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# Perception of climate extreme trends over three Ethiopian eco-environments: Comparison with records and analysis of determinants

**Aklilu Mekasha[1]*, Chillot Yirga[1], Kindie Tesfaye[4], Lisanework Nigatu[2] and Alan J. Duncan[3]**

[1]Ethiopian Institute of Agricultural Research (EIAR) P. O. Box 2003, Addis Ababa, Ethiopia.
[2]Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia.
[3]International Livestock Research Institute (ILRI) P. O. Box 5689, Addis Ababa, Ethiopia.
[4]International Maize and Wheat Improvement Center (CIMMYT), ILRI Campus, P. O. Box 5689, Addis Ababa, Ethiopia.

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**Understanding household perceptions of climate change and determinants of such perceptions are important for planning community/household based climate change mitigation and adaptation strategies. In this study, herding/farming households' perceptions were studied and compared with recorded trends of extreme rainfall and temperature indicators from nearby weather stations across three eco-environments (pastoral, agro-pastoral and mixed crop-livestock highland system) in Ethiopia. Factors influencing household perceptions were assessed using a multinomial logit model. Results indicated that the majority of households (52.5-98.8%) across the three eco-environments perceived increasing numbers of extreme warm days and warm nights and decreasing numbers of extreme cool days and cool nights. In most cases, the household perceptions agreed with the recorded extreme temperature trends. Household perceptions of the studied extreme events were significantly affected by literacy, eco-environment, contact with the agricultural extension service, and presence of relief aid. We conclude that policy programs that enhance the literacy level of household and strengthen eco-environment-based extension services may increase the level of awareness and understanding of climate change by households which could help them to better adapt to climate change.**

**Key words:** Determinant, Ethiopia, household, perception, rainfall, season, temperature.

## INTRODUCTION

Climate change as a reality has been increasingly recognized with the advent of a growing number of scientific studies (Henry, 2000; Thornton et al., 2006; Trenberth et al., 2007). In many cases, analysis of weather monitoring station data is a primary source of evidence (Trenberth et al., 2007). In Sub-Saharan Africa, however, scientific studies based on station data lag behind other parts of the world mainly because of low station density, lack of data continuity and heterogeneity in the quality of records (Seleshi and Zanke, 2004).

*Corresponding author. E-mail: mekashaaklilu@gmail.com. Tel: +251 923731128.

Similarly weather information from monitoring stations seldom reaches herders and farmers who rather rely on age old traditional knowledge and perceptions accumulated through long historical exposure to the different facets of local climate (Nyong et al., 2007; Ishaya and Abaje, 2008).

Numerous studies have investigated how local knowledge and perceptions (Hansen et al., 2004; Viscusi and Zekhauser, 2006; Maddison, 2007; Semenza et al, 2008;Gbetibouo,2009**;** Deressa et al., 2011; Ofuoku, 2011;Piya et al., 2012; Silvestri et al., 2012) or social awareness (Saroar and Routray, 2010; Sarkar and Padaria, 2010; Acquah, 2011; Mandleni and Anim, 2011; Akerlof et al., 2013) are related to weather monitoring stations' records from climate change perspectives (Maddison, 2007; Benedicta et al., 2010). Among others, studies by Maddison (2007) in eleven African countries showed that significant number of African farmers' perceptions of increased temperature and decreased rainfall are somewhat equivocal with records from weather monitoring stations. Farmers' perceptions that climate is changing were found to be consistent among neighborhoods (Maddison, 2007; Bryan et al., 2013) and overwhelming in some cases (Benedicta et al., 2010; Enujeke, and Ofuoku, 2012) while trends derived from weather station data were found to show a much less clear picture of climate change (New et al., 2006).

The joint CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI) (http://cccma.seos.uvic.ca/ETCCDI) have developed and recommended 27 precipitation and temperature extreme indices for detecting climate change. Yet there are no agreed standard indices available for using human perceptions in climate change studies. Available literature to date reports perceptions based on general descriptions of temperature and rainfall trends (Hassan and Nhemachena, 2008; Maddison, 2007; Deressa et al., 2011). Such generalizations, however, are ambiguous to understand as they are not validated against weather station data. Secondly, people seem more able to detect and remember extreme weather events (Bento et al., 2013) than more gradual changes in averages (Hulme et al., 2009). Thirdly, because of media exposure, peoplemay falsely attribute occasional but normal events such as yield reductions, changes in vegetation phenologies and/or droughts to climate change where in reality they represent extremes of a time series whose mean is stable (Byrd et al., 2001; Weber, 2010). However, these short comings of perception studies could be partially dealt with by matching perceptions with analysis of standard meteorological extreme indices using records from nearby weather observatory stations.

Climate change perceptions can also be shaped by psychometric, cultural, demographic, social and institutional factors (Vedwan, 2006; Dhaka et al., 2010; Acquah, 2011; Hasan and Akhter, 2011; Silvestri et al., 2012). For example the way in which the climate change issue is addressed in mass media, education and extension determines households' awareness. Farming experience is also highly related to experience with local climatic normal, extreme events and general environmental responses. For instance, the Borana and Guji pastoralists of southern Ethiopia have an ecologically sound range management culture. Their seasonal movements, grazing and watering resources are managed by traditional rules and regulations that have evolved in response to local climate (Coppock, 1994; Abebe, 2000; Desta, 2000; Angassa and Oba 2007; Abate et al., 2010). Similarly the mixed crop-livestock farming highlanders who have adopted a sedentary life based on crop farming have also developed cropping and farming cultures in response to their local climate (Gebru, 2001; Vedwan, 2006; Lamma and Devkota, 2009). The agro-pastoral households have also developed efficient herding and farming cultures based on opportunistic use of experience from both pastoralism and farming.

Despite this rich traditional knowledge, there are few rigorous studies that relate household perceptions to weather station data in Sub-Saharan Africa. A prior understanding of these households perceptions on climate extreme trends and their relationship with weather monitoring station data and other factors at play could help to create community sensitization on climate change; such understanding could also enable policy makers and development planners to design and popularize community based climate resilient adaptation strategies. Thus this paper presents results of relating household perceptions on selected rainfall and temperature extremes indicators and comparing them with values computed from nearby daily weather station data over three seasons and major eco-environments of Ethiopia. It also assesses major environmental, social and/or institutional factors that influenced household perceptions taking the case of pastoralists in Liben, agro-pastoralists in Mieso and mixed crop-livestock highland farmers in Tiyo districts of Oromia National Regional State in Ethiopia.

## MATERIALS AND METHODS

### Analysis of extreme rainfall and temperature trends

#### *Data source, station selection and quality control*

Long term (1967-2008) daily rainfall and temperature data from stations located at Negele-Borana in Liben district in the pastoral eco-environment, Mieso district in the agro-pastoral eco-environment, and Asela and Kulumsa in Tiyo district in the mixed crop-livestock highland eco-environments of the country were sourced from the National Meteorological Agency of Ethiopia. Prior to analysis, the data of all these stations were plotted against time in days of the year format and subjected to visual examination for quality control. Special codes for missing values were removed. Typing errors, duplicated years and outliers defined as values above or below the mean plus or minus 4 times the standard

**Table 1.** Extreme precipitation and temperature indices and their definition.

| S/N | Index | Definition of the index | Unit |
|---|---|---|---|
| 1 | PRCPTOT | Seasonal total rainfall: determined by summing daily precipitation events in a season with daily rainfall ≥1 mm. | mm/day |
| 2 | SDII | Simple daily intensity index: determined as season's seasonal total rainfall on wet days (precipitation ≥1 mm) divided by number of rainy days with rainfall ≥1 mm in a season. | mm/day |
| 3 | TN10p | Cool nights: Percentage of days in a season when the daily minimum temperature is less than 10$^{th}$ percentile of base period (1971-2000). | Days |
| 4 | TX10p | Cool days: Percentage of days in a season when the daily maximum temperature is less than 10$^{th}$ percentile of base period (1971-2000). | Days |
| 5 | TN90p | Warm nights: Percentage of days in a season when the daily minimum temperature is greater than 90$^{th}$ percentile of base period (1971-2000). | Days |
| 6 | TX90p | Warm days: Percentage of days in a season when the daily maximum temperature is greater than 90$^{th}$ percentile of base period (1971-2000). | Days |

deviation (Tank et al., 2009) were treated on a case by case using information from the day before and after the event and also by reference to nearby stations.

***Defining the extreme parameters and trend analysis***

The quality controlled data were subjected to the RClimDex package developed to run under the open source R software (R Development Core Team, 2012) to compute number of extreme cool days (TX10p), number of extreme cool nights (TN10p), number of extreme warm days (TX90p) and number of extreme warm nights (TN90p), seasonal total rainfall (PRCPTOT) and simple daily intensity index (SDDI) for the major rainy, small rainy and dry seasons as defined in Table 1 after ETCCDI's (http://cccma.seos.uvic.ca/ETCCDI) definition. The period from 1971 to 2000 was used as the base period in the analysis. A linear trend was then fitted (on mean values of the two station in case of Tiyo district) using Kendal's *tau* and the slope of the line was computed using the Sen's slope estimator in order to determine the rate of change in extreme events. The statistical significance of the slopes was tested at 5% probability level.

**Household perception survey**

***Site and household selection***

A total of 217 households were selected through a mix of purposive and stratified random sampling. First, the three districts, one from each of the three major eco-environments of the country were selected purposively so as to represent the pastoral, agro-pastoral and mixed crop-livestock highland eco-environments. Once the districts are selected, the lowest administrative units (Kebeles) in each of these districts were stratified into three strata using subjective expert judgment based on relative proportion of land allocated to crops and livestock, and agro-ecological settings of the Kebeles. From each stratum one Kebele was randomly selected and household censuses conducted to collect names and ages of the household heads. Household heads above 50 years old (supposed to have rich knowledge of local environment) were identified and later sampled randomly for selection of households. The number of households surveyed was proportional to the number of households in the district; a total of 81, 44 and 92 households in the pastoral, agro-pastoral and mixed crop-livestock highland systems were randomly selected for interview.

***Household interview***

A structured questionnaire was prepared, pretested and administered with 217 selected household heads whose age range from 51 to 82 with mean of 63 years old. Data collected included household level data such as literacy level of the household head, land holding, livestock ownership, social and /or institutional responsibility of the household head, distance from market, access to extension services and relief aid (Table 2). The interview also included information on perceptions of the respondent about trends of rainfall amount, daily rainfall intensity, and frequency of extreme cool days, cool nights, warm days and warm nights for the major rainy, small rainy and dry seasons (Table 3).

***Perception analysis: Theoretical framework***

According to the Oxford dictionary perception is defined as the way in which something is regarded, understood, or interpreted. In the climate literature models two perception theories emerge prominently (Tansey and O'riordan, 1999). These are the psychometric and cultural theories. The psychometric theory is all about individualism and perception is treated as an exclusive property of individuals (Tansey and O'riordan, 1999). The cultural theory on the other hand is about people. It focuses on what is shared by people who form their outlook through their interaction in the social world (Tansey and O'riordan, 1999). According to Tansey and O'riordan (1999) culture is a shared interpretative framework for such groups or the common way that a group of persons make sense of the world. They share common sets of plans, laws, rules, regulations, customs, belief, norms and rituals to which individuals abide. According to the psychometric theory a human being uses close observation to assess his local climate and makes day to day decisions about farming, travel, clothing and others to match his local weather conditions. Thus, from experience *per se* human beings can assess significant changes in local climate.

Those who oppose this theory, however, say that "the deviations in the long term mean termed climate change is difficult to recognize unless one uses certain statistical analysis and that climate change is a constructed issue" (Storch, 2011). According to this group there are different classes of constructions (Stehr and Storch, 1995; Pasquaré and Oppizzi, 2012). One is through objective analysis of observations and interpretation by theories and the other is what is maintained and transformed by the public media (Stehr and Storch, 1995; Pasquaré and Oppizzi, 2012). Thus, according to this theory farmers' and herders' perceptions of

**Table 2.** Description of the independent variables.

| Variable | Description | Value |
|---|---|---|
| **Household characteristics** | | |
| Literacy | Household head literacy status. | 1= literate, 0= illiterate |
| Land holding | Household head's land holding. | hectare |
| Livestock ownership | Household head's livestock holding | Tropical livestock unit (TLU) |
| Distance from market | Household head's residential house distance from nearby market place | km |
| **Institutional factors** | | |
| Social/institutional responsibility | Household head's social and / or institutional responsibility such as serving as priest, 'kebele administration, etc. | 1= yes, 0=no |
| Access to ext. service | Household head's access to extension service including material benefits on livestock and crop over the last decades in his farm life. | 1= yes, 0=no |
| Access to relief aid | Household head food relief aid and or safetynet assistance received over the last decades in his farm life | 1= yes, 0=no |
| **Environmental factors** | | |
| **Eco-environment** | | |
| Pastoral | Household head living in pastoral eco-environment. | 1 yes, 0= otherwise |
| Agro-pastoral | Household head living in agro-pastoral eco-environment. | 1 yes, 0= otherwise |
| Mixed crop-livestock highland | Household head living in mixed crop-livestock highland eco-environment | 1 yes, 0= otherwise |
| **Season** | | |
| Major rain season | Household head's response for the major rain season | 1 yes, 0= otherwise |
| Small rain season | Household head's response for the small rain season | 1 yes, 0= otherwise |
| Dry season | Household head's response for the dry season | 1 yes, 0= otherwise |

**Table 3.** The dependent variables and definition used for the study.

| S/N | Variable | Definition of the variable | Unit |
|---|---|---|---|
| 1 | TR | Seasonal total rainfall: Perceived amount of rainfall in a season | polycotomous: 1 = increasing; 2, decreasing; 3 = no change |
| 2 | IR | Intensity of rainfall: Perceived strength of rainfall during raining time in a season | Polycotomous: 1= increasing; 2, decreasing; 3 = no change |
| 3 | CD | Frequency of cool days: Number of days with extreme coolness of the day time hours in a season | Polycotomous: 1= increasing; 2, decreasing; 3 = no change |
| 4 | CN | Frequency of cool nights: Number of days with extreme coolness of the night time hours in a season | Polycotomous: 1 = increasing; 2, decreasing; 3 = no change |
| 5 | HD | Frequency of warm days: Number of days with extreme warmness of the day time hours in a season | Polycotomous: 1 = increasing; 2, decreasing 3 = no change |
| 6 | HN | Frequency of warm night: Number of days with extreme warmness of the night time hours in a season | Polycotomous: 1 = increasing; 2, decreasing; 3 = no change |

changes in the extremes of rainfall and temperature indices might be derived from external sources such as extension services or mass media. According to Weber (2010), Frank et al. (2011) and Akerlof et al. (2013) knowledge of local climate is derived from personal experiences, local sources of knowledge and external sources of techno-scientific information. This indicates that herding/farming household perceptions of changes in those indices could be a result of personal experiences and influences from external agents. Based on these theories we used empirical models to identify what might be responsible for the observed household perceptions of rainfall and temperature extremes from sets of given environmental, social/ institutional and personal variables as given subsequently.

***The empirical model and model specification***

A multinomial logit (MNL) model commonly used for climate change adaption studies (Deressa et al., 2009, Hassan and Nhemachena, 2008; Bryan et al., 2013) and adoption decision studies involving multiple choices was used to identify the determinants of household perceptions of rainfall and temperature extreme indicators. The model was estimated based on households' responses using three choices namely increases (j=1), decreases (j=2) and no change (j=3) in specified climate extreme variables. Each household head was asked to give as single perception choice (j=1…J) to each rainfall and temperature extreme indicator denoted as y=1…Y. Thus for each extreme indicator taking one perception choice with sets of conditioning factors and household characteristics, the MNL model takes the following form:

$$P(y = j \setminus x) = \frac{\exp(x\beta j)}{1 + \sum_{h=1}^{J} \exp(x\beta h),\ j = 1,..J}$$

The MNL model requires assumption of independence of irrelevant alternatives (IIA) to hold which states that the probability of choosing a certain perception alternative by a given household needs to be independent from the probability of choosing another perception alternative (that is, Pj/Pk is independent of the remaining probabilities).

The parameter estimates of the MNL model offer only the direction of the effect of the independent variables on the dependent (response) variable, and estimates do not signify either the actual magnitude of change nor probabilities. Hence differentiating the equation above with respect to the explanatory variables provides marginal effects of the explanatory variables given as:

$$\frac{\partial Pj}{\partial x_k} = Pj(\beta_{jk} - \sum_{J=1}^{J-1} P_j \beta_{jk})$$

Where X is a vector of perception characteristics (specified in Table 3), β is a set of estimated parameters and J is a number of choices.

The marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent or explanatory variable (Greene, 2000).

***Dependent variables***

A total of six dependent variables (Table 3) which included household perceptions of trends in seasonal total rainfall, intensity of rainfall, frequency of extreme cool days, frequency of extreme cool nights, frequency of extreme warm days and frequency of extreme warm nights were identified. Six independent MNL models were run to regress these dependent variables on sets of environmental and social and/or institutional factors hypothesized to affect household perceptions.

***Independent variables***

Nine independent variables namely, household head characteristics (literacy level, land holding and livestock ownership), access to institutional services (social and /or institutional responsibility, distance from market**,** access to extension and relief aid services), environmental factors (eco-environment and season) were used in the model to assess the effect of changes in the above response variables on household perceptions (Table 2).

**Hypotheses to be tested**

***Household characteristics***

According to Hidalgo and Pisano (2010) environmental perceptions in relation to climate change are related to knowledge of the respondents. In line with this studies have shown that education increases climate change perception and awareness (Maddison, 2007; Deressa et al*.,* 2009; Acquah 2011; Hasan and Akhter, 2011; Enujeke and Ofuoku, 2012; Tesso et al*.,* 2012). Hence literate household heads might have more access to information and also analysis of environmental factors than their illiterate or uneducated counterparts. Literate household heads are expected to perceive changes in rainfall and temperature extreme indicators more than the illiterate household heads.

Land and livestock holdings represent wealth and farm activities. The size of these holdings influences farmers planning and execution of activities which could be affected by climate (Deressa et al*.,* 2009). Studies have shown that livestock ownership is positively related to climate change perception and adaptation decisions (Deressa et al., 2011; Silvestri et al., 2012; Mandleni and Anim, 2011). We hypothesize that farming and herding households with large land and livestock holding sizes may know climate change better than those with few livestock for several reasons. Firstly they have more social interactions and communications with neighbors for the management of their land and livestock. Secondly, they need to adjust their farming and herding practices and operational calendars in response to the changing local level climate extremes. Thirdly, they may be wealthier through sale of their farm produce and livestock and this wealth can improve access to communication media.

***Household access to institutional services***

Household heads with social and /or institutional responsibilities such as serving the community as religious leaders, arbitration, and involvement in various capacities within the 'Kebele' administration gives opportunity for communication with various people who might include those informed about climate change. Hence, we hypothesis that household heads with social and /or institutional responsibility could perceive rainfall and temperature extremes changes better than others with fewer responsibility.

Distance from input markets has been found to positively affect household perceptions of climate change and adaptation to the changes (Mandleni and Anim, 2011). In contrast, studies by Tesso et al. (2012) showed that distance from market was negatively related to farmers' perceptions of climate change. We hypothesize that households close to market outlets may have more awareness about climate change than distant ones. Those household heads close to market centers have a tendency to frequent market areas where they meet many people and share ideas about changes in rainfall and temperature extremes.

Extension services are an important source of information on climate and climate related issues (Deressa et al., 2009, 2011; Hassan and Nhemachena, 2008). Access to information on rainfall and temperature has been found to positively relate to climate change awareness and hence adaptation measures (Deressa et al., 2009; Dhaka et al., 2010; Mandleni and Anim, 2011; Enujeke and Ofuoku, 2012; Tesso et al*.,* 2012). In contrast, studies by Silvestri et al. (2012) showed that climate change perceptions of agro-pastoralists are negatively affected by livestock extension field visits. We hypothesize that herders and farmers close to extension services have better interaction with extension agents and hence have information on rainfall and temperature extremes. This is because extension agents themselves could teach them about climate change.

Studies have shown that food or other relief aid positively affects climate change perceptions of agro-pastoral households (Silvestri et al*.,* 2012). We hypothesize that relief aid recipient households have a better perception of rainfall and temperature extremes than the non-recipient households. This is because on the one hand relief aid recipients understand that increased frequencies of climatic extremes might expose them to repeated crop failures and livestock mortalities which lead them to be relief aid recipients. On the other hand donors and other informed relief aid workers could

**Table 4.** Model fitting diagnostic characteristics of the multinomial logit model.

| Diagnostics | TR | IR | CD | CN | HD | HN |
|---|---|---|---|---|---|---|
| Base category | No change | No change | No change | No change | No change | No change |
| Number of observation | 651 | 651 | 651 | 651 | 651 | 651 |
| Wald $X^2$ | 375068.67 | 248.16 | 61251.05 | 107282.83 | 1116.16 | 574.34 |
| $P>X^2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Pseudo $R^2$ | 0.3918 | 0.326 | 0.2555 | 0.2869 | 0.3236 | 0.2651 |
| Log pseudo likelihood | -375.6573 | -424.9048 | -349.1884 | -427.9930 | -268.6830 | -416.2042 |

TR = Seasonal total rainfall; IR = intensity of rainfall; CD = number of extreme cool days; CN = number of extreme cool night; HD = number of extreme warm days, HN = number of extreme warm night.

tell them of changes in rainfall and temperature extreme trend.

#### *Environmental factors*

Ethiopia is topographically very diverse but three major eco-environments with distinct climate and land use patterns have been specified. These diverse eco-environmental settings could affect perceptions of change in patterns of rainfall and temperature extremes among households living in each eco-environment. Previous studies in the Ethiopian mixed crop-livestock highlands have shown that farmers living in different eco-environments perceive climate change and hence take certain adaptation measures (Deressa et al., 2011) appropriate to their conditions. However studies by Tesso et al. (2012) did not find a significant effect of eco-environment on farmers' perceptions of climate change. We hypothesize that households living in different eco-environment may perceive changes in frequencies of occurrence of rainfall and temperature extremes from experience. Pastoral and agro-pastoral households have developed system behaviours focusing on mobility in response to the warm dry climate of pastoral areas and have knowledge on the occurrence of climatic extremes to which they have responded with certain management strategies. This is less important among the more stable and sedentary mixed crop-livestock highlanders.

Rainfall and temperature patterns differ among seasons over the different regions of the country. The rainfall of small rainy season plays vital role for land preparation and planting of long season crops such as sorghum and maize while the major rain season is important for planting short duration crops over most parts of the country. Studies by McSweeney et al. (2010) indicated significant increase in frequency of hot days and hot nights and conversely significant declining trends in frequencies of cold days and nights for the different seasons of Ethiopia. Seasonal differences in duration and magnitude of occurrence of rainfall and temperature variables affect choices of adaptation options to climate change (Hassan and Nhemachena, 2008). This difference could be one factor to affect household perceptions of changes in patterns of rainfall and temperature extremes. We hypothesize that because of their agricultural significance households perceive patterns of change in rainfall and temperature extremes better for the major and small rainy seasons than the dry season in the country.

#### *Estimation of empirical model parameters*

For all response variables, the multinomial logit model was estimated by taking the no change perception response as a baseline category against which other alternatives were compared. A multicollinearity test was conducted by employing an Ordinary Least Square (OLS) model using a Variance Inflation Factor (VIF) (Myers, 1990; O'brien, 2007). The VIF was found to be less than 10 for all variables indicating multicollinearity was not a serious problem in all the cases. We then ran Hausman's test to check the validity of the models for Independence of the Irrelevant Alternatives (IIA) assumption. The Hausman's test, however, failed to reject the null hypothesis of independence of the rainfall and temperature change perception options, indicating the multinomial logit model specifications are adequate to model rainfall and temperature extreme perception of the study household. As evidenced from Table 4 the likelihood ratio test of the models were found to be highly significant (P<0.0000) indicating strong explanatory power of the models. For each of the six multinomial logit models we ran, the marginal effect and interpretations of model output are based on marginal effects of the multinomial logit. For all models the output for the increased and decreased perceptions are interpreted by comparing with the no change perception category.

## RESULTS

### Household perception of extreme weather events vis-à-vis observed records

#### *Pastoral eco-environment*

In the pastoral eco-environment, the majority of households perceived an increasing number of extreme warm days (WD) and warm nights (WN), and conversely a decreasing number of extreme cool days (CD) and cool nights (CN) across all seasons. The perceptions were in line with recorded significant increasing trends in WD and WN across seasons. The decreasing trends from observed data were significant only for the major and small rainy seasons but were broadly in line with the decreasing trends in CD and CN perceived by the household. The majority of pastoral households (61.0-94.0%) also perceived decreasing trends in seasonal total rainfall (TR) and daily rainfall intensity (IR) across all seasons. Perceptions on IR were in line with observed data which also showed decreasing trends in all seasons. On the other hand, the observed data for TR showed a significant decline only in the major rainy season (Table 5).

#### *Agro-pastoral eco-environment*

Similar to the pastoral eco-environment, in the agro-

**Table 5.** Comparison of recorded and perceived trends of rainfall and temperature extremes for three distinct seasons in a pastoral eco-environment.

| Climate extreme event | Recorded | Perceived | | |
|---|---|---|---|---|
| | | Increasing (%) | Decreasing (%) | No change (%) |
| **Major rainy season** | | | | |
| Seasonal total rainfall | Decreasing (-1.47* mm/year) | 6.2 | 93.8 | 0 |
| Daily rainfall intensity | Decreasing (-0.16* mm/day/year) | 24.7 | 75.3 | 0 |
| number of extreme warm days | Increasing ( 0.39* days/year) | 97.5 | 2.5 | 0 |
| number of extreme warm nights | Increasing (1.22* days/year) | 75.3 | 24.7 | 0 |
| number of extreme cool days | Decreasing(-0.23* days/year) | 8.6 | 91.4 | 0 |
| number of extreme cool nights | Decreasing (-0.29* days/year) | 32.1 | 67.9 | 0 |
| **Small rainy season** | | | | |
| Seasonal total rainfall | No change(-0.83 mm/year) | 4.9 | 91.4 | 3.7 |
| Intensity of Rainfall | Decreasing (-0.064* mm/day/year) | 23.5 | 74.1 | 2.4 |
| number of extreme warm days | Increasing (0.39* days/year) | 98.8 | 1.2 | 0 |
| number of extreme warm nights | Increasing (0.70* days/year) | 72.8 | 27.2 | 0 |
| number of extreme cool days | Decreasing (-0.21* days/year) | 8.6 | 91.4 | 0 |
| number of extreme cool nights | Decreasing (-0.34* days/year) | 34.6 | 64.2 | 1.2 |
| **Dry season** | | | | |
| Seasonal total rainfall | No change(-0.99 mm/year) | 4.9 | 81.5 | 13.5 |
| Intensity of Rainfall | Decreasing (-0.092* mm/day/year) | 4.9 | 82.7 | 12.3 |
| number of extreme warm days | Increasing (0.43* days/year) | 96.3 | 2.5 | 1.2 |
| number of extreme warm nights | Increasing (0.89* days/year) | 72.8 | 27.1 | 0 |
| number of extreme cool days | Decreasing (-0.21* ) | 9.9 | 90.1 | 0 |
| number of extreme cool nights | Decreasing (-0.36* days/year) | 38.3 | 60.5 | 1.2 |

* Trends are significant P <5% probability level.

pastoral eco-environment, the majority of households perceived increasing numbers of extreme warm days (WD) and warm nights (WN), and conversely decreasing numbers of extreme cool days (CD) and cool nights (CN) across all seasons. However, the station data for CD indicated significant decreases only in the major rainy and dry seasons while the observed decrease was significant only in the major rainy season. Contrary to household perceptions, the recorded trends in WD revealed significant decreasing trends in the small rainy season. The majority of agro-pastoral households also perceived decreasing seasonal total rainfall (TR) and daily rainfall intensity (IR) across all seasons. However, the recorded trends showed no significant change in these parameters across all seasons (Table 6).

### *Mixed crop-livestock highland eco-environment*

In the mixed crop-livestock highland eco-environment, most of the households perceived increasing numbers of extreme warm days (WD) and warm nights (WN), and conversely decreasing numbers of extreme cool days (CD) and cool nights (CN). The perceptions for the major rainy and dry seasons agree with the recorded station data for WN which also showed increasing trends. For the small rainy season, however, station data indicated that only WD showed significant increasing trends. On the other hand, the recorded station data did not show significant changes in CD and CN except for the small rainy season where a decrease was seen in the small rainy season. With regard to rainfall extremes (TR and IR), households were equally divided between perceiving these to be increasing and decreasing in the major rainy seasons plus also the small rainy season in case of TR. Similarly for dry season, the respondents were equally divided between perceiving decreasing trends and no change (Table 7).

### *Determinants of household perceptions*

Results of the estimated marginal effects of the multinomial logit models are presented in Tables 8 to 10. The results show that most of the explanatory variables have statistically significant explanatory power at less than 10, 5 or 1% probability level and discussed subsequently.

### *Household characteristics*

Literacy of the head of the household significantly affected

**Table 6.** Comparison of recorded and perceived trends of rainfall and temperature extremes for three distinct seasons in an ago-pastoral eco-environment.

| Climate extreme event | Recorded | Perceived | | |
|---|---|---|---|---|
| | | Increasing (%) | Decreasing (%) | No change (%) |
| **Major rainy season** | | | | |
| Seasonal total rainfall | No change (-0.40 mm/year) | 4.5 | 95.5 | 0 |
| Intensity of Rainfall | No change (-0.038 mm/day/year) | 9.1 | 88.6 | 2.3 |
| Number of extreme warm days | No change (0.13 days/year) | 68.2 | 29.5 | 2.3 |
| Number of extreme warm nights | No change (0.14 days/year) | 68.2 | 29.5 | 2.3 |
| Number of extreme cool days | Decreasing (-0.16* days/year ) | 29.5 | 65.9 | 4.6 |
| Number of extreme cool nights | Decreasing (-0.29* days/year) | 29.5 | 63.6 | 6.8 |
| **Small rainy season** | | | | |
| Seasonal total rainfall | No change (-0.93 mm/year) | 11.4 | 86.4 | 2.3 |
| Intensity of Rainfall | No change (-0.066 mm/day/year) | 9.1 | 86.4 | 4.6 |
| Number of extreme warm days | Decreasing (-0.17* days/year) | 72.7 | 27.3 | 0 |
| Number of extreme warm nights | No change (0.102 days/year) | 68.2 | 29.5 | 2.3 |
| Number of extreme cool days | No change (-0.069 days/year) | 29.5 | 65.9 | 4.5 |
| Number of extreme cool nights | No change (-0.053 days/year) | 25 | 68.2 | 6.8 |
| **Dry season** | | | | |
| Seasonal total rainfall | No change (-0.14 mm/year) | 25 | 50 | 25.0 |
| Intensity of Rainfall | No change (-0.046 mm/day/year) | 17.7 | 65.5 | 21.8 |
| Number of extreme warm days | No change (0.29 days/year) | 65.9 | 29.5 | 4.5 |
| Number of extreme warm nights | No change (0.054 days/year) | 65.9 | 25 | 9.1 |
| Number of extreme cool days | Decreasing (-0.16* days/year) | 38.6 | 52.3 | 9.1 |
| Number of extreme cool nights | No change (0.020 days/year) | 13.6 | 79.5 | 6.8 |

*Trends are significant at P <5% probability level.

perceptions of trends in seasonal total rainfall, daily rainfall intensity and number of extreme warm days among others. Being literate significantly decreased the probability of perceiving increased seasonal total rainfall, daily rainfall intensity and number of extreme warm days by 9.2, 9 and 7.8%, respectively and significantly increased the likelihood of increased perception of the number of warm days by 10.5%. These are in line with the recorded trends especially for the pastoral and agro-pastoral environment and imply that education enables household heads to be aware of changes in climate extremes as expected.

The size of farmland owned by households is related to perceptions on number of extreme cool days and warm nights. A unit increase in households' land holding size significantly increased the probability of increased perception of the number of extreme cool days by 1.9%. It significantly decreased the increased perception of the number of extreme warm nights by 2.9% and significantly increased the likelihood of decreased perception by 2.3%. However, these perceptions are not in line with the observed trends indicating that it is not the size of the farm, but the specific characteristics of the farm that may dictate household perceptions of changes in rainfall and temperature extremes trend.

A unit increase in livestock holding of the household significantly increased the probability to perceive increased seasonal total rainfall and daily rainfall intensity by 0.3 and 0.1%, respectively. It however, decreased the likelihood of decreased perception of seasonal total rainfall and daily rainfall intensity by 0.3 and 0.2%, respectively. Moreover, a unit increase in livestock ownership of the household significantly increased the probability of decreased perception of number of extreme warm days by 0.2% and significantly decreased the increased perception of the number of extreme warm nights by 0.2%. These perceptions are not supported by the observed trends. This might be due to better rainfall and temperature conditions in recent years that might result in better availability of pasture and water for livestock production.

### *Household access to institutional services*

Having social and /or institutional responsibility significantly increased the probability of perceiving decreased seasonal total rainfall and daily rainfall intensity by 11.8 and 10.6%, respectively and increased the likelihood of perceiving decreased seasonal total rainfall by 5.8%. This

**Table 7.** Comparison of recorded and perceived trends of rainfall and temperature extremes for three distinct seasons in a mixed crop-livestock highland eco-environment.

| Climate extreme event | Recorded | Perceived | | |
|---|---|---|---|---|
| | | Increasing (%) | Decreasing (%) | No change (%) |
| **Major rainy season** | | | | |
| Seasonal total rainfall | Decreasing (-1.202* mm/year) | 47.8 | 51.1 | 1.1 |
| Intensity of Rainfall | No change (0.012 mm/day/year) | 48.9 | 51.1 | 0 |
| Number of extreme warm days | No change (0.051 days/year) | 77.2 | 14.1 | 8.7 |
| Number of extreme warm nights | Increasing (0.094* days/year) | 66.3 | 26.1 | 7.6 |
| Number of extreme cool days | No change (-0.032 days/year) | 18.5 | 77.2 | 4.4 |
| Number of extreme cool nights | No change (0.062 days/year) | 29.3 | 65.2 | 5.5 |
| **Small rainy season** | | | | |
| Seasonal total rainfall | No change (0. 147) | 47.8 | 47.8 | 4.4 |
| Intensity of Rainfall | No change (0.027 mm/year) | 28.3 | 67.4 | 4.4 |
| Number of extreme warm days | Increasing (0.109* days/year) | 65.2 | 29.3 | 5.4 |
| Number of extreme warm nights | No change (0.071 days/year) | 71.7 | 22.8 | 5.4 |
| Number of extreme cool days | Decreasing (-0.238* days/year) | 35.9 | 62.0 | 1.1 |
| Number of extreme cool nights | No change (0.070 days/year) | 30.4 | 66.3 | 3.3 |
| **Dry season** | | | | |
| Seasonal total rainfall | No change (-0.137 mm/year) | 13.0 | 45.7 | 41.3 |
| Intensity of Rainfall | No change (0.013 mm/day/year) | 16.3 | 44.6 | 39.2 |
| Number of extreme warm days | No change (0.016 days/year) | 90.2 | 6.5 | 3.3 |
| Number of extreme warm nights | Increasing (0.276* days/year) | 67.4 | 31.5 | 1.1 |
| Number of extreme cool nights | No change (-0.021 days/year) | 42.4 | 54.3 | 3.3 |
| Number of extreme cool days | No change (-0.038 days/year) | 27.2 | 69.6 | 3.3 |

*Trends are significant P<5% probability level.

**Table 8.** Marginal effects of explanatory variables from the multinomial logit perception models on seasonal total rainfall and intensity of rainfall.

| Explanatory variable | Seasonal total rainfall (TR) | | | Daily rainfall intensity(IR) | | |
|---|---|---|---|---|---|---|
| | Increase | Decrease | No change | Increase | Decrease | No change |
| Literacy | 0.0280 | -0.0915*** | 0.0635*** | 0.0240 | -0.0896** | 0.0240 |
| Land holding | -0.0055 | 0.0096 | -0.0041 | 0.0122 | -0.0026 | 0.0123 |
| Livestock ownership | 0.0025*** | -0.0025*** | -1.60E-05 | 0.0013** | -0.0017** | 0.0013** |
| Social/institutional responsibility | -0.0579*** | 0.1185*** | -0.0606** | -0.0431 | 0.1063** | -0.0431 |
| Distance from market | 0.0012 | -0.0021 | 0.0009 | -0.0005 | 0.0002 | -0.0005 |
| Access to ext. service | 0.0978* | -0.0789 | -0.0189 | -0.2040*** | 0.1905*** | -0.2040*** |
| Access to relief aid | -0.2355*** | 0.2272*** | 0.0083 | 0.1098** | -0.1258** | 0.1098** |
| Pastoral | -0.2143* | 0.2320** | -0.0177 | 0.1936** | -0.1476 | 0.1936** |
| Agro-pastoral | -0.4866*** | 0.5983*** | -0.1117** | 0.1064 | -0.0008 | 0.1063 |
| Major rainy season | -0.16456*** | -0.1623*** | 0.3268*** | -0.1682*** | -0.1505** | -0.1682*** |
| Small rainy season | -0.1323*** | -0.0414 | 0.1737*** | -0.0717** | -0.1062** | -0.0717** |

*, **, ***significant at < 10, <5 and < 1% P level, respectively.

indicates that as expectations social and/ or institutional responsibility enables farmers and herders to be more aware of climate extreme trends and that their perceptions on rainfall extremes may have been influenced by interactions with other peoples.

Contrary to expectations, a unit increase in distance from market center significantly increased the likelihood of decreased perception of number of extreme cool days by 0.3% and decreased the likelihood of increased perception by 0.2% and significantly decreased the

**Table 9.** Marginal effects of explanatory variables from the multinomial logit perception models on number of extreme cool days and cool nights.

| Explanatory variable | Number of cool days (CD) | | | Number of cool nights (CN) | | |
|---|---|---|---|---|---|---|
| | Increase | Decrease | No change | Increase | Decrease | No change |
| Literacy | -0.0071 | -0.0106 | -0.0033 | 0.0317 | -0.0339 | 0.0022 |
| Land holding | 0.0178** | -0.0135 | -0.0075 | 0.0057 | -0.0025 | -0.0031 |
| Livestock ownership | -0.00013 | -0.0007 | -0.0005 | 0.00013 | -0.00056 | 0.00042 |
| Social/institutional responsibility | -0.0212 | -0.0019 | 0.0491* | -0.0517 | 0.0537 | -0.0020 |
| Distance from market | -0.0024** | 0.0029** | 0.0023** | -0.0022** | 0.00154 | 0.00065 |
| Access to ext. service | -0.0606 | 0.0694 | 0.0083 | -0.1886*** | 0.2149*** | -0.0263 |
| Access to relief aid | -0.1270*** | 0.1706*** | -0.0377 | -0.0609 | 0.0693 | -0.0084 |
| Pastoral | -0.2591** | 0.4812*** | -0.0682 | -0.2090** | 0.3324*** | -0.1234** |
| Agro-pastoral | -0.1682 | 0.4166*** | -0.1222 | 0.0545 | 0.0656 | -0.1201** |
| Major rainy season | 0.0317 | -0.0216 | 0.0663 | 0.0996** | -0.0925** | -0.0071 |
| Small rainy season | -0.0385 | 0.0358 | 0.0669 | 0.0812** | -0.0787** | -0.0025 |

*, **, *** significant at <10, 5 and 1% P level, respectively

**Table 10.** Marginal effect of explanatory variables from the multinomial logit perception models on number of extreme warm days and warm nights.

| Explanatory variable | Number of warm days (HD) | | | Number of warm nights (HN) | | |
|---|---|---|---|---|---|---|
| | Increase | Decrease | No change | Increase | Decrease | No change |
| Literacy | 0.1045** | -0.0777** | -0.0275 | 0.0302 | -0.0363 | 0.0061 |
| Land holding | -0.0099 | 0.0112 | -0.0012 | -0.0294*** | 0.0232** | 0.0062 |
| Livestock ownership | -0.0013 | 0.0016** | -0.00033 | -0.0017** | -0.00076 | 0.0025** |
| Social/institutional responsibility | -0.0029 | -0.0263 | 0.0291 | 0.0219 | -0.0586 | 0.0367 |
| Distance from market | 0.0024 | -0.00012 | -0.0023** | 0.00065 | 0.00024 | -0.00088 |
| Access to ext. service | -0.0477 | 0.0729 | -0.0252 | 0.1629*** | -0.1028* | -0.0602*** |
| Access to relief aid | 0.1123** | -0.0861** | -0.0261 | 0.0216 | 0.0104 | -0.0319 |
| Pastoral | 0.3607*** | -0.3171*** | -0.0436 | 0.4042*** | -0.3944*** | -0.0098 |
| Agro-pastoral | 0.3074** | -0.2172** | -0.0902** | 0.1185 | -0.0268 | -0.0917* |
| Major rainy season | 0.0878** | -0.0709** | -0.0169 | -0.0095 | 0.0342 | -0.0247* |
| Small rainy season | 0.1137** | -0.1156** | 0.0019 | -0.0266 | 0.0423 | -0.0157 |

*, **, *** Significant at < 10, 5 and 1% P level, respectively.

probability of increased perception of the number of cool nights by 0.2%.This implies that though households far away from input centers have less access to information from market centers, they can perceive from experience the changes in number of extreme cool days and night better than those nearby to market centers.

As expected access to extension services significantly increased the probability of perceiving increased number of extreme warm nights by 16.3%. It significantly decreased the probability of increased perception of daily rainfall intensity and number of extreme cool nights by 20.0 and 18.9%, respectively. Moreover, access to extension services significantly decreased the likelihood of perceiving decreased number of extreme warm nights by 10.3%, respectively. It also significantly increased the probability of decreased perception of number of cool nights by 21.5%. However, unlike expectations access to extension services significantly increased the probability of perceiving increased seasonal total rainfall by 9.8% and decreased the likelihood of perceiving decreased daily rainfall intensity by 19.0%. Relief aid assistance also significantly increased households' likelihood of perceiving decreased seasonal total rainfall and number of extreme cool days by 22.7 and 17%, respectively. It significantly decreased the likelihood of increased perception of seasonal total rainfall and number of extreme cool days by 23.6 and 12.7%, respectively. Access to relief aid significantly increased the probability of perceiving increased number of warm days by 11%, but significantly decreased the likelihood of perceiving decreased number of extreme warm days by 8.6%. However, access to relief aid significantly increased the probability of perceiving increased daily rainfall intensity by 11.0% and decreased the likelihood of perceiving decreased daily rainfall intensity by 12.6%. This indicates that herding/farming households close to extension and relief aid services for information, advice and material benefits perceived as expected especially on number of extreme warm and cool days and nights. The results emphasize the importance of extension and relief aid services in climate change perception.

### *Eco-environmental factors*

Compared to being in the mixed crop-livestock highland eco-environment, being in the pastoral eco-environment significantly increased the probability of perceiving decreased seasonal total rainfall, number of extreme cool days and number of extreme cool nights by 23.2, 48.0 and 33.0%, respectively. It also significantly decreased the likelihood of perceiving increased rainfall and number of extreme cool days by 21.4 and 25.9%, respectively. Moreover, being in the pastoral eco-environment significantly increased the probability of increased perception of intensity of rainfall, number of extreme warm days and number of extreme warm nights by 19.4, 36.0 and 40.0%, respectively. It significantly decreased the likelihood of increased perception of number of extreme cool nights by 20.9% and significantly decreased the likelihood of decreased perception of number of extreme warm days and number of extreme warm nights by 31.7 and 39.0%, respectively. Except for the intensity of rainfall, these are in line with the recorded trends and indicate that households in the pastoral eco-environments perceive climate extreme trends better than households in the mixed crop-livestock highland eco-environment. This might be related to the fact that pastoral areas are located in areas of high climate variability and frequent crop failures and livestock mortality to drought. As a result climate change is of major concern to them.

Similarly compared to being in the mixed crop-livestock highland eco-environment, households being in the agro-pastoral eco-environment significantly increased probability of perception of decreased number of extreme cool days by 41.7% and significantly decreased the likelihood of increased perception by 16.8%. It however, significantly increased the probability of perceiving increased rainfall and number of extreme warm days by 59.8 and 59.8%, respectively. It also significantly decreased the likelihood of perceiving decreased rainfall and number of warm days by 48.7 and 21.7%. This shows that unlike expectations agro-pastoralists are not better in perceiving recorded trends in climate extremes than the mixed crop-livestock highland farmers.

Compared to the dry season, the major rain season significantly decreased the probability of household perceptions of increased seasonal total rainfall and daily rainfall intensity by 16.0 and 16.8%, respectively. It significantly decreased the likelihood of perceiving decreased seasonal total rainfall by 16.0%, daily rainfall intensity by 15.0%, and number of extreme cool nights by 9.3%, and number of extreme warm days by 7.0%. It also significantly increased the probability of increased perception of number of extreme cool nights and number of extreme warm days by 10.0 and 8.8%, respectively.

Similarly compared to the dry season, the small rain season significantly decreased the likelihood of increased perception of seasonal total rainfall and daily rainfall intensity by 13 and 7% respectively. It also significantly increased the probability of increased perception of number of extreme cool nights by 8.2%; decreased the likelihood of decreased perception of intensity of rainfall, number of extreme cool nights and number of extreme warm days by 10.6, 7.9 and 11.6%, respectively. Moreover, it significantly increased the probability of perceiving increased number of extreme warm days by 11.0% and significantly decreased the likelihood of decreased perception of number of extreme warm days by 11.6%. These show that though seasons have agricultural significance, its effect on household perceptions are not clearly defined.

## DISCUSSION

### Household perception of extreme weather events vis-à-vis observed records

From the above results it is evident that households from the three eco-environments perceived increasing numbers of extreme warm days and warm nights, and conversely decreasing numbers extreme cool days and cool nights. The perceptions on rainfall extremes, however, were variable across season and eco-environments in such a way that majority of households in the pastoral and agro-pastoral eco-environments perceived decreasing total rainfall and intensity of rainfall, whereas the respondents were equally divided between perceiving increases and decreases for the major and small rainy seasons in the mixed crop-livestock highland eco-environment. The results are in line with other reports from similar environments (Dhaka et al., 2010; Acquah and Onumah, 2011). On the other hand, the relationship between household perceptions and station data were not systematic; in the pastoral eco-environment household perceptions were in line with the significant trends observed in recorded data, but in the agro-pastoral or mixed crop-livestock highland eco-environment the relationship was not clear. Maddison (2007) also found similar inconsistencies for rainfall and temperature between farmers' perceptions and recorded weather station data across many African countries. The results also revealed more inconsistencies among recorded data than household perception across eco-environments. This is in line with reports of Degefu and Bewket (2014) that showed considerably varied trends of climate extremes among neighboring stations within a given eco-environment.

### Determinants of household perceptions

Herding/farming households' perceptions on rainfall and temperature extremes are significantly affected by a number of factors and the factors affecting each extreme variable may not be the same. Generally literacy, eco-environment, distance from market, social/institutional responsibility, access to extension and relief aid services caused/helped the majority of households to perceive increasing number of extreme warm days and warm nights, and conversely decreasing number of extreme cool days, cool nights, daily intensity of rainfall and seasonal total rainfall as expected. This shows that there is a need to consider these factors at policy level while planning community based climate change measures. So far the Ethiopian government has enacted various policy programs and strategies aimed at mitigating and adapting climate change. Some of this includes climate resilient green economy strategy, and agriculture and rural development polices and strategies which focuses on low/or no greenhouse gas emission, agricultural growth and energy development to reach the level of middle income by 2025.The implementation of these policies and strategies need the active participation of citizens at different capacities. As Ethiopia is a low income agrarian country, the grates emissions of greenhouse gases and the effects of the changing climate are both at small holder subsistence agricultural practices. Awareness and active participation of the rural population of the country engaged in small scale subsistence farming and herding is thus far important. The present study's finding of variation in households' perception of climate extremes trend indicates the need for eco-environment based policies and strategies to first make awareness on local and global scale changes in climate extremes. The policies and strategies should focus more on educating farming and herding households by incorporating climate change issues in both the formal and informal school curriculums and the adult education programs. The deployment of intermediate level trained agricultural extension workers close to farmers and herders also play vital role in information exchange with local communities. The extension workers, therefore, need to have regular access to information from the National Meteorological Agency of the country about their respective local weather report.

On the other hand, though they play an important role in climate change adaptation strategies (Deressa et al., 2011; Silvestri et al., 2012; Mandleni and Anim, 2011) farm land size, and livestock holding size of households could not help perceive changes in climate extremes. The implication is that households with large farmland size and livestock holding are better adapted to climate change and they may have less perception of climate extremes are changing. This shows climate extremes change is of less worry to better off households and there is a need to work on eco-environment based climate change adaptation strategies. The pastoral and agro pastoral eco-environment being under warm climate and low and erratic rainfall is dependent on livestock. In these areas, the policy programs need to focus on improving productivity of animals through better breeding, feeding and health care systems. On the other hand, in the mixed crop-livestock highlands the policy strategies need to focus on improving both crop and livestock productivity.

## Conclusions

From the results of the present study it is apparent that herding/farming household perceptions of extremes of climate are similar for temperature extremes trend across eco-environments and seasons, whereas the perceptions on rainfall extremes vary with eco-environments and seasons. Moreover, household perceptions are sometimes at variance with recorded significant trends across eco-environments and seasons. Households in the pastoral eco-environment perceive changes in climate extremes better than households either in the agro-pastoral or mixed crop-livestock highland eco-environments. Household perceptions of the studied extreme events were significantly affected by a number of factors. Policy programs that enhance the literacy level of households and eco-environment based extension services may increase the level of awareness and understanding of climate change by households which help them better adapt to climate change.

## Conflict of Interests

The authors have not declared any conflict of interests.

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