Agriculture & Food Security

RESEARCH

Open Access

# Climatic extremes' resilient livelihoods of rural households in the Eastern Ethiopia

Daniel Assefa Tofu[1*], Mesfin Mengistu Mekuria[2] and Gemechu Shale Ogato[2]

**Abstract**

Climate change is affirmed as a major challenge to global food security in the twenty-first century and a threat to availability of adequate food for the population. This study was conducted to analyze rural households' vulnerability to climatic extremes, and their resilience capacities in the eastern Ethiopia. The study employed both quantitative and qualitative methods of data, and analysis to achieve the objectives. While 397 sample households were randomly selected for household survey, key informants and focus group discussion participants were purposively selected. To analyze the quantitative data, both descriptive and inferential statistics were employed while thematic content analysis was employed to analyze the qualitative data. Rainfall variability, increase in local temperature, frequent drought, irregularity in rainfall, and pest infestation were identified as the key climatic extremes in the study area. The findings of the study asserted that rural local households in the study area have very high vulnerability to climatic extremes underpinned by their dependence on rain-fed farming. Reduction in crop yield (93%), and decline in production and productivity of livestock (91%) were confirmed as the major impacts of climatic extremes in the study area. Contrary to very high vulnerability to climatic vulnerability, local farming households' resilience capacities were confirmed to be very poor. Moreover, the overall resilience capacity index was 0.44, which is below the minimum threshold and underpinned by low absorptive (0.45), low adaptive (0.47), and low transformative (0.4) capacity of farmers. Furthermore, the indexes derived from the five resilience building blocks imply that the level of household resilience is still poor (0.47). The very high vulnerability to extreme climate conditions and the very low livelihood resilience of rural farmers requires integrated strategies to reduce vulnerability and enhance livelihood resilience by governmental and non-governmental organizations. More importantly, it is worth to initiate rural livelihoods diversification and sustainable natural resource conservation, and management strategies. Above all, it is worth to integrate climate-resilient social protection programs into rural poverty reduction policies at national, regional, and local levels to reduce vulnerability, and enhance resilience of rural households in the study area.

**Keywords** Absorptive capacity, Adaptive capacity, Climatic extremes, Resilience, Transformative capacity, Vulnerability

*Correspondence:
Daniel Assefa Tofu
danasse19@gmail.com
[1] School of Natural Resources, Ambo University, Ambo, Ethiopia
[2] School of Agricultural Economics and Rural Development, Ambo University, Ambo, Ethiopia

## Introduction

Climate change is affirmed as a major challenge to global food security in the twenty-first century and a threat to availability of adequate food for the population [67, 68, 90], [58], [18]. Vulnerability to climate change may refer to inability among households to engage in strategies to cope with and adjust to extremes such as droughts that form part of current climate variability and which may increase in frequency and/or intensity in future [31].

Climate change resilience may refer to the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning and transformation [56]. Adaptive capacity may refer to the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences [56]. There will be at least 700 million small-scale agricultural producers in 2030, for example, and we are not on the right pathway to build their resilience to extreme events within a short period of time [18, 67, 68].

Climate change and the associated weather extremes continue to pose considerable risks to humans by affecting their livelihood systems. In other words, climate change is affirmed to already causing severe problems of drought, flooding and unpredictable weather, creating losses in food production and destroying peoples' livelihoods [20, 29, 31, 39, 84]. According to contemporary findings in climate change, and disaster research, intense and frequent heat extremes due to increases in temperature, marine heat waves, precipitation variability, agricultural and ecological droughts, and an increase in the proportion of extreme tropical cyclones are the key climatic extremes induced by climate change [52, 55, 67, 68]. The propagation of these extreme episodes poses important challenges for the environment, water, and biodiversity, and causes the most damage to agriculture. This is because climate change is a complex problem involving wide-ranging interactions between the environment, natural resources (land, climate, and water), production (e.g., crops and animals), and people. These interactions are likely to change the ecological and agricultural landscape and therefore influence agricultural production [24, 37, 90], [106]. It has direct impacts through modification of physical characteristics such as temperature levels and rainfall distribution, and has indirect impacts in terms of posing changes to other species such as pollinators, pests, disease vectors, and invasive species [34, 97]. As a result, currently, global agriculture and the people dependent on it are hardly affected by climate change [53, 67, 68, 84, 89].

The current and predicted impacts of climate change on the environment and agriculture demand a more novel model like a social-ecological system. Unless such an innovative system is adopted, feeding a global population will be a challenge, and agriculture will continue to bear the brunt of disaster impacts as new risks and correlations emerge [36]. A social-ecological systems perspective of resilience recognizes that humans and nature are intricately interconnected, each affecting the other, often in unpredictable ways [19]. Humans cannot survive without the environment and the ecosystem services it provides, according to a social-ecological systems model of resilience [110]. Under the view of resilience, the social, economic, and ecological systems' capacity to absorb, adapt or transform depends on their exposure and sensitivity to climate-induced hazards and their ability to access climate-smart opportunities or investments that support climate-smart responses [63]. Furthermore, resilience must be built at the individual, community, government, and global levels so that the economic, social, and environmental foundations for generating food security and nutrition for current and future generations are not jeopardized anywhere in the world [50].

In Africa, aggregate change in climate and variability in temperature and rainfall is asserted to be an added factor to already hot environment [67, 68, 91, 112]. In other words, climate change affects agricultural productivity, farm household revenues, and asset values, and it has a wide range of effects on both livelihood and the rural economy [66, 120]. The situation is worst for the population in sub-Saharan Africa (SSA), where rain-fed agriculture is the main source of rural livelihoods and employment opportunities [6, 67, 68]. Due to this reality, poverty and deprivation are becoming the most common situations in the rural areas of SSA [25].

Ethiopia, home to more than 120 million people in Africa, is also among the most vulnerable Countries [74, 76, 104, 108]. Dependence on rain-fed small-scale agriculture for livelihood and the national economy in the face of an unpredictable climate makes the country highly susceptible to the adverse impacts of climate change and variability [101, 120]. Besides, high rates of population growth, land degradation, weak agricultural research and extension services, poor infrastructure for agricultural marketing, low access to rural finance, lack of insurance, inadequate transport network, low use of improved seeds, fertilizers, and chemicals, and the use of traditional farm implements[79, 101, 116]. These are added factors increasing the sensitivity of the sector to climate change-tempted shocks. Another similar study also proves that susceptibility to climate-related hazards and shocks is high for those for whom rain-fed agriculture (crop production, livestock, and fishing) is the main source of livelihood and income [101, 113].

Ethiopian farmers have developed and employed a variety of adaptation strategies in response to the risks associated with climate change and variability, such as changing planting dates and crop varieties; soil and water conservation; irrigation practice; and livestock management [12, 59, 100, 103]. Despite the importance of strategies to improve productivity and live with changed systems, the sector requires more innovative approaches in the face of current extremes. Because climate-related risks to livelihoods, food security, water supply, health, and economic growth are predicted to increase with global warming [57]. In addition, agriculture is not just about food production alone since it is a complex, multi-dimensional, and multi-faceted sector that concerns the efficient use of natural resources, productivity enhancement, and preservation of ecosystems in a manner that can sustain the needs and improvements of human livelihoods in the future [24]. Hence, climate-smart farming focused on sustainable land, soil moisture, and biomass management models could help boost productivity and sequester significant amounts of carbon in soils, thus contributing to the mitigation of GHGs and improving farmers' income [117].

It is of paramount importance to evaluate the livelihood resilience of rural farming households which aims to provide a theoretical reference for relevant authorities to understand the livelihood resilience as well as vulnerability level and establish a resilient management system for the study area [70]. However, such vital studies are scant in Ethiopia, and East Africa. According to Debie and Ayele [28], cultivation of more fertile farmland, saving performance, diversification of income-earning activities, intensification of livestock husbandry practices, access to irrigation, and familiarity with practical technologies are significant determinants to household resilience of smallholder farmers. Alinovi et al. [9] studied livelihood strategies and household resilience to food insecurity in Kenya. They revealed that creating access to basic services, for example, access to credit, water, social safety-nets (transfers per capita), and other related poverty situations are important factors to build resilient livelihood and to reduce household vulnerability to climate change. Tofu et al. [106] studied livelihood resilience to climate change-induced risks in the Borana zone, south Ethiopia. Their finding indicated that the smallholders' adaptive capacity is below the scale of the minimum threshold, implying that livelihoods and their households are poorly resilient. In general, understanding the vulnerability situations and efforts to build resilient livelihood appears vital in the face of climate change. However, studies conducted on the livelihood resilience of smallholders in the poorest and most vulnerable groups, vulnerable ecological areas, poverty-stricken areas and disaster-prone areas are very limited in the Eastern Ethiopia where the study was conducted.

Hence, a comprehensive study was conducted in the study area to address the aforementioned research gaps with the following specific objectives: to identify the key climatic extremes in the study area, to analyze the vulnerability of rural farming households to climatic extremes in the study area, to examine livelihood resilience capacities of rural farming households in the study area, and recommend sustainable and integrated vulnerability reduction, and livelihood resilience building strategies for the study area and beyond.

## Methods and materials

### Study area description

This study was carried out in Chiro district, West West Hararghe Zone of Oromia region of Ethiopia which is located at 8°55′N 40°15′E [33]. Chiro district is situated 326 km from Addis Ababa, the capital city of Ethiopia (Fig. 1). It is bordered on the northwest by Mi'eso, on the west by Guba Koricha, on the east by the Galetti River, on the north by Doba, on the Doba, on the south by Gemechis, and on the northeast by Tulo (Chiro district agriculture and natural resource office). The district is divided into three major agro-ecological zones, including 22 kebeles in the lowland, 13 kebeles in the midland, and 4 kebeles at highland altitude. It is mainly characterized by steep slopes and mountains with rough topography, which is highly vulnerable to erosion problems [40].

The minimum and maximum temperature of the district is affirmed to be 12 °C and 23 °C, respectively. The minimum and maximum rainfall of the district is asserted to be 900 mm and 1800 mm, respectively [42]. The type of rainfall is bimodal, with the main rainy season being from June to September for the highland and midland areas and from March to April for the lowland. Besides, the short rainy season is from March to May for highland and midland and around July for lowland. Although the general character of the rainfall is erratic in nature across the agroecology, it is below normal for the lowland areas. Mixed agriculture (crop and livestock) farming is the main livelihood system of rural farmers in the study area [102]. Khat and coffee are important cash crops in the district [33].

### Research design and approach

In this study, a mixed-research approach that included both positivism and post-positivism techniques was used. A positivist approach is an approach important to collect objective data using quantitative data collection methods and tools. In this approach both the researcher and researched "object" are viewed as independent entities, and the emphasis of positivist researchers are in seeking a reality of understudy which is measurable and objective. For this reason, within the positivist paradigm, quantitative methods are commonly favored over qualitative approaches [88]. On the other hand, the post-positivism approach is the methodology applied to gather subjective data employing qualitative data collection methods and tools. The good thing is that the post-positivists paradigm still holds

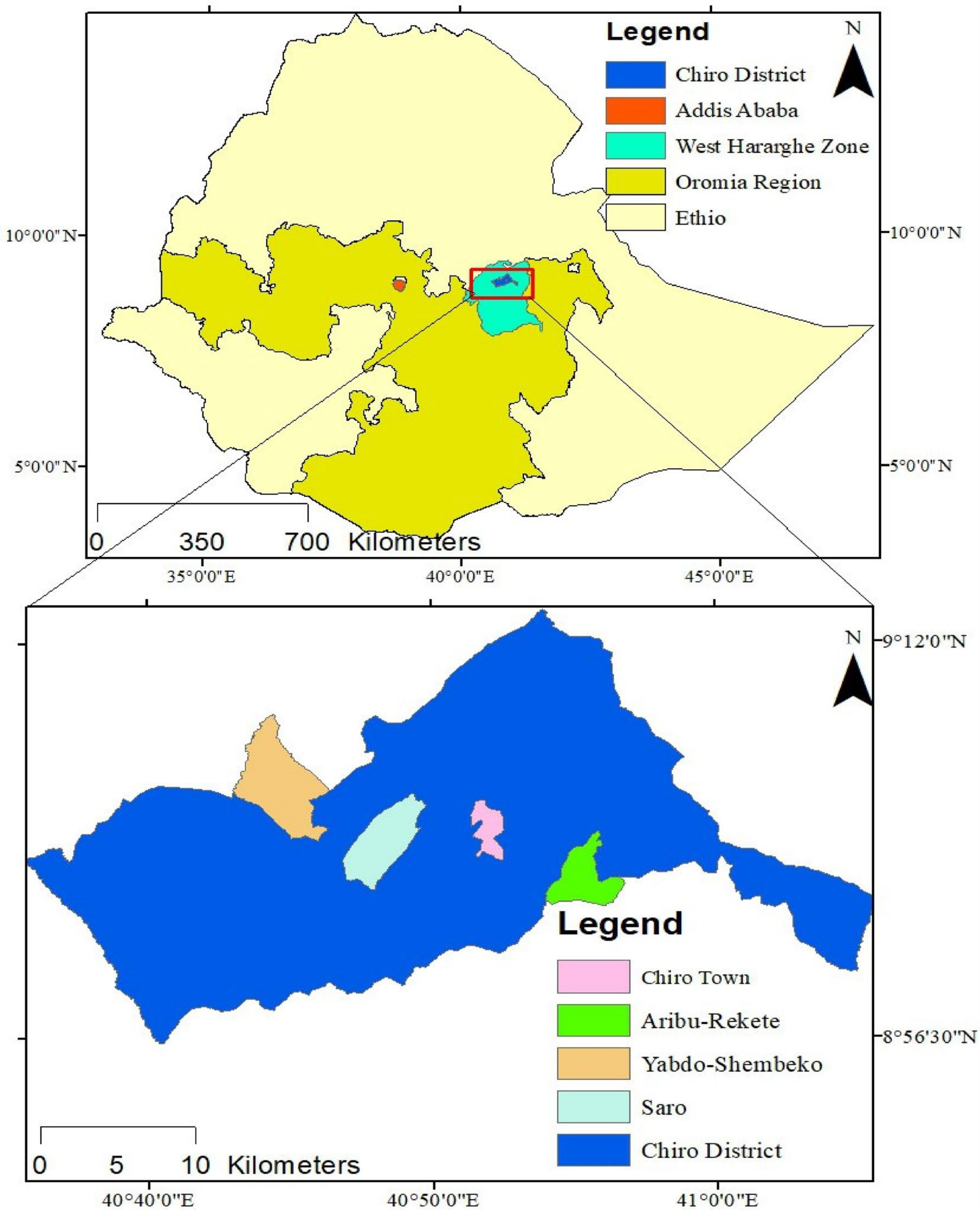


**Fig. 1** Map of the study area

beliefs about the importance of objectivity and generalizability, but it provides additional room to researchers to modify their claims to understandings of truth based on probability and their lived experience, rather than certainty which is actually the focus of positivism [46].

In this study, both research approaches were simultaneously employed with the intent to have sufficient data from varying sources. Applying a mixed approach of positivism and post-positivism methodologies at once in research is vital to increase the chances of validation. Mixing paradigm, therefore, be viewed as a pragmatic style to conducting research and has risen in popularity over the last 20 years [21, 60]. In this context, gathering data using both quantitative and qualitative methods and tools produces a range of results, which are subsequently triangulated to provide an overarching finding [88]. With regard to research designs, the study combined descriptive research design (to collect quantitative data using household survey questionnaire), and exploratory research design (to collect qualitative data employing key informant interview, and focus group discussions).

Based on this, the data required to understand the farmers' absorptive capacity, adaptive capacity, and transformative capacity in the face of climatic extreme episodes were collected and analyzed using positivism research methodologies. On the other hand, farmers' lived experiences, opinions, ideas, and perceptions about how vulnerable rural households' livelihoods are to climatic variability and extremes were gathered, analyzed, and presented by applying a post-positivism research approach.

## Sampling procedures

This study employed a multistage sampling method, and procedure to select the study site and respondents. In the first stage, Chiro district was purposively selected from the Haraghe zone. It was selected because considerable numbers of smallholders are dependent on aid and are heavily affected by climate change. In the second stage, three kebeles (the lowest government structure in Ethiopia), namely Saro, Yabdo-Shembeko, and Aribu-Rekete kebeles, were randomly sampled from the study site. Finally, a total of 397 respondents for objective data collection were determined from the total households of 9428 using Yemane's (1967) formula $n = N/1 + N\ (e^2)$ at $P < 0.05$, and the sample households were drawn by proportional random sampling procedures to the total populations of each district. Furthermore, for subjective data gathering, participants were selected purposively to participate in a total of nine focus group discussions (FDGs) and 13 key informant interviews (KIIs). The numbers of FGDs and KIIs were arrived at through data saturation (e.g., data saturation is the level when the discussants and interviewees began to rises similar issues to already addressed question points). The FGDs and KII discussants were selected from different social groups, including elderly men and women farmers, youth farmers, and experts, based on the level of their exposure to climate, livelihood systems of the community, vulnerability, and experience, and their selection was made purposefully with the help of village facilitators.

## Data types, sources and collection techniques

The study used both primary and secondary sources to collect secondary and primary data. The primary sources of data were local environment, governmental, and non-governmental offices in the study area, rural households, key informants, and focus group discussants in the study area. The secondary sources of the study were annual reports and empirical studies at different levels. To collect primary data, both positivism [94] and post-positivism (i.e., FGDs, KIIs, and observations of study site field) methods were used. While a semi-structured questionnaire was used to collect objective data through the positivism approach, open-ended guiding checklists were used to collect qualitative data applying post-positivism methods. For instance, recurrently occurred climatic extremes observed in the study area were captured using semi-structured questionnaire based on the farmers' experience. On the other hand, the desk review method was used to collect secondary data.

The survey tool for the sample household data collection was derived from the results of the qualitative research and content analysis of the empirical pieces of literature related to the topic. Mainly, the survey tool included the socio-economic, psycho-cognitive, and bio-physical variables that enabled us to make a fact-based conclusion about the study area. To accomplish the interview schedule, enumerators were recruited and trained to be familiar with the objectives of the study, the survey tools, and mechanisms of the interview schedule. The actual data were then collected by trained enumerators under the close supervision of the researchers. The qualitative data, on the other hand, were gathered by the researchers themselves with the assistance of facilitators from various kebeles in the district using open-ended questions focusing on common extreme episodes, the impacts of extreme episodes, and situations of vulnerability and capacity to build resilience to climate change and variability-induced extreme events. The focus group discussions (FGDs) were held with 8–12 participants, and tape and voice recorders were also used to avoid distortion of information during iterative discussions.

## Method of data analysis

The study combined quantitative and qualitative methods of data analysis underpinned by its comprehensive nature. Specifically, simple descriptive statistics (mean, percentages, and frequencies), and an index generating multivariate model (Principal Component Analysis), were employed for analyzing the quantitative data of the study.

Principal component analysis (PCA) is a multivariate technique that analyzes a data table in which observations are described by several inter-correlated quantitative dependent variables with the goal to extract the important information [1]. It is a technique employed for reducing the dimensionality of datasets consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set and at the same time minimizing information loss [78]. It does so by transforming to a new set of variables, the principal components (PCs), which is new uncorrelated variables that successively maximize variance while preserving as much 'variability' as possible and sample's information [61]. With this it makes the data simple to understand and increase the interpretability. According to Holland (2019) the first principal components (Y1) are given by the linear combination of the variables X1, X2, ...,Xp,

$$Y_1 = \alpha_{11}X_1 + \alpha_{12}X_{2+} + \alpha_{1p}X_p$$

or, in matrix notation,

$$Y_1 = \alpha_1^T X$$

The first PC is calculated such that it accounts for the greatest possible variance in the data set. Of course, one could make the variance of $Y_1$ as large as possible by choosing large values for the weights $a_{11}$, $a_{12}$, ... $a_{1p}$. To prevent this, weights are calculated with

$$a_{11}^2 + a_{12}^2 + \cdots + a_{1p}^2 = 1$$

the constraint that their sum of squares is 1.

The second PC is calculated in the same way, with the condition that it is uncorrelated with (i.e., perpendicular to) the first PC and that it accounts for the next highest variance.

$$Y_2 = a_{21}X_2 + a_{22}X_2 + \ldots a_{2p}X_p$$

This continues until a total of p PCs has been calculated, equal to the original number of variables. At this point, the sum of the variances of all of the PCs will equal the sum of the variances of all of the variables, that is, all of the original in-formation has been explained or accounted for. Collectively, all of these transformations of the original variables to the PCs iare:

$$\mathrm{Y} = XA$$

The rows of matrix $A$ are called the eigenvectors of matrix Sx, the variance-matrix of the original data. The elements of an eigenvector are the weights $a_{ij}$, and are also known as loadings. The elements in the diagonal of matrix Sy, the variance–covariance matrix of the principal components, are known as the eigenvalues. Eigenvalues are the variance explained by each PC, and to repeat, are constrained to decrease monotonically from the first principal component to the last. These eigenvalues are commonly plotted on a screen plot to show the decreasing rate at which variance is explained by additional principal components.

The positions of each observation in this new coordinate system of PCs are called scores and are calculated as linear combinations of the original variables and the weights $a_{ij}$. For example, the score for the rth sample on the $k$th PC is calculated as

$$Y_{rk} = \alpha_{1k}X_{r1} + \alpha_{2k}X_{r2} + \cdots + \alpha_{pk}X_{rp}$$

In interpreting the PCs, it is often useful to know the correlations of the original variables with the PCs. The correlation of variable Xi and PC $Y_j$ is:

$$r_{ij} = \sqrt{a_{ij}^2 Var(Y_j)/S_{ii}}$$

Since reduction of dimensionality that focused on a few PCs versus many variables is a goal of PCs analysis, several criteria have been proposed for determining how many PCs should be investigated and how many should be ignored. Among many, we used the criteria of ignoring the PCs whose variance explained are less than 1.

#### *Measuring the resilience capacity*

To measure the resilience capacity of farm households, the composite climate resilience index (CRI) was developed. The composite index of CRI was calculated as a function of five pillars or resilience-building blocks utilizing PCA [23, 65, 71]. The major components or building blocks of resilience in Fig. 2 below included in the analysis were income and food access (IFA), access to basic services (ABS), assets (AST), social safety networks (SSN), and adaptive capacity (AC) [35]. The formula is:

CRI = f(IFAi,t, ABSi,t, ASTi,t, ACi,t,)

CRI is the function of the household that depends on the levels of IFA, ABS, AST, SSN, and AC at time

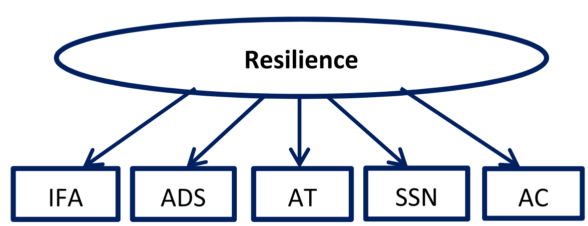


**Fig. 2** Analysis of resilience structure according to RIMA (Resilience Index Measurement and Analysis)

t, plus the error term. Higher values of the resilience index show more resilience in households or communities and vice versa [16]. The indicators of each component are measured on different scales, hence, they were standardized to fall in the range of 0 to 1 [80, 95]. The functional relationship between resilience and the major components or pillars of resilience was taken into account by ensuring that resilience increases with an increase in the value of each indicator or component.

After analyzing the resilience index for the identified sub and major components, the resilience capacity of the farmers' livelihood in the study area was analyzed by categorizing all components under three capacities. Absorptive capacity, adaptive capacity, and transformative capacity are the capacities capable of determining the resilience of farmers' livelihoods to prevent the impacts of changing climatic situations or to bounce back livelihood systems after a shock to the previous normal.

#### *Qualitative data analysis*

Qualitative data collected through key informant interview, and focus group discussion were analyzed with the help of thematic content analysis [86], [105], [47]. The responses from the key informant interviews, and focus group discussions were recorded both electronically, and by hand on the notebook as some of the participants preferred not to be recorded by any audiovisual tools. Moreover, relevant environmental events were recorded through audiovisual tools and hand during participant observation and transect walk sessions. As the number of key informant interviews is manually manageable and the researchers were familiar with the data, no software was employed to analyze the qualitative data. The major criteria underpinning the application of thematic content analysis were: transparency, maximizing validity, maximizing reliability, comparative analysis, and reflexive approach in the process of analysis [86], [105]; [47]. The application of thematic content analysis technique in this study to analyze the qualitative data involved the following six steps [86]: Step one: Reading and Re-reading the recorded qualitative data to be familiar with the content; Step two: Organizing the qualitative data by questions; Step three: Coding the data into exhaustive, mutually exclusive, and specified categories or themes; Step four: Reviewing and revising the coding system; Step five: Looking for patterns across categories or themes; and. Step six: Summarizing findings, and recognizing limitations of the data.

## Results and discussions

### Livelihood strategies of rural households in Chiro District

Crop-livestock mixed farming was identified as the major livelihood of farming households in the study area. With regard to types of crop produced in the study area, sorghum was reported as the major crop type produced in the study area followed by maize and coconut. They also reported Teff even if they did not appreciate its production as that of Khat crop which is becoming the main source of income and taking higher shares of the livelihoods of the individual households in the study area as a cash crop. Regarding livestock, cattle and small remnants, especially goats, were reported to be common in the study area. According to the discussants, Hararaghe was known for meat bulls in the country underpinning the generation of hard currency from meat export. However, they affirmed that climate extremes have significantly disrupted their agriculture dependent livelihoods, and income sources. Discussants of the focus group discussions, and the key informant interviews opined that marketing of khat crop in the form of petty trade is practiced as the major non-farm activities to support the farmers' livelihood with additional income.

The implication for the aforementioned finding is that rural households in the study area are much affected by climatic extremes and sustainable livelihood improvement interventions are required. Generally, livelihood diversification strategies, sustainable natural resource management strategies, and mainstreaming social protection programme into rural poverty reduction strategies may reduce the vulnerability of rural households in the study area, and enhance their resilience capacity. Some scholars propose the four roles for climate-resilient social protection: (i) Reduce overall climate vulnerability: Reducing vulnerability at large in a way that reduces climate risk; (ii) Compensate for negative impacts of climate change responses: Limiting the impacts of climate change response measures; and (iii) Underpin climate change adaptation and mitigation responses: Facilitating adaptation and mitigation behaviours and practices, and supporting livelihoods transformations [18, 37].

### Common climatic extremes in Chiro District

Results in Fig. 3 below show that rainfall variability, increase in local temperature, frequent drought, rainfall reduction, pest infestation, and livestock disease prevalence are common climatic extremes in the study area reported by 96%, 95%, 94%, 92%, 89%, and 87% of the respondents, respectively.

In addition to the above quantitative information, the discussants, and the key informants in qualitative methods of data collection (focus group discussion, and key informant interview substantiated that the effect of

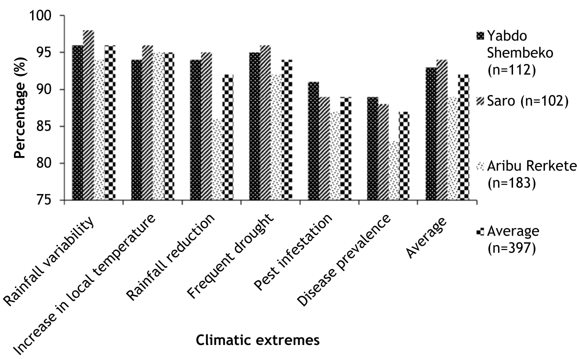


**Fig. 3** Commonly experienced climatic extremes in the Chiro district

climate change and variability has reached to the climax that it is becoming impossible to forecast the onset and succession of rainfall. According to the discussants of the key informant interview, they have been suffering from climatic extremes in the study area for the last fifteen years. For example, when farmers prepare their land, they mostly do not get the rain at the appropriate time, and even if it rains, there is a possibility to offset early before the usual succession period. In addition to this, there is also very high inconsistency during the rainy periods in Ethiopia [100, 103].

Discussants of the focus group discussions, and the key informants also affirm that the amount of rain varies during the rainy seasons (sometimes very high, and sometimes below the minimum, affecting the growth and yearly harvest). They also assert that the variability in rainfall, and temperature, and the climatic extremes have significantly affected the yield of their crops, and the food security status of the rural households in the study area. For instance, they exceptionally reported the consistence increase in temperature in their area for the last fifteen years with negative effects on their livelihoods. Moreover, they affirmed that they have been living with flood and drought which have affected their livelihoods. Specially, drought was reported to occur frequently, and that had led to degradation of the productive capacity of the poor and keeps them extremely susceptible. That also exposed the community to look for external support in a steady manner.

The aforementioned findings imply that the livelihoods of the rural households in the study area were much affected by the common climatic extremes and the variability of rainfall, and temperature in the study area. The result is also consistent with reports from other parts of Ethiopia, and other sub-Saharan African countries, where rainfall is projected to be uncertain and the mean annual temperature rise over Africa is likely to exceed 2 °C [67, 68, 82, 120]. Bekele et al. [11] affirmed that that Ethiopia had experienced 15 drought episodes between 1965 and 2015, some of which resulted in substantial humanitarian crises. Similar reports also indicate that the climate in Africa is already exhibiting significant changes, evident by changes in average temperature, changes in the amount of rainfall and patterns, and the prevalence of frequency and intensity of weather extremes and these changes are negatively affecting agricultural production in Sub-Saharan Africa [69, 74, 76]. According to contemporary findings in climate change, and disaster research, Intense and frequent heat extremes due to increases in temperature, marine heat waves, precipitation variability, agricultural and ecological droughts, and an increase in the proportion of extreme tropical cyclones are the key climatic extremes induced by climate change [52, 55, 67, 68].

### Perceived farmers' vulnerability to the climatic extremes in Chiro District

All the respondents (100%) participated in the rural household survey opined that they are highly vulnerable to the climatic extremes prevalent in the study area. Similar situation was also confirmed from focus group discussants, and the key informants. The participants also asserted that their dependence on rain-fed agriculture, which is highly exposed and sensitive to the impacts of climate change-induced extreme events, underpinned their high vulnerability to climatic extremes in the study area. However, participants of the study affirm that vulnerability of the smallholder farming households differs from household to household, and site to site across the study area. This is because vulnerability of the household is not only determined by external factors but also by the farmers' socioeconomic capacity specific to the individual households. This implies that both the soft resources (e.g., indigenous knowledge, education and training, and intact knowledge accumulated from life experience) and hard or material resources (e.g., land, water, cars, motorcycles, and others) owned by individual farmers matter in determining the households' vulnerability.

Of course, according to the survey, farmers across the study sites were exposed and sensitive to climatic extreme episodes. For instance, farmers in the lowland (Saro kebele) community are more vulnerable to the impacts of climate change-induced shocks as compared to farmers in the highlands (Aribu Rekete kebele). For this, three reasons were identified by the discussants and the key informants. The first reason reported was the highest scarcity of water in the lowland agro-ecology as compared to the highlands. In other words, the prolonged dry season, combined with the area's low moisture content was claimed to significantly affect the brave farmers living in the lowlands. For example, farmers in low land agro ecology in the district were reported to lose their lifeblood livelihood systems underpinned by the water scarcity in the low land agro ecology. In other words, a little increment in local temperature was reported to have the ability to exacerbate the already hot weather and lead to complicated provocations, including the shortage of feed for their animals and resultant transmittable animal diseases and poor moisture content and pests for crop production.

The second reason identified was that the existence of the *Khat* plant in the highlands helps them pass the hardship period. In the highland, the average land size is between 0.5 and 1 hectare, but in the lowland, it is relatively good, with 2 to 4 hectaresfor individual farmers. The third reason identified was farmers' involvement in non-farm activities (petty trade practice particularly by women in trading of khat, goats and industrial commodities) in highland agro-ecology. Because of this, in *Harerge*, women are active economic actors and are believed to be sources of income for their households. For instance, one of the key informants stated the following:

> *"Even if we find a woman involved in petty trade in the lowland, she should be moved from the highland agro-ecology by marriage. This is because, as a cultural lifestyle, women raised in the highland area are far more inclined to trade than women raised in the lowland area (Source: Key informant expert, Agriculture, and Natural Resource Office, Chiro District).*

In general, the level of vulnerability of farmers to climate change-induced shocks was very high based on both the opinions of participating farmers from different agro-ecology and key informant experts from district-level offices. This is the same as the situation in many developing countries like Tanzania. For instance, Tanzania's population well-being and recent positive economic development trajectory are particularly vulnerable to climate change, as evidenced by the widespread damage and hardships imposed by regular drought and extreme rainfall events [49]. This is mainly because climate change is interacting with non-climate drivers and stressors to exacerbate the vulnerability of agricultural systems, particularly in semi-arid areas of the African continent [67, 68, 82, 120]. Accordingly, in this region, different biophysical and socio-economic attributes contributed to their own roles both in exposure, sensitivity, and adaptive capacity differences among smallholder farmers farming in different agro-ecologies and different types of cropping seasons, resulting in huge impacts, particularly in Ethiopia [7, 74, 76], [28], [113]. This implies that the various components of a livelihood asset, both tangible and intangible assets, on which rural people build their lives, are actually limited among the poor, making them highly vulnerable to climatic shocks [52, 54, 67, 68]. In general, studies by scholars in different corners of Africa concluded that the region is one of the most vulnerable continents to climate change and climate variability, a situation aggravated by the interaction of "multiple stresses" occurring at various levels and a low adaptive capacity to withstand as well as bounce back the impacts [15, 18, 37, 90]; [106].

### Adversity posed by climatic extremes on subsistence production of the farmers' in Chiro District

93% and 91% of the respondents opined that crop yield reduction and production and productivity decline in livestock, respectively, are the key reasons underpinning the existing food insecurity and poverty in the study area. Moreover, soil fertility decline, reduced patterns of grass (natural livestock feed), and problem in Belg rainfall were reported to contribute for the aforementioned undesirable situation by 82%, 77%, and 91% of the respondents, respectively (Fig. 4).

The discussants in all focus group discussions also affirmed that rainfall variability, and soil fertility decline are among the major causes of crop yield decline in the study area. Furthermore, the key informants affirmed that shortage of rainfall, and climatic extremes have significantly affected the rural livelihoods in the study area. In other words, they asserted that the undesirable situation of naturally rainfall deficient environment has been exacerbated by climatic extremes in the study area. This finding complies with the assertion of [15] who affirm that climate change is associated with worsening water stress rain-deficient areas contributing for challenges for agriculture.

A shortage of grass, scarcity of water, rising temperatures, and widespread disease all play important roles in reducing livestock production and productivity. The rainfall variability, coupled with the increase in local temperature and deforestation underpin the soil

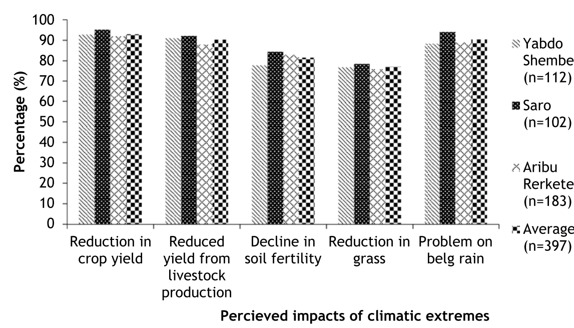


**Fig. 4** Impacts of experienced climate extremes in Chiro District

fertility decline in the study area. The pooled effects of climatic hazards have affected farmers' ability to produce sufficient food for yearly consumption and made them food insecure. As a result, many poor smallholders are dependent on food aid to fill the yearly food gap that consistently happens due to the shared effects of climate change and other socio-economic factors, including the ability to adopt improved farming technologies. This is in agreement with the finding of [49] who attests that changes in rainfall reliability, onset, and cessation are exacerbated by other stresses such as land degradation and insecurity of land tenure in rainfall-dependent rural communities in Africa underpinning crop failure and resultant hunger. Other scholars also assert that climate change has interaction with other factors to significantly affect the African ecosystems, and agriculture for now, and the future [82], [8], [67, 68, 120].

According to the discussants, and the key informants, Hararghe is known for bimodal rainfall (short and long rainy periods). The long rainy period mostly occurs for three months (June to September) and the short rainy period occurs for two months (March and April). Undeniably, both are important for livelihood, but the short rainy season requires more courtesy among the farmers in west Hararghe. They sow their important food crop called Sorghum during this period, especially in March. In comparison to Maize, Teff, Wheat, Haricot beans, Barley, and other crop types, Sorghum is the most widely cultivated cereal for food security in the study area. However, due to high variability or complete failure of short rainy period (Belg season rainfall), crop productivity has been declining from time to time and resulting in chronic food insecurity in the study area. As a result of this, a large number of the households were reported to be dependent on external food support. This situation was well explained by one of the key informants who stated the following:

> *"In the past, before 1997, the farmers didn't miss even a single belg rain, but after that, there was great variability in belg rain in the Chiro district. Currently, it comes in four-year intervals and sometimes it disappears even within four-year intervals. This has been the main reason for persistent food insecurity among farmers. Subsequent dependence of farmers on external aid is directly associated with the patterns of Belg rain, which determines the production of the crucial crop (sorghum). Currently, both the local government and non-government organizations (mainly CARE Ethiopia) allocate huge budgets to fill the "existential food gap." (Key Informant, Chiro District).*

The aforementioned result complies with previous findings by different scholars. For instance, Senbeta [92] found that the trend of gradual and extreme weather change, such as drought, rain delay, erratic precipitation, and heavy and unseasonal rain, has challenged the livelihood of the mid and lowlands of the West-Arsi zone in Ethiopia. Winkler [115] noted that the faster the climate alters, particularly in terms of rainfall and temperature, the greater the risk of associated damage to rain-fed farming. This is consistent with the research reported by the World Bank. According to World Bank [117], agriculture in Sub-Saharan Africa has the lowest productivity, and climate change (through warming, changes in rainfall, increased flooding, extreme heat events, pests, and loss of irrigation water) has severe consequences for agricultural production and worsened the food insecurity situation in the region.

#### Livelihood resilience to the effects of climatic extremes in Chiro District

The results in Table 1 indicate the analysis of livelihood resilience capacity to the climatic extremes in Chiro district. The purpose was to appraise the relative capacity of the households to climatic shocks to absorb, adapt, and transform their livelihood systems under the perspective of the social-ecological system model. This is because, initially, the resilience idea arose in response to complex socio-ecological systems and their ability to adapt while remaining within critical thresholds due to climate change [38]. In addition to this, resilience necessitates successful management of socio-ecological systems to understand the contextual factors that drive changes in resource-use patterns and influence the societal capacity to adapt in the face of stress [50]. Furthermore, the recent report published by the Organization for Economic Coordination and Development (OECD suggests that resilience in the agricultural sector should be distinguished in the way that: risks that are best managed at the farm level are normal business risks, less frequent risks that require market interventions such as insurance and futures markets are larger risks; and catastrophic risks requiring emergency assistance should be identified as frequent risks [77] Accordingly, the households' capacity to absorb, adapt, and transform the climatic stress was assessed and presented in the section below.

*1. Absorptive capacity* is concerned with social, economic, and ecological systems' ability to maintain their original structure by absorbing infrequent and low-intensity risks [63]. It is the capacity that enables the household to stand with climate change and variability-tempted extremes.

The stability component of the absorptive capacity had the index value of 0.49 while the access to informal

**Table 1** Components loading weights of the three resilience capacities and their sub-components

| | Resilience capacity dimensions | COP1 | COP2 | Index |
|---|---|---|---|---|
| I | Absorptive capacity | | | |
| 1 | Stability | | | **0.49** |
| | Soil and water conservation practices | 0.61 | | 0.61 |
| | Climate awareness | 0.57 | | 0.57 |
| | Soil fertility | | 0.81 | 0.29 |
| | Land scape | 0.48 | | 0.48 |
| 2 | Access to informal safety nets (SSN) | | | **0.51** |
| | Social group network | 0.70 | | 0.70 |
| | Network with relatives | 0.70 | | 0.70 |
| | Network with religious group | 0.12 | | 0.12 |
| 3 | Kind & cash saving experience | 0.69 | | 0.69 |
| 4 | Access to remittances | | 0.69 | 0.17 |
| 5 | Access to humanitarian assistance | 0.68 | | 0.68 |
| 6 | Early warning system | | 0.69 | 0.16 |
| II | Adaptive capacity (AC) | | | |
| 1 | Income and food access (IFA) | | | **0.55** |
| | Monthly income | 0.72 | | 0.72 |
| | Consumption from own production | 0.62 | | 0.62 |
| | Consumption from aid | | 0.87 | 0.30 |
| 2 | Access to basic services (ABS) | | | **0.35** |
| | Access to water | | 0.81 | -0.22 |
| | Access to health service | 0.60 | | 0.60 |
| | Access to veterinary service | 0.68 | | 0.68 |
| | Access to extension service | | 0.44 | 0.35 |
| | Access to school service | | | |
| | Access to road service | | | |
| 3 | Diversification of livelihood strategies | | | **0.54** |
| | Mixed farming | 0.26 | | 0.26 |
| | Cash crop production | 0.69 | | 0.69 |
| | Petty trade | 0.68 | | 0.68 |
| 4 | Technology adoption | | | **0.56** |
| | Use of fertilizer | 0.64 | | 0.64 |
| | Use of improved seed | 0.39 | | 0.39 |
| | Agricultural chemicals | 0.66 | | 0.66 |
| 5 | Demographic profile | | | **0.40** |
| | Gender | | 0.81 | 0.20 |
| | Age | 0.60 | | 0.60 |
| | Family size | 0.57 | | 0.57 |
| | Education | | 0.41 | 0.11 |
| | Number of labor force in the household | 0.51 | | 0.51 |
| 6 | Asset ownership (AST) | | | **0.34** |
| | Car | 0.48 | | 0.48 |
| | Motor cycle | | 0.44 | 0.33 |
| | Mobile | | 0.61 | 0.16 |
| | Television | 0.40 | | 0.41 |
| | Radio | 0.42 | | 0.42 |
| | Farm equipment | 0.16 | | 0.16 |
| | Land | 0.35 | | 0.35 |
| | TLU | 0.38 | | 0.38 |

**Table 1** (continued)

| | Resilience capacity dimensions | COP1 | COP2 | Index |
|---|---|---|---|---|
| 7 | Access to financial services | | 0.61 | 0.37 |
| 8 | Capacity building training | | 0.52 | 0.47 |
| 9 | Access to climate information | 0.55 | | 0.55 |
| 10 | Practice of small-scale irrigation | 0.59 | | 0.59 |
| III | Transformative capacity | | | |
| 1 | Access to formal safety nets (SSN) | | | **0.57** |
| | Social assistance received | 0.57 | | 0.57 |
| | Formal social group network | 0.72 | | 0.72 |
| | Involvement in farmers' cooperative | | 0.80 | 0.41 |
| 2 | Availability of markets | | 0.38 | 0.28 |
| 3 | Access to basic services (ABS) | | | **0.46** |
| | Electricity | 0.25 | | 0.25 |
| | Water | 0.26 | | 0.26 |
| | Health service | 0.66 | | 0.66 |
| | Veterinary service | 0.66 | | 0.66 |
| 4 | Access to infrastructure | 0.31 | | 0.31 |
| 5 | Access to agricultural services | 0.44 | | 0.44 |
| 6 | Collective action | 0.57 | | 0.57 |
| 7 | Social cohesion | 0.39 | | 0.39 |
| 8 | Participation in local decision-making | | 0.77 | 0.22 |
| 9 | Local government responsiveness | | 0.52 | 0.35 |
| | Ground total | | | **0.44** |

safety nets (SSN) component had the index value of 0.51. This implies that the stability component of the absorptive capacity is below the threshold (0.5). Soil and water conservation practices (0.61) and climate awareness (0.57) variables had index values above the threshold implying relatively better absorptive capacity. On the other hand, soil fertility status (0.29), and landscape (0.48) had index values below the threshold (0.5) poor absorptive capacity. Social group network (0.70), network with relatives (0.70), Kind and cash saving experience (0.69), and access to humanitarian assistance (0.68) had index values above the threshold implying relatively better absorptive capacity. On the other hand, network with religious group (0.12), access to remittances (0.17), and early warning system (0.16) had the index values below the threshold (0.5) implying poor absorptive capacity of the rural farming households (Table 1).

The aforementioned analysis was also complemented by the views of the focus group discussants and the key informants from Chiro district who affirmed that the rural farming households in the study area have demonstrated experiences in soil and water conservation practices and saving/storage culture, particularly storage of the surplus yield of sorghum by burying it for about four to five years in the ground, supporting the households in many emergency periods, although they have poor cash-saving habits.

The aforementioned analysis implies that the absorptive capacity of the rural households in the study area must be improved by focusing on the access to informal safety nets (SSN) component of the absorptive capacity which had the index value above the threshold. The index values for some variables of this component (social group network, network with relatives, kind and cash saving experience, and access to humanitarian assistance also imply that much attention must be given to these variables to improve the resilience of rural farming households to climatic extremes in the study area. Moreover, strengthening the ongoing soil, and conservation practices, and climate awareness creation programmes will improve the absorptive capacity of the rural farming households in the study area. The aforementioned analysis also asserted the interaction between climate change, and other factors in determining the resilience of rural households.

Scholars attest absorptive capacity of rural households must be managed from the perspective of the social-ecological model to achieve the goals of sustainable rural livelihoods. For instance, practicing sustainable soil, and water conservation is affirmed to have the added values of reducing soil erosion, restoring soil fertility, rehabilitating degraded lands, improving micro-climate, and improving agricultural production and productivity [10, 44, 75, 109].

Given the importance of community life and social connection in Africa (for example, extended family and a variety of ceremonies and celebrations), it would be interesting to see how helpful social capital is for the welfare and poverty status of the households [26]. In addition to this, given the importance of community life and social connection, encouraging the creation of and sustaining of existing social capital is of paramount importance for poverty reduction purposes in SSA. For instance, during the period of emergence, quick support comes from local social relations and groups rather than from another area [26]. Furthermore, to manage the sudden hazard, developing an effective early warning system could contribute to fostering livelihood resilience by improving coping mechanisms and even enhancing adaptive capacity [10, 22]. As communication through early warning systems provides an opportunity to reduce disaster risk by enhancing preparedness, it contributes to strengthening livelihood resilience at the local level [41, 45]. Scholars also assert that social protection can improve poor households' livelihood capital, which in turn can encourage their capacity to cope with natural disasters. In other words, several existing studies affirm that poverty reduction tools, such as social protection (SP), can also be applied to anticipate and absorb the impacts of natural disasters [37].

*2. Adaptive capacity:* this is the capacity that permits the household to live with the extreme episodes. Kaur et al. [63] explained by relating the socio-ecological systems' ability to improve their original structure to manage future risks and thereby use existing strategies to manage risks more effectively to bounce back better in the aftermath of climate shocks [63].

The Income and food access (IFA), diversification of livelihood strategies, technology adoption, access to climate information, and practice of small-scale irrigation component of the adaptive capacity of the rural farming household had the index value of 0.55, 0.54, and 0.56, 0.55, and 0.59, respectively, implying relatively better adaptive capacity of rural farming households in the study area. On the other hand, access to basic services (ABS), demographic profile, asset ownership (AST), access to financial services, and capacity building training component of the adaptive capacity of the rural farming households had the index value of 0.35, 0.40, 0.34, 0.37, 0.47, respectively, implying very poor adaptive capacity (index values below the threshold) of the rural farming households in the study area **(**Table 1**).**

The aforementioned analysis was also complemented with the qualitative information from the focus group discussants, and the key informants. For instance, it was asserted that farmers who have more monthly income and the ability to secure the consumption needs of their household from their own production are in a better position to adapt to the adversity of climatic shocks relative to the ones who are with these challenges. Moreover, access to basic services (including access to water, school, health, road, veterinary, and electricity services) was affirmed to be very poor in the study area. It was also asserted that farmers' in the study area follow diversified livelihood strategies. For instance, they practice mixed farming (i.e., crop and livestock production) as the livelihood system. Moreover, they practice petty trade of Khat which is the major cash crop produced in the study area. It was also further confirmed that women in the study area were the major participants in petty trade and that made them the sources of income in the community. In other words, women in the study area are considered as the major sources of income and made the key role players in the financial systems of the households in the study area. This was also proved by the men's focus group discussants too. According to the local culture in the study area, women are more involved in marketing activities while men mainly take the responsibility for production.

According to the discussants, and the key informants, households led by males, with more young people, with small family size, with a large number of productive family members, and led by heads with a higher level of education are confirmed to be less vulnerable to climatic shocks. For instance, the better the education status, the better the ability to comprehend scientific information related to climate variability and the importance of adopting new farming technologies and planning to use proactive strategies that enable them to curb the severity of impacts. Moreover, the smaller the family size, the lower the dependence ratio, making it easier to manage the consumption needs and other living costs of the household. In the same fashion, the more productive members of the household mean there are possibilities for high productivity because the surplus force can be used as production power.

According to the discussants, and the key informants, compared to households led by older people, households led by younger people are assumed to be more adaptable to new technologies and to have the physical strength to work longer hours. Similarly, male-headed households are also assumed to be more adaptive because, in developing countries like Ethiopia, male counterparts are allowed and are responsible for focusing on outdoor tasks. This provides them with the chance to participate in meetings and other social occasions and creates opportunities to acquire innovative information and new ways of doing things for the productivity and betterment of their households.

According to the information from the focus group discussants and the key informants, households with better ownership of assets, better access to financial services, better access to capacity building training, and better access to climate change information have better adaptive capacity. Moreover, the farm households who have an alternative practice of small-scale irrigation are in a better state to adapt to shocks compared to the farmers who solely depend on rain-fed agriculture. Accordingly, majority of the farmers in the study area were applying small-scale irrigation using water pumps, particularly those farmers who were planting khat crops, and that was claimed to assist their livelihoods to adapt better to the changing climate. This was also confirmed through personal observation during the fieldwork. Generally, the quantitative, and qualitative analysis conducted for the adaptive capacity of the rural farming households indicate very poor resilience, and very high vulnerability of the rural livelihoods system of the rural farming households in the study area.

The above analysis implies that the adaptive capacity of the rural farming households must be improved by focusing on the different components, and the variables in each component. In other words, improving the income and food access (IFA), promoting diversification of livelihood strategies, improving technology adoption, improving access to climate information, improving practice of small-scale irrigation, improving access to basic services (ABS), considering demographic profiles in different service provisions, improving asset ownership (AST), improving access to financial services, and provision of capacity building training to all concerned stakeholders are worth to enhance the adaptive capacity and the resultant resilient rural livelihoods of the farming households in the study area [80].

Adaptation to and resilience against the impacts of climate change is an urgent and growing priority around the world as levels of greenhouse gases in the atmosphere continue to increase with associated climatic risks [27]. Most of the external aid, from the government and NGOs, was based on food aid. Credit-based programs and development-oriented projects should be prioritized as adaptation strategies because they can provide additional income rather than just emergency assistance [83]. Furthermore, the use of improved technology, seeds, and farming practices increases cereal yields, allowing the world to feed itself with less land and lower carbon emissions [48].

Therefore, developing countries should increase the use of advanced technology and improve farming practices to achieve sustainability in food production [5]. Furthermore, the empirical results imply that targeting females, increasing access to agricultural extension services, and creating more awareness about changes in temperatures are important in promoting adaptation and, in turn, securing resilience to climate change and variability-tempted episodes [32]. In general, since agriculture will continue to be a major part of many African economies for a long time, the right kinds of investments, including expanded irrigation, could lead to productivity gains that improve the lives of a large percentage of the rural population [117]. Intangible variables such as institutions and entitlements, knowledge and information, and innovation should all be considered to ensure adaptive capacity to climate change-induced shocks [64].

3. *Transformative capacity* is capacity that refers to systems' ability to fundamentally change their structure and enable new strategies that allow them to move beyond vulnerability thresholds [63].

The access to formal safety nets (SSN) component of the transformative capacity had the index value of 0.57 while the access to basic services (ABS) component had the index value of 0.46. This implies that the access to formal safety nets (SSN) component of the transformative capacity had relatively better resilience compared to the poor resilience of the access to formal safety nets (SSN) component of the transformative capacity of rural farming households in the study area with index value below the threshold (0.5) (Table 1). The aforementioned analysis was also complemented by the qualitative information from focus group discussion, and the key informant interview.

According to the discussants and the key informants, farm households who have access to formal safety nets such as social assistance received, formal social group networks, and involvement in farmers' cooperatives are capable of early recovery from possible impacts of shocks and transforming the opportunities at hand to build resilience. Furthermore, access to markets, basic services, infrastructure, and agricultural services are attested as the most important variables in transforming livelihood systems from highly vulnerable to more resilient livelihood system. The transformed livelihood system increases households' ability to reduce vulnerability as well as their capacity to restore the affected livelihood system to its previous normal state. Moreover, farmers who have access to financial services like credit, market, infrastructure, agricultural or extension services, and those who own multiple types of basic services are more likely to adapt and build resilience to climate change and variability-induced extreme episodes. Similarly, collective action by institutions (both government and non-government), the strength of social cohesion, and the installation of access for farmers to participate in local decision-making were affirmed to help farmers adapt to and prevent the underlying impacts of climatic extremes. Furthermore, if the local government is on board and responsive to the climatic episodes that will support the farmers' ability to transform their lives and build resilience.

On the path to building transformative capacity among the farming communities, they need to assess sectoral readiness. The government's preparedness for the natural climatic variability and its impacts ignited by anthropogenic causes should be assessed first [49]. There is much scientific evidence that vulnerability to climate change is exacerbated by unequal access to resources and decision-making on what to do [30, 87]. Accordingly, the absence of effective coordination and creating a platform for a participatory decision-making process has been identified as a major and typical institutional weakness [93]. The majority of unheard voices in decision-making belong to the poor, and yet they are the ones hardest hit by climate change impacts [43, 73, 119]. Capacity building among the communities' capacity to acquire new skills and knowledge that are required for adaptation is essential to transforming livelihoods [73]. For community capacity enhancement, it is also important to have access to and ownership of resources and assets for increasing the adaptive capacity of vulnerable communities [73, 114].

Moreover, in developing countries, local governments are critical role players in climate change adaptation. Because they have an important influence and control over water, transport, waste management, land use planning, and building codes, all of which are key assets for enhancing adaptation and adaptive capacity [17]. Under the big umbrella of the future plan for resilience, it is also important to give attention to the underlying challenges. During this time, formal social protection works for solutions to reduce the current and future vulnerabilities of the poor and marginalized in the context of climate change and disasters. The solutions may include a range of measures, including the provision of consumption support during lean periods, developing a culture of savings to encourage investments in risk reduction measures; supporting livelihood diversification to adapt to longer-term changes in climate variables; and providing insurance products to manage residual risk, which is of paramount importance [3].

The results in Fig. 5 below indicate that the household's capacity to absorb, adapt, and transform the livelihood systems from the current states of vulnerability to resilience is poor in the study area. According to the surveyed respondents, the current situation of the absorptive, adaptive, and transformative capacity of the farmers is limited to 0.45, 0.47, and 0.4, respectively. On average, the resilience capacity of households to climate change-tempted extremes is 0.44, which is below the minimum capacity of resilience (0.5). In other words, the overall livelihood resilience capacity of farming households in the study area was confirmed to be 0.44 (44%). This was underpinned by poor absorptive capacity (45%), poor adaptive capacity (47%), and poor transformative capacity (40%) of the rural farming households in the study area. This suggests that the capacity of the farmers in the study area to deal with climatic shocks is poor because they have limited absorptive capacity that includes all the various risk management strategies by which households moderate or cope with the impacts of shocks on their livelihoods and basic needs [111]. It was also poor

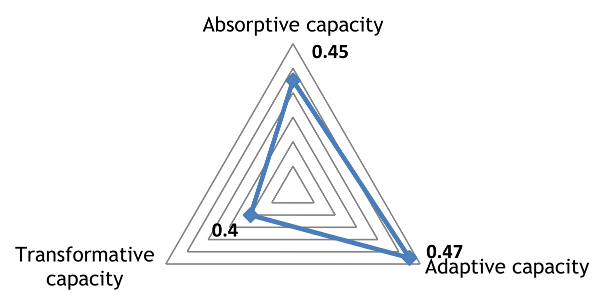


**Fig. 5** Resilience capacities of the Chiro district

because they have a weak adaptive capacity that reflects the capacity to learn, combine experience and knowledge, adjust responses in a proactive way to change external drivers and internal processes, and continue operating in the face of climatic extremes [14]. Furthermore, the observed poor resilience is attributable to their limited transformative capacity, i.e., the capacity to create an enabling environment through investment in good governance, infrastructure, formal and informal social protection mechanisms, basic service delivery, and policies that constitute the necessary conditions for systemic change [13]. In general, from this, we learn that resilience is not something secured by individual effort, rather, it requires capacities ranging from the individual to national levels [111].

The indexes derived from the resilience building block also imply that the level of household resilience is poor. The spider diagram (Fig. 6) below shows that households are relatively better in the state of income and food access while they are poor in the aspect of asset accumulation. In general, the five building blocks of resilience indicate that rural farming households in the study area had poor livelihood systems' resilience with a very low resilience index of 0.47 at the time of the study. This is below the minimum criteria of resilience level in the face of puzzling climate change and climatic extremes.

### Challenges and opportunities to build resilient livelihood in Chiro District

According to the focus group discussants, and the key informants, building resilience in the face of climate change is not an easy path. Despite, the pressing challenge, they affirmed that they have begun the implementation of developmental approaches to rehabilitate the degraded land through physical (e.g., tracing, trench, stone, and soil band) and biological structure works (e.g., planting seedling). They further asserted that the activities were managed and also supported with finance from the governmental and non-government organizations. The key aim of these activities was to strengthen the adaptive capacity of farmers and thereby build their resilience in all aspects. However, due to potential barriers such as an increase in local temperature (97%), frequent drought (94%), Belg rain variability (95%), pest infestation (92%), water scarcity (91%), livestock disease prevalence (88%), and grass shortage (75%), the potential efforts that have been undertaken by different institutions both to mitigate the vulnerability and build adaptive capacity were not showing promising progress (Fig. 7). These exacerbated the limited capacity of production and their ability to feed themselves. As a result, 29 kebeles in the district were receiving social assistance in a consistent manner since 2004. This is because; crop failures and livestock deaths posed significant economic losses and chronic food insecurity in the African region [117]. The situation was exacerbated by climate change presenting severe threats and eroding the essential livelihood assets the poor and the marginalized in the region [6].

The discussants, and the key informants affirm that the good political will from the local government to conserve the natural environment, the ongoing tree planting, and conservation initiatives, the presence of governmental, and non-governmental organizations working on rural livelihoods improvement, and the good working culture of the local communities are the existing opportunities of building resilience of rural farming households in the study area.

Scholars affirm that it is worth identifying, and utilizing the existing opportunities of building resilience of rural households in the study area. In relation to this, Adams et al. [2] attest that climate change is not exclusively an environmental problem that needs to be addressed only from the perspective of scientific or technical ways. In

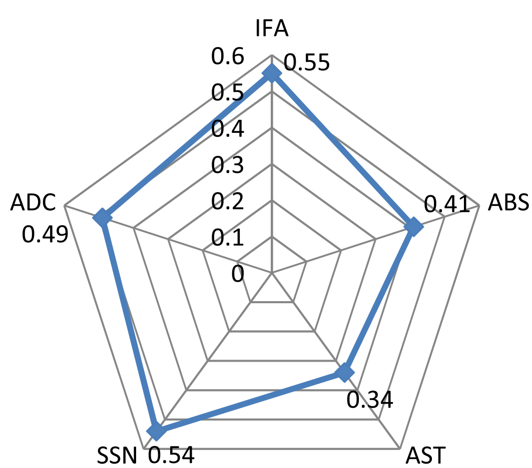


**Fig. 6** Level of resilience based on resilience building blocks of the household

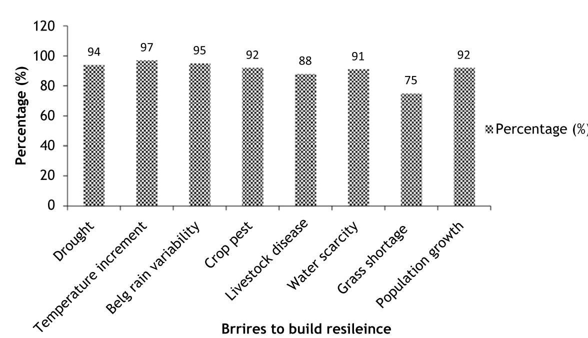


**Fig. 7** Barriers to build resilient livelihood in Chiro district

other words, looking into untapped resources that could be from human creativity or innovation or from the natural environment is an important area which needs our conscious attention. For instance, intact indigenous knowledge, accumulated from life experience from recurrent shocks, the practice of land rehabilitation, and institutional experiences of searching for solutions accrued among both the local government and developmental practitioners have much contribution to build climate resilient rural livelihoods.

Furthermore, the worthy practice of producing cash crops, situational analysis and understanding of farmers about the continuity of climate-induced episodes, and experience of adopting improved technology such as the water pump and small-scale irrigation practices have significant contribution in building the livelihood resilience of the rural households. This implies that rural people are not helpless victims of environmental shocks who fail to defend themselves and their livelihoods through various strategies [83]. Therefore, both national and local capacities must be strengthened to support the efforts to build resilience among the poor [36]. Furthermore, cooperation between individuals and governments, and between national and sub-national levels, is crucial in ensuring effective adaptation responses to climatic stress and the building of sustainable livelihoods for the people dependent on rain-fed agriculture [56]. The urgency to respond to climate change makes it a bit challenging to comply with the requirements of the Paris Agreement, but it also provides opportunities to help African households, communities, economies, infrastructure, and businesses adapt to climate change and transition towards climate-resilient development pathways that boost growth and reduce poverty [4].

## Conclusion and recommendations

In conclusion, farming/ agriculture was identified as the major livelihood of the rural farming households in the study area; rainfall variability, increase in local temperature, frequent drought, rainfall reduction, pest infestation, and livestock disease prevalence are common climatic extremes in the study area reported by 96%, 95%, 94%, 92%, 89%, and 87% of the respondents, respectively; Crop yield reduction and production and productivity decline in livestock were identified as the key reasons underpinning the existing food insecurity and poverty in the study area; the overall livelihood resilience capacity of farming households in the study area was confirmed to be 0.44 (44%) which is below the threshold (0.5). This was underpinned by poor absorptive capacity (45%), poor adaptive capacity (47%), and poor transformative capacity (40%) of the rural farming households in the study area.

In general, the five building blocks of resilience indicate that rural farming households in the study area had poor livelihood systems' resilience with a very low resilience index of 0.47 at the time of the study. This is below the minimum criteria of resilience level (0.5) in the face of puzzling climate change and climatic extremes. Increase in local temperature (97%), frequent drought (94%), Belg rain variability (95%), pest infestation (92%), water scarcity (91%), livestock disease prevalence (88%), and grass shortage (75%) were identified as the pressing challenges of building rural households' livelihood resilience in the study area. Finally, presence of good political will from the local government to conserve the natural environment, the ongoing tree planting, and conservation initiatives, the presence of governmental, and non-governmental organizations working on rural livelihoods improvement, and the good working culture of the local communities were identified as the existing opportunities of building resilience of rural farming households in the study area.

The following recommendations are forwarded to reduce rural households' vulnerability to climatic extremes, and build livelihoods' resilience in the study area and beyond:

- Sustainable management, and conservation of existing natural resources to build the livelihoods resilience capacities of rural households;
- Diversification of rural livelihoods to reduce the vulnerability of rural households to climatic extremes;
- Collaboration, and cooperation of stakeholders in the study area to support vulnerable rural households in the study area;
- Integration of farmers' assets into formal development initiatives in local development processes;
- Integration of climate resilient social protection programmes into poverty reduction, livelihoods' improvement, and food security policies and strategies at local, regional, and national levels;
- Integration of farmers' indigenous knowledge, and innovations into climate change adaptation, and mitigation policies, and strategies at national, regional, and local levels;
- Local capacity development training to farming households, and local development experts in different sectors of agricultural development offices;
- Promoting the application of information communication technologies (ICTs) to effectively manage knowledge, and information at local development level;
- Provision of credit, extension services, and other socio-economic services to enable local farming households sustainably develop agriculture; and

- Utilization of irrigation, and other water technologies to adapt to water shortage in the study area.

We admit that the finding of our study is not a panacea for local development challenges of rural households in Chiro district. Hence, quantitative studies like climate change modeling and prediction must be undertaken in the study area. Moreover, further characterization of climatic extremes in the study area with the help of remote sensing, and GIS technologies may significantly contribute for further understanding of climatic extremes with sustainable solutions in the study area and their interaction with non-climatic factors in affecting the livelihoods of rural households in the study area.

**Acknowledgements**
The authors are grateful for the financial support from the United States of America for International Development (USAID). They are also grateful to World Vision Ethiopia and the International Livestock Research Institute (ILRI) for founding the fund with USAID and for contributing technical support during the research work, respectively. The authors would like to acknowledge Ambo University for hosting the project and providing coordination during the life of the research project work. Researchers would also like to express their gratitude to Chiro district's poor aid-dependent farmers, development agents, and experts for providing relevant data and cooperating with them during fieldwork.

**Author contributions**
DAT (Ass. Prof.) designed the data collection tools, undertook fieldwork and most of the analysis, and developed the manuscript. Mr. MMM contributed data collection. Dr. GSO contributed by reading and editing the manuscript. Accordingly, all the authors read and approved the final manuscript.

**Funding**
The research fund for this study was obtained from the United States of America for International Development (USAID) under the Productive Safety Net Programme (PSNP).

**Availability of data and materials**
The first author will provide data upon reasonable request.

## Declarations

**Ethics approval and consent to participate**
Ethics approval and consent to participate Ethical clearance was obtained from the Research Ethical Review Committee (RERC) of Ambo University, Director of Research and Community Services, and permission and supporting letter was taken from the West Hararghe zone and given to Chiro district. Verbal informed consent from each participant was obtained during data collection. The farmers' were given the right to refuse to take part in the study as well as to withdraw at any time during the study. All participants, farmers' and experts were assured of confidentiality.

**Consent for publication**
The authors obtained permission from all participants in the Chiro district and Ambo University to publish the work.

**Competing interests**
We declare that there is no known competing interest in this research output.

Received: 20 October 2022 Accepted: 8 October 2023
Published online: 03 November 2023

**References**

1. Abdi H, Williams JL. Principal component analysis. WIREs Comput Statis. 2010. https://doi.org/10.1002/wics.101.
2. Adams H, Ahmediv I, Alanizv R, Andre S, Barthelt C, Bhargava M, Bronen R, Diana M. Contreras M.D, Henryx C.N, Fernando N, Shepard HS, Huqiv S, Lawless C, Lewis D, Loster T, McNamara K, Milani A, Tom Mitchell T, Nawrotzk R, Olson L, Prasad V, Rahmanxix A, Rhyneri J, Sosa R.A, Sietz D, De Souza R, Thomalla F, Tellman E, Vivo G, Williamsiv C, Wrathalli D, and Zommers Z. Livelihood resilience In a Changing world: 6 global policy Recommendations for A more sustainable Future 2015.
3. ADB (Asian Development Bank). Strengthening Resilience Through Social Protection Programs. Asian Development Bank Guidance Note. 2018.
4. ADB (ASIAN DEVELOPMENT BANK). (2019). 2019 ANNUAL REPORT. ISBN 978–92–9262–176–6 (print), 978–92–9262–177–3 (electronic), 978–92–9262–178–0 (ebook) Alinovi, L, D'Errico, M, Mane, E, and Romano, D. (2010). Livelihoods Strategies and Household Resilience to Food Insecurity: An Empirical Analysis to Kenya. Report of Development in Dakar, Senegal, 28–30 June, 2010.
5. Alvi S, Jamil F. Impact of climate change and technology adoption on cereal yields in South Asian Countries. Eur J Sustain Develop. 2018. https://doi.org/10.14207/ejsd.2018.v7n3p237.
6. Aniah P, Kaunza-Nu-Dem KM, Quacou EI, Abugre AJ, Abindaw AB. The effects of climate change on livelihoods of smallholder farmers in the upper East Region of Ghana. Int J Sci Basic Appl Res. 2016;28(2):1–20.
7. Asfaw A, Bantider A, Simane B, Hassen A. Smallholder farmers' livelihood vulnerability to climate change-induced hazards: agro-ecology-based comparative analysis in north central Ethiopia (Woleka Sub-basin). Heliyon. 2021. https://doi.org/10.1016/j.heliyon.2021.e06761.
8. Aggarwal P. Data augmentation in dermatology image recognition using machine learning. Skin Research & Technology. 2019;25(6):815–20.
9. Alinovi L, Mane E, Romano D. Measuring Household Resilience to Food Insecurity: Application to Palestinian Households, in Agricultural Survey Methods (eds R. Benedetti, M. Bee, G. Espa and F. Piersimoni), John Wiley & Sons, Ltd, Chichester, UK. 2010. https://doi.org/10.1002/9780470665480.ch21.
10. Baudoin, M, Henly-Shepard, S, Fernando, N, Sitati, A, and Zommers, Z. Early warning systems and livelihood resilience: Exploring opportunities for community participation. December 2014. UNU-EHS Working Paper. 2014
11. Bekele H, Jima HG, Regesu HA. Undernutrition and associated factors among lactating women: community-based cross-sectional study in Moyale District Borena Zone Southern Ethiopia. Hindawi. 2020. https://doi.org/10.1155/2020/4367145.
12. Belloumi M. The relationship between trade, FDI and economic growth in Tunisia: an application of the autoregressive distributed lag model. Econ Syst. 2014;38:269–87.
13. Béné, C, Frankenberger, T, and Nelson, S. Design, Monitoring and Evaluation of Resilience Interventions: Conceptual and Empirical Considerations. IDS WORKING PAPER Volume 2015 No 459. 2015. www.thetopsprogram.org/about-tops
14. Berkes F, Colding J, Folke C. Navigating social-ecological systems: building resilience for complexity and change. Cambridge: Cambridge University Press; 2003.
15. Boko M, Niang I, Nyong A, Vogel C, Githeko A, Medany M, Osman-Elasha B, Tabo R, Yanda P. Africa. climate change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge UK: Cambridge University Press; 2007. p. 433–67.
16. Boukary AG, Diaw A, Wünscher T. Factors affecting rural households' resilience to food insecurity in Niger. Sustainability. 2016;8(3):181.
17. Bourne A, Pasquini L, Donatti IC, Holden P, and Scorgie S. Strengthening the role of local authorities to support community - based adaptation: The case of South Africa. Enhancing Adaptation to Climate Change in Developing Countries. 2017.
18. Costella C, Aalst MV, Georgiadou Y, Slater R, Reilly R, McCord A, Holmes R, Ammoun J, Barca V. Can social protection tackle emerging risks from climate change, and how? A framework and a critical review. Clim Risk Manag. 2023;40(100501):1–16.

19. Cote M, Nightingale JA. Resilience thinking meets social theory situating social change in socio-ecological systems (SES) research. Progress Human Geogr. 2012;36:475.
20. Cotter J, Tirado R. Food security and climate change: the answer is biodiversity. a review of scientific publications on climate change adaptation in agriculture. United Kingdom: Greenpeace International; 2008.
21. Creswell J, Plano Clark VL. Designing and conducting mixed methods research. 2nd ed. Thousand Oaks, CA: Sage; 2011.
22. Daniel AT. Climatic hazards, its effect and coping mechanisms of farmers of Ada'a Berga District of West Shewa Zone, Oromia Ethiopia. J Earth Sci Clim Change Clim Change. 2018;9:9.
23. Demeke M, Tefera N. Sustainable resilience for food and nutrition security: the case of farming rural households in Ethiopia; agricultural development and economics division (ESA). Rom: Food and Agricultural Organization; 2013. p. 2013.
24. Devendra C. Climate change threats and effects: challenges for agriculture and food security. Academy of Sciences Malaysia. 2012
25. Diao X, Hazell P, Thurlow J. The role of agriculture in African development. World Develop. 2010;38(10):1375.
26. Diawara B, Chikayoshi S, Hanson K. Social capital and poverty reduction: empirical evidence from Senegal. Rev Appl Soc Econom Res. 2013;6:41.
27. Dicker S, Unsworth S, Byrnes R, and Ward B. Saving lives and livelihoods: The benefits of investments in climate change adaptation and resilience. March 2021
28. Debie E, Ayele WA. Determinants of smallholder households' resilience to livelihood insecurity in Goncha district, Northwest highlands of Ethiopia. Distributed under a Creative Commons CC. 2021. https://doi.org/10.20944/preprints202112.0437.v1.
29. Edame, G. E, Ekpenyong, A. B., Fonta, W. M., and EJC, Duru (2011). Climate Change, Food Security and Agricultural Productivity in Africa: Issues and policy directions. International Journal of Humanities and Social Science.
30. Ensor J, Berger R. Understanding climate change adaptation. Rugby: Practical Action Publishing; 2009.
31. Eriksen S, Ulsrud K, Lind J. The urgent need to increase adaptive capacities: evidence from Kenyan drylands. In: Nærstad A, editor. Africa can Feed itself. Oslo: The Development Fund; 2007.
32. Etwire MP, Al-Hassan MR, Kuwornu MKJ, Osei-Owusu Y. Smallholder farmers' adoption of technologies for adaptation to climate change in Northern Ghana. J Agric Extension Rural Develop. 2013;5(6):121.
33. Etafa W, Wakuma B, Fetensa G, Tsegaye R, Abdisa E, Oluma A, et al. Nurses' knowledge about palliative care and attitude towards end- of-life care in public hospitals in Wollega zones: A multicenter cross-sectional study. PLoS One [Internet]. 2020;15(10):e0238357.https://doi.org/10.1371/journal.pone.0238357.
34. FAO (Food and Agriculture Organization). Climate change and food security: risks & responses. 2015.
35. FAO (Food and Agriculture Organization). Resilience index measurement and analysis—II (RIMA-II). Rome: Food and Agriculture Organization of the United Nation; 2016.
36. FAO (Food and Agriculture Organization. Boosting smallholder resilience for recovery: Safeguard vulnerable pastoralist and agro-pastoralist households in East and West Africa and the Sahel FAO COVID-19 response and recovery programme Africa. Accra. 2021. https://doi.org/10.4060/cb3768en.
37. Fitrinitia IS, Matsuyuki M. Role of social protection in coping strategies for floods in poor households: a case study on the impact of Program Keluarga Harapan on labor households in Indonesia. Int J Disaster Risk Reduction. 2022;80(103239):1–11.
38. Folke C. Resilience (Republished). Ecol Soc. 2016;21(4):44. https://doi.org/10.5751/ES-09088-210444.
39. Gebreegziabher, T-B. (2007). Potential of the African Environment for the Intensification of Agricultural Production. In: Nærstad. A, (eds). Africa can feed itself. The Development Fund. Oslo Norway
40. Gemechu, F., Babu M., and Zewdu, A. On-Farm Demonstration of Improved Varieties of Faba bean (*Vicia faba*L) in Gemechis, Chiro and Tullo Districts of West Hararghe Zone Oromia National Regional State of Ethiopia. Journal of Agricultural Extension and Rural Development. 2018.
41. Glantz MH, Baudoin M-A. Working with a changing climate, not against it: Hydrometeorological disaster risk reduction: a survey of lessons learned for resilient adaptation to a changing climate. Boulder: Consortium for Capacity Building; 2014.
42. Gosa A. Characterization and analysis of farming system in Chiro District, West Hararghe Zone. J Natural Sci Res. 2016;6:19.
43. Gurung RAR, Weidert J, Jeske A. Journal of the scholarship of teaching and learning. Focusing Students study. 2010;1:28.
44. Haile M, Herweg K, Stillhardt B. Sustainable land management—a new approach to soil and water conservation in ethiopia land resources management and environmental protection department Mekelle University, Ethiopia, and swiss centre for development and environment. Bern: National Centre of Competence in Research (NCCR) North-South University of Bern; 2006.
45. Hall P. Early warning systems: reframing the discussion. The Australian J Emerg Manage. 2007;2(22):1324–540.
46. Hamati-Ataya I. Beyond (Post)positivism: the missed promises of systemic pragmatism. Int Stud Quart. 2012;56(2):291–305. https://doi.org/10.1111/j.1468-2478.2011.00710.x.
47. Hancock, B, Ockleford, E, and Windridge, K. An introduction to qualitative research. National Institute for Health Research (NIHR). 2009.
48. Henderson RD, Cochrane HJ. A Survey of Global Impacts of Climate Change: Replication, Survey Methods, and a Statistical Analysis. NBER Working Paper No. 23646. Issued in August 2017
49. Hepworth D, Rooney R, Dewbery Rooney G, Strom-Gottfried K, Larsen J. Direct social work practice theory and skills. Belmont: Brooks/Cole; 2010.
50. Hertel W.T, Elouafi I, Frank Ewert F, and Tanticharoen M. Building Resilience to Vulnerabilities, Shocks and Stresses—Action Track 5. A paper from the scientific group of the Un food systems summit March. 2021
51. MS Holand. Principal components analysis (PCA) department of geology, University of Georgia, Athens, GA 30602–2501 3 December 2019 the level of livelihood assets ownership among vulnerability group in east coast of Malaysia. European J Sustain Develop 7 3-151. 2019.
52. Hoq MS, Raha SK, Hossain MI. Livelihood vulnerability to flood hazard: understanding from the flood-prone Haor ecosystem of Bangladesh. Environ Manage. 2021;67:532–52.
53. Huong NTL, Yao S, Fahad S. Assessing household livelihood vulnerability to climate change: the case of Northwest Vietnam. Hum Ecol Risk Assess Int J. 2019;25(5):1157–75.
54. Ibrahim ZA, Hassan HK, Kamaruddin R, Anuar RA. The level of livelihood assets ownership among vulnerability group in east coast of Malaysia. Eur J Sustain Develop. 2018. https://doi.org/10.14207/ejsd.2018.v7n3p157.
55. IPCC (Inter-governmental Panel on Climate Change). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Cambridge, United Kingdom and New York, NY, USA: Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press; 2021. p. 3–32.
56. IPCC (Intergovernmental Panel on Climate Change). Climate Change Synthesis Report. 2014.
57. IPCC (Inter-governmental Panel on Climate Change). Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. In Press. 2018.
58. IPCC (Intergovernmental Panel on Climate Change) Summary for Policymakers, in: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.001, 2022d.
59. Jeffcott J. Adaptation to climate change and variability in eastern Ethiopia Haramaya University Ethiopia. Am J Greenhouse Gas. 2013;3(1):2568.
60. Johnson RB, Onwuegbuzie AJ, Turner LA. Toward a definition of mixed methods research. J Mixed Methods Res. 2007;1:112–33.
61. Jolliffe IT, Cadima J. Principal component analysis: a review and recent developments. Phil Trans R Soc A. 2016;374:20150202. https://doi.org/10.1098/rsta.2015.0202.
62. Kandji, T.S, Verchot, L, and Mackensen, J. Climate Change Climate and Variability in Southern Africa: Impacts and Adaptation in the

Agricultural Sector. United Nations Environment Programme. 2006. Web: www.unep.org
63. Kaur N, Agrawal A, Steinbach D, Panjiyar A, Saigal S, Manuel C, Barnwal A, Shakya C, Norton A, Kumar N, Soanes M, and Venkataramani V. Building resilience to climate change through social protection: Lessons from MGNREGS, India. 2019.
64. Kassa T, Kamaylo K, Galtsa D. Oyka E Youth Participation in Agricultural Enterprises as Rural Job Creation Work and Its Determinants in Southern Ethiopia. Hindawi Advances in Agriculture. 2022. https://doi.org/10.1155/2022/5760331.
65. Keil A, Zeller M, Wida A, Sanim B, Birner R. What determines farmers' resilience towards ENSO related drought? An empirical assessment in Central Sulawesi. Indonesia Climate Change. 2008;2008(86):291–307.
66. Kim MK, Pang A. Climate change impact on rice yield and production risk. J Rural Dev. 2009;32(2):17–29.
67. Kogo BK, Kumar L, Koech R. Transforming food systems in Africa under climate change pressure: role of climate-smart agriculture. Sustainability. 2021;13(4305):1–17.
68. Kogo BK, Kumar L, Koech R. Climate change and variability in Kenya: a review of impacts on agriculture and food security. Environ Dev Sustain. 2021;23:23–43.
69. Kotir HJ. Climate change and variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security. Environ Dev Sustain. 2011;2011(13):587–605. https://doi.org/10.1007/s10668-010-9278-0.
70. Li X, Shi X. Smallholders' livelihood resilience in the Dryland Area of the Yellow River Basin in China from the perspective of the family life cycle: based on geodetector and LMG metric model. Land. 2022;2022(11):1427.
71. Lokosang LB, Ramroop S, Zewotir T. Indexing household resilience to food insecurity shocks: the case of South Sudan. Agrekon. 2014;2014(53):137–59.
72. Ludwig, F, van Scheltinga, TC, Verhagen, J, Kruijt B, van Ierland, E, Dellink, R, de Bruin, K, de Bruin, K, and Kabat, P. (2007). Climate change impacts on Developing Countries - EU Accountability. Policy Department Economic and Scientific Policy
73. Malakar, Y. (2013). Increasing Adaptive Capacity: What Is the Role of Local Institutions? Published by Wiley Periodicals, Inc., 350 Main Street, Malden, MA 02148, USA, and 9600 Garsington Road, Oxford, OX42 DQ.
74. Mekonnen Z, Kidemu M, Abebe H, Semere M, Gebreyesus M, Worku A, Tesfaye M, Chernet A. Traditional knowledge and institutions for sustainable climate change adaptation in Ethiopia. Current Res Environ Sustain. 2021;3(100080):1–11.
75. Mekuria W, Vedcamp E, Haile M, Nyssen J, Muys B, Gebirehiwot K. Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. J Arid Environ. 2007;69:270–84.
76. Matewos T. The state of local adaptive capacity to climate change in droughtprone districts of rural Sidama, southern Ethiopia. Clim Risk Manag. 2020;27:1–12.
77. Mesfin, D, Belay Simane, B, Belay, A, Recha, WJ, and Schmiedel, U. Assessing the Adaptive Capacity of Households to Climate Change in the Central Rift Valley of Ethiopia. Climate. 2022
78. Mishra PS, Sarkar U, Taraphder S, Datta S, Swain PD, Saikhom R, Panda S, Laishram M. Multivariate statistical data analysis—principal component analysis (PCA). Int J Livestock Res. 2017;7(5):60–78. https://doi.org/10.5455/ijlr.20170415115235.
79. NAPA (National Adaptation Program of Action). Climate change national adaptation program of action (NAPA) of Ethiopia Country Report. Addis Ababa, Ethiopia. 2007.
80. Nahid N, Lashgarara F, Farajolah Hosseini JS, Mirdamadi MS, RezaeiMoghaddam K. Determining the resilience of rural households to food insecurity during drought conditions in Fars province Iran. Sustain. 2021;13(15):8384.
81. Nærstad A. Africa can feed itself. Oslo: The Development Fund; 2007.
82. Niang I, Ruppel OC, Abdrabo MA, Essel A, Lennard C, Padgham J, Urquhart P. Africa impacts, adaptation, and vulnerability contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University Press; 2014.
83. Niemistö N. The resilience of rural ethiopian livelihoods. a case study from Hararghe zone, Eastern Ethiopia. 2011.
84. Ochieng J, Kirimi L, Mathenge M, Gitau R. Effects of climate variability and change on agricultural production the case of small-scale farmers in Kenya. NJAS Wageningen J Life. 2016;77(1):71.
85. OECD. Strengthening agricultural resilience in the face of multiple risks. Paris: OECD Publishing; 2020. https://doi.org/10.1787/2250453e-en.
86. Ogato SG, Bantider A, Geneletti D. Dynamics of land use and land coverchanges in Huluka watershed of OromiaRegional State, Ethiopia. Environ Syst Res. 2021;10. https://doi.org/10.1186/s40068-021-00218-4
87. Pasteur K. From vulnerability to resilience. Rugby: Practical Action Publishing; 2011.
88. Phoenix C, Osborne N, Redshaw C, Moran R, Stahl-Timmins W, Depledge M, Fleming LE, Wheeler BW. Paradigmatic approaches to studying environment and human health. Environ Sci Policy. 2013;25:218–28.
89. Roy R, Gain AK, Hurlbert MA, Samat N, Tan ML, Chan NW. Designing adaptation pathways for flood-affected households in Bangladesh. Environ Dev Sustain. 2021;23:5386–410.
90. Savage A, Bambrick H, Gallegos D. Climate extremes constrain agency and long-term health: a qualitative case study in a Pacific small Island developing state. Weather Climate Extremes. 2021;31(100293):1–11.
91. Savary S, Ficke A, Aubertot J, Hollier C. Crop losses due to diseases and their implications for global food production losses and food security. Food Secur Sci Sociol Econom Food Product Access to Food. 2012;4(4):519.
92. Senbeta FA. Climate change impact on livelihood, vulnerability and coping mechanisms: a case study of West-Arsi Zone Ethiopia. Lund: Lund University; 2009.
93. Spiess, C. K, E. M. Berger, and O. Groh-Samberg. Overcoming Disparities and Expanding Access to Early Childhood Services in Germany: Policy Considerations and Funding Options. UNICEF Innocenti Research Centre Working Paper IWP-2008–03. 2008.
94. Survey Methods (eds R. Benedetti, M. Bee, G. Espa and F. Piersimoni), John Wiley & Sons, Ltd, Chichester, UK. https://doi.org/10.1002/9780470665480.ch21
95. Tambo JA. Adaptation and resilience to climate change and variability in north-east Ghana. Int J Disaster Risk Reduct. 2016;17:85–94. https://doi.org/10.1016/j.ijdrr.2016.04.005.
96. Tango International. Methodological guide: a guide for calculating resilience capacity. produced by TANGO international as part of the resilience evaluation, analysis and learning (REAL) associate pastoralists' and agro-pastoralists' livelihood resilience to climate change-induced risks in the Borana zone, south Ethiopia: using resilience index measurement approach. Pastoralism. 2018. https://doi.org/10.1186/s13570-022-00263-3.
97. Teshome M. Rural households' agricultural land vulnerability to climate change in Dembia woreda. Northwest Ethiopia Environ Syst Res. 2016;5(14):1–18.
98. Tofu AD, Wolka K. Climate change induced a progressive shift of livelihood from cereal towards *Khat (Chata edulis)* production in eastern Ethiopia. Heliyon. 2023;9(2023): e12790.
99. Tofu AD. Smallholder farmers' perception and responses to climate change and variability in West *Shewa*, Oromia, Ethiopia. J Geogr Environ Earth Sci Int. 2018;18(1):1–16.
100. Tofu AD, Woldeamanuel T, Haile F. Smallholder farmers' vulnerability and adaptation to climate change induced shocks: the case of Northern Ethiopia highlands. J Agric Food Res. 2022;8(2022): 100312.
101. Tofu AD. Farmers' perception to climate change and variability: the case of Mareka District of Dawuro Zone, South Ethiopia. J Environ Earth Sci. 2018;8(6):18.
102. Tofu AD, Wolka K. Climate change induced progressive shift of livelihood from cereal towards *Khat (Chata Edulis)* production in eastern Ethiopia. Heliyon. 2022. https://doi.org/10.1016/j.heliyon.2022.e12790.
103. Tofu AD, Kebede WK, Woldeamanuel T. The impact of alternative energy technology investment on environment and food security in northern Ethiopia. Sci Rep. 2022. https://doi.org/10.1038/s41598-022-14521-2.
104. Tofu AF. Determenants of farmers' adaptation strategies to climate change and variability the case of Mareka District of Dawuro Zone South Ethiopia American. J Human Ecol. 2016. https://doi.org/10.11634/216796221605784.

105. Tofu AD, Wolka K. Climate change induced a progressive shift of livelihood from cereal towards *Khat (Chata edulis)* production in eastern Ethiopia. Heliyon. 2023;9(2023): e12790.
106. Tofu, A.D., Haile, F., & Tolossa, T. (2023). Livelihood vulnerability and socio-economic determinants of households to climate change-induced recurrent drought in Ethiopia. GeoJournal. https://doi.org/10.1007/s10708-023-10904-8.
107. UNDP (United Nations Development Program). Human development report 2015 work for human development. New York: United Nations Development Program; 2015.
108. United State Agency for International Development (USAID). Climate change and conflict in pastoralist regions of Ethiopia. Washington: Mounting Challenges Emerging Responses; 2011.
109. Vancampenhout K, Nyssen J, Gebremichael D, Deckers J, Poesen J, Haile M, Moeyersons J. Stone bunds for soil conservation in northern Ethiopian highlands: Impacts on soil fertility and crop yield. Soil Tillage Res. 2006;90(1–3):1–14.
110. Vasseur L, Jones M. Adaptation and resilience in the face of climate change: protecting the conditions of emergence through good governance. New York: GSDR Brief; 2015.
111. Vaughan E. Resilience measurement practical guidance note series 3: Resilience capacity measurement produced by mercy corps as part of the resilience evaluation, analysis and learning (REAL) Associate Award. 2018.
112. Wamlawa J. The consequence of emerging cash crops on small-scale rural farmers livelihood: a case study of the energy crop jatropha curcas l in kenya. New Zealand: Massey University; 2011.
113. Wassie SB, Mengistu DA, Birlie AB. Agricultural livelihood resilience in the face of recurring droughts: empirical evidence from northeast Ethiopia. Heliyon. 2023;9(e16422):1–18.
114. Williamson T, Hesseln H, Johnston M. Adaptive capacity deficits and adaptive capacity of economic systems in climate change vulnerability assessment. Forest Policy Econ. 2012;15:160–6.
115. Winkler EC. The ethics of policy writing: how should hospitals deal with moral disagreements about controversial medical practices. J Med Ethics. 2005;31(10):559.
116. World Bank. The perception of and adaptation to climate change in Africa. 2007. http://www.thefreelibrary.com/The+perception+of+and+adaptation+to+climate+change+in+Africa
117. World Bank. Ethiopia Country Brief. 2009. Accessed on 13 Oct 2009 from http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/ETHIOPIAEXTN/0,,menuPK:295939~pagePK:141132~piPK:141107~theSitePK:295930,00.html
118. Yamane T. Statistics: an introductory analysis. 2nd ed. New York: Harper and Row; 1967.
119. Yohe G, Tol R. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Glob Environ Chang. 2002;12:25–40.
120. Zeleke G, Teshome M, Ayele L. Farmers' livelihood vulnerability to climate-related risks in the North Wello Zone, northern Ethiopia. Environ Sustain Indicators. 2022;17(100220):1–14.

## Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.