Discover Food

Research

Consumption expenditure effects of adoption against drought tragedy in drought prone area of Eastern Hararghe, Ethiopia

Jafer Mume Ahmed[1] · **Jema Haji**[2] · **Moti Jaleta**[3] · **Kedir Jemal**[2]

Received: 12 August 2024 / Accepted: 2 June 2025
Published online: 02 July 2025

Abstract
Annual consumption expenditure of the households seriously affected by climate shocks in the country where the major livelihood of the community depends on rain based agriculture where adaptation should be key strategy against climate shocks effect. This study investigated the effects of crop diversification and irrigation practices adoption on consumption expenditure against drought in drought prone area of Eastern Hararghe. Both primary and secondary data was used for this study. Irrigation practices and crop diversification practices were mainly practiced and considered as climate smart agricultural practices here. Multistage procedure applied and data collected from 430 samples during 2023 year. From Hararghe zone four districts were randomly selected. To investigate effects of crop diversification and irrigation practices on consumption expenditure two-stage least square model was used. Three months scales' standard precipitation index was applied to analysis drought using 33 years rainfall data. Result revealed that livestock, drought experience, labor, adopting crop diversity, irrigation practices and household income positively increased consumption expenditure whereas market distance, family size and drought affected negatively. So, it is crucial to more advances farmers and experts' information on climate shocks particularly drought and adoption practices that minimize drought effects. The policymakers ought to develop farmers' income generating activities and weather related information service to enhance adoption of crop diversification and irrigation facilities to combat the current and future drought effect.

Keywords Drought tragedy · Consumption expenditure · Irrigation · Crop diversification · 2SLS

1 Introduction

Climate change is expected to create major disturbances to the global food and water availability system. It has significant effect on the amount of precipitation and temperature distribution both spatially and temporally [1], which affects the availability of water [2]. The availability of water also affects the amount of water available for irrigation [3, 4]. The amount of water required for irrigation will be one of the major determinants of future water security [5]. As a result, the amount of available water will not be enough to meet the needs of the irrigation system due to the future effects of climate change [6, 7]. This is mainly due to irrigation water demands for crops will increase in the future [8]. Ref [9] indicated that irrigation water withdrawals will increase in the future due to global warming and precipitation changes.

✉ Jafer Mume Ahmed, mjaafer24@gmail.com | [1]Department of Agricultural Economics, Fedis Agricultural Research Center, Oromia Agricultural Research Institute, Addis Ababa, Ethiopia. [2]Agricultural Economics and Agribusiness School, Haramaya University, Dirre Dawa, Ethiopia. [3]International Maize, and Wheat Improvement Center (CMMYT) Sustainable Agri-Food System Program, Addis Ababa, Ethiopia.

Climate change increases water demand for irrigation and decreases crop yields. Moreover, climate change is expected to affect agriculture worldwide [10]. It leads to significant reduction in crop yield; even to the level irrigation will not be enough to mitigate the severe and detrimental effects of climate change on crop production. The results herald positive implications for irrigation demand and for food security may be dire [11]. This is due to extreme heat is likely to cause significant decreases in agricultural yields [12].

Agriculture is backbone of the economy and most important sectors for rural farmers' labor, reduction of the poverty level and income earning from export item in Ethiopia [13]. Even if it plays a significant role, Ethiopia's agricultural sector suffers from high levels of climate variability and drought which is increasing from time to time [14, 15]. The climate of Ethiopia is noted for its history of extremes event such as drought and shifting trends in temperature and precipitation patterns [16]. The projections show that temperature will rise relative to the current state [17] and reduce precipitation that will have adverse effects on crop production in Ethiopia [18]. Moreover, as the temperature continues to rise, the negative impact of climate change on crops will be increase, therefore, irrigated agriculture is very important to increase yield and stabilize yield [19]. The rising temperatures and increased evapotranspiration will increase the amount of crop water needed in the future [20]. As a result water supply will become less available in Ethiopia [21].Therefore, climate shocks such as drought significantly affecting agricultural yields that leads to food production losses. Climate shocks can be explained as amount of rainfall deviations from long term normal condition [22]. Drought is also complex components of climate shocks which can be due to moisture deficit that last from month to decades [23].

In Ethiopia for instance in Oromia region, the recent drought has affected around 7,594,827 people of the pastoral and agrarian of nearly in 73 woreads of seven zones were estimated to be affected by the drought including East Hararghe Zone. The drought situation further worsens the food security, water shortages at the community levels after 2021 [24], which lead to a loss of household income and reduce consumption expenditure [24, 25]. The spending by households on consumption good including food commodity and non-food commodity such as cloths, education, family health expense and purchases of assets are termed as consumption [26] whereas the money amount expense for buying that item is considered as expenditure for consumption [27]. The effects of drought on consumptions is directly through reduction or failure of agricultural yields and productivity of farm [28, 29] as results of agricultural drought, which is also true in this particular area of study. Drought has the most overwhelming effect on agricultural yield and cause Ethiopia to depend on food aid for decades [30]. Moreover, food scarcity problem will increase if adaptation measures are not considered in Ethiopia [31]. Therefore, adaption strategies such as soil conservation, irrigation practices and crop diversification are mostly recommended and adopted [32].

Crop diversification (CrD) is practices that plays significant role in improving soil fertility and enhancing agricultural yield, productivities, dietary diversity and resilience against climatic change like shortage of rainfall, flood and drought [33, 34]. The small holder farmer also diversifies their cropping activities so as to diversify their food, farm income and enhances productivities of their farm land. This is why farmers in moisture stress areas including those in Eastern Ethiopia do not depends on the cultivation of single cropping only. According to [34, 35] crop diversity has significant effect against climate shocks such as drought. In Ethiopia even if crop diversification was assumed to enhances food nutrition and climate shocks risk minimizing [36] the adopting SAPr was found bellow satisfactory [37] and needs further research. Moreover, the selection of crop type and crop production largely depend upon the local socio-economic conditions including improved market facilities, increasing the availability of organic manure, farmer training and farmers' participation in the available farmers knowledge sharing visit [38]. Crop diversification and reducing dependence on only rain-fed agriculture are important [39]. Thus, adopting of the adaptation strategies are best mechanism of minimizing negative effect of climate related shocks on agriculture [40]. The other component of practices that is widely used in the area was irrigation application. Rain water harvesting for irrigating cash crop also practicing in the area were effective awareness was created and promoted to enhances reducing negative effect of climate change on farmers livelihood. The study by [21] demonstrated that effect of climate change on the water will be reduced with the application of effective irrigation practices in Ethiopian. The irrigation application assumed to increase farmers' welfare through increasing farm yield, farm income level, and poverty reduction [41] by minimizing agricultural crop failure and climate change effects [42]. The attention was given for promoting and applying of small-scale irrigation in this country. Despite of this attention for irrigation development, this sector has not sufficiently improved [43] as whole. For example, in Ethiopia, farmers' participation in irrigation practices is very lower [44]. The study conducted by [45], found the role of irrigation in increasing consumption in other area.

Generally, even if Ethiopia has long time exposure to drought, and climate shock events is growing from time to time [28, 46], farmers'adoption and implementation of smart practice against drought found at lower level in sub Saharan African countries, including an Ethiopian country [37, 47] resulting in low production [48, 49]. In addition to this, it is not

clear to what level crop diversity and irrigation application have resulted in the anticipated consumption expenditure effect in relation to observed drought in the area. Climate shocks including drought in specific is expected to rises in occurrence and scale in the future, causing the rain fed based livelihood in developing world countries at unlimited risk. Therefore, identifying role of crop diversification and irrigation activities in reducing negative impacts of drought on consumption expenditure ought to be priority issue in moisture deficit area. Unlike most of the studies mentioned above, this particular research was undertaken in drought prone area where drought cause crop failure frequently [50, 51] while farm productivity is decreasing from year to year due to drought [52].The finding from this study can generate crucial information for the farm community that depends on rainfall based agricultural yields for their livelihood and policymakers, so as to understand the trends and effects of drought and encourages the adoption and application of appropriate practices. Therefore the main objective of this study is to identify the effects of crop diversification and irrigation practices on consumption expenditure in the study area.

2 The study methodology

2.1 Describing study area

This research was done at Karamile/Goro gutu, Gursum, Babile, and Kersa woreads in the areas of Hararghe zone, which is among 18 zone of Oromia Region. This zone spans 24,933 square kilometers and is situated at 07′ 36′ N & 09′ 41′ N 41′ 18′ E & 43′ 00′ Es. According to [52], there are 34.7% midland, 7.7% highland, and 67.8% lowland among them. There were also 2,723,850 total zonal populations, of which 1,383,198 were men & 1,340,652 were women dwellers. There are 2,502,365 peoples that were living in rural areas compared to 211,606 urban dwellers [53]. According to [52], the average yearly rainfall starts from less than 700 m.m in the lowlands or lower kolla to around 1,200 mm in the highlands. The temperature likewise varies from 14 to 25 °C. In the area, it is typical for the amount of precipitation to vary from year to year and to be unevenly distributed, mainly during the growth seasons. Moreover, the area was found to be affected by drought that causes food-insecurity problem [54] and also that aggravated by repeated drought [24, 55] the agricultural production is also reduced [52], which caused crop yield loss repeatedly [50]. The map of study area was shown as the following (Fig. 1).

2.2 Data description

Using a prepared questionnaire, the primary data was collected, covering details on the plot, the types of crops planted, the types of farm activities, irrigation infrastructure, and issues related to climate shocks for each crop grown on each plot of land, income and detailed consumption aspects. Additionally, the enumerators received one day of training on the questionnaire's content and how to use the Kobo Tool Box program on smart phones and tablets to collect data. The Ethiopian National Meteorological Service Agency provided the meteorological data for the last 33 years (1990–2022) of monthly precipitation records for four representative stations. Four study area districts were randomly chosen from each district using the multistage sampling procedure. Ultimately, the [56] algorithm also applied for establishing size of sampled number and respondents were grouped then considered by applying probability proportional to population size (PPPS) technique. There were 430 respondents, with extra 56 respondents included as a backup in case there were any data gathering issues.

2.3 Descriptive analysis

Additionally, both econometrics approaches as well as the descriptive technique were applied for computing and evaluating the gathered data. Several analytical techniques were applied to the data examination process because the data comprised both qualitative and quantitative information. During data analysis STATA version.16, SPSS software, ArcGis 10.8 version, MS Excel and MS Excel based MAKESENS_1_0 was used in drought analysis. Drought indices of SPI-3 value were also interpolated using multivalued spline technique over study area and then extracted by households' location to join drought and household data using ArcGis.

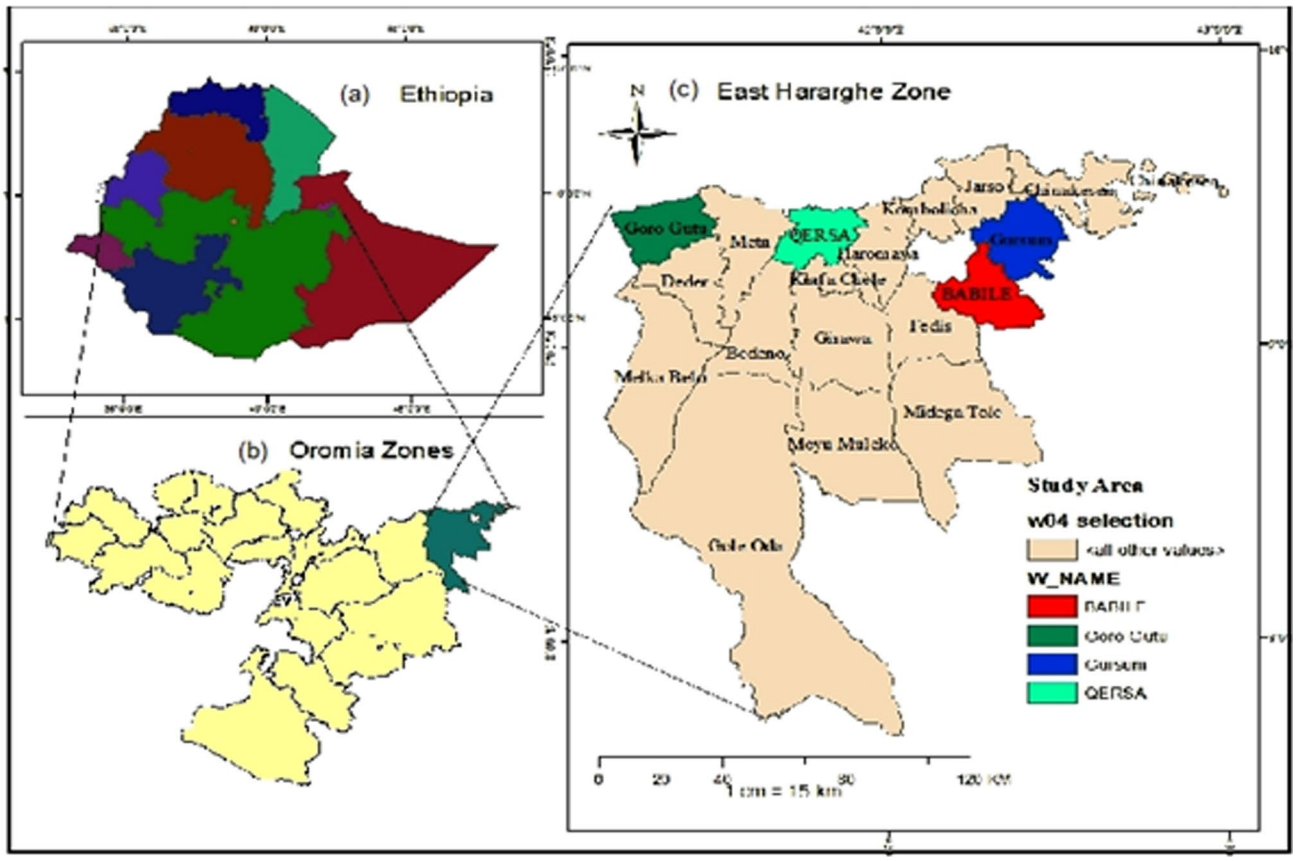

Fig. 1 The study area map

2.3.1 Measuring drought, households' demographic and socio-economic characteristics

For this particular parts of the research mean, percentage, standard deviation and frequency of data from response of adopters of SAPr practice and non-adopter farmers was used to analysis. The statistical significances for both continuous and discrete were conducted by applying t-test and chi-squire test, respectively in this study. To analysis drought situation in the study area, standard precipitation index method that was developed and applied by [22] was also used in addition to farmers' perception on drought to quantify rainfall shortages based on 3 months' time scales following [22] that recommended for multiple time scale. The formula for Standardized Precipitation Index (SPI) used as:

$$SPI_{ij} = \frac{\mathbf{X_{ij-\mu_{ij}}}}{\boldsymbol{\sigma_{ij}}} \quad (1)$$

where SPI of the ith season at the 3th time scale. The total amount of rainfall for ith season is X_{ij}. The mean and standard deviation are presented as μ_{ij} and σ_{ij}.

After that, a gamma probability density function fitted to the rainfall data was used. Next, the probability is equally transformed from the cumulative distribution to the standard normal distributions, which has a variance of one and a mean of zero which termed as SPI-value that used to analyze agricultural drought [22]. In this particular study 3-months-SPI was computed using MS Excel for each rainfall station. Then SPI was set equal 1 if the value of SPI is less than – 1.5, indicating a severe drought, otherwise, 0 for respective season.

2.3.2 Variables and definition

The most and widely applied smart agricultural practice is **small-scale irrigation**, which is considered if farmers were at least practiced rainwater harvesting, using cannel-based irrigation, and using ground water to grow vegetables, other cash crops, and as supplementary water for other crops. Irrigation is crucial for maintaining agricultural production and reducing adverse influences due to drought or insufficient rainfall. Similarly, **crop diversification** is the other widely used climate smart component, which is meant to reduce effects of drought. Furthermore, Eastern Hararghe farmers cultivate a variety of crops, including sorghum, maize, groundnuts, haricot beans, sweet potatoes, vegetables, and khat, to withstand the impacts of drought and increase productivity as crop diversification practices. Definition and expected effects of the variables were shown as (Table 1).

2.4 Study framework

The following (Fig. 2) shows the visual representation that outline the key steps involved in conducting and finalizing this research work in the form of flowchart. It starts from defining research question to data analysis and interpretation.

Under defining research problem and setting objectives, the problem that research and the objective of the study was explained. During literature review the review of the previous studies that support this research work were reviewed. Similarly under identifying research methodology research methodology justified, sampling technique selection, developing model acceptability justification, developing questionnaire in data collecting tool box & test. Under data collection section, following data and monitoring data gathering. Data preparation, clearing, justifies statistical technique and data analyzes. Finally Interpreting the finding and compare with previous research finding was done.

Table 1 Variables and hypothesis used for model analysis

Variables	Measurements	Expected effect on adoption
Dependent variables		
Log(Cosumtn.Expr)	Total annual per adult consumption expenditure in Birr	
Independent variables		
Log(total households' income)	Annual income in ETB(Ethiopian Birr)	+
Age	Age of family head in year	±
Gender	Male headed family = 1, otherwise 0	+
Household size	size of family in number	±
Land area	Area of land in hectars	+
Education of head	Education in formal years schooling	+
Access to extension	Access to extension = 1	+
Market distance	Distance to market in kms	−
Climate information	1 if accessed 0 if not	+
Farm experience	Farm experience in years	+
Livestock holding	Total livestock holding in TLU	+
Social memberships	1 if membership, 0 if not	+
Market information	1 if accessed, 0 if not	+
Non/off-farm activity	1 if participated, 0 otherwise	+
Drought/shock experience	Drought experience in the last 10 years	+
Number of Oxen	Oxen owned in number	+
Number of farm plot	Plot owned in number	+
Labor force	Number of active family members	+
SPI-summer-22	1 if spi-summer is less than − 1.5, or 0 for 2022	+
SPI-summer-20	1 if spi- summer is less than − 1.5, or 0 for 2020	+
SPI-spring-20	1 if spi-spring is less than − 1.5, or 0 for 2020	+

NB: SPI-summer and SPI-spring are indicators of drought(standardized precipitation index)

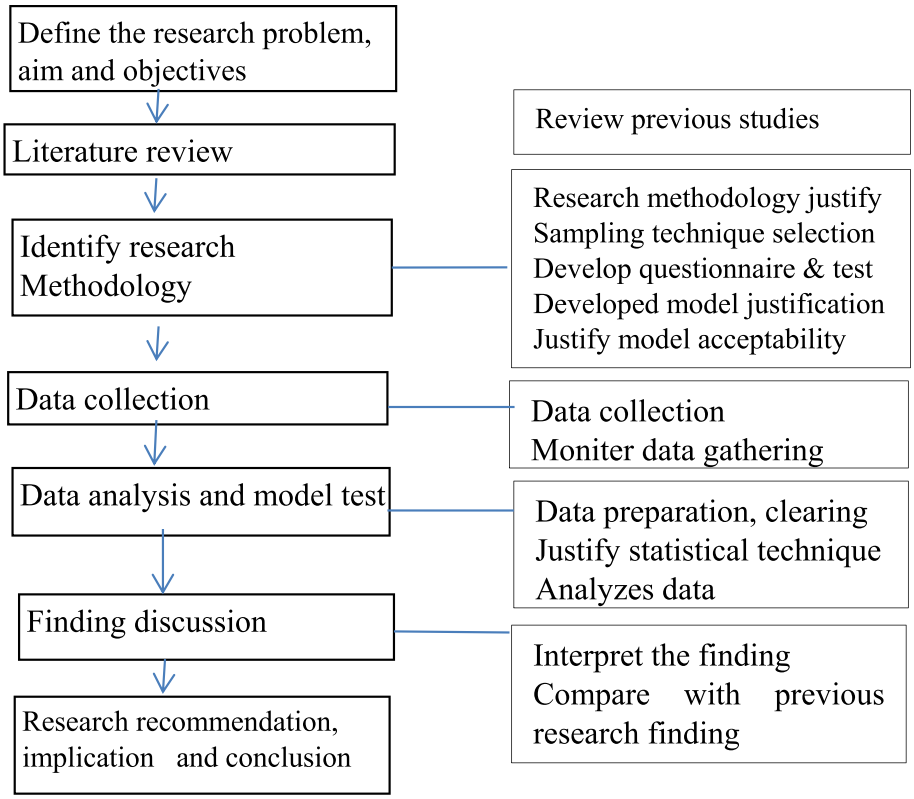

Fig. 2 Flowchart of study framework

2.5 Determinants of annual consumption expenditure

To identify determinates of annual consumption expenditure multiple linear regression was applied as:

$$\log(y_i) = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_3drought(spi)_{.} + \cdots + a_ix_i + u_i \quad (2)$$

where, y_i is per adults annual consumption expenditure (PaCE). And the drought variables also included in the model as summer Spi and spring Spi used for 2022 drought year as dummy variable in the study.

a_0 is the intercept and $a_1a_2 \ldots \ldots \ldots a_i$ are the coefficient of the parameter (slopes). u_i is represents the disturbance terms and x_i are explanatory variables including crop diversity and irrigation variables as dummy in the model. The models' dependent is logarism of total per adult consumption expenditure and therefore one change in dependent variable is interpreted as percentage change per adult PaCE, for a unit changes in the dependent variables. However, endogenity issue was observed due to included annual income (logarism) in the model. Moreover, analyzing of the model showed that the error term is correlated with endogenous variable confirming the application ordinary least square regression model could resulted in inconsistent and biased estimate [57].Therefore, instrumental variable based technique of two-stage-least-square model (2SLSM) was applied to estimate the parameter due to its importance when dealing with endogeneity problem [58].

The presence of the endogeneity issue was confirmed by Durbin and Wu-Hausman test. The null hypothesis test states that the variables are exogenous and this test was found to be statistically significant. Therefore, this significant confirms presence of endogeineity issue and rejection of null hypothesis. In this study, annual income in logarism form affects annual total consumption expenditure per adult and consumption expenditure can also determine income level. Therefore, access to climate information, participation in non-farm income generating activities and household income without log form were found as valid instrument. There variables determined total income (log-income). Therefore, the instrumental variable based 2SLSM was used as the following equation:

$$\begin{aligned} ivregress\ 2sls\ \ \log(y_i) &= a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_3drought(spi)_{.} + \cdots \\ &\quad + a_ix_i(endogenous\ variable = instrument\ variables) \end{aligned} \quad (3)$$

2.6 Limitation of the study

The main challenges that faced during investigation of consumption expenditure effects of adoption against drought tragedy was lack of record keeping for each food commodity purchased and prices. In addition, the information generated was based on data from the farmers that may not be responded correctly to some questions that related to income for fear of possible increment of taxes.

Furthermore, the study was conducted mainly based on the information that was generated from the household survey during a single cropping season due to the limitation of budget, time and logistics. Due to this, the study was used cross sectional data instead of panel data which may reveals changes over time.

3 Results and discussion

3.1 Socio-Economics and demographic characteristics

Result showed differences between adopter and smart agricultural practices (SAPr) non-adopter focusing on their socio economic factors. Regarding SAPr practices non-adopter, farmers that do not applied any of crop diversification and irrigation practices on at least one of their farm plot were considered in this particular study. It this study, out of total sampled respondents, non-adopters accounted for about 9.5% of farmers. The results from descriptive statistics showed that farm experience, education, drought experience, ox number and market distance were the variable that showed significant mean differences between the two groups (Table 2).

Result revealed that, mean of farmer experience in the farm activities of non-adopter is 19.12 years while that of adopters was 23.4 years in farming with significant mean difference at 1% probability level. This implies that more experience in farming enhances farmers to adopt the SAPr such as crop diversity and irrigation practices than non-experienced one. This shows more experienced farmers may found it simpler to identify what to do so as to minimize the effect of drought and increase benefit from their farm. It also showed that the average formal year of schooling of adopters was grade 5.1 whereas that of non-adopters was grade 3.8 showing the significance mean differences at 5% probability. The educated farmers adopted and implemented the appropriate SAPr that increase their agricultural yield and increase their consumption expenditure.

The sampled farmers were asked regarding the years they faced the drought/climatic shocks in the last ten years. The result revealed that, the mean drought/climatic shocks experience of adopters was found to be around 3.7 year whereas that of non-adopter was 3.1 years. Result showed that there is a significant mean difference in drought experience at 1% for the last ten years. This implies that previous drought experiences of the farmers may encourage them in the ways to adopting and implementing different smart agricultural practice on their farm. The results also showed that, on average adopters had 1.3 ox in number of livestock while non-adopters had 0.9 ox in number of livestock with significance mean difference at 1% probability level. The livestock are used as a power of draught, transportation and income source for rural households. On average non-adopter were found at 11.2 km whereas adopters of practices were found at distance of 6.1

Table 2 Results of socio economies and demographic characteristics of sampled respondents

Variables	Adopter (n = 389)		Non-adopter (41)		Mean difference	t-values
	Mean	Std.Erer	Mean	Std.Erer		
Age of respondent	38.37	0.57	36.85	1.55	1.51	0.825
Farm experience	23.35	0.41	19.12	1.21	4.23	3.217***
Education respondent	5.12	0.19	3.78	0.55	1.34	2.191**
Dry/shock experience	3.73	0.07	3.17	0.19	0.56	2.519***
Family size	6.21	0.11	6.34	0.34	0.13	0.369
Farm size	0.47	0.01	0.45	0.03	0.02	0.639
Labor force	4.93	0.08	4.68	0.28	0.25	0.978
Number oxen	1.29	0.07	0.93	0.22	0.37	1.537*
Market distance	6.15	0.73	11.25	0.29	5.10	5.548***

Source: Own survey results, 2023; ***,** and * shows at 1%, 5% and 10% significant, respectively

km from the market with significance mean difference at 1% probability level. Farmers that access market in short distance can get farm input and information for input simply compared to distant farmers. So they adopted SAPr mainly irrigation and crop diversity practices simply. This enhances farmers to increase their consumption expenditures against drought.

In the area as it was shown in the Table 3, 62.9% of the adopters of crop diversification practices accessed extension service. Similarly, 60% of irrigation practices adopters and 72% of the adopters of combined practices accessed extension service while 37.1% of adopters of diversification, 40% of irrigation adopters and 28% of combined practices adopters not accessed extension service. In the case of non-adopters of SAPr practices 65.9% of non-adopters accessed extension service whereas non-adopter of smart practices that do not obtained extension accounts for 34.1%. Precipitation and temperature are the main seasonal elements that influence agricultural activity. Both are influenced by climate change. A key factor that influence adoption and implementation of SAPr practices mainly crop diversification and irrigation application is having access to weather information. The result shows that 62.1% of crop diversity practices adopter and 70% of irrigation practices adopters' accessed information. Similarly, 56% of both combined practices adopters accessed information. In the area, 37.9% of crop diversity practices adopter and 30% of irrigation practices adopters not accessed climate information whereas 44% of both practices combined adopters not accessed climate information. In the case of non-adopters of smart practice 58.5% of them accessed weather information while 41.5% of them not accessed information in the area. This implies that adoption of SAPr practices requires on time weather information to respond to and minimize the effect of climatic shocks (Table 3).

The results in the following (Table 3), showed that 56.9% of crop diversity practices adopters and 48.8% of irrigation practices adopters were male headed. In the study area also 53.4% of both combined practices namely crop diversity and irrigation practices adopters are male headed households. On the other hand, 43.1% of crop diversification practices adopters and 51.2% of irrigation practices adopters were female headed household. Regarding non-adopters of smart practices 56.1% of non-adopter are male headed while 43.9% of non-adopters were female headed. Sex of the household head is significant variable that influences SAPr practices adoption. The family head membership in farmer social associations is very important variable in rural area. According to the result, 67.2% of crop diversity practices adopters and 66.2% of irrigation practices adopters participated in the social group. Out of the SAPr practice non adopter, 58.5% of non-adopters participated in social group and 41.5% of non-adopters not participated in any social organization as presented in the following (Table 3). This implied family head participation in the organizational membership determined crop diversity and irrigation practices adoption. This also implies that significant number of farmers that adopted SAPr can reduce the adverse impacts of drought on their farm so as to increase their consumption expenditure in drought area.

Table 3 Descriptive results of sampled respondents for dictate variable

Variables	Adoption and application of crop diversity and irrigation practices				Total
	Non-adopter	Crop diversity	Irrigation	Crop diversity and irrigation	
Extension					
Otherwise	34.1	37.1	40	28	33.3
Access	65.9	62.9	60	72	66.7
Sex of respondent					
Female	43.9	43.1	51.2	46.6	46.3
Male	56.1	56.9	48.8	53.4	53.7
Climate information					
No	41.5	37.9	30	44	39.5
Yes	58.5	62.1	70	56	60.5
Non/off-farm activity					
Otherwise	29.3	17.2	17.5	16.6	18.1
Yes	70.7	82.8	82.5	83.4	81.9
Social group					
No	41.5	32.8	33.8	32.6	33.7
Yes	58.5	67.2	66.2	67.4	66.3

Source: Own survey results, 2023; ***,** and * shows at 1%, 5% and 10% significant, respectively

Table 4 Area shares of different crops in the study area (%)

Crop/group of crop grown in the area	Mean	SE
Local sorghum	7.87	0.455
Maize	33.16	1.102
Wheat	2.20	0.421
Burly	1.24	0.275
Stress tolerant sorghum	14.54	0.844
Coffee	0.041	0.041
Groundnut	3.69	0.487
Khat	24.13	1.036
Sweet potato	1.16	0.255
Improved Pulses	4.22	0.443
Vegetables	7.77	0.831
% area share of high value cash crop	55.53	0.984

Source: Survey result,2023; High value cash crop & stress tolerant include khat, coffee, vegetable, sweet potato, Groundnut

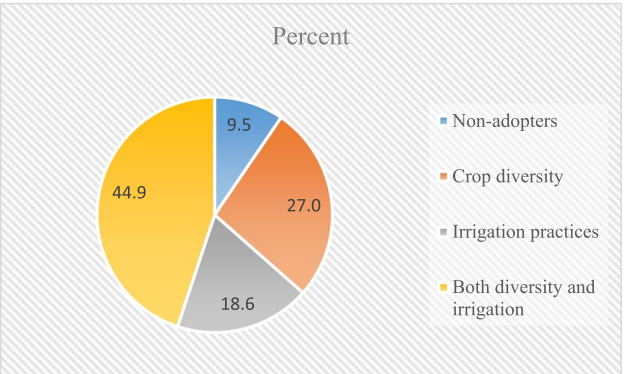

Fig. 3 Adoption and application of crop diversity and irrigation practices

3.2 Proportion of area under high value cash-crops, stress tolerant and other cereal

Farmers in the area were adopting and practicing several SAPr practices including crop diversification in order to minimize the negative effect of climate shocks mainly drought which also confirmed by [51, 55]. In this descriptive parts of study, crop diversifying activity was considered as land area allocated to high value cash-crops, stress tolerant and early maturing crop to enhance climate shocks effect minimization in the area. The descriptive results (Table 4), showed the area allocated to high value cash crop and stress tolerant is 55.5% and out of which 24.13% and 14.54% were allocated for *khat* and stress-tolerant, respectively. This shows significance of *khat* crop which used as main cash crop in Hararghe area. So, this share of area allocated to *khat*, groundnut, coffee, sweet potato, vegetables and improved pulse are considered as crop diversifying activities. Study conducted by [59] also noted that, crop diversity is important in reducing effect drought.

3.3 Major smart agricultural practices (SAPr) adopted

Regarding components of smart agriculture (SAPr) that adopted in the area, and also considered as practices are crop diversification and irrigation practices. The following (Fiure.3) showed the percentage of farmers that adopted different practices in single and combination of practices. It revealed that 27.0% of the farmers adopted crop diversity practices only whereas 18.6% of them adopted irrigation practices and 44.9% of the farmers adopted both combined irrigation practices and crop diversification. The non-adopters of the practices account for around 9.5% of the respondents as in (Fig. 3) bellow. This implies that significant number of farmers adopted combination of the SAPr practices to reduce the adverse impacts of drought on their livelihood so as to increase their farm income and per adult consumption expenditure in drought area.

3.4 Components of income and consumption expenditure

Annual farm income of the farm households includes income from sell of farm product including from sold crop, cattle and others in the area. When evaluating means annual farm income, SAPr adopters (crop diversification and irrigation) were found to have more farm income that obtained from their farm. On average total annual farm income for the sampled SAPr practices adopters in the area was 34675.2ETB whereas average annual farm income of non-adopters was around 27535.4ETB. This also indicated that the sampled households who do not-adopted and adopted have a significant mean differences at 10% in the annual farm income that annually obtained from cash crops including *khat*, livestock product and by-product etc.

The total annual consumption expenditure (ACE) is part of household expenses made by households in the in one year. It is expenses that used to buy several commodity mainly foods items and non-foods items for the whole family members need within the last 12 months prior to survey. On average SAPr adopters had higher annual consumption expenditure relative to non-adopters as shown below (Table 5). As shown in the following, results showed total annual consumption expenditure of the adopter was about 40926.7ETB whereas that of non-adopters of practices was 34324.9ETB. The findings revealed that, significant mean differences in mean at 1% of significant level in terms of annual consumption expenditure (ACE). This implies that adoption of SAPr practices improved the income of households that encourage consumption expenditure of the household.

Food and non-food expenses, as well as production costs, were included in farmer consumption expenditures. However, food spending covers the cost of food that they bought or other foods that were not grown on their farms, as well as the worth of food that they generated from their own agricultural land. The result showed that, out of total consumption expenditure, annual food expenditure accounted for about 67.98% whereas non-food expenditure was 32.02 for adopters of SAPr. Similarly annual food expenditure of non-adopter accounts for about 73.35% and non-food expenditures accounts for 26.65% out of total annual household expenditure. This implied that, rural farmers distribute their annual income to fulfill the gap of family need. Moreover, the amount of annual food consumption expenditure is greater than the annual expenses used up for commodities other than food consumption. This is mainly due to food consumption expenditure is determined by family size and food is also basic item that needed daily by everyone to survive. And also the ratio of family food consumption expenditure is mostly used as a standard determinant of the households' welfare according to [60]. The mean difference between the two groups shows significance variation in annual food expenditures at 10% level. It implied that adopters consume more compared to non-adopters due to consumption increases as income increases from adopted practices. The group of non-adopters also increased their food expenditure as adopters did to feed the family, even in time of shock, they may purchase food by selling their livestock assets and other asset to feed family.

Results also showed non-food consummation expenditure significances differences in mean at 1%. This implies that adopters may increase their non-food expenditure due to increased more yields and farm income generated due to SAPr adoption on the farm. It is evident that when smallholder farmers experience climate shocks, especially drought, rural households prefer to reduce their use of non-important products and services in comparison to those who adopted practices (Table 5).

3.5 Drought analyses

The Standardized Precipitation Index (SPI) which applied to identify aspect of drought using rainfall data of 33 years (1990–2022) at a three-month time scale was applied/used. This means to quantify drought in terms of three months

Table 5 Annual per adult consumption, food, non-food expenditure and farm income

In ETB annually	Adopter		Non-adopters		Mean difference	t-value
	Mean	SE	Mean	SE		
Total expenditure	40,926.7	659.1	34,324.9	1642.4	6601.9	3.14***
Non-food expend	13,104.6	403.7	9148.2	1033.4	3956.4	3.07***
Food Expenditure	27,822.1	581.8	25,176.7	1529.7	2645.5	1.42*
Total farm income	34,675.2	1580.0	27,535.4	3825.5	7139.7	1.42*

Source: Own survey results,2023; ***,** and * shows at 1percent,5percent and 10 percent significant, respectively; ETB=Ethiopian Birr

scale SPI which is mostly used in representation of effective agricultural drought. Therefore, the SPI value was used to investigate drought magnitude, severity and also intensity of drought according to [61]. The negative values of SPI indicated drought occurrences whereas positive indicated absence of drought. In this analysis, 3-months SPI which is applied to compares the specified 3-months rainfall with similar three months of 33 years was applied in this study. Following the [22], the drought level category was divided into mild, moderate, severe and extreme.

As indicated in the following (Fig. 4), the rain fall data of Babile, Karamile/Goro-gutu and Gursum station was used and 3-months scale SPI was computed as drought indexes for Summer season. The result showed that, in the three districts the summer season SPI-3 values showed fluctuation of drought which is mostly severe drought in the area. In Babile district in 1991, 2003, 2011, 2012, 2015, 2019 and 2020 showed extremely drought (– 3.199), severe drought (– 1.786), extremely drought (– 3.214), severe drought (– 1.6077), extremely drought (– 2.784), severe drought (– 1.786) and extremely drought (– 3.423) has occurred with precipitation deficits in summer seasons. In Gursum district severe drought (– 1.848) in 1999, extremely drought (– 2.1916) in 2000, extremely drought (– 2.1988) in 2001, server drought (– 1.785) in 2005, extremely drought (– 2.296) in 2008, extremely drought (– 2.4295) in 2013, extremely drought (– 2.2187) in 2014, severely drought (– 1.7288) in 2022 was occurred in the area as presented in (Fig. 4). This shows that how the severity of the drought in increasing from time to time which negatively affecting the moisture stress area of Eastern Hararghe in genera. As observed from the following (Fig. 4) results, the up-ward or positive values of spi showed rainfall presence or wet months whereas down words or negative vales revealed severity of the drought situation. It also showed the severity of the drought is increasing from year to years. Therefore, unless appropriate adoption of SAPr practices such as crop diversifying practices and irrigation is promoted and facilitated, the situation of drought will be the series problem for those whose their main livelihood is depends on rainfed agriculture.

3.6 Determinants of per adult consumption expenditure(PaCE)

In the evaluation of factors affecting consumption expenditure, two-stage least square (2SLS) and multiple linear regression model were applied for comparison. Variance inflation factors (VIF) was also undertaken to test multicollinearity test among independent variables and confirmed that data was free from multicollinearity problem (Appendix Table 7). Similarly, the Breusch-Pagan test was also used and the result showed that there is no heteroscedasticity problem in the models (Chi2(1) = 1.26, Prob > chi2 = 0.2623) (Appendix Table 8).The model R-squared value shows that the variables found in the model explained about 62.3% of variation in per adult consumption expenditures, with other factors that were not included accounting for 37.7% of variation in the expenditures. An examination of the F-statistic value revealed the jointly correlation between the independent and dependent variables. The per adult consumption expenditure are influenced by multiple variables at the same time, as indicated by the 32.18 value of F-statistics (Table 6).

The endogeneity test was also conducted by using Durbin and Wu-Hausman test and *p* values were significant. This revealed that the null hypothesis which states variable are exogenous was rejected, thus annual household income variable (in log form) was endogenous as shown in (Appendix Table 9). The analysis of the equation using ordinary least square model (OLS) generate biased and inconsistent estimate. All instrumental variables (access to climate information and participation in non-farm income generating activities were found as determinants of total annual household income (log) and F(1,407) = 12.0661 and Chi^2 = 12.3809 from Durbin and Wu-Hausman test was revealed endogeneity issue. From (Appendix Table 9), the test of weak instrument showed that there was no weak instrument and instrumental variables were valid. Following two-stage-least square model, the test statistic value of 165.859 greater than its critical value of 22.3 and there was no problem of weak instrument

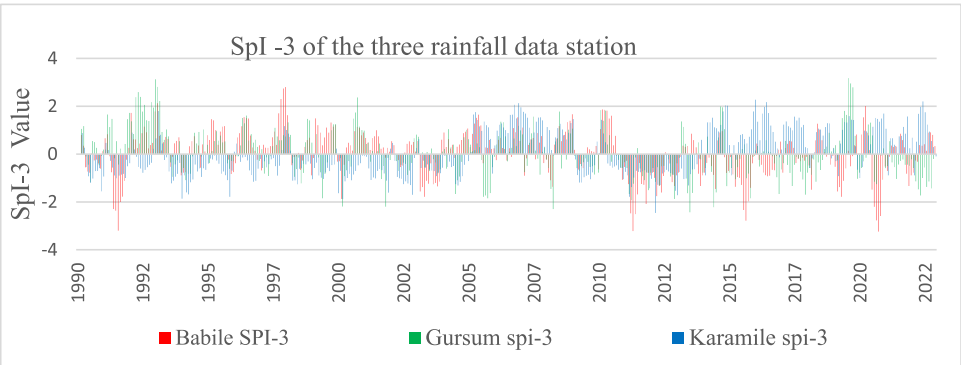

Fig. 4 Three districts monthly Spi-3 value of drought

Table 6 Determining annual consumption expenditure: OLS and 2SLS estimates

ln_Cons.Expdit(log)	OLS		2SLS	
	Coeff (SE)	t-values	Coeff (SE)	t-values
Age	− 0.0001 (0.0010)	− 0.06	− 0.0001 (0.0010)	− 0.12
Farm experience	0.0007 (0.0013)	0.52	0.0005 (0.0013)	0.41
Education respondent	0.0001 (0.0030)	0.03	0.0003 (0.0030)	0.1
Drought experience	0.0265 (0.0074)	3.58***	0.0255 (0.0073)	3.49***
Access extension Se	0.0190 (0.0224)	0.85	0.0183 (0.0220)	0.83
Sex of respondent	0.0501 (0.0211)	2.37**	0.0505 (0.0208)	2.43**
Family size	− 0.0429 (0.0046)	− 9.34***	− 0.0409 (0.0046)	− 8.97***
Farm size	0.0411 (0.0509)	0.81	0.0462 (0.0502)	0.92
Labor force	0.0427 ((0.0070)	6.08***	0.0396 (0.0070)	5.67***
Plot number	0.0019 (0.0099)	0.2	0.0024 (0.0098)	0.24
LivstkTLU	0.0137 (0.0075)	1.84*	0.0129 (0.0074)	1.74*
Market distance	− 0.0033 (0.0017)	− 1.89*	− 0.0029 (0.0017)	− 1.69*
Markt information	0.0005 (0.0215)	0.02	0.0015 (0.0212)	0.07
Crop diversification	0.0678 (0.0221)	3.07***	0.0587 (0.0219)	2.68***
PartcPSNP	0.0144 (0.0290)	0.5	0.0191 (0.0286)	0.67
Spi-summer-2022	− 0.1626 (0.0342)	− 4.76***	− 0.1531 (0.0338)	− 4.53***
DroghtErlV	0.0360 (0.0212)	1.7*	0.0280 (0.0210)	1.34
SS irrigation	0.0570 (0.0221)	2.58**	0.0520 (0.0218)	2.38**
Spi-spring-2022	− 0.0041 (0.0068)	− 0.6	− 0.0021 (0.0067)	− 0.32
Annual Income(log)	0.1190 (0.0121)	9.84***	0.1564 (0.0161)	9.74***
cons	7.7837 (0.1590)	48.96***	7.3988 (0.1918)	38.58***
F(21, 408) =	32.18			
Prob > F =	0			
R^2 =	0.6235		0.6147	
Wald chi2(21) =			691.02	
Prob > chi2			0	
Obs = 430				

Sources: Own survey results, 2023; ***,** and * shows at 1%, 5% and 10% significant, respectively

in the analysis. According to [62], the instrument variables are relevant when F-statistic is exceeded or greater than 9.08 with three instrument and 10.83 with five instrument variables. The test of instrument exogeneity revealed that the instrument is uncorrelated with the error term in the model. The STATA command *estat overid* test also applied to check exogeneity of the instrument. The test of Sargan (score) showed that chi2(2) is 1.22203 with *p* value of 0.5428, and Basmann chi2(2 is 1.15711 with *p* value of 0.5607 that revealed the insignificant test statistic. This also confirmed validity of instrument and correctly specification of the model (Appendix Table 9). Therefore, IV based 2SLS model was applied to correct endogeneity issue.

As shown in the following (Table 6), different variable influenced the consumption expenditure. These variables includes drought variables(Spi-summer-2022), drought experience, sex, size of family, family labour forces, number of livestock, market distance, adoption of irrigation and crop diversification practices influenced consumption expenditure significantly. It revealed that, per adult consumption expenditure was increased by 5.1% as the household head was male. Farm activates are labor intensive and also female do not easily get information regarding to input facilities and other improved agricultural technologies. This results agreed with finding of [63], that showed being household head is female influenced significantly the likelihood of being poor. The consumption expenditure was decreased by 4.1%, as family size increased by one person. This implies that large family size in rural area reduces welfare status of family. More household members create more burdens on family resources including income and forced the households to reduce not only non-food consumption but also food consumption. These also due to large family member consume what one or two family member produced in most of the rural families. Studies by [64] also revealed the negative relation between family size and consumption expenditure. The other finding also contradicts this [65–67], that noted the large family size related positively to family consumption expenditure. Similarly, family active workers influenced positively and significantly per adult consumption at 1% significant level.

It showed that consumption expenditure was increased by 4.0% as family labor increased by one person. This implies that a large family labor force enhances improvement of agricultural production and family income generation. This shows more number of active labor forces members of family positively affect family welfare or consumption expenditure. This agreed with [68] that showed this generated income increases family consumption expenditure Livestock in tropical livestock influenced the consumption expenditure positively and significantly at 10% significant level. The consumption was increased by 1.3% as livestock number was also increased by one unit. This shows that families with large livestock in rural area indicate wealth status of the family and served as crucial asset to generate income. This agrees with [69, 70], that showed livestock used as a ways of storing wealth for rural families. The household assets including livestock number have significant role in reducing adverse impact of climate shocks on family consumption expenditures. In rural area, livestock used as a means of wealthy storing and are a significant asset for rural families as source of farm income, providing expense for purchasing both food and non-food commodities. This confirms studies by [69, 71] that revealed large livestock can reduce negative effects of climate shocks like droughts on consumption (Table 6).

The annual consumption expenditure was influenced negatively and significantly by market distance at 10% level. The per adult consumption expenditure reduced by 0.3% as market distance increased by a unit of kilo meter. The shorter market distance mean farmer can get agricultural input and sold agricultural production simply and to purchase other consumption good that increase consumption expenditure. This results supported by [72, 73] that revealed access to market road increase diversification of income that increases per capita consumption. Farmers in short distance can get market information on what to produces to the market so as to increase family income and per adult consumption expenditure. This results agree with [74, 75] that showed role of access to road in increasing income and finding [74, 76–78] that revealed effect of access to market road in reducing poverty by enhancing agricultural production and product for marketing.

Drought variable (Spi-summer-2022) was evaluated as a standard precipitation index from previous 33 years rainfall that reduces total annual per adult household consumption expenditure. This drought/climate shocks influenced consumption expenditure negatively and significantly at 1% significant level. The consumption expenditure was reduced by 15.3% as previous year rain fall condition was drought. The importance's of applying this indicator agree with [79] that showed the importance of climate variables that affect significantly crop yield. The results also agreed with finding [80] that revealed rainfall amount reduction resulted in decreases of per adult income per day by 18.3%. This implies drought affects farmers' agricultural production negatively that challenges the farmers' income source and food products. The results also in line with [81] study that revealed the negative association between higher temperature and consumption per adult. Moreover, the results showed that climate shocks reduce the likelihood of being food self-sufficiency of the households.

In minimizing negative effects of drought on agricultural production, farmers were incentivized by prevailing drought to adopt crop diversification and irrigation practices on their farms. The model results revealed that total annual consumption expenditure increased positively and significantly at 1% significance level as the farmer adopt crop diversification. The consumption expenditure found to be increased by 5.9% as farmers adopted crop diversification practices. This implies that farmers in the area adopted crop diversification activities to diversify their income source and minimize risk of crop yield loss due to drought. This also agreed with finding of [82] that revealed diversity of crop increases the resilience of agricultural products against climate shocks. In addition to this, adoption and application of irrigation practices influenced per adult consumption expenditure positively and significantly at 5% significant level. The consumption expenditure per adult was increased by 5.2% as farmer adopted irrigation practices on their farm. This implied that application of irrigation helps the farmers to increase production and productivity of their farm. This results consistent with [83–85] that revealed contribution of irrigation in increasing farmers income and livelihoods resilience against shocks through growing higher value cash crops for the market even more than once in a year. It is also minimize risk of crop yield loss due to drought. This results supported with finding of [86, 87] who showed role irrigation water in increasing income and ensures food security. Thus we can observe that adoption of climate smart practices such application irrigation water and crop diversification increases the consumption expenditure of the small holder farmers in drought area. These results agree with [88, 89] that showed positive impacts of climate smart practices adoption on households' welfare.

The annual household income (logarism) has influenced farmer's consumption expenditure positively and significantly at 1% level of significant. The results revealed that consumption expenditure was found to be increased by 15.6% as annual household income increased by 1%. Moreover, the results showed that using instrumental variable based 2SLS estimator improved the effects income on consumption expenditure to 15.6% compared to OLS model application when total annual income was treated as endogenous variable. Similarly, more household income allowed them to consume desire amount of food commodities and other than food items. Therefore, this founding show that as household income

increased the consumption expenditure found to be increased. This also agreed with finding of [90] that revealed household income encourage household consumption.

4 Conclusion and recommendation

This study investigated factors influencing per adults consumption expenditure (PaCE) in drought prone area of Eastern Hararghe, Ethiopia. The model results revealed that family size negatively influenced consumption expenditure. But, family active workers influenced consumption expenditure positively as large labor forces enhance agricultural yield. Livestock related positively to consumption expenditure. Market distance related negatively to consumption expenditure. Drought/climate shocks as indicated by Spi-summer-2022 negatively influenced consumption expenditure.

Generally, it was observed that drought is significantly reduced consumption expenditure of the farmers. Livestock, drought experience, family labor and household income positively increased consumption expenditure whereas market distance, family size and drought (Spi-summer-2022) affected per adult consumption expenditure negatively and significantly. Similarly, adoption of irrigation and crop diversification activates significantly increased consumption expenditure. Policymakers ought to encourage institutional services including information related to drought situation and weather related information delivery system so as to enhance adoption of SAPr practices. Income generating activities should be established and encouraged for smallholder farmers to increase consumption expenditure. The other important policy implication from the finding is also that observing the drought trends it is imperative that GOs and NGOs that work to support the farmers against drought should focus on promoting the adoption of smart agricultural practices.

Acknowledgements The authors like to thanks the Oromia Agricultural Research institute for releasing limited financial provision for survey data gathering and office of Fadis Agricultural Research Center for the support of data gathering vehicles to complete all the field data collection.

Author contributions We announced that, we all are the authors of this research work. Regarding the author's contribution JMA: Contributed in Methodology, Formal data analysis, Writing-original draft, Writing-review and editing. JH: Contributed in Methodology, Supervision, Validation, Writing-review and editing. MJ: Also contributed in Methodology, Supervision, Writing-review and editing, Validation and KJ: contributed in Supervision, Validation and Writing-review and editing. Finally, state that all authors read and approved the final manuscript for publication.

Funding The research paper was funded by the Oromia Agricultural Research Institute, Addis Ababa, Ethiopia. However, there is no direct fund for the publication of this article.

Data availability Concerning availability of data, the authors confirm that the data that support this research results are available based on request from authors.

Declarations

Ethics approval and consent to participate The research review and ethics approval committee of the Fadis Agricultural Research Center confirmed that no ethical approval is required for this study.

Informed consent Informed consent was obtained from all individual participants included in the study.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

Appendix

See Tables 7, 8, 9.

Table 7 Multicollinearity test

Variable	VIF	1/VIF
Spring-Spi	1.38	0.7269
Summer-Spi	1.38	0.72712
Family size	1.29	0.77641
Labor force	1.27	0.78799
Education of respondent	1.25	0.80162
Age respondent	1.23	0.81059
Non-farm activities	1.18	0.84683
Irrigation	1.16	0.86368
Number of oxen	1.15	0.87076
Farm experience	1.13	0.88381
Crop diversification	1.13	0.88497
Access to extension	1.13	0.88703
Organization membership	1.12	0.89281
Livestock TLU	1.11	0.90355
Sex Respndt	1.1	0.91185
Market distance	1.09	0.91928
PSNP participation	1.08	0.93008
Access climate infor	1.07	0.93154
Market information	1.07	0.93729
Farm size	1.06	0.94107
Plot number	1.06	0.94285
Drought experience	1.06	0.94755
Mean VIF	1.16	

Table 8 Diagnostic test of the model

Tests	Test name	Statistics value	Prob/decision
Hettest (Breusch-Pagan test) ($Chi^2(1)$)	Hetroscedasticity	1.26	0.2623
Vif test	Multicollinearity	1.16	No problem

Table 9 Endogeneity, test for weak instrument and instrument validity test of the model

Endogenity test	Test name	Test statistics	Value	Prob/decision
estat endog	Endogenity	Durbin (score) chi2(1)	12.3809	0.0004
		Wu-Hausman F(1,407)	12.0661	0.0006

estat firststage

Variable	R^2	Adjusted R^2	Partial R^2	F(3,406)	Prob > F
Lntotalanual income	0.6306	0.6096	0.5507	165.859	0
Minimum eigen statistic value		165.859			
Critical values					
Ho: Instruments are weak		# of endogenous regressors		1	
		# of excluded instruments:		3	
		5%	10%	20%	30%
2SLS relative bias		13.91	9.08	6.46	5.39
		10%	15%	20%	25%
2SLS size of nominal 5% Wald test		22.3	9.54	8%	13%
LIML size of nominal 5% Wald test		6.46	3.69	3.32	4.36
Tests of overidentifying restrictions		Sargan (score) chi2(2)	1.22203	$p = 0.5428$	
Estat overid		Basmann chi2(2)	1.15711	$p = 0.5607$	

References

1. Kaini S, Nepal S, Pradhananga S, Gardner T, Sharma AK. Representative general circulation models selection and downscaling of climate data for the transboundary Koshi river basin in China and Nepal. Int J Climatol. 2020;40:4131–49. https://doi.org/10.1002/joc.6447.
2. Du P, Xu M, Li R. Impacts of climate change on water resources in the major countries along the Belt and Road. PeerJ. 2021;9:e12201. https://doi.org/10.7717/peerj.12201.
3. Kaini S, Nepal S, Pradhananga S, Gardner T, Sharma AK. Impacts of climate change on the flow of the transboundary Koshi River, with implications for local irrigation. Int J Water Resour Dev. 2021;37(6):929–54. https://doi.org/10.1080/07900627.2020.1826292.
4. Jakimavičius D, Adžgauskas G, Šarauskienė D, Kriaučiūnienė J. Climate change impact on hydropower resources in gauged and ungauged lithuanian river catchments. Water. 2020;12(11):3265. https://doi.org/10.3390/w12113265.
5. El-Nashar W, Elyamany A. Adapting irrigation strategies to mitigate climate change impacts: a value engineering approach. Water Resour Manage. 2023;37(6):2369–86.
6. Dawit M, Dinka MO, Leta OT, Muluneh FB. Impact of climate change on land suitability for the optimization of the irrigation system in the Anger River Basin. Ethiop Clim. 2020;8(9):97. https://doi.org/10.3390/cli8090097.
7. Allani M, Mezzi R, Zouabi A, Béji R. Impact of future climate change on water supply and irrigation demand in a small mediterranean catchment. Case study: Nebhana dam system, Tunisia. J Water Clim Change. 2020;11(4):1724–47. https://doi.org/10.2166/wcc.2019.131.
8. Mostafa S, Wahed O, El-Nashar W, El-Marsafawy S, Abd-Elhamid H. Impact of climate change on water resources and crop yield in the Middle Egypt Region. J Water Supply Res Technol AQUA. 2021;7:1066–84.
9. Obembe OS, Hendricks NP, Krishna Jagadish SV. Changes in groundwater irrigation withdrawals due to climate change in Kansas. Environ Res Lett. 2023;18:094041.
10. da Silva EH, Antolin LA, Zanon AJ, Junior AS, de Souza HA, dos Santos Carvalho K, Junior NA, Marin FR. Impact assessment of soybean yield and water productivity in Brazil due to climate change. Eur J Agron. 2021;129:126329.
11. Kaini S, Harrison MT, Gardner T, Nepal S, Sharma AK. The impacts of climate change on the irrigation water demand, grain yield, and biomass yield of wheat crop in Nepal. Water. 2022;14:2728. https://doi.org/10.3390/w14172728.
12. Ortiz-Bobea A, Ault TR, Carrillo CM, Chambers RG, Lobell D. Anthropogenic climate change has slowed global agricultural productivity growth. Nat Clim Change. 2021;11:306–12.
13. Endashaw S, Wondimhunegn A, Teklebirhan A. Impact of economic sectors on inflation rate: evidence from Ethiopia. Cogent Econ Financ. 2022;10(1):2123889. https://doi.org/10.1080/23322039.2022.2123889.
14. Federal Democratic Republic of Ethiopia. Nat Adap Plan 2019; https://www4.unfccc.int/sites/NAPC/Documents/Parties/NAPETH%20FINAL%20VERSION%20%20Mar%
15. Conway D, Nicholls RJ, Brown S, Tebboth MG, Adger WN, Ahmad B, Biemans H, Crick F, Lutz AF, De Campos RS, Said M, Singh C, Zaroug MA, Ludi E, New M, Wester P. The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. Nat Clim Change. 2019;9(7):503–11. https://doi.org/10.1038/s41558-019-0502-0.
16. Malede DA, et al. Recent approaches to climate change impacts on hydrological extremes in the Upper Blue Nile Basin. Ethiopia Earth Syst Environ. 2022;6(3):669–79.
17. BisareBitire B. Appraisal of climate change mitigation and adaptation regulatory frameworks in Ethiopia and their congruency with the UN climate change convention. Int J Clim Change Strat Manag. 2023;15(5):638–51.
18. Araya A, Prasad PVV, Gowda PH, Afewerk A, Abadid B, Foster AJ. Modeling irrigation and nitrogen management of wheat in northern Ethiopia. Agric Water Manage. 2019. https://doi.org/10.1016/j.agwat.2019.01.014.
19. Kassaye AY, Guangcheng S, Xiaojun W, Eshetu S, Shiqing W. Impact of climate change on the staple food crops yield in Ethiopia: implications for food security. Theoret Appl Climatol. 2021;145:327–43.
20. Wakjira C. Impacts of Climate Change on Irrigation Water Requirement for the Major Grown Crop Production: a Case of Didesa Sub-Basin, Nile Basin of Ethiopia; 2022.
21. Tamiru PO, Gordana K, Felix KA. Impact of climate change on future availability of water for irrigation and hydropower generation in the Omo-Gibe Basin of Ethiopia. J Hydrol Region Stud. 2022;44:101254.
22. McKee T, Doesken N, Kleist J. The relationship of drought frequency and duration of time scales conference on eighth conference on applied climatology. American Meteorological Society (Anaheim CA), 1993;179–186
23. World Food Programme (WFP) and Central Statistics Agency of Ethiopia (CSSA). Comprehensive Food Security and Vulnerability Analysis (CFSVA), Addis Ababa, Ethiopia; 2019.
24. World Health Organization (WHO). Horn of Africa crisis: Public Health Situation Analysis: drought, food security, conflict, displacement; 2022.
25. Dercon S, Hoddinott J, Woldehanna T. Shocks and consumption in 15 Ethiopian villages, 1999–2004. J Afr Econ. 2005;14:559–85.
26. Ndubueze-Ogaraku ME, Oyita GE, Anyanwu SO. Analysis of household consumption expenditure on selected staple foods in Ika North East Local Government Area of Delta State, Nigeria. 2016.
27. Schorfheide F. Loss function evolution of DSGE model. J Appl Econ. 2010;15:645–70.
28. Bekele M, Bezabih M, Elias H, Fisker P, GETBrehiwot T, Kuma T. Building resilience to climate change in Ethiopia what do we know so far? In: Development economics research group working paper series. University of Copenhagen; 2020.
29. Castells-Quintana D, Del Pilar Lopez-Uribe M, McDermott T. Adaptation to climate change: a review through a development economics lens. World Devlopmt. 2018;104:183–96.
30. Marie M, et al. Farmers' choices and factors affecting adoption of climate change adaptation strategies: evidence from northwestern Ethiopia. Heliyon. 2020;6(4):1.
31. Tessema Roba N, Kebede Kassa A, Yadeta Geleta D. Modeling climate change impacts on crop water demand, middle Awash River basin, case study of Berehet woreda. Water Pract Technol. 2021;16(3):864–85.
32. Gebru G, Ichoku H, Phil-Eze P. Determinants of smallholder farmers' adoption of adaptation strategies to climate change in Eastern Tigray National Regional State of Ethiopia. Heliyon. 2020;6(7):e04356.

33. Nazir A, Lohano H. Resilience through crop diversification in Pakistan. Clim Change Commun Resil. 2022. https://doi.org/10.1007/978-981-16-0680-9_28.
34. Renard D, Tilman D. National food production stabilized by crop diversity. Nature. 2019;571(7764):257–60.
35. Bradshaw B, Dolan H, Smit B. Farm-level adaptation to climatic variability and change: crop diversification in the Canadian prairies. Clim Change. 2004;67(1):119–41. https://doi.org/10.1007/s10584-004-0710-z.
36. Wondimagegn Mesfin BF, Haji J. Pattern, trend and determinants of crop diversification: empirical evidence from smallholders in Eastern Ethiopia. J Econ Sustain Dev. 2021;2(8):78–89.
37. Mazhar R, Ghafoor A, Xuehao B, Weia Z. Ostering sustainable agriculture: do institutional factors impact the adoption of multiple climate-smart agricultural practices among new entry organic farmers in Pakistan? J Clean Prod. 2021;283: 124620.
38. Kaini S, Gardner T, Sharma AK. Assessment of socio-economic factors impacting on the cropping intensity of an irrigation scheme in developing countries. Irrig Drain. 2020;69(3):363–75. https://doi.org/10.1002/ird.2427.
39. Abrha M, Lewoye B. The impacts of climate change on peasant's crop production in major crop producing zones in Ethiopia. Discover Sustain. 2024;5:443. https://doi.org/10.1007/s43621-024-00628-1.
40. Dang H, Nuberg I, Bruwer J. Factors influencing the adaptation of farmers in response to climate change: a review. Clim Dev. 2019;11(9):765–74.
41. Asayehegn K. Negative impact of small-scale irrigation schemes: a case study of central tigray regional state, Ethiopia. J Agric Res Rev. 2012;1(3):80–5.
42. Pinstrup A, Watson D. Role of Government in Global, national and local food systems: food policy for developing countries. Ithaca: Cornell University; 2011.
43. Bont C, Komakech H, Veldwisch G. Neither modern nor traditional: farmer-led irrigation development in Kilimanjaro Region, Tanzania. World Dev. 2019;116:15–27.
44. Awulachew S, Ayana M. Performance of irrigation: an assessment at different scales in Ethiopia. Exper Agr. 2011;47(1):57–69.
45. Sinyolo S. The impact of smallholder irrigation and water security on household welfare: the case of Tugela Ferry irrigation scheme in KwaZulu-Natal, South Africa. In: School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal; 2013.
46. Shekuru A, Arega B, Bizuneh Y. Variability and trends of temperature and rainfall over three agro ecological zones in North Shewa, central Ethiopia. *Research Square*, 2020;1–22.
47. Asrat P. Land management decision in a changing climate: Exploring climate-smart agricultural practices, land productivity and livelihood impacts in the Dabus sub-basin of the Blue Nile River. Ph.D. dissertation, Addis Ababa University. 2018; localhost/xmlui/handle/123456789/
48. Keba A. Review on adoption of improved agricultural technologies in Ethiopia. Policy. 2019;4(1):11–9. https://doi.org/10.11648/j.hep.20190401.12.
49. Natnael AB. Impact of technology adoption on agricultural productivity and income: a case study of improved teff variety adoption in North Eastern, Ethiopia. Agric Res Tech Open Access J. 2019;20(4):556139. https://doi.org/10.19080/ARTOAJ.
50. Mulugeta M, Tiruneh G, Alemu Z. Magnitude and associated factors of household food insecurity in fedis district, Eastern Hararghe, Oromia Region Ethiopia. Agri and Food Sec. 2018;7(1):1–8.
51. Zeleke T, Beyene F, Deressa T, Yousuf J, Kebede T. Vulnerability of smallholder farmers to climate change-induced shocks in East Hararghe Zone, Ethiopia. Sustainability. 2021;13:2162. https://doi.org/10.3390/su13042162.
52. EHZ FED (East Hararghe Zone Finance and economic development). General Description of East Hararghe Zone, Harar; East Hararghe, Ethiopia; 2018.
53. Central Statistics Agency (CSA). Population and Housing Census of Ethiopia; 2007.
54. Lamesa S, Wetebeji M, Yismaw M. The Climate change adoption strategy in responses to food insecurity: the paradox of improved potatoes variety adoption in Eastern Ethiopia. Cogent Food Agric. 2019. https://doi.org/10.1080/23311932.2019.1640835.
55. Tesfaye W, Seifu L. Climate change perception and choice of adaptation strategies: Empirical evidence from smallholder farmers in east Ethiopia. Int J Clim Change Strat Manag. 2016;8(2):253–70.
56. Kothari CR. Research methodology: methods and techniques. New Delhi: New Age International Publishers; 2004.
57. Green W. Econometric analysis. Oxeford: Oxeford University Press; 1991.
58. Gujurati D, Porter D. Econometrics. Mexico: McGraw Hill; 2020.
59. Degani E, Leigh SG, Barber HM, Jones HE, Lukac M, Sutton P, Potts SG. Crop rotations in a climate change scenario: short-term effects of crop diversity on resilience and ecosystem service provision under drought. Agr Ecosyst Environ. 2019;285:106–625.
60. Pahlevi MR, Andita DY, Gumilar E, Nursafitri F, Sofiani SS. Examining factors affecting the food expenditure in Indonesia. 2016; p. 493–498
61. Mekonen A. Livelihood zone-based perception and adaptation strategies of rural households' to rainfall and temperature variability in the Northeastern Highlands of Ethiopia, Debremarkos University; 2022.
62. Ullah S, Akhtar P, Zaefarian G. Dealing with endogeneity bias: the generalized method of moments (GMM) for panel data. Ind Mark Manage. 2018;71:69–78.
63. Kebede T, Sharma MK. The determinant of poverty in Ethiopia". Ethiop J Econ. 2014;12(1):113–30.
64. Terefe AT, Aredo MK, Workagegnehu AM, Tesfaye WM. Effects of climateshocks on rural households welfare in Etiopia evidence from panel data. Congent Food Agric. 2024;10:1. https://doi.org/10.1080/23311932.2024.
65. Zehiwot H, Marisennayya S. Determinants of household consumption expenditure in Debremarkos Town, Amhara Region, Ethiopia. Am Sci Res J Eng Technol Sci. 2019;62(1):124–44.
66. Wegayehu E, Yibeltal M, Pandey D. Determinants of household consumption expenditure in Tepi Town, SNNPR, Ethiopia. Int J Intell Comput Technol. 2020;4(1):40–56.
67. Alemzewud M. Patterns and determinants of Household consumption Expenditure of female headed Households, in the case of Sekela district, Amhara regional state of Ethiopia; 2020.
68. Bakri S, Ramli N, Hashimc E, Mahdinezhadd M, Jalile N. Understanding behavior of consumption expenditure of households. Int Bus Educ J. 2017;10(1):43–52.
69. Acosta A, Nicolli F, Karfakis P. Coping with climate shocks: the complex role of livestock portfolios. World Dev. 2021;146:105546.

70. Ba M, Mughal M. Weather shock copping strategy and households well being. Evidence from rural Mauitania. J Dev Stud. 2022;58:482–502.
71. He X, Chen Z. Weather, cropland expansion, and deforestation in Ethiopia. J Environ Econ Manag. 2022;111: 102586.
72. Barbier EB, Hochard JP. The impacts of climate change on the poor in disadvantaged regions. Rev Environ Econ Policy. 2018;12(1):26–47. https://doi.org/10.1093/reep/rex023.
73. Aderogba BA, Abiodun A. Assessing the impact of road infrastructure on poverty reduction in developing economies: the case of Nigeria. Mod Econ. 2019;10(80):2430–49.
74. Kishor B, Basanta P. Impact of vegetable farming on farmer's livelihood patterns in Dhankuta. Nepal Nepal J Geogr. 2021;14(2):131–50.
75. Jemal M, Genet G. Affecting marketing of vegetable product: the case of Qewet Woreda, Ethiopia. J Bus Manag. 2019;21(3):82–93.
76. Teka AM, Woldu GT, Fre Z. Status and determinants of poverty and income inequality in pastoral and agro-pastoral communities: Household-based Evidence from Afar Regional State, Ethiopia. World Dev Perspect. 2019;15(5):100–23.
77. Haloi K, Simhachalam A. Impact of the MGNREGS rural roads connectivity initiatives on the socio-economic sphere in Jorhat District", Assam. Res Highlights. 2021;8(10):91–2.
78. Qin X, Wu H, Shan T. Rural infrastructure and poverty in China. PLoS ONE. 2022;17(6):34–56.
79. Gorst A, Dehlavi A, Groom B. Crop productivity and adaptation to climate change in Pakistan. Environ Dev Econ. 2018;23(6):679–701.
80. Wineman A, Mason N, Ochieng J, Kirimi L. Weather extremes and household welfare in rural Kenya. Food Security. 2017;9:243–55.
81. Gao J, Mills BF. Weather shocks, coping strategies, and consumption dynamics in rural Ethiopia. World Dev. 2018;101:268–83.
82. Birthal PS, Hazrana J. Crop diversification and resilience of agriculture to climatic shocks: evidence from India. Agric Syst. 2019;173:345–54.
83. Belay A, Recha JW, Woldeamanuel T, Morton JF. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia". Agric Food Sec. 2017;6(1):24.
84. Tamera N, Demeke M, Kayitakire F. Building sustainable resilience for food security and livelihood dynamics: the case of farming rural households in Ethiopia. JRC Eur Commun, Ispra, Italy. 2017.
85. Tesfay MG. Impact of irrigated agriculture on welfare of farm households in northern Ethiopia: panel data evidence. Irrig Drain. 2020;70(2):306–20.
86. Mango N, Makate C, Tamene L, Mponela P, Ndengu G. Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. Land. 2018;7(2):49.
87. Mengistie D, Kidane D. Assessment of the impact of small-scale irrigation on household livelihood improvement at Gubalafto District, North Wollo, Ethiopia. Agriculture. 2016;6(3):27.
88. Wekesa BM, Ayuya OI, Lagat JK. Efect of climate - smart agricultural practices on household food security in smallholder production systems: micro - level evidence from Kenya. Agric Food Secur. 2018;7(80):1–14.
89. Ogada MJ, Rao EJO, Radeny M, Recha JW, Solomon D. Climate-smart agriculture, household income and asset accumulation among smallholder farmers in the Nyando basin of Kenya. World Dev Perspect. 2019;2020: 100203.
90. Hiron M, Boyd E, Mcdermott CA, Sare R, Morel A, Mason J, Malhi Y, Norris K. Under standing climate resilience in Ghananian cocoa communities- advancing bio cultural perspectives. J Rural Stud. 2018;63:120–9. https://doi.org/10.1016/j.jrurstud.2018.08.010.