

Local Climate Trends and Farmers' Perceptions in Southern Tigray, Northern Ethiopia

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Abstract

This study aimed to investigate local climate changes, farmers' perception to changes, and factors affecting perception to climate change. For trend analysis, station based rainfall records for the period 1978-2012 was gathered, and for perception analysis, a survey based on 600 randomly selected farming households was carried out in four districts. Multi-stage random sampling method was applied to select sample populations. Nonparametric analyses were used for analyzing trends and testing significance. In the survey, farming households were asked their observation about changes in local climate using structured questionnaires. We also utilized logistics regression to identify factors that influenced perceptions of farming households on climate change. Results indicate that while annual rainfall showed no change across the region, seasonal rainfalls have exhibited significant trend changes in the last three decades. The study confirmed that the change in rainfall trend varies by agro-ecology. *Kiremt* (summer) rainfall in lowlands increased significantly by about 106mm/decade, whereas highlands experienced non-significant change. Besides, when the highlands lose a significant amount of *Belg* (spring) rainfall (35mm/d), lowlands didn't. Regarding perception, about 87% and 50% respondents perceived *Belg* and *Kiremt* rainfall decreasing, respectively. Their observation was consistent with statistical findings. This study learned that gender, education, farm experience, extension, climate information, economic status, drought experience, and local agro-ecology positively influenced farmers' perception. Yet, irrigation negatively affected farmers' perception. Results suggest further works in the areas of information dissemination, inclusion of local knowledge in adaptation programs, and irrigation developments to reduce impacts.

Key words: *seasonal rainfall, climate change, farmers' perceptions, perception determinants, Northern Ethiopia*

Introduction

Ethiopia's climate is changing, and a number of projections emphasizing further changes are on the way. Projections expect warming in all seasons across the country, which may cause a higher frequency of heat waves and higher rates of evaporation (Conway & Schipper, 2011). Also, a

likely increase in mean annual rainfall in East Africa highlands, including Ethiopia, is anticipated (Christensen et al., 2007). More specifically, the National Meteorological Agency (NMA) expects rainfall to decline in northern parts, whereas the

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southern part of the country might see increasing rainfall of as much as 20% (NMA, 2007).

Rising temperatures, increasingly erratic rainfall, and more frequent and severe floods and droughts are major concerns, especially for those who are highly dependent on natural resources, such as agriculture, for their livelihoods. In the agriculture sector, the consensus is that changes in temperature and precipitation will result in changes in land and water regimes that will later affect agricultural productivity (World Bank, 2003).

Ethiopia is a large country comprised of different agro-ecologies and climate features resulting from its location and altitude variations. This suggests the need for climate investigations at the local level. Some studies have been carried out in different parts of the country because large-scale climate projections and trend generalizations may not necessarily reflect situations at the local and agro-ecological level. The following are among those available. Bewket (2009) in his study of rainfall variability and crop production in the *Amhara* region of Ethiopia found increasing annual and *Kiremt* (summer) rainfall in *Dessie* and *Lalibela* stations. He also learned of a drop in *Debretabor* (*Kiremt*) and *Dangla* (*Belg* rains) in the central-west part of the country in the period 1975-2003. Dereje et al. (2012) also found positive *Kiremt* rainfall trends at *Bahirdar*, *Gondar*, *Srinka*, and *Mettema* stations, whereas negative trends of *Belg* (spring) rainfall were identified at *Kombolcha* and *Srinka* stations in the period of 1978-2008. Another study by Hadgu et al. (2013) explored negative trends for both *Belg* and *Kiremt* rainfall in northern Ethiopia, though trends in *Kiremt* were non-significant. Sileshi & Zanke (2004) and Vest et al. (2013) saw no trend for all annual and seasonal rainfall in Northern Ethiopia in general. These studies, although in the northern and central parts of the country, are good indicators of how climate elements vary across locations in Ethiopia.

Southern Tigray is an area that is highly vulnerable and sensitive to climate related extreme events such as droughts. The historic drought of 1984/5 left serious damages in this part of the country. From then onwards, reports from DPPC (1999 & 2004) and FAO (2008 & 2009) indicated repeated failures in crop production because of localized droughts associated with variable and erratic rainfall in *Belg* and *Kiremt* seasons. Reports from

these organizations show partial or total failure of production at least in 11 of the last 17 years due to rainfall variability since 1997.

Despite increasing intensity and frequency of climate hazard in southern Tigray, empirical studies are deficient in this field. With global warming a certainty, it is imperative to make investigations on climate elements at the local level. Investigating how farmers perceive climate change and how they respond to the changes will have valuable inputs for further development directions. How local people perceive climate change determines how they formulate strategies to reduce possible impacts of those changes on their livelihoods (Deressa et al., 2010, Prager & Posthumus, 2010). Therefore, local perspectives can be combined with scientific climate scenarios to draw policy recommendations for future adaptation strategies (Patino & Gauthier, 2009).

Yet, farmers' perceptions and adaptation practices to climate change are context- and location-specific. Societies differ in culture, education, demographics, resource endowments, and biophysical and institutional characteristics. This heterogeneity influences the way they perceive change in their local climate and the way they respond to the change (Maddison, 2007; Posthumus et al., 2010).

Some attempts were made to analyze how farmers perceive climate change in Ethiopia. Admassie & Adnew (2007), Deressa et al. (2010), and Hadgu et al. (2013) investigated farmer's perceptions to local climate change and adaptation strategies. However, they did not determine how consistent farmers' perceptions were with realities (statistical discoveries) and how socio-economic factors influenced perceptions. It would be more useful when farmers' perceptions are surveyed and compared with statistical discoveries and factors affecting perceptions are explicitly identified. The fact that perception leads to adaptations means we have to identify barriers of perceptions and pave a way for effective adaptation strategies.

Therefore, the purposes of this study were (1) to investigate trends of seasonal and annual rainfalls, (2) to identify farmers' perceptions on trends of local climate and compare them with findings of statistical analysis, and (3) to identify factors influencing farmers' perception of climate change and the extent of influence in southern Tigray.

Compared to previous works, this study differs in many ways. First, it combines comparisons of meteorological data based on statistical findings with community perceptions. Second, it explores the influences of different factors on community perception, and third it compares results at station and agro-ecological levels in its analysis.

Material and Methods

Study Area Description

Southern Tigray is one of the seven zones in Tigray regional state of Ethiopia located between 12°14'53.9"-13°06'08"N latitude and 39°10'45.7"-39°53'41.7"E longitude. Having a total area of 499,616.1 ha, the study area comprises five rural districts and three town administrations. Rugged topography, including mountains, plateaus, valleys and gorges, characterizes the physical landscape of southern Tigray. Generally, the topography contains four main traditional divisions of arable Ethiopia. *Kola*/lowland covers 40.4 % of the area ranges between 1400 to 1800 mean above sea level (m.a.s.l.) and has low rainfall and high temperatures relative to others. *Woina-dega*/middle highland shares 29% of area extending between 1800-2400 m.a.s.l. This area has medium rainfall amount and moderate temperature. *Dega*/highland extends between 2400-3400 m.a.s.l and has

relatively higher rainfall and cooler temperatures and covers about 30%. *Wurch*/very-cold areas are locations above 3400 m.a.s.l with high rainfall and low temperatures and cover 0.45% of the study area.

Ofla-alaje highland and *kola* (lowland) agro-ecologic zones are the two dominant agro-ecological zones in southern Tigray where the former is located in the western part (including Alaje, Endamehoni and Ofla districts) and the later one in the eastern part (including Alamata and Raya-azebo districts). The two agro-ecological zones are agriculture-based mixed farming production systems in which crop cultivation is practiced along with livestock rearing (MARD, 2009).

The area has a mainly semiarid climate with a bimodal rainfall type. The main rainy season, which lasts from June to September (locally called *Kiremt*), follows the premonsoon rainy season, February to May, (locally called *Belg*) that adds a small amount of rain to the area. Agriculture is rain-fed and led by small-scale farmers with an average landholding size of less than one hectare per household. Like the rest of country, agriculture is the mainstay of the economy, and it directly supports about 86.4% of the population for employment and livelihood. Total population of the study areas was 717,420 with a population density of 144 people per Km² in 2013 (CSA, 2012).

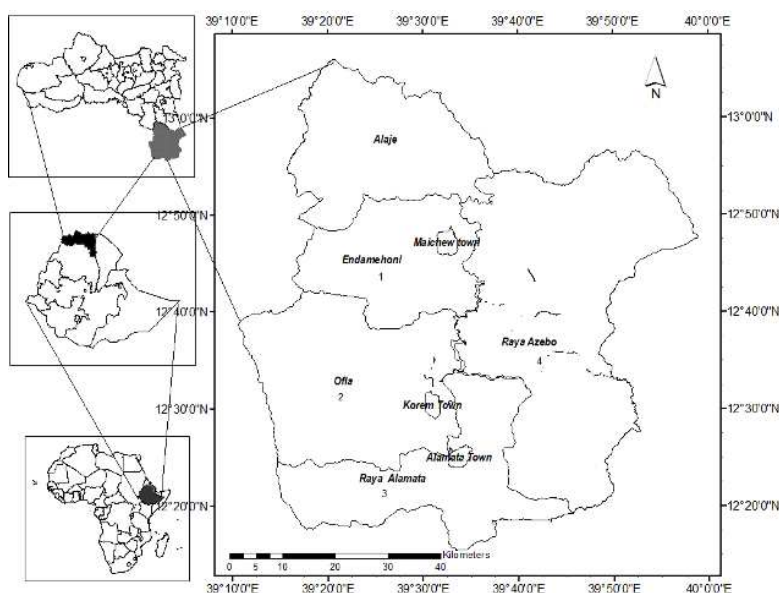


Figure 1: Location of Study Area

Produced using ArcGIS 10.0 (ESRI@ArcMap 10.0)

Table 1

Selected meteorological stations and their characteristics

	Station Name		
	Alamata	Korem	Maichew
Altitude (m)	1578	2478	2440
Latitude	12°25'09" N	12°30'28" N	12°47'02" N
Longitude	39°33'22" E	39°31'11" E	39°32'00" E
Years of observation	1978-2012	1980-2012	1978-2012
Years of no data	1981, 90 & 91	1980 & 81	1989 & 90
Agro-ecol. Zone	Low land	Highland	Highland

Source: Meteorological data series from NMAE, 2013

In addition, the sector is highly susceptible to climate variability and seasonal shifts in rainfall, resulting in drought. Almost annually, the study area experiences localized droughts because of abnormally low and untimely rainfall, causing crop failure to jeopardies rural livelihoods and food security (DPPC, 1999 & 2004; FAO, 2008 & 2009). Southern Tigray was selected for this study because recurrent drought and crop failures are common in the area.

Data and Sampling Procedure

This study is conducted based on a cross-sectional survey design where data are collected from a representative sample at one specific point in time. Historic temperature and rainfall records were assembled for Alamata, Maichew, and Korem stations from the National Meteorological Services Agency of Ethiopia (NMSAE) with varied duration. WMO recommended a minimum of a 30 year data series for a study to detect trends in hydro-climatic time series. It was possible to get such records for rainfall from three stations, whereas temperature records were repeatedly broken up in all three stations. Therefore, temperature trend analysis was impossible due to absence of uninterrupted station based records in the study area.

Considering the maximum flexible thresholds of 10% missing values adopted by Ngongondo et al. (2011), Alamata, Maichew, and Korem observatory stations were taken for rainfall trend analysis. Rainfall records from the three stations were

continuous since 1980 with varied duration and few missing. Hence, by averaging neighboring records, we could fill those missing particular months.

Regarding spatial distribution, the highland agro-ecology contains Maichew and Korem meteorological stations, whereas the lowland agro-ecology contains Alamata station. This categorization helps to have a comparative analysis at station, agro-ecological, and areal levels and gives highlights about how rainfall characteristics are spatially distributed in the study area.

Farmers' ability to perceive climate change is a first key step for making decisions to adapt. To identify how farming households perceive the state of rainfall in their locality, a survey was conducted in the study area. The survey covered five *Kebelles* from each of four districts (Alamata, Endamehoni, Ofla and Raya-azebo) to have twenty *Kebelles* in total. The survey was made between April and October 2013. From each *Kebelle*, 30 households (HHs) were randomly selected using a multistage sampling procedure from the two agro-ecological zones to constitute a sample of 600 HHs for the survey. Structured and semi-structured questionnaires were distributed to heads of the selected farming HHs based on which heads were asked to express their perceptions on whether changes have been observed on climatic elements and associated extreme events in their localities in the last two decades. Farmers were asked what their experiences were about extreme events such as drought and others in the stated time. The selected *Kebelles* from which respondents had been randomly selected are showed in Figure-2.

Data Analysis

Different methods of data analysis were used in this study. Some of the major methods are discussed here.

Areal Weighted Averages

When trends at the regional level were investigated, areal weighted average rainfall was intended using the monthly rainfall series of all stations located within an area under consideration. We follow the Nicholson, (1985) formula to calculate our areal weighted average rainfall:

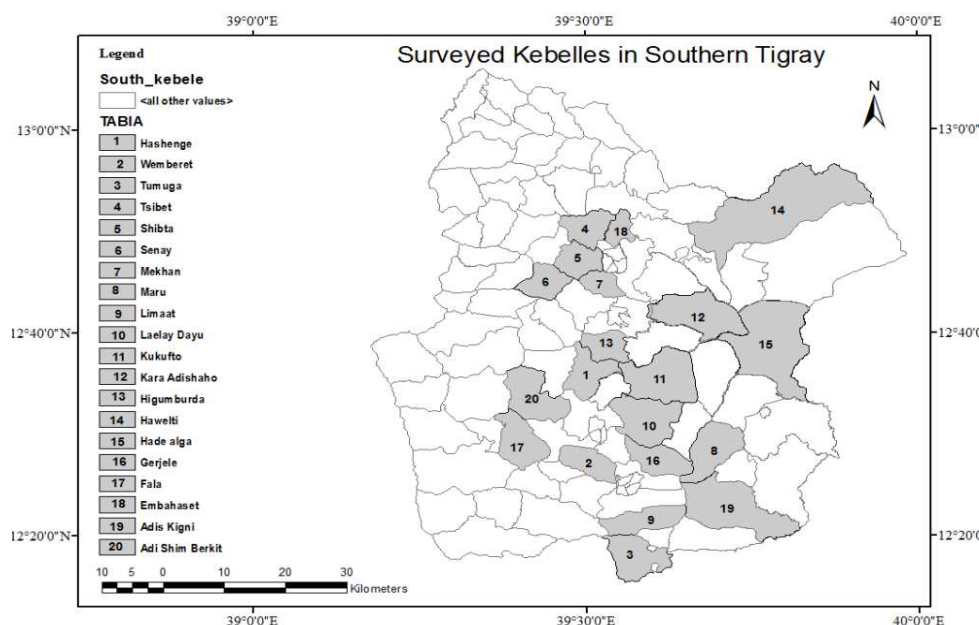


Figure 2: Surveyed Kebeles of Southern Tigray Zone, 2014

Produced using ArcGIS 10.0 (ESRI@ArcMap 10.0)

$$R_j = \frac{\sum X_{ij}}{I_j}.$$

Where R_j is areal/regional integrated rainfall for year j , X_{ij} is rainfall recorded at station i for year j , and I_j is the number of stations having rainfall record for year j .

Detecting Outliers

As Gonzalez-Rouco et al., (2011) urges, primary emphasis was given to identify outliers in the climate data. Outliers are values greater than a threshold value of a specific time series data that can affect detection of inhomogeneity. For non-normally distributed data like rainfall, the Turkey fence is recommended for trimming the outlier (Ngongondo et al., 2011). The Turkey fence used in this study was set only for upper limit assuming that any rainfall value below zero is automatically an outlier. Values outside the Turkey fence were considered as outliers and such outliers were set to a limit value corresponding to $\pm 1.5 \times IQR$. Hence, the fence is represented as:

$[Q_3 + 1.5 \times IQR]$ as upper limit

Where: Q_3 is upper quartile point, 1.5 standard deviations from the mean and IQR is interquartile range.

Mann-Kendall Analysis

Mann Kendall analysis is a statistical test widely used for analyzing trends in climatologic (Mavromatis & Stathis, 2011) and hydrologic time-series studies (Yue & Wang, 2004). There are two advantages of using this test. First, it is a non-parametric test and does not require data to be normally distributed. Second, it has low sensitivity to abrupt breaks due to inhomogeneous time series (Tabari et al., 2011). Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set (Blackwell, 2012). Data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, S , is assumed to be 0 (e.g., no trend). If a data value from a later period is higher than a data value from an earlier period, S is incremented by 1. On the other hand, if the data value from a later period is lower than a data value sampled earlier, S is decremented by 1. According to this test, the null hypothesis (H_0) assumes that there is no trend ($S=0$) and this is tested against the alternative hypothesis (H_1), which assumes that there is a trend ($S \neq 0$) (Onoz & Bayazit, 2012).

Let $X_1, X_2, X_3, \dots, X_n$ represent n data points where x_j represents the data point at time j . Then the Mann-Kendall statistic (S) is given by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sign}(X_j - X_i)$$

$$\text{Sign}(X_j - X_i) = \begin{cases} +1 & \text{if } (X_j - X_i) > 0 \\ 0 & \text{if } (X_j - X_i) = 0 \\ -1 & \text{if } (X_j - X_i) < 0 \end{cases}$$

Where S is Mann-Kendal's test statistics, X_i and X_j are annual and seasonal rainfall values of years i & j ($j > i$), and n is length of the time series (Motiee & McBean, 2009). A positive/negative value of S indicates an upward/downward trend (Drapela & Drapelova, 2011).

Kendall (1975) assumed for a data series $n \geq 10$, the statistic S is approximately normally distributed with the mean and variance and computed (Yenigun et al., 2008) as follows:

$$E(s) = 0$$

The variance (σ^2) for S -statistics, in a situation where there may be ties (same values) in the x value, is given by:

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^m t_i(t_i-1)(2t_i+5)}{18}$$

Where summation term in the numerator is used only if the data series contains tied values, m is the number of tied groups, and t_i is the number of data points in the tied group. The standard test statistic Z_s is calculated as follows:

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{\text{var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{var}(S)}} & \text{if } S < 0 \end{cases}$$

The presence of a statistically significant trend is evaluated using Mann-K value. In a two-sided test for trend, the null hypothesis (H_0) should be

accepted if $|Mann - K| < Z_{1-\alpha/2}$ at a 0.05 level of significance. $Z_{1-\alpha/2}$ is the critical value of Mann-K from the standard normal table. For instance, for 5% significance level, value of $Z_{1-\alpha/2}$ is 1.96.

Theil-Sen's Slope

Theil-Sen slope (Sen, 1968), also known as "Kendall's slope" or "Nonparametric linear regression slope", is an alternative to the standard linear regression slope. It is popular in earth sciences (meteorology and climatology) for measuring temperatures and precipitations over time. A straight line can represent the Theil-Sen slope, but, it is "distribution free" and permits use of merely ordinal measurement scales. This method could also be used with missing data and remain unaffected by outliers or gross errors (Karpouzou et al., 2010). Slope (change per unit time) was estimated following the procedure of Sen (1968) and a detailed outline of the procedure is given in Partal & Kahya (2006) and Karpouzou et al. (2010).

Meteorological Drought Assessment

Meteorological drought is a type of drought that occurs due to prolonged period of below average precipitation to cause natural shortage of available water. To support comparisons between perception of drought occurrences and statistical findings, the Standardized Anomaly Index (SAI) was used as a tool. SAI was used to determine dry and wet years and to assess frequency and severity of meteorological droughts from rainfall records, as in Bewket (2009) & Hadgu et al., (2013). The formula was:

$$S = \frac{(P_t - P_m)}{\sigma}$$

Where, S is standardized anomaly index; p_t is total annual rainfall of year t ; p_m is long time average annual rainfall; and σ is standard deviation of annual rainfall over period of observation. Values of S will be cast in to one of the drought severity classes; such as, extreme drought ($S < -1.65$), severe drought ($-1.28 > S > -1.65$), moderate drought ($-0.84 > S > -1.28$), and no drought ($S > -0.84$). The class intervals correspond with the 95, 90, and 80 percentiles, assuming that annual rainfall data are normally distributed.

Detecting farmers' Perception of Local Climate Change

Different studies adopt various systems to determine whether farmers perceive climate change. Detecting perception of farmers on climate change is a difficult task in developing countries, especially in Africa. Farmers in the developed world have access to the wealth of climate and weather information; they easily can learn about changes and variations in climate without having to sense them. However, the case is different when African farmers use various traditional methods to forecast weather and climate. These farmers detect long-term climate fluctuations and changes after they sense them, for which sensitivity matters individually.

Studies conducted in Africa in this case applied different approaches to identify perceptions. Meze-Hausken (2004) & Deressa et al. (2010) in Ethiopia, Komba & Muchapondwa (2012) in Tanzania, and Maddison (2007) followed the easiest approach, which is to ask farmers if they have observed changes in their local climate across some decades. Their results show mixed results on farmers' ability to detect climate changes in their environment.

Following this easy approach, we made a survey and asked sample farming-households if they have seen any change in climate variables, mainly rainfall and temperature, in the last two decades (1990s and 2000s). Then, we checked if findings from the survey were consistent with reality on ground.

Logistic Regression

Farmers' perception of climate change is a precondition for effective adaptation. Evidence in Africa reveals that large numbers of agriculturalists already perceived hotter climate, less predictable rains with shorter duration and then started farm level responses. However, perceptions are context and location specific due to heterogeneity in factors that influence them such as culture, education, gender, age, resource endowments, agro-ecology, and institutional factors (Maddison, 2007; Deressa et al., 2010).

The study used a logistics model to identify factors influencing farmers' perceptions of climate change, as in Ndambiri et al. (2012). In the model, the dependent variable is dichotomous in nature,

taking a value of 1 or 0. Although the Ordinary Least Squares (OLS) method may compute estimates for the binary choice models, certain assumptions of the classical regression model will be violated. These include non-normality of disturbances, heteroscedastic variances of the disturbances, and questionable value of R^2 as a measure of goodness of fit (Gujarati, 2003). For instance, given:

$$y_i = \beta_0 + \beta_1 \chi_i + \varepsilon_i \quad [1]$$

where: $y_i = 1$ if a farmer perceives climate change and $y_i = 0$ if a farmer does not, β_0 is intercept, β_1 is parameter to be estimated, χ_i is variable in question, and ε_i is disturbance term.

This model is a typical linear regression model, but because the regression is binary or dichotomous, it is called a linear probability model (LPM). However, in a regression model, when the dependent variable is dichotomous in nature, taking value 1 or 0, use of linear probability models becomes a major problem. This is because predicted value can fall outside the relevant range of zero to one probability value. Thus, if linear probability models are used, results may fail to meet statistical assumptions necessary to validate conclusions based on the hypothesis tested (Feder et al., 1985).

Gujarati (2003) recommended Logit and probit models to overcome the problem associated with LPM. These models use Maximum Likelihood Estimation (MLE) procedures and ensure that probabilities are bound between 0 and 1. Both logit and probit transformations estimate cumulative distribution, thereby eliminating the interval 0, 1 problem associated with LPM. The logistic cumulative probability function can be represented by:

$$P_i = F(Z_i) = \frac{1}{1 + e^{-Z_i}} \quad [2]$$

where P_i is the probability that i^{th} person will be in I - first category, $Z_i = \beta_0 + \beta_1 \chi_i + \varepsilon_i$ where β_0 is intercept of the model; β_1 is model parameters to be estimated; χ_i are the independent variables and e represents base of natural logarithms, which is approximately equal to 2.718. In equation (2), Z can range from positive infinity to negative

infinity. The probability of a farmer perceiving climate change lies between 0 and 1. If we multiply both sides of the equation (2) by $1 + e^{-z_i}$ we get:

$$(1 + e^{-z_i})P_i = 1 \quad [3]$$

Dividing by P and then subtracting 1 leads to:

$$e^{-z_i} = \frac{1}{P_i} - \frac{1 - P_i}{P_i} \quad [4]$$

By definition; however, $e^{-z_i} = \frac{1}{e^{z_i}}$ so that the equation (4) becomes:

$$e^{-z_i} = \frac{P_i}{1 - P_i} \quad [5]$$

By taking the natural logarithm of both sides of equation (5), we get:

$$Z_i = \log\left(\frac{P_i}{1 - P_i}\right) \quad [6]$$

In other words:

$$\log\left(\frac{P_i}{1 - P_i}\right) = Z_i = \beta_0 + \beta_i X_i \quad [7]$$

This makes the logistic probability model. Therefore, it can be noted that the logistic model defined in the equation (7) is based on the logits of Z, which constitutes the stimulus index. Marginal effects can also be computed to show changes in probability when there is a unit change in independent variables. Marginal effects are computed as:

$$\frac{\partial P_k}{\partial X_k} = \frac{\beta_k e^{-z_k}}{(1 + e^{-z_k})^2} \quad [8]$$

Therefore, this logistic regression model was used to determine those factors, which influenced farmers' perception on climate change. The dependent variable is farmers' perception of climate change, a binary variable indicating whether or not a farmer has perceived climate change. It was regressed on a set of relevant explanatory variables hypothesized based on literature to have influence on perception to climate change, which are in Table-2.

Table 2

Hypothesized explanatory variables and their descriptive statistics for logistics regression model, 2014

Independent variables	Unit	Mean	Std. Deviation	Direction of influence
Sex (Gender)	Dummy: 1 = Male, 0 = Female	.708	.46	+/-
Age (years)	Continuous	43.83	10.50	+/-
Level of education (educ)	Dummy: 1= primary & above, 0 = no education	.53	.50	+
Experience in Agriculture (exp)	Continuous	20.75	10.72	+
Access to CC information(info)	Dummy: 1 = Yes, 0 otherwise	.65	.4789	+
Access to credit(crdt)	Dummy: 1 = Yes, 0 otherwise	.69	.46	+
Access to extension (extn)	Dummy: 1 = Yes, 0 otherwise	.75	.43	+
Access irrigation(irigt)	Dummy: 1 = Yes, 0 otherwise	.37	.48	+/-
Distance to Market (Dist)	Continuous	10.82	6.2	-
No. of livestock FHH has (TLU)	Continuous	3.54	3.47	+/-
off farm activities(offrm)	Dummy: 1 = Yes, 0 otherwise	.25	.43	+/-
Economic status of FHH(eco)	Dummy: 1= poor, 0 = not poor	1.57	.66	+/-
Drought experience(drt)	Dummy: 1 = Yes, 0 otherwise	.79	.41	+
Local Agro-ecology(agro)	Dummy: 1 = highland, 0 = lowland	.50	.5004	+/-

Table 3

Average, maximum, and minimum annual and seasonal rainfall in Southern Tigray (1978-2012)

Stations	Properties	Annual Rainfall (mm)	Kiremt Rainfall (mm)	Belg rainfall (mm)
Alamata	Average	668.40	341.48	241.25
	Max	1003.53	768.70	445.80
	Min	262.40	19.40	30.60
Maichew	Average	787.13	457.82	219.97
	Max	965.30	710.50	578.10
	Min	477.70	158.00	31.40
Korem	Average	983.40	591.22	237.83
	Max	1380.20	979.10	505.80
	Min	630.95	290.80	65.40

Source: Calculated based on NMSA data series, 2014

Using these variables, the model is specified as:

$$Z_i = (\beta_i \chi_i) + \varepsilon_i \quad [9]$$

where: Z_i is the perception by the i^{th} farmer that climate is changing, χ_i is the vector of explanatory variables of probability of perceiving climate change by the i^{th} farmer, β_i is the vector of the parameter estimates of the regressors hypothesized to influence the probability of farmer is perception about climate change.

Accordingly, the empirical specification of the logistic regression model is:

$$Z_i = \beta_0 + \beta_1 \text{sex} + \beta_2 \text{exp} + \beta_3 \text{educ} + \beta_4 \text{crdt} + \beta_5 \text{info} + \beta_6 \text{extn} + \beta_7 \text{irigt} + \beta_8 \text{TLU} + \beta_9 \text{offrm} + \beta_{10} \text{eco} + \beta_{11} \text{drt} + \beta_{12} \text{agro} + \beta_{13} \text{mktdst}$$

Software Used

Different software is used for this study. SPSS version 17 was used for performing statistical Mann-Kendall test. The null hypothesis was tested at 95% confidence level for annual, seasonal, and monthly rainfall records. Theil Sen's slope for rainfall trend test was calculated using Single Case Research (SCR): a web based calculators for SCR analysis (Version 1.0) (Vannest et al., 2011). Besides this, Stata software version11 was used to run the logistics model to determine factors influencing farmers' perceptions on climate change. The null hypotheses were tested against .01, .05, and .1 significance level in relation to the determinant factors. Other software, like Microsoft Excel 2010 and ArcGIS 10, were also used.

Results and Discussion

Monthly Rainfall Trends

The rainfall system in Southern Tigray is a bimodal type where the main rainy season (*Kiremt-JJAS*) is preceded by a small rainy season (*Belg-FMAM*).

At Stations Level

Mann-Kendall results show all Belg rain-giving months (FMAM) at Maichew, three-fourth (FMM) at Alamata, and two in four (FM) at Korem show negative signs in the time 1978-2012. Among those months, February at Alamata (10mm/d), at Korem (2mm/d), and at Maichew (4mm/d); May at Alamata (13mm/d) and Korem (19mm/d) and March at Maichew station (13mm/d) showed decreasing trends all significant at 0.05 level.

Whereas, among Kiremt rain-giving months, 75% (JAS) of months in Maichew, 50% (JnS) in Korem, and 25% (S) in Alamata stations showed negative trends of rainfall, but only June at Maichew station was significant (10 mm/ decade) at 0.05 level.

At Agro-Ecological Level

Results at the agro-ecologic level are reflections of results at station level analysis. Hence, Table-4 shows that February and May rainfall was drying significantly at 0.01 and 0.05 level in the lowland (kola) agro-ecological zone, while the February rainfall trend was negative and significant at 0.05 level in the highlands.

Table 4

Agro-ecologic level trends of monthly rainfalls of Kiremt and Belg season in Southern Tigray, Northern Ethiopia (1978 To 2012)

Months	Highland Mann-K	Slope	Lowlands Mann-K	Slope	Regional Mann-K	Slope
February	-.264*	-3.19	-.327*	-9.67	-.276*	-6.25
March	-.194	-9.13	-.086	-8.04	-.113	-6.98
April	-.012	-.17	.009	.62	.025	-2.45
May	-.219	-12.33	-.257*	-13.33	-.267*	-18.90
June	-.153	-4.21	.169	1.50	-.106	-1.82
July	.324**	34.71	.517**	52.69	.422**	38.80
August	.138	13.86	.252*	50.50	.207	29.80
September	-.105	-3.88	-.099	4.35	-.139	-5.89

Mann-K = Mann-Kendall trend test, Slope (Sen's slope) = the change rainfall (mm)/decade; ns = non-significant trend and **, * indicates significant trend at 0.01 and 0.05 significant level. Calculated based on NMSA data series, 2013

Of the Kiremt rain-giving months, kola agro-ecologic zone had positive trend for all except September, with July and August significant at 0.01 and 0.05 level, respectively. In the highland region, July and August rainfall trends showed increasing trends with the former significant at the 0.01 level.

At Areal (Regional) Level

Although most of the rain giving months of the two rainfall regimes have negative trends, regional scale analysis results show that the drying trend of February and May rainfalls were significant at 0.05 level, as in Table 4 above. July rainfall, on the other hand, had a significant positive trend at 0.01 level.

Seasonal Rainfall Trends

Kiremt rainfall is relatively higher in the highland agro-ecology, whereas *Belg* rainfall is a bit higher in the lowland areas compared to the highland shares. The annual share of *Kiremt* and *Belg* rains were 58.7% and 26.9% in the highland agro-ecology and 52.7% and 35.7% in the lowland agro-ecological zone.

At Station Level

Mann-Kendall analysis shows that *Kiremt* rainfall was significantly increasing in all but Maichew station. The magnitude of the positive trend ranges from 107 mm/d in Alamata to 86 mm/d in Korem station, all significant at the 0.01 and 0.05 level,

respectively. Regarding *Belg* rainfall, all three stations showed negative trends, but only Maichew's trend was significant (44.5 mm/d) at the 0.01 level.

At Agro-Ecologic Level

Agro-ecologically, rainfall during *Kiremt* season exhibited a significantly growing trend in the lowlands (107 mm/d), whereas findings in Table 5 show *Belg* rainfall had a significant declining trend in the highland areas. Rainfall during *Belg* season has an extreme inter-seasonal variability in the highland areas with CV values above 47%.

Table 5

Trends of seasonal rainfalls in Southern Tigray, Northern Ethiopia (1978 To 2012)

		Season Kiremt RF	Belg RF
Highland	Mann-K	.161 ^{ns}	-.312**
	Slope	31.936	-35.000
Lowlands	Mann-K	.351**	-.204 ^{ns}
	Slope	106.79	-33.47
Regional	Mann-K	.254*	-.267*
	Slope	55.16	-36.25

Mann-K = Mann-Kendall trend test, Slope (Sen's slope) = the change rainfall (mm)/decade; ns = non-significant trend and **, * indicates significant trend at 0.01 and 0.05 significant level. Source: Calculated based on NMSA data series, 2013

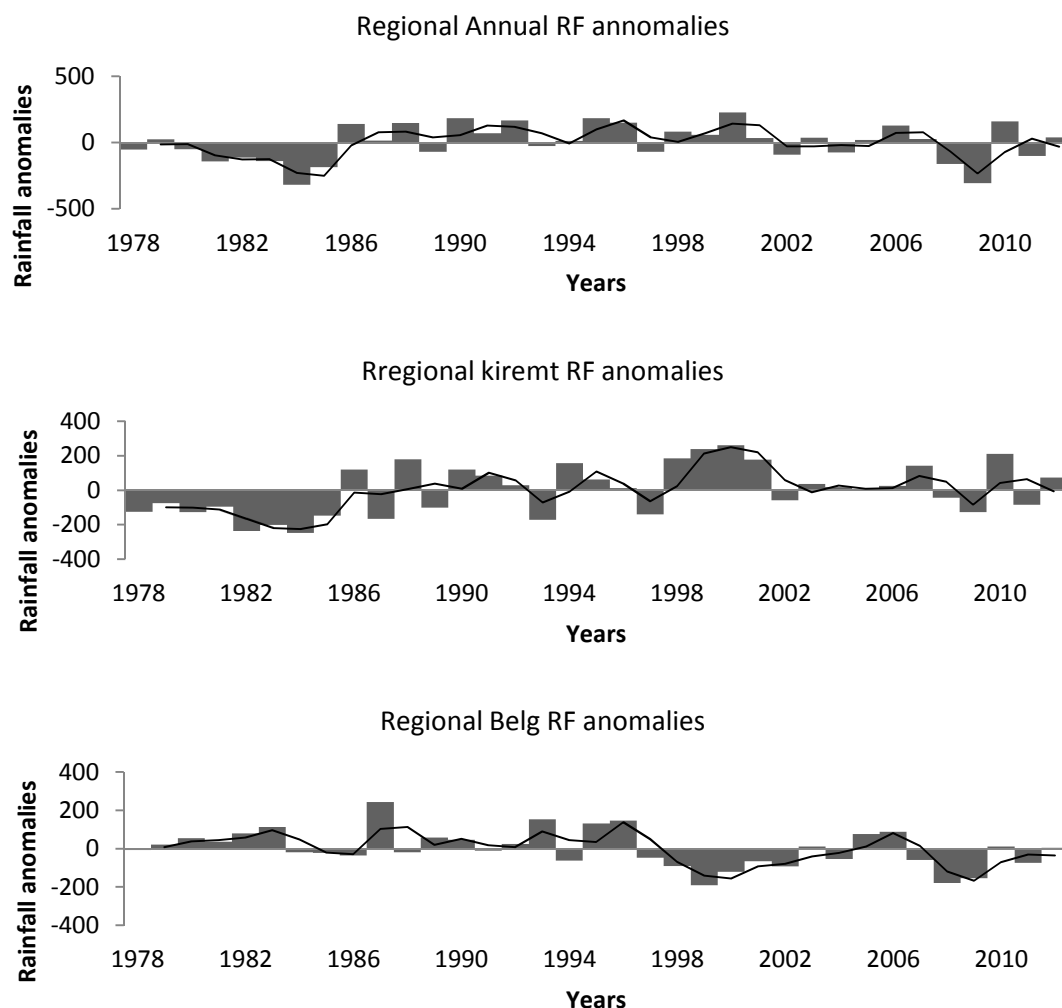


Figure 3: Annual & Seasonal Rainfall Anomalies with a two-year moving average (1978-2012)
Source: Calculated based on NMSA data series, 2014

Table 6

Trends of annual rainfalls in Southern Tigray, Northern Ethiopia (1978To 2012)

		Season Annual RF
Highland	Mann-K	-.032 ^{ns}
	Slope	-4.347
Lowlands	Mann-K	.153 ^{ns}
	Slope	40.20
Regional	Mann-K	.081 ^{ns}
	Slope	13.67

Mann-K = Mann-Kendall trend test, Slope (Sen's slope) = the change rainfall (mm)/decade; ns = non-significant trend and **, * indicates significant trend at 0.01 and 0.05 significant level. Calculated based on NMSA data series, 2013

At Areal Level

As in Table 5 above, Mann-Kendall trend analysis indicated that while Kiremt rainfall was significantly increasing (55.2mm/d), Belg rainfall was significantly decreasing (36.25mm/d) at aggregate level in the study period.

Annual Rainfall Trends

Though Alamata (40mm/d) and Korem (63mm/d) stations recorded non-significant positive trends for annual rainfall, the decreasing trend for Mai-chew station, as in Table-6, was significant (58 mm/d) at the 0.05 level.

Besides, the interplay between the significant growth of Kiremt rainfall and significant decline in Belg rainfall did not cause any significant change in the trend of annual rainfall both at agro-ecologic or regional level.

Monthly rainfall results show variation in the spatio-temporal distribution of rainfall in the study area. It also indicates the gradual concentration of rainfall in a few months to increase the prevalence of lengthy dry-spells. The declining trends in February and May (in *Belg* season) and June and September (in *Kiremt* season) also show the commonplace nature of late start and early ending rainfall to affect the number of rainy days (and the growing season) and crop production during the two rainy seasons. When rainfall comes late and stops early, it does not only cause failure in harvest but also a delay in land preparation for the next productive season and prevents planting of long cycle high-yielding crops (Maize and Sorghum) during Belg season. DPPC and FAO have reported this phenomenon in their assessment of Belg production of the study area since 1997.

Seasonal rainfalls have shown different trends without having significant effect on the amount of annual rainfall of southern Tigray, according to results of Mann-Kendall trend analysis. The study found that while Kiremt rainfall increases significantly, Belg rainfall decreases significantly. Some other studies also found a positive trend for Kiremt rainfall in Northern Ethiopia. Seleshi & Zanke (2004) and Verdin et al. (2005) found a non-significant trend for Kiremt rainfall over northern Ethiopia. Hadgu et al. (2013) reported a positive but non-significant trend for Kiremt rainfall at Alamata station in the period 1980 to 2009. While in the northern central part of the country, Bewket (2009) saw positive trends for Kiremt rainfall in Lalibela and Desse stations. Regarding Belg rainfall, findings agree with Hadgu et al., (2013) who found a declining trend at Alamata station. Dereje et al. (2012) also noticed a declining Belg trend in Srinka and Kombolacha stations, which are located in the north-central highlands of the country near the study area.

This significantly drying trend for Belg rainfall means a lot for local farmers who used to rely on Belg rains for food production. When it gets dry, production that could cover food demand for about two months is lost. For an already food insecure

community, having lost crop production in Belg season will jeopardize the food security in the study area.

Moreover, Belg rain was also important for availability of water and regeneration of grazing lands before Kiremt season starts. Farming households interviewed for this study were worried because they depend on Belg rains, especially for land preparation and planting of long cycle high-yielding crops (Maize and sorghum). Elders pointed out that these two crops are the main food sources that sustain food demands of farming households for longer periods compared to other crop types.

The Belg trend result may also tell the story of the gradual transformation of the study area from a bimodal rainfall type to a mono-modal rainfall type, where rainfall will be available only in Kiremt season, resulting in a longer dry season following every Kiremt season. If this happens, the situation may disrupt the water system, grazing land, and livestock production in addition to causing a decline in crop production.

Perception of Farming Households on Rainfall Changes

To investigate perception of farmers on climate change, farming households were asked to state what they had observed regarding long-term changes in precipitation. They were asked to specify what they had observed specifically— increase, decrease or no change—in seasonal precipitation. The results of this analysis are presented below.

Generally, an average of 75% and 88% of respondents observed the trend of declining rainfall and increasing temperature. Chi-square test results $\chi^2(1, N = 600) = 13.5, p < .001$ for rainfall and $\chi^2(1, N = 600) = 23.4, p < .001$ for temperature show that perceptions of farming households significantly vary by agro-ecological zone. While 13% more respondents from the lowland agro-ecology perceived a decline in rainfall, an almost similar amount of respondents from the highlands realized temperature was decreasing. Variations in rainfall characteristics between the two agro-ecological zones and the spatio-temporal variations in climate related events, such as localized droughts, negative

anomalies and rainfall irregularities, may have influenced farmers to vary senses to climate trends.

Furthermore, farming households were asked to specify what type of change they observed for rainfall and temperature in the last two decades. There was some variation in perception, especially in seasonal rainfall. Out of 600 respondents, 50% (55% from lowlands and 44% from highlands) perceived a non-declining Kiremt rainfall (no change and positive trend) in the last two decades. Only 45% of farming households from the lowlands and 56% from the highlands felt there was a declining rainfall during Kiremt season. The variation in perception on Kiremt rainfall was significant at the agro-ecological level, $\chi^2(1, N = 600) = 6.83, p < .001$.

On the other hand, about 85% of farming households from the lowlands and 89% from the highland agro-ecological areas presumed a decline trend for Belg rainfall, with no significant variation across study area.

Knowing whether farmers' perceptions on climate change are consistent with reality (statistical findings) is an important step in adaptation practices. Perception should be consistent with realities in order to have effective adaptation practices. When farmers' perceptions are different from reality, their decisions to respond to climate change at the right time and space would deviate, becoming risky for farmers.

Mann-Kendall trend results show an increasing Kiremt rainfall and a declining Belg rainfall in the last three decades (1980-2012) across all scales. It seems there was lack of congruence between trend analysis results and perception. For the last two decades (1990-2010), Kiremt rainfall does not show any trend (zero trend), whereas Belg is declining. Therefore, perceptions of farming households on seasonal rainfall for the last two decades can be considered consistent with Mann-Kendall analysis results.

From discussions with elder members of the community, we understand that farmers evaluate rainfall seasons in view of whether it has effected production at a particular time. Small changes in quantity of rain, the timing of onset, cessation dates, and frequency and duration of dry spells might cause serious effects in farmers' production and livelihoods. To that end, rainfall in the study

area was erratic and unreliable, resulting in crop reduction and failure (FAO, 2009).

On the association between household characteristics and perception, cross tabulation with chi-square test was carried out. About 93% of farming households who perceived Kiremt and Belg rainfall decline were found in the age group of 31-64 years. The variations in perception across age were significant, $\chi^2(4, N = 600) = 10.85, p < .05$ for Kiremt and $\chi^2(4, N = 600) = 70.23, p < .001$ for Belg rains. Chi-square results show substantial association between experience and perception, as experience is associated with age of farmers. Among those who perceived a declining Belg rainfall, 82% had farming experience of more than 10 years. Additionally, about 42% of those had attained at least primary education.

Determinants of Perception On Rainfall Change

Farmers should perceive changes in the climate situations to respond effectively through adaptation practices. It is through adaptation that they can minimize adverse effects of climate change in their agricultural production in particular and livelihoods in general. However, ability of farming households to perceive climate change is affected by various socioeconomic and institutional factors. Table-7 below presents the logistics regression coefficient together with marginal effects after the dependent variable (perception) was regressed on a set of explanatory variables that have been discussed beforehand. Yet, we discussed those factors that had significant influence on farmers' perception to climate change in southern Tigray. The others can be seen from the table.

About 93% of farming households who perceived Kiremt and Belg rainfall decline were found in the age group of 31-64 years. Chi-square results indicate that variations in perception across age were significant, $\chi^2(4, N = 600) = 10.85, p < .05$ for Kiremt and $\chi^2(4, N = 600) = 70.23, p < .001$ for Belg rains. Chi-square results also show substantial association between experience and perception, as experience is associated with age of farmers. Age was put out of the model due to its multicollinearity effect with experience and some other predictor variables

Table 7

Results of the logistic regression model and marginal effects for perception of farming households to climate change in Northern Ethiopia, 2014

Rainfall decreased	Logistic R.	Marginal effect
	Coef.	Dy/dx
Sex	.640**	.070**
Education level	1.158***	.126***
Farm experience (yrs)	.402**	.044**
Access to extension	.497*	.054*
Access to climate info	.928***	.101***
Access to credit	.025	.003
Access to irrigation	-1.02***	-.111***
Livestock possession (TLU)	-.003*	-.0003*
Distance to market center	-.017	-.002
Off-farm activities	.622**	.068**
Economic status	.606**	.066**
Drought exposure	2.14***	.234***
Local agro-ecology	1.05***	.114***
Constant	-3.12***	
Observation	600	
Log likelihood	-211.276	
LR X ² (13)	254.44	
(p-value)	(.000)	
Pseudo R ²	0.3758	

***, **, * indicate significant at 1%, 5% and 10% level of significant respectively

Further, the econometric model also shows that among household characteristics, sex, level of education, and farming experience positively and significant influenced perception to climate change. Farming household heads with education and more farming experience are more likely to perceive changes in climate than those with less farming experience and less education. The point that education and farming experience have significant association with perception implies the capability of experienced and educated farmers to better access information about climate change compared to those with less experience and education. Studies show that with more experience and education, farmers develop knowledge and skill that may help them sense risks better (Maddison, 2007; Gbetibouo, 2009 & Deressa et al. 2011).

Male-headed households are 7% more likely to perceive climate change compared to female-headed farming households. This might be due to the fact that females are confined more to house

and agricultural work for most of the day, which gives them less of chance to share information with others. Male farmers move between places in such a way that they can meet people and use mass media to share experiences and ideas about contemporary climate. However, Maddison (2007) and Deressa et al. (2011) found no variation in perception of climate change because of gender.

Among the factors related to institutional features, access to climate information, extension and credit services showed positive effects on farmers' perception of climate change. While 76% and 55% of respondents had access to extension and credit services, respectively, about 60% of respondents get climate information from agricultural development agents (DAs), Radio/TV, and local leaders.

While probability of observation increases by 5.4% and 10.1% with access to extension and climate information, respectively, it decreases by 11% with access to irrigation. While 55% of respondents have access to credit, it was not found to significantly affect perception of climate change. This might be for the reason that those farmers with irrigation access may not feel the pressure of water stress other farmers feel due to shortage of rainfall and lengthy dry spells. Maddison (2007) and Deressa et al. (2011) have reported similar results on access to extension services in that it significantly influences perceptions of climate change.

Moreover, 37% of respondents have access to irrigation services, and the average distance between respondents' localities and a nearby market center was about 10.8 KM.

Besides economic status of farming households, exposure to drought and agro-ecology were found to have a positive and significant influence on farmers' perceptions of climate change. The more economically secure farmers are, the more likely they will be to perceive climate change. Survey results show that while about 54.5% of respondents have off-farm earnings, some 52% were economically poor households. In addition, according to logistics model results. Economic security might create chances for farming households to have access to media, such as radio/TV and other means, to get access to climate information, which would help them to understand what is going on in their environment. Contrary to our findings, Deressa et al. (2011) reported that farmers with

farm income are more likely to perceive climate change than those with off-farm incomes. Farmers who are predominantly dependent on farm income might sense climate change better; however, those who sensed the change make decisions to respond through different ways of adaptation. In this scenario, those who perceived climate change tend to diversify their income, realizing that farm income alone will not be enough for their future livelihoods.

Conclusion

Mann-Kendall trend analysis results for monthly, seasonal, and annual at station, agro-ecological, and areal based have shown significant insights about how regional climate is changing in southern Tigray. Monthly rainfall in February, March, and May experienced a significant declining trend in at least two of the three stations. All *Belg* rain-giving months also had negative rainfall trends at the highland agro-ecological area.

Among *Kiremt* rain-giving months, July and August at Alamata and July at Korem station showed significant increasing rainfall trends. Yet Maichew station, except July, which had a non-significant positive trend all the three months, had negative rainfall trends. Consequently, rainfall during *Kiremt* season at Alamata (107mm/d) and Korem (86mm/d) station increased significantly. The trend was also significant at the areal level.

Belg rainfall, contrary to *Kiremt*, exhibited a declining trend in all the stations, but the declining trend was significant at Maichew station (44.5mm/d). As a result, *Belg* rains in the highland agro-ecological area (35mm/d) and the study region (36mm/d) in general had shown significant drying trends.

Despite the findings of increasing trend in *Kiremt* rainfall at Alamata and Korem stations and decreasing trend of *Belg* rainfall at areal level, annual rainfall did not show any significant trend at the regional level. Nevertheless, a significant

declining trend was found, particularly at Maichew station, since the end of the 1970s.

With regard to perceptions of farming households, about 75% of respondents perceived change in rainfall in their localities. The perception by the farming community was more or less consistent with reality from the Mann-Kendal trend analysis, especially of the last two decades. There was significant variation in perception among respondents by agro-ecology. Otherwise, farming communities accurately perceived the declining trend of *Belg* rainfall in all districts, which were in accordance with Mann-Kendall trend analysis results. However, perceptions of farming households are reliant on various factors. Among the group, this study found that education level, farming experience, access to extension services and climate information, off-farm income, and exposure to drought and local agro-ecology positively and significantly affect farmers' perceptions of climate change. Access to irrigation and livestock possession showed significant negative effects on perception to climate change.

Subsequently, more of the factors that were found to affect perceptions of climate change are related to institutional and infrastructural developments. Therefore, a lot has to be done in awareness creation work on climate change at the local and regional level. Substantial work related to local knowledge of inclusive farm level adaptation approaches, environmental conservation work, small and medium irrigation developments, and protection of livelihoods in general are suggested in order to combat the effect of this threatening trend in climate change in the study area.

Acknowledgements

This study was carried out with the support of various organizations. We acknowledge the efforts of NMSA, Mekelle branch for supplying necessary climatic data and Aksum University for delivering financial support to carry out the survey for this study.

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