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

[1,2]M.G. Abrha and [1]S. Simhadri

[1]Department of Geography, Faculty of Science, Osmania University Hyderabad-500007, India
[2]Department of Geography and Environmental Studies, Aksum University, Aksum, Tigray, Ethiopia

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Corresponding Author:
M.G. Abrha
Department of Geography and Environmental Studies, Aksum University, Aksum, Tigray, Ethiopia
Email: misge682000@gmail.com

Abstract: This study aimed to investigate changes in local climate, farmers' perception to the change and factors affecting perception of farmers to climate change. For trend analysis, we gathered station based rainfall records for the period 1978-2012, while for perception analysis survey was carried out. 600 farming households were randomly selected from four districts using a multi-stage sampling method. Nonparametric analysis was used for analyzing trends and testing significance. Farming households were asked their observation about changes in local climate using structured questionnaires. We also utilized logistic 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, *Kiremt* and *Belg* rainfalls exhibited significant increasing and decreasing trends in the last three decades respectively. The study confirmed that the change in rainfall trend varies by agro-ecology. *Kiremt* rainfall in the lowlands increased by about 106 mm/decade; yet, highlands got non-significant change. Besides, when the highlands lost significant amount of *Belg* rainfall (35 mm/d), lowlands didn't show any significant reduction. As to perception, about 87 and 50% of respondents perceived *Belg* and *Kiremt* rainfall decreasing respectively where their observation was more or less 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.

Keywords: *Seasonal Rainfall*, Climate Change, Farmers' Perceptions, Perception Determinants, Northern Ethiopia

Introduction

Although agriculture has frequently been challenged by climate change effects (NMA, 2007), the sector remains the backbone of the Ethiopian economy. It directly supports about 85% of the population for employment and livelihood. It contributes about 50% of the country's Gross Domestic Product (GDP) and generates about 90% of the export earnings, with small-scale farmers dominating the production of crops. However, rainfall is the foremost source of water for crop production as irrigation covers not more than 5% of the cultivated land in the country (Awulachew *et al*., 2010). Therefore, success or failure in agricultural sector implies enormous effect, ranging from the survival of the subsistence farmers to the state of country's economy at large.

Ethiopia's climate is changing and a number of projections emphasized 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 and Schipper, 2011). Also, a likely increase in mean annual rainfall in East Africa highlands including Ethiopia is anticipated (Christensen *et al*., 2007). More specifically, National Meteorological Agency (NMA)

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expects rainfall to decline in northern part, whereas southern part of the country might see an increasing trend of rainfall as much as 20% (NMA, 2007).

Rising temperatures, increasingly erratic rainfall, more frequent and severe floods and droughts have significant concerns especially to those highly dependent on natural resources, like agriculture, for their livelihoods. In agriculture sector, the consensus is that changes in temperature and precipitation will result changes in land and water regimes that will later affect agricultural productivity (WB, 2003).

Ethiopia is a large country comprised of different agro-ecologies and climate features resulted from its location and altitude variations, which implies the need for climate investigations at local level. Some studies were carried out in different parts of the country because large-scale climate projections and trend generalizations may not necessarily reflect situations at local and agro-ecological level. Bewket (2009) in his study of rainfall variability and crop production in *Amhara* region of Ethiopia, found increasing annual and *Kiremt* (summer) rainfall in *Dessie* and *Lalibela* stations. He also learned a drop in Debretabor (*Kiremt)* and Dangla (*Belg* rains) in 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) learnt negative trends for both *Belg* and *Kiremt* rainfall in northern Ethiopia, though trends in *Kiremt* were non-significant. Besides, Seleshi and Zanke (2004; Vste *et al*., 2013) learned no trend for all annual and seasonal rainfall in Northern Ethiopia in general. These studies, although in Northern and central part of the country, are good indicators of how climate elements vary across locations in Ethiopia.

Southern Tigray is an area highly vulnerable and sensitive to climate related extreme events such as droughts. The historic drought of 1984/5 had left serious damages in this part of the country. From then onwards, reports from DPPC (1999; 2004; FAO, 2008; 2009) indicated repeated failures in crop production because of localized droughts associated to 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 on this field. With global warming a certainty, it is imperative to make investigations on climate elements at 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 and Posthumus, 2010). Therefore, local perspectives can be combined with scientific climate scenarios to draw policy recommendations for future adaptation strategies (Patino and Gauthier, 2009).

Yet, farmers' perception and adaptation practices to climate change are context and location specific. Societies differ in culture, education, demographics, resource endowments, biophysical and institutional characteristics. This heterogeneity influence 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 the country. Admassie and Adnew (2007; Deressa *et al*., 2010; Hadgu *et al*., 2013) investigated farmer's perceptions to local climate change and adaptation strategies. However, they did not see how consistent farmers' perceptions were with realities (statistical discoveries) and how socio-economic factors influence 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.

The purposes of this study, therefore, 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 to climate change and extent of influence in southern Tigray.

Method

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 (Alaje, Alamata, Endamehoni, Ofla and Raya-azebo) and three town administrations (Alamata Town, Korem and Maichew), as in Fig. 2.

Rugged topography including mountains, plateaus, valleys and gorges characterize the physical landscape of Southern Tigray. Generally, the topography contains four main traditional divisions of arable Ethiopia, as in Fig. 1. *Kola*/lowland that cover 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 part has medium rainfall amount and moderate temperature. *Dega*/highland extending between 2400-3400 m.a.s.l has relatively higher rainfall and cooler temperatures and covers about 30%. *Wurch*/very-cold areas are locations of above 3400 m.a.s.l with high rainfall and low temperatures and cover 0.45% of the study area.

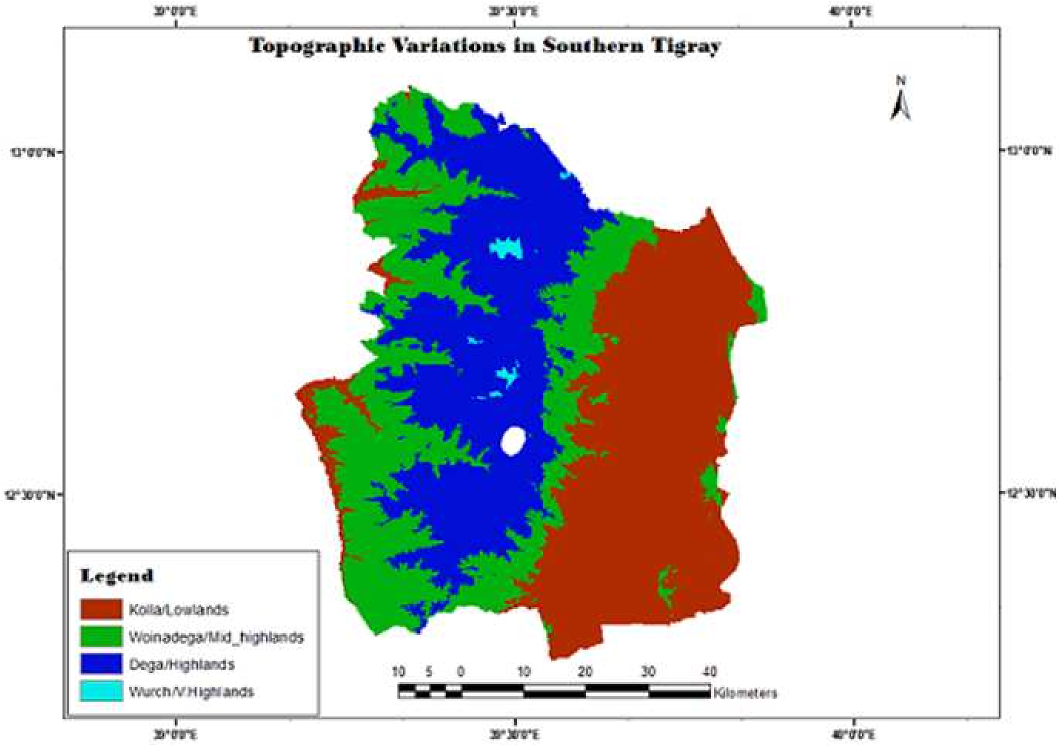

Fig. 1. Variations in topography and agro-ecological zones in Southern Tigray

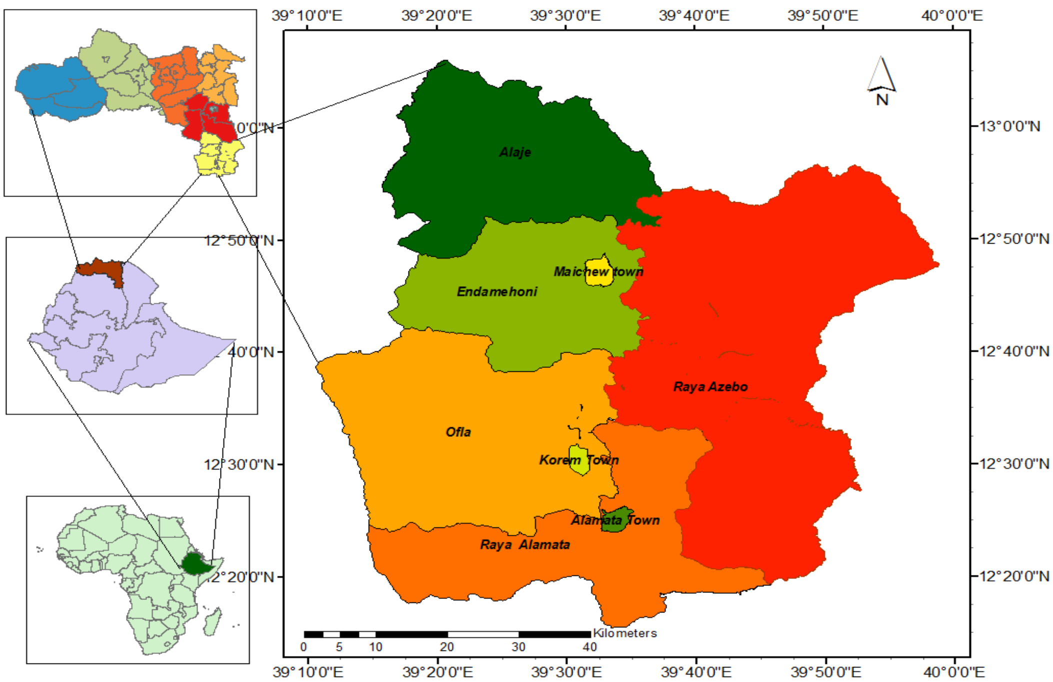

Fig. 2. Location of study area Together with districts that comprised Southern Tigray Zone

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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 western part (including Alaje, Endamehoni and Ofla districts) comprising the highlands and the later one in the eastern part (including Alamata and Raya-azebo districts) comprising lowlands, as in Fig. 1 above. 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 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 rain to the area. Agricultur 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 mainstay of the economy, where it directly supports for about 86.4% of the population for employment and livelihood. Total polulation of the study areas was 717,420 with a population density of 144 people per Km^2 in 2013 (CSA, 2012).

In addition, the sector is highly susceptible to climate variability, 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, 2006; FAO, 2008; 2009). Southern Tigray was selected for this study because recurrent drought and crop failures are common in this area.

Data and Sampling Procedure

This study is made based on a cross-sectional survey design where data are collected from representative samples at a specific point in time. Historic temperature and rainfall records of varied duration were assembled for Alamata, Maichew and Korem stations from National Meteorological Services Agency of Ethiopia (NMSAE). WMO recommended a minimum of 30 years data series required to detect trend in climatic study. Accordingly, three stations delivered rainfall records recommended years, as in Table 1. Although offered, temperature records were broken repeatedly in all stations. Therefore, temperature trend analysis was impossible due to absence of uninterrupted records.

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 once missing values were filled by averaging neighboring records.

Agro-ecologically, highland 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 level to give 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 decision to adapt. To identify how farming Households (HHs) perceive the state of climate in their locality, a survey was conducted between April and October 2013. The survey covered twenty *Tabias* of four districts (Alamata, Endamehoni, Ofla and Raya-azebo), five Tabias from each. Using multistage sampling procedure, 30 HHs were randomly selected from each Tabia to constitute 600 HHs in total.

Structured and semi-structured questionnaires were used to ask selected farming HH heads to express their perceptions on whether changes have been observed on climatic elements and associated extreme events in their localities in last two decades. Selected *Tabias* from which respondents were randomly selected are showed in Fig. 3.

Data Analysis

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

Areal Weighted Averages

For agro-ecological/regional trend analysis, areal weighted average rainfall was applied based on 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:

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

Where:

R_j = Areal/regional integrated rainfall for year j

X_{ij} = Rainfall record at station i for year j

I_j = The number of stations having rainfall record for year j

Table 1. Meteorological stations, geographic characteristics and available rainfall records

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

Source: Meteorological data series from NMAE, 2013

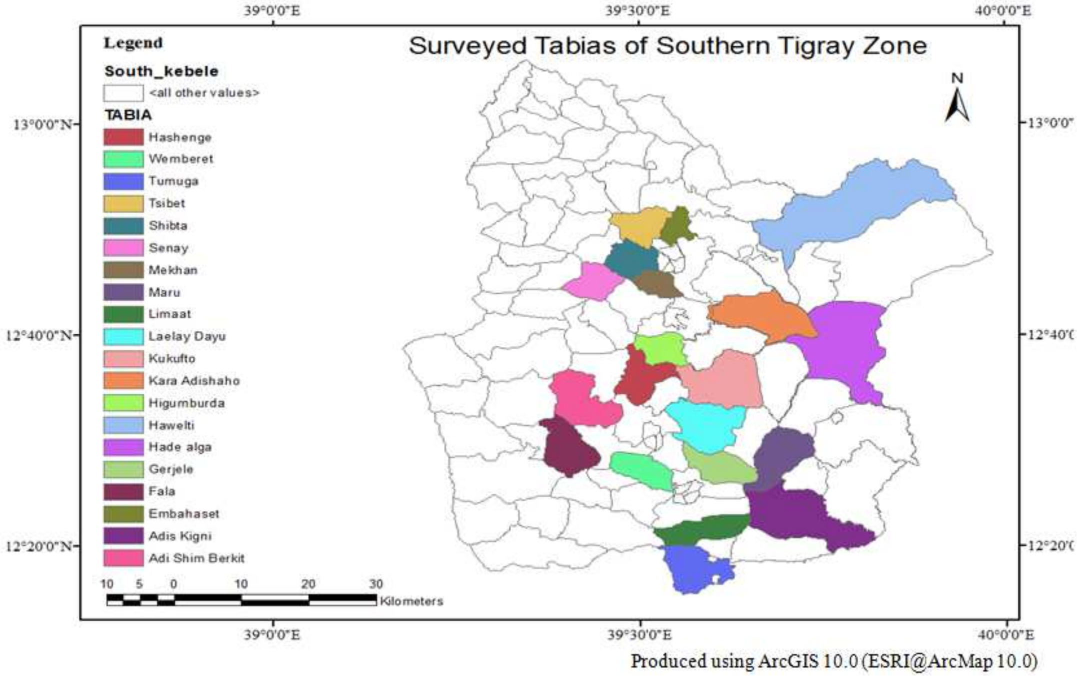

Fig. 3. Surveyed Tabias of Southern Tigray Zone, 2014

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 in homogeneity. 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 ±1.5×IQR. Hence, the fence is represented as:

$$\left[Q_3 + 1.5 \times IQR\right] \text{ as upper limit}$$

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 and Stathis, 2011) and in hydrologic time-series studies (Yue and 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 and Bayazit, 2012).

Let $x_1, x_2, x_3, \ldots, x_n$ represent n data points where x_j represents the data point at time *j*. Then the Mann-Kendall statistic (*S*) is given by:

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

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

where, *S* is Mann-Kendal's test statistics; X_i and X_j are rainfall values for years *i* and *j* (*j*>*i*) and *n* is length of the time series (30 years for instance) (Motiee and McBean, 2009). A positive/negative value of *S* indicates an upward/downward trend (Drapela and 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:

$$E(s) = 0 \tag{2}$$

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

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)}{18} \tag{3}$$

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:

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{\text{var}(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{\text{var}(S)}} & if \quad S < 0 \end{cases} \tag{4}$$

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 $|\text{Mann-}K| < Z_{1-\alpha/2}$ 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 (Karpouzos *et al*., 2010). Slope (change per unit time) was estimated following the procedure of Sen (1968) and detail outline of the procedure is given in Partal and Kahya (2006) and Karpouzos *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 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, 90and 80 percentiles assuming that annual rainfall data are normally distributed.

Approach to Detect 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 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 ones after they sense it, for which sensitivity matters individually.

Studies made in Africa in this case applied different approaches to identify perceptions. Meze-Hausken (2004; Deressa *et al*., 2010) in Ethiopia, Komba and 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 are consistent with reality on ground.

Logistic Regression

Farmers' perception to climate change is a precondition for effective adaptation. Evidences in

Africa reveal that large numbers of agriculturalists already perceived hotter climate, less predictable rains with shorter in 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 logistics model to identify factors influencing farmers' perceptions to climate change, as in Ndambiri *et al*. (2012). In the model, dependent variable is dichotomous in its nature, taking value of 1 or 0. Although 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:

$$y_i = \beta_0 + \beta_i \chi_i + \varepsilon_i \quad (1)$$

Where:

$y_i = 1$ = If a farmer perceives climate change and $y_i = 0$ if a farmer does not
β_0 = Intercept
β_i = Parameter to be estimated
χ_i = Variable in question
ε_i = Disturbance term.

This model is a typical linear regression model but, because the regressand is binary or dichotomous, it is called a Linear Probability Model (LPM). However, in regression model, when 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 ith person will be in I - first category, $Z_i = \beta_0 + \beta_i \chi_i + \varepsilon_i$ where β_0 is intercept of the model; β_i 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 subtract 1 leads to:

$$e^{-z_1} = \frac{1}{P_i} = \frac{1-P_i}{P_i} \quad (4)$$

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 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:

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

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:

$$\frac{\partial P_k}{\partial \chi_k} = \frac{\beta_k e^{-z_k}}{\left(1+e^{-z_k}\right)^z} \quad (8)$$

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 a farmer has perceived climate change. It was regressed on a set of relevant explanatory variables hypothesized based on literatures to have influence on perception to climate change, which are in Table 2.

Table 2. Hypothesized explanatory variables and their descriptive statistics for logistic regression model, 2014

Independent variables	Unit	Mean	Std. deviation	Direction of influence
Sex (Gender)	Dummy: 1 = Male, 0 = Female	0.708	0.4600	+/-
Age (years)	Continuous	43.830	10.5000	+/-
Level of education *(educ)*	Dummy: 1 = primary and above, 0 = no education	0.530	0.5000	+
Experience in Agriculture (exp)	Continuous	20.750	10.7200	+
Access to CC information *(info)*	Dummy: 1 = Yes, 0 otherwise	0.650	0.4789	+
Access to credit *(crdt)*	Dummy: 1 = Yes, 0 otherwise	0.690	0.4600	+
Access to extension *(extn)*	Dummy: 1 = Yes, 0 otherwise	0.750	0.4300	+
Access irrigation *(irigt)*	Dummy: 1 = Yes, 0 otherwise	0.370	0.4800	+/-
Distance to Market (Dist)	Continuous	10.820	6.2000	-
No. of livestock FHH has (TLU)	Continuous	3.540	3.4700	+/-
Off farm activities (offrm)	Dummy: 1 = Yes, 0 otherwise	0.250	0.4300	+/-
Economic status of FHH *(eco)*	Dummy: 1 = poor, 0 = not poor	1.570	0.6600	+/-
Drought experience *(drt)*	Dummy: 1 = Yes, 0 otherwise	0.790	0.4100	+
Local Agro-ecology *(agro)*	Dummy: 1 = highland, 0 = lowland	0.500	0.5004	+/-

Using these variables, the model is specified as:

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

Where:

Z_i = The perception by the i^{th} farmer that climate is changing

χ_I = The vector of explanatory variables of probability of perceiving climate change by the i^{th} farmer

β_I = 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:

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

Software Used

Different software are 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, Stata software version11 was used to run the logistics model. The null hypotheses were tested against 0.01, 0.05 and 0.1 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*), as seen in Table 3.

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 (10 mm/d), at Korem (2 mm/d) and at Maichew (4 mm/d); May at Alamata (13 mm/d) and Korem (19 mm/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) 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 agro-ecologic level are reflections of results at station level analysis. Hence, Table 4 show that February and May rainfall were drying significantly at 0.01 and 0.05 level in the lowland (kola) agro-ecological zone, while February rainfall trend was negative and significant at 0.05 level in the highlands.

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 trend with the former significant at 0.01 level.

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)	Bega rainfall (mm)
Alamata	Average	668.40	341.48	241.25	85.70
	Max	1003.53	768.70	445.80	226.00
	Min	262.40	19.40	30.60	20.10
Maichew	Average	787.13	457.82	219.97	109.34
	Max	965.30	710.50	578.10	302.70
	Min	477.70	158.00	31.40	25.40
Korem	Average	983.40	591.22	237.83	154.35
	Max	1380.20	979.10	505.80	333.60
	Min	630.95	290.80	65.40	154.34

Source: Calculated based on NMSA data series, 2014

Table 4. Trends of rainfall at monthly, seasonal and annual level in Southern Tigray, Northern Ethiopia (1978 to 2012)

	Highland	Lowlands	Regional			
Variables	Mann-K	Slope	Mann-K	Slope	Mann-K	Slope
February	-0.264^{*}	-3.190	-0.327^{*}	-9.67	-0.276^{*}	-6.25
March	-0.194	-9.130	-0.086	-8.04	-0.113	-6.98
April	-0.012	-0.170	0.009	0.62	0.025	-2.45
May	-219.000	-12.330	-0.257^{*}	-13.33	-0.267^{*}	-18.90
June	-0.153	-4.210	0.169	1.50	-0.106	-1.82
July	0.324^{**}	34.710	0.517^{**}	52.69	0.422^{**}	38.80
August	0.138	13.860	0.252^{*}	50.50	0.207	29.80
September	-0.105	-3.880	-0.099	4.35	-0.139	-5.89
Kiremt RF	0.161^{ns}	31.940	0.351^{**}	106.79	0.254^{*}	55.16
Belg RF	-0.312^{**}	-35.000	-0.204^{ns}	-33.47	-0.267^{*}	-36.25
Annual RF	-0.032^{ns}	-4.347	0.153^{ns}	40.20	0.081^{ns}	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 a Real (Regional) Level

Although most of 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 comparing 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 lowland agro-ecological zone.

At Station Level

Mann-Kendall analysis show that Kiremt rainfall was significantly increasing in all but Maichew station. Magnitude of the positive trend ranges from 107 mm/d in Alamata to 86 mm/d in Korem station, all significant at 0.01 and 0.05 level respectively. Regarding Belg rainfall, all the three stations showed negative trends, but only Maichew's trend was significant (44.5 mm/d) at 0.01 level.

At Agro-Ecologic Level

Table 4 indicates, *Kiremt* rainfall exhibited a significant positive trend for the lowlands (107 mm/d); whereas, Belg rainfall experienced significantly falling trend for highland areas. Rainfall during Belg season has an extreme inter-seasonal variability in the highland areas with CV values of above 47%.

At a Real Level

As in Table 4 above, trend analysis results specified that while Kiremt rainfall significantly improved by 55.2 mm/d, Belg rainfall significantly lessened by 36.25 mm/d at aggregate level.

Annual Rainfall Trends

Though Alamata (40 mm/d) and Korem (63 mm/d) stations recorded non-significant positive trends for annual rainfall, the decreasing trend for Maichew station was significant (58 mm/d) at 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, as shown in Table 4 above.

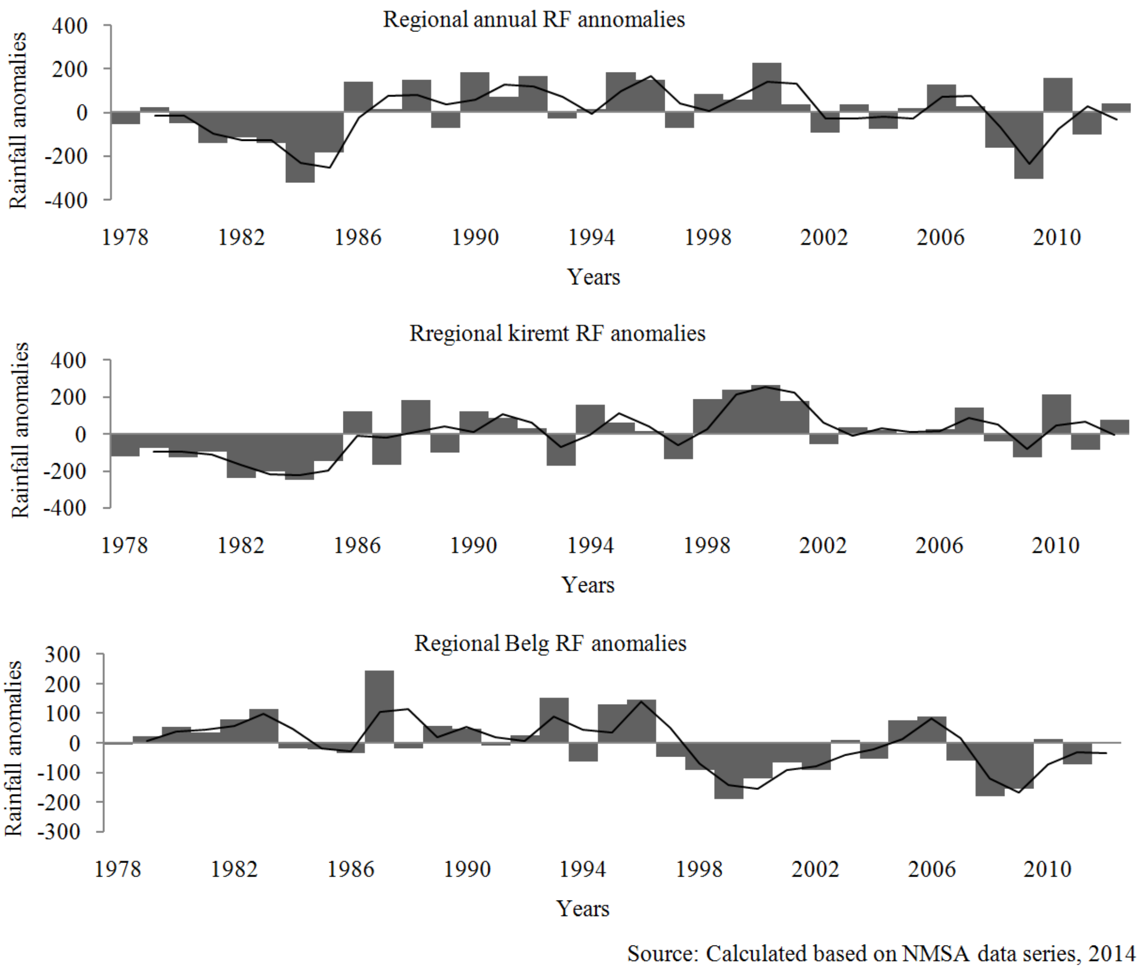

Fig. 4. Annual and seasonal rainfall anomalies with a two-year moving average (1978-2012)

As Fig. 4 below sows, annual and seasonal rainfalls experienced a comparable dry and wet seasons. The 1980s and the 2000s have particularly exhibited negative anomalies compared to the 1990s. Dry seasons particularly in the 1980s caused the historic drought period of 1984 that resulted a famine that distracted the socio-economic system of communities in the study area.

Monthly rainfall results tell variation in spatio-temporal distribution of rainfall in the study area. It also indicates the gradual concentration of rainfall in to a few months to increase prevalence of lengthy dry-spells. The declining trends in February and May (in *Belg* season), June, and September (in *Kiremt* season) also designate commonness of late start and early ending of rainfall to affect number of rainy days (&growing season) and crop production during the two rainy seasons. When rainfall comes late and ceased early, it does not only cause failure in harvest, but also delay in land preparation for next productive season and prevent 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 annual rainfall amount of southern Tigray, according to results of Mann-Kendall trend analysis. The study found that while Kiremt rainfall grows significantly, Belg rainfall decreases significantly too. Some other studies also found positive trend for Kiremt rainfall in Northern Ethiopia. Studies by Seleshi and Zanke (2004) and Verdin *et al*. (2005) found 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 northern central part of the country, Bewket (2009) learned positive trends for Kiremt rainfall in Lalibela and Desse stations. Regarding Belg rainfall, finding agrees 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 to the study area.

This significantly drying trend for Belg rainfall means a lot for local farmers who used to relay on Belg rains for food production. When it gets dry, production that could cover food demand of about two months is lost. For already food insecure community, having lost crop production in Belg season will jeopardize the food security problem 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). Elderlies point out that these two crops are the main food sources that sustain food demands of farming households for longer period comparing to other crop types.

Belg trend result may also tell 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 to result longer dry season following every Kiremt season. If this happens, the situation may disrupt water system, grazing land and livestock production besides 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 and temperature. They were further asked to specify what they had observed specifically; increase, decrease or no change. The results of this analysis are presented below.

Regarding temperature, more than three-fourth of respondents perceived temperature change in day and night time. While 85.5% of farming households felt warmer temperature at daytime, 88.5% stated that nighttime temperature has increased.

Survey results on temperature trends show variation by agro ecology. While 96% of respondents from the lowlands felt an increase in day temperature, 75% of respondents from highland agro ecology believed daytime temperature has grown up. Chi square test results on daytime temperature indicated a significant variation in perception of farming community by agro ecology, $\chi^2(2,N = 600) = 55.3$, $p<0.001$. Besides, 89.7% respondents from lowland and 87.7% from highland perceived a warming nighttime temperature in their locality. Similarly, for night time temperature, perception of farming households was found significant by agro-ecology zone, $\chi^2(2,N = 600) = 23.75$, $p<0.001$.

As to perception on precipitation, an average of 75% respondents have observed a declining trend. Chi-square test results show that perceptions of farming households significantly vary by agro ecological zone, $\chi^2(1,N = 600) = 13.5$, $p<0.001$. While 13% more respondents from the lowland agro-ecology perceived decline in rainfall. 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 last two decades. Only 45% of farming households form lowlands and 56% from highland felt a declining rainfall during Kiremt season. The variation in perception on Kiremt rainfall was significant at agro-ecological level, $\chi^2(1,N = 600) = 6.83$, $p<0.001$.

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 important step in adaptation practices. Perception should be consistent with realities in order to have effective adaptation practices. When farmers' perception is different from reality, their decisions to respond to climate change at right time and space would deviate, thus, it becomes risky for farmers.

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

From discussion with elder members of community, we understood that, farmers evaluate rainfall seasons in view of whether it has effected good production at particular time. Small change 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 level, rainfall in the study area was erratic and unreliable that resulted for 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 declining were found in the age group of 31-64 years. The variations in perception across age were significant, $\chi^2(4,N = 600) = 10.85$, $p<0.05$ for Kiremt and $\chi^2(4,N = 600) = 70.23$, $p<0.05$ 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. Besides, about 42% of those perceived were those who attained primary education at least.

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 5 below presents the logistic 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 declining were found in the age group of 31-64 years. Chi-square results indicate that variations in perception across age were significant, $\chi^2(4,N = 600) = 10.85$, $p<0.05$ for Kiremt and $\chi^2(4,N = 600) = 70.23$, $p<0.001$ 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 multi-collinearity effect with experience and some other predictor variables.

Further, 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 experienced and uneducated. Studies show that with more experience and education, farmers develop knowledge and skill that may help them sense risks better (Maddison, 2007; Gibetibouo, 2009; Deressa *et al*., 2010).

Male-headed households are highly likely by 7% more 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 works for most of days that make them have less chance of sharing information with others relative to males. Male farmers move between places in such a way that they can meet people and mass media to share experiences and idea about contemporary climate. Maddison (2007; Deressa *et al*., 2010); however, 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 to climate change. While 76 and 55% of respondents had access to extension and credit services respectively, about 60% respondents get climate information from agricultural Development Agents (DAs), Radio/TV and local leader.

While, probability of observation increases by 5.4 and 10.1% more with access to extension and climate information respectively, it decreases by 11% with access to irrigation. Albeit 55% of respondents have access to credit, it was found not significant to 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 are feeling due to shortage of rainfall and lengthy dry spells. Maddison (2007; Deressa *et al*., 2010) have reported similar result on access to extension services that it significantly influenced perception of climate change.

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

Besides, economic status of farming households, exposure to drought and agro-ecology were found to have positive and significant influence on farmers' perceptions on climate change. The more economically secured 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, logistics model results show Economic security might pave 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*. (2010) reported that farmers with farm income are more likely to perceive climate change than those with off-farm incomes.

Table 5. 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. Coef.	Marginal effect Dy/dx
Sex	0.640**	0.070**
Education level	1.158***	0.126***
Farm experience (yrs)	0.402**	0.044**
Access to extension	0.497*	0.054*
Access to climate info	0.928***	0.101***
Access to credit	0.025	0.003
Access to irrigation	-1.02***	-0.111***
Livestock possession (TLU)	-0.003*	-0.0003*
Distance to market center	-0.017	-0.002
Off-farm activities	0.622**	0.068**
Economic status	0.606**	0.066**
Drought exposure	2.14***	0.234***
Local agro-ecology	1.05***	0.114***
Constant	-3.12***	
Observation	600.00	
Log likelihood	-211.276	
LR X^2(13) (p-value)	254.44 (0.000)	
Pseudo R^2	0.3758	

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

Farmers predominantly dependent on farm income might sense climate change better; however, those who sensed the change take decision 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 would no more 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 significant declining trend in at least two of the three stations. All *Belg* rain-giving months had also 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 at Maichew station, except July that had a non-significant positive trend all the three months had negative rainfall trends. Consequently, rainfall during *Kiremt* season at Alamata (107 mm/d) and Korem (86 mm/d) station increased significantly. The trend was also significant at the areal level.

Belg rainfall, contrary to the *Kiremt* one, exhibited a declining trend in all the stations, but the declining trend was significant at Maichew station (44.5 mm/d). As a result, *Belg* rains in the highland agro-ecological area (35 mm/d) and the study region (36 mm/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 a real level, annual rainfall did not show any significant trend at regional level. Nevertheless, a significant declining trend was consequently found particularly at Maichew station since end of 1970s.

With regard to perceptions of farming households, about 75% of respondents perceived change in rainfall in their localities. More or less the perception by the farming community was 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 perceived well about the declining trend of *Belg* rainfall in all districts, which were in accordance with Mann-Kendall trend analysis results. Perceptions of farming households are; however, reliant on various factors. Among the group, this study have found education level, farming experience, access to extension services and climate information, off-farm income and having exposure to drought and local agro-ecology positively and significantly affecting farmers perception to climate change. Access to irrigation and livestock possession showed significant negative effects on perception to climate change.

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

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Author’s Contributions

Misgina Gebrehwot Abrha: Designing and organizing the study, data collecting (primary and secondary), data entry and statistical analysis, writing the manuscript and reading and approving final version for submission.

S. Simhadri: Designing and organizing the study, Mentorship works and Reading and approving final version for submission.

Ethics

We, the authors, declare no conflict of interest regarding this work.

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