts poor countries more severely than rich countries. Evidence of negative impact of temperature increase on total factor productivity (Burke et al., 2015; Dell et al., 2012; Letta and Tol, 2019) and labour productivity has been shown (Graff Zivin and Neidell, 2014; Henseler and Schumacher, 2019). In a like manner, Shakhawat Hossain et al., (2020) shows that seasonal precipitation and temperature in Bangladesh play a role in the determination of farmers' land values and floods are responsible for reductions in farmland value, especially in lowland areas. Their analysis also indicated that projected climate change scenarios will have a negative impact on the value of land.

For instance, climate change is expected to increase the occurrence of droughts and floods by altering the intensity, frequency, and distribution of rainfall. Also, climate change-induced higher temperatures will increase crop water requirements due to an increase in evapotranspiration rate and thereby increase agricultural water demand, in addition to further worsening the water scarcity problem, especially in the MENA (i.e., Middle East and North Africa) region (Jat et al., 2016; Sowers et al., 2011). Other studies estimate the yield losses for maize in 2030, between 1% to 4% in Central, Eastern and West Africa and in Southern Africa at 29% (Pereira 2017). In Latin America, Lobell et al., (2017) estimate the regional losses in Brazil at 5% in Brazil itself, and around 2% in the Andean region. In a more recent study, Jägermeyr et al., (2021) estimate the global end-of-century losses at 24%.

4.1.3 Impacts in nexus

The nexus between climate change impacts, women, production and economic growth results from the interlinkages between women, production and economic growth. There are at least two reasons explaining the importance and contribution of women to economic growth. First, women account for one-half of the potential human capital in any economy (Grantham et al.,

2021; IMF, 2019; Mankiw et al., 1992). Second, human capital or resource is a key determinant of economic growth (Mankiw et al., 1992; Solow, 1956). Thus, the full utilisation of women's domestic, care and economic activities (both formal and informal) will not only imply a full utilisation of the available human capital and stock but also have a positive impact on economic growth. This view is based on neoclassical growth theory which posits that higher labour force participation rates and education levels will impact economic growth positively through efficient allocation of labour resources and an increase in labour productivity. However, in many countries there exist gender gaps in educational attainment notwithstanding the global progress made in the last three decades. Additionally, the labour force participation rates of men exceed those of women considerably across the world (World Economic Forum, 2021).

The historical development of agricultural praxis can partially explain today's gender norms and female labour participation (Alesina et al., 2013; Uberti and Douarin, 2022). Countries with historical plough farming (e.g., in Europe, North Africa, North America) drove the labour differentiation between men and women with women specializing in work at home (e.g., processing of cereals), while men focused on working on the field (Alesina et al., 2013). In these historically plough farming countries the increasing economic development resulted in increased female labour force participation ("Feminisation U-Theory"). In countries without historical plough farming (e.g., in SSA countries) the increase of female labour force participation was slower (Uberti and Douarin, 2022). Andrijevic et al., (2020) showed the link between climate change and gender equality. In many developing countries the development of gender inequality is linked to the development of climate change and the challenges for mitigation and adaptation. Many countries with high gender inequality are in mid-stages of demographic transition. The expected population growth may slow down the reduction of inequality. Of particular importance are the impacts on girls. Girls carry over the impacts of the inequalities (in health, empowerment, education, and labour force participation) as adults when they are women. Thus, to foster future climate resilient development, reducing gender inequalities is of high relevance (Andrijevic et al., 2020).

The following observations can be concluded for the climate change – women – economic growth nexus: -i- women play an important role in economic growth and development and women are a vulnerable group mostly because of cultural and institutional barriers that constrains their access to labour market, finance, and reproductive inputs. -ii- Closing the gender gaps in education and labour force participation will improve women's bargaining power in the household with positive impacts on children's well-being and future productivity. -iii- Climate change reduces women's economic output as a result of their reliance on climate-sensitive sectors and limited capacity to adapt to the vagaries of extreme weather conditions. -iv- The predicted adverse impacts of climate change on economic activities shrink women's opportunities in the formal and informal economy, worsen gender inequality and reduce their bargaining power in the household and negatively impact children's well-being and future productivity. -v- Thus, the impacts of climate change harm economic growth twice by reducing current and future economic growth.

4.2 Adaptation

The reviewed studies propose policy recommendations to increase gendered adaptation and to reduce the climate change impacts. Furthermore, the policy measures aim at preventing an increase of gender inequalities and gender gaps. Most of the policy recommendations address the problems of vulnerability and women's empowerment, which therefore address the household and production level challenges. The complex and regional contexts create a diverse set of specific research needs in order to consider the full nexus between women, production and growth.

4.2.1 Women and growth

Economists have argued that properly accounting for women's contributions in the informal sector and reducing gender inequality in unpaid reproductive work will enhance economy-wide productivity and promote economic growth (Braunstein et al., 2011; Grantham et al., 2021; IMF, 2019; Seguino and Were, 2014). For instance, Braunstein et al., (2011) showed that reducing gendered wage gaps will directly affect production, in addition to inducing more investment in human capacities (which includes the standard human capital measures such as skills and education plus the ability to work with others, emotional maturity, self-confidence, and patience) at the household level with benefits to labour productivity and reduced unit labour costs.

Reducing gender gaps in education has further benefits to economic growth and development through its positive impact on children's well-being and future productivity. Greater educational equality enhances women's ability to participate in decision-making, which increases their bargaining power within the household and positively impacts on children's health, education, and survival. Hence, through the dynamic and cumulative process of human capital formation, greater gender equality benefits women today as well as future generations. This is to say that reducing gender gaps in education and labour force participation has generational benefits by improving women's bargaining power in the household, particularly given that women tend to spend a larger share of their income on education, nutrition, and health of children than men do (Paul Schultz, 2002; Xu, 2007).

Besides improving women's general education, training and education programs on adaptation strategies and climate change impact should also be offered as customized measures to men and women considering the gendered differences and socio-economic status (Chingala et al., 2017; Nnadi et al., 2019; Zamasiya et al., 2017). Capacity building programs and training for men and women should be offered at community level as group-based approaches to strengthen the position of women in the labour force (Ngigi et al., 2017). Also, climate information services should be offered while considering the regional and gendered differences (Nnadi et al., 2019; Ojo et al., 2021). They should be offered in local languages, local calendars and appropriate media format to make them accessible to local women (Nnadi et al., 2019). Communication networks need to be created which allow horizontal knowledge management for women to exchange knowledge and experiences and to learn from each other (Dey et al., 2018).

The removal of discrimination towards women and gender inequality in labour force participation rates and education overwhelmingly reduces economic and societal costs — and the cost savings can help in generating economic growth. Bandara (2015) showed that for African countries, a 1% increase in the gender gap in effective labour (the combined effects of gender gaps in education and labour force participation) could result in a 0.43-0.49% reduction in output per worker. This means that close to US\$255 billion of output is wasted by African countries. These results are corroborated by Fofack (2012) who shows that increasing the stock of female human capital in Sub-Saharan African (SSA) countries could increase per capita GDP growth by more than half a percentage point. Moreover, a McKinsey Global Institute, (2015) report found that increasing women's economic participation to equal that of men, could add up to \$28 trillion, or 26%, to annual global GDP in 2025. In addition, estimates by the International Monetary Fund (IMF) (2019), reveal that gender gaps in the labour market could result in a loss of economic output that ranges from 10% of GDP in advanced economies to over 30% of GDP in the MENA and South Asia regions.

4.2.2 Production and growth

Improving access to productive resources for women is an important measure to strengthen adaptive capacities (land, water and capital) (Antwi-Agyei et al., 2015; Atuoye et al., 2021; Chandra et al., 2017; Ojo et al., 2021). Also, female-earmarked subsidies and supply with input

factors (seed, fertilizer, pesticides) can help female farmers. Social protection mechanism and compensation schemes should integrate risk transfer mechanisms such as weather-index insurance (Chandra et al., 2017). Investment in water supply and irrigation technologies can benefit women, firstly in terms of the predicted positive impact on agricultural production, income and food security (Mahajan, 2017; Nnadi et al., 2019) and secondly, by reducing the time taken to haul water, which could reduce girls' absence from schools (Nauges and Strand, 2017). These adaptation measures could be combined with or supplement other existing measures in gendered oriented climate smart programs (Adzawla et al., 2019).

Gendered adaptation measures include technological changes, increasing women's empowerment, and changes in social norms. All these aspects are linked to economic growth (Uberti and Douarin, 2022). Increased gender equity supports adaptation and mitigation objectives and at the same time, economic growth (Andrijevic et al., 2020). Women empowerment is central to adaptation. On the one hand it is a precondition for implementing gendered adaptation measures, on the other hand adaptation measures can increase women's empowerment (Chanana-Nag and Aggarwal, 2020; Hariharan et al., 2020). Adaptation in terms of technologization (e.g., in field work) and infrastructure can reduce women's overall workload. Particularly in physically hard work the reduced labour drudgery benefits women's health (Gartaula et al., 2020). Both set-off time for economic activities and improved health can contribute to economic growth.

Labour market reforms and policies must guarantee the same salary for men and women in agricultural and other sectors. Furthermore, it should allow women non-farm employment opportunities to allow them to earn non-agricultural dependent income in local communities (Atuoye et al., 2021; Mahajan, 2017). Negative impacts on women caused by adaptation measures need to be considered and counteracted if for example the technologization of field labour reduces the demand for women's wage labour which represents important source of income for rural women (Gartaula et al., 2020).

4.2.3 Research directions

Increasing the adaptive climate resilience for women and for the society is the primary objective of gendered adaptation measures. The strong interlinkages between adaptation and mitigation measures, and the economy and society as a whole can support multiple objectives, like sustainable development goals (food security, social, economic, energy, climate) and environmental protection (Mazorra et al., 2020; Onah et al., 2021). Given the regional differences and the aforementioned interlinkages, adaptation measures need to address climate vulnerability and adaptive capacities with respect to the regional dynamic links between social, ecological and agricultural conditions (Ahmed et al., 2016; Bhattarai et al., 2015; Chandra et al., 2017). These factors are defined by specific social, political, and environmental contexts and they vary at different levels (household, community, national) (Bhattarai et al., 2015). A better understanding of farmers' regional needs allows for the precise implementation of adaptation options that consider farming and socio-economic conditions and vulnerabilities (Bhadwal et al., 2019; Van Aelst and Holvoet, 2016).

Research addressing the heterogeneity in the impacts of climate change across different social groups (by intersectionality, gender, age, income, etc.) within a similar agro-ecological setting can inform on specific vulnerabilities and coping mechanisms of female and male farmers, as well as their local knowledge on agricultural adaptation to climate change (Chandra et al., 2017; Ginbo, 2022; Kaijser and Kronsell, 2014). This knowledge provides more detailed insights which aid in designing effective strategies and policy instruments to address variations in climate sensitivity among different groups (Ginbo, 2022). Specific regional and socio-economic indicators need to be developed to support evaluations on the status of and options for adaptation (Gutierrez-Montes et al., 2020).

Research needs to address the interdependency between gendered adaptation measures and women's gender empowerment in diverse farming households (Hariharan et al., 2020). More research is required on the multiple drivers of mobility and the multiple directions of movement to better understand short-distance and in-country migration, particularly in Africa and Asia and their gendered impact (Cundill et al., 2021). Better knowledge on migration can help to design measures to reduce the negative impacts of male migration (i.e.: females being left behind without infrastructure) (Leal Filho et al., 2022) and to strengthen the positive impacts on female empowerment (i.e.: more power over decisions in households and communities). Aside from increasing women's resilience, empowerment and participation in decision making processes at household and community level, research should also aim to increase the participation of women in climate change research and politics. In both domains, restrictive barriers for gender, race and nationality exist (Gay-Antaki, 2021; Swim et al., 2018).

5 Conclusion

This paper has presented the socio-economic literature on the impact of climate change with focus on gendered impacts on production and adaptation policies. The studies analyze different aspects of relevance to assess the impacts of climate change or to design or assess adaptation options. The early rather qualitative studies are complemented by growing body of studies based on quantitative data. However, most of the quantitative studies are based on the analysis of micro-economic data. The analyses focus on the household or individual level and are mostly restricted to partial aspects (partial analysis). Presenting the findings of the partial analysis helps to understand the relationship between climate change, women, production and economic growth as holistic problem. The main threads coming out of this review are: (1) women from developing countries tend to be more vulnerable to various impacts of climate change, (2) the impacts of climate change and adaptation measures on women are complex and regionally different as they are strongly dependent on geographical and socio-economic context, (3) women have less resilience and possibility to adapt as individuals, households, and in production, than men, (4) the impacts of climate change affect growth and thus, counteracting these impacts on women can support growth.

As emphasized in many studies of gender and growth economics and by studies addressing the topics of climate change and gender, the gender specific development policies are of high relevance for effective and efficient measures. The knowledge on the region, and society specific impacts can help to assess costs and benefits of policy measures, which in many cases have multiple outcomes and different objectives. Primarily addressed as adaptation or mitigation measures, they are at the same time, climate action policies with the objective to improve women's economic empowerment, food security, water supply, health, education, adding up in improving gender equality and economic growth. Depending on concrete measures, other goals can be impacted positively: improving production, energy supply and infrastructure. Thus, gendered climate policies can directly or indirectly address multiple sustainable development objectives at the same time and if designed effectively can be cost-effective investments for development policies.

Although, general problems of climate change impacts and adaption garnered from the represented countries is useful, the regional coverage can be extended. Thus, future research can analyze case studies in regions which are currently underrepresented in the literature (e.g.: Latin America). The same applies for the economic sectors. The sector which the reviewed studies focuses research on is agriculture, which is of high relevance to climate impacts and gender. Future research could analyze the impacts of climate change in other sectors (e.g., tourism, transportation and energy). As in gender economics, the quantitative studies at macro-

economic scale are underrepresented. Analyzing the impacts of climate change or adaptation measures at the aggregate scale can provide information on macro-economic impacts, budgetary costs and economic growth through a gendered lens. Such analysis can support policy making, which from a governmental perspective is often oriented to the national impact of policy measures.

The analysis of the surveyed data often allows for only a partial analysis focusing on specific aspects of economic problems. This is because it is challenging to survey enough different data to consistently represent the whole economic system. Computable General Equilibrium (CGE) models can support the analysis. Based on economic theoretic models they represent the normative economic behavior and require statistical data as inputs, which are available for many developing countries. CGE models simulate the economic interlinkages between economic agents and sectors and thus represent the economic system in a holistic way. The development of CGE models to address gendered analysis of climate change and adaptation is still in its infancy and this is a subject of a future research agenda. Beside the economic quantitative analysis, interdisciplinary analysis is required to understand the linkages between environmental, economic and social systems. Only by considering these multiple aspects can effective and efficient policies be designed to avoid counter-productive effects of policies (Lau et al., 2021).

The presentation in this study only represents a selection of the vast literature. We reviewed studies of different research focuses and study regions. In most of our descriptions we do not provide quantitative data, thus our analysis presents and compares the main findings qualitatively. The range of analyzed studies varies in terms of research questions, study regions, analysis level and methods, such that comparing quantitative results appear less suitable and could be even misleading. Mindful of these caveats, the findings from the presented literature suggests useful areas and directions for a future research agenda on climate change, the role of women and adaptation.

6 References

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