Research Article

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Climate Change Adaptation Strategies And Their Determinants In Agro-Pastoral Areas Of Southern Ethiopia

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1. Abstract

Now day's climate change is a threat to human beings around the globe and mainly to developing countries. Ethiopia is one of the developing countries in Africa with diversified agro-climatic conditions. The livelihood of the majority of people living in the country depends on agriculture in which pastoralists and agro-pastoralists living in arid and semiarid areas are among them. Most of the time these pastoralists and agro-pastoralist are prone to climate change variability impacts. To adapt with to the threats of climate change agro-pastoralists in the study area use many adaptation strategies, but their adaptation strategies were determined by many factors. So this study aims to identify climate change adaptation strategies and their determinants in the agro-pastoral area of the Bena-Tsemay district in Southern Ethiopia. Primary data were collected through semi-structured questionnaires, observation, and interviews. Besides, the secondary data were also obtained from both published and unpublished sources. The Multinomial logistic regression model with the help of Statistical Package for Social Sciences [SPSS] version 23 and STATA version 14 were used to analyze the data. The multinomial logistic regression was used to estimate the influence of agro-pastoralists' socioeconomic characteristics on the decision to use climate change adaptation strategies. The result showed that age, Gender, marital status, family size, education level, farm experience, climate change perception, household income, purchasing grain, health problem, total land holding, access to climate change information, and access to an extension service had a significant influence on the agro-pastoralists decisions to use climate change coping strategies.

2. Keywords:
Climate Change, Adaptation Strategies, Agro-Pastoralists, Multinomial Logit, And Determinant

3. Introduction

Nowadays, climate change is acknowledged as one of the most is challenging and complex problem confronting the agricultural development worldwide [1]. Climate change particularly affects the fragile ecology of arid and semi-arid lands and puts agro-pastoral communities under severe strains due to the adverse consequences of increasingly erratic rainfall patterns and higher temperatures [2]. Climate change is a global issue caused by an increase in greenhouse gas emissions including carbon dioxide [CO_2], methane [CH_4], and nitrogen [N_2O] linked to human activities. Scientific communities have recognized and realized that climate change has global coverage and clearly shows itself by affecting the world communities with different magnitudes [3, 4]. The more dramatic explanation of the scope of the challenge is described as the earth entering 'the sixth mass extinction of species resulting from the loss of biodiversity threatening valuable ecosystem services and human well-being [5]. As to experts, this is the major and fastest warming development that they have discerned in the Earth's history.

Climate change is apparently shifting rainfall patterns and more recurrent or unpredictable remarkable weather events such as overflows, drought, and high-temperature effects most of the time in Africa today. These influences are reasons for the damage to the agricultural production ability of the region to its enormous level. As a result of these complicated factors, rural farming communities are suffering from climate change impacts like destroying livestock herds, food scarcity, and great loss of the ecosystem. Moreover, the mass migration of people is another impact [6]. Climate change indicators in countries in the East and Horn of Africa already include prolonged droughts, desertification, flash floods, and land degradation, all of which will likely be exacerbated by climate change variability in the medium and long term.

Complex climate profile due to its highly varied geography, with a wide range of climate classifications from very arid to very humid were experienced in Ethiopia. Climate change variability and its impact in Ethiopia are mainly driven by biophysical setup such as altitude, with the country's highlands and lowlands showing significant differences in temperature and rainfall [7]. Climate change models and research

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conducted on climate change suggest that in the future Ethiopia will see further warming of 0.7°C to 2.3°C by the 2020s and between 1.4°C to 2.9°C by the 2050s. The country is one of the extremely vulnerable to the impacts of climate change in the Horn. Climate change variability and its impacts may hold back Ethiopian economic growth or reverse the potential gains made in the economic development of the country and thus exacerbate social and economic challenges. The geographic location on the globe and the diversity in agro ecological conditions, which have their own implications on food production with their effect on the local climate, is also another cause of the country's vulnerability. On top of this, current climate change and variability impacts have appeared as key determinants of threats to the lives and livelihoods of the rural poor in Ethiopia. Variability in seasonal or annual rainfall patterns has been shown to have a negative impact on the production of some major cereals [8, 9, 10]. The country is extremely vulnerable to climate change so the country is repeatedly affected by climate-based threats for example floods and drought.

Moreover, six major flood incidents have arisen in various places of the state in the year's interval from 1988 to 2006. Conversely, the vulnerability of populations living under different social, economic, political, institutional, and environmental conditions is not similar as a result of dissimilarities in adaptive capacity, exposure, and sensitivity [11]. Across the country, millions of farmers, agro-pastoralists, and pastoralists are already experiencing the changing seasonal patterns of temperature and rainfall, which are expected to depress livestock production, particularly the goat farming sub-sector by the coming decades in arid agro-pastoral systems [12]. Thus, climate change is among the world environmental changes that probably harm natural and human systems, economies, and infrastructure. Such an increase in the atmospheric temperature is responsible for global warming, variability in the global and regional climate, and impacts on land ecosystems [13].

Climate change variability has expansive ramifications for Ethiopian farmers as most of the communities in the country practice rain-fed agriculture. The communities living in the country have many adaptation strategies against adverse effects of climate change, yet endeavors are still at a relatively early phase: it is practically more acceptable to state that the endeavors are fragmented and limited. Research conducted by [14], in the southern part of Ethiopia shows that adaptation strategies took place as small changes. A great part of the actual endeavors to climate change adaptation strategies are occurring with regard to unseemly approaches no strong adaptation practices, poor institutional frameworks and implementation practices.

In practice, it is not always clear whether the adaptation strategy is hard or soft. Similarly, what renders risk acceptable, tolerable, or intolerable is subjective, political, economic context-specific, and socially constructed [15]. Hence, adaptation is a need as its effects manifest relatively very quickly. This implies that adaptation measures are paramount for agro-pastoralists' well-being as agriculture mainly livestock production is their main source of income. Significant investigations have been carried out on climate change adaptation and their determinants in certain regions of the country [16, 17, 18]. However, none of them have focused on the South Omo Zone of the Southern Nation regional state, Ethiopia, particularly the Bena-Tsemay district, which is the present study area. Thus, climate change adaptation strategies employed by agro-pastoralists in the study area and their determinant factors have not been adequately assessed and documented. To address the current research gap, the present study was conducted to identify climate change adaptation strategies and their determinants in agro-pastoral area [Bena-Tsemay] of Southern Ethiopia. Evidence at the micro level is very important to introduce site-specific coping interventions.

4. Materials And Methods

4.1. Description Of The Study Area

Bena Tsemay is one of the ten districts in the South Omo Zone. It is named after the ethnic groups of Banna and Tsamai people who are living in this district. It covers an area of 2923 km^2. The total land holding of the area is agricultural land 113,880ha, grazing land 77,116.7ha, shrubs 20,747ha, forest land 25,224ha, and mountain 64,280ha. The total population estimate of the district is about 74,846 of which 38,404 are male and female 36,442. The population density of the district is 20 persons per km^2. Generally, the altitude of the district ranges between 600-1500 meters above sea level. Its astronomical locations are at 5.010N -5.730N latitude and 36.380E - 37.070E longitude. There are two major agro ecologies namely lowland and midland found in the district. The district is characterized by semi-arid and arid climatic conditions with mean annual rainfall averaging from 350 mm to 838 mm. [19, 20].

Benea-Tsemay district has experienced a bimodal rainfall pattern, with a long rain season from April to June and small rains in September and October. The mean annual rainfall ranges between 800-1300mm and the mean value of annual temperature ranges between18-380c. In general, the study area has erratic, variable rainfall and high ambient temperature. The area is characterized by highly sloppy land features even more than 17%. The District has animal resources with an estimated of about 459,779 cattle, 146,868 sheep, 741,237 goats, and 97205 poultry local and improved, 28877 equines, and 32500 bee colonies. The average land holding of the district ranges from 0.15-2.1 hectares [19, 20].

The main farming activity of the study area is a mixed crop-livestock production system [19]. The vegetation cover of the study area is a mixture of Acacia, Boswellia, and Commiphora woody species and short grass types with varying densities of woody vegetation. The major food crops grown in the study area are cereals [maize, sorghum, teff, and pearl millet], pulse and oils crops [common bean, pigeon pea, ground nut, and sesame], root and tuber crops [sweet potato, cassava, taro, Irish potato, and yam], fruits [banana, mango, avocado, papaya, Kazmir and citrus], coffee and spices [coffee, and turmeric]and vegetables [cabbages, hot pepper, onion, and tomato] in respective order of their total production

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and potential [20]. The soil of the area is categorized into three: silt 10%, Sandy loam 60%, and clay 30%.

4.2. Source Of Data And Methods Of Collection

The data used for this study were collected from both primary and secondary sources. Primary data were collected from 246 agro-pastoralists through the cross-sectional households' survey method. The primary data consisted of demographic, basic socioeconomic characteristics, institutional factors, and perceived climate change situations and adaptation practices in the study area were collected from sample households, key informants, and focus group discussions. The related kinds of literature in the field of climate change and researchers' experience in the study site were used as input to prepare questionnaires. The study also used secondary data from journals, bulletins, and governmental offices to supplement data from primary sources.

4.3. Sampling Procedures And Sampling Size

A multi-structured sampling technique was used in order to draw valid inferences from the sample in relation to its respective population size. Bena-Tsemay district is divided into two agro-ecologies. Using the stratified random sampling technique, the total kebeles were stratified into two agro-climatic zones: lowland, and midland. By using the purposive sampling technique, four representative kebeles were selected with the more kebeles from the agro-climatic zone that is dominating the study area. The criteria for the selection were presumed representatives of the sample areas in terms of various environmental attributes like; the status of climate change impact. The information to know the status of climate change impact was gathered from the district agricultural office. Finally, from the sample, each kebele shares a proportionate probability to size [PPS] based on the number of households.

Then [21], formula was used to determine sample HHs to be taken for [1]. Where;

$$n = \frac{z^2 pq}{d^2}$$ --Equation

n= required sample size, Z = 95% confidence limit (=1.96)

P = proportion of the population to be included in the sample (= 20% = 0.2) of the population,

q = 1-P = 1-0.2 (= 0.8), d = margin of error (= 5% = 0.05)

Assuming the total population is greater than 10,000, then the sample size can be calculated as: -

$$n = \frac{(1.96)^2 * (0.2 * 0.8)}{(0.05)^2}$$

= 3.842*0.2*0.8/0.0025 = 246; therefore, the sample size for this study is 246 households.

The next step was determining the number of sample households for each agro-ecologies and kebeles from the sample using the probability proportional to size method to make an equal representation of households in each kebele.

$$ni = \frac{nxNi}{\sum Ni}$$ --Equation [2].

Where n = the sample size the research uses, ni = sample households of the i^{th} kebele, and Ni = total sample households of the i^{th} kebele. A total of 246 households were selected for the purpose of the household survey. The reason for the selection of this method is it is a scientific way that is free of bias in sampling by taking into account the confidence limit, margin of error, and the appropriate population proportion taken in the sample size.

5. Methods Of Data Analysis

5.1. Descriptive Data Analysis

In this study, the sample households' demographic and socioeconomic data were summarized and presented using descriptive statistics such as frequency, percentage and presented in the form of figures, and tables. Also, mean comparison [t-test] and proportion Chi-square tests were used in order to compare the difference among groups for different socioeconomic and demographic variables. This test is mainly employed to know whether the difference is statistically significant or not between the two agro-ecologies. For this analysis, both SPSS version 23 and STATA version 14 were used.

5.2. Econometric Data Analysis

In this study, the determinants of agro-pastoralists' adaptation strategies to climate change were analyzed using a multinomial logit [MNL]. This method was used to analyze the choices the agro-pastoralists make a choice to adapt with climate change and the factors that determine those choices. The multinomial logit model was used based on the previous literature on determinants of agro-pastoralists' adaptation strategies to climate change [22]. This model suits that type of analysis as it permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories [23]. However, the model requires that households are associated with only their most preferred option from a given set of adaptation strategies. The unbiased and consistent parameter estimates using the multinomial logit regression model need to assume independence of irrelevant alternatives that requires that the probability of using a certain adaptation strategy by a given household is independent of the probability of choosing another adaptation method. We are aware that collecting and using only the most preferred adaptation strategy for each household risks underemphasizing the known importance to agro-pastoralists using multiple adaptation strategies, but the approach has allowed a high level of specification of the relations between the dependent variable adaptation strategies and the underlying independent socioeconomic variables.

The model is specified as follows.

Let Y denote a random variable with values {1, 2…J} for a positive integer J and X set of variables [17]. In this study, Y is a dependent variable and represents the adaptation alternatives (strategies) from the set of adaptation measures, whereas the X represents the factors that influence the choice of the adaptation strategies which contain household attributes as shown in Table 1, and P1, P2…Pj as associated probabilities, such that

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P1 + P2 + … + Pj = 1. This tells us how a certain change in X affects the response probabilities P(y = j/x), j = 1, 2 …J. Since the probabilities must sum to unity, P(y = j/x) is determined once the probabilities for j = 2…J are known.

$$P\left(y = \frac{1}{x}\right) = 1 - (P2 + P3 \ldots Pj) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

In the multinomial logit model, it is usual to designate one as the reference category. The probability of a household using one of the adaptation strategies is then compared to the probability of membership in the reference category. Consequently, for a dependent variable used in this model with j categories, that requires the calculation of j − 1 equations, one for each category relative to the reference category, to describe the relationship between the dependent variable and the independent socio-economic variables. The choice of the reference or base category is arbitrary but should be theoretically motivated. The estimation of the multinomial logit model for this study was conducted by normalizing one category which is named as "base category" or "reference estate." The adaptation strategies were grouped into six because agro-pastoralists used more than one strategy, and the base category was "No adaptation strategies." The theoretical explanation of the model is that in all cases, the estimated coefficient should be compared with the base group or reference category [24]. Therefore, the choice of the base or reference category is based on empirical literature and is theoretically motivated. The generalized form of probabilities for dependent or an outcome variable with j categories is:

$$\Pr\left(yi = \frac{j}{x}\right) = \text{prij} = 1 + \frac{\exp(x'\beta j)}{1 + \sum_{j=2}^{J} \exp(x'\beta j)}, j = 1, 2 \ldots J, \text{ For } j > 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

The parameter estimates of the multinomial logit model only provide the direction of the effect of the independent variables on the dependent [response] variable; estimates represent neither the actual magnitude of change nor the probabilities. Differentiate equation. [2] With respect to the explanatory variable provides the marginal effect of the independent variables which give as;

$$\frac{\partial pi}{\partial xk} = Pj(\beta jk - \sum_{j=1}^{j=1} Pj\beta jk) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

Marginal effect of marginal probabilities is the function of probabilities and measures the expected change in probabilities where particular adaptation choice is being made by a unit change of the independent variable from the mean [25].

5.3. Variable Description And Hypothesis

The choice of the explanatory or independent variables was dictated by empirical literature, behavioral hypotheses suggested by it, and data availability. Hypotheses have been developed around explanatory variables concerning their expected influence on agro pastoralists adaptation strategies Table 1, shows the description of and hypotheses around, or expected signs of, explanatory variables used in this study.

Table 1: Description of variables and hypothesis for the impact of the independent variables on the dependent variable

Explanatory variables	Description	Expected sign
Agro ecology	Dummy, 1 = midland, 0 = lowland	-
Age	Continuous (years)	+
Gender	Dummy, 1 = male, 0 = female	+/-
Marital status	Dummy, 1 = married, 0 = single	+/-
Family size	Continuous (years)	+
Education level	Dummy, 1 = literate, 0 = illiterate	+
Farming experience	Continuous (years)	+
Climate change perception	Dummy, 1 = yes, 0 = no	+
Household income	Continuous (Ethiopian Birr)	+
Do you purchase grain	Dummy, 1= yes, 0 = no	+/-
Health problem	Dummy, 1= yes, 0 = no	-
Total land holding	Continuous (hectares)	+
Livestock holding	Continuous (TLU)	+
Access to climatic information	Dummy, 1 = yes, 0 = no	-
Access to extension	Dummy, 1 = yes, 0 = no	-

Source: Own definition based on an extensive review (2023)

6. Results And Discussions

6.1. Categorical Socio-Economic Characteristics Households

Categorical socioeconomic characteristics of households such as; Gender of the household heads, marital status, education level, perception of the household about climate change, purchase of crop to overcome climate change impacts, health problem, access to climate-related information, and access to extension are presented in [Table 2]. The result shows that the proportion of male household heads in lowland [94.44%] and midland [90.38%] was higher in both agro ecologies than female household heads. The result agrees with the study of [26], who noted that the proportion of male household heads was higher than female heads in selected districts of the east Gojjam zone, Amhara region, Ethiopia. The result shows that most of the respondents are males because in the study area female household heads have no right to give information about the household. The majority of the sample households in both agro ecology lowland [97.78%] and

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midland [81.41%] were married. The result shows that statistically there is a significant difference [P < 0.01] between the marital status of sample households of lowland and midland agro ecology. The education status of the sample household heads shows that 43.33% of sample households in the lowland and 35.90% in the midland were literate. The majority of sample household heads in both agro ecology 57.67% in lowland and 64.10% in midland were illiterate. This is because agro-pastoralists do not have awareness about education.

Table 2: Categorical socio-economic characteristics of households

Variables	Agro-ecology			Chi-square
	Lowland	Midland	Total	
	N (%)	N (%)	N (%)	
Gender of households				
Male	85(94.44)	141(90.38)	226 (91.87)	1.260 ns
Female	5(5.56)	15(9.62)	20 (8.13)	
Marital status				
Married	88(97.78)	127(81.41)	215 (87.40)	13.883***
Single	2(2.22)	29(18.59)	31 (12.60)	
Education status				
Literate	39(43.33)	56 (35.90)	95 (38.62)	3.219 ns
Illiterate	51(57.67)	100 (64.10)	151 (61.38)	
Perception about climate change				
Yes	41 (54.44)	41 (73.72)	82 (66.67)	9.540***
No	49 (45.56)	115 (26.28)	164 (33.33)	
Do you purchase grain				
Yes	74(82.22)	144(92.31)	218 (88.62)	5.756**
No	16(17.78)	12(7.69)	28 (11.38)	
Is there health problem				
Yes	59(65.56)	90(57.69)	149 (60.57)	1.478 ns
No	31(34.44)	66(42.31)	97 (39.43)	
Access to information				
Yes	31(34.44)	66(42.31)	97 (39.43)	1.478 ns
No	59(65.56)	90(57.69)	149 (60.57)	
Access to extension				
Yes	51(56.67)	94(60.26)	145 (58.94)	0.304 ns
No	39(43.33)	62(39.74)	101 (41.06)	

N = Number of households; χ^2 = Chi-square; % = percent; ns = Non significant;*** *p<0.01, **p<0.05*, **p< 0.1* significance level
Source: Survey results, 2023

Perceptions of climate change may affect how agro-pastoralists will respond and adapt with their multiple impacts. In other words, it is the perceived changes that are likely to motivate adaptation strategies. Similarly, understanding the perception of agro-pastoralists about climate change and variability impacts in the study area is used to build consensus among local stakeholders on the impact of climate change to implement important and appropriate adaptation strategies. The survey result shows that most of sample respondents 45.56% of sample in the lowland and 26.28% in the midland perceive climate change. The most, 54.44% of the sample respondents in lowland and 73.72% in the midland agro ecologies do not perceive climate change. Statistically, there is a significant difference [P < 0.01] between sample agro-pastoralists of lowland and midland agro ecology. This means sample households who have no perception in the midland agro ecology are higher than those who have perception about climate change. Perception strongly affects how agro-pastoralists respond to climate variability impacts and opportunities, and the precise nature of their behavioral responses to this perception will shape the adaptation options, processes, and outcomes [27]

Purchasing grain is one of the most important variables that affect adaptation option to climate change. Most of the agro pastoralist 82.22% in lowland and 92.31% in lowland used to purchase grain to strengthen the adaptation options. Statistically, there is a significant difference [P < 0.05] between sample agro-pastoralists of lowland and midland agro ecology. This means sample households who purchase grain to strengthen adaptation option in both agro ecologies were higher than those who do not purchase grain. Most of the time if the household head have a health problem he or she do not practice adaptation strategies. Most of the sample households 65.56% in lowland and 57.69% in midland face health problem, while 34.44% in lowland and 42.31% in the midland responded that they do not face health problem.

Access to climate change information is one of the most important factors that affect agro-pastoralists readiness to overcome climate

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change impacts. The result of this study shows that 34.44% of sample respondents in lowland and 42.31% in midland have access to climate change information. Most of the respondents 65.56% in the lowland and 57.69% in the midland do not have access to climate change information in the study area. Agro-pastoralists who have access to extension services adapt positively with climate change impacts. This means agro-pastoralists having access to agricultural extension services normally adopt more adaptation strategies than their counterpart [28]. The result shows that most of agro pastoralists 56.67% in the lowland and 60.26% in the midland have access to agricultural extension services. The others 43.33% in the lowland and 39.74% in the midland do not have access to agricultural extension services. Most of the time pastoralists and agro-pastoralists in the study area are prone to climate change impacts due to their lack of access to agricultural extension services.

6.2. Continuous Socio-Economic Characteristics Of Households

Continuous socio-economic characteristics of sample households such as; the age of household, family size, farming experience, total land holding, livestock holding, and income of the household are presented in [Table 3]. The average age of the sample respondents of lowland and midland was 35.79 ± 6.73 and 38.31 ± 8.78 respectively. Overall the average age of sample respondents in the study area was 37.39 ± 8.17 and statistically, there is a significant difference [$p < 0.05$] between the average age of lowland and midland sample households. This implies that the average age of sample households in the midland is higher than the average age of sample households in the lowland agro ecology. The average family size of the sample respondents in the lowland and midland were 8.94 ± 2.85 and 7.85 ± 2.24 respectively [Table 3]. Statistically, there is a significant difference [$p < 0.01$] between the average family size of lowland and midland agro ecology. The result shows that the average family size of the lowland households was higher than that of the midland agro ecology. The result in this study was higher than the average household size reported by [26], which is 5.85 ± 1.74 persons in East Gojjam, Zone, Amhara Region Raya Kobo district and the study [29], in Habru district which is 7.44 ± 4.15 persons.

Table 3: Continuous socio-economic characteristics of households

Variables	Agro-ecology			t-test
	Lowland	Midland	Total	
	Mean ± SD	Mean ± SD	Mean ± SD	
Age of household heads	35.79 ± 6.73	38.31 ± 8.78	37.39 ± 8.17	-2.356**
Family size	8.94 ± 2.85	7.85 ± 2.24	8.25 ± 2.53	3.341***
Farming experience	20.60 ± 8.00	18.87 ± 7.02	19.50 ± 7.43	1.772*
Land holding	2.81 ± 1.92	2.27 ± 1.52	2.47 ±1.70	2.411**
Livestock holding (TLU)	3.66 ± 1.47	3.07 ± 1.14	3.29 ± 1.30	3.538***
Income of HHs	4217 ± 3848.55	3023.65 ± 2236.32	3460.24 ± 2979.29	3.077***

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$ significance level; SD = Standard deviation; TLU = tropical livestock unit

Source: Survey results, 2023

Farming experience is among the most important variables that influence agro-pastoralists to adapt with climate change impacts. The more farmers have experience, the more they have likely to adopt adaptation strategies than the less experienced farmers [30]. The average farming experience of the sample respondents in lowland and midland agro-ecologies was 20.60 ± 8.00 and 18.87 ± 7.02 respectively. The overall average farming experience of sample respondents in the study area was 19.50 ± 7.43. Statistically there is a significant difference [$p < 0.1$] between the average farming experience of sample households in lowland and midland agro ecologies. The average total land holding of sample households in lowland and midland was 2.81 ± 1.92 and 2.27 ± 1.52 hectares respectively. The average total land holding of households in lowlands was significantly [$p<0.05$] higher than the average total land holding of households in midland. The overall average total land holding of sample households in the study area was 2.47 ±1.70 hectares. The average land size in the study district [2.52 ± 1.75 hectare] was higher than the value [1.02 ha] reported by [31] in Birkot, Gunagado and Degehabour districts of Eastern Ethiopia of Somali region.

The average livestock holding of sample households in lowland and midland were 3.66 ± 1.47 and 3.07 ± 1.14 TLU respectively. The average total livestock holding of households in lowland was significantly [$p<0.01$] higher than the average total livestock holding of households in midland. The overall average livestock holding of sample households in the study area was 3.29 ± 1.30 TLU. The average income of the sample respondents of lowland and midland were 4217 ± 3848.55 and 3023.65 ± 2236.32 respectively. The overall average total income of sample respondents in the study area was 3460.24 ± 2979.29 and statistically, there is a significant difference [$p < 0.01$] between the average total income of lowland and midland agro ecology sample households. This means the average income of lowland sample households was higher than that of the midland sample households, because households in lowland have a huge number of livestock than midland and also they are practicing small amount of crop production through irrigation.

6.3. Climate Change Indicators

The sample respondents revealed that drought occurrence, animal death, occurrence of pests and disease, drought, animal death, occurrence of pests

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and disease and some of them don`t know about the indicators of climate change [Table 4]. In Ethiopia, the pastoral and agro-pastoral communities that cover 12% of the population keep livestock in drought prone arid and semi-arid regions [32]. Most of the times the climate change indicators are intense and unpredictable. Due to intense and unpredictable climate change indicators agro-pastoralists can be either reactive or proactive depending on whether it happens before or after climate change. Reactive measures address after they have experienced the impact of climate change indicator, while proactive measures are expected to engage climate change [33].

Table 4: Climate change indicators

Variables	Agro-ecology			Chi-square
	Lowland	Midland	Total	
	N (%)	N (%)	N (%)	
Drought occurrence	12(13.33)	10(6.41)	22(8.94)	15.340***
Animal death	10(11.11)	20(12.82)	30(12.20)	
Occurrence of pests and disease	21(23.33)	45(28.85)	66(26.83)	
Drought, animal death,occurrence of pests and disease	32(35.56)	30(19.23)	62(25.20)	
I don`t know	15(16.67)	51(32.69)	66(26.83)	

N = Number of households; χ^2 = Chi-square; % = percent; *** $p<0.01$ significance level

Source: Survey results, 2023

Regarding the climate change indicators the finding shows that 13.33% of agro-pastoralists in lowland and 6.41% in midland responded that drought occurrence is one of the indicators of climate change. Drought occurs due to continuous dry seasons experienced throughout the recent 30 years and the ongoing effects of El Niño in East African nations in general especially Ethiopia and the study area specifically, made food insecure for a large number of people because of climate change [34]. On the other hand, 11.11% of sample agro-pastoralists in the lowland and 12.82% in the midland revealed that animal death is the way of climate change indicator. Also, 23.33% of sample agro-pastoralists in the lowland and 28.85% in the midland responded that the

occurrence of pests and disease is another way of climate change indicator. Finally, 35.56% of sample agro-pastoralists in the lowland and 19.23% in the midland responded that drought occurrence, animal death, the occurrence of pests, and diseases are the indicators of climate change. In the study area, 16.67% of sample respondents in the lowland and 32.69% in the midland do not know about the indicators of climate change. There is a significant difference [p < 0.01] among the perception of sample households between lowland and midland agro-pastoralists in the study area.

6.4. Impact Of Climate Change

Climate change is our planet's greatest existential threat. If we don't limit greenhouse gas emissions from the day-to-day activities of human beings in the coming decades, the consequences of rising global temperatures causes massive crop failure and fishery collapse, the disappearance of hundreds of thousands of aquatic and terrestrial species, and the well-being of the entire communities becoming uninhabitable. The outcomes of climate change may still be avoidable if human beings reduce the activities that aggravate climate change. Nowadays climate change is already causing suffering and death on both human beings and livestock. From raging human-made activities and natural events, its compounding effects can be felt outside our windows today. The consecutive occurrence of climate change leads to a decline in crop yields, and loss of livelihood assets and opportunities, more of the time the impacts of climate change are extremely sensible in the agro-pastoral areas and rural smallholder farmers' context [35]. The decline in livestock production and productivity in these regions is thus linked to the consecutive occurrence of climate change [36]. In the study area, agro-pastoralists classify the impact of climate change based on the level of its effect as severe, moderate or less severe no impact [Table 5].

Table 5: Impact of climate change

Variables	Agro-ecology			Chi-square
	Lowland	Midland	Total	
	N (%)	N (%)	N (%)	
Severe	20(22.22)	102(65.38)	122(49.59)	55.121***
Moderate	68(75.56)	42(26.92)	110(44.72)	
Less severe	2(2.22)	8(5.13)	10(4.06)	
No impact	-	4(2.57)	4(1.63)	

N = Number of households; χ^2 = Chi-square; % = percent; *** $p<0.01$ significance level

Source: Survey results, 2023

The result in Table 5 shows that 22.22% of agro-pastoralists in lowland and 65.38% in midland responded that the impact of climate change in the area is severe. Also, 75.56% of sample agro-pastoralists in the lowland and 26.92% in the midland revealed that the impact is moderate, on the other hand, 2.22% of sample agro-pastoralists in the lowland and 5.13% in the midland responded that the impact of climate change in the study area is less severe and the rest 2.57% of sample respondent in midland responded that they do not face climate change impact and no one in lowland responded that they do not face climate change impact. This is because in midland agro ecology some of the respondents practice trading, while most of the time the livelihood of agro-pastoralists in lowland

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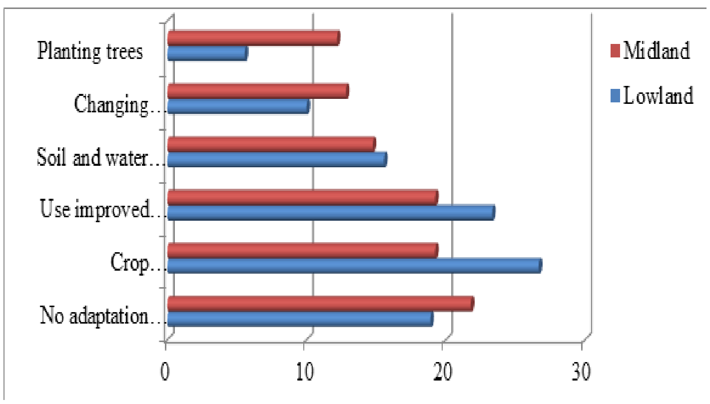
depends on livestock production. There is a significant difference [p < 0.01] between the impact of climate change among lowland and midland agro-pastoralists in the study area.

6.5. Agro-Pastoralists Adaptation Strategies To Climate Change

Climate change adaptation strategies involve action taken by public or private sectors such as farmers, communities or organizations, and or firms in combat to climate change and each level of government such as local, regional, and national to arrange for infrastructure and institutions to reduce the adverse impact of climate change [37]. In the Bena-Tsemay district, agro-pastoralists use adaptation strategies to alleviate the negative climate variability impacts. Agro-pastoralists in the district use various adaptation strategies in response to the adverse effects of climate variability. Figure 1 shows the major adaptation strategies that agro-pastoralists use to mitigate the negative impacts of climate variability.

Figure 1: Agro-pastoralists adaptation strategies to climate change



Source: Survey results, 2023

The result shows that 5.56% of agro-pastoralists in the lowlands and 12.18% in the midland use planting trees as an adaptation strategy. Changing planting dates is another way of adapting with climate change variability impacts in the study area. As indicated in Figure 1, 10% of agro-pastoralists in the lowland and 12.83% in the midland use changing planting dates to adapt with climate variability impacts. In the study area, 15.56% of agro-pastoralists in the lowland and 14.74% in the midland use soil and water conservation as an adaptation strategy to reduce climate change variability effects [Figure1]. Because of socioeconomic differences, not all agro-pastoral members are equally vulnerable to the negative impacts of climate variability and recurring droughts. As a result, agro-pastoralists in the study area assist each other by providing grains as a gift or loan at the community level [38]. However, due to the recurring and ongoing drought severity, it is becoming increasingly difficult for better-off households to provide such assistance. Similarly, [39], found that continuous food rationing and traditional asset redistribution mechanisms become ineffective if there are too many losses due to constant extreme events and too many people in need.

Frequent drought occurrence and high rainfall variability seriously challenged pastoralists and agro-pastoralists in South Omo Zone. Agro-pastoralists adopted various adaptation strategies in response to adverse climate variability impacts. Agro-pastoralists were forced to engage in use of improved crop varieties that are early maturing and withstand rain fall shortage. Figure 1, shows that 23.32% of agro-pastoralists in lowland and 19.23% in midland uses improved crop varieties to adapt with climate variability impacts. Crop diversification is one of the adaptation strategies to mitigate climate change effects [1]. Most of agro-pastoralists use crop diversification as the main adaptation strategy. Based on this 26.67% of sample respondents in lowland and 19.23% in midland uses crop diversification as a main adaptation strategy. In other way 18.89% of agro-pastoralists in lowland and 21.79% in midland do not use any adaptation strategies in the study area.

6.6. Determinants Of Agro-Pastoralists Adaptation Strategies To Climate Change

The multinomial logistic regression model was used to estimate the effect of the socioeconomic characteristics of sample households on the agro-pastoralists decision to use climate change adaptation strategies [Table 6]. The estimation of the multinomial logistic regression model for this study was undertaken by normalizing one category, which is normally referred to as the "base or reference category." In this analysis, the first category [no adaptation strategies] is the reference state. The Ordinary Least Square regression model was fitted and tested for multicollinearity using the variance inflation factor [VIF]. The variance inflation factors for all variables are less than 10 [1.04 – 1.58], which indicates that multicollinearity is not a serious problem in this model.

Table 6: Parameter estimates of multinomial logit regression model of climate change adaptation strategies

Variables	Crop diversification	Soil and water conservation	Changing planting date	Use of improved crop varieties	Planting trees
Agro-ecology	-0.573(0.567)	-0.166(0.641)	-0.475(0.750)	-0.471 (0.558)	-0.493(0.806)
Age	0.014 (0.036)	0.055 (0.040)	0.009 (0.050)	0.019 (0.036)	0.104** (0.048)
Gender	1.864 (1.184)	0.768 (0.997)	0.548 (1.014)	0.697 (0.855)	-1.905** (0.896)
Marital status	0.616 (0.691)	1.941** (0.914)	1.760* (0.986)	0.255 (0.653)	-1.185 (0.924)
Family size	-0.229** (0.095)	-0.496*** (0.122)	-0.676*** (0.152)	-0.179* (0.094)	-0.140 (0.136)

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Education level	0.010 (0.164)	0.477** (0.202)	-0.015 (0.217)	0.164 (0.164)	0.039 (0.240)
Farming experience	0.041 (0.036)	-0.035 (0.041)	-0.087* (0.050)	-0.088** (0.041)	-0.035 (0.049)
Climate change perception	0.057 (0.484)	-1.188** (0.545)	1.386* (0.761)	-0.121 (0.494)	-0.529 (0.686)
Household income	0.317 (0.318)	0.935** (0.384)	1.010** (0.481)	0.089 (0.319)	0.090 (0.444)
Do you purchase grain	-0.200 (0.676)	-1.120 (0.880)	-2.468** (1.145)	-0.097 (0.666)	0.377 (0.955)
Is there health problem	-0.944** (0.462)	-0.708 (0.535)	-2.091*** (0.694)	-0.523 (0.481)	-0.314 (0.671)
Total land holding	-0.047 (0.135)	-0.147 (0.166)	-0.434** (0.204)	0.205 (0.134)	-0.419* (0.248)
Livestock holding	0.143 (0.178)	0.074 (0.203)	-0.251 (0.255)	0.227 (0.179)	-0.109 (0.246)
Access to information	-0.654 (0.464)	0.209 (0.565)	0.027 (0.651)	-0.240 (0.469)	-2.460*** (0.638)
Access to extension	-0.089 (0.464)	-1.294** (0.537)	-3.460*** (0.776)	0.497 (0.484)	-0.548 (0.636)
Constant	-1.507 (3.584	-4.874 (4.122)	4.015 (4.554)	0.639 (3.451)	5.796 (4.872)
Diagnostics					
Base category	No adaptation strategies				
Number of observations	246				
LR chi-square	193.930				
Log likelihood	-333.365				
Pseudo-R^2	0.2253				

***, **, and * significant at $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively; standard errors in parentheses

6.6.7. Climate Change Perception: The results in Table 7 show that having a climate change perception increased the likelihood of changing the planting date as an adaptation strategy at [$p < 0.05$] significance level as compared to the base category and decreases the likelihood of soil and water conservation as adaptation strategies at [$p < 0.05$] significance level. Specifically, the results show that having a climate change perception increased the probability of changing the planting date by 5.2% and decreases soil and water conservation by 15.2% as a climate change adaptation strategy [Table 7]. As hypothesized, agro-pastoralists that have climate change perception had better opportunities to practice change planting date measures than agro-pastoralists that have no climate change perception but are less likely to practice soil and water conservation than their counterpart.

Table 7: Marginal effects from the multinomial logit model of climate change adaptation strategies.

Variables	**Crop diversification**	**Soil and water conservation**	**Changing planting date**	**Use of improved crop varieties**	**Planting trees**	**No adaptation strategies**
Agro-ecology	-0.071 (0.092)	0.027 (0.055)	-0.005 (0.025)	-0.024 (0.082)	0.002 (0.042)	0.083 (0.081)
Age	-0.002 (0.005)	0.004 (0.004)	-0.000 (0.002)	-0.001 (0.005)	0.005* (0.003)	-0.006 (0.006)
Gender	0.248*** (0.072)	0.057 (0.065)	0.012 (0.026)	0.097 (0.096)	-0.340** (0.165)	0.050 (0.136)
Marital status	0.059 (0.099)	0.136*** (0.038)	0.037** (0.019)	0.021 (0.091)	-0.089 (0.088)	-0.121 (0.105)
Family size	-0.008 (0.016)	-0.038*** (0.012)	-0.019** (0.007)	0.005 (0.014)	0.005 (0.007)	0.052*** (0.014)
Education level	-0.029 (0.025)	0.047** (0.019)	-0.005 (0.007)	0.016 (0.023)	-0.002 (0.013)	-0.027 (0.026)
Farming experience	0.017*** (0.005)	-0.002 (0.004)	-0.003 (0.002)	-0.016*** (0.006)	-0.01 (0.003)	0.005 (0.006)

Climate change perception	0.065 (0.073)	-0.152** (0.064)	0.052** (0.026)	0.017 (0.071)	-0.025 (0.041)	0.045 (0.070)
Household income	0.007 (0.051)	0.083** (0.036)	0.029* (0.017)	-0.046 (0.047)	-0.007 (0.025)	-0.070 (0.049)
Do you purchase grain	0.036 (0.107)	-0.097 (0.085)	-0.084* (0.045)	0.059 (0.096)	0.002 (0.053)	0.088 (0.106)
Is there health problem	-0.094 (0.075)	-0.016 (0.050)	-0.060** (0.029)	0.011 (0.072)	0.004 (0.036)	0.146** (0.070)
Total land holding	-0.006 (0.021)	-0.015 (0.016)	-0.016* (0.009)	0.056*** (0.019)	-0.026* (0.014)	0.007 (0.021)
Livestock holding	0.017 (0.029)	-0.001 (0.019)	-0.013 (0.010)	0.035 (0.026)	-0.013 (0.014)	-0.022 (0.027)
Access to information	-0.084 (0.073)	0.070 (0.051)	0.015 (0.022)	0.033 (0.067)	-0.131*** (0.038)	0.091 (0.072)
Access to extension	0.076 (0.068)	-0.118** (0.055)	-0.209*** (0.057)	0.181*** (0.059)	-0.015 (0.033)	0.086 (0.061)

***, **, and * significant at $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively; standard errors in parentheses

6.6.8. Household Income:

Household income had a significant and positive effect on soil and water conservation and changing planting dates as an adaptation strategy to climate change. Household income significantly affects soil and water conservation at [$p < 0.05$] and changing planting date at [$p < 0.1$] significance level. This means if the household income increased by 1 Ethiopia birr results in an 8.3% and 2.9% increase in the probability of practicing soil and water conservation and changing planting dates as an adaptation strategy to climate change [Table 7]. As hypothesized, agro-pastoralists that have high incomes had better opportunities to practice soil and water conservation and change planting dates.

6.6.9. Do You Purchase Grain:

The agro-pastoralist's capacity to purchase grain significantly and negatively affects the probability of practicing changing planting dates as an adaptation strategy to climate change at [$p < 0.1$] significance level. This means those agro-pastoralists who do not have the capacity to purchase grain decreases practicing of changing planting date as an adaptation strategy by 8.4% more than those who have the capacity to purchase grain in the study area.

6.6.10. Health Problem:

The health problem of household heads significantly and negatively affects the probability of practicing changing planting dates as an adaptation strategy to climate change at [$p < 0.05$] significance level. This means that agro-pastoralists who face health problem decreases practicing of changing planting date as an adaptation strategy by 6.0% more than those who do not face health problem.

6.6.11. Total Land Holding:

The total land holding of the household heads had a significant and positive effect on the use of improved crop varieties as an adaptation strategy to climate change at [$p < 0.05$] and a negative effect on changing planting date and planting trees as an adaptation strategy to climate change impacts at [$p < 0.1$] significance level. This means if the total land holding of the household heads increases by 1 hectare increases the probability of using improved crop varieties as a climate change adaptation strategy by 5.6% and decreases the probability of practicing changing planting dates and planting trees by 1.6% and 2.6%. A household who have more land holdings practices uses improved crop varieties more as climate change strategies. But, less in practicing changing planting dates and planting trees than those who have less land in the study area. This finding contradicts with the findings of [22,28], who say that households with more land are less likely to diversify into non-farm livelihoods and are more likely to invest in long-term benefits such as tree plantations.

6.6.13. Access To Climate Information:

Access to climate change information is an important variable that affects climate adaptation options. It significantly and negatively affects planting trees as an adaptation strategy to climate change at [$p < 0.01$] significance level. The results in Table 7 show that having no access to climate information had impacted adaptation to climate change negatively. The household head that has no access to climate information has a negative and significant impact on planting trees to adapt to climate change. This means a household head that has no access to climate change information results in a 13.1% decrease in the probability of planting trees than those who have access to climate change information.

6.6.14. Access To Extension:

The result in Table 7 indicates that access to extension is positively and significantly related with the use of improved crop varieties as adaptation strategies to climate change at [$p < 0.01$] and also negatively and significantly related to soil and water conservation at [$p < 0.05$] and changing planting date at [$p < 0.01$] significance level. This means having access to extension packages increased the likelihood of practicing the use of improved crop varieties by 18.1% and decreases the likelihood of practicing soil and water conservation and changing planting date by 11.8% and 20.9%. Access to extension services has increased the chances of using some adaptation strategies and decreasing others. This study is slightly similar to the study of [40], who indicates that Access to extension services, farmer-to-farmer, and private social networks, has increased the chances of using some adaptations and decreased others.

7. Conclusions

This study was conducted in the Bena-Tsemay district of South Omo Zone, Southern Ethiopia with the aim to identify climate change adaptation strategies and their determinants in agro-pastoral areas of Southern Ethiopia. To adapt to climate change variability impacts ago-pastoralists use many adaptation strategies such as planting trees, changing planting dates, soil and water conservation, use of improved crop varieties, and crop diversification. Also, many agro-pastoralists in the study area do not use adaptation strategies. The multinomial logit result shows that the age of the household head, Gender of the household head, marital status, family size, education level, farm experience, climate change perception, household income, purchasing grain, health problem, total land holding, access to climate change information, and access to an extension service is the major determinants that hinder agro-pastoralists decision to use climate change adaptation measures in the study area. Thus, there is a need for synergic work between young and elder agro-pastoralists, training agro-pastoralists to become proactive than to become reactive to climate change impacts, and agro-pastoralists' access to reliable changing climate information. In addition, improving access to extension services is crucial in enhancing agro-pastoralist adaptation decision-making and planning.

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