Article

Climate Change Perception and Vulnerability Assessment of the Farming Communities in the Wettest Parts of Ethiopia

Dessalegn Obsi Gemeda[1*]; Diriba Korecha[2]; Weyessa Garedew[3]

[1*]Jimma University College of Agriculture and Veterinary Medicine, Department of Natural Resources Management, Jimma University, Ethiopia

[2]Famine Early Warning Systems Network, Addis Ababa, Ethiopia.

[3]Jimma University College of Agriculture and Veterinary Medicine, Department of Horticulture and Plant Sciences, Jimma University, Ethiopia.

*Correspondence: author e-mail: dasoobsi@gmail.com

Abstract: This study assesses the perception and vulnerability of the farming communities to climate change in the southwestern parts of Ethiopia. Data were collected from 442 households in four districts: Jimma Arjo, Bako Tibe, Chewaka, and Sekoru. The vulnerability of the farming communities was assessed using the households' livelihood vulnerability index. A total of 40 indicators were applied to calculate household livelihood vulnerability to climate change, which were categorized into five major capitals: natural, social, financial, physical, and human. The household perceptions of climate change results showed that there existed a statistically significant relationship between climate change perceptions and changes in rainfall pattern (75.6%, $p<0.001$), temperature pattern (69.7%, $p<0.001$), drought (41.6%, $p=0.016$), flood (44.1%, $p=0.000$), and occurrence of early (53.2%, $p<0.001$) and late rain (55.9%, $p<0.001$). The results showed that households in Sekoru district were the most vulnerable (0.61), while Jimma Arjo district were less vulnerable (0.47) to the effect of climate change. The vulnerability of the households in the study areas is mainly related to the occurrence of drought, lack of much-needed infrastructure facilities and weak institutional support. Links with the financial organization are also lacking among the household. The findings of this study will support policymakers to design climate change adaptation strategies to combat climate change impacts. To support disaster risk management on the one hand and increase the resilience of vulnerable societies to climate change on the other hand, we recommend a detailed assessment in the remaining districts of the region.

Keywords: Southwest Ethiopia; Farming Communities; Climate change; Perception; Vulnerability; Capital; Livelihood vulnerability index

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1. Introduction

The global mean temperature is increasing, reducing agricultural yield and threatening people's livelihoods [1]. An increase in global warming can reduce agricultural yields and threaten food security [2]. Declining agricultural yields expose farming communities to food insecurity and malnutrition; when the agricultural system is exposed to climate extremes, it reduces yield production and aggravates community vulnerability, while having adaptive capacity, the vulnerability of the communities to climate change will be minimized. It is, therefore, crucial to assess household perceptions of climate change and the level of vulnerability of farming communities to inform decision-makers to design effective climate change adaptation strategies.

Household perception of climate change is one of the main elements that can enhance the adaptation process. Farmers who perceive the impacts of climate change are more likely to use various climate change adaptation options to minimize their vulnerability [3]. Developing countries are more vulnerable to the effects of climate change than developed countries due to their financial and technical weaknesses and low capacity to adapt [4, 5]. In contrast, developed nations generally have a low degree of vulnerability and a high degree of adaptive capacity, which itself is a function of natural, technological, human, financial, and social capital [6].

Several studies have shown that Africa is more exposed to climate change than other continents due to its heavy reliance on rain-fed agriculture and limited adaptive capacity [7-12]. Africa is the most vulnerable to climate change [13]; however, it has the lowest emission of GHGs [7]. The eastern and western African countries are projected to be most affected by climate change [14].

Similar to other African countries, the farming communities in SW parts of Ethiopia are vulnerable to climate change due to heavy dependence on agriculture, which is climate-sensitive. A study by [15] indicated that the amount of rainfall in the wettest parts of Ethiopia is inconsistent, and some stations even experienced a declining trend during the crop growing season. The extent of climate change vulnerability varies across regions, economic sectors, and social groups. Climate change has an enormous impact on poor, young, elderly, and marginalized people because of their poor adaptive capacity [16-18]. Some social groups within the same livelihood system have various capacities to minimize the effects of climate change. Poor households are the most at risk of climate change due to a lack of access to risk management [19].

Vulnerability is the outcome of a high susceptibility to harm and a weak capacity to cope and adapt [18]. Vulnerability is the degree to which a system is susceptible to or unable to cope with climate change impacts [20]. Vulnerability to climate change is a function of exposure, sensitivity, and adaptive capacity [21-28]. Vulnerability has a positive correlation with exposure and sensitivity and a negative relationship with adaptive capacity; that is, the higher the exposure and sensitivity are, the more vulnerable, while the higher the adaptive capacity is, the less vulnerable [24, 29-30].

Vulnerability assessment is a prerequisite to designing climate change adaptation strategies [31-33]. To date, various techniques have been used to assess community vulnerability to climate change. For instance, three indicators, namely, exposure, sensitivity, and adaptive capacity, have been used to measure community vulnerability to climate change [24, 30, 34-36]. Others used both econometric and indicator-based methods. The econometric method uses household-level socioeconomic survey data [37], while the indicator-based method uses natural, social, financial, physical, and human capitals and then systematically combines to measure vulnerability status [21, 24, 28, 38-43]. The present study used an indicator-based approach, which is the most common method of demonstrating the power of each factor in vulnerability assessment [44-45].

Several climate change trend assessments have been conducted in SW Ethiopia [46-51]. Although climate change trend assessments have been conducted by different scientists in the past, the vulnerability of households to climate change in SW Ethiopia has received less attention in previous studies. Although the impacts of climate change have already been reported by various scientists in SW Ethiopia, climate change perception and vulnerability assessments are not well documented, especially in SW Ethiopia. In line with this fact, Ethiopia's Climate Resilient Green Economy Strategy claims a lack of climate change vulnerability assessment, monitoring and mainstreaming of climate adaptation [52]. This study therefore aims to address the existing research and knowledge gaps on community vulnerability to climate change in SW Ethiopia. Moreover, the present study is more comprehensive and includes natural, social, financial, physical and human capital to assess household vulnerability to climate change.

2. Materials and Methods

2.1. Study area descriptions

This study was conducted in four Zones [West Shewa, Buno Bedele, East Wollega and Jimma] from western parts of Oromia (Fig 1). Four districts namely, Sekoru, Chewaka, Jimma Arjo and Bako Tibe were purposively selected in the present study. All districts are located in the southwestern part of Oromia. The study area's economy relies heavily on rain-fed agriculture, one of the most vulnerable to climate change. A summary of the study area, including the location, population, topography, climate, especially rainfall and temperature of each district, is provided below.

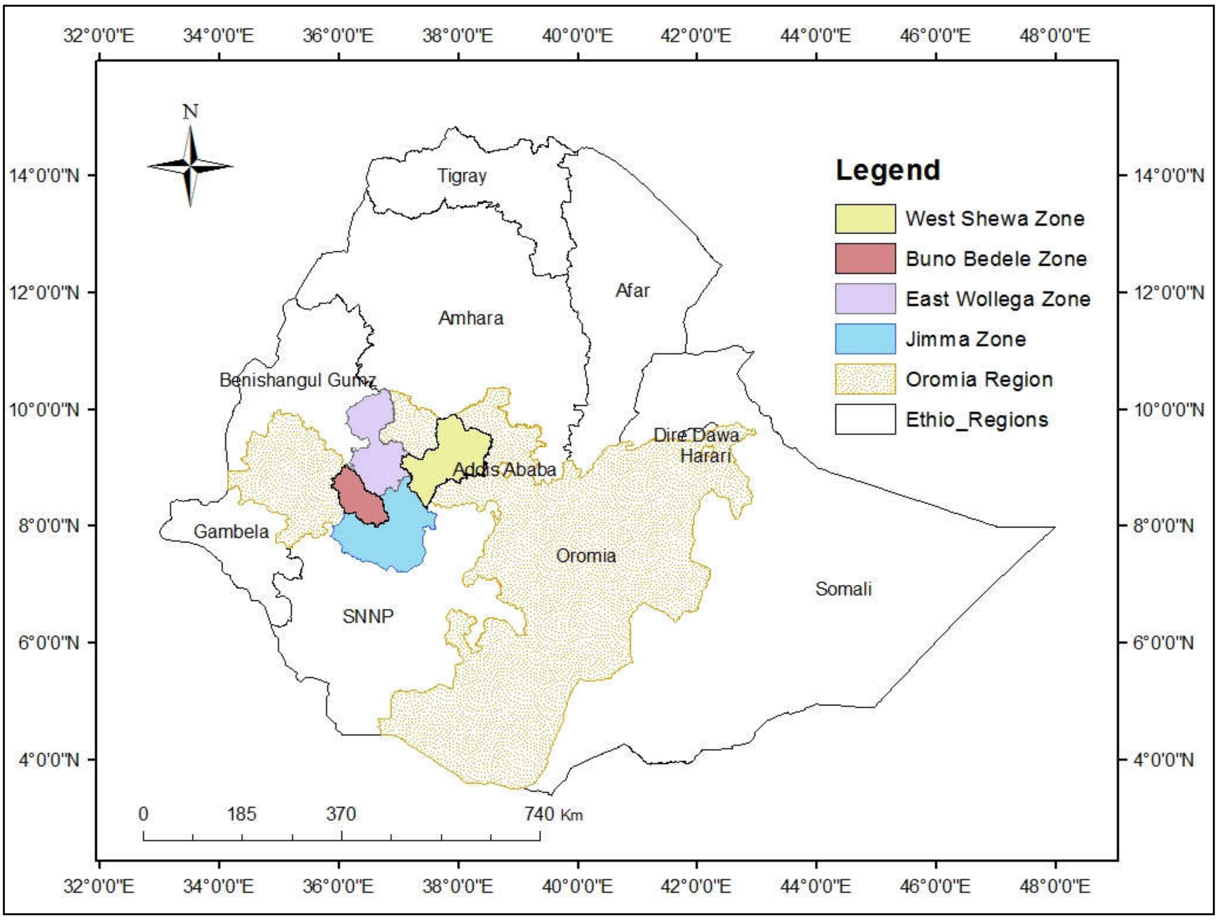

Figure 1. Map of the study area.

Sekoru is one of the 20 districts in Jimma Zone. The district lies between 7.55^{0}N and 7.92^{0}N and 37.25^{0}E to 37.42^{0}E. The district has a total population of 136,320, of which 68,469 and 67,851 are males and females, respectively, as documented by the Central Statistical Agency of Ethiopia [53]. The average annual rainfall is approximately 1,360 mm, with mean annual minimum and maximum temperatures of 13.3^{0}C and 26.2°C, respectively [54].

Chewaka, which is one of the districts in the Buno Bedele zone, is located between 80.43°N and 9.50^{0}N and 35.58^{0}E and 36.14^{0}E. The district has a total of 28 villages (*Kebeles*) with an estimated population of 75,111 and 15, 649 households [55]. The annual rainfall ranges from 800-1200 mm, and the mean temperature varies between 19.8^{0}c and 28.5^{0}C. Chewaka is the largest resettlement area in the southwestern parts of Ethiopia [56]. Maize, sorghum, rice, sesame, and soybean are the most stable crops.

Jimma Arjo district is located in the southwestern parts of the East Wollega Zone and situated between 8.22^{0}N and 8.55^{0}N and 36.20^{0}E and 36.41^{0}E and with a total area of 773 km^2. The district has a population of 86,329, of which 42,093 and 44,236 are males and females, respectively [53]. This district is characterized by a humid tropical climate and receives a mean annual rainfall of 1702 mm with mean minimum and maximum temperature variations between 11.2°C and 13.2°C and 23.8°C and 25°C, respectively [15].

Bako Tibe district is located in the West Shewa Zone and is situated between 8.55^{0}N and 9.14^{0}N and 37.01^{0}E and 37.17^{0}E. The district has a total population of 123,031, of which 61,018 and 62,013 are males and females, respectively [53]. The district receives maximum rain from June to September. The district receives an average annual rainfall of 1006 mm with mean minimum and maximum temperatures between 12.9°C and 28°C, respectively [15]. Teff, maize, and wheat are the main cereal crops grown in this area.

2.2. Study design

A mix of quantitative and qualitative research designs [57-58] is used to assess the vulnerability of farming communities to climate change. Structured questionnaires: Close-ended and open-ended questionnaires were developed to assess household perceptions of climate change and the degree of vulnerability to climate change based on five household capitals: natural, social, financial, physical, and human capital [25, 59]. The five types of capital, including demographic, educational status, climate change and variability, income status of the household, and accessibility to different services and infrastructures, were included based on the literature and key informant interviews. All influencing factors were combined, depending on their association, into five types of capital, with 12 sub-indicators for natural capital, seven for social capital, seven for financial capital, eight for physical capital and six for human capital. After the identification of all subcomponents, equal values were given (normalization as zero and one). A questionnaire-based survey of 442 randomly selected households from purposively selected districts and villages in the study area.

2.2.1. Sampling procedure and sample size

A multistage cluster sampling technique was used to select four of the six zones from the southwestern parts of Oromia. Thus, Sekoru, Chewaka, Jimma Arjo and Bako Tibe districts were selected from Jimma, Buno Bedele, East Wollega, and West Shewa Zones, respectively. Next, four districts, Sekoru (Jimma), Jimma Arjo (East Wollega), Chewaka (Buno Bedele), and Bako Tibe (West Shewa), were selected in consultation with stakeholders based on community exposure to climate change. After the study districts were identified, key informant interviews with district agricultural experts with relevant knowledge on climate change and then sample villages were selected for household interviews. Finally, four villages, namely, Abelti in Sekoru (N=84), Gudure in Chewaka (N=147), Hare in Jimma Arjo (N=121), and Oda Gibe in Bako Tibe (N=90), were selected for data collection.

The main criteria for choosing study sites are the presence of meteorological stations, the variability of rainfall, the occurrence of climatic extremes such as excessive precipitation and increasing temperatures, changes in the climate suitability of some crops, and stakeholder recommendations. In addition to the exposure of communities to climate change, study area selection also takes into account the presence of long historical weather stations, agroecological zones, and topographic variation. The selected sites have significant topographical variation; thus, the elevations are Jimma Arjo (1280.67 to 2563.77 m), Bako Tibe (900 to 1281 m), Chewaka (1130- 2053 m), and Sekoru (1300 to 1800 m). After study villages were identified, a proportional sampling method was used, and a total of four hundred forty-two (442) households were sampled using the technique developed by [60] sample size determination at the 95% confidence level. Accordingly, there were a total of 147 in Chewaka, 121 in Jimma Arjo, 84 in Sekoru, and 90 in Bako Tibe.

In this study, the triangulation method proposed by [61] and used by several authors [62-65] was adopted to use multiple techniques that utilize both quantitative and qualitative data. Ref. [62] demonstrated that triangulation techniques allow researchers to rely on multiple types of data to enhance the accuracy of their conclusions. Triangulation methods enable the integration of the reliability and validity of meteorological data outputs with community perceptions of climate change and community exposure to climate change impacts. The Delphi method [66-69] also adopted to design the questionnaire from eight key informants on community vulnerabilities, adaptation strategies and the existing barriers to adaptation.

2.2.2. Household perceptions of climate change

A household survey was conducted to assess the farmers' perceptions of climate change and the extent of household vulnerability to this change. This study adopted a binary logistic model [70], which uses a binary-based response, that is, the value of one (1) indicates the probability of perceiving climate change, and zero (0) if otherwise. In the binary logistic model, the response probability depends on a set of explanatory variables [71-72] as shown in (Eq.14).

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$$Y_i = \alpha_i + \times_i \beta_i + \varepsilon_i \quad (14)$$

where Y_i is a dependent variable (household awareness level of climate change). Y_i=1 if the household is aware of climate change, and Y_i=0 otherwise (the probability of not being aware of climate change). X_i is the 1 × K vector of other determinants influencing awareness of climate change, β_i is the K × 1 vector of unidentified parameters, and ε_i is the error term.

2.2.3. Livelihood vulnerability index analysis

The livelihood vulnerability index was calculated using five types of capital: natural, social, financial, physical, and human. Each capital/asset is standardized as an index, as recommended by many authors [21, 24, 28, 73]. After standardization of each indicator, the subcomponents were averaged [25, 36] using Eq. 15.

$$M_v = \frac{\sum_{i=1}^{5} Index_{sv}}{n} \quad (15)$$

where M_v is the average index value of one major component, $Index_{sv}$ is index value of each indicator for the respective major components of vulnerability, and n is the number of indicators for each major component of vulnerability.

Indictor-based climate vulnerability assessment was employed by creating a single indicator composite index [22] and normalizing them (zero and one). The household livelihood vulnerability index (HLVI) was applied to assess livelihood vulnerability to climate change [18, 26, 32, 36, 74-75]. Once equal values for the five major components for a district were obtained, the overall HLVI was calculated based on five major capitals, i.e., natural (N), social (S), financial (F), physical (P), and human (H) capital using (Eq. 16).

$$HLVI = \frac{W_{e1}{}^{N} + W_{e2}{}^{S} + W_{e3}{}^{F} + W_{e4}{}^{P} + W_{e5}{}^{H}}{W_{e1} + W_{e2} + W_{e3} + W_{e4} + W_{e5}} \quad (16)$$

where HLVI is the household livelihood vulnerability index, while W_{e1}, W_{e2}, W_{e3}, W_{e4}, and W_{e5} are the weights of indicators for natural (N), social (S), financial (F), physical (P), and human (H) capital, respectively.

For this study, W_{ei}=1 for all i due to the simplicity and uniform importance of the five capitals. The five livelihood assets are equally important in household vulnerability analysis. Each of the five capitals has different sub-components. Hence, natural capital (12 sub-indicators), social capital (7 sub-indicators), financial capital (7 sub-indicators), physical capital (8 sub-indicators) and human capital (6 sub-indicators). Equal values were assigned [76-79] to all sub-components assuming that all contribute to vulnerability to climate change. The higher the value of HLVI, the most vulnerable, while the lower the value, the less vulnerable [24]. In the present study, household vulnerability index score values near one indicate high vulnerability, while values near zero indicate high resilience.

3. Results and discussion

3.1. Sociodemographic variables

The results of the sociodemographic characteristics of the respondents showed that there were 359 (81.2%) male-headed households of the 442-household head, which was almost five times greater than that of female-headed households. Previous studies have shown that male-headed households are more likely to implement climate change adaptation strategies than female-headed households [80-82]. The lower representation of female household heads in the study area was related to cultural patterns. Concerning household age distribution, nearly 13% ranged from 20 to 30. This indicates that some percent of young people the households in the study area.

Regarding marital status, most of the households' heads were married (85.1%), while approximately 8.1, 3.6 and 3.2% were widowed, divorced, and single, respectively. The majority of the household heads, 235, were illiterate (53.2%), while 207 (46.8%) were literate. Of the total literate household heads, 207 (46.8%), 178 (40.3%), and 29 (6.6%) had attained primary and secondary school, respectively. It is clear that educated families can easily evaluate the effect of climate change on their livelihoods and have a major influence on taking appropriate adaptation strategies. Education can enhance individual knowledge [83], which increases resilience to climate shocks. Studies show that there is a positive correlation between education and farmers' willingness to adopt an adaptation strategy to climate change impact [82, 84-86].

Household ages between 31-40, 41-50, and above 51 accounted for 29.2, 25.3, and 32.8%, respectively. Regarding religious affiliation, Islam is the dominant religion in the sample households, with a share of 49.3%, followed by Protestant (35.1%) and Orthodox Tewahedo, with a share of approximately 15.6%. Most of the households had large family sizes. Accordingly, 47.3% of the households had a family size greater than seven, which is greater than the national average family size of 4.9 [87].

Approximately 41% and 11.8% of the household heads had family sizes of 4-6 and 1-3, respectively. The age structure of the household heads in the study area indicates that approximately 42% of the population was concentrated under the age of 15 years, while older age (>65 years) was small (4%). Age composition has a strong influence on the food security of the household. Economically active age groups (15-64) accounted for 54% of the sampled household heads. The sampled household age dependency ratio was 0.87 (87%), which exceeds the country age dependency ratio of approximately 0.77 (77%) [88].

3.2. Farming communities' perceptions about climate change

Because of an increase in temperature and rainfall fluctuations in the study area, the majority of the households (323 out of 442) perceive climate change. The results show that there is a significant relationship between climate change perceptions and changes in rainfall pattern ($p<0.001$), change in temperature pattern ($P<0.001$), drought occurrence ($p=0.016$), recent drought occurrence ($p<0.001$), recent flood occurrence ($p=0.000$), flood frequency ($p=0.009$), and the occurrence of early rain and late rain ($p<0.001$). Most of the households perceive that there is a change in rainfall (75.6%) and change in temperature patterns (69.7%) (Table 1).

Although statistically significant results have been obtained on the occurrence of climate extremes such as droughts and floods, more than 50% of the sampled households do not perceive the occurrence of droughts and floods in the study area. For instance, the majority of the farming community (66.3%) in the study area did not perceive drought occurrence in recent decades. However, 33.7% said they had drought problems in the study area. Some of the elders in the study area confirmed that rainfall is declining and that it may not rain at the right time to prepare the land for agriculture, which could affect the agricultural system. Farming communities claim that the beginning and end of the rainy season are often confusing and different from normal conditions. Similarly, 55.9% and 56.8% of the respondents do not perceive recent floods and frequent flood occurrences in the study area, respectively. However, the results of key informant interviews indicate that extreme events such as droughts and floods have recently increased in the study area. The contrasting findings are because more than 50% of the households were illiterate and did not clearly elaborate about climate change, while the key informants had an analytical capacity to express their knowledge and experiences on drought and flood occurrence.

The farming communities perceived the occurrence of early rain (53.2%, $p<0.001$) and late rain (56%, $p<0.001$). Investigation of farmers' perceptions of climate change is a precondition for assessing adaptation strategies [82]. Rainfall irregularity is one of the key problems of the rain-fed dependent agricultural economy. High interannual variability in rainfall and temperature has been observed recently in the southwestern parts of Ethiopia [15, 54].

Table 1. Estimates of the probit model on climate change perception.

Indicators of climate change	Perceived	Not perceived	Chi-square	P value
Change in rainfall pattern	75.6	24.4	37.14	<0.001**
Change in temperature pattern	69.7	30.3	50.38	<0.001**
Occurrence of drought events	41.6	58.4	5.76	0.016*
Recent drought occurrence	33.7	66.3	17.83	<0.001**
Recent flood occurrence	44.1	55.9	13.48	0.000**
Recent flood frequency	43.2	56.8	6.66	0.009**
Occurrence of early rain	53.2	46.8	16.27	<0.001**
Occurrence of late rain	55.9	44.1	50.79	<0.001**
Taking action against climate change	43.2	56.8	44.81	<0.001**
Crop loss due to rain deficit	47.5	52.5	33.88	<0.001**
Food insecurity due to climate change	49.3	50.7	22.65	<0.001**
Climate change affects human health	47.7	52.3	17.18	<0.001**

Significance levels: * $P \leq 0.05$; ** $P \leq 0.01$

Note: the values in the raw are percentages based on the sample size of 442.

Concerning the association between crop loss and food insecurity with climate change, the number of perceived respondents was comparable with those who did not perceive climate change (p value <0.001). The key informants occasionally recognized the occurrence of drought and floods affecting agricultural crops in the past. The key informants felt that they indicated the increasing trend of extreme drought across the study area. Taking action on the adverse effects of climate change was another concern for the farming communities. The results revealed that approximately 43% (p<0.001) took measures such as crop diversification, crop rotation, and the use of improved crop and livestock varieties, while approximately 57% did not take any actions against climate change effects. A study by [89] indicated that if people do not believe in the occurrence of climate change, they may not implement adaptation actions. Household heads who aware of climate change grow multiple crops at one and alternately grow different crops to improve the soil's nutrients. According to an interview with key informants in Jimma Arjo district, farmers grow Niger seeds and linseed when soil fertility is reduced.

Farmers also grow crops such as peas and beans to increase soil fertility in the study area. Concerning human health issues, there was a significant relationship between climate change and human health (47.7%, p<0.001). Climate change, particularly the increase in temperature in highland areas, likely increases the risk of malaria. A study on Sub-Saharan African countries revealed that malaria prevalence has a significant positive correlation with temperature and precipitation [90].

3.3. Indicator of household vulnerability to climate change

Compared with other sources of revenue, the livelihoods of the farming communities were the most vulnerable to climate change. Weak natural, social, financial, physical, and human capital increases the vulnerability of farming communities to the impacts of climate change. Ref. [16] highlighted that climate change aggravates the problems of vulnerable and poor people in marginal areas. In contrast, access to natural, social, financial, physical, and human capital increased community resilience to climate change [39, 91-92].

3.3.1. Natural capital

The first major component was natural capital, which was assessed by 12 indicators of the household vulnerability index, including availability of fertile land, existence of water resources for irrigation, grazing land, potable water, use of rivers and streams for drinking, climate suitability for agriculture, drought occurrence, flood hazards, exposure to cold temperatures, exposure to hot temperatures, and occurrence of late and early rain. For all 12 sub-indicators, the equal values were given and normalized (0 and one).

The farming communities in the study area were vulnerable to climate change effects. The existing physical capital in the study area is insufficient to fight the effects of climate change. In terms of natural capital, there are large differences between districts. For instance, scores for the natural capital vulnerability index ranged from 0.33 for Jimma Arjo to 0.62, 0.63, and 0.68 for Bako Tibe, Sekoru, and Chewaka districts, respectively. This clearly shows that Chweaka district has less natural capital than Sekoru, Bako Tibe and Jima Arjo districts (Table 2).

Table 2. Natural capital vulnerability index of Jimma Arjo, Bako Tibe, Chewaka and Sekoru districts.

Indicators of household vulnerability index	Composite index			
	Jimma Arjo	Bako Tibe	Chewaka	Sekoru
Availability of fertile land for agriculture	0.45	0.62	0.76	0.94
Existence of water resources for irrigation	0.58	0.77	0.73	0.82
Existence of grazing land for livestock	0.19	0.76	0.68	0.83
Potable water for household	0.57	0.47	0.61	0.67
Agricultural drought occurrence	1.00	1.00	1.00	1.00
Climate suitability for agricultural production	0.09	0.22	0.57	0.23
Rainfall deficit in the study area	0.08	0.56	0.60	0.35
Floods hazardous	0.12	0.68	0.70	0.45
Extreme cold occurrence	0.08	0.46	0.70	0.69
Exposures to extreme high temperature	0.10	0.74	0.56	0.74
Occurrence of late rain	0.37	0.56	0.60	0.41
Occurrence of early rain	0.36	0.61	0.66	0.40
Natural capital vulnerability index	**0.33**	**0.62**	**0.68**	**0.63**

The high vulnerability of Chewaka district may be associated with agricultural drought (1.00), availability of fertile land for agriculture (0.76), the existence of water resources for irrigation (0.73), flood hazards (0.70), extreme cold (0.70), the existence of grazing land (0.68), and the occurrence of early rain (0.66) and late rain (0.60). Natural capital helps communities restore their former state when livelihoods face environmental challenges [41].

Sekoru district was the second most vulnerable based on natural capital, which was connected with the occurrence of agricultural drought (1.00), fertile land (0.94), grazing land (0.83), water resources (0.82), high temperatures (0.74) and extreme cold (0.69). Comparable results were found for Sekoru (0.63) and Bako Tibe (0.62). It is clear that poor rural households with limited land resources for agricultural production are vulnerable to climate change. Moreover, infertile land and limited financial capital to afford chemical fertilizers are the main challenges faced by households in adapting to the effects of climate change.

The scores of agricultural droughts (1.00), water resources (0.77), grazing land (0.76), extreme temperature (0.74), flooding hazard (0.68), fertile land (0.62), and early rain (0.61) were among the major driving forces for the natural vulnerability of Bako Tibe smallholder farmers. The key informant interviews highlight that increases in food shortages in the region are related to an increase in rainfall irregularities during the main growing season and an increase in climate extremes such as droughts and floods. The presence of fertile land (0.45), grazing land (0.19), climate suitability for agricultural production (0.09), exposure to floods (0.12), extreme temperatures (0.10), extreme cold (0.08), and rainfall deficits (0.08) makes Jimma Arjo district less vulnerable than the other three districts.

3.3.2. Social capital

The second major component was social capital, which was assessed using seven indicators (community-based organization membership, access to climate information, access to chemical fertilizers, linkage with financial institutions, access to government subsidies, access to disaster relief assistance and obtaining loans without a contract from friends). All seven components are given equal values and normalized (0 and one). The results of the social capital index score indicated that Jimma Arjo district was less vulnerable (0.29), while Chewaka (0.42) was moderately vulnerable compared to Bako Tibe and Sekoru districts (0.55). At Jimma Arjo district, among the seven subcomponents of social vulnerability indicators, access to government subsidies (0.63) and disaster relief assistance (0.51) are the two major factors that influenced the vulnerability of the farming communities (Figure 2).

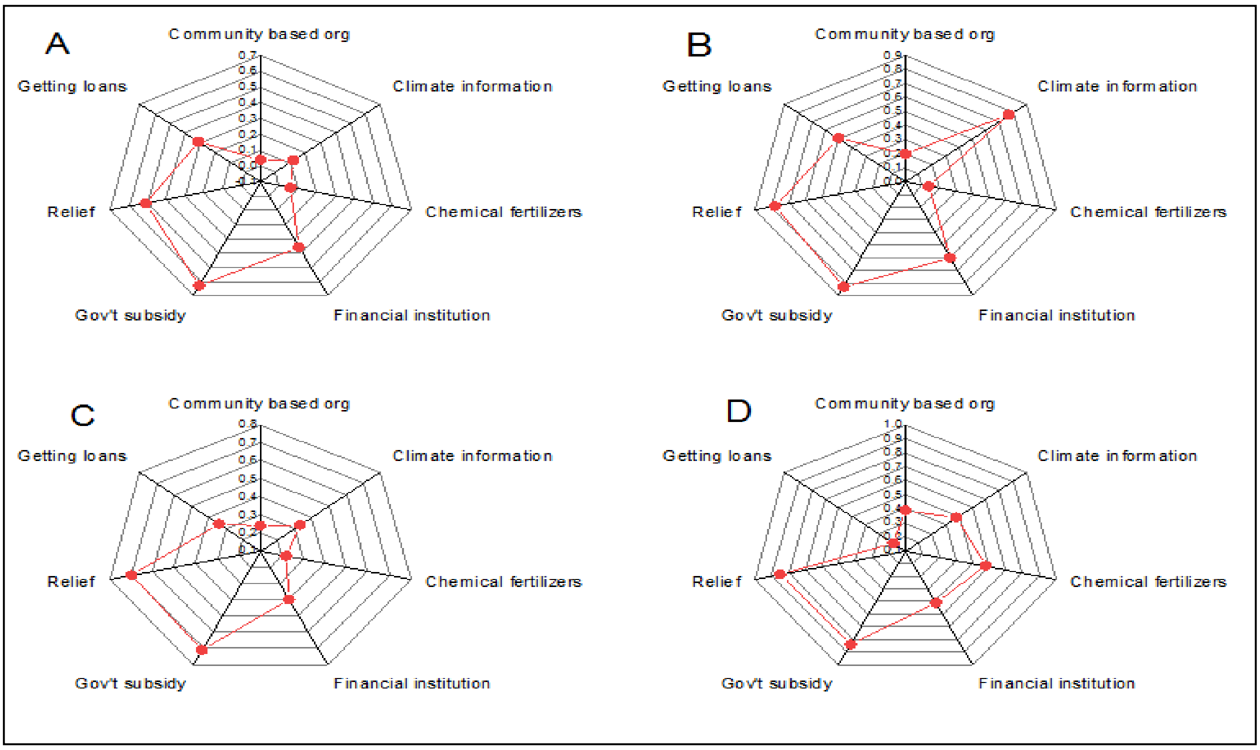

Figure 2. Social capital vulnerability index for A) Arjo district, B) Bako Tibe district, C) Chewaka, and D) Sekoru districts.

The existence of community-based organization (0.04), access to chemical fertilizers (0.06), access to climate information (0.12), the culture of obtaining loans from friends (0.31), and access to financial information (0.36) makes Jimma Arjo district less vulnerable to the impact of climate change. In Chewaka district, access to government subsidies (0.71) and access to disaster relief assistance (0.70) recorded higher indices compared to chemical fertilizers (0.22), community-based organizations (0.24), access to climate information (0.33), obtaining loans from friends (0.34), and access to financial institutions (0.40). Even though the overall social vulnerability for Bako Tibe and Sekoru were identical (0.55), there was a high disparity among the subcomponents of social vulnerability. Both Bako Tibe and Sekoru districts experienced low levels of community access to government subsidies and disaster relief assistance. Social capital plays a crucial role in enhancing public adaptive capacity to bounce back depleted resources [91].

3.3.3. Financial capital

The third main component was financial capital, which included seven: access to banking services, use of microcredit services, use of micro saving services, borrowing from financial institutions, ability to purchase food in the event of crop loss, off-farm income, and diversification of household income (Table 3). The results show that there is great variation among the three districts. For instance, microcredit services (0.83), microcredit savings (0.83), and the culture of borrowing from financial institutions (0.79) increased the vulnerability level of the farming communities in Sekoru district. This means that a large number of households in the district were reluctant to use microcredit services and did not benefit from the existing financial institutions due to religious influence. However, the government is encouraging the local community to use existing microcredit services with low interest to increase their livelihoods. These problems are reported by the key informant interviews. A large proportion of Islamic religions are not interested in using microcredit services and saving because they perceive that all microcredit services have interest. The majority of Islamic religions are more interested in using interest-free microfinance, which is based on the Shariah profit loss sharing mechanism [93].

Table 3. Financial capital vulnerability index of Jimma Arjo, Bako Tibe, Chewak and Sekoru districts.

Indicators of household vulnerability index	Composite index			
	Jimma Arjo	Bako Tibe	Chewaka	Sekoru
Use of bank services	0.62	0.73	0.40	0.51
Use of microcredit services	0.61	0.44	0.40	0.83
Use of micro saving services	0.60	0.46	0.45	0.83
Borrow from financial organization in the past	0.38	0.46	0.66	0.79
Ability to purchase food in case of crop loss	0.21	0.37	0.73	0.55
Off-farm income generation mechanisms	0.69	0.56	0.79	0.55
Household income diversification	0.50	0.62	0.63	0.51
Financial capital vulnerability index	**0.52**	**0.52**	**0.58**	**0.65**

In Chewaka district, off-farm income (0.79) and ability to purchase food in case of crop loss (0.73) and borrowing from the financial organization (0.66) recorded higher index scores among the seven identified financial capital types that influenced the vulnerability level of the household. In Bako Tibe district, use of bank services (0.73) and income diversification (0.62) experienced higher index scores, while off-farm income (0.69) and use of bank services (0.62) recorded the highest index scores in Jimma Arjo district. A study by Ref. [94] financial capital encompasses both household income and household savings. The overall index scores in Jimma Arjo and Bako Tibe districts were identical (0.52). The availability of credit services plays an important role in poverty alleviation [95]. Due to low financial capital, vulnerable groups were not able to afford the rising costs of goods [91, 96].

3.3.4. Physical capital

Physical capital was the fourth main component, which includes eight subcomponents: household land assets, cultivated farmland in hectares >1.5, use of solar energy for cooking, use of agricultural machinery, access to modern irrigation systems, access to health centers < 1 km, access to electricity for cooking, and access to road transportation facilities (Table 4). The results show that four out of eight physical capital types, access to electricity, use of agricultural farm machinery, use of solar energy, and utilization of modern irrigation facilities, scored higher index values, while the areas of household cultivated farmland (<1.5 ha), access to health centers (<1 km), household land assets, and access to road transport scored lower index values.

Jimma Arjo was the most vulnerable (0.67), followed by Bako (0.67) and Chewaka (0.62), while Sekoru (0.61) was relatively less vulnerable than other districts in terms of physical capital. Jimma Arjo was the most vulnerable due to limited access to electricity (0.96), use of agricultural farm machinery (0.95), access to health centers (0.89), and use of solar energy (0.85). The physical capital of Bako Tibe is lower than that of Chewaka and Sekoru districts due to access to electricity (0.96), use

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of modern irrigation infrastructure (0.94), use of agricultural farm machinery (0.91), and use of solar energy (0.90).

Access to health facilities (0.18) had the lowest indicator score in Chewaka, while access to road facilities (0.07) had the lowest indicator score in Sekoru district. Jimma Arjo household land assets had the lowest indicator score (0.17), while access to road transport had the lowest score (0.17). The scores for cultivated farmland in hectares (0.41) and household land assets (0.42) at Chewaka and access to road transport (0.42) and cultivated farmland in hectares (0.52) at Jimma Arjo have lower values, indicating that the household has some resources. Households with good access to physical capital have better livelihood strategies than those without [97].

Table 4. Physical capital vulnerability index of Jimma Arjo, Bako Tibe, Chewaka and Sekoru districts.

Indicators of household vulnerability index	Composite index			
	Jimma Arjo	Bako Tibe	Chewaka	Sekoru
Household land assets	0.17	0.18	0.42	0.19
Cultivated farmland in hectare in hectare <1.5	0.52	0.71	0.41	0.59
Use of solar energy for cooking	0.85	0.90	0.92	0.89
Use of agricultural farm machinery	0.95	0.91	0.88	0.87
Modern irrigation infrastructure	0.78	0.94	0.85	0.90
Access to health centers within <1 km	0.89	0.56	0.18	0.47
Access to electricity for cooking	0.96	0.96	0.79	0.93
Access to road transport services	0.42	0.17	0.53	0.07
Physical capital vulnerability index	**0.69**	**0.67**	**0.62**	**0.61**

3.3.5. Human capital

Human capital is a key indicator of household vulnerability to climate change. In the present study, six subcomponents of human capital, namely, the education status of the household, knowledge of crop varieties, knowledge of improved livestock varieties, household size, household dependency ratio, and household head, were used to assess the existing human capital (Figure 3). According to interviews with key informants, farming communities have access to improved crop varieties, but the supply and demand are not balanced. Some people are unable to obtain improved crop varieties on time from offices of agriculture and natural resources.

Two of the six human capital types, (1) knowledge of crop varieties and (2) male household heads, scored the lowest index values across the four districts. In contrast, four subcomponents, namely, dependency ratio, knowledge of improved livestock varieties, household size, and household education status, scored higher index values in four districts. Regarding livestock varieties, some households benefited from artificial insemination by veterinarians, but compared to improved crop varieties, opportunities to obtain improved livestock varieties are limited across the study area. Educated households are likely to be more aware of climate change and adopt a new technology to minimize climate change-related risks [85, 98-99].

The results show that there is great variation in the dependency ratio across the study areas. For instance, the dependency ratios for Bako Tibe, Jimma Arjo, Sekoru and Chewaka were 0.59, 0.70, 1.03 and 1.15, respectively. Compared to the other districts, Bako Tibe has fewer economically in-active family members, which might be due to the lower number of children. The higher dependency ratio in Chewaka and Sekoru districts might be due to the high human fertility rate, which was influenced by cultural and religious beliefs to use family planning. Having many children is encouraged, and limiting the number of children is a sin in the Islamic religion [98]. Islamic religion discourages the use of family planning to limit the number of children [99].

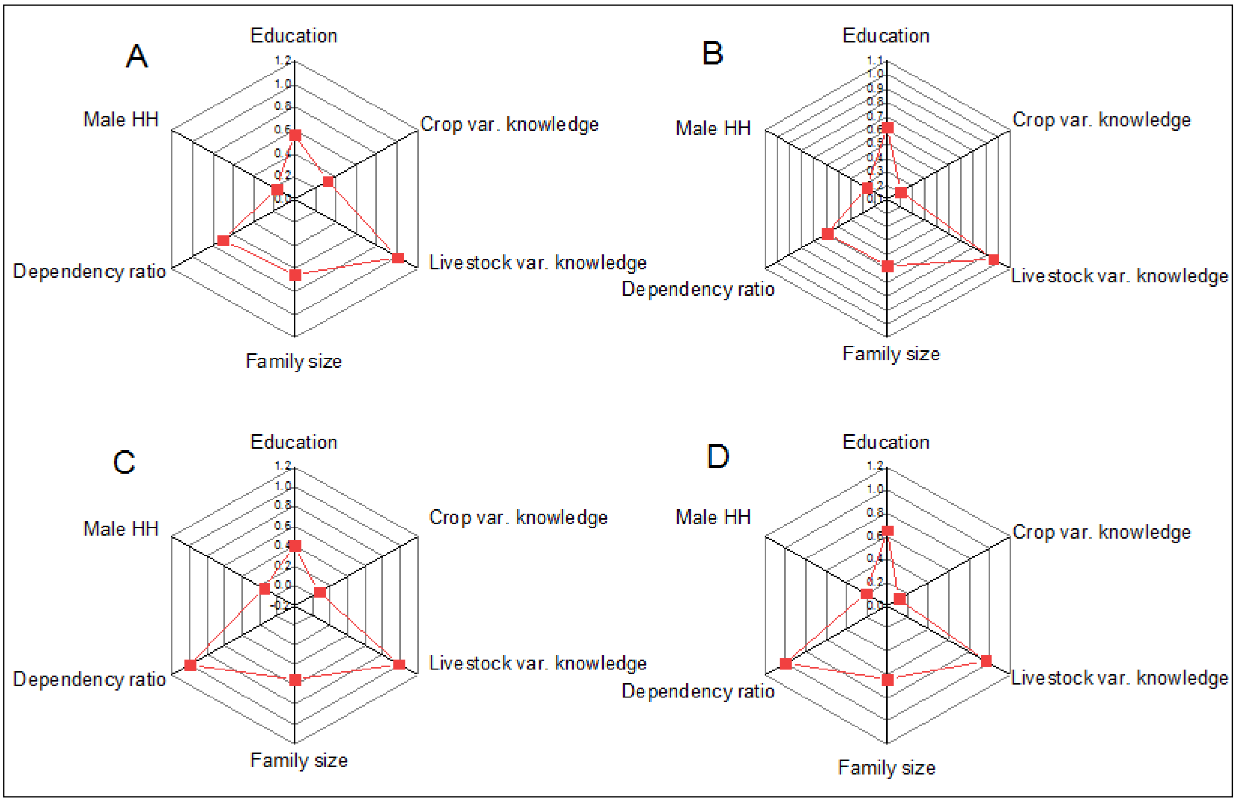

Figure 3. Human capital vulnerability index for A) Arjo district, B) Bako Tibe district, C) Chewaka, and D) Sekoru district.

A higher dependency ratio increased the vulnerability of the household member due to less capacity to afford food prices [75]. The score values for education status were 0.40, 0.56, 0.62, and 0.65 in Chewaka, Jimma Arjo, Bako Tibe, and Sekoru districts, respectively. The educated household has the capacity to deal with climate change and find alternative options [21]. Therefore, the high dependency ratio, limited knowledge on improved varieties of livestock, large household family size, and low educational status of the household heads are the main reasons for household vulnerability to the effects of climate change in the study area.

3.4. Household vulnerability based on five indicators

The radar pectoral of the five major capitals is presented in Figure 4. Results show that Jimma Arjo has relatively better social capital (0.29) and natural capital (0.33). The lowest vulnerability to climate change in Jimma Arjo district was due to the existence of community-based organization (0.04), access to chemical fertilizers (0.06), less exposure to rainfall deficit (0.08), less exposure to extreme cold (0.08), and climate suitability for agriculture (0.09).

The results of the physical capital index revealed that Jimma Arjo scored the highest values (0.69), followed by Bako Tibe (0.67), while Chweaka and Sekoru districts scored 0.62 and 0.61, respectively. Regarding the human capital index, Sekoru and Jimma Arjo districts scored 0.60, while Jimma Arjo scored 0.57. Bako Tibe (0.54) and Chewaka (0.55) scored comparable values. Sekoru district had a lower financial capital (0.65), while Chewaka districts had a moderate social vulnerability index (0.58), and Jimma Arjo and Bako Tibe districts had a lower social vulnerability index (0.52).

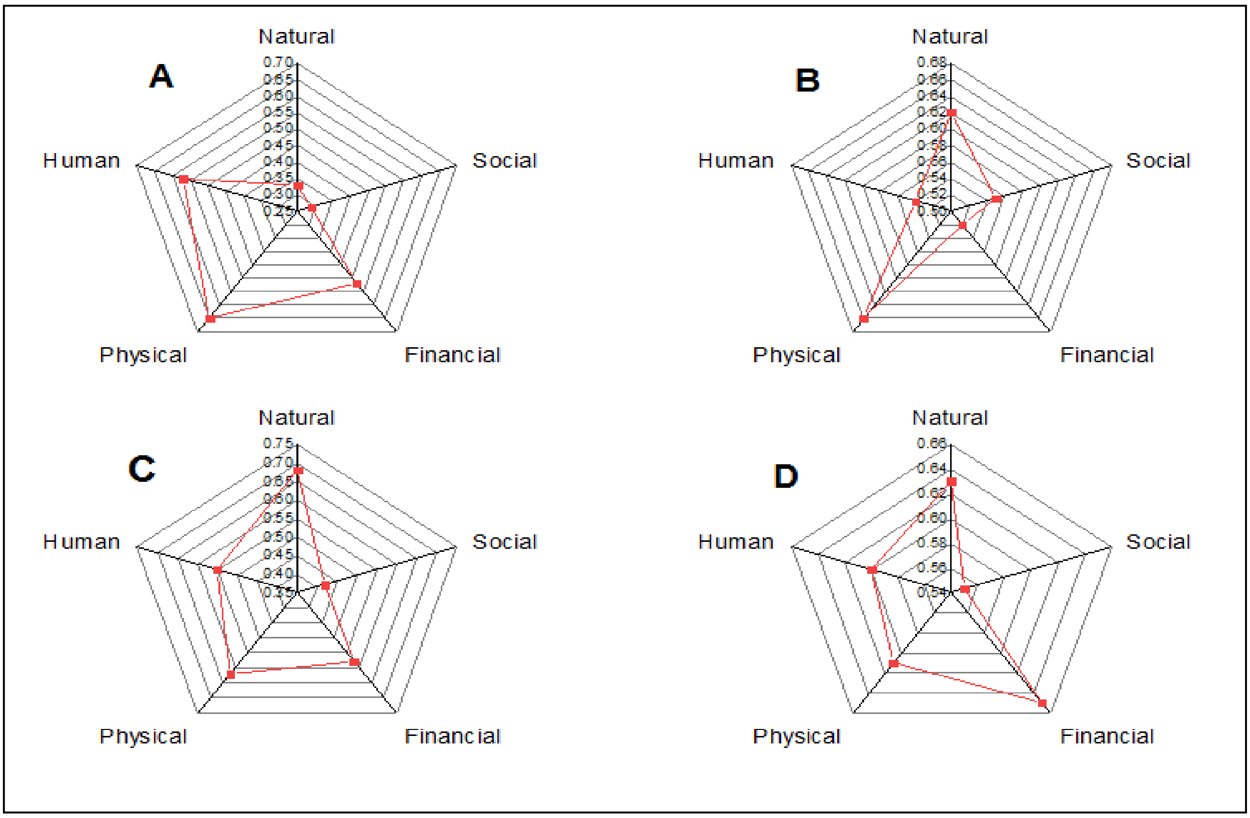

Figure 4. Radar pictorial presentation of overall household vulnerability indices based on five major capitals for A) Arjo district, B) Bako Tibe district, C) Chewaka district, and D) Sekoru district.

Our analysis of the overall household vulnerability index shows that the highest vulnerability is detected in Sekoru district (0.61), followed by Bako Tibe (0.58) and Chewaka (0.57), while Jimma Arjo district experienced the lowest level of vulnerability (0.48) to climate change impact. The overall vulnerability at Bako Tibe and Chewak is more or less comparable, while there is a significant difference between Sekoru and Jimma Arjo districts.

4. Conclusions

The cumulative effects of rainfall irregularities and extreme weather events, such as erratic and excess rainfall, exposed the farming communities to the impacts of climate change. Weak physical and natural capital in Bako, Chewaka and Sekoru and poor financial capacities in Jimma Arjo, Chewak and Sekoru exacerbated the community's vulnerability to climate change. The results show that the educated households in the study area can easily understand the impact of climate change on agricultural production. Public education and awareness-raising are therefore required to minimize the gap between literate and illiterate households. Educated households also described several adaptation options and willingness to combat climate change impacts. Therefore, education is a key factor that influences the household head to adopt climate change adaptation.

The study results show that there is a significant correlation between climate change perceptions and changes in rainfall and temperature patterns as well as the occurrence of climate extremes such as drought and floods. People who can understand changes in rainfall and temperature patterns and the occurrence of extreme weather events such as drought and excessive precipitation will be able to recognize climate change and take necessary adaptation actions. Rainfall irregularities such as the occurrence of early rain and late rain significantly affect agricultural production, and consequently, more than half of the household heads perceived these problems. The findings of the household survey revealed that irregularity of rainfall is a key problem that significantly affects agricultural production in the study area. The key informants highlight that climate extremes, particularly drought and flood, affect agricultural crops.

It is evident that climate change significantly affects the rain-fed dependent agricultural economy, leading to food insecurity. The results of the study showed that the farming communities in Sekoru district were more exposed to the effects of climate change than those in Bako Tibe, Chewaka, and Jimma Arjo districts. Hence, Sekoru (0.61) is highly vulnerable to climate change, followed by Bako Tibe (0.58) and Chewaka (0.58), whereas the lowest vulnerability score was in Jimma Arjo (0.47). The vulnerability of households is mainly associated with climate change impacts such as changes in rainfall and temperature patterns and the occurrence of droughts and floods. Moreover, the lack of much-needed infrastructure facilities, weak institutional support and limited access to natural, social, physical, financial and human capital increased community vulnerability to the effects of climate change.

There is high variation in the extent of household vulnerability to climate change among the districts because of differences in natural, social, physical, financial, and human capitals. The government and other nongovernmental organizations can increase the adaptive capacity of farming communities by providing improved varieties of crops and livestock, affordable agricultural inputs, weather information, and enhancing microcredit services and other possible strategies to minimize the vulnerability of the local community to the effects of climate change. Since the future trend of climate change is full of uncertainties, climate change resilience mechanisms should be in place by governmental and nongovernmental organizations to ensure the sustainability of farmers' livelihoods in the regions and beyond.

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