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Review

Impact of Climate Change on Marginal and Small Farmers' Livelihood and their Adaptation Strategies-A Review

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Abstract: The objective of this paper has been to review the impact of climate change on the livelihoods of marginal (those cultivating less than one-hectare land) and small farmers (cultivating between 1 and 2 hectares land) and their coping and adaptation strategies enhancing their resilience to climate change. This paper reviewed literature including peer-reviewed papers, reports, and books related to climate change impacts on agriculture and livelihoods of marginal and small farmers in developing countries. The findings reveal that marginal and small farmers are vulnerable to climate change and variability, on account of their marginalized status, direct reliance on agriculture for their livelihoods, and inadequate resources and capacity to deal with adversities. The review found that climate change is negatively impacting livelihoods of marginal and small farmers by reducing crop and animal yields, crop failures, crop and animal diseases outbreak, livestock mortality, shortage of pasture and water for livestock all of which eventuates in reduced farm income, food insecurity and a downward spiral in social and economic indicators like health, education, and wellbeing. Although marginal and small farmers are using diverse coping and adaptation strategies some of which are climate-smart as well, they are constrained by several social, economic, and institutional factors which reveal the need for planned or policy-driven adaptation practices. The literature suggests mainstreaming adaptation into development planning and programs as the best option to help farmers in their adaptation practices and also to avoid working at cross-purposes but more judiciously use of resources.

***Keywords*:** adaptation strategies, agriculture, climate change, coping strategies, livelihood

JEL Code: Q1, Q22, Q100, Q120, Q150, Q540

1. Introduction

Climate change is a significant global environmental challenge being faced by humanity (Arbuckle et al., 2015; Malhi et al., 2021; Mishra, 2017) and is emerging as a potent threat to agriculture-based livelihoods (Obokata et al., 2014). Climate change refers "to any change in climate over time, whether due to natural variability or as a result of human activity" (Intergovernmental Panel on Climate Change (IPCC), 2007). The impacts of climate change are being felt around the world in the form of rising temperatures, shifting rainfall patterns, melting glaciers, and increased occurrences of weather events like floods, droughts, and cyclones (Dessai & Hulme, 2001; FAO, 2018; Ganguly &

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Panda, 2010).

The synthesis report of the Intergovernmental Panel on Climate Change (IPCC) (2001) states that the climate system of the earth has demonstrably changed on both global and regional scales since the preindustrial era largely due to human-induced greenhouse gas emissions. The global average temperature has shown an increase of 0.9 ^{o}C since the nineteenth century (Arora, 2019) and is expected to increase between 3 ^{o}C to 5 ^{o}C by 2100 (United Nations Framework Convention on Climate Change (UNFCCC), 2019). World Meteorological Organization (WMO) (2021) confirmed that in a persistent long-term climate change trend, the decade 2011-2020 was the warmest on record and that 2016, 2019, and 2020 were the top three warmest years ever recorded.

Climate change is not just an environmental challenge but is an issue of great concern for nations around the globe due to its estimated impacts on food, water, natural ecosystem, and health (Muralidhar et al., 2012). Climate change has the potential to cause loss and damage to human life, productive systems, property, infrastructure, and wider social, economic, and natural systems (UNFCCC, 2019). Climate change is expected to be more severe for the agriculture sector in developing countries (FAO, 2018; Keane et al., 2009; Kumar & Viswanathan, 2019; United Nations Conference on Trade and Development (UNCTAD), 2021). FAO (2019) states that the agriculture sector bear about 26% of the economic impacts of climate-induced disasters in developing countries and climate change is expected to increase the losses further by causing more frequent and extreme weather events (including droughts, floods, unpredictable rainfalls), spreading pests and diseases, degrading ecosystem and increasing water scarcity and will ultimately lead to food and livelihood insecurity and forced migration. Small and subsistence farmers are particularly vulnerable to the negative impacts of climate change on agriculture (Fan & Rue, 2020; FAO, 2008; Jamshidi et al., 2018; Menike & Arachchi, 2016; Morton, 2007; Vermeulen, 2012) for that they rely heavily on agriculture for their livelihoods and survival and have inadequate resources and capacity to deal with the adverse impacts of climate change (Zurovec & Vedeld, 2019).

In the background of above, the present paper is an attempt to review published literature such as peer-reviewed research papers, reports, and books on the impacts of climate change on the lives and livelihoods of marginal and small farmers and the adaptation strategies adopted by them to cope with adverse situations. The subsequent part of this paper discusses the literature on the impact of climate change on agriculture, livelihoods of marginal and small farmers, their coping and adaptation strategies, factors influencing their adaptation strategies, need and benefits of climate-smart agriculture, need for planned or policy-driven adaptation strategies, and mainstreaming the planned adaptation strategies into development planning and programs.

2. Climate change and agriculture

Agriculture provides livelihoods to more than 2.5 billion people across the world (FAO, 2019, 2021a) and also contributes a significant part of the gross domestic product in many economies (FAO, 2021b). But due to its dependence on weather and climatic parameters, it is highly vulnerable to climate change (Arunanondchai et al., 2018; FAO, 2019, 2021a; Malhi et al., 2021; Zurovec & Vedeld, 2019). Climate change can affect crop yields as well as the types of crops that can be grown in certain areas, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests and diseases (Kumar, 2014; Porter et al., 2014). However, the general impacts of climate change may be negative or positive depending on the geographical location and socioeconomic development of a region and crops being produced (Mendelsohn et al., 2006; Mulinya, 2017). Mendelsohn et al. (2006) stated that the poor nations of the world bear the bulk of damages caused by climate change. Among many reasons, they highlighted location as the major reason and stated that poor nations suffer the most as they are situated in low latitudes which are already very hot. Besides, they acknowledged the economic reasons such as the share of GDP in agriculture, technology assets, and methods of adaptation to some extent as the factors responsible for adverse impacts. According to IPCC (2007), warming of climate will impact agricultural productivity more primarily in regions where temperatures are already near to maximum temperature needed for crop productivity. Moreover, the expected rise in temperature will have different impacts on similar crops in different regions. For instance, the rise of 1 to 3 ^{o}C above mean temperature will have beneficial impacts on crop yields in temperate regions, while in lower latitudes particularly in seasonally dry tropics the temperature increase of even 1 to 2 ^{o}C will negatively affect crop productivity. Also, a more than 3 ^{o}C rise in temperature will have negative impacts on agricultural productivity in all

regions (IPCC, 2007).

The 2020 World Population Data Sheet reveals that the world population is expected to reach 9.9 billion by 2050 (Population Reference Bureau, 2020) and agriculture is required to produce 49% more food by 2050 (FAO, 2019). However, climate change is projected to increase the occurrences of droughts and floods, both of which are harmful for food production (Mar et al., 2018). Intergovernmental Panel on Climate Change (IPCC) in its fifth assessment report indicates that during the last 3 decades, climate change has already led to a 1 to 5% decline in global agricultural productivity (Porter et al., 2014). It is estimated that by 2080, global agricultural production will be decreased by 15.9% with developing countries facing a disproportionately huge reduction of 19.7% (Cline, 2007). FAO (2016) predicts that by the end of the present century, production of key staples will be declined by 20-45% in the case of maize yields, 5-50% in wheat, and 20-30% in rice and soybean yields by 30-60% due to climate change.

Agriculture is critical for ensuring food security, livelihoods, and a range of other essential products like energy, fiber, and feed. But climate change and variability are negatively impacting agriculture (Zwane, 2019). In the absence of adaptation, climate change is likely to reduce the food availability and access of millions of rural people by adversely affecting their agricultural-dependent livelihoods. Agriculture is not only a victim of climate change but is also a driver of climate change through its significant contribution to global greenhouse gas emissions. Therefore, achieving food security and sustaining livelihoods while adapting to climate change and mitigating greenhouse gas emissions has become the most pressing concern which can be addressed by the adoption of Climate-smart agriculture (CSA) (FAO, 2021b).

3. Impact of climate change on livelihoods of marginal and small farmers

Climate change is a formidable threat to the livelihoods of people across the globe especially for those whose livelihoods depend on climate-sensitive sectors like agriculture. A livelihood consists of the capabilities, assets, and activities that are needed for making a living. Livelihood is considered to be sustainable when it can cope with and recover from stresses and shocks and sustain or improve its assets, capabilities, and activities both at present and future without undermining the natural resource base (Chambers & Conway, 1991; Serrat, 2017). According to United Nations Development Programme (2007), climate shocks affect livelihoods in numerous ways. They lead to crop loss, decrease employment opportunities, raise food prices and devastate properties and assets and thus leave people with limited choices. Since marginal and small farmers are directly dependent on agriculture for their livelihoods any reduction in agricultural yield will significantly impact their food and livelihood security, nutrition, income, and well-being (Hertel et al., 2010). According to Lowder et al. (2021), there are more than 608 million farms in the world of which marginal farmers (cultivating less than one hectare) hold 70% and operate 7% of all agricultural land while small farmers (cultivating between one and two hectares) hold 14% and control 4% of the land (Figure 1). Taking together, marginal and small farmers whose estimated number is approximately 510 million hold 84% of all farms worldwide and operate only about 12% of all agricultural land. Smallholder farmers (up to 2 hectares landholders) represent the backbone of the farming sector, particularly in low-income countries, and produce about 35% of food consumed worldwide (Lowder et al., 2021) and above 80% of food consumed in a large part of developing world (Ahmed, 2019; United Nations Environment Programme, 2013). Although small farmers contribute considerably to global food security and nutrition, yet constitute the majority of the poor and hungry in the world. (Ahmed, 2019; Fan & Rue, 2020)

Small farmers are particularly vulnerable to climate change because of their marginalized status, small landholdings, and high reliance on climate-dependent agriculture (Debela et al., 2015; Frank & Buckley, 2012; Gain et al., 2012; Harvey et al., 2014). Moreover, they possess limited resources to sustain or increase agricultural yield and have little or no access to technical assistance, financial assistance, or government support (Fan & Rue, 2020; Vorley et al., 2012). They generally use rudimentary technology and have limited access to market information (Lipton, 2013). Besides, many smallholders in developing countries are food insecure and reside in highly remote and environmentally fragile areas with low-quality infrastructure which in turn limits their access to markets, financial assistance, or government support (Morton, 2007; Harvey et al., 2014). Given their marginalized status and other socio-economic and development constraints, the predicted increase in temperature and changes in rainfall pattern will adversely affect agricultural productivity and thus, increase their livelihood insecurity which results in the sale of livestock and assets at disadvantageous prices, indebtedness, migration to other places in search of employment, dependence on food aid, and

reduced expenditure on health and education of children (Easterling et al., 2007).

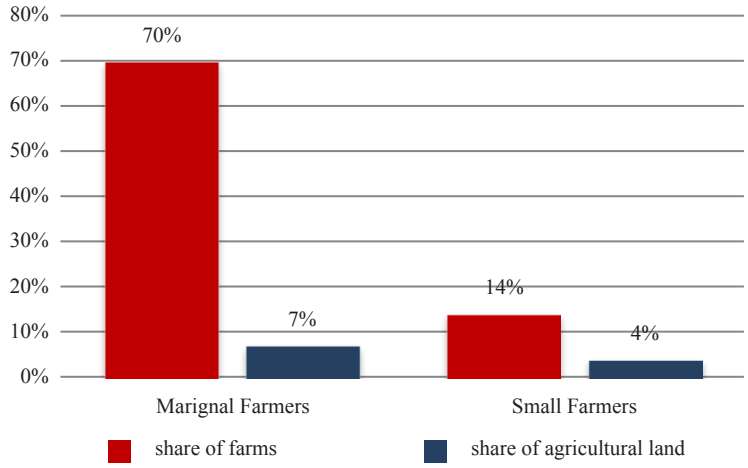

Figure 1. Percentage share of marginal and small farmers in total farms and agricultural land worldwide source: Lowder et al., 2021

Several researchers in their studies confirmed the adverse impacts of climate change on livelihood and other socio-economic indicators. Ubisi et al. (2017) studied perceived effects of climate change on crop production and household livelihoods of smallholder farmers in Limpopo, South Africa, and found that climate change has negatively affected small farmers' livelihood via prolonged droughts and reduced rainfall resulting in reduced crop yields and frequent crop failures which undermined their food security and wellbeing.

Harvey et al. (2018) studied climate change impact on smallholder coffee and basic grain (maize/bean) farmers across six Central American landscapes and found that climate change was negatively affecting the production of coffee, maize, and bean with the majority of all farmers reporting reduced crop yields and crop loss due to extreme weather causing increased food insecurity and decreased household income. Similarly, Aniah et al. (2016) studied the effects of climate change on livelihoods of smallholder farmers in the Upper East Region of Ghana and found that smallholder farmers were under significant stress of livelihood insecurity as their key livelihood activities such as crop farming and livestock rearing, fishing and other natural resource-based activities such as basket weaving and shea butter processing was being adversely affected by climate change through rippling effects such as droughts, floods, pests, and diseases outbreak in crops and animals, post-harvest losses and subsequently reduced crop yields and animal production.

Ochieng et al. (2016) studied the effects of climate variability and change on agricultural production and revenue from all crops, and maize and tea separately among small-scale farmers in Kenya, and the result indicated that climate change has a non-linear relationship with revenue from all crops, maize and tea, and that temperature negatively affects all crops and maize revenues and positively tea revenue. Conversely, rainfall positively affects all crops and maize revenues but negatively tea revenue. Overall the study showed that climate change had the potential to considerably affect small-scale farmers' livelihoods by either decreasing or increasing the crop revenues.

Matewos (2019) in his study found that climate change-induced impacts were affecting the health and livelihood status of small farmers in the study area. The major impacts included increased incidences of climate-related epidemics like Malaria and cholera, crop failure, crop loss, increased incidences of livestock diseases, livestock mortality, shortage of water and pasture for livestock, and increased food insecurity causing hunger among smallholders.

Mubaya et al. (2010) investigated the perceived impacts of climate change-related parameters on smallholder farmers in Zambia and Zimbabwe and found that rainfall causing floods and droughts was the most significant climate parameter which affected small farmers in the study area. Small farmers identified adverse impacts of floods and droughts on water availability, crop yields, human and livestock health, and other socio-economic factors. The reduction in crop yields eventuated in reduced income and poverty which in turn reduced small farmer's capacity to send their children to school and to meet daily household needs. Reduction in crop yields and income resulted in food insecurity

among smallholder farmers which triggered migration of, especially young farmers to other countries to supplement household income. Migration was, in turn, reported to have resulted in a sharp decrease in household income causing reduced agricultural yields and prevalence of HIV/AIDS.

4. Climate change and shift in gender roles in agriculture

Climate change impacts men and women differently (IUCN, 2015; UNFCCC, 2020). In several contexts, women are disproportionately affected by climate change because they have less access to and control over the resources (finance, land, labor, fertilizers, improved seeds), have less decision-making authority and face additional social, cultural, and institutional constraints which limit their ability to adapt effectively (Kristjanson et al., 2017; UN Women Watch, 2009). Women are primarily responsible for gathering and securing food, water, and fuel for cooking and heating purposes (IUCN, 2015; United Nations Environment Programme et al., 2020; UN Women Watch, 2009). These traditional roles of women are increasingly challenged by climate change (UN Women Watch, 2009). In addition to challenging the existing roles of women, climate change is also leading to significant socio-economic shifts resulting in changing traditional roles of women towards, economic activities, decision making, and leadership (United Nations Environment Programme et al., 2020). Male out-migration, for example, is increasing the role of women in agriculture and leading to the feminization of agriculture globally which besides giving them new responsibilities traditionally carried out by men give them greater decision-making power and greater control over productive and economic resources (FAO, 2017; United Nations Environment Programme et al., 2020). However, these traditional and expanding roles of women in economic activities have the potential to expose them to new security risks like sexual and gender-based violence or barring them to attain education (United Nations Environment Programme et al., 2020).

5. Adaptation and coping strategies

The adverse impacts of climate change on agriculture have become a major threat to agriculture-based livelihoods worldwide. Adaptation to climate change and other shocks is critical in increasing the resilience of those depending on agriculture for their livelihoods (Zurovec & Vedeld, 2019). To cope with adverse situations and to secure and sustain their livelihoods, farmers have to adapt to new situations by bringing variations in their farming and land management practices (Jarvis et al., 2011). The studies conducted by Hassan and Nemachena (2008) and Seo and Mendelsohn (2006) have revealed that adaptation can reduce adverse impacts significantly.

Over the generations, farmers are using diverse coping and adaptation strategies to secure and sustain their livelihoods in changed climatic conditions (Cooper et al., 2008). Coping and adaptation strategies are often used interchangeably as a response to hazards but they have different time scales (Dessalegn, 2018). Coping strategies refer to short-term, autonomous, and location-specific activities that aim at dealing with the particular hazard that takes place in an existing structure (Ashraf & Routray, 2013). Adaptation, on the other hand, refers to medium to long-term adjustments in social and ecological settings (Smit & Pilifosova, 2003) which either improve existing security and wealth or decrease vulnerability and poverty (Davies & Hossain, 1997). Coping strategies help to reduce the negative impacts of climate change for a short period only and are risk scattering in nature (Cooper et al., 2008). Adaptation, on the other hand, helps farm households not only in reducing negative impacts of climate change on their livelihood and wellbeing but also to seize the opportunity to gain from the changing environment (Eriksen et al., 2011).

5.1 *Coping strategies*

Various coping strategies used by farmers include migration, eating less food, changing diets, harvesting wild fruits, buying of food, earning income from off-farm activities, selling of livestock, land, and other farm assets, depending on aid from the government, family, and friends (Aniah et al., 2019), dissavings (Ellis, 2000), borrowing money primarily from informal sources (Ahmed, 2019; Singh et al., 2018) and reducing expenditure on health, education, and agricultural inputs (Ahmed, 2019). Aniah et al. (2019) argue that continuous use of coping strategies like selling of productive assets such as livestock, poultry, and land drag households to continuous livelihood and food insecurity. They further found in

their study that the households who sold their productive assets were unable to restore their assets which in turn reduced their capacity to cope with other-like situations and thus endangered their food production and availability.

5.2 *Adaptation strategies*

In addition to short-term coping strategies, small farmers adopt several long-term on-farm and off/non-farm adaptation strategies. On-farm adaptation strategies refer to those activities or strategies that farmers undertake on their farms to compensate for the negative impacts of climate change or variability on their livelihoods. Off-farm/non-farm adaptation strategies are those strategies or activities that farm households perform outside their farm to reduce their vulnerability to negative impacts of climate change or variability (Aniah et al., 2019).

5.2.1 *On-farm adaptation*

The literature suggests various on-farm adaptation strategies being adopted by small farmers which include changing planting and harvesting dates/timings (Aulong et al., 2012; Challinor et al., 2014; Deressa et al., 2009; Gedefaw et al., 2018; Panda et al., 2013; Partey et al., 2018; Yamba et al., 2019), adopting improved varieties of crops such as high yielding, drought resistant and early maturing crops (Aniah et al., 2019; Antwi-Agyei et al.,2014; Aulong et al., 2012; Deressa et al., 2009; Hussain & Mudasser, 2007; Panda et al., 2013; Simon & Shallone, 2013), crop diversification (Bryan et al., 2013; Deressa et al., 2009; Jha et al., 2018), mixed cropping, tree planting on farmland (Jain et al., 2015; Partey et al., 2018), mixed crop-livestock farming systems (Aulong et al., 2012; Panda et al., 2013), minimizing tillage (Gedefaw et al., 2018), improved farm management practice, irrigation and dry season farming (Aniah et al., 2019; Yamba et al., 2019), use of fertilizer (Challinor et al., 2014) and taking crop insurance (Jha et al., 2018).

5.2.2 *Off-farm/non-farm adaptation strategies*

In addition to these on-farm adaptation strategies, small farmers also adopt off-farm/non-farm adaptation strategies such as migration (Aniah et al., 2019; Aulong et al., 2012; Dallmann & Millock, 2017; Jha et al., 2018; Mehar et al., 2016; Panda et al., 2013; Viswanathan & Kumar, 2015) and livelihood diversification (Aulong et al., 2012; Davis et al., 2010; Mehar et al., 2016; Panda et al., 2013; Patnaik & Das, 2017).

5.2.2.1 *Livelihood diversification*

Livelihood diversification is an important adaptation strategy being implemented by farm households as a response to risks and opportunities associated with climatic and non-climatic factors (Davis et al., 2010; Patnaik & Das, 2017). Livelihood diversifications enable households to get other sources of income when production is inadequate to feed the occupants (Hesselberg & Yaro, 2006).

Livelihood diversification refers to the process by which rural households build a varied portfolio of activities and social support capacities to survive and to enhance their standards of living (Ellis, 2000). Livelihood diversification involves taking on both farm and non-activities and also selling labor to be paid in cash or in-kind and the remittances to earn extra income (Carter, 1997; Stark & Levhari, 1982). On-farm diversification like rearing of the dairy livestock, poultry, and cattle apart from crop cultivation is often seen as common additional activities performed by farm households (Kattumuri et al., 2015). Farmers also engage themselves in off-farm/non-farm employment such as part-time work or self-employed ventures (Singh et al., 2019), wage employment either on others' agriculture land or in non-farm sectors such as construction work, etc (Bhatta et al., 2015), running of shops like a general store, repair shops, etc. to cope with adverse situations compromising their income and consumptions (Tripathi & Mishra, 2017).

According to International Fund for Agricultural Development (2010), income from the non-farm sector contributes more than 50% of income earned by farming communities in developing countries. Non-farm activities, in addition to absorbing rural surplus labor also help in decreasing uncertainties in household income and increasing agricultural productivity and thus help farm households to adapt successfully (Yaro, 2013). Increased income earned from diverse livelihood sources enables farm households to improve their capacity to cope with the risks associated with climate change (Patnaik & Das, 2017; Tripathi, 2017). Empirical findings suggest that livelihood diversification to nonfarm sectors rather than depending on farming only has enabled farming communities to earn better incomes, food

security, increased agricultural productivity by overcoming capital constraints, and also to better manage environmental stresses (Babatunde & Qaim, 2010; Barrett et al., 2001; Hoang et al., 2014; Seng, 2015). Temesgen et al. (2010) in their study noted that the farmers who had non-farm sources of income were more food secure and less likely to liquidate their assets to cope with adverse situations created by climate shocks. Thus, diversification both on-farm and off-farm determine the robustness of coping strategies adopted by farmers (Hailu & Hasan, 2012; Thornton et al., 2007). According to Bhatta et al. (2015), the larger the diversification portfolio on the farm and off-farm, the more successful is the farmer in adapting to adverse situations.

5.2.2.2 *Migration*

Migration is often considered as an effective adaptation strategy by farm households to sustain their livings in adverse situations caused by climate and environmental change (Barnett & Webber, 2010; Bhatta et al., 2015; Jha et al., 2018; Piguet, 2013). Migration as an adaptation strategy is more popular in countries and among communities with the least access to land (Winters et al., 2009) and those communities with better access to education (Estudillo & Otsuka, 2010). Studies conducted by researchers like Aniah et al. (2019), Singh et al. (2018), Dallmann and Millock (2017), Viswanathan and Kumar (2015), Jha et al. (2018), Bhatta and Aggarwal (2015) Dovie (2010) reported that small and subsistence farmers migrate to other places to find alternative livelihoods in the face of crop loss or decreased agricultural productivity as a result of climate change impacts. Migration helps farm households to generate additional income to sustain household consumption in adverse circumstances. Besides generating additional income, migration helps farm households to learn new techniques and farming methods to increase agricultural income (Jha et al., 2018). Remittances sent by migrating family members ease credit constraints limiting the implementation of adaptation strategies (Patnaik & Narayanan, 2015), and thus increase the resilience of the farm household to deal with extremes (Jha et al., 2018; Singh et al., 2019). Research reveals that the adaptation capacity of migrating households is more as migration helps them to adopt more adaptation strategies due to support from host regions in the form of remittances, knowledge, resources, and networks (Jha et al., 2018). Notwithstanding potential benefits, migration does not represent the first adaptive response to climate change. It is often considered a last resort when other adaptation strategies fall short of meeting household requirements (Maharjan et al., 2020). Migration is also not always possible for all communities affected by climate change (Adams, 2016; Melde et al., 2017). Lack of finance, necessary knowledge and skill, and also lack of social network at destination place are the important factors influencing migration decision. Migration as a response strategy is also determined by employment prospects at potential destinations (Mueller et al., 2020). Social factors, like strong attachment to a place of origin, fear of the unknown place, or family obligations also explain why people do not choose migration (Flavel et al., 2020).

Climate-induced migration may be temporary or permanent (Flavel et al., 2020). Duration of migration depends on the type of climate event causing displacement among the population. Evidence revealed that fast onset of climatic events like floods, droughts, heat waves results in temporary migration followed by a return to the place of origin, while the slow onset of events like sea-level rise, ocean acidification, glacial retreat, degradation of forest, and land, biodiversity loss and desertification leads to permanent migration (Sherbinin, 2020). Temporary migration is often considered an effective adaptation option as temporary migration helps migrants in retaining household membership and sharing income with the rest of the household (Mueller et al., 2020).

6. Factors influencing farmers' adaptation practices

Although small-scale farmers have inherent capacity to cope with adverse situations created by climate variability and change (Abdul-Razak & Kruse, 2017; Takahashi et al., 2016), yet their efforts are expected to be inadequate to adapt successfully to the challenge of the unprecedented and increasingly erratic climate regime (FAO, 2008; Pettengell, 2010). Mabe et al. (2014) argue that for designing suitable policies to support effective adaptation, understanding the factors influencing adaptation practices of farmers is necessary. The researchers like Deressa et al. (2009), Mehar et al. (2016), Tripathi and Mishra (2017), Below et al., (2012), Brown et al. (2016), Gomez (2015), Kibue et al., (2016) and Somda et al. (2017) in their respective studies noted several socio-economic and technical factors like education, age farming experience, gender, access to extension services on appropriate adaptation mechanisms, access to farm

credit, climate information, farm income, and farm size, lack of irrigation facilities, lack of necessary farm inputs, poor regional infrastructure and the high cost of production which determine farmers' adaptation practices (Kassem et al., 2019).

7. Role of co-operatives and fair-trade organization

According to Frank and Buckley (2012) to effectively adapt to adverse situations created by climate change, small farmers need modern techniques, skills, and knowledge and also to be connected with existing technologies which are presently out of their reach. Frank and Buckley based on analysis of case studies and theoretical literature suggest that farmers can enhance their adaptive capacity by becoming a member of a farmer organization like co-operative and participating in fair-trade as these associations help in better accessing credit and savings institutions and extension services, ensuring increased and more stable incomes and accessing market information. Fairtrade provides farmers with better prices, stable market links, and resources for social and environmental projects (Raynolds, 2009, 2012). Fairtrade farmers obtain higher prices, have better access to credit, are economically more stable, and are more likely to undertake environmentally friendly farming practices (Dragusanu et al., 2014).

8. Climate-smart agriculture

Effective adaptation needs appropriate technology, innovations, and policy-enabling institutions that can reduce the vulnerability of farmers to climate-induced risks and create opportunities to sustain livelihoods and enhance resilience (Gifford et al., 2011). Adoption of climate-smart agriculture (CSA) is regarded as one such approach having the potential to increase agricultural productivity, achieve food and livelihood security while reducing/removing greenhouse gas emissions (FAO, 2021b; Partey et al., 2018).

FAO (2010) defined climate-smart agriculture as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals." CSA aims at developing the technical, policy, and investment conditions to attain sustainable development of agriculture in the face of climate change. CSA also aims at achieving food security and strengthening livelihoods, especially of smallholders by improving the management and use of natural resources and adopting suitable methods and technologies for production, processing, and marketing of agricultural produce (FAO, 2013). Although CSA is a new term given to a set of agricultural innovations, policies, and tools, the concept is already rooted in several indigenous practices and methods such as fallow systems, crop rotation, and water and soil conservation practices, etc which have helped farmers in agriculture. In addition to promoting indigenous practices, the advances in CSA research has resulted in the development, dissemination, and promotion of new methods, tools, and policies such as solar power drip irrigation system, integrated tree-crop livestock system, high yielding and drought-resistant seeds, agricultural insurance, climate information system, development of national and regional climate action plans for adapting and mitigating climate-induced impacts on agriculture and livelihoods (Partey et al., 2018).

Several studies conducted on CSA implementation and benefits suggest that CSA has the potential to increase crop yield, enhance the efficiency of inputs, increase net farm income and reduce greenhouse gas emissions (Asrat & Simane, 2017; Ghosh, 2019; Imran et al., 2018; Khatri-Chetri et al., 2016; Kurgat et al., 2020; Sapkota et al., 2015). Despite several potential benefits, the adoption of CSA technologies is fairly low among farmers (Kurgat et al., 2020; Partey et al., 2018). According to Kurgat et al. (2020) adoption of CSA technologies is influenced by several factors such as household characteristics, household assets such as land, labour, finance, access to institutional support like input-output markets, extension services, and social groups, access to information, farm characteristics and beliefs.

9. Planned or policy-driven adaptation

Climate change has increased uncertainty and risk for agricultural-based livelihoods. Since the adaptive capacity of small farmers is low, autonomous adaptation is not sufficient (Dev, 2011; Tripathi, 2016). Thus, strengthening the

adaptive capacity of small farmers is important to assist them to cope with climate change-induced threats to their food and livelihood security (Asfaw et al., 2017). For this, planned or policy-driven adaptation is essential (Kumar, 2014; Dev, 2011). Planned adaptation strategies should include those policies and initiatives which promote growth and diversification, reinforce institutions, protect natural resources, marketing water, and environmental services, improve international trade, improve resilience to disasters and enhance disaster management system, promote risk-sharing including social safety nets, crop insurance, and weather insurance and investment in research and development, education and health sector (Dev, 2011). In the same line, Menike and Arachchi (2016) suggested that the governments should introduce reforms promoting economic growth, technology, information and skills, infrastructure, and institutions to foster adaptation among marginal and small farmers.

Adger et al. (2005) noted that adaptation generally involves building adaptive capacity which means enhancing the ability of individuals, groups, or communities to adapt to changes and applying adaptation decisions which implies converting that capacity into actions. The important measures needed to build adaptive capacity include spreading knowledge about climate change, bringing awareness of potential impacts, protecting natural resources, promoting economic growth, and exploiting new opportunities. Since the adaptive capacity of a system is constrained by factors related to development such as poverty, social and political marginalization, adaptation policies should be targeted to the socio-economic development of those most affected (Ayers et al., 2014). But the adaptation policies must be mainstreamed into development planning, programs, and projects (Singh et al., 2019; Klein et al., 2003). Mainstreaming involves integrating climate change adaptation into existing development planning and actions (Klein et al., 2003). Mainstreaming enables a more integrated and less piecemeal approach towards achieving a climate-resilient development approach (Kumar & Viswanathan, 2019) and also the sustainable, effective, and efficient use of resources (Klein et al., 2003).

10. Conclusions

Evidence reveals that climate change is real and is negatively impacting agricultural productivity and employability which is expected to be severe in the future. Marginal and small farmers are particularly vulnerable to the negative impacts of climate change because they are directly dependent on agriculture for their livelihoods and survival and have limited resources and capacity to deal with adverse situations. Several research studies confirmed that climate change is negatively impacting livelihoods of marginal and small farmers by reducing crop and animal yields, crop failures, crop and animal diseases outbreak, livestock mortality, shortage of pasture and water for livestock all of which eventuates in reduced farm income, food insecurity and a downward spiral in social and economic indicators like health, education, and wellbeing. Adaptation is critical to improve the resilience of agriculture, in general, and for farmers, in particular, to secure and sustain their livelihoods in changed climatic conditions. Climate-smart agriculture is increasingly recognized as an important approach for adapting and sustaining agriculture and achieving food and livelihood security while reducing greenhouse gas emissions. Although marginal and small farmers are using diverse coping and adaptation strategies, some of which are climate-smart as well, to deal with adverse impacts of climate change on their lives and livelihoods, they are increasingly constrained in their pursuit by factors like inadequate information and knowledge on climate change, lack of extension services on appropriate adaptation mechanisms, lack of access to farm credit, lack of irrigation facilities, lack of necessary farm inputs, poor regional infrastructure, and the high cost of production. Thus, increasing their resilience and adaptive capacity is important to assist them to cope with climate change-induced threats to their food and livelihood security. Literature suggests various policies to stimulate adaptation like promoting growth and diversification, extension services on agriculture, financial support, social safety nets, climate forecasting mechanism, rural infrastructure, efficient irrigation, education, training, health, and creating employment opportunities. But these policy initiatives should be mainstreamed into development planning and projects to avoid working at cross-purposes but more judiciously use of resources.

References

Abdul-Razak, M., & Kruse, S. (2017). The adaptive capacity of smallholder farmers to climate change in the Northern

Region of Ghana. *Climate Risk Management, 17*, 104-122. https://doi.org/10.1016/j.crm.2017.06.001
Adams, H. (2016). Why populations persist: mobility, place attachment and climate change. *Population and Environment, 37*, 429-448. https://link.springer.com/article/10.1007/s11111-015-0246-3
Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change, 15*, 77-86. https://doi.org/10.1016/j.gloenvcha.2004.12.005
Ahmed, A. (2019). *Climate change and the dryland resources of Nigeria*. Mauritius: LAP Lambert Academic Publishing. https://www.researchgate.net/publication/331044122_Climate_Change_and_the_Dryland_Resources_of_Nigeria
Aniah, P., Kaunza-Nu-Dem, M. K., Quacou, I. E., Abugre, J. A., & Abindaw, B. A. (2016). The effects of climate change on livelihoods of smallholder farmers in the upper east region of Ghana. *International Journal of Sciences: Basic and Applied Research (IJSBAR), 28*(2), 1-20.
Aniah, P., Kaunza-Nu-Dem, M. K., & Ayembilla, J. A. (2019). Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro-ecological zone of Ghana. *Heliyon,* 5, e01492. https://doi.org/10.1016/j.heliyon.2019.e01492
Antwi-Agyei, P., Stringer, L. C., & Dougill, A. J. (2014). Livelihood adaptations to climate variability: Insights from farming households in Ghana. *Regional Environmental Change, 14*(4), 1615-1626. https://doi.org/10.1007/s10113-014-0597-9
Arbuckle, J. G. J., Morton, L. W., & Hobbs, J. (2015). Understanding farmer perspectives on climate change Adaptation and Mitigation: The roles of trust in sources of climate information, climate change beliefs, and perceived risks. *Environment and Behavior, 47*(2), 205-234. https://doi.org/10.1177/0013916513503832
Arora, N. K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *Environmental Sustainability, 2*, 95-96. https://doi.org/10.1007/s42398-019-00078-w
Arunanondchai, P., Fei, C., Fisher, A., McCarl, B. A., Wang, A., & Yang, Y. (2018). How does climate change affect agriculture? *The Routledge Handbook of Agricultural Economics* (pp. 20). *Routledge*: Abingdon-on-Thames, Uk.
Asfaw, A., Simane, B., Hassen, A., & Bantider, A. (2017). Determinants of non-farm livelihood diversification: Evidence from rainfed-dependent smallholder farmers in north central Ethiopia (Woleka sub-basin). *Development Studies Research, 4*(1), 22-36. https://doi.org/10.1080/21665095.2017.1413411
Ashraf, M., & Routray, T. (2013). Perception and understanding of drought and coping strategies off farming households in north-west Balochistan. *International Journal of Disaster Risk Reduction, 5*, 49-60. https://doi.org/10.1016/j.ijdrr.2013.05.002
Asrat, P., & Simane, B. (2017). Adaptation benefits of climate-smart agricultural practices in the blue nile basin: empirical evidence from north-west Ethiopia. In W. Filho, B. Simane, J. Kalungu, M. Wuta, P. Munishi, & K. Musiyiwa (Eds.), *Climate Change Adaptation in Africa: Fostering Resilience and Capacity to Adapt* (pp. 45-59). AG Cham: Springer International Publishing.
Aulong, S., Chaudhuri, B., Farnier, L., Galab, S., Guerrin, J., Himanshu, H., & Reddy, P. (2012). Are south Indian farmers adaptable to global change? A case in an Andhra Pradesh catchment basin. *Regional Environmental Change, 12*(3), 423-436. https://doi.org/10.1007/s10113-011-0258-1
Ayers, J., Huq, S., Wright, H., Faisal, A. M., & Hussain, S. T. (2014). Mainstreaming climate change adaptation into development in Bangladesh. *Climate and Development, 6*(4), 293-305. https://doi.org/10.1080/17565529.2014.977761
Babatunde, R. O., & Qaim, M. (2010). Impact of off-farm income on food security and nutrition in Nigeria. *Food Policy, 35*(4), 303-311. https://doi.org/10.1016/j.foodpol.2010.01.006
Barnett, J., & Webber, M. (2010). Accommodating migration to promote adaptation to climate change. *Policy Research Working Paper* (pp. 5270). Office of the Senior Vice President and Chief Economist. https://doi.org/10.1596/1813-9450-5270
Barrett, C., Bezuneh, M., & Aboud, A. (2001). Income diversification, poverty traps and policy shocks in Cote d'Ivoire and Kenya. *Food Policy, 26*(4), 367-384. https://doi.org/10.1016/S0306-9192(01)00017-3
Bhatta, G. D., Aggarwal, P. K., & Shrivastava, A. (2015). Livelihood diversification and climate change adaptation in Indo-Gangetic plains: Implication of rainfall regimes. *The Journal of Agriculture and Environment, 16*, 77-94. https://pdfs.semanticscholar.org/005a/89b228eb26fa62194d11ca51e186d0c94b29.pdf
Bhatta, G. D., Aggarwal, P. K., Shrivastava, A. K., & Sproule, L. (2015). Is rainfall gradient a factor of livelihood diversification? Empirical evidence from around climatic hotspots in Indo-Gangetic plains. *Environment, Development and Sustainability, 18*(6), 1657-1678. https://doi.org/10.1007/s10668-015-9710-6
Below, T. B., Mutabazi, K. D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., & Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental*

Change, 22(1), 223-235. https://doi.org/10.1016/j.gloenvcha.2011.11.012
Brown, P. R., Bridle, K. L., & Crimp, S. J. (2016). Assessing the capacity of Australian broadacre mixed farmers to adapt to climate change: Identifying constraints and opportunities. *Agricultural Systems, 146*, 129-141. https://doi.org/10.1016/j.agsy.2016.05.002
Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of Environmental Management, 114*, 26-35. https://doi.org/10.1016/j.jenvman.2012.10.036
Carter, M. R. (1997). Environment, technology, and the social articulation of Risk in West African agriculture. *Economic Development and Cultural Change, 45*(3), 557-591.
Challinor, A., Watson, J., Lobell, D., Howden, S., Smith, D., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, *4*(4), 287-291. https://doi.org/10.1038/nclimate2153
Chambers, R., & Conway, G. R. (1991). *Sustainable rural livelihoods: practical concepts for the 21st century*. Institute of Development Studies. https://www.ids.ac.uk/download.php?file=files/Dp296.pdf
Cline, W. R. (2007). *Global Warming and Agriculture: Impact Estimates by Country.* Washington: Center for Global Development and Peterson Institute for International Economics.
Cooper, P. J. M., Dimes, D., Rao, K. P. C., Shapiro, B., Shiferaw, B., & Twomlow, S. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems and Environment, 126*, 24-35. https://doi.org/10.1016/j.agee.2008.01.007
Dallmann, I., & Millock, K. (2017). Climate variability and inter-state migration in India. *CESifo Economic Studies, 63*(4), 560-594. https://doi.org/10.1093/cesifo/ifx014
Davies, S., & Hossain, N. (1997). *Livelihood adaptation, public action and civil society: A review of the literature*. Institute of Development Studies. https://www.researchgate.net/publication/254314877
Davis, B., Winters, P., Carletto, G., Covarrubias, K., Quiñones, E. J., Zezza, A., Stamoulis, K., Azzarri, C., & DiGiuseppe, S. (2010). A cross-country comparison of rural income generating activities. *World Development, 38*(1), 48-63. https://doi.org/10.1016/j.worlddev.2009.01.003
Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile basin of Ethiopia. *Global Environmental Change, 19*(2), 248-255. http://dx.doi.org/10.1016/j.gloenvcha.2009.01.002
Dessalegn, B. (2018). Transitory coping strategies of food-insecure smallholder farmer households: The case of Ilu Gelan district, West Shoa Zone, Oromia Reginal State, Ethiopia. *Agriculture & Food Security, 7*, 70. https://doi.org/10.1186/s40066-018-0204-2
Debela, N., Mohammed, C., Bridle, K., Corkrey, R., & Mcneil, D. (2015). Perceptions of climate change and its impacts by smallholder farmers in pastoral/agropastoral systems of Borana, South Ethopia. *Springer Open Journal, 4*, 236. https://doi.org/10.1186/s40064-015-1912-9
Dev, S. M. (2011). *Climate change, rural livelihoods and agriculture (focus on food security) in Asia-Pacific region*. Indira Gandhi Institute of Development Research, Mumbai. http://www.igidr.ac.in/pdf/publication/WP-2011-014.pdf
Dessai, S., & Hulme, M. (2001). Climatic implications of revised IPCC emission scenarios, the Kyoto Protocol and quantification of uncertainties. *Integrated Assessment, 2*(3), 159-170. https://doi.org/10.1023/A:1013300520580
Dovie, D. B. (2010). Climate change, water and disasters: Perspectives from Ghana's three northern regions. *WRC-CCA Report Series No. 1*. Water Resources Commission, Accra. https://doi.org/10.13140/RG.2.2.20842.31682
Dragusanu, R., Giovannucci, D., & Nunn, N. (2014). The economics of fair Trade. *The Journal of Economic Perspectives, 28*(3), 217-236. https://scholar.harvard.edu/nunn/publications/economics-fair-trade
Easterling, W. E., Aggarwal, P. K., Bati, M. P., Brander, K. M., Erda, L., Howden, S. M., Kirilenko, A., Morton, J., Soussana, J. F., Schmidhuber, J., & Tubiello, F. N. (2007). Food, fibre and forest products. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Climate Change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 273-313). Cambridge, United Kingdom: Cambridge University Press. https://www.researchgate.net/publication/301634420_Food_fibre_and_forest_products
Ellis, F. (2000). The determinants of rural livelihood diversification in developing countries. *Journal of Agricultural Economics, 51*(2), 289-302. https://doi.org/10.1111/j.1477-9552.2000.tb01229.x
Eriksen, S., Aldunce, P., Bahinipati, C. S., Martins, R. D. A., Molefe, J. I., Nhemachena, C., & Ulsrud, K. (2011). When not every response to climate change is a good one: Identifying principles for sustainable adaptation. *Climate and Development, 3*(1), 7-20. https://doi.org/10.3763/cdev.2010.0060

Estudillo, J. P., & Otsuka, K. (2010). Rural poverty and income dynamics in Southeast Asia. In R. Evenson & P. Pingali (Eds.), *Handbook of Agricultural Economics* (pp. 3434-3468). Elsevier.

Fan, S., & Rue, C. (2020). The role of smallholder farms in a changing world. In S. G. Paloma, L. Riesgo, K. Louhichi (Eds.), *The Role of Smallholder Farms in Food and Nutrition Security* (pp. 13-18). https://doi.org/10.1007/978-3-030-42148-9_2

FAO. (2008). Climate change adaptation and mitigation in the food and agriculture sector. *Climate change, Energy and Food.* High level conference on Food security: The challenges of climate change and Bioenergy, FAO, Rome. http://www.fao.org/3/au034e/au034e.pdf

FAO. (2010). *Climate-smart agriculture: Policies, practices and financing for food security, adaptation and mitigation*. Food and Agriculture Organization, Rome.

FAO. (2013). *Climate smart agriculture sourcebook.* Food and Agriculture Organization, Rome. pp. 545. http://www.fao.org/3/i3325e/i3325e.pdf

FAO. (2016). *Climate is changing. Food and agriculture must too.* Food and Agriculture Organization, Rome. http://www.fao.org/3/i5758e/i5758e.pdf

FAO. (2017). *The future of food and agriculture-Trends and challenges.* Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/3/i6583e/i6583e.pdf

FAO. (2018). *Climate-Smart Agriculture Case Studies 2018. Successful approaches from different regions.* Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/3/CA2386EN/ca2386en.pdf

FAO. (2019). *FAO's work on climate change: United Nations Climate Change Conference 2019*. Food and Agriculture Organization of the United Nations, Rome. pp. 38. http://www.fao.org/3/ca7126en/ca7126en.pdf

FAO. (2021a). *The impact of disasters and crises on agriculture and food security: 2021*. Food and Agriculture Organization of the United Nations, Rome. https://doi.org/10.4060/cb3673en

FAO. (2021b). *Climate-smart agriculture case studies 2021-Projects from around the world.* Food and Agriculture Organization of the United Nations, Rome. pp. 81. https://doi.org/10.4060/cb5359en

Flavel, A., Milan, A., & Melde, S. (2020). Migration, environment and climate change: Literature review. *First report in the "Migration, environment and climate change" series*. German Environment Agency. pp. 84. http://www.umweltbundesamt.de/publikationen

Frank, J., & Buckley, C. P. (2012). Small-scale farmers and climate change. How can farmer organisations and fairtrade build the adaptive capacity of smallholders? *Sustainable Markets Group*. International Institute for Environment and Development, London. https://pubs.iied.org/pdfs/16518IIED.pdf

Gain, A. K., Giupponi, C., & Renaud, F. G. (2012). Climate change adaptation and vulnerability assessment of water resources systems in developing countries: A generalized framework and a feasibility study in Bangladesh. *Water*, *4*, 345-366. https://doi.org/10.3390/w4020345

Ganguly, K., & Panda, G. R. (2010). Adaptation to climate change in India: A study of union budgets. *Oxfam India, working papers series-I*. Centre for Budget and Governance Accountability. https://doi.org/10.13140/RG.2.1.4083.4161

Gedefaw, M., Girma, A., Denghua, Y., Hao, W., & Agitew, G. (2018). Farmer's perceptions and adaptation strategies to climate change, its determinants and impacts in Ethiopia: Evidence from Qwara district. *Journal of Earth Science & Climatic Change, 9*, 481. https://doi.org/10.4172/2157-7617.1000481

Ghosh, M. (2019). Climate-smart agriculture, productivity and food security in India. *Journal of Development Policy and Practice, 4*(2), 166-187. https://doi.org/10.1177/2455133319862404

Gifford, R., Kormos, C., & McIntyre, A. (2011). Behavioral dimensions of climate change: Drivers, responses, barriers, and interventions. *WIREs Climate Change, 2*(6), 801-827. https://doi.org/10.1002/wcc.143

Gomez, N. (2015). Climate change and adaptation on selected crops in Southern Philippines. *International Journal of Climate Change Strategies and Management, 7*(2), 290-305. https://doi.org/10.1108/IJCCSM-03-2013-0014

Hailu, R., & Hassen, A. (2012). Livelihood diversification among the agricultural land scarce peasants in the Central highlands of Ethiopia. *International Journal of Agricultural Science, Research and Technology, 2*(1), 1-8. https://www.researchgate.net/publication/314258148

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., Rajaofara, H., & MacKinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society B-Biological Sciences, 369*(1639), 20130089. http://dx.doi.org/10.1098/rstb.2013.0089

Harvey, C. A., Saborio-Rodriguez, M., Martinez-Rodriguez, M. R., Viguera, B., Chain-Guadarrama, A., Vignola, R., & Alpizar, F. (2018). Climate change impacts and adaptation among smallholder farmers in central America. *Agriculture & Food Security, 7*(57), 20. https://doi.org/10.1186/s40066-018-0209-x

Hassan, R., & Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics, 2*(1), 83-104. https://doi.org/10.22004/ag.econ.56969

Hertel, T. W., & Rosch, S. D. (2010). Climate change, agriculture, and poverty. *Applied Economic Perspectives and policy, 32*(3), 355-385. https://doi.org/10.1093/aepp/ppq016

Hesselberg, J., & Yaro, J. A. (2006). An assessment of the extent and causes of food insecurity in northern Ghana using a livelihood vulnerability framework. *GeoJournal, 67*(1), 41-55. https://doi.org10.1007/s10708-006-9007-2

Hoang, T. X., Pham, C. S., & Ulubas o_glu, M. A. (2014). Non-farm activity, household expenditure, and poverty reduction in rural Vietnam. *World Development, 64*, 554-568. https://doi.org/10.1016/j.worlddev.2014.06.027

Hussain, S. S., & Mudasser, M. (2007). Prospects for wheat production under changing climate in mountain areas of Pakistan-An econometric analysis. *Agricultural System*, *94*(2), 494-501. https://doi.org/10.1016/j.agsy.2006.12.001

Imran, M. A., Ali, A., Ashfaq, M., Hassan, S., Culas, R., & Ma, C. (2018). Impact of Climate Smart Agriculture (CSA) Practices on Cotton Production and Livelihood of Farmers in Punjab, Pakistan. *Sustainability, 10*(6), 2101. https://doi.org/10.3390/su10062101

International Fund for Agricultural Development. (2010). *Rural Poverty Report 2011*. IFAD, Rome. http://www.fao.org/fileadmin/user_upload/rome2007/docs/IFAD%20Rural%20Poverty%20Report%202011.pdf

IPCC. (2001). *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. In J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, & K. S. White (Eds.). Cambridge, UK: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/03/WGII_TAR_full_report-2.pdf

IPCC. (2007). *Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. Linden van der, C. E. Hanson (Eds.). Cambridge, UK: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf

IUCN. (2015). *Gender and climate change. Issues Brief*. International Union for Conservation of Nature. https://www.iucn.org/sites/dev/files/import/downloads/gender_and_climate_change_issues_brief_cop21__04122015.pdf

Jain, M., Naeem, S., Orlove, B., Modi, V., & DeFries, R. S. (2015). Understanding the causes and consequences of differential decision-making in adaptation research: Adapting to a delayed monsoon onset in Gujarat, India. *Global Environmental Change, 31*, 98-109. https://doi.org/10.1016/j.gloenvcha.2014.12.008

Jamshidi, O., Asadi, A., Kalantari, K., Azadi, H., & Scheffran, J. (2018). Vulnerability to climate change of smallholder farmers in the Hamadan province, Iran. *Climate Risk Management, 23*, 146-159. https://doi.org/10.1016/j.crm.2018.06.002

Jarvis, A., Lau, C., Cook, S., Wollenberg, E., Hansen, J., Bonilla, O., & Challinor, A. (2011). An integrated adaptation and mitigation framework for developing agricultural research: Synergies and trade-offs. *Experimental Agriculture, 47*, 185-203. https://doi.org/10.1017/S0014479711000123

Jha, C. K., Gupta, V., Chattopadhyay, U., & Amarayil S. B. (2018). Migration as adaptation strategy to cope with climate change: A study of farmers' migration in rural India. *International Journal of Climate Change Strategies and Management*, *10*(1), 121-141. https://doi.org/10.1108/IJCCSM-03-2017-0059

Kassem, H. S., Bello, A. R. S., Alotaibi, B. M., Aldosri, F. O., & Straquadine, G. S. (2019). Climate change adaptation in the delta Nile region of Egypt: Implications for agricultural extension. *Sustainability*, *11*, 685. https://doi.org/10.3390/su11030685

Kattumuri, R., Darshini, R., & Tashina, E. (2015). Local adaptation strategies in semi-arid regions: study of two villages in Karnataka, India. *Climate and Development, 9*(1), 36-49. https://doi.org/10.1080/17565529.2015.1067179

Keane, J., Page, S., Kergna, A., & Kennan, J. (2009). *Climate change and developing country agriculture: An overview of expected impacts, adaptation and mitigation challenges, and funding requirements*. ICTSD-IPC platform on climate change, agriculture and trade, issue brief No.2. International Centre for Trade and Sustainable Development, Geneva, Switzerland and International Food & Agricultural Trade Policy Council, Washington DC, USA. https://www.files.ethz.ch/isn/110742/j-keane-web_final.pdf

Kibue, G. W., Liu, X., Zheng, J., Zhang, X., Pan, G., Li, L., & Han, X. (2016). Farmers' perceptions of climate variability and factors influencing adaptation: Evidence from Anhui and Jiangsu, China. *Environmental Management, 57*(5), 976-986. https://doi.org/10.1007/s00267-016-0661-y

Khatri-Chhetri, A., Aryal, J. P., Sapkota, T. B., & Khurana, R. (2016). Economic benefits of climate-smart agricultural practices to smallholders' farmers in the Indo-Gangetic Plains of India. *Current Science, 110*(7), 1251-1256. https://www.jstor.org/stable/24908014

Klein, R. J. T., Schipper, L., & Dessai, S. (2003). Integrating mitigation and adaptation into climate and development

policy: Three research questions. *Environmental Science & Policy, 8*(6), 579-588. https://doi.org/10.1016/j.envsci.2005.06.010

Kristjanson, P., Bryan, D., Bernier, Q., Twyman, J., Meinzen-Dick, R., Kieran, C., Ringler, C., Jost, C., & Doss, C. (2017). Addressing gender in agricultural research for development in the face of a changing climate: where are we and where should we be going? *International Journal of Agricultural Sustainability, 15*(5), 482-500. https://doi.org/10.1080/14735903.2017.1336411

Kumar, C. P. (2014) Impact of climate change on agriculture. *International Journal of Engineering Research and Management, 1*(4), 151-156. https://www.academia.edu/7859708/Impact_of_Climate_Change_on_Agriculture

Kumar, K. S. K., & Viswanathan, B. (2019). Mainstreaming climate change adaptation. In N. K. Dubash (Ed.), *India in a Warming World: Integrating Climate Change and Development* (pp. 519-536). England, UK: Oxford University Press. https://doi.org/10.1093/oso/9780199498734.003.0028

Kurgat, B. K., Lamanna, C., Kimaro, A., Namoi, N., Manda, L., & Rosenstock, T. S. (2020). Adoption of climate-smart agriculture technologies in Tanzania. *Frontiers in Sustainable Food System, 4*, 55. https://doi.org/10.3389/fsufs.2020.00055

Lowder, S. K., Sanchez, M. V., & Bertini, R. (2021). Which farms feed the world and has farmland become more concentrated? *World Development, 142*, 105455. https://doi.org/10.1016/j.worlddev.2021.105455

Lipton, M. (2013). *Staples production: Efficient subsistence smallholders are key to poverty reduction, development and trade*. Paper presented at the Global Commodities Forum, UNCTAD, Geneva. https://unctad.org/meetings/en/Presentation/SUC_GCF2013_18-03-2013_Michael-LIPTON_Study.pdf

Mabe, F. N., Gifty, S., & Samuel, D. (2014). Determinants of choice of climate change adaptation strategies in northern Ghana. *Research in Applied Economics, 6*(4), 75-94. https://doi.org/10.5296/rae.v6i4.6121

Maharjan, A., Safra de Campos, R., Singh, C., Das, S., Srinivas, A., Bhuiyans, M. R. A., Ishaq, S., Umar, M. A., Dilshad, T., Shrestha, K., Bhadwal, S., Ghosh, T., Suckall, N., & Vincent, K. (2020). Migration and Household Adaptation in Climate-Sensitive Hotspots in South Asia. *Current Climate Change Reports, 6*, 1-16. https://link.springer.com/article/10.1007/s40641-020-00153-z

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability, 13*, 1318. https://doi.org/10.3390/su13031318

Mar, S., Nomura, H., Takahashi, Y., Ogata, K., & Yabe, M. (2018). Impact of erratic rainfall from climate change on pulse production efficiency in lower Myanmar. *Sustainability, 10*(2), 402. https://doi.org/10.3390/su10020402

Matewos, T. (2019). Climate change-induced impacts on smallholder farmers in selected districts of Sidama, Southern Ethiopia. *Climate, 7*(5), 70. https://www.mdpi.com/2225-1154/7/5/70/htm

Melde, S., Gemenne, F., Blocher, J., Laczko, F., & Vigil, S. (2017). *Making Mobility Work for Adaptation to Environmental Changes-Results from the MECLEP global research*. IOM, Geneva. https://environmentalmigration.iom.int/making-mobility-work-adaptation-environmental-changes-results-meclep-global-research

Menike, L. M., & Arachchi, K. (2016). Adaptation to climate change by smallholder farmers in rural communities: Evidence from Sri Lanka. *Procedia Food Science, 6*, 288-292. https://doi.org/10.1016/j.profoo.2016.02.057

Mishra, P. K. (2017). Socio-economic impacts of climate change in Odisha: Issues, challenges and policy options. *Journal of Climate Change, 3*(1), 93-107. https://doi.org/10.3233/JCC-170009

Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor countries. *Environment and Development Economics, 11*, 159-178. https://doi.org/10.1017/S1355770X05002755

Mehar, M., Mittal, S., & Prasad, N. (2016). Farmers coping strategies for climate shock: Is it differentiated by gender? *Journal of Rural Studies, 44*, 123-131. https://doi.org/10.1016/j.jrurstud.2016.01.001

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences of the United States of America, 104*(50), 19680-19685. https://doi.org/10.1073/pnas.07018 55104

Mubaya, C. P., Njuki, J., Liwenga, E., Mutsvangwa, E. P., & Mugabe, F. T. (2010). Perceived impacts of climate related parameters on smallholder farmers in Zambia and Zimbabwe. *Journal of Sustainable Development in Africa, 12*(5), 170-186. https://www.semanticscholar.org/paper/Perceived-impacts-of-climate-related-parameters-on-Mubaya-Njuki/c6c613a4b2f9a5d68b3a7d3f70f0f06a0cc2c2a9

Mueller, V., Sheriff, G., Dou X., & Gray, C. (2020). Temporary migration and climate variation in eastern Africa. *World Development, 126*, 104704. https://doi.org/10.1016/j.worlddev.2019.104704

Mulinya, C. (2017). Factors affecting small-scale farmers coping strategies to climate change in Kakamega county in Kenya. *IOSR Journal of Humanities and Social Science, 22*(2), 100-109. https://doi.org/10.9790/0837-220202100109

Muralidhar, M., Kumaran, M., Jayanthi, M., Muniyandi, B., Ponniah, A. G., Nagothu, U. S., & Eknath, A. (2012). Case

study on the impacts of climate change on shrimp farming and developing adaptation measures for small-scale shrimp farmers in Krishna district, Andhra Pradesh, India. *Network of Aquaculture Centers in Asia-Pacific, 126*. www.enaca.org/aquaclimate

Ochieng, J., Kirimi, L., & Mathenge, M. (2016). Effects of climate variability and change on agricultural production:The case of small scale farmers in Kenya. *NJAS-Wageningen Journal of Life Sciences, 77*, 71-78 http://dx.doi.org/10.1016/j.njas.2016.03.005

Obokata, R., Veronis, L., & McLeman, R. A. (2014). Empirical research on international environmental migration: A systematic review. *Popul Environ, 36*, 111-135. https://doi.org/10.1007/s11111-014-0210-7

Panda, A., Sharma, U., Ninan, K. N., & Patt, A. (2013). Adaptive capacity contributing to improved agricultural productivity at the household level: Empirical findings highlighting the importance of crop insurance. *Global Environmental Change, 23*(4), 782-790. https://doi.org/10.1016/j.gloenvcha.2013.03.002

Partey, S. T., Zougmore, R. B., Ouedraogo, M., & Campbell, B. M. (2018). Developing climate-smart agriculture to face climate variability in West Africa: Challenges and lessons learnt. *Journal of Cleaner Production, 187*, 285-295. https://doi.org/10.1016/j.jclepro.2018.03.199

Patnaik, U., & Das, P. K. (2017). Do development interventions confer adaptive capacity? Insights from rural India. *World Development, 97*, 298-312. https://doi.org/10.1016/j.worlddev.2017.04.017

Patnaik, U., & Narayanan, K. (2015). How effective are coping mechanisms in securing livelihoods against climatic aberrations?: Evidences from rural India. *International Journal of Climate Change Strategies and Management, 7*(3), 359-374. https://doi.org/10.1108/IJCCSM-07-2014-0085

Pettengell, C. (2010). *Climate change adaptation: Enabling people living in poverty to adapt Oxfam International*. Oxford, UK. http://www.oxfam.org.uk/resources/policy/climate_change/downloads/rr_climate_change_adaptation_full_290410.pdf

Piguet, E. (2013). From primitive migration to climate refugees: The curious fate of the natural environment in migration studies. *Annals of the Association of American Geographers, 103*(1), 148-162. https://doi.org/10.1080/00045608.2012.696233

Population Reference Bureau. (2020). *2020 world population data sheet.* https://www.prb.org/worldpopdata

Porter, J. R., Xie, L., Challinor, A. J. , Cochrane, K., Howden, S. M., Iqbal, M. M., Lobell, D. B., & Travasso, M. I. (2014). Food security and food productionsystems. *Climate change 2014: impacts, adaptation, and vulnerability, part A: Global and sectoral aspects*, *contribution of working group ii to the fifth assessment report of the intergovernmental panel on climate change.* Cambridge, NewYork: Cambridge University Press. http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5Chap7_FINAL.pdf

Raynolds, L. (2009). Mainstreaming Fair trade coffee: From partnership to traceability. *World Development, 37*(6), 1083-1093. https://doi.org/10.1016/j.worlddev.2008.10.001

Raynolds, L. (2012). Fair trade: Social regulation in global food markets. *Journal of Rural Studies, 28*, 276-287. https://doi.org/10.1016/j.jrurstud.2012.03.004

Sapkota, T. B., Jat, M. L., Aryal, J. P., Jat, R. K., & Khatri-Chhetri, A. (2015). Climate change adaptation, greenhouse gas mitigation and economic profitability of conservation agriculture: Some examples from cereal systems of Indo-Gangetic Plains. *Journal of Integrative Agriculture, 14*(8), 1524-1533.

Seng, K. (2015). The effects of nonfarm activities on farm households' food consumption in rural Cambodia. *Development Studies Research, 2*(1), 77-89. https://doi.org/10.1080/ 21665095.2015.1098554

Serat, O. (2017). The sustainable livelihoods approach. *Knowledge Solutions*. Singapore: Springer. pp. 21-26. https://doi.org/10.1007/978-981-10-0983-9_5

Seo, N., & Mendelsohn, R. (2006). Climate change impacts on animal husbandry in Africa: A Ricardian analysis. *Policy Research Working Papers.* World Bank. http://hdl.handle.net/10986/7423.

Sherbinin, A. (2020). *Climate impacts as drivers of migration*. Migration Policy Institute. https://www.migrationpolicy.org/article/climate-impacts-drivers-migration

Simon, M., & Shallone, K. C. (2013). Estimating the role of agricultural technologies in improving rural household welfare: A case of Masvingo. *Russian Journal of Agricultural and Socio-Economic Sciences, 14*(2), 67-73. https://agris.fao.org/agris-search/search.do?recordID=RU2013207974

Singh, C., Rahman, A., Srinivas, A., & Bazaz, A. (2018). Risks and responses in rural India: Implications for local climate change adaptation action. *Climate Risk Management, 21*, 52-68. https://doi.org/10.1016/j.crm.2018.06.001

Singh, N. P., Anand, B., Singh, S., & Khan, A. (2019). Mainstreaming climate adaptation in Indian rural developmental agenda: A micro-macro convergence. *Climate Risk Management, 24*, 30-41. https://doi.org/10.1016/j.crm.2019.04.003

Smit, B., & Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and

equity. *Climate Change, Adaptive Capacity and Development, 8*, 879-906. https://www.researchgate.net/publication/281322507_Adaptation_to_Climate_Change_in_the_Context_of_Sustainable_Development_and_Equity/citation/download

Somda, J., Zougmoré, R., Sawadogo, I., Bationo, B. A., Buah, S., & Abasse, T. (2017). Adaptation processes in agriculture and food security: Insights from evaluating behavioral changes in West Africa. In J. Uitto, J. Puri, R. van den Berg (Eds.), *Evaluating Climate Change Action for Sustainable Development* (pp. 255-269). New York: Springer Publishing. https://doi.org/10.1007/978-3-319-43702-6_14

Stark, O., & Levhari, D. (1982). On migration and risk in less developed countries. *Economic Development and Cultural Change, 31*(1), 191-196. https://doi.org/10.1086/451312

Takahashi, B., Burnham, M., Terracina-Hartman, C., Sopchak, A. R., & Selfa, T. (2016). Climate change perceptions of ny state farmers: the role of risk perceptions and adaptive capacity. *Environmental Management, 58*, 946-957. https://doi.org/10.1007/s00267-016-0742-y

Temesgen, T. D., Ringler, C., & Hassan, M. R. (2010). *Factors affecting the choices of coping strategies for climate extremes: The case of farmers in the Nile basin of Ethiopia. IFPRI discussion papers 1032. International Food Policy Research Institute, 01032*. http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/5198/filename/5199.pdf

Thornton, P. K., Boone, R. B., Galvin, K. A., BurnSilver, S. B., Waithaka, M. M., Kuyiah, J., Karanja, S., González-Estrada, E., & Herrero, M. (2007). Coping strategies in livestock-dependent households in East and Southern Africa: A synthesis of four case studies. *Human Ecology, 35*(4), 461-476. https://doi.org/10.1007/s10745-007-9118-5

Tripathi, A. (2016). *How to Encourage Farmers to Adapt to Climate Change?* Working Papers id:10934, eSocialSciences. Institute of Economic Growth. https://ideas.repec.org/p/ess/wpaper/id10934.html

Tripathi, A. (2017). Socioeconomic backwardness and vulnerability to climate change: Evidence from Uttar Pradesh state in India. *Journal of Environmental Planning and Management, 60*(2), 328-350. http://dx.doi.org/10.1080/09640568.2016.1157059

Tripathi, A., & Mishra, A. K. (2017). Knowledge and passive adaptation to climate change: An example from Indian farmers. *Climate Risk Management*, *16*, 195-207. https://doi.org/10.1016/j.crm.2016.11.002

Ubisi, N. R., Mafongoya, P. L., Kolanisi, U., & Jiri, O. (2017). Smallholder farmer's perceived effects of climate change on crop production and household livelihoods in rural Limpopo province, South Africa. *Change and Adaptation in Socio-Ecological Systems, 3*, 27-38. https://doi.org/10.1515/cass-2017-0003

UNCTAD. (2021). *Trade and environment review 2021: Trade climate readiness for developing countries.* United Nations, Geneva. https://unctad.org/system/files/official-document/ditcted2020d3_en.pdf

United Nations Development Programme. (2007). *Fighting climate change: Human solidarity in a divided world.* Human Development Report, New York, PalgraveMacmillan. http://hdr.undp.org/sites/default/files/reports/268/hdr_20072008_en_complete.df

United Nations Environment Programme. (2013). *Smallholders, food security and the environment. Rome: IFAD.* UNEP. https://www.ifad.org/documents/38714170/39135645/smallholders_report.pdf/133e8903-0204-4e7d-a780-bca847933f2e

United Nations Environment Programme, UN Women, UNDP, & UNDPPA/PBSO. (2020). *Gender, climate change and security: Sustaining inclusive peace on the frontlines of climate change.* https://wedocs.unep.org/bitstream/handle/20.500.11822/32638/GCS.pdf?sequence=1&isAllowed=y

United Nations Framework Convention on Climate Change. (2019). *UN climate change annual Report 2018.* UNFCCC Secretariat, Bonn, Germany. https://unfccc.int/sites/default/files/resource/UN-Climate-Change-Annual-Report-2018.pdf

United Nations Framework Convention on Climate Change. (2020). *UN climate change annual Report 2019.* UNFCCC Secretariat, Bonn, Germany. https://unfccc.int/sites/default/files/resource/unfccc_annual_report_2019.pdf

UN WomenWatch. (2009). *Women, gender equality and climate change. Fact Sheet.* The UN Internet Gateway on Gender Equality and Empowerment of Women. http://www.un.org/womenwatch/feature/climate_change/

Vermeulen, S. J., Aggarwal, P. K., Ainslie, A., Angelone, C., Campbell, B. M., Challinor, A. J., Hansen, J. W., Ingram, J. S. I., Jarvis, A., Kristjanson, P., Lau, C., Nelson, G. C., Thornton, P. K., & Wollenberg, E. (2012). Options for support to agriculture and food security under climate change. *Environmental Science and Policy, 15*(1), 136-144. https://doi.org/10.1016/j.envsci.2011.09.003

Viswanathan, B., & Kumar, K. K. (2015). Weather, agriculture and rural migration: Evidence from state and district level migration in India. *Environment and Development Economics, 20*(4), 469-492. https://doi.org/10.1017/S1355770X1500008X

Vorley, B., Del Pozo-Vergnes, E., & Barnett, A. (2012). *Small producer agency in the globalized market: Making choices in a changing world*. IIED, HIVOS, The Hague, London. http://www.hivos.net/hivos-Knowledge-Programme/Publications

Winters, P., Davis, B., Carletto, G., Covarrubias, K., Quinones, E. J., Zezza, A., Azzarri, C., & Stamolis, K. (2009). Assets, activities, and rural income generation: Evidence from a multicountry analysis. *World Development, 37*(9), 1435-1452. https://econpapers.repec.org/article/eeewdevel/v_3a37_3ay_3a2009_3ai_3a9_3ap_3a1435-1452.htm

World Meterological Organization. (2021, January 15). *2020 was one of three warmest years on record.* WMO Press release no. 14012021. https://public.wmo.int/en/media/press-release/2020-was-one-of-three-warmest-years-record

Yamba, S., Appiah, D. O., Siaw, L. P., & Casadevall, S. R. (2019). Smallholder farmers' perceptions and adaptive response to climate variability and climate change in southern rural Ghana. *Cogent Social Sciences, 5*(1), 1646626. https://doi.org/10.1080/23311886.2019.1646626

Yaro, J. A. (2013). *Building resilience and reducing vulnerability to climate change: Implications for food security in Ghana*. Friedrich Ebert Stiftung. https://library.fes.de/pdf-files/bueros/ghana/10517.pdf

Zurovec, O., & Vedeld, P. O. (2019). Rural livelihoods and climate change adaptation in laggard transitional economies: A case from Bosnia and Herzegovina. *Sustainability, 11*, 6079. https://doi.org/10.3390/su11216079

Zwane, E. M. (2019). Capacity development for scaling up climate-smart agriculture innovations. In S. Hussain (Ed.), *Climate change and agriculture*. IntechOpen. https://doi.org/10.5772/intechopen.844405