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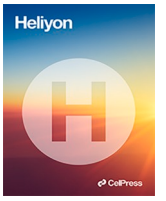

Review article

Impact and adaptation of climate variability and change on small-holders and agriculture in Ethiopia: A review

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ABSTRACT

Ethiopia is highly vulnerable to climate variability and change due to depend on the rain-fed agricultural system. The paper provides comprehensive review of impact and adaptation of climate variability and change on small-holder farmers and agriculture in Ethiopia. The study used secondary data from journal articles, books and technical reports, and discussed and organized with desk review. The study explored that climate variability and change has significantly affected crop and livestock production, fisheries and aquaculture, and food security. The study found that over 38 million people seriously interrupted from their living condition associated to climate related crises since 2000s up to 2010s in Ethiopia. Locust upsurge with the pest spreads reduces 1,228,352, 1,026,132 and 843,241 quintals of cereal crop productions in Oromia, Somali and Tigray regions of Ethiopia, respectively in 2020 production year. Drought declined 26% of number of cattle herd sizes in Dire and Yabelo District, Borana zone, southern Ethiopia in 2010/2011year. Although Effect of climate variability and change has become a serious problem on crop cultivation, pastoralism, and agro-pastoralism in Ethiopia, pastoralism, and agro-pastoralism are more vulnerable comparatively. Small-holder farmers have practiced soil and water conservation, improved crop and livestock variety, tree planting, livestock mobility, crop diversification, planting date adjustment, irrigation, agronomic practices, livelihood diversification, integrating livestock with crop production to reduce adverse impact of climate variability and change in the country. Livestock ownership, farm size, extension service, credit service, distance to market, and access to climate information were major factor of adaptation strategies. It concluded that farmers have practiced different adaptation strategies to reduce impact of climate variability and change in different part of the country. The study suggest that scholars should conduct their studies in disaggregate way for impact and adaptation to climate related problem and the corresponding factors across agro-ecologies in Ethiopia.

1. Introduction

Climate variability and change has an adverse impact on human beings and natural systems [1]. It has affected livelihoods, health and well-being, ecosystems and species, infrastructure, and economic, social and cultural assets [1]. Impacts of climate variability and change will not be uniform, and that there will be losers and gainers depending on the environment, operating and managing system [2]. In general climate variability and change has influenced the whole sectors in the world but the adverse effects have been observed on agricultural production and productivity in developing countries [3]. Adverse impacts of climate variability and change were also

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observed in the case of farmers who planted late and used low plant populations in East Africa [2]. Severely impacted agricultural production in the region especially the marginal rain-fed farming and fragile pastoral livelihoods are vulnerable. Because, many livelihoods across the region are heavily dependent on agriculture [4]. Evidence suggested that the semi-arid regions of central Kenya had been more profoundly impacted by climate changes and variability, including more erratic rainfall patterns and temperature regimes [5]. But it affects the farming system in different way across crops in Kenya. For instance, temperature has a negative effect on maize production and its revenues [6]. Pastoralists suffered extreme drought and loss of their cattle in Ethiopia, Kenya-Somalia border [7]. In Ethiopia all rural livelihood systems: crop cultivation, pastoralism, and agro-pastoralism are highly sensitive to climate and are vulnerable to hazards in multiple ways [8]. The empirical evidence revealed that climate variability and change indicator, temperature had a significantly negative impact on food availability and accessibility for long run in sub-Saharan African countries [9].

Human interruption on natural environment is a driver factor for climate variability and change [1]. For instance, forest decreased/destructed from 54.5% to 48.9% and 41.2% while agricultural farm land increased from 21.8% to 29.7% and 39.8% under land use change scenarios, respectively [10]. Similar study found that in 2000, 2008, and 2014, agricultural land covered 33.0%, 69.1%, and 72.2% of River Mpanga Catchment (RMC) area, respectively [11]. This indicated that the natural environment and forest coverage were changed through time to time. For example, dense forests and open forests decreased by 10.4% and 9.8% from 2000 to 2016, respectively [12]. By this implication, climate variability and change issue is serious problem not only in the present but also in the future [6]. Based on the projection study, the mean annual temperature exhibited a significant warming trend of 0·12–0·54 °C per decade for the coming years and annual rainfall will change by 10% up to 40% in 2080 [13]. Predictions for the future effects of climate variability and change show that annual temperature will increase by 1 °C in 2020 and 2 °C and 2.5 °C in 2030 and 2040, respectively [6]. In general, studies indicated that there is decreased rainfall and increased temperature [10,14,15]. The western borders of Ethiopia have experienced a significant amount of warming since preindustrial times up to the present day [4]. The eastern lowland region, highland region and western borders of Ethiopia, will be warmer than the current climate throughout the year resulting in more frequent days above 40 °C, 30 °C and 40 °C, respectively in the 2050s [4]. As result the production of teff, maize and sorghum will decline by 25.4%, 21.8% and 25.2% by 2050s, respectively [16] and the grain yield will be reduced from 36% to 40% 2050s with effect of climate variability and change [17].

Adaptation is a fundamental response to the effect of current and future climatic changes in semi-arid farming systems of the Sub-Saharan Africa [5]. Climate variability and change needs an appropriate adaptation measures and minimization of the effects at national and farm levels through designing policies that prevent destruction of the natural environment [6]. Adaptations to climate variability and change must be undertaken within the multifaceted context and addressing climate change complementing overall governance for sustainable use [18]. Adaptation responses are also tailored to the specific environmental, socio-economic and cultural conditions of a particular areas or community or national since climate change impacts vary between geographic areas [19]. Small-holder farmer used different adaptation strategies such as irrigation, agro-chemical application and drought resistant varieties with integrating of modern and local knowledge systems and technologies to facilitate in the forest-savanna transitional zone of Ghana [20]. The adaptation measures adopted by the farming households include irrigation, crop rotation, and changing crop variety in Tyhume Valley communities, Eastern Cape Province, South Africa [21]. Early maturity crop varieties, use of terraces and intercropping are the most common adaptation strategies to Climate variability and change in Mbeere South, Meru South, and Maara Sub-Counties in Kenya [5]. Among adaptation mechanisms are understanding of current response measures to climate variability and change to inform planned adaptation, designing approaches and policies that build the livelihood asset based adaptation, reducing vulnerability to multiple stressors, designing adaptive strategies with a multi-sector perspective [22]. Aggressive adoption of integrated pest management practices and introduction of new inputs countered more virulent/contagious challenges [19]. Similarly, the majority of Ethiopian farmers have already exercised different adaptation strategies to climate change and variability, but efforts are still relatively a minimal and fragmented [23]. Thus, the objective of the review is assessment of impact and adaptation of climate variability and change on small-holders and agriculture in Ethiopia.

1.1. Review questions

The study is guided by the following research questions.

- What are the main impacts of climate variability and change on small-holders and agriculture in Ethiopia?
- What are the major farmers' adaptation strategies to climate variability and change in Ethiopia?
- What are the major factors affecting farmers' adaptation strategies to climate variability and change in Ethiopia?

1.2. Objectives of review

- To identify the main impact of climate variability and change on small-holders and agriculture in Ethiopia
- To review the major farmers' adaptation strategies to climate variability and change in Ethiopia
- To review the major factors affecting farmers' adaptation strategies to climate variability and change in Ethiopia

2. Methodology

The study was involved mainly collection of secondary data from various sources such as peer reviewed journal articles, books and technical reports from Google and Google scholar. More specifically the study involved that the desk review of relevant literature on

the area of impact and adaptation of climate variability and change on small-holders and agriculture in Ethiopia. The study used literatures for topics crop production, livestock production, fisheries and aquaculture, and food security 13, 9, 9 and 10, respectively. In general, the study used more than 90 literatures which were reported in period of 2007–2023. The references of literatures are organized and arranged using reference management software, mendeley. A review study needs critical assessments of a segment of a previous research studies through descriptions, summary, classification, and comparison of those works [23]. Paraphrased relevant information were discussed and organized in coherent manners throughout the paper and presented in form of narration (statement), tables and figures. The paper gives some basic information and knowledge for conducting scientific study on this thematic area. It could be used to conceptualize and update the government and non-government organizations, reviewers, national and international development practitioners for intervention and minimization of impact to climate variability and change. In general, it is important to update the national and international audiences on that specified thematic area.

3. Result and discussion

3.1. Ecological and socio-economic aspects of Ethiopia

Ethiopia is landlocked country and located in horn of Africa, bordering with Kenya, South Sudan, Sudan, Eritrea, Djibouti and Somalia [24]. Geographically, Ethiopia extends from 3° 24′ to 14° 53′ northern latitude and from 33° oo' to 48° oo' eastern longitude [25]. It has approximately 1.1 million km^2 landmass [24,25] and its altitude ranges from 125 m below sea level to 4533 m above sea level [25] and covering high mountains, flat-topped plateaus, gorges, valley bottoms and aquatic and wetland environments [26]. Ethiopia has many different agro-ecological zones and farming systems that vary within short distances [27]. Although Ethiopia has highly diverse agro-ecological zone, it is manly divided into Kur (Extreme cold and dry highlands) > 3700; Wurch (Cold and dry highland), 3200–3700; Dega (Cool andmoist highlands), 2300–3200; Woina Dega (mid-highlands), 1500–2300; Kola (humid and moist lowlands), 500–1500, and Bereha (Hot and dry lowlands) < 500 [28] and has more than 13 major vegetation types and various ecosystems [26].

Ethiopia is the second most populous country in Africa after Nigeria, with an estimated population of 115 million people in 2021 and with an annual growth rate of 2.5% [24]. In the past decades Ethiopian population were increased an alarming rate (1980s, 1990s, 2000s and 2010s), (42.6, 53.5, 73.5 and 83.7 million) based on estimation of national census in Ethiopia, respectively [29]. The projection population study also estimated that Ethiopian population gradually increased from 83.7 million in 2012 to 133.5 million in 2032 and 171.8 million in 2050 [29]. About 80% of Ethiopian population live in rural areas that depend on agriculture for their livelihood [24,30]. The primary school net enrolment was increased from 95% in 2017 to 97% in 2020 and the gender parity index for grades 1–8 is 0.9, and only about 58% of girls and 54% of children complete the primary cycle in rural areas [24]. Moreover, majority of populations of the country are rural residents with low income, getting less than one dollar per day [31] and the income is derived from crop and livestock in rural livelihoods [8]. About 74% of farmers are smallholder farmers in Ethiopia and with subsistence farming system (hand to mouth) [32]. Similarly, around 98% of rural farmers and 64% of small town households have practiced agriculture including both crops and/or livestock production [33]. In the country, the average farm size of smallholder farmers is 0.9 ha [34]. The employment to population ratio is highest in rural areas compared to urban areas. In rural areas, 71.4% of the persons aged 15 years and above are employed but only 46.6% are employed in urban areas [35]. Agricultural sector shares an employment opportunities to 66% of the population of the country and contributes to 33% of GDP in 2019 year [36]. Ethiopian economy growth has declined from 10.4% in 2005–2019 to 6.1% in 2020 [24] and about 67% of the small family farms in live below the national poverty line [32]. The poor farmers are the most vulnerable to climate change and variability. This is due to high human environmental interactions caused by combined effects of high population density and small ratio of land holdings, and high dependency on rain-fed cropping system [37].

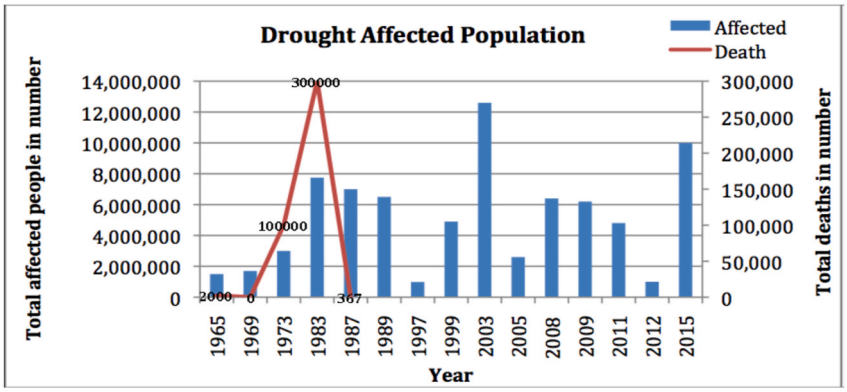

Fig. 1. Effect of climate variability and change (drought) in Ethiopia, Adapted from [48].

3.2. Impacts of climate variability and change on farmers' livelihoods in Ethiopia

Ethiopian traditional livelihood systems are highly susceptible to climate variability and change due to their close links to the natural environment [19]. Climate related hazards in Ethiopia include drought, floods, heavy rains, strong winds, frost, heat waves (high temperatures). Frequent occurrence of droughts and floods have deteriorated the livelihoods of rural people [38–40]. Farmers are progressively vulnerable to climate change risks in Dembia woreda, Northwest Ethiopia [15]. An increasing in temperature and a fluctuating rainfall patterns would like increase some agricultural pests and waterborne pathogens, and these pathogens change and affect crop and livestock production [19]. A study found that low rainfall and agricultural pests are the most important factors influencing livelihood activities in agro-pastoral systems of Borana Plateau of Ethiopia [41]. Rainfall variability and a rising temperature have affected rural people in Konso district of SNNP regional state, Ethiopia [42]. The serious damage of floods were including damage of farm land, loss of harvested and standing crops, loss of houses and house properties, and damage of settlements a semi-closed basin in northern Ethiopia [43]. High score of exposure to climate change and variability were related to drought risks and long-term impact of climate change [44]. Drought had significant social and economic effects historically in Ethiopia. A recent year, in 2003 it affected over 12, 600, 000 people in Tigray, Oromiya, Amhara, Somali and Afar Regions (Fig. 1). Similarly, 10, 000, 000 people were affected in Somali and Afar Regions in 2015 (Fig. 1). The effects of climate change and variability (frequent occurrence of extreme weather events) seriously affected agricultural production and food security [45–47]. The loss of crops and livestock often results in severe household food shortages and psychological stress and insecurity among the affected people [45].

3.2.1. Impacts of climate variability and change on crop production in Ethiopia

The result of the study confirmed that there is a long-run relationship between crop productions and climate variability and change in Ethiopia [3]. For instance, productivity of sorghum was challenged by recurrent droughts, insects, diseases [49]. Crop yields such as teff (Eragrostis teff) and sorghum were affected by climate variability and change indicators such as recurrent drought, occurrence of flooding and variable rainfall in Northern Ethiopia [47]. A typical study analyzed economic impact of climate variability and change on crop production in Ethiopia by considering temperature and precipitation variability for terms of four seasons (winter, spring, summer and fall) [50]. An increasing temperature reduces the net revenue per hectare by US$997.85 and US$1277.28 during winter and summer, respectively. Whereas an increasing temperature increases the net revenue per hectare by US$375.83 and US$1877.69 during spring and fall, respectively [50]. In same way, the study showed that marginally increasing precipitation increases the net revenue per hectare by US$225.08 during spring. In addition, marginally increasing precipitation reduces the net revenue per hectare by US$464.76, US$18.88 and US$64.19 during winter, summer and the fall, respectively [50]. Due to climate variability and change crop damaging, farmers lost 22,728$ and 30,772$ money to purchase crop for their household consumption in Woina-Dega and Kolla agro-ecological zones, respectively [42] and an estimated of 3230 and 5181quintal of crops were damaged by climate variability and change in Kolla and Woyina Dega agro-ecological zones with in Konso district, SNNP regional state, Ethiopia, respectively [42]. On other hand locust upsurge with the pest spreads reduces 1,228,352, 1,026,132 and 843,241 quintals of cereal crop productions in Oromia, Somali and Tigray regions of Ethiopia, respectively (Table 1). Desert locust has damaged different crops but the worst affected cereal crops were sorghum (112,476), maize (41,041) and wheat (24,419) quintals in some regions of Ethiopia [51].

3.2.2. Impacts of climate variability and change on livestock production in Ethiopia

In Ethiopia climate variability and change poses particular risks to poor farmers and pastoralists who have an immediate daily dependence on climate sensitive livelihoods and natural resources. An increased climate variability and change has physiological effects of higher temperatures on livestock production and productivity, and loss of livestock number as a result of droughts, floods and disease epidemics [52]. The potential effects of climate variability and change on livestock production are changing of livestock feed availability, reducing rainfall/water accessibility, affecting animals' health, growth and reproduction, reducing number of cattle herds, changing of forage crop quality and quantity, spreading of diseases, reducing livestock performance and maturity, changing of income and prices in many parts of Ethiopia [38,53,54]. For instance, pastoralists and agro-pastoralist regions are highly disposed to adverse impacts of climate variability and change in East Guji and Borana Zone, southeastern of Ethiopia [54,55]. Similarly, a study indicated that pasture and water availability were became scarce, and livestock assets and productivity were highly reduced, due to adverse impacts of climate variability and change in Fentale District of Oromia Region, Ethiopia [56]. Severity of the drought affected livestock in Borana zone. The livestock are very weak and emaciated body conditions due to searching for food and water and finally leading to death (Fig. 2). Drought declined the number of cattle herd sizes substantially by 26% in Dire and Yabelo District, Borana zone, Oromia Regional State, southern Ethiopia in 2010/2011 [57]. A study found that about 483,400 and 572,350 Ethiopian Birr

Table 1
Crops loss per quintal due to desert locust in some regions of Ethiopia, Adapted from [51].

Regions of Ethiopia	Total cereal loss	Maize	Sorghum	Wheat	Barely	Vegetable	Total
Afar	202,882	3633	175	614	–	453	4875
Amhara	96,780	–	15,430	–	–	–	15,430
Oromia	1,228,352	3813	32,234	5000	–	–	41,047
SNNP	134,420	1748	2410	–	–	–	4158
Somali	1,026,132	30,000	41,271	18,805	–	–	90,076
Tigray	843,241	1847	20,956	–	6005	–	28,808
Grand total	3,531,807	41,041	112,476	24,419	6005	453	184,394

(ETB) of valued livestock forage was damaged by climate variability and change, and consequently, about 939,280 and 1,003,800 ETB could be obtained from livestock production, was lost by climate variability and change in Kolla and Woyina Dega agro-ecological zones in Konso district, SNNP region, Ethiopia, respectively [42].

3.2.3. Impacts of climate variability and change on fisheries and aquaculture in Ethiopia

In coastal regions, fisheries, aquaculture and related activities provide livelihoods for millions of people and contribute significantly to the food security and economic well-being [59]. Fishery is an important economic activity in the coastal zones [60]. Climate variable indicators such as rainfall, temperature and sea level have a relationship with local communities and their livelihood activities, namely fishing, farming and seaweed farming [61]. There was fluctuation of rainfall, temperature, and humidity over the years in coastal regions [62,63]. Environmental impact and climate change contributed to low production in aquaculture practice [64,65] and climate variability and change affected fish production and aquaculture sector directly by influencing fish stocks and comprehensive supply of fish for consumption in Ethiopia [62,66]. The life expectancy of the lake will relatively decrease under effect of climate variability and change on sediment yield in the Central Rift Valley Basin of the country [67].

3.2.4. Impacts of climate variability and change on food security in Ethiopia

According to the FAO food security can be defined as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life while food insecurity exists when people do not have adequate physical, social or economic access to food as defined above [68]. It is composed of availability (enough food produced), access (affordable or getting food), utilization (nutritional uptake from food), and stability (supply, access and utilization ensured) [69]. Food availability could be threatened through direct climate impacts on crops and livestock production from increased flooding, drought, shifts in timing and amount of rainfall, and high temperatures, or indirectly through increased soil erosion from more frequent heavy storms or through increased pest and disease pressure on crops and livestock caused by warmer temperatures [69]. Food access could be affected by climate change impacts on productivity in important cereal producing regions of the world, which, along with other factors, could raise food prices and erode the ability of the poor to afford purchased food. It is also threatened by extreme events that impair food transport and other food system infrastructure [69]. An increasing atmospheric CO2 has an impact on nutrition by reducing the nutrient content of crops, creating nutritional challenges [19]. It could also impact food utilization through increased disease burden that reduces the ability of the human body to absorb nutrients from food [69]. Warmer and more humid conditions caused by climate change could impact food availability and utilization through increased risk of spoilage of fresh food and pest and pathogen damage to stored foods (cereals, pulses, tubers) that reduces both food availability and quality [69].

In Ethiopia, climate change and variability has a serious impact on food security status of the rural people [16]. One of the major adverse impacts of climate variability and change is food insecurity, arising from occurrences of droughts and floods, outbreak of diseases such as malaria, water borne diseases associated with floods, respiratory diseases associated with droughts, and land degradation due to heavy rainfall in the country [38,70]. With inadequate sources of food and income as a result of the drought, vulnerable rural households face widespread hunger and malnutrition [39]. Recent trends show that rainfall has decreased significantly in the period March–September since the 1990s across most of the country [8]. In late 2015, a Government-led multi-agency meher assessment found that10.2 million people were food insecure, while 2 million required agricultural input support to resume food production [39]. About 2.5 million people were at risk of food insecurity because of damaging of crop productions by desert locust [71]. In addition, estimated of 976,381 farmers were affected by desert locust and have required humanitarian food assistance. More

Fig. 2. The severity of the drought affected livestock of Borana zone in 2023 [58].

humanitarian food assistance needs are in Somali and Oromia regions that experienced larger crop loss [51].

3.3. Farmers' adaptation strategies to climate variability and change in Ethiopia

Climate change adaptation method takes place at international level (cooperation between industrialized and developing countries), national level (emphasis on poverty reduction, development policy geared more toward vulnerable sectors, support adaptation at local or community levels) and local level (establishment of social institutions, prevent marginalization of sections of population, encouragement of diversification of income sources, provision of knowledge, technology and financial support) [1]. Adaptation measure requires involvement of multiple stakeholders including government organizations and institutions (policymakers and extension agents), none government organizations, researchers, communities, and individual farmers [53]. The strong dependence of the country on agriculture which is very sensitive to climate variability and change, the government of Ethiopia has given top priority or consideration to the agricultural sector and has designed policies and programs [72]. The policies and programs include the plan for accelerated and sustainable development to end poverty, the environmental policy, the agriculture and rural development policy and strategy, Ethiopian climate-resilient green economy policy, Ethiopian climate smart agriculture policy (integrated soil fertility management, water harvesting, and agroforestry) and strategic investment framework for sustainable land management [38,46]. Some actions were taken to improve the adaptive capacity of smallholder farmers and reduce the vulnerability of the country to current and projected climate change and variability and increase production and productivity [38]. The responses are promoting drought insurance programs; strengthening drought and flood early warning systems; water harvesting schemes in arid, semi-arid, and dry sub humid areas; improving rangeland resource management practices in pastoral areas; realizing food security through a multi-purpose large-scale water development project in the Genale-Sawa Basin; establishing a community-based Carbon Sequestration Project in the Rift Valley System [38].

The local community have developed and implemented widespread adaptation strategies to reduce vulnerability to climatic variability and change using their indigenous knowledge [73]. Individual farmers have used different adaptation strategies to mitigate the adverse impacts of climate variability and change at local level [40]. For instance a study explored that Impact of climate variability and change and farmer's response strategies are diverse in different rural setting [74]. It needs suited adaptation strategies for different contexts and agro-ecological settings [75]. Adaptation measures were identified and recommended specifically to cope up the effect of climate variability and change [75]. In Ethiopia, a study was conducted on 50 districts of different agro-ecologies with 1000 sample household farmers and identified the main adaptation strategies to climate variability and change including irrigation, planting drought tolerant and early maturing crop varieties, strengthening institutional set-ups working in research, educating farmers and encouraging ownership of livestock [50]. Purchasing grass and feeding enset (Ensete ventricosum) leaf are the most commonly adaptation mechanisms to alleviate feed shortages during the dry season (serous drought) in the Damot Gale District of Wolaita Zone [76] and temporary migration to areas with better pasture is alos the most commonly coping strategy to climate-related problems so as to address feed and water shortage in pastoralists/agro-pastoralists area of Ethiopia [54].

However, farmers have used different adaptation strategies to climate variability and change in different part of Ethiopia (Table 2), majority of farmers have used at least one adaptation strategy to climate variability and change in the local areas [23]. According to studies undertaken by Hirpha et al. (2020) and Belay et al. (2017) showed that 82.9% and 85% of farmers implement various adaptation options to climate variability and change in their localities, but the remaining 17.1% and 15% of farmers have not carried out any adaptation measures, respectively in the Central Rift Valley of Ethiopia. Similarly, scholars reported that about 81.2% (359) respondent farmers have used at least one adaptation strategy to climate variability and change aggregately, while the remains 18.8%

Table 2
Farmers' adaptation strategies to climate variability and change in different part of Ethiopia.

Study areas in different part of the country	Farmers' adaptation strategies to climate change and variability in Ethiopia	References
Nile Basin of Ethiopia	Using of crop varieties, Tree planting, Soil conservation, Early and late planting, and Irrigation	[80]
Borana, Southern, Ethiopia	Livestock mobility, Drought-tolerant species (Camel), Cultivation of cereals and fodder, Asset diversification	[81]
Dera Woreda, South Gondar Zone	Crop-diversification, Soil and water conservation and Seasonal migration	[79]
Central Rift Valley of Ethiopia	Crop diversification, Planting date adjustment, Soil and water conservation and management, Integrating crop with livestock, and Tree planting	[53]
Muger Sub-Basin of Upper Blue-Nile Basin of Ethiopia	Small-scale irrigation, Agronomic practices, Livelihood diversification, and Soil and water conservation measures	[77]
Abeshege District, Gurage zone, Ethiopia	Soil and water conservation, Small scale irrigation, Changing planting date, and Using improved crop and livestock variety	[82]
Nile Basin of Ethiopia	Agro-forestry, Soil conservation, Improved variety, Manure, Minimum tillage, and Crop diversification	[83]
Agro-pastoral dry lands of Northeastern Amhara, Ethiopia	Portfolio diversification, Enhancing livestock productivity, Agro-ecological practice and Diversification of non-agricultural income	[84]
Central Rift Valley Adama District	Using improved crop varieties, Planting trees, Watershed management, Adjusting planting date, and Terracing	[23]
Fentale District of Oromia Region, Ethiopia	Integrating livestock with crop production, Livestock mobility and diversification, Cash for work, and Food aid	[56]
Central Gondar Zone, Amhara Regional State, Northwest Ethiopia	Use of improved crop varieties, Early and late planting, Soil and water conservation, Mixed cropping, Use of irrigation, and Income source diversification	[85]

(83) of sample households not used any adaptation measures in Muger Sub-Basin of the Blue-Nile basin, Ethiopia [77]. The proportion of adopter farmers have used small-scale irrigation, agronomic practices, livelihood diversification, and soil and water conservation measures and the percentage 28.7%, 27.4%, 11.5%, 13.6%, respectively in disaggregate way [77]. The result of the study showed that significant number of respondents (86.4%) frequently participate in soil and water conservation (SWC) for improving production and reducing climate variability and change, while the remain 14.6% of the respondents do not practices this technology [78]. Among adopter categories of SWC practices, 55.6%, 18.85% and 42.8% were highly involved in terracing, vegetation cover, and compost preparation respectively [78]. In the same way, a study showed that (89.1%) of sampled households employed at least one adaptation strategy but the remaining 10.9% are none adopter of any climate variability and change adaptation strategies [79]. Based on the importance of each strategy to their livelihood and agricultural activities, crop-diversification (38.2%), soil and water conservation (31.8%) and seasonal migration (19.1%) were identified as the major adaptation strategies both in the dega and woina dega agro-ecological zones of the study area [79]. This implied that still small numbers of farmers have used adaptation strategies to climate variability and change and also their perception and implementation varies from region to region in Ethiopia.

3.4. Factors of adaptation strategies to climate variability and change in Ethiopia

There are different factors of adaptation strategies to climate variability and change at international, national and local level. At the international level, the Paris Agreement (PA) enhances the implementation of the United Nations Framework Convention on Climate Change (UNFCCC) and aims to strengthen the global response to the threat of climate variability and change through an integrated approach [86]. This effort to apply appropriate adaptations deficit caused by poor countries are less able to take effective adaptation action to climate variability and change [87]. There is an evidence indicated that there is inequality between least developed and developed countries in terms of affecting global climate [88]. For instance, developed countries contribute 53–61%, and developing countries 39–47%, for increasing in global air temperature approximately [89]. The major influences in that, farmers are mainly depend on agriculture for their livelihoods, which is very sensitive to climate variability and change at the national level [33,72]. In addition, smallholder farmers' landholdings are fragmented into small plots and on the average less than 1 ha of land [32]. There is no significant proportional use of mechanizing farming in Ethiopia [90]. Some of the major barriers for climate variability and change adaptation gains from the on-going national initiatives include lack of strong coordination mechanism both at the federal and regional levels, lack of efficient outreach mechanism on environment to local communities, economic challenge, i.e., limited finance for environment etc. [38]. Determinates of adaptation strategies to climate variability and change are varying from place to place in different part of Ethiopia at local level (Table 3). The techniques of adaptation are also differing depending on capacities, knowledge and wealth status of individual farmers. A study indicated that, wealth status, social capital, temperature, lack of information on adaptation methods and financial constraints have influenced farmers' choices of adaptation strategies to climate variability and change [80].

Furthermore sex, age, literacy status, family size, land holding, livestock number, access to climate information, farmers' perception to climate change, extension services, on-farm income, off/non-farm income, access to credit, agro-ecological setting and market distance are significant factors of CCAS in Ethiopia [23,82]. Determinants of adaptation strategies have significantly affected farmers' adaptation strategies to climate change and variability either positively or negatively. A study showed that sex of household head has a positive relationship with soil conservation, crop varieties and planting trees at 1% significant level. A researcher described that male-headed households are more likely to adopt climate variability and change adaptation strategies and agricultural technologies [80,79]. Age of household head affected adaptation to climate change and variability positively and significantly. A unit increases in age of the household head, probability of planting trees and irrigation increase by 0.5% and 0.06%, respectively [80]. On other hand a study showed that age of household head has a negative correlation with soil and water conservation and seasonal

Table 3
Factors of adaptation strategies to climate variability and change in different part of Ethiopia.

Study areas in different part of Ethiopia	Factors of adaptation strategies to climate change and variability	References
Coffee-based farming system of Southwest Ethiopia	Age of household head, Access to climate information, Access extension services, Education level, farm size, income from coffee, and agro-ecological setting	[91]
North-central Ethiopia (Woleka sub-basin)	Financial constraints, Lack of affordable technologies, Lack of knowledge, Limited access to early warning, Uncertainty about the future, Shortage of land and Scarcity of water	[92]
Yabello District, Borana Zone, Oromia National Regional State, Ethiopia	Sex of household head, Education status of household head, Size of livestock holding, Market distance from homestead, Access to credit, Access to early warning information, Access to training, and Pastoral/agro-pastoral income	[93]
Dabus watershed, North-West Ethiopia	Household size, Gender of household head, Size of cultivated land, Education, Farm experience, Non-farm income, Income from livestock, Climate information, Extension advice, Farm-home distance, and Number of parcels.	[94]
Abobo and Itang District, Gambella, Ethiopia	Age, education, Farm income, Extension contact, Access to credit service, and Land holding size	[95]
Central highlands of Ethiopia	Formal education, Lacked information Shortage of water for irrigation, and Shortage of money to buy necessary inputs,	[40]
Eastern Tigray Regional State of Ethiopia	Age, Education, Livestock holding, Cooperatives membership, Extension services, Farmers income, Households perception, Distance to market, and agro-ecological setting	[96]
Eastern Hararghe zone of Oromia of Ethiopia.	Gender of household head, Household size, Farm size, Distance from market, and Number of farm plots	[97]

migration at $p < 1\%$ and $p < 10\%$ respectively. A unit increase in age of the household, probability of using soil and water conservation and seasonal migration is decreased by 0.7 and 0.8 times, respectively [79]. The author also explained that older farmers are less likely to take such climate change adaptation strategies than younger farmers. Because, younger households are active and energized than older households in the application of soil and water conservation and seasonal migration which require more labor force [79]. Furthermore, a study stated that a unit increase in the age of a household head would, decrease likelihood of practicing climate change adaptation activities. The author argued that younger farmers are flexible in decision-making process, and seeking support and information from government and non-governmental institutions and they are risk taking as compared to older farmers [23]. Education had a positive and strong relationship with climate change adaptation strategies. The level of education increases, probability of adapting to climate change increases [53].

A study showed that education of household head increases, likelihood of adapting to climate change increases significantly. A unit increase in number of years of schooling would result in a 1% increase in the probability of soil conservation and a 0.6% increase in change in planting dates to adapt to climate change [80]. Family size has a positive effect on climate change adaptation techniques at $p < 0.01$ significant level. The marginal effect result showed that a unit increases in productive family members, likelihood of adopting planting food and fodder trees, integrating crop with livestock, and soil and water conservation measures increases by 1.3%, 2.35% and 4%, respectively [53]. Farm land has a positive and significant association with most of adjustment methodologies. The size of farmland increases, chance of planting diverse feed trees and integrating crop with livestock production increases [53]. Similarly, a study revealed that farm land of household affected farmers' decision to take climate variability adaptation strategies positively [82]. A researcher found that livestock holding have influenced stallholders' choice of livelihood diversification strategies negatively at 1% significant level. The study reveals that a unit increase in a number of livestock would result in 15.7% decrease probability of creating another source of livelihoods like petty trading and small business as an alternative means of income [77]. Farmers who have access to professional advice from extension workers are more likely to practice climate change adaptation strategies compared to those who do not get access to professional advice. Hence, researcher revealed that access to expertise of agricultural extension workers has determined the level of adaptation climate change and variability significantly [23]. Access to extension service has positive and significant correlation with likelihood of choosing adaptation strategies such as crop-diversification, soil and water conservation and seasonal migration at $p < 0.01$, $p < 0.1$ and $p < 0.05$, respectively. A unit increase in the extension contact is likely to increase the probability of the farmer to adapt the three adaptation measures by 51, 13 and 19% respectively [79]. Access to information is an important intuitional factor to make decision on adaptation strategies to climate change and variability through TV, radio, magazine, newspaper, and personal observation and development agents. An individual exposed to climate information is more likely to take an immediate action to cope with risks related to climate change. The result shows that access to information has positive and significant impact on home feeding, use of crossbred animals, and marketing during shock [98]. Similarly, another a study reported that access to climate information has strong positive relationship with climate change adaptation strategies [80]. In addition, farmers' perception to climate change is affecting adaptation options of farmers positively at significant level. While the results of linear regression model presented that the amount of rainfall received and temperature affected coffee production significantly in the study area [82]. A study showed that distance from market center is negatively related to adaptation strategies to climate change and variability. Greater distance to marketplace and size of farmland affected the use of agronomic practices negatively. The author explained that farmers in the remote area have less opportunity cost to adapt labor-intensive adaptation practices [77].

4. Conclusion and future direction

The adverse impact of climate variability and change has wide-ranging effects on small-farmers' livelihoods in Ethiopia. Especially, it affects agricultural production in the country. Climate variability and change has affected over 12, 600, 000 people in Tigray, Oromiya, Amhara, Somali and Afar Regions, and over 10, 000, 000 people were also affected in Somali and Afar Regions in 2003 and 2015, respectively. It reduces 1,228,352, 1,026,132 and 843,241 quintals of cereal crop productions in Oromia, Somali and Tigray regions of Ethiopia, respectively in 2020 production year. An increasing temperature reduces the net revenue per hectare by US $997.85, US$1277.28, US$375.83 and US$1877.69 during winter, summer, spring and fall, respectively in Ethiopia. The potential effects of climate variability and change on livestock production are changing of livestock feed availability, reducing rainfall/water accessibility, affecting animals' health, growth and reproduction, reducing number of cattle herds, changing of forage crop quality and quantity, spreading of diseases, reducing livestock performance and maturity, changing of income and prices in many parts of Ethiopia. Effect of climate variability and change, drought declined the number of cattle herd sizes substantially by 26% in Dire and Yabelo District, Borana zone, southern Ethiopia in 2010/2011 production year. The study concluded that even though Effect of climate variability and change has become a serious problem on crop cultivation, pastoralism, and agro-pastoralism in Ethiopia, pastoralism, and agro-pastoralism are more vulnerable comparatively. The major adaptation methods to climate variability and change are using improved crop and livestock variety, tree planting, soil conservation, livestock mobility, drought-tolerant species (camel), crop diversification, planting date adjustment, small-scale irrigation, agronomic practices, livelihood diversification, integrating livestock with crop production. In general, farmers have practiced different adaptation strategies to reduce the adverse impact of climate change and variability. The major determinants of adaptation strategies to climate variability and change were sex and age of household, education level, family size, livestock ownership, farm size, access to extension service, access to credit service, distance to market, and access to climate information. Adaptation strategies should be designed and targeted to base on agro-ecological zone instead of recommending and implementing uniform interventions. Woreda agricultural office should give an attention for small-scale irrigation, technology dissemination, soil and water conservations, agronomic practices, livelihood and crop-diversification in appropriate way. Institutional factors such as extension service, credit service, and market access should be given consideration and implementing at

grass root level. Finally, the study may help small-holder farmers in decision-making when perceiving the challenges of climate variability and change on agricultural production, and their adaptation strategies and corresponding variables.

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