



# Determinants of smallholder farmers' adaptation strategies to climate variability in Suha watershed, Upper Blue Nile basin, Northwest Ethiopia

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## Abstract

This study assessed how smallholder farmers perceive climate variability, what adaptation strategies they practice, and factors that determine their adaptation use in the Suha watershed, north-west Ethiopia. Both cross-sectional and longitudinal research designs were employed to obtain survey data from selected households and a long period of meteorological records from Ethiopia's nation metrological agency. A descriptive analysis was used to summarize farmers' perceptions, to see the actual seasonal/annual variability of rainfall and temperature, and to identify the different adaptation responses to climate variability. A binary logit model was mainly used to identify the determinant factors for adaptation responses. The descriptive statistics showed seasonal and annual rainfall variability across highland, midland, and lowland agroecology over the last three decades. The analysis model also indicated that the agro-ecological location of farmers, age, education, farm size, income from farming, access to information, extension service, and livestock ownership were the determinant variables for crop diversification strategy. Similarly, soil and water conservation as an adaptation strategy was positively influenced by the agro-ecological location of farmers, age, household head, educational attainment, family size, access to information, extension service, and livestock ownership. Besides, the agro-ecological location of farmers, academic status, farm income, and access to climate information were influential factors in practicing improved crop varieties in the watershed. However, the agro-ecological location of farmers and livestock ownership has negatively influenced on the practice of soil and water conservation in the watershed. This result is critical for context-based interventions in tropical highland settings, where dissected topography and convectively dominated rainfall could lead to local climatic variability. Therefore, taking an efficient adaptation measure to climate variability needs to consider the influence of different factors based on the agro-ecological zone of the farmers.

**Keywords** Adaptation strategies · Binary logit model · Climate variability · Determinants

## Introduction

Climate variability is one of the serious challenges on the earth. The increased concentration of greenhouse gasses has raised the average temperature and altered the amount and pattern of global rainfall. Evidence like mean earth surface temperature shows that it has been increasing by about 0.3 to 0.6 °C, and sea levels have risen by some 10 to 25 cm in the last 100 years (Yohannes et al. 2020). Warming in the Sub-Saharan region is projected to be higher than the global average, and rainfall is expected to decrease in some areas (Belay et al. 2017). The increased temperatures and changes in rainfall distribution patterns have resulted in drought and flood events in many semi-arid parts of Africa (Abegaz and Abera 2020). Inter-annual precipitation variability and rising

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temperature trends have also been observed in most East African countries, including Ethiopia (IPCC 2012). Ethiopia has experienced unusual warm and cold temperature over the last five decades, while the warmest days have increased in recent years, mainly by 0.37% per decade (Atinkut and Mebrat 2016).

Millions of agrarian societies in developing countries heavily depend on rain-fed agriculture for their livelihoods. It has affected society's natural and social systems (Belay et al. 2017). Smallholder farmers, particularly in Ethiopia, face the challenge of climate variability and its related problems. Such problems include the unpredicted pattern of rainfall, ever-warming temperatures, changes in the length of growing seasons, seasonal outbreaks of crop pests and diseases, strange weeds, flooding, shortage of water, and land degradation (Alemayehu and Bewket 2016; Bewket 2012).

In Ethiopia, agriculture, the backbone of the economy, depends mainly on seasonal rain, which is highly subjected to the fluctuating and unpredictable features of the climate in recent times in the country. Despite the country's low per-capita and greenhouse gas emissions, researchers estimate that climate change costs the country from 2% to 6% of its overall output yearly (World Bank 2020). The above figure implies that it is higher than the projected economic cost of 1.5% to 3% of Africa's gross domestic product due to climate change by 2030 (Abegaz and Abera 2020). Because of this, Ethiopia became one of the most extensive recipients of food aid, reaching about 20% to 30% in sub-Saharan Africa (Atinkut and Mebrat 2016).

Among the different parts of Ethiopia, Amhara region is also one of the most vulnerable to climate variability. The increased temperature and a decrease in precipitation have become a serious problem in the region that frequently affects the agricultural sector (Atinkut and Mebrat 2016). Climate change and variability are apparent in the study area, manifesting as frequent erratic rainfall, and fluctuation of mean temperature (Ademe et al. 2020; Tessema and Simane 2020). Scholars have claimed that understanding the perceptions of local people about climate change is critical for taking an adaptation response and its success (Tessema and Simane 2020).

Smallholder farmers have used numerous adaptation alternatives in response to climatic variability to reduce the effects of climate variability on their lives and livelihoods based on their perceptions. In this context, smallholder farmers are "those farmers owning small plots of land on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labor" (Wondimagegnhu et al. 2019). They differ from the other farmers in their limited resources. Of those mechanisms, the agricultural adaptation options, which include diverse crop types, use of local crop varieties, and small-scale irrigation and water harvesting measures, can be mentioned (Aniah et al. 2019; Mihiretu et al. 2020). These adaptation

mechanisms are essential for the rural community to adjust to the variability and help them cope with adverse consequences of climate (Change 2007). These strategies are usually classified as managing (short-term strategies and spontaneous) or adaptive practice (long-term measures) (Alemayehu et al. 2020; Mihiretu et al. 2019).

However, there is a significant disparity in the use of these strategies among smallholder farmers in the study (Osumanu et al. 2017). The reason behind this is that the techniques are implemented in a constantly changing biophysical, social, and political context (Bawakyillenuo et al. 2016). For instance, a study conducted by Mihiretu et al. (2020) revealed that agro-ecological site, sex of household, family member size, plot size, off-farm income, livestock holding, frequency of extension contact, and training were some of the factors that influence adaptation to climate variability. Other research reports made by Belay et al. (2017) and Yohannes et al. (2020) also pointed out that the use of adaptation strategies is a function of the household head's educational status, household size, household head's sex, ownership of livestock, credit, and extension services. Hence, predictor variables influence the adaptation strategies either positively or negatively on the ground (Atinkut and Mebrat 2016).

In this aspect, different studies have attempted to deal with this issue in Ethiopia (Mihiretu et al. 2020). These studies have been carried out to inform the different adaptation responses for the agricultural operation (Araya et al. 2020; Berger et al. 2015; Conway and Schipper 2011; Kelelew et al. 2018) and as a basis for grasping climate variability impacts more generally (Mihiretu et al. 2019; Urgessa and Gonfa 2020; Yohannes et al. 2020). Most of them were conducted at the national level, making it difficult to generalize the case in a specific watershed. Only a few studies such as Atinkut and Mebrat (2016) at Dabat district in south Gonder; Asrat and Simane (2018) at Dabus watershed, northwest Ethiopia; and Belay et al. (2016) at Choke watershed in the Central part of northwest Ethiopia highlands were found. However, due to variations in agro-ecological zones and socio-economic variables, adaptation strategies need to be peculiar to a particular area (Tessema and Simane 2020). In addition, the availability of weather information and the overall perception of smallholder farmers in every locality also differs and affects the application of those strategies both spatially and temporally. This study focuses on the Suha watershed, located in the northwestern highland of Ethiopia at the headwaters of the Blue Nile River, where several climate changes and variability-related events were found due to the complex physio-climate features. Some studies have examined the determinants of smallholder farmers' adaptation strategies to climate variability at a national scale in Ethiopia or for selected regions, as mentioned above. However, none of them touched the case in our study area.

Consequently, the aim of the study was mainly to investigate the factors that affect smallholder farmers' choice to use adaptation measures for climate variability in the Suha watershed at the local level. Specifically, the study tried to address (i) to assess smallholder farmers' perceptions about climatic variability at the household level in three agro-ecological zones. Knowing the perceptions of local people about climate variability is critical to facilitate the decision process of selecting and using appropriate adaptation mechanisms. For someone to take an autonomous action to climate change, the respondents must first perceive climate change. (ii) To identify the existing farmer adaptation techniques in response to climate variability, this task is essential to distinguish whether the smallholder farmers are using appropriate adaptation techniques or not in the area. In addition, (iii) to highlight the influential factors that deter the choice and practice of adaptation strategies in the study watershed. To tackle or at least minimize the effects of climate variability on their lives and livelihoods, farmers in the area have been pursuing various adaptation options. However, multiple variables like the educational status of the household head, access to extension and financial services, climatic knowledge, agroecology, and so on all influence the adoption of specific adaptation methods in different ways. Hence, understanding the factors related to adaptation mechanisms aid policymakers in addressing the problems of sustainable development in the face of climatic variability in the future.

## Description of the study area

Suha sub-watershed is part of the fourteen Abay/Blue Nile sub-basins called the North Gojjam sub-basin. The watershed has around 790 km<sup>2</sup> and is geographically located between 10°10'–10°40' N latitude and 37°50'–38°30' E longitude. The topography is undulating and variable, including rugged hills, mountains, and gentle plains. The slope gradient varies from 0 to 50%, although the dominant slope class is 15 to 30% (Mekuriaw et al. 2020). In its relative location, the watershed is found in the southeastern part of Choke Mountain, which is the head of the Blue Nile/Abay river in Ethiopia. Runoff from this watershed directly drains into the Abay River (Simane et al. 2013).

The Suha watershed is found in three traditional agro-climatic zones: Dega (2300–3200 m), Woina Dega (1500–2300 m), and Kolla (500–1500 m) (G/Eyesus et al. 2003). A large portion of the watershed falls under the Woina Dega (69.04%) and Kolla (19%) agro-climatic zones. Dega (11.9%) takes the remaining portion of the agro-climatic zone. Rainfall in the study area generally has a bimodal nature in its temporal distribution: Kiremt and Belg, i.e., the area falls within Kiremt (main rainfall season), Belg (little rainfall season), and Bega (dry season). The area

receives a mean annual rainfall of around 1021 mm: the average monthly minimum and maximum temperatures in the watershed range from 9.4 to 25.1 °C.

The soil types and their characteristics are closely related to the parent material and the past geological processes it has undergone at different times. According to FAO soil classification, the most dominant types in the watershed are Nitisols and cambisols (Mekuriaw et al. 2020). These groups of soils constituted 47% and 31% of the study's watershed, respectively.

In addition, vegetation cover and distribution patterns strongly link with an area's climatic condition in different parts of the earth. Thus, vegetation distribution in the study area is highly governed by the local climatic conditions in the specific site (agro-ecological zone). The lower altitude of the study area, mainly classified as Kolla (common land), is covered with shrubs, bush, and stunted acacia vegetation, whereas the majority part, locally known as Woina Dega (midland) and Dega (highland), is dominated by vegetation like Bahir zaf (*Eucalyptus*), Tid (*Juniperus procera*), Zigba (*Podocarpus gracilior*), and kosso (*Hagenia abyssinica*) (Mekuriaw et al. 2020).

The watershed is located in the east Gojjam zone of Amhara Regional State, North Western Ethiopia (Fig. 1). It lies in four districts (woredas): Debay Tilatgin, Enemay, Shebel Berenta, and Dejen. According to Central Statistics Agency (CSA) (2007), the district's total population, including the capital, was 499,684. The most significant portion of the population (93.6%) lives in rural areas, whereas the remaining belongs to the urban group. Females constituted slightly more significant than half (50.8%) of their counterparts in the population. The sex ratio was estimated to be 97 males for every 100 females.

Agricultural (mixed) economic activities are the primary income source for many people. Since the watershed has vast agricultural land, farmers cultivate various crop types, including cereals, legumes, oilseeds, and cash crops. Of the total land of the watershed, the majority is employed for agriculture, particularly crop cultivation and livestock rearing, which confirms the mixed agricultural practice.

The watershed lies mainly within the areas where agricultural land becomes a seriously tight spot for agriculture-based livelihood. It has been among the densely populated, severely degraded, and highly exploited areas for several millennia. Topsoil degradation is accompanied by seasonal and annual fluctuations in temperature and rainfall in the area (Assefa 2011). Therefore, climate variability coupled with rapid land cover change is one of the critical issues in the study watershed, among other environmental problems.

The period of a dry spell during the spring and late coming of summer seasons in the area exposes the local community to drought (particularly in the lower part of the watershed) due to insufficient rainfall and high temperature. The

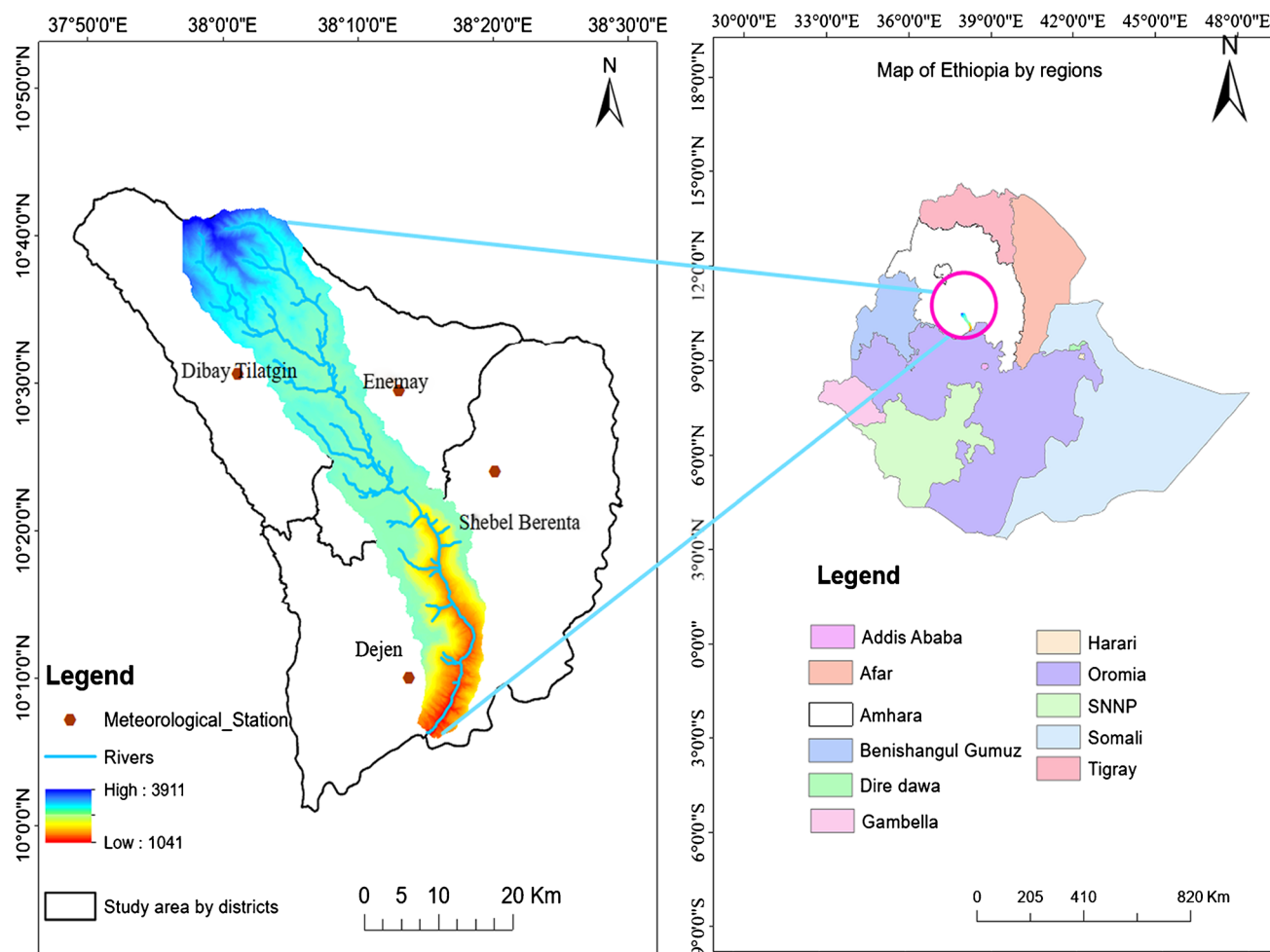


Fig. 1 Location of the study area

onset and cessation of the summer season frequently deviate from their usual time and affect the previously known average value of precipitation and temperature in the area. The aforementioned situation of the area drags the attention of the researchers to select it.

## Research methods

### Research design

A research design is selected depending on the objectives we set to achieve, the research type we apply, and the data type and the data gathering tools we use. The study employed both cross-sectional and longitudinal research designs. It held a cross-sectional survey to get socio-economic and demographic data from sample farmers while the longitudinal one was used to obtain a long period of rainfall and temperature records (1990 to 2020) from the National Meteorological agency of Ethiopia. On the other hand, a research approach mainly depends on the nature of the issue being

investigated, the researcher experience, and the interest/willingness of the end-user of the investigation (Creswell 2014). Creswell also suggested that an individual who conducts research work should make self-explicit to the philosophical ideas that they are following and supporting. Such information helps to explain why the researchers chose a qualitative, quantitative, or mixed-methods approach. This research used mixed methods, which require the involvement and collection of quantitative and qualitative data. As Creswell (2014) puts it, this approach's central presumption gives an increasingly more comprehensive image of the study issue than either approach alone (quantitative or qualitative).

### Sampling technique

The research intends to investigate the determinant factors that affect the implementation of adaptation strategies against the impact of climate variability from different perspectives. For this reason, it is necessary to implement well-defined technique of sample size determination to manage

the studied variables and the sample household. It is up to the researcher to weigh the factors of accuracy, cost, homogeneity of the accessible population, type of sampling, and kind of study and determine the best sample size for one’s research.

Hence, this study applied a multi-stage sampling technique to select the districts, kebeles, and household heads, starting from the general (areas having the same agro-ecological zone) to the most specific level (household representatives). At first, the watershed was considered because of its vulnerability to climate variability, and it was classified into related agro-ecological zones as of highland, midland, and lowland based on the traditional agro climatic zone particularly by considering rainfall and temperature distribution as well as altitude. Second, out of the four districts found in the study watershed, three representative districts (Debay Tlatgen, Enemay, and Shebel Berenta) from the three agro-ecological zones were taken intentionally just for ease of data collection and management (Table 1). Taking samples from the different agro-ecological zone is supposed to be important to understand the similarities and differences in vulnerability and adaptation strategies to climate variability depending on the local context in the specific agroecology. Again, proportionally representative kebeles from each districts were chosen for the designated agro ecological zones. Lastly, a list of the household units for each kebele was obtained from its respective administration body.

Majority of the population is engaged in agricultural economic activities and has a homogeneous lifestyle in their livelihood; and for this, a simple random sampling technique was used to choose respondent household heads from their lists by considering the issue of proportionality. For this purpose, the formula of Cochran (1977) was used to determine the required sample size (384) at a 95% confidence level with a 5% degree of variability, and finally, the required data were randomly generated for the cross-sectional survey. This formula allows us to calculate an ideal sample size given a desired level of precision, confidence, and the estimated proportion of the attribute present in the population. It is set as

$$n = (z^2)pq/e^2$$

where  $n$  is the desired sample size,  $e$  is the desired level of precision (i.e., the margin of error = 0.05),  $p$  is the (estimated) proportion of the population that has the attribute in question (0.5),  $q$  is  $1 - p$ , and  $Z$  is the  $Z$  score found in the  $z$  table at a given level of confidence (1.96).

Based on the above formula, around 384 with 10% contingent respondents were recruited for the survey, and structured and semi-structured questionnaires were dispatched to them. Of these respondents, 350 filled and returned the questionnaire properly while the remaining data were obtained using contingent respondents (34). Hence, household-level data that focuses on the socio-economic and demographic characteristics, as well as the perceptions (measured using the Likert scale having five levels) of the respondent about climate variability and its impacts, the types of adaptive responses, and the determinant factors against the implementation of adaptation measures, were gathered using survey questionnaires from the samples mentioned above. Focus group discussions (FGD) (one group having six members from each agro-ecology) and key informant interviews (KII) with individual farmers and agricultural development agents (one group having four members from each agroecology) were also conducted using semi-structured checklists and field observations to generate additional in-depth qualitative information to support the quantitative data obtained from the household survey. The discussants and key informants had access to information about climate variability and the experience of responding to it through adaptation techniques, and they had lived in the research area for more than 20 years. The timeframe considered for gathering the survey data was from August to October 2021. The National Metrological Agency of Ethiopia provided a long time monthly precipitation and temperature records (1990–2020), which was used, to cross-check the perception and understanding of climate variability in the study area by the smallholder farmer.

**Table 1** Sample sizes taken from each agroecology in the study watershed

District (Woredas)	RKAs <sup>a</sup>	Agroecology	Elevation	Household heads (HH)	Sample HH
DebayTilatgen	Nabira Micheal	Dega (highland)	3200	1576	59
Enemay	Endeshign Sekela Debir Debir Gutera Ediget Bandinet	W/Dega (Midland)	2100	6270	231
Shebel Berenta	SihuaTefases & Yegnat agene	Kolla(lowland)	1200	2543	94
Total				10,389	384

<sup>a</sup>Rural kebel administrative

## Data analysis

After the relevant data were gathered from the respondents and other sources, the study first tried to assess smallholder farmers' perceptions about climate variability in the past three decades. It then tried to identify the adaptive strategies in the area and the factors that deter the practice of it in the rural community. Smallholder farmers implement different strategies to adapt to the already-changing climate elements in their localities. This is because a single strategy is insufficient to adapt climate variability; and various options are supposed to be more effective. However, the practice of adaptation options was affected by the awareness level, the socioeconomic and demographic status, and the support obtained from the local institutions to the farmers (Mihiretu et al. 2020; Weldegebriel and Prowse 2017).

**Trend analysis of climate data** Hence, for the analysis of the data, both descriptive statistics to summarize the quantitative data (percentages, means, and frequency) and inferential ones to see the trend (MK test and Sen's slope estimator) and identify the determinate predictors (binary logit regression model) were used. The trend analysis was conducted to compare and confirm the perceptions of farmers about climate variability with the actual temporal local climate patterns using the coefficient of variation, Mann–Kendall's test, and Sen's slope estimator based on the metrological data. Normality and homogeneity of variance were checked for the parametric test throughout the series, but some outliers and missing data may be there to use the parametric test. Hence, the non-parametric statistical test has an advantage over the parametric test and is more suitable for non-normally distributed, outlier, censored, and missing data, which are frequently encountered in meteorological data. As a result, Mann–Kendall (MK) test is widely used to detect trends in rainfall and temperature records. Therefore, it is because of this reason that the MK test was used for this study. Also, coefficient of variation (CV) is one of the widely used methods to analyze internal rainfall and temperature variability, calculated as the proportion of standard deviation to the average value in the given time scale (Ademe et al. 2020; Kahsay et al. 2019). The rainfall amount with a CV of less than 20% is interpreted as a low variable, the one with a CV of 20–30% is moderately irregular, and lastly, a CV of more than 30% is highly variable. Inter annual variability of annual and seasonal rainfall was calculated as:

$$CV(\%) = \sigma/\mu \times 100 \quad (1)$$

where CV (%) is the coefficient of variation,  $\sigma$  is the standard deviation, and  $\mu$  is the mean of the variable (rainfall). The Z standardized test statistic and Sen's slope parameters are extensively used in the MKT test procedure. The

Mann–Kendall test statistic computes the difference between all later measured values and all early measured records for a given time series over a given period. If a data record from a later period is greater than a data record from the last time, the statistic S is increased by 1. If the data record from a later time is less than the data record/value taken earlier, its correspondent S statistics decrease by 1. The outcome of all such increasing and decreasing result and the final value of S was calculated using the following formula:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_j - x_i) \quad (2)$$

where  $x_j$  and  $x_i$  are annual/seasonal values in the year  $j$  and  $i$ ,  $j > i$ , respectively,  $n$  is the number of data points, and  $\text{sgn}(x_j - x_i)$  is calculated using the equation:

$$\text{sgn}(x_j - x_i) = \begin{cases} 1 & \text{if } x_j - x_i > 0 \\ 0 & \text{if } x_j - x_i = 0 \\ -1 & \text{if } x_j - x_i < 0 \end{cases}$$

The positive or negative value of  $S$  designates an upward or downward trend. When the trend is considered linear, the Sen slope estimation test is used to represent the quantification of changes per unit of time (Abegaz and Abera 2020).

Sen's slope method calculates the slope (i.e., the change in linear rate) and intercepts. The slope estimator approaches (Sen 1968) predict the size of the change/trend. When the value of  $\beta$  becomes positive, it shows an increasing trend with time, while a negative value of  $\beta$  indicates a downward trend. The slope ( $T_i$ ) of the data pairings is calculated here (Sen 1968). The slope  $T_i$  between any two values of a time series  $x$  could be computed using the following formula:

$$T_i = (x_j - x_k)/(j - k) \quad \text{for } i = 1, 2, 3 \dots N \quad (3)$$

where  $x_j$  and  $x_k$  are assumed as record values at a periods  $j$  and  $k$  ( $j > k$ ) correspondingly, and the median of  $N$  records of  $T_i$  is designated as Sen's estimator of the slope, i.e., given as:

$$Q_i = \{1/2(N/T_2 + (N + 2)/T_2), \text{ if } N \text{ is even } (N + 1)/T_2, \text{ if } N \text{ is 0} \quad (4)$$

Here,  $Q_i$  indicates the  $\beta$  value of the slope estimator in Sen's slope method.

**Model specification for determinant variables** Several models could be suggested for the analysis of the influential predictor variables that affect the use of adaptation measures, including linear, logit, or probit models. The logit regression families are the most common functional ones used in adoption studies with the binomial and multinomial dependent variables (Mihiretu et al. 2020). This study employed a binary logistic regression model since the response variable had dichotomous natures. Besides, this model is suitable to use when continuous, discrete, and dichotomous variables

are mixed under the predictor category (Osumanu et al. 2017). Also, the assumption of mutual exclusiveness of observation, the issue of multi collinearity, and the presence of a large-enough sample size were considered in the selection process and use of this model (Belay et al. 2017).

The model was found appropriate based on the above assumption in which the dependent variable exhibits two classes of virus, the independent factors that were coded in dummy manners. Therefore, handling such responses from the respondents is reasonable, which other models do not easily do. Because of its non-linearity, the linear regression model is typically unsuitable for measuring the effect of explanatory factors on nominal categorical variables, and the probability of considering a specific adaptation strategy in a binary model is expressed as follows.

$$\frac{\ln y}{y - 1} = b + c_1 \times 1 + c_2 \times 2 + c_3 \times 3 \dots c_m \times m \tag{5}$$

$$\text{logit}(y) = b + c_1 \times 1 + c_2 \times 2 + c_3 \times 3 \dots c_m \times m \tag{6}$$

where *b* is the constant, *m* is the number of predictors, and C1–cm is the regression coefficient.

The regression of the binary model using SPSS provides both the direction and the factor of the effect of the independent variables on the dependent (response) variable in the form of an odds ratio. Therefore, estimating the odds ratio helps to understand the effect of a unit of change in the predictor variable over the respective response

variables by how many times/factors. Hence, *y* probability of a case belonging to category 1 is expressed as:

$$y/(y - 1) = \text{odds} \tag{7}$$

The explanatory variables could be grouped as demographic, socio-economic, institutional, and environmental based on their characteristics, which are listed in Table 2. The predictor variables consist of both categorical and continuous types. In general, the logit model has advantages over the other models in examining dummy criterion variables in the dependent group. It also enables us to determine the relevant predictors influencing on the use of adaptation measures against the climate variability in the watershed area. Before the data analysis was conducted, model fitness tests and evaluations were conducted to check whether the coded data in the SPSS was suitable for the selected model or not by using the Hosmer–Lemeshow test, goodness-of-fit statistic, and the classification tables (Osumanu et al. 2017; Yohannes et al. 2020).

Lastly, to administer and analyze the demographic, socio-economic, institutional, and climate data, XLSTAT version 19 and SPSS version 25 were employed, whereas, for the study map preparation, ArcMap 10.6 was used. Generally, the overall flow of the analysis is presented in Fig. 2.

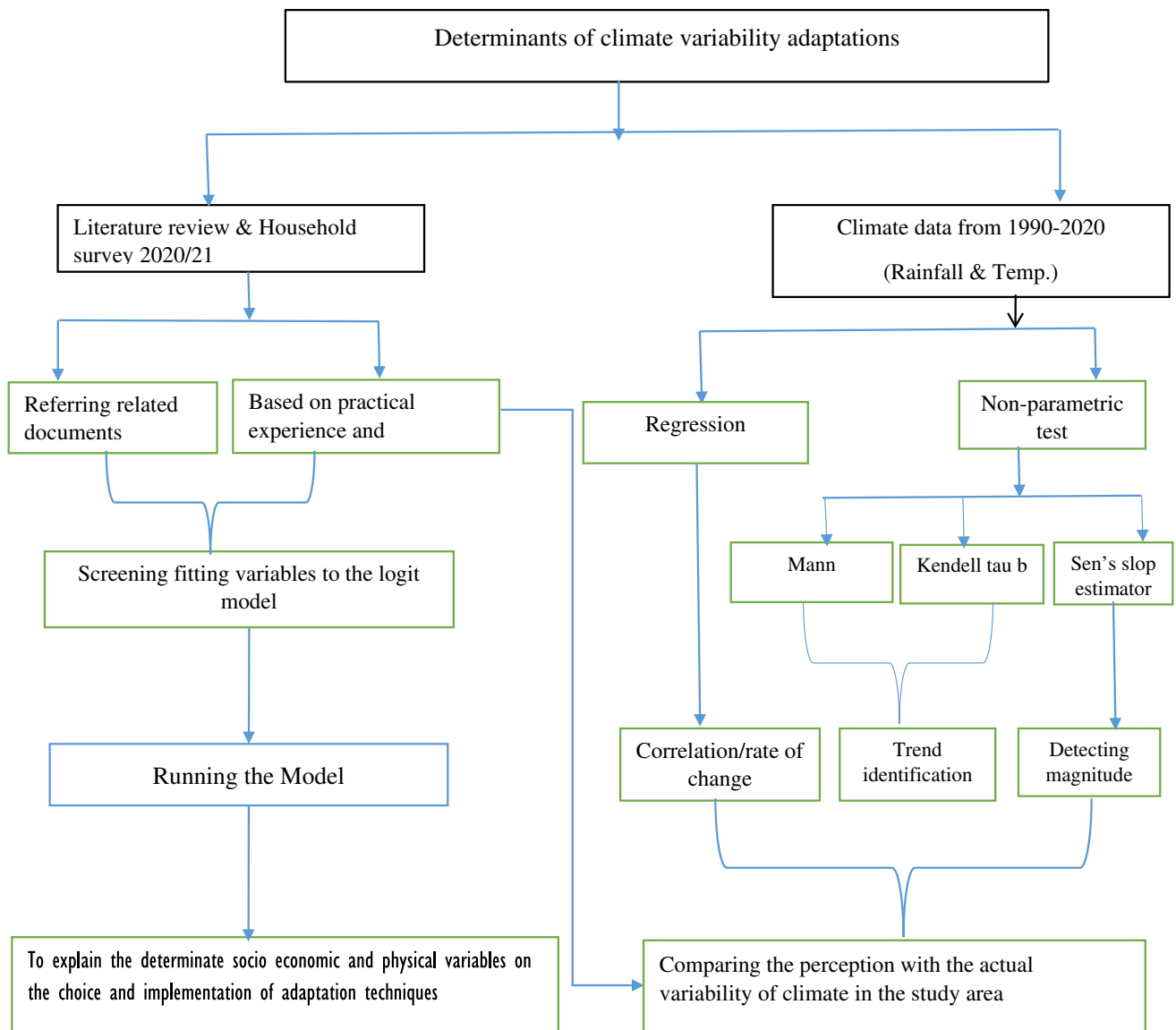
### Variable description

Before the analysis was carried out, both explanatory and response variables were identified using different literature. In response to climate variability, smallholder farmers took

**Table 2** Explanatory variable description and their hypothesized association with dependent variables

Explanatory variables	Description	Expected sign	Source
AEZ	Dummy, 1 = W/Dega, 0 = otherwise	±	Atinkut and Mebrat (2016); Kelelew et al. (2018)
Age of the HH	Continuous (years)	+	Kahsay et al. (2019) and Kelelew et al. (2018)
Sex of the HH	Dummy, 1 = male, 0 = female	±	Belay et al. (2017) and Osumanu et al. (2017)
Household size	Continuous (number)	±	Lemessa et al. (2019) and Marie et al. (2020)
Educational status	Continuous (years)	±	Asare-Nuamah and Botchway (2019) and Conway and Schipper (2011)
Farm size	Continuous (hectare)	+	Atinkut and Mebrat (2016)
Farming experience	Continuous (years)	+	Kelelew et al. (2018); Mihiretu et al. (2019)
Farm income	Continuous (ETB)	+	Tessema and Simane (2020) and Urgessa and Gonfa (2020)
Non-Farm income	Continuous (ETB)	–	Yohannes et al. (2020)
Access to market	Dummy, 1 = yes, 0 = no	+	Marie et al. (2020); Osumanu et al. (2017)
Access to climate information	Dummy, 1 = yes, 0 = no	+	Marie et al. (2020) and Tessema et al. (2018)
Access to extension	Dummy, 1 = yes, 0 = no	+	Mihiretu et al. (2019) and Silvestri et al. (2012)
Livestock ownership	Continuous, tropical livestock unit (TLU)	+	Araya et al. (2020) and Belay et al. (2017)
Water Access	Dummy, 1 = yes, 0 = no	+	Osumanu et al. (2017) and Yohannes et al. (2020)

ETB Ethiopian birr, HH household head, AEZ agro-ecological zone



**Fig. 2** The methodological flow of the study

various measures, depending on their overall situation and experiences. The most common types of adaptive strategies were primarily identified using field survey data from household head responses (Table 6). In this research, the dependent variable is farmers' adaptation strategies and options to climate variability, whereas the independent factors were the various socio-economic, demographic, institutional, and environmental components. Independent factors influenced smallholder farmers' choice and practice of adaptation techniques in different parts of the country, including the study area. From the identified adaptation strategies, the top three were taken into further analysis to see their interaction with explanatory variables. Explanatory variables are mainly categorized as demographic, socioeconomic, institutional, and environmental characteristics of the study population, as shown in Table 2.

## Results

### Smallholder farmers' perceptions of climate variability

Smallholder farmers' perceptions about the existing climate variability over the last three decades (1990–2020) was assessed based on agro-ecological location using a bundle of indicators from various sources in the study watershed (Belay et al. 2017; Yohannes et al. 2020). The household survey and the descriptive summary practically indicated that 89% of the respondents were aware of climate variability. They have also experienced the adverse effects of climate variability in their life. The descriptive analysis regarding rainfall variability indicated that more



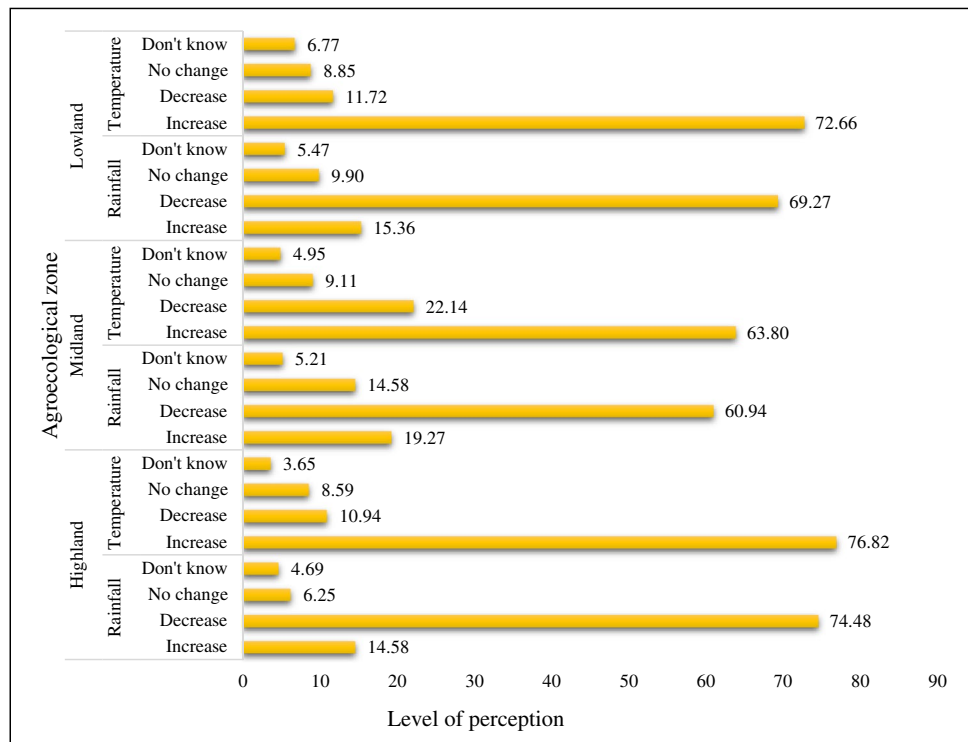
than 74.48%, 60.94%, and 69.27% of the smallholder farmers perceived that rainfall is decreasing from time to time in highland, midland, and lowland areas, respectively. This indicated that most of the respondents in each agroecology have recognized the decreasing pattern of rainfall in the watershed. However, 14.58%, 19.27%, and 15.36% of the respondents from the above respective agro-ecological zones understood that the average amount rainfall increased in their area in the same period. There is also a considerable number of respondents in the no-change/variability category (6.25% from highland, 14.58% from midland, and 9.90% from lowland) across the agro-ecological zone. The remaining respondents reported that they did not recognize the presence of rainfall variability in their local area at all.

Regarding temperature variability and change, many respondents across the three-agro ecological zones (76.82% in highland, 63.80% in midland, and 72.66% in lowland) perceived the temperature was increasing. In comparison, 10.94%, 22.14%, and 11.72% of the respondent perceived that the temperature was decreasing in the above agro-ecological zones. Moreover, 8.59%, 9.11%, and 8.85% of the households responded that there was no temperature change/variability in the highland, midland, and lowland in the study watershed respectively. The remaining respondents, which account for 3.65%, 4.95%, and 6.77% of the above agro-ecological zones, reacted that they did not perceive change in temperature in the study watershed (Fig. 3).

The evidence gained from key informant interviews and focus group discussions confirmed the above narrative regarding the farmers’ perceptions about rainfall and temperature. The discussants and key informants stated the occurrence of rainfall and temperature variability with many tangible indicators in their area. They said that previously “rainfall and temperature distribution had a regular pattern on their annual and seasonal bases. But now, the rainfall and temperature distribution patterns have become difficult to define.” Some of the evidence mentioned by the discussants were, for instance, the occurrence of late-onset and early cessation of the main (Kiremt) rainfall season, erratic rainfall, high day and low night temperature during winter (Bega), and devastating frost during autumn (Mehir), all of which were seen in the three agro-ecological zones alternatively. According to the justification given by discussants, such climate variability and anomalies have affected the overall agricultural operations and resulted in insufficient agricultural production in their area.

In addition to measuring the level of perception among the respondents, an independent chi-square test was used to identify whether there is a difference/association among the household groups in their perception behaviors across the different agro-ecological locations. The test result indicated a substantial difference among the three locations between the perceived and non-perceived groups regarding climate variability (Table 3). In the lowland agro-ecological location, for instance, 79.1% and 90% of the respondents perceived a decreasing rainfall and increasing temperature

**Fig. 3** Smallholder farmers’ perception of climate variability in the Suha watershed



than the midland and highland locations, respectively. The difference in perception of climate variability among the three agro-ecological locations is statistically significant ( $\chi^2 = 31.71, p < 0.01$ ) and ( $\chi^2 = 11.73, p < 0.01$ ). This also indicated that perception of climate variability was highly associated with agro ecological differences.

### Actual variability and trends of rainfall and temperature

#### Variability and pattern of rainfall

Rainfall in the study watershed generally has a bimodal nature in its temporal distribution—Kiremt and Belg. A summary of the mean seasonal and annual rainfall variability of the watershed (1990–2020) is presented in Table 4. The annual rainfall of the watershed varied from 720 mm (the minimum amount in the driest year, 1990) to 1322 mm (the maximum amount in the wettest year, 2002) per annum. During the given period, its mean annual rainfall was 1021 mm, with a standard deviation of 113.6 mm and an 11.1% coefficient of variation. As depicted in Table 4, Kiremt (a local term which means summer) is the main rainy season in the study site, contributing about 75% of the annual rainfall. A study conducted by Ayalew et al. (2012) in the Amhara Region as a whole, Melesse et al. (2011) in the Abay basin, and Mekonen and Berlie (2020) in the northeastern part of the Amhara region found that Kiremt season supplies the highest share of the total yearly rainfall. Many other studies (Bewket and Conway 2007;

Gebrehiwot and van der Veen 2013; Mekonen and Berlie 2020; Suryabhagavan 2017) also reported that the Kiremt season contributes the highest amount (64–85%) to the annual rainfall amount, whereas the Belg season contributes less amount (5–30%) in many parts of Ethiopia including the study site.

According to Hare (2003), the variability in annual and Kiremt times was “modest” (20–30); however, it was high and erratic ( $CV > 30$ ) during the Belg and Bega seasons, respectively.

Research reports showed more rainfall variability in the Bega and Belg seasons than in the Kiremt in the north-central and northwest parts of Ethiopia (Alemayehu et al. 2020; Ayalew et al. 2012; Mekonen and Berlie 2020). The result agreed with the finding of Abegaz and Abera (2020), where there was moderate variation in both annual and Kiremt (June–September) rainfall as compared to the rainfall in the Belg (February–May) and Bega (October–January) seasons. In the Awash basin and Gambela region, a similar finding at the watershed level stated that Belg rainfall is more inconstant than Kiremt rainfall (Alemu 2019; Getahun et al. 2021).

Before the trend analysis was carried out, the autocorrelation of the data had been considered using the Hamed and Rao method to check the appropriateness of the rainfall data for the trend analysis. Besides, the MK test and Sen’s slope estimator were used to see the seasonal and annual rainfall trends in the study watershed over the given period (1990 to 2020). The trend analysis was done for the three rainfall seasons (Bega, Belg, and Kiremt) and

**Table 3** Perception of smallholder farmers among the three agroecology

	Highland		Midland		Lowland		$\chi^2$ value	p value
	HH	%	HH	%	HH	%		
<b>Rainfall</b>								
Perceive	40	63.5	139	60.4	72	79.1	31.71	0.001**
Don't perceive	23	36.5	91	39.6	19	20.9		
Total	63	100	230	100	91	100		
<b>Temp</b>								
Perceive	38	60.3	136	58.9	81	90.0	11.73	0.003**
Don't perceive	25	39.7	95	41.1	9	10.0		
Total	63	100	231	100	90	100		

HH house hold head; \* and \*\* indicate levels of sig. at  $p < 0.01$  and 0.05 respectively

**Table 4** The seasonal and annual MK trend analysis of rainfall in the Suha watershed (1990–2020)

Rainfall/mm	Min	Max	Mean	SD	CV (%)	MK <sub>Z</sub>	Trend	p-value	Sen's slope
Bega	16	205	80.0	51.4	64.2	0.049	↑	0.696	0.511
Belg	65	356	176.2	73.1	41.5	0.196	↑	<b>0.017*</b>	2.414
Kiremt	535	917	767.2	85.6	11.2	-0.092	↓	0.465	-1.056
Annual	720	1322	1021	113.6	11.1	0.045	↑	0.721	0.949

MK<sub>Z</sub> Mann–Kendall; ↑ increasing; ↓ decreasing; \* statistically significant at 0.05.

the year (Table 4 and Fig. 4). The analysis of the MK test revealed that only the Belg season exhibited a statistically significant increasing trend. However, the Bega season rainfall showed a non-significant increasing trend. Instead, during the Kiremt season, a statistically non-significant decreasing trend was observed at  $p \leq 0.01$ . The result generally indicated the presence of an inter-seasonal and intra-annual variability of rainfall distribution in the study watershed.

A linear regression (Fig. 4) was also employed to visualize the time series rate of rainfall change against the given period, which is defined by the slope of the regression line, and the result revealed that all except Bega season depicted an increasing trend. Although an increased trend was observed in an annual rainfall, it was not statistically significant ( $p < 0.05$ ). This would be associated with the reduction of Kiremt rainfall which is the highest rainfall supplier in the watershed.

### Temporal variability and trend of temperature

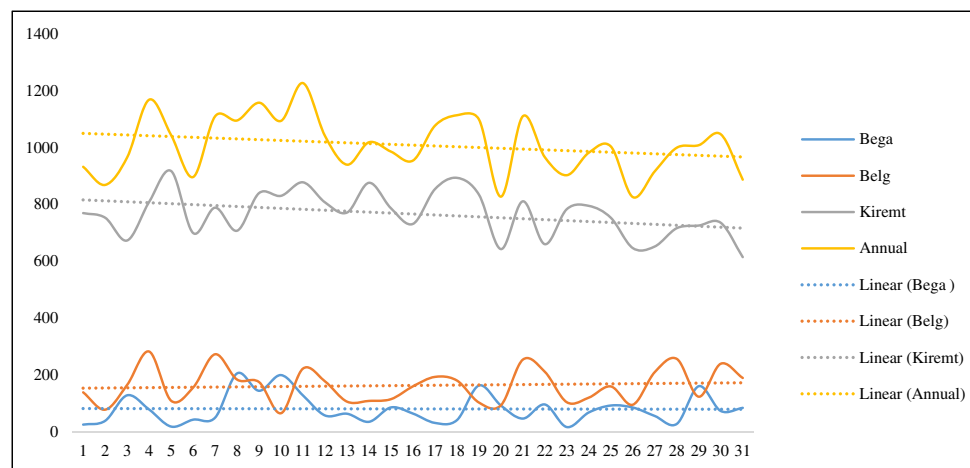
Mean annual and monthly temperature data were also analyzed to determine the actual variability and trend of temperature change in the selected watershed from 1990 to 2020. Table 5 presents the descriptive statistic mainly the mean and standard deviation values of temperature during the study period of analysis. The annual mean temperature in the study watershed ranges from 11.9 °C (minimum) to 24.5 °C

(maximum) with an annual mean temperature of 17.6 °C, and the coefficient of variation was estimated to be 9.76 %. In the case of seasonal temperature variability, the highest and lowest coefficient of variation were recorded during the Bega (11.23) and Kiremt (9.27) seasons, respectively. Belg and Bega were the hottest and coldest seasons, with 18.4 °C and 16.9 °C, respectively. The temperature condition during Kiremt season showed between the two, at 17.5 °C with 1.63 deviation.

The MK trend analysis under Table 5 showed a statistically significant ( $p < 0.05$ ) warming trend in the mean annual temperature in the study watershed. The warming trend of the mean annual temperatures was 0.03 °C per year. Similarly, the seasonal temperature showed an increasing trend in all cases except for the Bega season, though it was not statistically significant. For instance, during the Kiremt and Belg seasons, the temperature increased by 0.02 °C and 0.01 °C, respectively. However, during the Bega season, a decreasing trend was observed by about 0.03 °C per season. The increasing trend of temperature, both on an annual and on seasonal timescale, showed almost an equal rate. A similar finding by Belay et al. (2017) found that there is an increasing trend of temperature in Ethiopia’s central rift Valley by a rate of 0.37 °C.

The time series visualization of temperature in Fig. 5 revealed that except Bega, the rate of change for the seasons (Kiremt, Bega, and Belg) and annum from 1990 to 2020 was increasing. This finding (annual rate of change) is higher

**Fig. 4** Mean annual and seasonal rainfall trend in the Suha watershed (1990–2020)

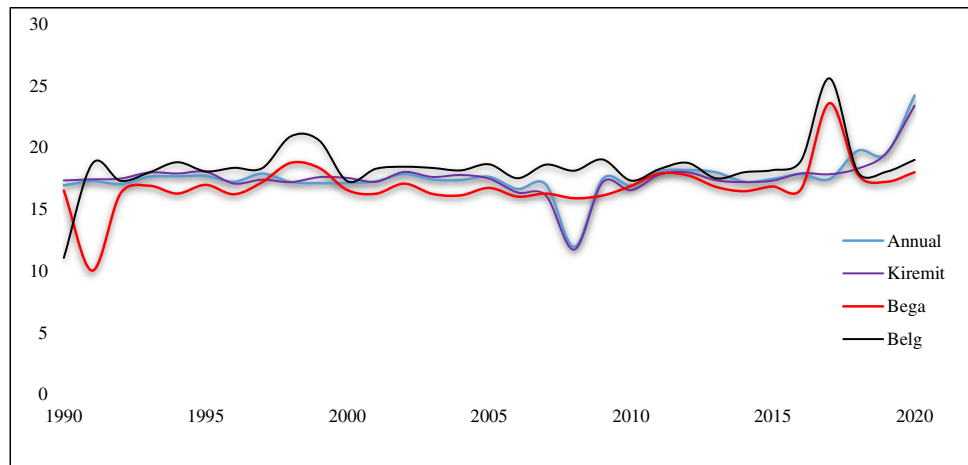


**Table 5** The seasonal and annual Mk analysis of temperature in the Suha watershed (1990–2020)

Variable	Minimum	Maximum	Mean	SD	CV	MKz	Trend	p-value	Sen’s slope
Annual	11.9	24.2	17.6	1.72	9.76	0.30	↑	<b>0.02</b>	0.03
Kiremt	11.7	23.4	17.5	1.63	9.27	0.14	↑	0.26	0.02
Bega	10.0	23.6	16.9	1.89	11.23	0.21	↓	0.10	−0.03
Belg	11.1	25.6	18.4	2.04	11.07	0.10	↑	0.45	0.01

MK<sub>Z</sub> Mann–Kendall; ↑ increasing; ↓ decreasing; \* statistically significant at 0.05

**Fig. 5** Seasonal and annual temperature trend in Suha watershed (1990–2020)



than the national warming rate, estimated to be 0.025 °C per year since the 1960s (World Bank, 2020).

### Smallholder farmers' perceptions versus actual observation of climate variability

Smallholder farmers' perceptions are insufficient to generalize about the actual variability and trends of climate change/variability. The reason is that perception is highly personal, site-specific, and influenced by several factors (Niles and Mueller 2016). Therefore, it is necessary to compare farmers' perceptions of climate variability with actual meteorological data analysis to determine the proper type of adaptation measures to be used in the area. Regarding rainfall, in the perception study, many farmers believed that overall rainfall had decreased in their areas during the last three decades (Table 3). The analysis of the meteorological data also indicated a tendency for a declining trend of the main (Kiremt) rainfall seasons but a rising trend with non-statistical significance in the mean annual rainfall. The farmers' perception is consistent with the main wet season's meteorological rainfall data analysis.

Concerning on temperature, as stated in the perception analysis section, farmers' perception about the annual temperature was found that it was increasing over time. Similarly, the results obtained from the climate data analysis showed that both the seasonal and annual trends had been increasing, except for the Belg season in the last thirty years (Tables 4 and 5). In this regard, there is congruence between the perception of farmers and the analysis of the meteorological data about temperature variability in the study watershed. Generally, the observed data showed a decreasing during the main rainfall season, but an increasing trend in temperature, which is steady with the findings of other researchers (Ademe et al. 2020; Kahsay et al. 2019; and Sohail et al. 2022).

### Smallholder farmers' adaptation strategies to climate variability

Local-based adaptation measures are ideal and priceless alternatives from the list of short- and long-term solution against the adverse effect of climate variability. This environmental problem has provoked farmers to use various adaptation strategies in watersheds (Carr et al. 2022; and Urgessa and Gonfa 2020). Although it is supposed that farmers have been using different adaptive strategies in response to climate variability, they were asked to state the primary one employed by them. Table 6 showed that some of the strategies were adjustments in crop/animal production, whereas others were responses through natural resources management (Mihiretu et al. 2020; Tessema and Simane 2020). For instance, to overcome the challenges of climate variability, farmers used various adaptation techniques in relation to crop production such as adjusting crop calendar, crop diversification, and the use of improved varieties (crop and animals). On the other hand, natural resource management adaptive responses include soil and water conservation, agroforestry, and small-scale irrigation.

Of all these categories, soil and water conservation (SWC) was the most dominant strategy across the given agro-ecological zones. The application of this strategy was implemented mainly in the lowland area (96.5%), and the chi-square test also showed to be statistically significant ( $\chi^2 = 6.23, p < 0.05$ ).

As indicated under Table 6, crop diversification was also heavily implemented among the respondents in the watershed. It was ranked second, and about 71% of the respondents practiced this strategy in the watershed across the different agro-ecologies. In implementing this strategy, a statistically significant difference was observed from agroecology to agroecology ( $\chi^2 = 13.56, p < 0.05$ ). Of all groups, a large number of households in the highland area (more than 79.3%) practiced crop diversification as an adaptation

**Table 6** Adaptation measures taken by smallholder farmers to climate variability

Adaptive strategy		Agroecology zone			Total	Rank	$\chi^2$ value	p -value
		Highland	Midland	Lowland				
		%	%	%				
Soil water conservation	Yes	84.5	90.3	96.5	90.9	1	6.23	0.04
Agroforestry	Yes	69.0	68.4	46.5	63.1	4	4.03	0.13
Small-scale irrigation	Yes	62.8	48.1	62.1	54.0	6	7.13	0.02
Adjusting planting calendar	Yes	58.6	57.8	73.3	61.7	5	6.45	0.04
Improved varieties (plants and animals)	Yes	81.0	65.5	60.5	66.9	3	7.01	0.03
Crop diversification	Yes	79.3	67.0	74.4	70.9	2	13.56	0.01

\* and \*\* indicate levels of sig. at  $p \leq 0.01$  and 0.05, respectively

technique, followed by 74.4% in the lowland and 67% in the midland of the watershed.

The third dominant adaptation strategy was the use of improved varieties. About 81% of the respondents implemented this measure in the highland areas, followed by 65.5% in the midland area. As compared to the others, 66.9% of the respondents were using this strategy to combat the influence of climate variability. There was a statistically significant difference among the three AEZ regarding the application of improved crop varieties ( $\chi^2 = 7.01$ ,  $p < 0.05$ ). This is probably owing to the assistance of the local government's agricultural extension services and some non-governmental organizations (NGOs) working in this area (especially in the highlands).

Besides, about 69% of the highlanders practiced the strategy of agroforestry to decrease the influence of climate variability in their area, followed by 68.4% of the mid-landers and 63.15% of the lowlanders. However, the difference among the selected agro-ecologies in the case of agroforestry practices is statistically non-significant ( $\chi^2 = 4.03$ ,  $p < 0.05$ ). Previously, tree planting was carried out for having fence around their farmland/homestead and to get natural shade for their cattle during the long dry period. Recently, this situation has changed and has been performed in a planned manner just to earn a large amount of money from it in a way that improves the long-term income of the family. For instance, planting hybrid fruit and eucalyptus trees on the household's farm has become common practice based in the agro-ecological zone.

Correspondingly, about 62% of the respondents both in the highland and the lowland part of the watershed have implemented small-scale irrigation practices as an adaptive strategy by diverting small rivers and underground water (boreholes). In implementing this strategy, a significant difference among the three groups of householders in the study was found ( $\chi^2 = 7.13$ ,  $p < 0.05$ ). The implementation of this strategy was poor due to the insufficient accessibility of water from small rivers and insufficient

harvesting of water in the summer season. Due to this, most farmers focus on commonly cultivated cereal crops rather than vegetation and fruits, especially in the midland agro-ecological zone. Accordingly, about 61.7% of the smallholders in the watershed have used adjusted planting date practices to match the late coming and early end of the main rainfall season. A statistically significant difference was found among the given agro-ecological zones in the implementation of this strategy by the farmers ( $\chi^2 = 6.45$ ,  $p < 0.05$ ). Of the three groups, adjusting planting time is highly implemented in the lowland (73.3%) part of the watershed. However, the application of this measurement is statistically non-significant in both the highland and lowland areas, showing that the importance of SWC in reducing climate variability risks is equally vital in both cases.

Generally, the variation in the use of these strategies emerged due to awareness differences, the local impact, and the support provided by different government and non-government organs in various forms. FGD participants raised different issues related to the use of these strategies either individually or as a community, the barrier they face, and the support obtained from different stockholders related to the disparity in the implementation of the strategies in the watershed.

### Determinants of climate variability adaptation strategies

Based on their purpose, adaptation measures can be classified as autonomous (traditional) or planned (conventional) groups. An independent adaptation measure, also referred to as reactive adaptation, is taken by vulnerable people without the direct intervention of government organs to reduce hazards posed by climatic change/variability. However, this adaptation strategy is assumed to be inefficient in avoiding the vulnerability of climate variability without support of second type of intervention (Kahsay et al. 2019; Nicholas 2007).

Today, smallholder farmers are using different strategies to minimize the influence of climate variability in their locality rather than accepting the negative impacts. Hence, contrary to the autonomous one, the conventional adaptation strategy emanated from deliberate policy decisions by government agencies are promoting appropriate and effective adaptation measures (Belay et al. 2017; Osumanu et al. 2017). However, the use of these adaptation measures is not a straightforward operation. Several factors influence the decision and application of these adaptation measures in the area where they are operationalized. These factors are generally grouped as socio-economic, demographic, institutional, and environmental variables (Mihiretu et al. 2020; Osumanu et al. 2017).

As stated in the model specification section, a binary logit model was employed to identify the influence of those predictor variables upon the practice of the adaptive strategies. The model fitness test was done against the data using the omnibus test and other earlier tests. For the omnibus test, the chi-square result for the model row indicates that it was found significant relative to the null model ( $\chi^2 = 68.739$ ,  $p < 0.001$ ). This means that the predictor variables have a high joint effect in predicting the status of household adaptive capacity. In addition, the classification table for each predictor variable was also considered. It was found that the model adequately classified 60 to 80% of the variables.

Therefore, the use of this model was found to be an appropriate one for the analysis, and it has also been employed previously by various research works to identify the determinants that affect the decision of farmers to use climate change adaptation measures (Osumanu et al. 2017; Urgessa and Gonfa 2020; Yohannes et al. 2020). The issue of multicollinearity among the independent variables was verified using the variance inflation factor, which is greater than

ten for the continuous variables, and the contingency coefficient and 1.63 for dummy variables, respectively (Belay et al. 2017).

Predictor variables like non-farm income, access to water, and farming experience of the respondents were removed from the analysis due to the problem of multi-collinearity. In addition, in the following section, only those variables that were significant ( $p < 0.05$ ) were taken into consideration for the interpretation and discussion of each dependent variable (Table 7). Predictors such as access to credit and access to a market were not included in the discussion, since their influence on using the strategies was statistically non-significant across the three groups at  $p < 0.05$ . Conversely, among the response variables, only those strategies ranked from one to three were considered for the binary regression model to know why farmers could not practice them fully. So, based on this context, the findings of the analysis are presented in Table 7.

Agro-ecological location is one of those factors that affect the use of different adaptation measures in response to climate variability. It has been found that smallholder farmers who live in areas with less rainfall and higher temperatures (kola) than the national average are more likely to apply different measures (Atinkut and Mebrat 2016). The binary logit analysis results (Table 7) revealed that farmers in Woina Dega are more likely to use crop diversification than the other two areas' strategies. This is because it had a positive correlation with the location of a specific area and was found statistically significant at  $p < 0.05$  as compared to the other categories. Changing from Dega/kola agroecology to Woina Dega can increase the likelihood of using crop diversification by 1.16 times among households. However, the use of improved varieties and SWC showed a negative correlation with this agroecology, which was statistically significant at  $p < 0.01$ .

**Table 7** The result of binary logit regression analysis between the predictors and adaptation strategies.

Predictors	Crop diversification			Improved varieties			SWC		
	Coefficient	Odds ratio	<i>p</i> -value	Coefficient	Odds ratio	<i>p</i> -value	Coefficient	Odds ratio	<i>p</i> -value
AEZ	1.82	1.16	0.05**	-2.40	0.09	0.01*	-3.41	0.03	0.00*
HH age	0.08	1.08	0.02**	0.04	1.04	0.26	0.06	1.04	0.03**
HH head	-0.48	0.61	0.39	0.38	1.46	0.43	0.91	2.50	0.02**
HH education	1.76	5.84	0.03**	2.21	9.15	0.04**	2.05	7.83	0.05**
Family size	-0.15	0.85	0.86	-1.19	0.30	0.22	2.70	7.06	0.00*
Farm size	1.58	3.56	0.02**	-0.31	0.73	0.13	-0.12	0.65	0.07
Farm income	0.71	2.03	0.04**	0.68	1.98	0.05**	-1.21	0.24	0.47
Access to weather information	1.87	6.54	0.05**	2.35	10.51	0.02**	2.12	8.38	0.03**
Extension service	0.41	1.50	0.05**	-2.00	0.13	0.19	4.03	0.02	0.00*
Livestock owner	1.03	2.67	0.03**	-0.54	0.67	0.67	-1.01	0.87	0.03**
Constant	0.45	1.56	0.68	1.29	3.61	0.24	1.83	6.23	0.09

\* and \*\* indicates level of sig. at  $p \leq 0.01$  and 0.05 respectively; no adaptation was reference category

In this study, the respondents' age was also found one of the factors that determine the application of crop diversification and SWC adaptations positively. In this regard, it significantly affected these strategies at a  $p < 0.05$  value. It indicates that as the household head's age rises by one year, the likelihood of the respondents using crop diversification and SWC increases by 1.08 and 1.04, respectively. Rural households mostly devote their long lifetime to agriculture activities. The older the household head, the more experience they have in farming diversified crops and different types of SWC activities related to climate variability. This study goes with the finding of Carr et al. (2022) which stated that old-aged farmers invest much time in agricultural operations in cultivating various crops which is used as a buffer against the impacts of more significant climate variability and extreme.

The male household head was found as having positive relationship with the use of all adaptation strategies except for crop diversification. Of these variables, SWC had a positive influence and a statistically significant at  $p < 0.05$ . According to the findings, to be a male household head raised the likelihood of employing SWC techniques by 2.50 times (Table 7). As expected, male-headed households had more opportunities to implement adaptive methods like SWC than female households head did.

The educational status of the respondents was also found to have a positive association with all three of the farmers' adaptation strategies. Of the other determinant factors, education was the most influential (Kifle et al. 2022; Sohail et al. 2022), as it showed statistical significance across the three strategies/options at  $p < 0.05$ . When the farmer's education status becomes higher by one level or a unit increase in several years of education, the probability of practicing crop diversification, improving varieties, and SWC increases by 5.84, 9.15, and 7.83 times, respectively. This implies that smallholder farmer households with relatively better formal education (i.e., junior (1 to 8 grade) and above) are supposed to use diversified crops, accept and adopt a new variety of crops/animals, and implement soil and water technologies based on their awareness to get their potential benefits in related to climate change adaptation measures.

Among other alternatives, the size of a family member has a positive and significant correlation with SWC among the other adaptation approaches to climate variability (Table 7). The number of family sizes had influenced the practice of SWC practice and was found statistically significant at  $p < 0.01$ . However, this variable shows a negative relation with the other strategic options. The odds ratio result indicated that a unit increase in family members also changed the likelihood of adopting the SWC adaptation strategies by 7.06 times compared to the others.

Among the given adaptation options, farm size had the only positive and significant relationship with the use of

crop diversification at  $p < 0.05$ . That is, as the area of farmland increases, so does the likelihood of implementing crop diversification. Hence, when a unit of hectare increases in the smallholder farmers' plot size, the possibility of using crop diversification measures will increase by 3.56 times compared to the other strategies. This is because large farm sizes allow for practicing different crops and animals, which is vital to reduce the risks of unpredictable weather impacts. On the contrary, the farm size of a household is negatively associated with the adaptive measures of households in implementing improved varieties and soil and water conservation activities.

A direct income from farming had a positive and critical effect on farmers to take climate adaptation measures in the analysis except for SWC practice. This is because increasing the income level of smallholders allows them to see the costs of farming inputs relevant to dealing with climate change. When a farmer's income increases by one unit, the likelihood of implementing crop diversification and using improved varieties increases by 2.03 and 1.93 times, respectively. Hence, as indicated above (Table 7), crop diversification and improved varieties were statistically significant at  $p < 0.05$ .

Access to climate data is a vital variable that influences adaptation options. The analysis result (Table 7) showed that having access to this variable (climate information) had positively influenced in all the given adaptation strategies against climate change/variability. In another way, a respondent who obtained better access to weather information at different time scales, such as seasonal or mid-term forecasting, made a better-informed adaptation option. Respondents with better access to climate data had a high probability of practicing climate variability adaptation responses such as the application of improved varieties and soil and water conservation activities, which were found statistically significant at  $p < 0.05$ . Smallholder farmers adjust their farming activities when there is a seasonal fluctuation in temperature and rainfall. This operation is usually carried out based on the available weather information from different sources. For instance, late and early planting, cultivating drought-resistant crops, early harvesting of matured crops, and SWC activities are directly connected with these issues. Being well informed about rainfall and temperature variability increased the likelihood of crop diversification, improved varieties and SWC by 6.54, 10.51 and 8.38 times, respectively.

Table 7 indicated that access to agricultural extension services was also positively and significantly related to crop diversification. This is because when farmers have a frequent opportunity to access extension services and workers, the likelihood of getting important advice and inputs becomes high for them. In this regard, crop diversification has shown the tendency to increase with the provision of extension packages. Access to extension packages increased

the likelihood of crop diversification and SWC by 1.50 and 0.02 factors, both statistically significant at  $p < 0.05$  and  $p < 0.01$ , respectively.

The analysis in Table 7 also showed that livestock ownership had a positive and negative correlation with crop diversification and SWC, respectively. In this way, the result of this study showed that it had found a significant effect on crop diversification and SWC at  $p < 0.05$ . When the number of livestock for households increases by one unit (TLU), the likelihood of adopting crop diversification also increases by 2.67 times, whereas the likelihood of using SWC decreases by 0.87 times.

## Discussion

### Perception and trend of climate in the watershed

Smallholder farmers are supposed to use adaptation strategies to reduce rural poverty intensified by climate variability. To that end, knowing smallholder farmers' perception regarding climate variability is so important. As previously stated in the results section, the survey and the descriptive summary indicated that most sample household respondents (89%) perceived climate variability and felt its adverse effects in their experiences. For instance, more than 79.1% and 90% of farmers perceived the decreasing and increasing rainfall and temperature at lowland AEZ respectively. Farmers' perceptions, which are the reflection of climate variability at local impacts, differ with the variations in the AEZ conditions. A similar research result was found in a study conducted at the Fincha sub-basin of Ethiopia's Upper Blue Nile basin. The finding stated that out of 380 household surveys from the different agro-ecological systems, about 93% and 88% of the respondents reported the presence of increasing temperature and decreasing annual rainfall, respectively (Niles and Mueller 2016, Tessema and Simane 2020). The result also indicated that smallholder farmers perceived the occurrence of late-onset and early cessation of the main rainfall season, erratic rainfall, extreme temperatures during winter, and devastating frost during autumn. Another research conducted by Mihiretu et al. (2020) also showed that most of the respondents (more than 77%) perceived an increasing temperature and decreasing rainfall, respectively, in the main rainy season, which is similar to the finding of our this study.

In the analysis, the actual occurrence of rainfall and temperature also confirmed the existence of a considerable degree of variability during the investigation period in different time scales (annually and seasonally). Based on the actual rainfall variation analysis, high rainfall is concentrated during the Kiremt season than the others. Kiremt season also had the lowest CV value (11.2%) of any rainfall record as

compared to Belg (little rainfall period) and Bega (dry) season. The CV of Belg value (41.5%) falls between Kiremt and Bega. This implies that there is more inter-annual variability during the Belg than in the Kiremt season in the study area. Studies in the northwest highland of Ethiopia (Ayalew et al. 2012; Bewket 2009; Mekonen and Berlie 2020) revealed similar findings in that the CV of Belg season was higher and more variable than the Kiremt season. From October to January, Bega (dry season) is relatively dry (Table 4). It showed a very high CV (64.2%) of the other seasons.

In addition, the MK test and Sen's slope estimator result have revealed the existence of inter-seasonal and annual fluctuation in rainfall distribution. The declining trend of main rainfall season was found to be statistically significant ( $p = 0.05$ ), while that of Belg was non-significant. The annual rainfall showed a slight increment but statistically insignificant; perhaps this is due to Kiremt rainfall reduction, which affects the overall agricultural performance of smallholder farmers in the study area.

The result of this study is in line with the research reports made by Abegaz and Mekoya (2020) and Weldegerima et al. (2018). They stated the presence of a statistically non-significant increasing tendency of rainfall throughout the year and Bega season but a significant and positive trend in the Belg season at the national and watershed level. Also, Asfaw et al. (2018) found that in the Kiremt season in Ethiopia's north-central region, there was a statistically significant downward trend. However, the findings of Bekele et al. (2017) and Mengistu et al. (2014) were different from the above reports in which a statistically non-significant but increasing trend was recorded in Kiremt and decreasing trend during Belg seasons in Awash River Basin and over the Upper Blue Nile/Abbay River basin of Ethiopia respectively.

The warming trend of the mean annual and seasonal temperatures in the study watershed was also found to be significant, affecting the agricultural demand for water in the study area and the smallholder farmers' overall performance. The result of the study agreed with the research reports of Abegaz and Mekoya (2020) and Weldegerima et al. (2018), which stated the presence of a statistically non-significant increasing tendency of rainfall throughout the year and Bega season but a significant and positive trend in the Belg season at the national and watershed level. Also, Asfaw et al. (2018) found that in the Kiremt season in Ethiopia's north-central region, there was a statistically significant downward trend. However, the findings of Bekele et al. (2017) and Mengistu et al. (2014) were different from the above reports in which a statistically non-significant but increasing trend was recorded in Kiremt and decreasing trend during Belg seasons in Awash River Basin and over the Upper Blue Nile/Abbay River basin of Ethiopia respectively.

Such climate variability/change has provoked farmers in the watershed to use various adaptation strategies.



Local-based adaptation approaches are ideal and priceless alternatives for both short- and long-term solutions. SWC practices were essential to avoid the danger of flooding during the main rainy season and to improve soil moisture and organic matter retention.

### Adaptation techniques in the watershed

Various local adaptation measures have grown over time to mitigate the effects of climate change on agriculture (Asrat and Simane 2018). As stated in the “Results” section, the most common adaptation techniques practiced in the study watershed were enhancing agricultural productivity and agro-ecological resource management practices, including SWC, crop diversification, improved varieties, agroforestry, adjusting planting date, and small-scale irrigation.

Soil and water conservation practices were the most vital one in the watershed to minimize the danger of flooding and erosion during the main rainy season and to improve soil moisture and organic matter retention in the area. The practice of physical and biological measures such as using soil/stone bunds, making waterways, checking dams, and planting trees along the border of their plots was observed. The FGD participants also stated that to manage their soil status, crop rotation, leaving crop residuals, and counter plowing were commonly practiced at the household level. They also mentioned that this operation is carried out at the community level in their locality in the form of afforestation, reforestation, and floodway diversions with the help of development agents and watershed development committee teams organized by kebele/village and district government officials. According to Tessema and Simane (2020), SWC strategies are one of the resource management measures to improve agricultural production and to reduce the risk of climate change vulnerability by increasing resilience. Another research work also pointed out that applying this strategy reduces soil removal, helps to improve crop yields, and increases farmers’ adaptation to climate variability (Yohannes et al. 2020).

Crop diversification was also seriously implemented among the respondents in the watershed. Nevertheless, the application of this method is not uniform in the three-agro ecological zones. It is implemented for both to avert climate change risk and to intensify the yield of market-oriented crops since land is a limited resource in the area. This finding is in line with the research reports of Yohannes et al. (2020), which stated as farmers used this and other adaptation strategies to lessen the harmful consequences of climatic shocks in the Semien Mountains of Ethiopia. Similarly, Tessema and Simane (2020) also stated that crop diversification is used to cope with the effect of climate variability by different agro-ecologies, and of the three agro-ecological zones, many households in the highland area practice crop

diversification as an adaptation technique in the watershed. This is also supported by Debray et al. (2019). This strategy contributes indirectly by increasing the resilience of the general farming system to the changing climate in a given area. Another finding also added that out of the total smallholder farmers who perceived the existence of climate change, 85% attempted to adapt it using practices like crop diversification and others (Belay et al. 2017).

In the FGD, the discussants mentioned that crop diversification is very important to adopt the problem of climate variability in many aspects and the result agreed with previous works (Asrat and Simane 2018; Belay et al. 2017). Even though it was not mentioned in the summary table, FGD respondents gave testimony that some people, especially the young group, move from their local area to other places for some period to get a temporary job like daily labor when weather hazards such as extreme drought and flood-damaged their crop fields. Hence, temporary migration is also the other strategy used by the local people as a non-farm income-generating mechanism to escape and adapt to the problem in the area.

On the other hand, using improved crop varieties was also the most common strategy respondents adopted in this area. This is owing to the assistance provided by the local government’s agricultural extension services and non-governmental organizations. Most of the highlanders, followed by midlanders, practiced the strategy of agroforestry to decrease the influence of climate variability in their area. The application of improved crop varieties has become one of the adaptation techniques against climate change in many parts of the developing region (Kifle et al. 2022). However, the difference among the selected agro-ecologies is statistically non-significant.

In addition, smallholders in the watershed have adjusted planting date practices to match the late coming and early end of the main rainfall season. Of the three groups, adjusting planting time is highly implemented in the lowland (73.3%) part of the watershed, as indicated (Table 6). Research results by Tessema and Simane (2020) also revealed that adjusting the agricultural calendar/planting dates is implemented as adapting strategy for the increasing climate variability.

Agroforestry is a deliberate integration of trees/shrubs with crops and livestock in the same land management system (Amare et al. 2018). It can contribute to sustaining agricultural production and can absorb air pollutants (carbon dioxide) and other environmental wastes (Amare et al. 2019; Yohannes et al. 2020) as well as facilitate adaptation to climate change (Amare et al. 2019). Many respondents practiced this strategy in the watershed mainly to get fodder, construction materials for different purposes, fuel wood, and generate cash. Besides, they plant trees and bushes in their plot for the shed to protect animals from sunburn during the

hot season, fence for their cropland and home, and protecting sporadic food accident. However, this is carried out traditionally and the practice has become decreasing from time to time in the area due to increase in fuelwood demand and degradation of nearby forests. This also supported by the finding of Amare et al. (2019) that agricultural intensification, the increasing popularity of exotic tree species that generate greater economic benefits for farmers, loss of natural forest, and the demand for land decreases the practice of agroforestry particularly “farmland agroforestry.”

Small-scale irrigation is perhaps one of the most critical management strategies farmers use to cope with climate variability by providing water to crops and pastures during the dry season to offset intermittent soil moisture deficiencies (Sohail et al. 2022). Although irrigation has been used in the area mainly for vegetable production, its use is still limited and does not apply to most field crops. It is the least ranked in its implementation in the watershed compared to the other strategies. Relatively, there are best practices of it by farmers in the highland area. This is related to farmers’ low awareness and the incapacity to use both surface and groundwater due to limited technological and financial capabilities.

These adaptation measures have been extensively practiced for a considerable period in the study area and some other parts of the country. The first category of adaptation practices is believed to increase the resilience against climate change, particularly for an increase in climate variabilities like prolonged periods of drought and seasonal shifts in rainfall (Tessema and Simane 2020). Also, the second category, i.e., the agricultural management practices that increase agricultural production, supports climate change adaptation by strengthening agricultural resilience and reducing yield variability under climate variability and extreme events (Belay et al. 2016; Mihiretu et al. 2020). On the contrary, these strategies are not always associated with climate change adaptations. For example, the use of improved crop varieties and soil water conservation may be motivated by a desire to increase the crop’s agricultural output and household income (Belay et al. 2017; Urgessa and Gonfa 2020).

### Determinant factors of the adaptation techniques in the watershed

For instance, smallholder farmers who live in places with less rainfall and higher temperatures (kola) are more likely to apply different measures. Shifting from one agro-ecological zone to the other can increase the likelihood of using crop diversification by 1.16 times than SWC and the use of improved varieties. This is because the application of crop diversification has a positive association with the location of smallholder farmers and was found statistically significant

at  $p < 0.05$  as compared to the other categories (Table 7). In addition, when we compare the application of SWC and improved varieties based on location, farmers who live in Woina Dega agro-ecological zone were less likely to use improved varieties and SWC than farmers who lived in Dega/kola. This result is congruent with Atinkut and Mebrat (2016) and Kelelew et al. (2018). This implies that smallholder farmers’ living in different agro-ecological settings used various adaptation measures in response to climate variability. The disparity could be explained by the existing differences in natural resources such as soil and vegetation.

Age is the other factor that deters the application of those strategies against climate change/variability, which is explained when the household head’s age rises, the likelihood of the respondents using crop diversification and SWC increases and vice versa. This finding agreed with Asrat and Simane (2018), in which as farmers’ age increases, the knowledge and experience of considering different adaptation options also rise.

Having a male-headed household raised the likelihood of employing SWC techniques by 2.50 times (Table 7). The study also found a positive relationship between SWC and household headed with a statistically significant at  $p < 0.05$ . This result is similar to a study by Belay et al. (2017) that male-headed families are more likely than female-headed households to access technology and climate change information. Consequently, they were better able to evaluate the cost and benefit of implementing SWC strategies than the female-headed groups.

When the educational status of a farmer is correlated with the application of climate adaptation techniques, the tendency of practicing crop diversification, improving varieties, and SWC increases by 5.84, 9.15, and 7.83 times. This means that smallholder farmer households with relatively better formal education should use diversified crops and accept and adopt a new variety of crops, animals, and technologies. A research report by Belay et al. (2017) and Osumanu et al. (2017) also proved that better educational status and training tend to diversify their crop and apply new SWC technologies than non-educated farmers.

The number of family members had also positively influenced the practice of SWC as compared to the others. According to Belay et al. (2017), when the number of family members increases, the practice of using some adaptive measures also gets higher and higher since they are labor-intensive in a country like Ethiopia. As a result, some adaptation measures, such as soil and water conservation, are strongly linked to household size.

Regarding the size of farmland, it provides an opportunity to practice different adaptation mechanisms when it becomes large. For example, as the area of farmland increases, so does the likelihood of implementing crop diversification. In this study, the farm size of a household is negatively associated

with the adaptive measures of households in implementing improved varieties and soil and water conservation activities (Araya et al. 2020; Kelelew et al. 2018).

Direct income from farming had a positive and key effect on farmers' climate change adaptation, increasing the likelihood of implementing crop diversification and using improved varieties increased by 2.03 and 1.93 times, respectively. The increase in income allows smallholders to see the costs of farming inputs relevant to dealing with climate change. The finding inlines with Belay et al. (2017) and Tessema et al. (2018), which revealed that income positively correlated with soil conservation measures and the application of crop diversification to minimize the influence of climate change.

Well-informed farmers about rainfall and temperature variability also increased the likelihood of using improved varieties and SWC. Access to weather information at different time scales, such as seasonal or midterm forecasting, made a better-informed adaptation option. These results are similar to the findings from various studies, such as Mihiretu et al. (2020), which confirmed that access to the information on climate and training were significant factors behind farmers' responses.

Farmers with regular access to agricultural extension services and employees are more likely to diversify their crops. Farmers with frequent access to extension services are more likely to receive valuable advice and input. Crop diversification has shown the tendency to increase with the provision of extension packages. Belay et al. (2017) believe better access to agricultural extension services positively impacted climate adaptation strategies. Mixed farming, which mainly encompasses livestock and crop cultivation, is the leading economic activity in the study watershed.

Finally, livestock ownership was linked to crop diversity and SWC. When farmers' livestock number rises by one (TLU), the likelihood of using crop diversification and but SWC practice decreases by a certain level, respectively. Previously conducted studies have shown that being the livestock owner has a positive relationship with the adaptation of crop diversification (Belay et al. 2017; Kahsay et al. 2019). Generally, these variables are some of the determinant factors that affect the application of the adaptation methods in different directions (positively or negatively) in the study area. It implies that the issue needs further study to identify more hidden factors that deter the implementation of those mechanisms.

## Conclusion

Ethiopia is one of those countries suffering from climate variability, including the study watershed. This study tried to assess the perception, the indicator, the type of local

adaptation strategies, and the significant barriers that deter the use of adaptation measures against climate variability across the different agro-ecological zones in the Suha watershed.

Although there are considerable differences in demographic, socio-economic, and institutional categories, the findings of this study indicated that most smallholder farmers were aware of the increasing temperatures and changing rainfall patterns both temporally and spatially in the watershed over the three decades. The perception of farmers toward the variability of temperature and rainfall has shown a significant difference among the different agro-ecological zones. They have been observing and experiencing the variability in their lifetime in the study area. As a result, smallholder farmers' livelihoods, particularly agricultural operations and livestock production, have been adversely affected mainly emanated from recurrent drought, insufficient water availability, seasonal flooding, and late coming and early terminating of the main rainy season.

For this as a response, farmers were mainly practiced SWC, improved varieties, and crop diversification in the study area though it was affected by various factors. The model result showed that eight out of ten determinant variables were found significant at  $p$  values of 0.01 and 0.05. All the variables mentioned above were found to be statistically significant. A positive and statistically significant relationship between some independent variables such as the household agro-ecological location, age, educational status, farm size, farm income, agricultural extension service, access to weather information, and livestock ownership with the application of crop diversification was found. Similarly, AEZ, educational status of the respondent, farm income, and information access to climate were positively associated and statistically found to be significant with improved varieties. Furthermore, the implementation of SWC as an adaptation strategy was also positively correlated with household educational status, family sizes, access to climate information, agricultural extension services, and livestock. Surprisingly, SWC practice had found a negative but significant relationship with the livestock ownership of the respondents.

This implies that the use of context-based adaptation strategies by most farmers was under the influence of various demographic, socio-economic, institutional, and environmental factors. Smallholder farmers require the participation of multiple institutions for support, including technology provision and training, to strengthen the local-based adaptation strategies. Climate variability adaptation strategy implementers can establish policies and programs that support the successful implementation of it by learning more about how local farmers notice climate change and reactions. Thus, the findings of this study contribute valuable information to policy-makers, agricultural development workers, and smallholder farmers related to the following focal points.

First, to build an efficient climate-resilient society, policies and strategies should focus on fulfilling and empowering respondents in the rural community. This includes empowering farmers by providing access to credit with low-interest rates for those low income groups, provision of adequate extension services, and access to climate information by establishing local meteorology stations would be important. Besides access to formal and informal education (training), the proportional ratio between extension workers and farmers were also strongly tied to all adaptation strategy options. In this case, local governments and NGOs can be essential in disseminating and presenting weather information and capacitating rural agricultural extension workers and smallholder farmers just to intermingle the local adaptation measure with the conventional one.

Second, as stated by the FGD discussants, developing opportunities for the off-farm income-generating mechanism is vital as it supports some smallholder farms in times of crop failure and reduces the pressures on some resource (land) due to climate variability (shock) due to its less sensitivity to climate variability. Moreover, disseminating improved and suitable crop/animal variety is most important to build the adaptive capacity of the households in the area.

Lastly, the assistance to implement those climate adaptation mechanisms should consider the preferred input, best interest, and well-being of the stallholders' farmers. For instance, soil and water conservation have been implemented for dual purposes (natural resource conservation and a climate adaptation mechanism). However, this study discovered that its effectiveness depends on the specific context (agro-ecological zone) and the interest of the stockholders, particularly smallholder farmers in the watershed. Hence, this study gives an insight for researcher and other stockholders to uncover affecting factors in related to the application of adaptation measures and provides benefit for the rural communities by capturing more attention from local government bodies in many aspects. It would be vital to implement the result of the study in areas where there are similar agro-ecological zone and socio-economic scenarios. Hence, policymakers can establish policies and programs that support successful adaptation by learning more about how local farmers notice climate change/variability, and implement adaptation practices, and the barriers that most influence their adaptation practice.

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