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Original Article

Assessment of Climate Trend, Meteorological Drought and Farmers' Perception to Climate Change and Variability in Hadero Tunto District, Southern Ethiopia

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Adaptation, Climate change, Perception, Trend analysis, standardized precipitation index.

ABSTRACT

Currently, climate change and variability are a hot issue, and more attention needs to be paid to their impact on Ethiopia. Farmers' perception plays a significant role in successfully implementing of adaptation strategies to reduce climate change impacts. The main objective of this study was to assess climate trends, meteorological drought and farmers' perception of climate change variability in Hadero Tunto district, Kembata Tembaro Zone, Southern Ethiopia. To determine historical climate trends, 30 years of rainfall and temperature data were obtained from the Hawassa branch of the Ethiopian National Meteorological Service, and trend analysis was performed. The multistage sampling technique was used to select 150 farm households to be surveyed. The modified Mann–Kendall and Sens' slope estimator trend tests were applied to detect the statistical significance of the trend as well as the magnitude in the time series data. The standardized precipitation index was computed for short and long-term scales to characterize the moisture content in the study area. Results of the standardized precipitation index revealed that the total number of drought events was higher in spring than summer. Still, the most extreme drought was recorded in summer. The years 1987 and 2015 experienced extreme drought in summer with indices values of -2.89 and -2.03, respectively, while, -2.27 was the spring season of 2003. In the long-term scale, -1.7 was recorded as the severe value. The historical average annual maximum and minimum temperatures both showed a significant upward trend. Historical annual rainfall shows a negligible downward trend from 1987 to 2016. This trend of rising temperatures and changing rainfall threatens smallholders´ agriculture, who are already limited by access to basic equipment and land use challenges. The descriptive result revealed that most people perceived long-term variability in the rainfall amount and distribution pattern and an increasing trend and variability of temperature. Based on these results, the study recommends that agricultural extension services be enhanced to sensitize the farmers about climate change, thus improving their perception. Further, studies at a larger scale to illustrate the associations between farmers' perceptions of climate change with meteorological data to figure out the risk of climate change are also critical.

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INTRODUCTION

Nowadays, Climate change is recognized as one of the most challenging and complex problems facing agricultural development worldwide (Tesfahunegn *et al.*, 2016). It severely affects the livelihoods of the world community in general and agricultural production and food security of the farming community in particular (Gentle & Maraseni, 2012). Ethiopia is also cited as a good example of a developing country whose economy is highly influenced by climate change, because agriculture which is the backbone of the countries' economy is highly sensitive to rainfall variability and change in temperature (Wagesho, 2013). The Ethiopian climate is characterized by a history of climate extremes, such as drought and flood, and increasing and decreasing of temperature and precipitation, respectively (Teshome & Zhang (2019).). The frequent droughts experienced over the last three decades and the recent impacts of El Niño in East African countries in general and Ethiopia in particular, made millions of people food insecure due to climate change. For successful adaptation to changes in climatic variables, examining the meteorological parameters close to farmers' livelihood system in combination with their perceptions is very essential to enable them to respond to particular weather stresses.

Describing the intra-and inter-annual spatio-temporal trend of meteorological variables according to changing climate is also vital to assess climate-induced changes and suggest feasible adaptation strategies. Although subsistence farming has a long history of coping and adapting to some of these changes, effective adaptation strategies and actions should, therefore, be aimed at securing the well-being of smallholder farmers in the face of climatic changes. However, until recently, little attention has been paid to communities' experiences of climatic variability and their efforts to cope with their changing environments (Gedefaw *et al*., 2018). Adaptation policy designed by considering the knowledge and perceptions of smallholder farmers can bring successful and sustainable adaptation responses to the effects of climate change (Kassie et al., 2017). Understanding farmers' perceptions of how climatic variables fluctuate and changes is crucial in anticipating the impacts of changing climate. Accordingly, this paper evaluates the farmers' perception of toward climate change and its trends and the adaptation strategies used by smallholder farmers in response to changes in climate in the Hadero Tunto district.

MATERIALS AND METHODS

Study Area

The study was conducted in Hadero Tunto district, Kembata Tembaro Zone, South Nations,

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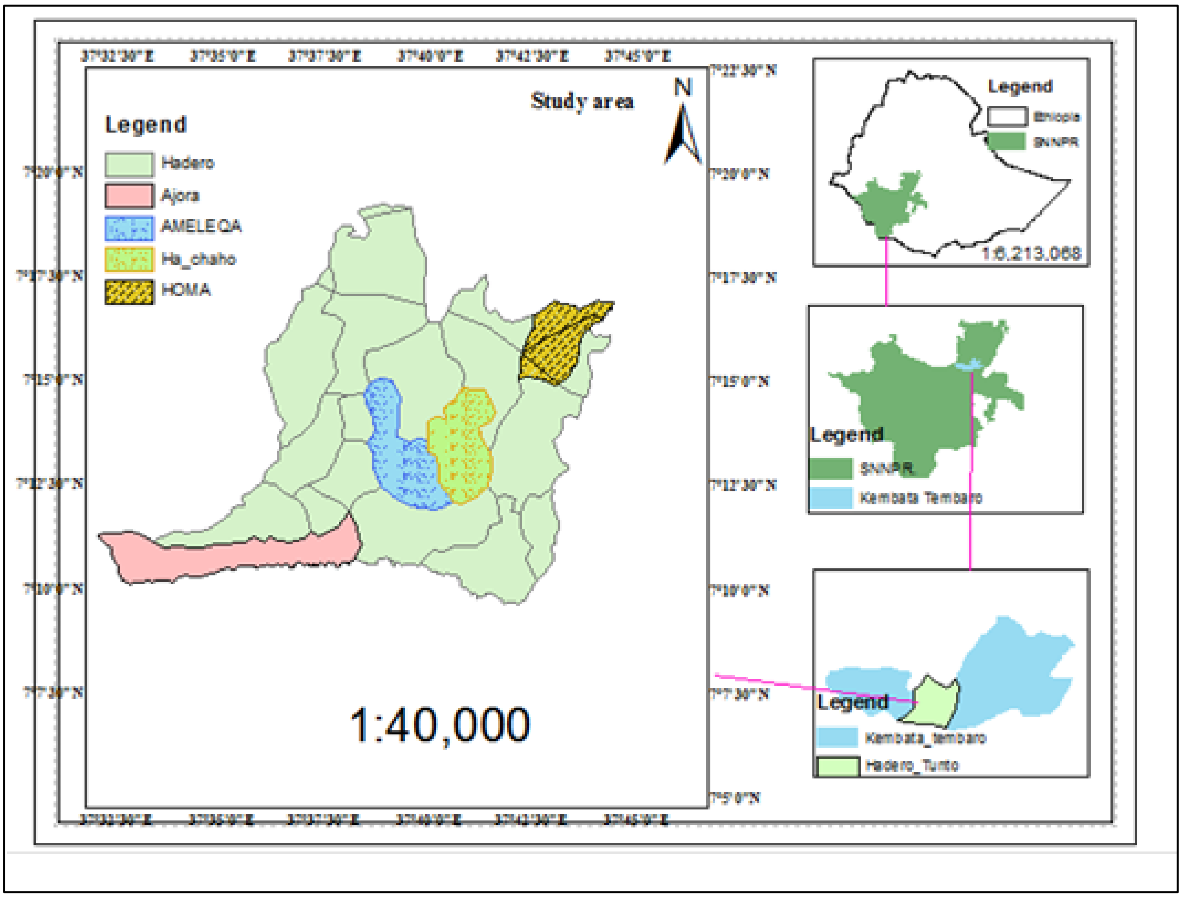
Nationalities and Peoples Regional State (SNNPRS), Ethiopia. It is situated between 70 7’0”- 70 7’20’’ N and 370 32’30’’-370 45’0’’E. It is located 382km south of the national capital, Addis Ababa, and 127km south west of Hawassa, the capital of SNNPR. It is characterized by three distinct agro-ecological zones, highlands, midland and lowland of which the midland is the dominant agro -ecology. The altitude of the district varies from 501-2800 meters above sea level. The average annual minimum and maximum temperature ranged between 7.90 c and 13.750 c and 24.20 c and 30.40 c in 2015/2016, respectively, with a mean annual rainfall range of 800 – 1500mm. It also has a bimodal rainfall distribution, such as the "spring" and "summer" seasons. Regarding livelihood activities, the area is characterized by a mixed farming.

Figure 1: Map of the study area



Sample Size and Procedure

In selecting representative sample households, this study employed a multi-staged sampling procedure. In the first stage, the study district was selected purposively among seven districts of the Kembata Tembaro Zone. In the second stage, three Kebeles were selected randomly among 15 rural kebeles' of the district. Accordingly, Ajora, Ha-Chacho, and Homa were selected from lowland, midland, and highland agro-ecologies. Additionally, one more kebele, Amelaqa, from midland agro-ecology was selected purposively, because of most of the kebeles are under this agro-ecology. Thus, a total of four kebeles were selected. In the third stage, households from each target kebeles were selected using simple random sampling techniques. In terms of survey design a cross-sectional research design was also used for this study. In order to achieve the objective, both primary and secondary data sources were used. Primary data were gathered from selected households using structured questionnaires, focus group discussions, and key-informant interviews. Secondary data, including; Monthly temperature and the rainfall data (1987-2016), were obtained from Ethiopian National Meteorological Agency

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(ENMA). A probability proportional to size sampling technique was applied to select 150 farm household heads in the study area (CSA, 2016). The total sample size was calculated using a sample size computation technique proposed by (Kothari, 2004).

Methods of Data Analysis

The nonparametric modified Mann–Kendall (MK) test statistic was employed to find out trends in temperature as well as rainfall (Mann, 1945; Kendall, 1975), while Sen' slope estimator (Sen, 1968), was used to estimate the magnitude of the trends. The descriptive statistical techniques such as minimum, maximum mean, standard deviation, and average annual temperature graphs were computed using Microsoft Excel 2007. The drought indices calculating software (DrinC), which was developed to provide a simple, though adaptable interface for the calculation of drought indices (Tigkas *et al.*, 2015), was used to calculate the Standardized Precipitation Index (SPI) values of the short, intermediate, and long-term drought indices. The household survey data management and analysis were conducted in SPSS Version 20.0 to characterize farmer's perception of long-term temperature and precipitation variability. The linear regressions were used to estimate the change in temperature and rainfall depending on the slope of the linear line equation.

RESULTS AND DISCUSSIONS

Variability and Trends in Temperature

Variability and Trends in Annual Maximum and Minimum Temperature

The average annual rainfall, maximum and minimum temperatures in the study area over the past 30 years are presented. The mean maximum temperature varied between 24.1^0 C, the lowest average maximum temperature of the time, and 26.6^0 C which was the highest average temperature. According to the data analysis result the warmest year in the district was 2015, while, the coldest year was 1992. A general trend of increased and annual variability also, characterized temperature distribution in the study area. The highest average minimum temperature was also manifested in the year 2015 and the lowest average minimum temperature was manifested in the year 1990, in the past three decades This may be related to the 2015–2016 El Niño which has thus far proven itself to be the worst disaster on record and caused successive harvest failures and widespread livestock deaths in some regions. The average temperature of the district understudy was 17.8ºC. which ranges between 16.7^0 C and 19.2^0 C, in the period (1987-2016).The mean annual temperature of the study area has increased, at a rate of 0.049^0C per year and 0.49^0 C per decade, respectively. According to Eshetu *et al.* (2014), the average temperature has increased markedly, with a 0.2^0 C to 0.28^0 C rise per decade, over the last 40-50 years. Thus, the average temperature of the study area was higher than this range which is 0.4 ^{0}C

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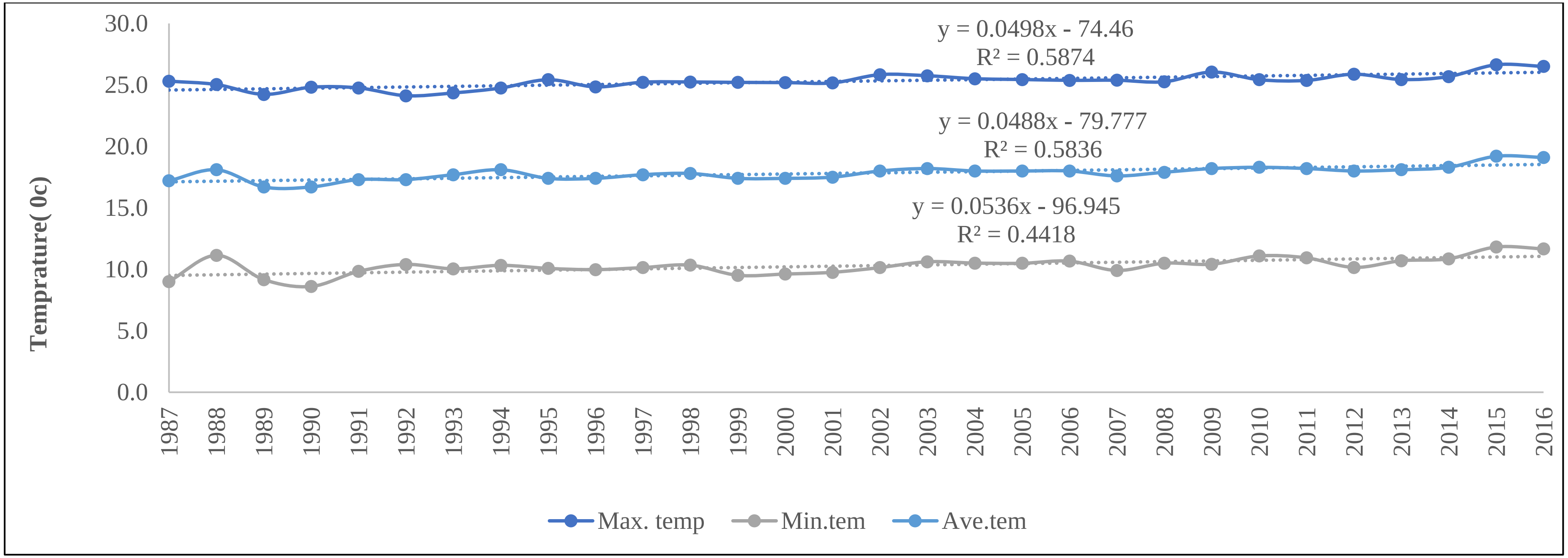
Table 1: Statistical summary of monthly and mean annual maximum temperature (1987-2016)

Sta.	Jan.	Feb.	Mar.	Apr.	Ma.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Mean	25.6	27.2	28.1	28.2	27.4	25.6	22.7	22.4	23.6	24.0	24.6	24.9	25.4
Stdv	0.61	0.88	0.93	0.93	1.06	1.02	0.98	0.85	0.80	0.79	0.67	0.71	0.85
Cv %	2.37	3.25	3.31	3.30	3.85	3.98	4.32	3.80	3.41	3.27	2.73	2.83	3.35
Slope	0.02	0.05	0.04	0.03	0.04	0.064	0.066	0.056	0.049	0.046	0.023	0.018	0.044

Note: *Stdv: Standard deviation, CV: Coefficient of variation*

Figure 2: Trend of maximum, minimum and average temperature (1987-2016)



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As demonstrated in *Table 2*, the MK trend test result also revealed, that the annual maximum temperature has been increasing, significantly, in the study area for the last three decades. It also showed the annual significant increment of mean minimum temperatures for the last 30 years.

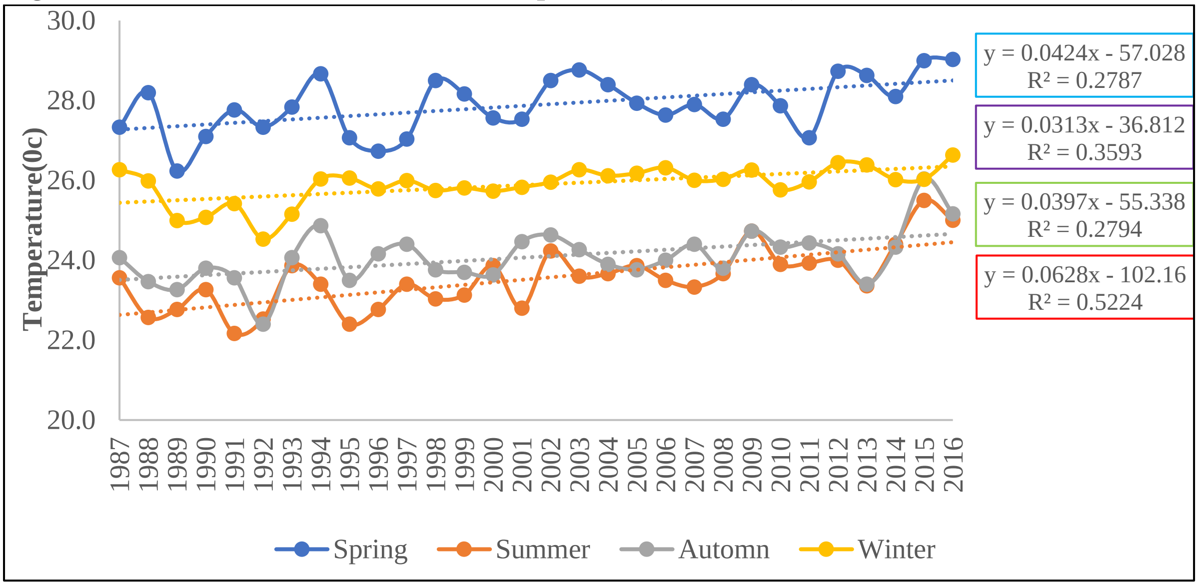
Table 2: Monthly and annual Mann-Kendall results for maximum and minimum temperature (1987-2016).

Time series	n	Z(of)		Sig.(0f)		Sen's slope (^{0}c/month	
		Maxi	Min	Maxi	Min	Maxi	Mini
January	30	1.81	3.93	ns	*	0.025	0.071
February	30	1.86	2.08	ns	*	0.05	0.067
March	30	2.65	1.59	*	ns	0.05	0.063
April	30	1.99	1.67	*	ns	0.047	0.052
May	30	2.34	2.6	*	*	0.059	0.05
June	30	3.14	3.25	*	ns	0.07	0.05
July	30	2.83	1.6	*	*	0.079	0.017
August	30	2.59	1.97	*	*	0.062	0.029
September	30	2.38	2.35	*	ns	0.05	0.045
October	30	1.22	1.29	ns	*	0.043	0.053
Annual		2.28	3.27	ns	*	0.038	0.086

Note: *n is the number of year, z is Mann–Kendall trend test, Slope (Sen's slope) is the change (days)/annual; * is statistically significant at P value 0.05 probability level; ns: is non-significant.*

The slope of the regression line is about 0.42^{0}C and 0.62^{0}C/decade respectively, for the spring and summer seasons during the period 1987-2016 (*Figure 3*). This reveals an increase in the mean seasonal maximum temperature of the area understudy for the last three decades.

Figure 3: Trend of seasonal maximum temperature (1987-2016)



Variability and Trends in Annual Rainfall

The mean annual rainfall of the area during the study period was 1082.3mm with a 148.8mm standard deviation and coefficient of variation of 13.7 %. The minimum and maximum rainfall ever recorded was 851.3 mm (in 2004-the driest year) and 1476.2 mm (in 1996-the wettest year) per year, respectively. As indicated in *Fig 4* from the slope of the linear regression line, the mean annual rainfall amount decreased by about 4.6 mm per decades for the last three decades.

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Figure 4: Trend of annual and seasonal rainfall (1987-2016)

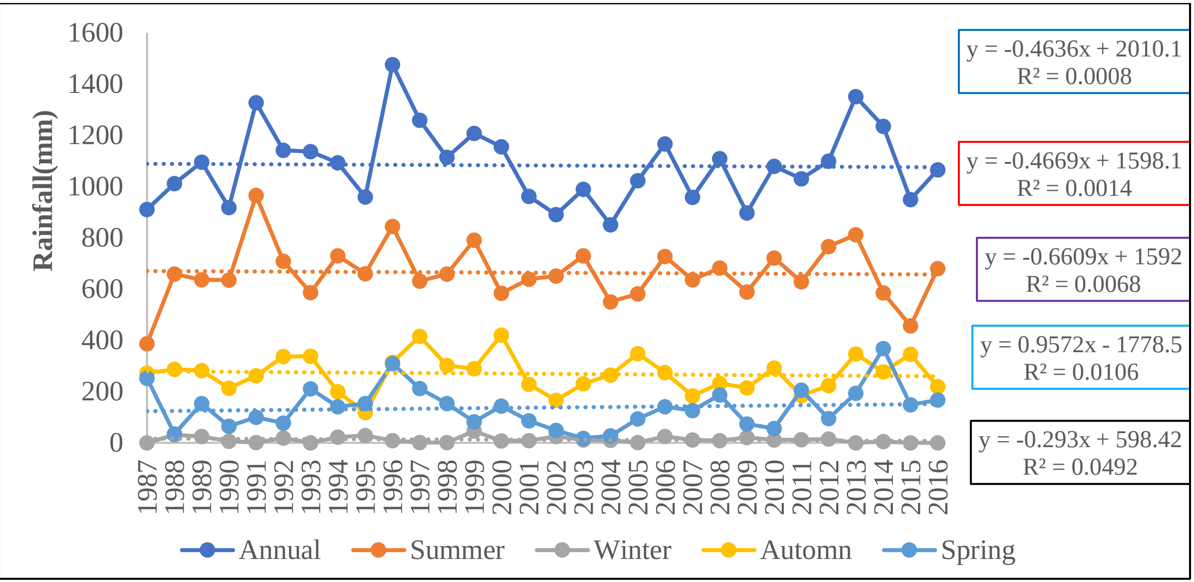

Table 3: Trend of MK of total annual rainfall (1987–2016)

Time period	n	z	Sen's slope(mm/year)
Annual	30	-0.11	-0.6
Where, n=number of years, Z=Mann-Kendall statistical			

Seasonal Rainfall Variability Trends

The analysis result indicated that summer is the major rainy season in the study area, contributing about 61.3 % of the total rainfall. This result agreed with the findings of (Koricha *et al*., (2012), who reported that main seasons contributed the highest the countries' annual rainfall.

Table 4: Descriptive statistic of seasonal rainfall in Hadero Tunto district

Statistics	Summer	spring	Autumn	Winter
Mean	663.7	137.4	269.3	12
Maximum	965.1	368.5	421	36.3
Minimum	387.2	17.7	117.9	0
Stdv	111.3	81.9	70.6	11.4
CV (%)	16.8	59.6	26.2	95.3
Slope	-0.466	0.975	-0.66	-0.359
R^2	0.0014	0.0106	0.0068	0.0492

The Mann-Kendall's test statistics results at seasonal scale showed highly variable but non-significantly increasing trend of spring, and variable and non-significantly declining trend of summer rain. The result is different from the finding of Wagesho *et al.* (2013), where statistically significant declining summer rainfall at watershed level was reported in different part of Ethiopia including the central highland.

Table 5: Trend statistics of Mann-Kendall for mean seasonal rainfall

Seasons	z	S	Sen's slope(mm/season)
Summer	-0.25	-15	-0.327
Spring	0.5	26	0.761
Autumn	-0.32	-19	-0.75
Winter	-0.89	-88	-0.114

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Inter-Annual Rainfall Variability

The analysis showed the annual maximum rainfall recorded was 1476.2 mm (1996), while the lowest rainfall was 851.3mm (2004). Further, the mean annual rainfall of the area understudy was 1082.3mm; while the standard deviation was about 148.8mm, whereas the coefficient of variation was 13.7% which shows that this much rainfall amount deviated from the mean. In general, the coefficient of variation of annual rainfall data revealed that rainfall in the district has demonstrated inter-annual variability for the last 30 years.

Inter Decennial Variability and Trend

The maximum mean annual rainfall was recorded within the first decade of the study period (which extends 1987-1996) which was 1476.2mm, while the minimum annual rainfall was under the second decade (which extends 1997-2006), which was 851.3 mm. From this, both the maximum and minimum recorded rainfall over the last decadal period starts a slight increase when compared to the rainfall recorded as a maximum and minimum in the second decadal period, but on average, the result indicated that the decreasing trend of decennial average maximum rainfall at the area in the past three decades.

Table 6: Inter-decennial rainfall Variability in Hadero Tunto district (1987-2016)

Year	1987-1996	1997-2006	2007-2016
Rainfall	1105.16	1062.13	1077.69

Magnitude and Frequency of Drought Events Within Different Time Scales

Drought months for three months (spring and summer rainfall) and 12 months (annual rainfall) were calculated using SPI. In this study, drought frequency was measured by the number of years that experienced negative SPI values in the total time series of 30 years. As indicated below in (*Figure 5)* the drought events in the summer in the entire period of analysis were found twice at its extreme level.1987 and 2015 experienced extreme droughts with standardized precipitation (SPI) values of -2.89 and -2.03, respectively. Since the months are very critical from an agriculture point of view and their rainfall is vital for the growth of different crops, such types of droughts cause the decline of agricultural productivity.

The result of drought events computed for the spring season, with near normal, moderate, severe, and extreme intensities revealed that, in all periods, extreme intensities were recorded in 2003 with extreme magnitude droughts of -2.27, while the years 1984 and 2004 were the years with severe drought has recorded. The total number of drought months at a 12-month timescale (annual) found in the study area was 14 from a total of 30 years, even-though its magnitude differs. The results for the drought duration value of the annual time scale revealed, that the year 2004 was the year with severely dry with a standardized precipitation value of -1.7. The years 1987, 1990, 2002 and 2009 with values of -1.22, -1.16, -1.38 and -1.33 respectively, were under moderate drought conditions, while the remaining years 1988, 1995,2001,2003,2005 and 2007 were the years with near-normal conditions (*Figure 5* below).

In general, results indicated that drought occurrences in the Hadero Tunto district showed temporal variation. The total number of drought events or their intensities was higher in spring than summer although, the most extreme drought was recorded in summer. Hence, summer rain accounts for 50–80% of annual rainfall totals in Ethiopia, which contributes significantly, to agricultural productivity and significant water reservoirs. This affects the agricultural production system of the smallholder farmers in the study area.

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Figure 5: Magnitude and frequency of SPI values at summer, spring, and annual time scales

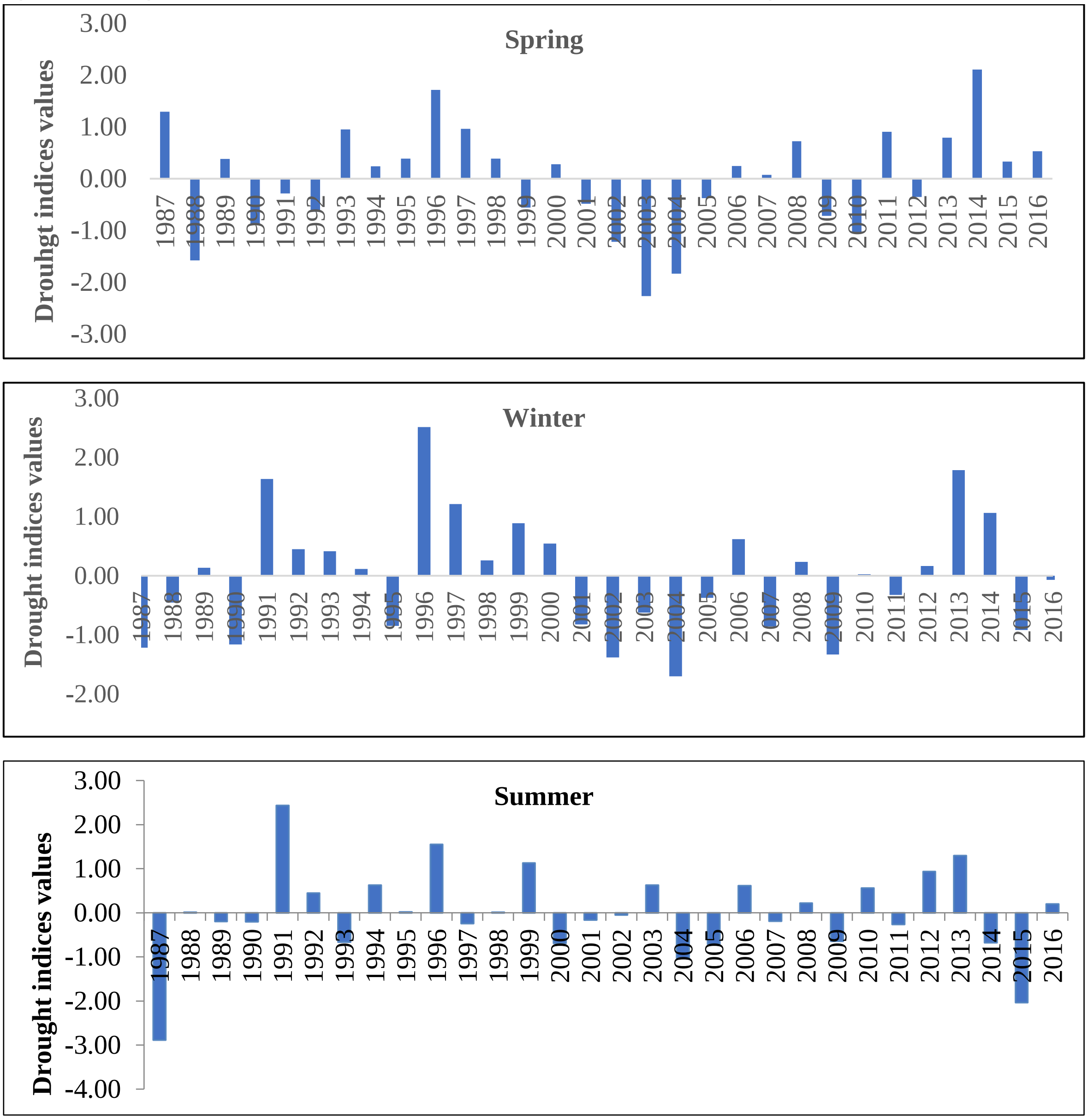

Table 7: The recurrence of dry, wet, and extreme rainfall in season and annual time scale

SPI	Category	SPI and number of recurrences				
		Winter	Spring	Summer	Autumn	Annual
2.+	Extremely wet	0	1	1	0	1
1.5 to 1.99	Very wet	1	1	1	2	2
1.0 to 1.49	moderately wet	5	1	2	3	2
-.99 to .99	near normal	24	22	23	21	20
-1.0 to -1.49	moderately dry	0	2	1	2	4
-1.5 to -1.99	severely dry	0	2	0	1	1
-2 and less	extremely dry	0	1	2	1	0

Farmers' Perception about Climate Change and Variability

The survey result indicated that about 90%, of sampled respondents perceived climate change mainly temperature and rainfall, in the past three decades. The remaining 4.7% and 5.3% of the respondents, did not know about climate changed or did not perceive the changes. Agro-

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ecologically, farmers of lowland areas were more aware (100%) of climate change than farmers of midland (88.6%) and farmers of highland (81.1%) in the study area, respectively. Evidence revealed that farmers in drier and hotter climates are more likely to respond to climate change than farmers in cooler and wetter areas (Tesso *et al*., 2013).

Table 8: Farmers' perceptions on observed climate change and variability (1987-2016)

Response category	Respondents' agro-ecology							
	Highland		Midland		Lowland		Total	
	n	%	n	%	n	%	n	%
Yes	30	81.1	62	88.6	43	100	135	90
No there is no	4	10.8	4	5.7	0	0	8	5.3
I do not know	3	8.1	4	5.7	0	0	7	4.7
Total	37	100	70	100	43	100	150	100

Source: Own survey result

Farmers ' Perception of Temperature Trends

According to the analysis, about 78.4 % of respondents in highland 85.7% of midland and 95.3% of lowland perceived that temperature increased in the last three decades. In general, the survey result revealed that out of the total household heads included in the survey, about 86.5% of the respondents perceived an increasing temperature in the study area over the past three decades. The result obtained from respondents is in line with the focus group discussion and key informant interviews, which indicated *"The annual as well as the seasonal temperature in our locality had shown an increased trend "*. This study is also in line with the empirical study of Tessema *et al*. (2013), which revealed that most farmers in Ethiopia know that the temperature is increasing.

Table 8: Farmers ' perception on temperature trends in Hadero Tunto district

Respondents' agro-ecology	Response category on the trends of temperature							
	Increase		decrease		No change		Total	
	n	%	n	%	n	%	n	%
Highland	29	78.4	5	13.5	3	8.1	37	24.7
Midland	60	85.7	7	10	3	4.3	70	46.6
Lowland	41	95.3	1	2.35	1	2.35	43	28.7
Total	130	86.5	13	8.5	7	5	150	100

Source: Own survey result

Perception of Farmers on Annual and Seasonal Rainfall Trends

The results showed that about 90 % of the farmers in the Hadero Tunto district perceived a change in rainfall (increase or decrease). Agro-ecologically, about 83.8% of the respondents in highland, 88.6% of the respondents in midland, and 97.7% of the respondents in lowland agro-ecologies recognized the change in rainfall. Furthermore, farmers who perceived change in rainfall had also been asked to note the trend in annual, onset, and cessation for both long and short rainy seasons through their experience. Likewise, about 82.7 % and 81.3% of the farmers in the study area noticed a decrease in annual and summer rainfall respectively, while 80.8% perceived a declining trend in spring rainfall totals.

The result obtained from the household survey was also confirmed by the participants of the FGDs and key informants, that, more than 85 % of key informants and participants of the FGDs had also recognized that:

> *"Until 30 years ago, rainfall in our locality had a more regular pattern and was more predictable generally, sufficient in all seasons for different agricultural activities, conversely, nowadays the rainfall pattern has become irregular, insufficient, and showed*

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poor seasonal distribution for both spring and summer seasons."

Perception of Farmers on Trends of Onset and Cessation Dates

Farmers who perceived, the change in annual and seasonal rainfall in their locality were also asked to characterize the timing of rainfall in both summer and spring seasons. Furthermore, it has been indicated that more than 96% of the farmers in the Hadero Tunto district perceived an increasing late onset and early cessation of summer rainfall. On the other hand, about 95% of the interviewed farmers in the study area also perceived the increased rate of late arrival and early cessation of spring rainfall (*Table 9*).

The participants of FGD in all selected kebeles had also confirmed that

" spring rainfall is as vital as that of summer because of the second most growing season but, due to the high variability and shortage of spring rainfall, our farming schedule has been also disordered"

The respondents" perception of the study area also corresponds with the empirical findings, where a decreasing trend of rainfall and an increasing temperature trend has been disclosed (Asfaw *et al*., 2018).

Table 9: Farmers ' perception of the trends of rainfall in the study area

Rainfall characteristics	Farmers' perception on rainfall variability (%)							
	Increased		Decreased		No change		Total	
	n	%	N	%	N	%	N	%
Annual rainfall amount	17	11.3	124	82.7	9	6	150	100
Summer rainfall amount	16	10.6	122	81.3	12	8.1	150	100
Spring rainfall amount	21	14	121	80.8	8	5.2	150	100
Late onset of rainfall	145	96.7	3	2	2	1.3	150	100
Early cessation of rainfall	143	95.3	4	2.6	3	2.1	150	100

Source: Own survey result

CONCLUSIONS

Understanding climatic parameters particularly temperature and rainfall trends and farmers' perception of changes in those climatic variables over specific areas, puts forward valuable information for planning and implementing local-level adaptation measures. Accordingly, this study has analyzed the trend of rainfall and temperature and farmers' perception of the changes in these variables in the Hadero Tunto district for the past 30 years. Consequently, results of historical rainfall and temperature data showed the climate variation in the study area for the study period. The annual and seasonal rainfall distributions and amount are also not uniform. The Mann–Kendall trend analysis result confirms significant upward trend in the annual minimum and maximum temperatures across the period. The analysis of both seasonal and annual standardized precipitation index has also shown that the area under study has experienced diverse droughts with different extents during the past three decades under consideration. The perception evaluation results also showed most farmers perceived changes in rainfall and temperature and experienced the effects of a changing climate over three decades. Nevertheless, this study was limited in scope and sample size; it is recommended further studies be undertaken at a larger scale to illustrate the associations between farmers' perceptions of climate change with meteorological data impact assessment to figure out the risk of climate change.

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