Ex-ante adaptation strategies for climate challenges in sub-Saharan Africa: Macro and micro perspectives

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A B S T R A C T
Farmers in sub-Saharan Africa are facing serious consequences from climate change, which pose obstacles to meeting UN Sustainable Development Goals (SDGs) such as zero hunger, ending poverty, ensuring healthy lives, and promoting wellbeing. In light of these growing challenges, we used data collected in 2018 from farm households in Ethiopia, Kenya, Tanzania, Malawi, and Mozambique to investigate the climate threats encountered by farmers and the ex-ante climate risk adaptation strategies they adopted. Drought, floods, hailstorms, and crop pests and diseases were the most common climate threats in these countries. Unlike previous studies, we also assessed the adaptive capacity at the macro level by using secondary data. We reviewed the factors that affect the adaptive capacity of each nation to address climate risks. At the micro-level, we assessed the factors influencing the choice of ex-ante adaptation measures by using primary data collected from 4351 farm households. Micro-level data also include the variables that indicate the adaptive capacity of farm households, such as asset ownership, demographic characteristics, and participation in local institutions. Results showed five major ex-ante climate risk adaptation strategies — change in farming practice, sustainable land management, seek alternative livelihood, saving, and other unspecified strategies — are prevalent in the region. We used a multivariate probit model to investigate the factors explaining the choice of ex-ante climate risk adaptation strategy. Results showed that female-headed households and households with married heads were more likely than male-headed households to change farming practices to adapt to climate risk. Surprisingly, land ownership was found to be insignificant in all cases. Relatively rich families tended to apply either change in farming practice or saving as a measure to adapt to climate risks. Training on climate-smart agriculture was found to enhance the adoption of sustainable land management as adaptation strategies by farm households. Our findings exhibit substantial differences within and among countries regarding the adoption of ex-ante climate adaptation strategies by farm households. In comparison to farmers in Mozambique’s northern region, farmers in all other locations were more likely to apply agricultural measures such as change in farming practice and sustainable land management, while they were more likely to apply non-agricultural measures to adapt to risk. Macro-level indicators show that national adaptive capacity is substantially low in all countries, but considerably varies across them.

1. Introduction

Climate change adaptation has become increasingly important to minimize vulnerability to growing climate risks (Aryal et al., 2020a; Conway and Schipper, 2011; Troni et al., 2018). Though climate change adaptation has the potential to reduce many of the harmful impacts of climate change and utilize any possible benefits, the measures often require additional costs to implement. Therefore, the existing capacity of an individual household, society, or nation to adapt to climate change is crucial (Berrang-Ford et al., 2014; Burton et al., 2001). Considerable variations in adaptation capacity are observed among regions, countries, and socioeconomic groups based on their socioeconomic status, institutional capacity, and governance structures (Bird et al., 2016; Burton et al., 2001; Chepkoech et al., 2020; Troni et al., 2018). A recent study in Kenya (Nthambi et al., 2021), for example, shows that poor governance is a major hurdle to the successful implementation of climate change adaptation programs. On this backdrop, this study examines the factors affecting how individual farm households choose...
ex-ante climate adaptation strategies in five countries in Sub-Saharan Africa (SSA), using primary data collected from household surveys. In addition, it assesses the adaptation capacity of the study countries using secondary data from multiple sources, including national statistical institutions and international institutions such as the World Bank, Food and Agriculture Organization (FAO), and United Nations Development Organization (UNDP).

Global warming has changed the precipitation pattern worldwide, leading to increased rainfall and temperature variability. As a result, droughts (Haile et al., 2020a; Haile et al., 2020b; Kassaye et al., 2020), floods, and heat stress have become more frequent, more intense, and longer in duration (Makondo and Thomas, 2020; Treberth, 2006). In addition, climate change has also increased the occurrence of crop pests and diseases (Salih et al., 2020). These amplified climate risks have heightened the vulnerability of people in developing countries, particularly those who rely on climate-sensitive sectors for their livelihoods (Aryal et al., 2020a; Kalimba and Culas, 2020; Kogo et al., 2021). In this context, an in-depth study of the climate risks faced by farmers in SSA and the adaptation strategies they adopt can inform designing or reforming climate adaptation policies in the region.

SSA is the world region most vulnerable to global climate change due to its reliance on rain-fed agriculture (Kotir, 2011; Mwamakamba et al., 2017). Only 4% of the total arable land in SSA is irrigated, which is low compared to about 20% globally and almost 38% in Asia (FAO, 2009; Kotir, 2011; Mwamakamba et al., 2017). Consequently, agriculture in SSA is highly vulnerable to rainfall variability and particularly to drought (Haile et al., 2020a; Hanjra and Williams, 2020). Several studies have documented the negative impacts of climate change on major cereal crops in SSA (Adhikari et al., 2015; Stuch et al., 2020). For instance, maize, a major staple crop in Africa, is highly vulnerable to droughts (Katengeza et al., 2019; Smale, 1995), and a severe drought in the grain filling period can reduce maize productivity by almost 50% (CIMMYT, 2013). In a recent study in Africa, Stuch et al. (2020) estimated a decline in mean maize yield for over 85% of harvested maize areas in West Africa, 29% in Southern Africa, and 32% in East Africa due to climate change. These studies show that farmers in SSA, who lack the resources and knowledge to adapt to climate change, face high risks (Muchuru and Nhamo, 1998; Zamasiya et al., 2017).

Severe climate events have already destroyed lives and livelihoods. Africa suffered from the worst famine caused by drought in the mid-1980s, which affected almost 20 countries and approximately 35 million people (Katengeza et al., 2019; Shiferaw et al., 2014). Ethiopia, Kenya, Malawi, Mozambique, and Zimbabwe were among the most affected countries (Shiferaw et al., 2014). The impacts were twofold: droughts reduced food production and also resulted in the reduced availability of drinking water (Sani and Chalchisa, 2016). The droughts thus increased both food and water insecurities and reduced the options available to adapt to climate risks (Davis-Reedy and Vincent, 2017). As a result, climate change is projected to have severe economic and social consequences in the African countries (Baarsch et al., 2020). Baarsch et al. (2020) showed that the mean climate-induced losses in Africa range between 10% and 15% of the GDP per capita growth, showing that most African economies are poorly adapted to climate change. Without proper adaptation planning and the necessary investments in social safety nets, climate risks can adversely affect efforts to achieve the UN Sustainable Development Goals (SDGs) in SSA (Alemaw, 2020; Baarsch et al., 2020; Cacho et al., 2020).

Extreme poverty and limited access to capital helps explain the low adaptive capacity of African farmers. Even with numerous efforts from both national and international societies, the number of people in Africa living in poverty increased from 278 million in 1990 to 413 million in 2015 (Beegle and Christiaensen, 2019). Further, since the majority of poor people earn their livelihoods from the agricultural sector, their conditions are more likely to worsen with increasing climatic variability. Low adaptive capacities arising from extreme poverty coincides with other factors-limited access to capital and formal credit markets for risk sharing, lack of proper infrastructure and technology, and increased exposure to climate risks—which escalates the vulnerability of poor African farmers (Field et al., 2014; Molua, 2020).

The agriculture sector, the lifeline of smallholder and marginal farmers in SSA, will be heavily impacted by extreme and prolonged heat stress and droughts, changing rainfall patterns, hailstorms, and floods (IPCC, 2007; Müller et al., 2011; Serdeczny et al., 2017). Crop pests and diseases and livestock diseases may also increase with climate change, deteriorating revenue sources for subsistence farmers. The production of important cereals, mainly rice, maize, and wheat, is projected to decline by approximately 10–15% due to crop pests and diseases (Deutsch et al., 2018). Crop production in temperate regions is expected to suffer even more from rising temperatures (Deutsch et al., 2018). Since the mean temperature in Africa is projected to rise by 3 to 4 degrees Celsius by the end of the 21st Century (1.5 times higher than the global mean temperature) (Bryan et al., 2013), losses due to pests and diseases may be higher in Africa than other regions.

On the whole, the exposure to climate risks has been increasing in SSA, while the capacity to adapt to them is low. Every country studied here faces serious malnutrition and hunger risks, measured in terms of the Global Hunger Index (Von Grebmer et al., 2019). Among the countries evaluated, 23.5% (Ethiopia) to 50.7% (Malawi) of the total population live in poverty. Existing food insecurity, hunger, malnutrition, and poverty will be exacerbated as climate risks increase, eventually disrupting economic development (Cacho et al., 2020; IPCC, 2014a). Adjusting agriculture to cope with climate risk is therefore imperative to accomplishing the SDGs in Africa (Baarsch et al., 2020; Cacho et al., 2020; Kalimba and Culas, 2020).

Several factors influence a household’s choice of adaptation strategies, including household socioeconomic conditions, demographic structure, and access to the institution such as market, and public utilities (Abid et al., 2020; Aryal et al., 2020a; Mulwa et al., 2017). Wealth, education, participation in non-farm employment, and the gender of the household head also drive household adoption of climate adaptation strategies (Aryal et al., 2020b; Magi-Ngenga et al., 2016; Mulwa et al., 2017; Ngigi et al., 2017; Partey et al., 2020; Rao et al., 2019). Access to extension services, agricultural training, social networks including farmer-to-farmer communication, and membership in farm associations and cooperatives positively influence the adoption of climate risk adaptation strategies (Amare and Simane, 2017; Aryal et al., 2018; Aryal et al., 2020b; Bryan et al., 2009; Bryan et al., 2013; Deressa et al., 2009; Nelson et al., 2009; Pande and Ackerman, 2009).

Recognizing the adverse consequences of climate change, many African countries have implemented national adaptation plans. However, they are not properly integrated with local-level adaptation plans and are far from considering spatial differences in climate risks and vulnerability, and do not address broader issues related to the cost of adaptations and their impacts on development at multiple levels of society (Adenle et al., 2017; IPCC, 2014b; Schaeffer et al., 2015). A deeper understanding of climate risks, adaptation strategies available to farmers, and factors influencing the choice of such strategies at the micro-level, and also the national capacity at the macro level to support adaptation is crucial to design and improve national policies and plans, and to adequately integrate local adaptation considerations into broader development planning (Adenle et al., 2017; Smucker et al., 2015). Thus, this study critically examines the climate risks experienced by subsistence farmers in SSA, their adaptation strategies, and the factors driving the choice of these strategies, using primary datasets from farm households in SSA. This study makes four important contributions to the existing literature in climate change adaptation: (i) to provide a comprehensive assessment of the climate risks faced by farmers in SSA and their adaptation strategies; (ii) to apply large datasets from SSA to comparatively assess factors driving the selection of adaptation measures; (iii) to provide a critical review of macro-level indicators that explain national capacity to support climate change adaptation; and (iv) to provide crucial
insights into how the choice of adaptation strategies differ among farm households across SSA, with policy implications and relevance at the regional level.

2. Data and methodology

2.1. Primary data collection and sampling

We used data collected in the second half of 2018 from 4351 farm households in five countries: Ethiopia (873); Kenya (851); Tanzania (1020); Malawi (730); and Mozambique (877). Fig. 1 depicts the distribution of sample households across SSA. Sample household selection involved several stages. In the first stage, five SSA countries were selected. In the second stage, two maize-growing regions in each country were selected. Out of 873 farm households in Ethiopia, 422 were from the Oromia region and 451 from the Southern Nations, Nationalities, and Peoples’ Region (SNNP) region; in Kenya, 476 were selected from the western region and 375 from the eastern region; in Tanzania, 541 were selected from the northern region and 479 from the eastern region; in Malawi, 208 households were from a low-altitude region and 522 were from a high-altitude region; in Mozambique, 614 were from the central region and 263 were from the northern region. In the third stage, several villages were selected. Finally, individual households were selected for the interview.

2.2. Secondary data

We gathered secondary data required for this study from multiple sources, including national and international organizations. These data are mainly used to compare key indicators that represent the capacity of an individual country to adapt to climate change. Moreover, these macro indicators largely explain why the farm households in SSA are more vulnerable to climate risks even though their exposure to such risks is similar to some of the developed countries.
2.3. Methodology

We divided the ex-ante risk adaptation strategies into five categories: (1) change in farming practices, (2) sustainable land management, (3) seeking an alternative livelihood, (4) saving, and (5) other unspecified strategies. We employed a multivariate probit model (detailed on the specification of the model is provided in Appendix 1) to assess the factors driving the household’s selection of ex-ante climate risk adaptation strategies. When the dependent variable is categorical, multiple, and mutually inclusive, the multivariate probit model is preferred because the different categories are interdependent. To test for the robustness of our results, we also estimated the multinomial logit model by classifying the climate adaptation measures into four major categories as follows: (1) did not adopt any ex-ante risk adaptation strategies, (2) used only agricultural strategy, (3) used only non-agricultural strategy, and (4) used both agricultural and non-agricultural strategy (for details on model specifications and empirical results, see Appendix 2). However, we only present and discuss the results from the multivariate probit model in the next section.

3. Results and discussion

3.1. Climate risk profile analysis

Africa is one of the regions most susceptible to the consequences of climate change (Adenle et al., 2017; Carabine et al., 2014; Davis-Reddy and Vincent, 2017; IPCC, 2007; Zougmore et al., 2018). The occurrence and gravity of droughts and rainfall variability in Africa are predicted to rise by the mid to late 21st Century (IPCC, 2007). Given the high level of exposure to climate risks and the low levels of adaptive capacity (given the high rates of poverty, low asset endowments, underdeveloped insurance markets, and limited public and private investment in climate adaptation), subsistence farm households that are reliant on rain-fed farming for sustenance are increasingly vulnerable to climate change (Englund et al., 2018; Katengeza et al., 2019). Additionally, due to the combined effects of climate change and population growth, SSA will face increasing water scarcity by 2025 (UNECA, 1999). Numerous country-level variations exist across these countries.

Drought is the most common climate risk in SSA. Between 1990 and 2010, 12 extreme droughts in Ethiopia killed more than 4 million people and affected more than 54 million others (You and Ringler, 2010). The drought of 2015–16 led to massive harvest failures and widespread livestock deaths in several regions of the country. In Kenya, where drought is a more severe climate risk than floods, 11 major droughts occurred between 1964 and 2004, which affected more than 1.5 million people (Earth Institute, n.d.; Parry et al., 2012). The country was hit by the droughts of 1991–92, 1992–93, 1995–96, 1998–2000, 2004–05, and 2008–09 (Ochieng et al., 2016; Orindi and Ochieng, 2005). Droughts usually affect all of Kenya, while floods are more localized and more common in parts of Nyanza province, western provinces, and coastal areas. Over the last 100 years, Malawi experienced 20 droughts. Eighty happened within the last four decades, affecting more than 24 million people (Government of Malawi, n.d.). With increases in climate change, the frequency and spread of droughts have increased in recent years (Government of Malawi, n.d.). The most recent droughts in Malawi occurred in 2001–02, 2005–05, and 2011–12 (Mswoya et al., 2016). The impacts of the 2016 drought in Malawi were so adverse that the government declared a “state of national disaster,” as almost 39% of the total population in Malawi became food insecure (Government of Malawi, n.d.). In Mozambique, drought is a persistent phenomenon and causes famine in the country (Aragón et al., 1998). For example, the drought of 1982–84 killed nearly 1 million people and affected almost 4 million (Aragón et al., 1998). All of southern Africa experienced severe drought in 1991–92, which affected nearly 1.4 million people in Mozambique. Tanzania experienced devastating droughts in 2003, 2005, 2011, 2014, and 2016 (Changrsquo and Ngana, 2010; Kijazi and Reason, 2009a, b).

Flooding is another major climate risk in SSA. Since 1900, Ethiopia has experienced 47 major floods, which affected almost 2.2 million people and took more than 2000 lives (You and Ringler, 2010). Six major floods have occurred in Kenya since 1950 (Ministry of Environment and Natural Resources (MENR), 2002). The frequency of both droughts and floods have increased in Kenya since 1990 (Ochieng et al., 2016). The major floods of 1997–98 in Kenya, which occurred due to the El Niño/thermal, affected almost 1 million people and caused an economic loss of approximately US$1.2 billion (Downing et al., 2009; Orindi and Ochieng, 2005). In Malawi, a 2015 flood affected about 2.8 million people, and damages amounted to approximately US$335 million (Government of Malawi, 2015). Mozambique is more exposed than other countries to floods and tropical cyclones (Baez et al., 2020), and floods are common in the northern region (Irish Aid, 2018). With a coastline of about 2700 km and nearly 60% of residents in coastal areas, rising sea levels and cyclones are also significant threats to the population. In 2019, two strong tropical cyclones—Idai in March 2019 and Kenneth in April 2019—hit the country. They resulted in severe food shortages and insecurity and affected 2 million people (Gulland, 2019). In Tanzania, the incidence of floods has been increasing in recent decades (Chang’a et al., 2017; Kijazi and Reason, 2009a). The most recent floods occurred in 2006, 2009, 2010, 2011, 2012, 2014, 2016, and 2017, causing significant economic losses (Kijazi and Reason, 2009b).

3.2. Macro statistics representing national capacity to adapt to climate change

Adaptive capacity, in our case, refers to the capacity of a system to adapt to reduce vulnerability to climate change. The adaptive capacity of a country is influenced by several factors, including environmental, social, cultural, political, and economic forces (Gitz and Meybeck, 2012; Smit and Wandel, 2006). Climate change often has uneven impacts on populations, as they are disproportionately exposed to and affected by climate risks. These differences in vulnerability result from a range of social, economic, historical, and political factors and their interactions (Smit and Wandel, 2006; Thomas et al., 2019). Considering this, we looked at different factors such as exposure to climate risks (measured in terms of global climate risk index) and adaptive capacity, which is shown by several factors as outlined in Table 1.

Macroeconomic indicators show that Malawi, Mozambique, and Tanzania have a lower capacity for climate adaptation than other countries under study due to their lower per-capita income and higher percentage of the population in poverty. In addition, Mozambique has the highest share of the people living in coastal areas than other countries under study and thus is more likely to experience climate extremes such as cyclones. As shown by the data in Table 1, poor governance is also one of the major hurdles in the successful implementation of climate change adaptation programs in SSA (Nhiambhi et al., 2021; Vinkle et al., 2017). The countries under study have below-average scores on the corruption perception index, which indicates poor governance as well as the weak institutional capacity to support vulnerable people. Rising share of external debt to the gross national income (GNI) indicates the growing dependence of the country on external debt to finance any public support programs required for climate change adaptation. Among the countries studied, the share of external debt in GNI is highest in Mozambique (68%) followed by Ethiopia (26.1%), Kenya (25.15), Tanzania (19.5%), and Malawi (18.6%). It means all these countries are financially weak to invest in climate change adaptation programs without support from international donors (Khan et al., 2020; Robinson and Dornan, 2017). Poverty, hunger (food insecurity), a higher dependence on agriculture for livelihoods, increasing external debt, and poor governance can combine to exacerbate low capacity to adapt to climate change (Ayers and Huq, 2009; Vink and Schouten, 2018).
Table 1

Climate risks and macro indicators of adaptive capacity.

<table>
<thead>
<tr>
<th>Climate risks index</th>
<th>Ethiopia</th>
<th>Kenya</th>
<th>Malawi</th>
<th>Mozambique</th>
<th>Tanzania</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global climate risks index</strong> for the period 1999–2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRI score (in 2020)</td>
<td>64.7</td>
<td>53.7</td>
<td>77.8</td>
<td>37.5</td>
<td>114.3</td>
</tr>
<tr>
<td>CRI rank (in 2020)</td>
<td>56.0</td>
<td>37.0</td>
<td>80.0</td>
<td>14.0</td>
<td>130.0</td>
</tr>
<tr>
<td><strong>Macro indicators that influence adaptive capacity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population (in millions)(^b)</td>
<td>114.0</td>
<td>53.8</td>
<td>19.2</td>
<td>31.3</td>
<td>59.7</td>
</tr>
<tr>
<td>Population density (people per square km)(^b)</td>
<td>115.0</td>
<td>94.0</td>
<td>203.0</td>
<td>40.0</td>
<td>67.0</td>
</tr>
<tr>
<td>People residing in coastal area (%)(^b)</td>
<td>0.0</td>
<td>8.1</td>
<td>0.0</td>
<td>43</td>
<td>25.0</td>
</tr>
<tr>
<td>Employment in agriculture (% of total employment)(^d)</td>
<td>66.1</td>
<td>54.4</td>
<td>43.6</td>
<td>70.3</td>
<td>65.3</td>
</tr>
<tr>
<td>Employment in agriculture, female (% of female employment) (ILO estimate)</td>
<td>58.06(^e)</td>
<td>60.53(^e)</td>
<td>43.35(^d)</td>
<td>80.17(^e)</td>
<td>67.43(^e)</td>
</tr>
<tr>
<td>Employment in agriculture, male (% of male employment) (ILO estimate)</td>
<td>73.06(^e)</td>
<td>48.60(^e)</td>
<td>43.93(^d)</td>
<td>59.67(^e)</td>
<td>63.35(^e)</td>
</tr>
<tr>
<td>Arable land (hectares per person)</td>
<td>0.15(^f)</td>
<td>0.12(^f)</td>
<td>0.22(^f)</td>
<td>0.20(^f)</td>
<td>0.26(^f)</td>
</tr>
<tr>
<td>Rural population (% of total population)</td>
<td>78.78(^g)</td>
<td>72.49(^g)</td>
<td>82.83(^g)</td>
<td>63.47(^g)</td>
<td>65.50(^g)</td>
</tr>
<tr>
<td>Female headed households (%)</td>
<td>25.40(^h)</td>
<td>36.10(^h)</td>
<td>25.60(^h)</td>
<td>33.47(^h)</td>
<td>25.43(^h)</td>
</tr>
<tr>
<td>Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population)(^i)</td>
<td>30.8</td>
<td>36.8</td>
<td>70.3</td>
<td>62.9</td>
<td>49.1</td>
</tr>
<tr>
<td>Overall economic development (GDP per capita)(^j)</td>
<td>858</td>
<td>1817</td>
<td>412</td>
<td>492</td>
<td>1122</td>
</tr>
<tr>
<td>Corruption perceptions index (score) in 2019(^k)</td>
<td>37.0</td>
<td>28.0</td>
<td>31.0</td>
<td>26.0</td>
<td>37.0</td>
</tr>
<tr>
<td>Global hunger index in the year 2020 score(^l)</td>
<td>28.9</td>
<td>25.2</td>
<td>23.0</td>
<td>28.8</td>
<td>28.6</td>
</tr>
<tr>
<td>Gini index (World Bank estimate)</td>
<td>35.0(^m)</td>
<td>40.8(^m)</td>
<td>44.7(^m)</td>
<td>54.0(^m)</td>
<td>40.5(^m)</td>
</tr>
<tr>
<td>External debt (% of GNI)</td>
<td>26.1(^d)</td>
<td>25.1(^d)</td>
<td>18.6(^d)</td>
<td>68.0(^d)</td>
<td>19.5(^d)</td>
</tr>
</tbody>
</table>

Notes:

\(^a\) CRI indicates a level of exposure and vulnerability to extreme events, which the index focuses on extreme weather events but does not take into account important slow-onset processes such as rising sea levels, glacier melting or more acidic and warmer seas. It is based on past data and should not be used as a basis for a linear projection of future climate impacts.

\(^b\) For more details on CRI, we refer to (Eckstein et al., 2020).

\(^c\) Taken from https://www.worldometers.info/world-population/population-by-country/ (accessed on September 21, 2020).

\(^d\) Multiple sources such as Centre for Coastal Zone Management and Coastal Shelter Belt (http://lomenvis.nic.in/index2.aspx?id=119&langid=1&mid=1).


\(^g\) GDP per capita – current US$ for 2019 from World Bank Development Indicators

\(^h\) CPI measures the perceived levels of public sector corruption in 180 countries/territories around the world. The score ranges from 0 (i.e., highly corrupt) to 100 (i.e., very clean) (for details, see: https://www.transparency.org/en/cpi/2019).

\(^i\) The global hunger index (GHI) score incorporates four major indicators: undernourishment, child wasting, child stunting, and child mortality. A low GHI score (i.e., closer to zero) refers to a better situation. The GHI score is categorized in four major groups as follows: Low (less than or equal to 9.9), moderate (10.0 to 19.9), serious (20.0 to 34.9), alarming (35.0 to 49.9), and extremely alarming (more than 50.0) (for details see: www.globalhungerindex.org)\(^k\)2015\(^b\), 2016\(^b\), 2017\(^b\), 2018\(^b\), 2019\(^b\).

Table 2

Descriptive statistics.

<table>
<thead>
<tr>
<th>Ex-ante climate risk management Strategies</th>
<th>Overall</th>
<th>Change farming practice</th>
<th>Sustainable land management</th>
<th>Seek alternative livelihood</th>
<th>Saving</th>
<th>Others unspecified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of household head</td>
<td>47.81 (13.13)</td>
<td>47.71 (12.97)</td>
<td>47.58 (12.85)</td>
<td>46.75 (12.58)</td>
<td>48.91 (12.73)</td>
<td>48.17 (13.36)</td>
</tr>
<tr>
<td>Female head</td>
<td>0.17 (0.38)</td>
<td>0.17 (0.38)</td>
<td>0.18 (0.38)</td>
<td>0.16 (0.37)</td>
<td>0.17 (0.38)</td>
<td>0.18 (0.38)</td>
</tr>
<tr>
<td>Married</td>
<td>0.84</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.81</td>
<td>0.83</td>
</tr>
<tr>
<td>Years of schooling</td>
<td>8.30 (3.74)</td>
<td>8.56 (3.68)</td>
<td>8.37 (3.93)</td>
<td>7.51 (3.46)</td>
<td>8.59 (3.64)</td>
<td>8.13 (3.80)</td>
</tr>
<tr>
<td>Household size</td>
<td>6.04 (3.38)</td>
<td>5.98 (2.64)</td>
<td>6.00 (2.86)</td>
<td>6.02 (2.57)</td>
<td>6.01 (2.99)</td>
<td>5.86 (2.62)</td>
</tr>
<tr>
<td>Distance to trading centre (hours)</td>
<td>1.04 (1.20)</td>
<td>1.06 (1.27)</td>
<td>1.06 (1.08)</td>
<td>1.15 (1.25)</td>
<td>1.15 (1.62)</td>
<td>1.07 (1.22)</td>
</tr>
<tr>
<td>Membership in farm association</td>
<td>0.27</td>
<td>0.27</td>
<td>0.37</td>
<td>0.24</td>
<td>0.25</td>
<td>0.32</td>
</tr>
<tr>
<td>Training on climate smart agriculture</td>
<td>0.28</td>
<td>0.29</td>
<td>0.30</td>
<td>0.26</td>
<td>0.26</td>
<td>0.21</td>
</tr>
<tr>
<td>Credit from formal sources</td>
<td>0.39</td>
<td>0.40</td>
<td>0.38</td>
<td>0.28</td>
<td>0.28</td>
<td>0.35</td>
</tr>
<tr>
<td>Tropical livestock unit</td>
<td>2.61 (4.35)</td>
<td>2.82 (4.72)</td>
<td>2.81 (3.83)</td>
<td>1.74 (3.55)</td>
<td>2.76 (3.98)</td>
<td>2.02 (3.55)</td>
</tr>
<tr>
<td>Land ownership (hectare)</td>
<td>3.38 (5.37)</td>
<td>3.21 (4.42)</td>
<td>2.80 (4.35)</td>
<td>2.87 (3.44)</td>
<td>3.17 (3.89)</td>
<td>2.95 (3.15)</td>
</tr>
<tr>
<td>Good economic status</td>
<td>0.35</td>
<td>0.38</td>
<td>0.35</td>
<td>0.21</td>
<td>0.41</td>
<td>0.31</td>
</tr>
<tr>
<td>Ethiopia: Oromia Region</td>
<td>0.09</td>
<td>0.07</td>
<td>0.15</td>
<td>0.10</td>
<td>0.03</td>
<td>0.08</td>
</tr>
</tbody>
</table>

3.3. Micro-level analysis

3.3.1. Descriptive statistics

Table 2 shows the characteristics of households based on the types of ex-ante climate risk management strategies adopted. The mean age of the head of the family was about 47.8 years, and roughly 17% of the family heads were female. The data show some variation in the female headship and the use of the ex-ante climate risk management strategy mechanism. On average, 85% of the household heads were married, and married heads tended to change farming practices and adopt sustainable land management. The average household had six members per family, and the maximum years of schooling of the adult members was 8.3 years. Households with a higher level of education tended to save, change farming practices, and adopt sustainable land management as ex-ante climate risk management strategies.

The mean farmland owned by a family in the study areas was about 3.4 hectares. Households with higher average landholdings changed farming practices and saved more to manage future climate risks. The average tropical livestock unit (TLU) for the region was 2.6 units; this was highest in families that changed climate practice and used sustainable land management as ex-ante climate risk management strategies (2.8), followed by families employing more savings as ex-ante climate...
risk management strategies (2.76), and lowest for those with unspecified ex-ante climate adaptation strategies (2). These results highlight that farm households use livestock as an investment and use it to adapt to shocks, including climate risks. Households with low TLUs had limited resources to cope with shocks as livestock is an important avenue for saving for future uncertainties. The economic status of the household shows the adaptive capacity of the farmer, and our result shows that about 35% of the households had good economic status. The families with high economic status tended to use saving (41%), changes in farming practices (37.5%), and sustainable land management as ex-ante climate adaptation strategies. Interestingly, only 21.2% of the household with good economic conditions sought alternative livelihood strategies to adapt to climate risk.

Only 27% of households had a membership in a farm association, and 36% of these households adopted sustainable land management strategies, while 24% of the households sought alternative livelihood strategies as ex-ante climate risk management strategies. Only 28% of the farm households had received training on climate-smart agriculture technology; of these, 30% adopted sustainable land management as an ex-ante climate adaptation strategy.

The average distance to the trading center is 1.04 h, and the survey data show that the distance to the trading center is highest for households that adopted saving as an ex-ante climate risk management strategy (1.2 h) followed by seeking alternative livelihood (1.1 h). Access to credit is also an important factor in adaptation because it helps in easing liquidity, particularly for poor households. This survey shows that 36% of households had access to formal credit while 28% of the households sought alternative livelihood options as ex-ante climate risk management strategies, indicating that households with limited access to formal credit are forced to seek alternative livelihood strategies.

### 3.3.2. Climate risks and adaptation strategies

In SSA, droughts, floods, hailstorms, pests, and diseases are the most common climate risks faced by farm households. Fig. 2 shows the frequency of the shocks experienced by households in the last 10 years. In the last decade, 99.1% of households experienced pests and disease, 98.4% experienced droughts, 91.6% experienced floods, and 86.6% experienced hailstorms. In Kenya, Ethiopia, Mozambique, and Malawi, over 98% of the surveyed households experienced climate shocks.

We further examined the frequency of climate risks faced by subsistence farming families in the last ten years, finding that a large proportion of subsistence farmers experienced climate shocks once. The percentage of farmers experiencing climate shock more than once decreases with the increase in the frequency of the shocks, regardless of the kind of shock. For example, 30.6% of households experienced drought only once, 31.4% experienced it twice, 22.2% experienced them thrice, and 14.2% experienced drought more than three times. Additionally,
6.3% of households experienced floods, 8.8% experienced hailstorms, and 13.5% experienced pests and disease infestation more than three times. These patterns held true across countries.

Climate shocks adversely affect the income and wellbeing of farming families and can push families into poverty and debt. Table 3 shows the percentage of families by the type of ex-ante adaptation strategies adopted by the household to adapt to climate risk.

It is important to note that households are keenly aware of climate risk, and a significant percentage of households have made attempts to adopt ex-ante climate risk management strategies. In SSA, 90.4% adopted at least one ex-ante climate risk management strategy. Across the five countries, we find that 98.9% of the households in Tanzania, 95% in Malawi, 91.6% in Ethiopia, 87.9% in Kenya, and 80.3% in Mozambique adopted ex-ante climate risk management strategies. Further analysis of the type of ex-ante climate risk management strategy adopted shows that change in farming practices was the most after common strategy with over 71.3% of the household adopting it, followed by a sustainable land management (21%), other unspecified strategies (19.5%), saving (18.8%), and seeking alternative livelihoods (15.3%).

### 3.4. Empirical results: factors influencing ex-ante climate risk management strategies (adaptation strategy)

#### 3.4.1. Combined analysis

The choice of one strategy may influence the choice of another strategy, and a household uses more than one ex-ante climate risk management strategy simultaneously. Therefore, the dependent variables are mutually inclusive, and we adopted a multivariate probit model for analysis. Table 4 shows the correlation of the dependent variables obtained from the multivariate probit model, which supports the use of the MPV model for analysis.

Table 5 shows the results of the multivariate probit model. The coefficients of age and age squared of the household head follow an inverted "U" for the adoption of alternative livelihood and saving, indicating that with the increase in the age of the household head, the probability of adopting alternative livelihood strategies and saving as a climate risk adaptation strategy (ex-ante climate risk measurement) increases until a certain age and then decreases. Female-headed households are generally poor with low endowment and are challenged when it comes to adaptation to climate risk. Notably, female-headed households were more likely to adopt changes in farming practices while they are less likely to adopt saving as ex-ante strategies to cope with climate risks. Households with married heads had a higher probability of changing farming practices and using sustainable land management as ex-ante climate risk management strategies and did not use saving. Education also plays a crucial role in resilience and the adoption of climate risk adaptation strategies. The coefficient of the maximum years of schooling of the adult members is positive and significant for saving, and it is negative and significant for seeking alternative livelihoods, which may be because households with a higher level of human capital are wealthier households. Many do not have to seek alternative employment and have sufficient resources to save for coping with future uncertainties.

Wealth or economic status influence the farm household's decision to adopt ex-ante climate adaptation strategies. Livestock assets are positive and highly significant for the adoption of seeking alternative employment, while they are negative and significant for adopting other unspecified ex-ante climate risk adaptation strategies. The dummy economic status is significantly positive for change in farming practices and saving as an ex-ante risk management strategy, while it is a negative and significant for sustainable land management and seeking alternative livelihood options. This may be because wealthy households do not need to seek alternative livelihood options to cope with future shocks.

The coefficient of membership in a farm association is positive and significant at the 1% level of significance for adopting change in farming practices, sustainable land management, and other unspecified ex-ante climate risk management strategies. Membership in a farm association provides farm households with access to information on farming and becomes an easy way to learn farming practices and sustainable land management. Households that received training on climate-smart agriculture were more likely to adopt sustainable land management. Through training, farmers learn new ways of doing things and can use this network for support and advice on land management and farming practices. Distance to the trading center is positively associated with adopting other unspecified climate risk adaptation strategies, while it is negatively associated with a change in farming practices.

#### 3.4.2. Country-level disaggregated analysis

Results also show the existence of spatial heterogeneity in the adoption of ex-ante climate risk management strategies. Compared to northern Mozambique, households in other regions were more likely to adopt ex-ante climate risk management strategies such as a change in farming practices and sustainable land management. They were less likely to adopt strategies such as seeking alternative livelihood strategies, saving, and other unspecified strategies.

We estimated a multivariate probit model for each country to analyze the factors that induce the adoption of ex-ante climate adaptation strategies at the country level. A summary of results from the multivariate probit model is provided in Table 6, and a detailed analysis is provided in Appendix 1 (Tables 1–5).

#### 3.4.2.1. Change in farming practices

Results show that in Kenya, the coefficient of the female-head dummy is negative and significant for the adoption of change in farming practices. Land owned is positively associated with change in farming practices in Kenya only. Higher economic status is positively associated with change in farming practices in Ethiopia, Kenya, Tanzania, and Mozambique, which clearly demonstrates the importance of wealth in adopting ex-ante climate risk management strategies across all countries. This is because farmers need some level of investment to change their farming practices. The distance to market was negatively associated with the change in farming practices in Tanzania, indicating that households farther from the market are less likely to change farming practices. Membership in a farm association emerges as the critical driver of adoption of changes in farming practices in Kenya and Malawi, where the coefficient of membership in a farm association is positive and significant for the strategy. Contrary to our expectations, the membership in farm association coefficient in a farm association is negative and...
### Table 5
Multi-variate probit analysis of factor influencing the choice of ex-ante climate adaptation strategy (regional level).

<table>
<thead>
<tr>
<th></th>
<th>Change farming practice</th>
<th>Sustainable land management</th>
<th>Seek alternative livelihood</th>
<th>Saving</th>
<th>Others unspecified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of household head</td>
<td>−0.0027</td>
<td>0.0105</td>
<td>0.0130</td>
<td>0.0116</td>
<td>0.0056</td>
</tr>
<tr>
<td>Age square of household head X (10000)</td>
<td>0.0035***</td>
<td>−0.0005***</td>
<td>−0.0207***</td>
<td>−0.0156***</td>
<td>−0.0046***</td>
</tr>
<tr>
<td>Female headY, X</td>
<td>0.1784</td>
<td>0.1334</td>
<td>−0.0498</td>
<td>−0.3158***</td>
<td>−0.0540***</td>
</tr>
<tr>
<td>MarriedX, X</td>
<td>0.2533***</td>
<td>0.1953</td>
<td>0.0593</td>
<td>−0.4536***</td>
<td>−0.0468***</td>
</tr>
<tr>
<td>Household size</td>
<td>−0.0099</td>
<td>−0.0059</td>
<td>0.0036</td>
<td>−0.0014</td>
<td>−0.0314***</td>
</tr>
<tr>
<td>Maximum years of schooling of the adult members</td>
<td>−0.0026</td>
<td>−0.0002</td>
<td>−0.0207***</td>
<td>0.0152**</td>
<td>0.0076</td>
</tr>
<tr>
<td>Tropical livestock unit (TLU)</td>
<td>0.0067</td>
<td>−0.0065</td>
<td>−0.0287***</td>
<td>0.0056</td>
<td>0.0117</td>
</tr>
<tr>
<td>Land ownership (hectare)</td>
<td>0.0103</td>
<td>0.0027</td>
<td>−0.0080</td>
<td>−0.0130</td>
<td>−0.0048</td>
</tr>
<tr>
<td>Good economic statusY</td>
<td>0.2674</td>
<td>−0.0996</td>
<td>−0.3237</td>
<td>0.2192</td>
<td>−0.0353</td>
</tr>
<tr>
<td>Membership in farm associationY</td>
<td>0.1140***</td>
<td>0.3213***</td>
<td>0.0048</td>
<td>0.0611</td>
<td>0.1371***</td>
</tr>
<tr>
<td>Training on climate smart agricultureX</td>
<td>0.0599</td>
<td>0.1447***</td>
<td>0.0391</td>
<td>−0.0692</td>
<td>−0.0972</td>
</tr>
<tr>
<td>Credit from formalX, Y sources</td>
<td>0.0623</td>
<td>−0.0252</td>
<td>−0.0606</td>
<td>0.0281</td>
<td>0.0418</td>
</tr>
<tr>
<td>Distance to trading centre</td>
<td>−0.0540***</td>
<td>0.0063</td>
<td>0.0007</td>
<td>0.0834***</td>
<td>0.0320</td>
</tr>
<tr>
<td>Ethiopia: Oromia RegionX</td>
<td>0.0478**</td>
<td>1.2686</td>
<td>−0.2216</td>
<td>−1.1300***</td>
<td>−0.6505***</td>
</tr>
<tr>
<td>Ethiopia: Southern Nations, Nationalities, and Peoples’ RegionX</td>
<td>1.2703***</td>
<td>1.2968***</td>
<td>−0.6933***</td>
<td>−0.3434***</td>
<td>−0.7802***</td>
</tr>
<tr>
<td>Kenya: Western Kenya RegionX</td>
<td>1.3523**</td>
<td>0.9941***</td>
<td>−0.7293***</td>
<td>−0.5357***</td>
<td>−0.6806***</td>
</tr>
<tr>
<td>Kenya: Eastern Kenya RegionX</td>
<td>1.1000**</td>
<td>0.6863***</td>
<td>−0.9043***</td>
<td>−0.3077</td>
<td>−0.4112***</td>
</tr>
<tr>
<td>Tanzania: Eastern RegionX</td>
<td>1.8656**</td>
<td>0.6468***</td>
<td>−0.0922</td>
<td>−0.1520</td>
<td>−2.2161***</td>
</tr>
<tr>
<td>Tanzania: Northern RegionX</td>
<td>2.2469***</td>
<td>0.8413***</td>
<td>−0.2670***</td>
<td>−0.3911***</td>
<td>−1.3653***</td>
</tr>
<tr>
<td>Malawi: Low altitudeX</td>
<td>1.0599***</td>
<td>0.5857***</td>
<td>−0.0314</td>
<td>−0.9183***</td>
<td>0.1956</td>
</tr>
<tr>
<td>Malawi: High altitudeX</td>
<td>0.9162***</td>
<td>0.7472***</td>
<td>0.0056</td>
<td>−0.9300***</td>
<td>0.1559</td>
</tr>
<tr>
<td>Mozambique: Central RegionX</td>
<td>0.0867</td>
<td>0.2034</td>
<td>−0.1974</td>
<td>−0.0796</td>
<td>−0.0961</td>
</tr>
</tbody>
</table>

Source: Authors’ calculations.

---

### Significant Results

- **Significance Levels**
  - *** = 1% level of significance.
  - ** = 5% level of significance.
  - * = 10% level of significance.

- **Variables**
  - "dummy variables.
  - "X excluded category: male head.
  - "Y excluded category: not married.
  - "Z excluded category: income less than expenses.
  - "T excluded category: Not a member of farm association.
  - "U excluded category: Not received training.
  - "V excluded category: No access to formal credit.
  - "W excluded category: Mozambique: Northern Region.

**Results Interpretation**

Significant for changes in farming practices in Ethiopia. Although training on climate-smart agriculture is an important way to induce changes in farming practices, it was positive and significant only in Mozambique. Though access to credit helps ease liquidity and enables farmers to invest in adaptations, the coefficient of access to formal credit was positive and significant only in Malawi and Mozambique.

**Sustainable land management**: Sustainable land management can also play a crucial role in coping with future climate risks and is an important ex-ante climate risk management strategy available to resource-poor farmers in developing countries. Though it is a crucial strategy, our results show that the adoption of sustainable land management is not as widespread as it is necessary for ex-ante climate change adaptation. The coefficient of the education of the household was significant and positive only for Kenya, while the land owned in hectares was significant and positive only in Tanzania and Mozambique. The coefficient of the higher economic status condition is negative and significant for...
Table 6
Multivariate probit analysis of factor influencing the choice of ex-ante climate risk coping strategy by country.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Ethiopia</th>
<th>Kenya</th>
<th>Tanzania</th>
<th>Malawi</th>
<th>Mozambique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of household head</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age square of HHS X</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female head a,b</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marriaged c,d</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years of schooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical livestock unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land ownership (hectare)</td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good economic status a,d</td>
<td>+</td>
<td>-</td>
<td>+++</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Membership in farm association</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Training on climate smart agriculture</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Credit from formal sources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to trading centre</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>+++</td>
</tr>
<tr>
<td>Ethiopia: Oromia Region a,h</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Kenya: Western Kenya Region a,j</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Tanzania: Eastern Region a,l</td>
<td></td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Malawi: Low altitude e,h</td>
<td></td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Mozambique: Central Region f,i</td>
<td></td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>-</td>
</tr>
</tbody>
</table>

Note (1) Change farming practice; (2) Sustainable land management; (3) Seek alternative employment; (4) Saving; (5) other unspecified
Robust standard errors in parentheses.

*** = 1% level of significance, ** = 5% level of significance, * = 10% level of significance.

- = dummy variables
- = excluded category: male head
- = excluded category: not married
- = excluded category: income less than expenses
- = excluded category: Not a member of farm association
- = excluded category: Not received training
- = excluded category: No access to formal credit
- = excluded category: Ethiopia: Southern Nations, Nationalities, and Peoples' Region
- = excluded category:Kenya: Eastern Kenya Region
- = excluded category:Tanzania: Northern Region
- = excluded category:Malawi: High altitude
- = excluded category: Mozambique: Northern Region
land management in Kenya, Malawi, and Mozambique, indicating that richer households are less likely to use sustainable land management to cope with future climate risks. Distance to the trading center is insignificant except in the case of Kenya, where it was positive and significant. Membership in a farm association was positive and significant in Ethiopia, Kenya, and Malawi. Access to credit was positive and significant in Malawi, while it was negative and significant in Kenya and Tanzania.

**Alternative livelihood:** As agriculture is sensitive to climate risks, farmers tend to diversify their income portfolio by engaging in less climate-sensitive sectors such as non-farm wage employment or non-farm self-employment. The coefficient of the household head is positive while age squared is negative in Malawi, indicating the existence of an inverted U-shaped relation between age and seeking alternative livelihoods. The relationship between education and seeking an alternative livelihood strategy is negative and significant for Ethiopia and Mozambique, which shows that educated households do not seek an alternative livelihood strategy to adapt to future climate risks. Wealth helps households invest in activities outside agriculture, and, as expected, the higher economic status is positive and significant in Ethiopia, Kenya, and Malawi. Membership in a farm association is also positive and significant in Ethiopia, while it was negative and significant in Malawi.

**Saving:** Farm households invest and save their earnings or income in different ways to cope with an unexpected emergency such as climate and health shocks. In Kenya, the age and age squared is positive and significant, indicating the inverted U-shaped relationship. With age, the probability of saving to cope with future climate risks increases. After a certain threshold age, saving to cope with future climate risks decreases. The coefficient of the marital status of the household head (1 if the head is married) is negative and significant in the case of Kenya and Mozambique. The coefficient of the maximum years of schooling of the adult members is positive and significant at the 1% level of significance only in the case of Mozambique. Again, economic status emerges as an important determinant of choosing saving as a strategy to cope with future climate risks in the case of Ethiopia, Malawi, and Mozambique. In Ethiopia and Kenya, membership in a farm association is positive and significant, indicating that households that are a member of a farm association are able to use their network to find alternative investment opportunities to cope with future climate risks. Access to formal credit was positive and significant in the case of Tanzania, while it was negative in the case of Malawi.

**Conclusion and policy recommendation**

This study showed a high proportion of farmers faced climate shocks, but not all of them have applied ex-ante climate adaptation strategies. Droughts, floods, hailstorms, pests, and diseases are common climate risks in SSA irrespective of the country, which highlights that climate risks are widespread in the region. Farm households commonly changed farming practices, applied sustainable land management measures, sought alternative livelihoods, and saved to adapt to climate risk.

Several household characteristics are found to influence the adoption of ex-ante climate adaptation measures in SSA. While households with female heads had a lower probability of adopting saving as an ex-ante climate risk management strategy, they are more likely to change farming practices. This is because females have a lower level of capital, such as skills and wealth, and have less time and energy, given gendered expectations around the household and reproductive labor.

Asset ownership and household’s wealth status are crucial economic factors explaining the adoption behavior of farmers. Farm households with higher livestock assets mostly did not seek alternative livelihoods to adapt to future climate risks. Likewise, wealthy households tended not to use sustainable land management or seek alternative livelihoods; instead, they either changed agricultural practices or used saving as an ex-ante adaptation strategy.

Participation in farm associations and agricultural training usually makes farmers able to change farming practices to address potential climate risks. We found the households with membership in village farm associations were more likely to change farming practices or use sustainable land management methods and other unspecified strategies to mitigate future climate risks. Training on climate-smart agriculture enhances knowledge and increases farmers’ likelihood of adopting sustainable land management practices to adapt to future climate risk.

At the macro level, we found that the level of exposure to climate risks varies significantly across the countries studied. Massive poverty, severe hunger, high dependency on the agricultural sector, and low overall economic development are major factors that reduces the adaptive capacity of the nation. As a consequence, these countries are more vulnerable to climate variability. The capacity of these nations were further constrained by the poor governance (measured in terms of corruption perception index) and weak investment capability (measured in terms of share of external debt to GNI).

The findings of our study have several policy implications. Firstly, agricultural policy on ex-ante climate adaptation mechanisms in SSA needs to be designed and reformed, giving due consideration to vulnerable groups such as female-headed households, and poor farmers. Secondly, there is a need to enhance integration between climate policy and other economic policies so that farmers residing in the regions with high climate risk are provided more economic opportunities and are able to diversify their livelihood. Thirdly, as poor farmers are more likely to lack resources – both human and non-human capital resources – required to invest in ex-ante climate adaptation measures, economic support and training needed for climate adaptation needs to be provided. At the national level, good governance and the economic development seem crucial to build up the national capacity to invest in adaptation.

**Declaration of Competing Interest**

We would like to inform that we do not have any conflict of interest.

**Supplementary materials**


**References**


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