Belay *et al. Agric & Food Secur (2017) 6:24*
DOI 10.1186/s40066-017-0100-1

Agriculture & Food Security

RESEARCH Open Access

# Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia

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## Abstract

**Background:** The agricultural sector remains the main source of livelihoods for rural communities in Ethiopia, but faces the challenge of changing climate. This study investigated how smallholder farmers perceive climate change, what adaptation strategies they practice, and factors that influence their adaptation decisions. Both primary and secondary data were used for the study, and a multinomial logit model was employed to identify the factors that shape smallholder farmers' adaptation strategies.

**Results:** The results show that 90% of farmers have already perceived climate variability, and 85% made attempts to adapt using practices like crop diversification, planting date adjustment, soil and water conservation and management, increasing the intensity of input use, integrating crop with livestock, and tree planting. The econometric model indicated that education, family size, gender, age, livestock ownership, farming experience, frequency of contact with extension agents, farm size, access to market, access to climate information and income were the key factors determining farmers' choice of adaptation practice.

**Conclusion:** In the Central Rift Valley of Ethiopia, climate change is a pressing problem, which is beyond the capacity of smallholders to respond to autonomously. Farmers' capacity to choose effective adaptation options is influenced by household demography, as well as positively by farm size, income, access to markets, access to climate information and extension, and livestock production. This implies the need to support the indigenous adaptation strategies of the smallholder farmers with a wide range of institutional, policy, and technology support; some of it targeted on smaller, poorer or female-headed households. Moreover, creating opportunities for non-farm income sources is important as this helps farmers to engage in those activities that are less sensitive to climate change. Furthermore, providing climate change information, extension services, and creating access to markets are crucial.

**Keywords:** Climate change, Adaptation, Diversification, Livelihoods, Multinomial logit model, Smallholder farmers

## Background

Scientific evidence indicates that the earth's climate is rapidly changing, owing to increases in greenhouse gas emissions [1, 2]. The increased concentration of greenhouse gases has raised the average temperature and altered the amount and distribution of rainfall globally [3, 4]. For example, in Sub-Saharan Africa, warming is expected to be greater than the global average and in parts of the region, rainfall will decline [5]. There is growing evidence that extreme events, such as droughts and floods, have been common incidences [3]. These have affected smallholder farmers in developing countries who heavily depend on rainfed agriculture for their livelihoods [2, 6, 7]. In Africa, climate change has affected both the natural and social systems [7, 8]. Impacts of climate

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change are felt more severely in semi-arid and arid areas [7, 9, 10]. Limiting the damage due to climate change has become a challenge for the global community now. In this regard, climate change mitigation and adaptation are crucial [11]. Adaptation can manage the impacts but cannot by itself solve the problem of climate change. Even with adaptation, there will be residual costs. Smallholder farmers, for instance, can switch to more adapted crop varieties, but they may have lower productivity [12]. In developing countries, adaptation of the agricultural sector to the changing climate is important for ensuring livelihoods of the poor communities [5]. Adaptation will require the involvement of multiple stakeholders, including policymakers, extension agents, NGOs, researchers, communities, and farmers. Climate change adaptation is mostly location-specific, and its effectiveness depends on local institutions and socioeconomic setting [13]. A better understanding of how smallholder farmers perceive climate change and the adaptation strategies they practice is needed to make policies and design programs aimed at promoting successful adaptation in the agricultural sector. A combination of factors influences the farmers' perception about climate variability and the decision to use the selected adaptation strategies [14, 15].

Farmers in developing nations are developing resilience to climate change-related risks like droughts and floods through practicing diverse adaptation strategies. In the West African Sahel, for instance, pastoralists have come up with strategies to cope with the erratic rainfall [5]. In Ethiopia, diverse practices are used in both the highlands and lowlands [16, 17]. The agricultural sector in Ethiopia accounts for about 42% of national GDP, 90% of exports and 85% of employment [14], and is mainly rainfed. The history of drought in Ethiopia dates back to 250 BC, since then droughts have occurred in different parts of the country at different times [18]. At present, the potential adverse effects of climate change on Ethiopia's agricultural sector are major concerns. In the Central Rift Valley of Ethiopia, climate change and variability is manifest through frequent droughts and floods, erratic rainfall and fluctuating mean temperature [19]. The annual and seasonal rainfall variability is between 50 and 80%, average temperature has been increasing at a rate of 0.37 °C every ten years, and the maximum daily temperature has increased by a cumulative 1.5 °C since 1900 [20]. Smallholder farmers are highly dependent on rainfed agriculture which is very sensitive to climate variability and change. Changes in the distribution and amount of rainfall which have resulted in low precipitation and frequent drought have been affecting agriculture [21].

This study aimed at (a) examining how the local community perceived the impacts of climate change, (b) identifying what adaptation practices they use, and (c) investigating the factors that determine their choice of adaptation strategies in the central rift valley of Ethiopia. The study area has climate-related risks such as water stress and increased incidences of pest and diseases [22].

## Methods

### Description of the study area

The study was done in Arsi Negelle district of West Arsi Zone, Oromia Regional State of Ethiopia (Fig. 1). The district is located at 250 km south of the national capital, Addis Ababa. Geographically, it is located between 7°17′N and 7°66′N, and between 38°43′E and 38°81′E. The temperature ranges between 10 and 25 °C, while annual rainfall varies between 500 and 1200 mm. The area has four distinct seasons including the dry season (December to February), the short rainy season (March to May), the main rainy season (June to August), and the autumn season (September to November) [23]. Topographically, the district is slightly undulating especially in the highlands and almost flat in the lowlands. Some parts of the highlands in the district are still covered by natural forest, bush and shrub. There are three large inland Lakes—Abijata, Shalla and Langano—in the district. The district has relatively fair agricultural potential, which is reflected in the diversity of crop and livestock production for food and income generation [24]. In comparison with other districts of the West Arsi Zone, Arsi Negele district has more severe extreme events such as recurrent drought. This study was conducted in three agro-ecological zones in the district that range between 1500 and 2800 m.a.s.l. The high altitude agro-ecological zone occupies the largest area followed by mid and low altitude agro-ecological zones, respectively.

### Sampling design and sample size

This study employed a multi-staged sampling technique, where a combination of sampling techniques was used to select the *Kebeles* (the lowest level administrative units under the Federal Democratic Government of Ethiopia) and households. In the first stage, Arsi Negelle district was selected purposely from the districts of West Arsi Zone, because it is one of the most severely affected districts by extreme climate change-related risks and is characterized by three distinct agro-ecological zones, highland, midland and lowland [22].

In the second stage, three *Kebeles* (one from each agro-ecological zone) were selected randomly (Table 1) with the assumption that smallholder farmers within each agro-ecological system may have differences in their traditional knowledge and skills, and that this may result in different adaptive capacities in the communities. As climate change may have different impacts in different agro-ecological zone, the farmers in the respective

**Table 1 Distribution of sampled households by the *Kebele*/village**

| *Kebele* name (and agro-ecology) | Total number of households | Number of sampled household heads | Male household heads (%) | Female household heads (%) |
|---|---|---|---|---|
| Meraro Hawilo (Highland) | 700 | 70 | 93 | 7 |
| Kersa Ilala (Midland) | 530 | 53 | 83 | 17 |
| Mudi Arjo (Lowland) | 770 | 77 | 84 | 16 |
| Total households | 2000 | 200 | | |

agro-ecologies may practice different adaptation strategies [25, 26]. These strategies are also shaped by biophysical, socioeconomic, and socio-cultural context of the areas. In the third stage, a sample of households in each target Kebele were identified and the sample size was determined proportionately [2].

### Data sources and data collection methods

This study employed both qualitative and quantitative data collection methods as recommended by Neuman [27]. The qualitative data at community level were collected through focus group discussions, key informant interviews, and observations. The focus group discussions for this study were held with separate groups of elders, youth and women in each *Kebele* comprising 6–10 individuals per group. The sessions were moderated by the researcher using a checklist including climate change parameters in the area, the resultant impact, farmers' response, and what factors influenced farmers' adaptation decisions. Similarly, key informant interviews were held with knowledgeable people from the community, including the agricultural staff, administrators from government offices, and NGOs. These were individuals who have access to information on weather forecasts, climate change impact, and constraints to adapting to climate change. In addition, data at the household level were collected through a household survey using structured questionnaires. Those were initially pretested to check their validity and appropriateness. For pretesting the questionnaire, nine households from non-sampled *Kebeles* were identified and interviewed prior to the actual interview of the target sample households. This allowed the restructuring of questions before intensive data collection. Based on the limitations identified in the pretest, the questionnaires were then amended and enriched for the actual interview. The sampling size for the households' survey was determined using the rule $N \geq 50 + 8m$ [28] in order to assure that the econometric model could be estimated with sufficient degrees of freedom, where $N =$ sample size, and $m =$ number of explanatory variables. Consequently, a total of 200 sample households were selected and interviewed: 70 from Merarow Hawilo (high altitude *Kebele*), 53 from Kersa Elala (mid-altitude *Kebele*), and 77 Mudi Arjo (low altitude *Kebele*). The local language, Afan Oromo, was used for effective communication for the household survey, focus group discussions and key informant interviews. Research assistants fluent in Afan Oromo and with good knowledge of local traditions were recruited and trained before conducting the survey.

### Descriptive data analysis

In this study, demographic and socioeconomic data were summarized and presented using descriptive statistics such as frequency, percentage, graphs, figures, and tables. Also $t$ test and Chi-square tests were used in order to compare the difference among groups for different socioeconomic and demographic variables. This test is mainly employed to know whether the difference is statistically significant or not. For this analysis, both Microsoft Excel and STATA version 13 were used.

### Econometric data analysis

In this study, the determinants of farmers' adaptation decisions to climate change were analyzed using a multinomial logit (MNL) [29]. In this study, the method was used to analyze the choices the farmers make regarding crop- and livestock-based adaptation strategies and what factors determine those choices. The MNL model was used based on the previous literature on determinants of farmers' adaptation to climate change [14, 30]. This model suits such type of analysis as it permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories [31, 32]. However, the model requires that households are associated with only their most preferred option from a given set of adaptation strategies. Unbiased and consistent parameter estimates using this model need to assume independence of irrelevant alternatives that requires that the probability of using a certain adaptation method by a given household is independent from the probability of choosing another adaptation method. We are aware that collecting and using only the most preferred adaptation option for each household risks underemphasizing the known importance to smallholder farmers of using multiple adaptation strategies [3], but the approach has allowed a high level of specification of the relations between adaptation strategies and underlying socioeconomic variables.

The model is specified as follows.

Let $Y$ denote a random variable with values {1,2…$J$} for a positive integer $J$ and $X$ set of variables [33]. In this study, $Y$ is a dependent variable and represents the adaptation alternatives (strategies) from the set of adaptation measures, whereas the $X$ represents the factors that influence choice of the adaptation strategies which contains household attributes as described in Table 2, and $P1$, $P2 \ldots Pj$ as associated probabilities, such that $P1 + P2 + \ldots + Pj = 1$. This tells as how a certain change in $X$ affects the response probabilities $P(y = j/x)$, $j = 1, 2 \ldots J$. Since the probabilities must sum to unity, $P(y = j/x)$ is determined once the probabilities for $j = 2 \ldots J$ are known.

$$P\left(y=1/x\right)=1-\left(P2+P3+\cdots Pj\right) \tag{1}$$

In the MNL model, it is usual to designate one as the reference category. The probability of membership in other categories is then compared to the probability of membership in the reference category. Consequently, for a dependent variable with $j$ categories, this requires the calculation of $j-1$ equations, one for each category relative to the reference category, to describe the relationship between the dependent variable and the independent variables. The choice of the reference category is arbitrary but should be theoretically motivated. The estimation of MNL model for this study was conducted by normalizing one category which is named as "base category" or "reference estate." The adaptation measures were grouped into eight because farmers used more than one strategy, and the base category was "No adaptation strategy." The theoretical explanation of the model is that in all cases, the estimated coefficient should be compared with the base group or reference category [34]. Therefore, the choice of the reference category is based on empirical literature and theoretically motivated. The generalized form of probabilities for an outcome variable with $j$ categories is:

$$\Pr\left(y_i=j|x\right)=pr_{ij}=\frac{\exp\left(x'\beta j\right)}{1+\sum_{j=2}^{j}\exp\left(x'\beta j\right)},\quad j=1,2\ldots J \tag{2}$$

$$\text{For} \quad j>1$$

The parameter estimates of the MNL model only provide the direction of the effect of the independent variables on the dependent (response) variable; estimates represent neither the actual magnitude of change nor the probabilities. Differentiating Eq. (2) with respect to the explanatory variable provides the marginal effect of the independent variables which give as

$$\frac{\partial pi}{\partial xk}=pj\left(\beta jk-\sum_{j=1}^{j=1}pj\beta jk\right) \tag{3}$$

Marginal effect of marginal probabilities is the function of probabilities and measures the expected change in probabilities where particular adaptation choice is being made by a unit change of the independent variable from the mean [35].

The choice of independent variables was dictated by empirical literature, behavioral hypotheses suggested by it, and data availability. Hypotheses have been developed around explanatory variables concerning their expected influence on farm level adaptations [36, 37]. Table 2 shows the description of and hypotheses around, or expected signs of, explanatory variables used in this study (Fig. 1).

**Table 2 Variable description and hypothesis for the impact of the independent variables on dependent variables**

| Explanatory variables | Description | Expected sign |
|---|---|---|
| Sex | Dummy, 1 = male, 0 = female | ± |
| Age | Continuous (years) | ± |
| Education | Continuous (years) | + |
| Household size | Continuous (number) | ± |
| Farming experience | Continuous (years) | ± |
| Farm size | Continuous (hectare) | + |
| Total annual income | Continuous (ETB) | + |
| Access to market | Dummy, 1 = yes, 0 = no | + |
| Access to climate information | Dummy, 1 = yes, 0 = no | + |
| Access to extension | Dummy, 1 = yes, 0 = no | + |
| Livestock ownership | Continuous, Tropical livestock unit (TLU) | + |

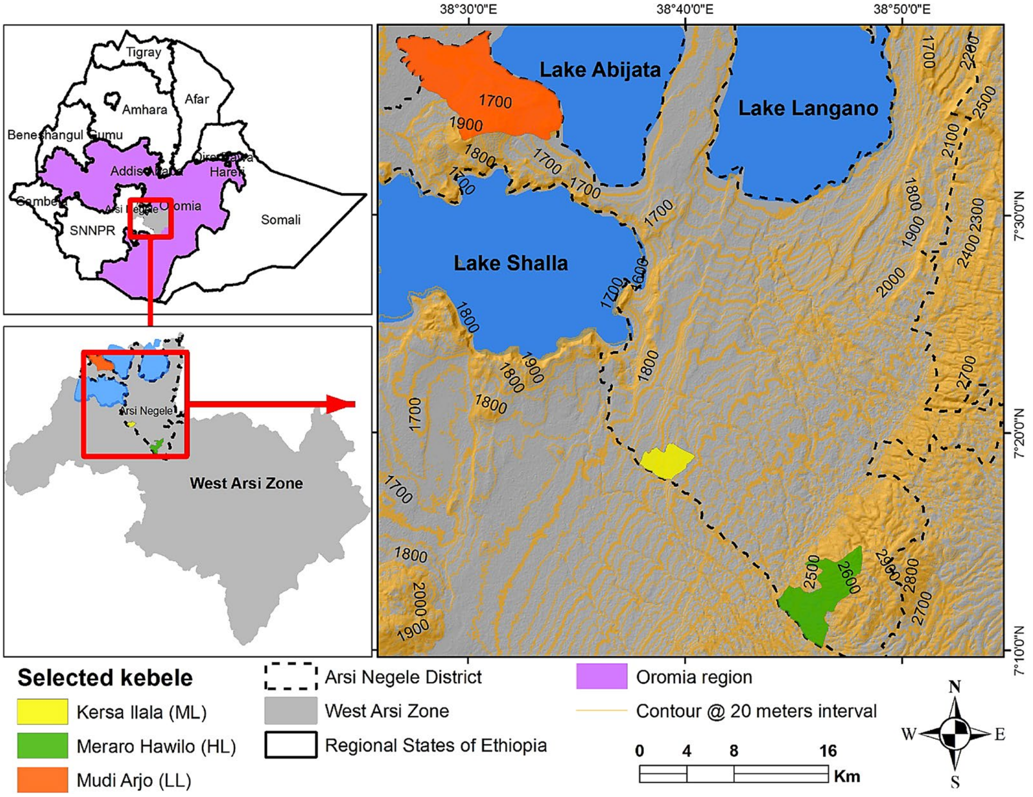

**Fig. 1** Map of the three study sites in Arsi Negele District, West Arsi Zone

## Results and discussion

### Smallholder farmers' perceptions of climate change

The result in Fig. 2 is based on the household survey regarding the perceptions and experience of climate change impacts by farmers in the different agro-ecological zones of the Arsi Negele district. In addition, the focus group discussions and key informant interviews show that up until 20 years ago, rainfall in the study area had a more regular pattern and was more predictable and also generally sufficient in all seasons for crop and livestock production. However, now the rainfall pattern has become unpredictable with a shorter duration for both short and long rainy seasons. The household survey results in Fig. 2 show that about 90% of the respondents perceived a long-term variability in weather and change in the climate in the study area over the last two decades, whereas the response from the remaining 10% of the respondents indicate that they did not perceive any change in climate in the same period. The results hold true across the three *Kebeles*. With respect to temperature variability and change, the respondents reported a change in temperature. The majority of the respondents (68.5%) perceived that the temperature had been increasing while 12.3% of the households perceived the temperature had been decreasing. However, 12.6% of the households had not observed any change, and 6.2% of respondents perceived that the temperature remained constant. Similarly, nearly 85% of households perceived that the rainfall amounts were declining. In

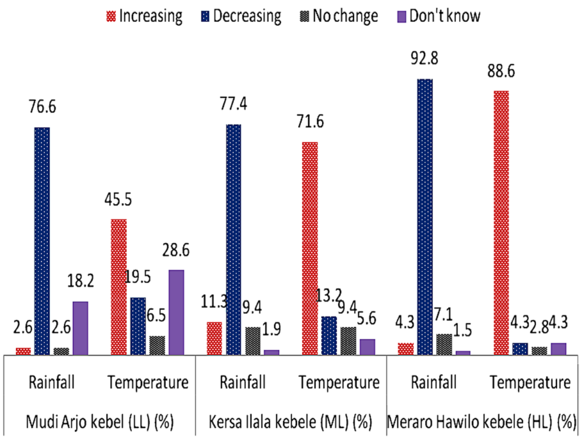

**Fig. 2** Smallholder farmers' perceptions about current climate change and variability

general, increase in temperature and decrease in precipitation were found to be the predominant climate-related changes perceived by smallholder farmers in the study area. The key informant interviews and focus group discussions indicated that over the last two decades, either early or late on set of rainy seasons, unexpected rainfall, declining rainfall, and extreme day and night temperature were common across the agro-ecological zones in the district. This result is in line with previous studies in Central Rift Valley that underlined frequency of drought and intensity of floods; where the annual and seasonal rainfall variability amounts to between 50 and 80%, while temperature has been increasing by 0.37 °C every 10 years, and the maximum daily temperature has increased by 1.5 °C over the last century [38]. The rainfall and mean temperature changes significantly vary within the area [19].

In addition to their perception, farmers indicated diverse sources of information regarding climate variability and change. Survey respondents were asked the question "what is your most preferred source of climate change information?" Results in Table 3 show that the majority of the respondents (40%) became aware of climate change as well as its impacts through their own experience and understanding. The contribution of diverse means of formal communication is also significant. Formal communication as a source of information is mentioned by more than 50% of the respondents. In this regard, the role of research organizations, mass media, agricultural extension agents, and seminars is underscored. Informal communication among the farmers themselves is also reported as an important source of information (Table 3).

**Table 3 Primary sources of information about climate change and its impacts**

| Climate change information sources | Percent |
|---|---|
| Own understanding | 40 |
| From researchers | 10 |
| From radio broadcasting | 18 |
| Development agent | 15 |
| Seminar/meeting | 12 |
| From other farmers | 5 |
| Total | 100 |

### Impact of climate change on smallholder farming

In the Central Rift Valley of Ethiopia, it is not only the presence of climate variability and change that is perceived by smallholder farmers, but also its impacts. The farmers indicated that climate change had caused prolonged drought, and high incidence of pests and diseases, that negatively affected livestock and crop production. This is emphasized by results from key informant interviews, focus group discussions and the household survey. Direct observations made during the data collection in 2015 show that the short rainy season (March, April and May), that is used for cultivation of some crops had elapsed without any cultivation activity. In some areas, attempts made by farmers to cultivate within the short rains were unsuccessful and farms with dried-up maize, sorghum and potato were seen everywhere due to the rains that began earlier than the expected time and ended immediately after sowing and first weeding of the young crop. Even in those farms that survived the extended drought, crops appeared physiologically less vigorous. As a result, the productivity of major crops had been declining progressively over the last two decades. Farmers mentioned that the erratic planting season forced them to discontinue crop planting. Even during the main rainy season (June, July, August and part of September), some farms were left uncultivated due to the late onset of the main rainy season, which started unusually late and recorded low rainfall amounts. As a result, both livestock and crop production activities were severely affected making it difficult for farmers to maintain food security. The majority of the households were therefore forced to depend on food aid programs from the government, especially in the lowland and mid-altitude agro-ecological zones. The farming situation in the highland agro-ecological zone was relatively more favorable than that of the mid-altitude and lowland area. The highland area of the district receives higher rainfall and farmers have relatively more fertile soils with a good potential for growing a variety of crops. However, 87.5% of households indicated that they were extremely worried about climate change and its impact and only 12.5% of the respondents were not concerned about climate change-related risks. Notably, 31.5% of the respondents clearly indicated that climate change and variability brought about reduction in crop yields (Fig. 3). Changes in the distribution and amount of rainfall have affected the agricultural system in the area such that it receives lower rainfall and faces more frequent drought [21].

### Climate change adaptation strategies by smallholder farmers

Based on the focus group discussions and key informant feedback, the smallholder farmers in the Central Rift Valley of Ethiopia have been using different strategies to respond to climate variability. Farm households were asked about their primary adaptation strategies in the face of climate change and variability. The results reported by smallholder farmers from the three

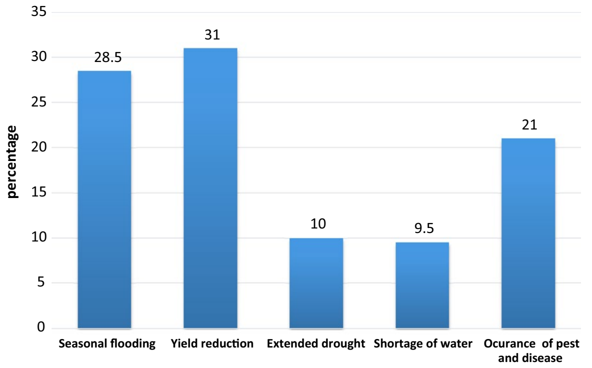

**Fig. 3** Impact of climate change on smallholder farming activities in the study area

agro-ecological zones of the district are presented in Table 4.

The results in Table 4 show that the most important practice farmers used to reduce the impacts of climate change particularly in the lowland, was to change crop planting dates and crop varieties. In case of extreme drought, the farmers migrated to the highland areas for some time. Currently, storage of crop residues (maize straw) as an emergency feed in dry periods is a common practice. In addition, maintenance of grain reserves, crop diversification, and using early maturing crop varieties were some of the adaptation mechanisms. Similarly, in the highlands, smallholder farmers used various adaptation strategies to climate change. Here, crops like barley, peas and beans were performing poorly and some farmers had already reduced the portion of land allocated for such crops. In some cases, farmers had already stopped their production. On the other hand, majority of the farmers opted to grow other crops like teff and maize, which used to be typical midland agro-ecology crops. Nevertheless, the productivity of these new crops was reported to be low. In addition, cultivation of drought tolerant crops such as Enset (*Ensete ventricosum*) as a source of both food and livestock feed was becoming popular.

**Table 4 Primary adaptation strategies to climate change and the proportion of respondents that practiced them**

| Adaptation strategies | Number of households | Percent of households |
|---|---|---|
| Change in planting date | 20 | 10 |
| Crop diversification | 45 | 23 |
| Intensive use of agricultural inputs | 29 | 14 |
| Crop and livestock integration | 16 | 8 |
| Supplementary irrigation | 5 | 3 |
| Soil and water conservation | 23 | 11 |
| Tree planting | 32 | 16 |
| No adaptation strategy used | 30 | 15 |
| Total | 200 | 100 |

Other adaptation strategies include intensification of agricultural production by using more inputs especially fertilizer per unit area, fruit and fodder tree planting, soil and water conservation practices, and using crop residues as livestock feed. This is in line with previous studies by Melka et al. [39], and Mukheibir and Ziervogel [40]. The results in Table 4 show that among the adaptation strategies practiced by smallholder farmers in the study area, crop diversification was practiced by more households, whereas only a few respondents practiced irrigation. Even though there are lakes in some parts of the study area, they are inaccessible for irrigation because there was need for high capital investments in designing the irrigation infrastructure. Few farmers were practicing irrigated farming from small rivers and underground water (boreholes). The majority of the households practiced crop diversification due to the campaign made by agricultural extension services from the local government and NGOs. The increased planting of trees was mainly to provide natural shade for their livestock and crops on-farm during the extended dry periods. Soil and water conservation techniques were used to avoid the risk of flooding as well as improve soil moisture and organic matter retention. However, most of the farmers were not applying any of the aforementioned adaptation strategies because of certain constraints (Table 5). The respondents articulated the need to integrate tree planting, crop production and livestock production as a package of climate smart agriculture [11, 12]. It also calls for provision of adequate information to ensure that farmers receive up to date weather forecasts. This is important for decision making to either use early and late planting as an adaptation strategy by farmers.

The results in Table 4 show that although diverse climate change adaptation strategies exist in the area, the farmers were not practicing them to their full potential due to constraints. The major constraint was the low level of education. About 17% of the respondents reported a low level of education as the major constraint to adaptation to climate change (Table 5). This was followed by shortage of labor, lack of access to information through mass media, shortage of farm implements, and financial constraints, respectively. Lack of sufficient money hindered farmers from getting the necessary agricultural inputs. Also the farmers did not have sufficient family labor and were not able to employ laborers. Shortage of farmland has been associated with the limited capacity of farmer to intensify their agricultural production.

**Table 5 Farmers' primary constraints to adapting to the changing climate**

| List of constraints | Total number of respondents | Respondents in % |
|---|---|---|
| Lack of climate forecasting information | 18 | 9 |
| Poor potential for irrigation | 22 | 11 |
| Lack of contact with extension personnel | 10 | 5 |
| Shortage of farm land | 14 | 7 |
| Shortage of labor for implement adaptation | 28 | 14 |
| Exposure or access to mass media | 26 | 13 |
| Shortage of necessary farm inputs | 26 | 13 |
| Low level of education | 34 | 17 |
| Shortage of money | 22 | 11 |
| Total | 200 | 100 |

Although irrigation has been practiced in the area for vegetable production, its extent is still limited and also does not apply to field crops. This is associated with the inability of farmers to use both surface and ground water due to limited technological and financial capacity. In this regard, farmers who used underground water for irrigation for vegetable production mentioned that they dug shallow wells of about 5–10 m deep. But they mentioned that underground water tables were receding progressively and they needed to dig deeper beyond 15 m, which needed specialized equipment and technology beyond their reach.

### Determinants of farmers' choices of adaptation strategies to climate change

A MNL model was employed to estimate the determinants of farmers' choices of adaptation practices to reduce the impact of climate change. In this analysis, "no adaptation option" was used as base category and the estimated coefficients compared with the base category. The likelihood ratio statistics indicated by the Chi-square test were found to be significant as indicated in Table 6. Then the model was tested for the validity of the independence of irrelevant alternatives using assumptions by Hausman specification test procedure. The use of the MNL model specification was found to be appropriate, and model has been used previously by different studies to estimate the determinants of climate change adaptation options by smallholder farmers [14, 15, 36, 41, 42]. The problem of multicolinearity among the explanatory variables was tested using variance inflection factor and Contingency Coefficient for continuous and dummy explanatory variables, respectively. In both cases, no problem of multicolinearity was detected. Hence, the parameter estimates of the MNL model were used to provide the direction of the effect of the independent variables on the dependent (response) variable, whereas estimates represent neither the actual magnitude of change nor the probabilities (Table 6). The marginal effects of marginal probabilities are a function of probabilities and measures expected to change within the probabilities. Particularly, adaptation choices are made by changing the independent variable from the mean [35]. In the following section, only the variables that were statistically significant at less than or equal to 10% probability levels are interpreted and discussed. Table 7 presents the marginal effects along with levels of statistical significance.

The results in Table 6 show that being a male-headed household increased the likelihood of tree planting, integrating crops with livestock, and soil and water conservation as adaptation strategies at 5 and 1% significance levels compared to the base category. Specifically, the results show that being a male-headed household increased the probability of tree planting by 31%, crop livestock integration by 8%, and soil and water conservation by 12% as climate change adaptation strategies (Table 7). As hypothesized, male-headed households had better opportunities to practice adaptation measures than the female-headed households. This finding is similar to a study by Deressa et al. [43] done in another part of Ethiopia that analyzed farmer's choices of climate change adaptation methods, which showed that male-headed households could be more likely to have access to technologies and climate change information than female-headed households. As a result, they were in a better position to practice diverse adaptation strategies than the female-headed ones [44].

The age of the household head had positively impacted the decision to practice some of the adaptation strategies and negatively in the case of others (Table 6). In this regard, age is positively related with the decision to intensify agricultural inputs. This means that as the age of the household head increases by a year, the probability of the households practicing agricultural intensification increases by 9%. However, the household head is not highly related with the probability of the household adapting to climate change by tree planting. This means that as the age of the household head increases by one year, the probability of the household planting trees will increase by 2.2% (Table 7). According to the findings, a unit increase in age of the household head resulted in a 9% increase in the probability of practicing soil and water conservation, whereas it resulted in a 12% increase in the practice of changing crop varieties as a climate change adaptation strategy.

The result in Table 6 shows that education has a positive effect on farmers' adaptation strategies and hence,

**Table 6 Parameter estimates of multinomial logit model for climate change adaptation decision**

| Explanatory variable | Crop diversification | Changing input use intensity | Change planting date | Tree planting | Integrating crop with livestock | Soil and water conservation |
|---|---|---|---|---|---|---|
| Sex | 1.030<br>(0.205) | 1.067<br>(0.224) | −0.032<br>(0.212) | −1.823*<br>(0.031) | 4.033<br>(0.983) | 4.298<br>(0.981) |
| Age | −0.042<br>(0.047) | 0.053*<br>(0.024) | 0.1764<br>(0.830) | −1.056*<br>(0.032) | −0.041<br>(0.173) | −0.041<br>(0.105) |
| Education | 0.054<br>(0.503) | 1.223**<br>(0.003) | 1.046*<br>(0.065) | 0.018*<br>(0.092) | −0.010<br>(0.922) | 0.010*<br>(0.092) |
| HH size | 0.0487<br>(0.458) | 0.089<br>(0.194) | 0.017<br>(0.830) | 0.080<br>(0.292) | 0.149*<br>(0.053) | 0.149*<br>(0.053) |
| Farming experience | 0.305<br>(0.025) | −0.015<br>(0.058) | 0.441<br>(0.025) | −0.024<br>(0.94) | 0.024<br>(0.943) | −0.037<br>(0.230) |
| Farm size | 0.290<br>(0.005) | 0.221<br>(0.508) | 0.368<br>(0.245) | 0.284<br>(0.401) | 0.284**<br>(0.040) | 0.356<br>(0.261) |
| Income | 0.215<br>(0.014) | 0.308<br>(0.016) | 0.019<br>(0.629) | 0.052**<br>(0.0286) | 0.052*<br>(0.065) | 0.011<br>(0.706) |
| Access to market | −0.071<br>(0.879) | 0.107*<br>(0.070) | −1.111<br>(0.161) | −0.042<br>(0.933) | −1.096<br>(0.221) | 0.406<br>(0.250) |
| Access to climate information | 2.370***<br>(0.000) | 3.233**<br>(0.001) | 2.048*<br>(0.018) | 3.949*<br>(0.024) | 3.949*<br>(0.024) | 2.822**<br>(0.006) |
| Access to extension | 3.087***<br>(0.000) | 1.999<br>(0.022) | 2.336<br>(0.051) | 2.508<br>(0.025) | 6.725<br>(0.991) | 2.483<br>(0.071) |
| Livestock ownership | 0.107<br>(0.070) | 0.111<br>(0.057) | 0.112**<br>(0.055) | 0.110*<br>(0.061) | 0.086*<br>(0.021) | 0.117**<br>(0.045) |
| Constant | −2.455<br>(0.043) | −1.717*<br>(0.078) | −1.884<br>(0.118) | −2.047<br>(0.997) | 2.504*<br>(0.042) | −16.252<br>(0.991) |
| Base category | No adaptation option | | | | | |
| Number of observation | 200 | | | | | |
| Prob > $\chi^2$ | 0.000 | | | | | |
| Log likelihood | −198.524 | | | | | |
| Pseudo *R* square | 0.590 | | | | | |

***, **, * Significant at 1, 5, and 10% probability level, respectively

it significantly increases adaptation options with a 1% probability level. The marginal effect in Table 7 shows that a unit increase in number of years of education could increase by 2% of the likelihood of adopting crop diversification, 1.4% change in planting date, 3.1% tree planting and 2% integrating crop with livestock production as adaptation measures. This is because educated farmers are expected to adopt new technologies based on their awareness of the potential benefits from the proposed climate change adaptation measures [15].

Family size has a significant and positive effect on climate change adaptation, increasing the probability ($p < 0.01$) of planting food and fodder trees, integrating crop with livestock, and soil and water conservation measures (Table 6). The marginal effect result in Table 7 shows that a unit increase in productive family members increases the likelihood of adopting the aforementioned adaptation strategies by 1.3, 2.35 and 4%, respectively. According to Kurukulasuriya and Mendelsohn [29] and Gbetibouo [45], the probable reason is that larger family size and a larger number of productive household members increase agricultural production because it is associated with labor-intensive agricultural practices. Thus, household size has a significant association with some of the adaptation categories.

The result in Table 6 show that farming experience has a positive effect on some climate change adaptation strategies. It helped to stimulate response to the negative effects of climate change on agriculture. This is because more experienced farmers are assumed to have better knowledge about weather information and its implication on agricultural practices.

Farm size has a positive and significant association with most of the adaptation strategies. That is, as the size of farmland increases, the probability of planting different fodder trees and integrating crop with livestock production increases. Farm size has therefore positively and significantly increased the likelihood of adaptation to climate change [37]. Furthermore, large farm sizes provide an opportunity for diversification of their crop and

**Table 7 Marginal effect due to independent variables**

| Explanatory variable | Crop diversification | Changing input use intensity | Change planting date | Tree planting | Integrating crop with livestock | Soil and water conservation |
|---|---|---|---|---|---|---|
| Sex | 0.127<br>(0.173) | 0.091<br>(0.227) | −0.049<br>(0.540) | 0.311**<br>(0.002) | 0.078***<br>(0.000) | 0.118***<br>(0.000) |
| Age | −0.028<br>(0.968) | −0.0026<br>(0.802) | 0.0010*<br>(0.069) | 0.022<br>(0.785) | −0.0008<br>(0.995) | −0.0001<br>(0.175) |
| Education | 0.02*<br>(0.096) | 0.014<br>(0.761) | 0.031*<br>(0.084) | 0.020*<br>(0.068) | 0.001*<br>(0.098) | 0.001<br>(0.988) |
| Family size | 0.027<br>(0.935) | 0.007<br>(0.868) | 0.004<br>(0.797) | 0.013*<br>(0.089) | 0.023*<br>(0.018) | 0.04*<br>(0.098) |
| Farming experience | 0.062<br>(0.045) | 0.132<br>(0.431) | −1.800**<br>(0.021) | 0.037*<br>(0.044) | 1.44e−06<br>(0.32) | −0.001<br>(0.473) |
| Farm size | 0.200*<br>(0.028) | 0.017<br>(0.535) | 0.013*<br>(0.059) | 0.024<br>(0.324) | .0015*<br>(0.036) | .0129*<br>(0.081) |
| Income | 0.002<br>(0.492) | 0.008**<br>(0.002) | 0.008<br>(0.891) | 0.008<br>(0.636) | 0.004*<br>(0.057) | 2.08e−06*<br>(0.0172) |
| Access to market | 0.026*<br>(0.040) | 0.027*<br>(0.024) | −0.096<br>(0.860) | −0.022<br>(0.958) | 0.028<br>(0.991) | 0.106<br>(0.250) |
| Access to climate information | 0.070*<br>(0.052) | 0.156<br>(0.021) | 0.390**<br>(0.0059) | 0.327***<br>(0.0016) | 0.649***<br>(0.000) | 0.425***<br>(0.000) |
| Access to extension | 0.185*<br>(0.094) | 0.240*<br>(0.086) | 0.193*<br>(0.082) | 0.055*<br>(0.061) | 0.074***<br>(0.000) | 0.354*<br>(0.056) |
| Livestock ownership | 0.100<br>(0.926) | 0.018<br>(0.753) | 0.095**<br>(0.006) | 0.125<br>(0.812) | 0.051**<br>(0.0091) | 0.008**<br>(0.005) |

***, **, * Significant at 1, 5, and 10% probability level, respectively

livestock enterprises, and it can help to distribute risks associated with unpredictable weather.

The results in Table 6 show that income of households has a positive and significant effect on changing farm input use intensity, integrating crops with livestock, and water conservation practices at a 10% level of significance. The marginal effect result in Table 7 shows that a unit increase in household income can increase the likelihood of use of necessary farm inputs and soil and water conservation practices by 0.8%. This finding is consistent with a study by Negash [42] which found that income has a positive relation with soil conservation measures, changes in planting date and use of crop diversification.

Access to input and output markets has a positive and significant effect on farmer input intensity and crop diversification at 10% significance level (Table 6). Easy access to input and output market increases the likelihood of changing input use intensity and crop diversification by 2.6% (Table 7). Market access could help farmers to buy fertilizer, pesticides, and improved crop varieties.

Access to climate information is an important variable that affects adaptation options. The results in Table 6 show that as expected, access to climate information had impacted adaptation to climate change. That is, a farmer who had better access to weather information (i.e., seasonal or mid-term forecasting) made better informed adaptation decision. Smallholder farmers who had access to weather information had a higher probability of implementing climate change adaptation strategies such as late and early planting, use of early maturing crops, planting food and fodder trees, and soil and water conservation measures at 1% level of significance. Being well informed about rainfall and temperature variability increased the likelihood of shifting planting date adjustments by 39% (Table 7). These findings are similar to the findings from various studies [15, 37, 39, 42, 46].

The result in Table 6 indicates that access to extension is positively and significantly related with adaptation options. As expected by the researchers, access to extension services increases the probability of adopting different adaptation practices. Having access to extension packages increased the likelihood of implementing soil and water conservation by 35.4%, tree planting by 5%, crop diversification by 18.55% and changing planting date by 19.3% (Table 7). In this regard, the result from the descriptive statistics shows that about 94% of the households had the opportunity to use crop and livestock extension packages. According to Nhemachena [47], better access to crop and livestock extension services has a strong and positive impact on climate adaptation strategies.

Livestock and crop production are the main economic activities in the area. The result in Table 6 indicated that livestock production has a positive association with the adoption of climate change adaptation strategies such as adjustment of planting season, integrating crops with livestock rearing and soil and water conservation practices at 5% level of significance. A number of studies have shown that livestock ownership has a positive association with the adaptation measures aforementioned [42, 48, 49]. However, the number of livestock is found to be negatively related with crop diversification, planting date adjustment and other agronomic activities [29].

## Conclusions

The results show that the majority of the farmers have perceived changes in rainfall and experienced the effects of a changing climate over a period of two decades. That is, extended dry periods and declining precipitation are more frequent across the agro-ecologies in the district. As a result, both livestock and crop production by smallholder farmers have already been adversely affected. The farmers are trying to adapt through the use of improved agricultural practices like increasing on-farm tree planting, soil and water conservation, adjustment of planting dates, crop diversification, improved crop varieties, and use of agricultural inputs like fertilizers and pesticides. Farmers' capacity to choose effective adaptation options is influenced by household demography, as well as positively by farm size, income, access to markets, access to climate information and extension, and livestock production. This implies the need to support the indigenous adaptation strategies of the smallholder farmers with a wide range of institutional, policy, and technology support, some of it targeted on smaller, poorer or female-headed households. In this case the role of government and NGOs is imperative. As the rainy seasons are recently becoming more and more unpredictable and uncertain, depending on rainfed agriculture in the area is less unlikely and hence policy driven actions to provide irrigation facilities based on both ground and surface water are vital. Moreover, creating opportunities for non-farm income sources is important as this helps them to engage in those activities that are less sensitive to climate change. Furthermore, providing climate change information, extension services, and creating access to markets are crucial. Therefore, including these activities in the existing formal extension channels of the Ministry of Agriculture and other line ministries will be useful to farmers.

### Abbreviations

GDP: gross domestic product; m.a.s.l.: meters above sea level; MNL: multinomial logit; NGOs: non-governmental organisations.

### Authors' contributions

AB designed the data collection tools, undertook fieldwork and most of the analysis, and developed the manuscript. JR contributed in developing the data collection tools, survey design and writing of the manuscript. TW and JM contributed to the research design, analysis, reviewed and made editorial comments on the draft manuscript. All the authors read and approved the final manuscript.

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### Acknowledgements

The authors are grateful for the financial support from the Department for International Development (DfID) under the Climate Impact Research Capacity and Leadership Enhancement (CIRCLE) programme for this study. They are also grateful to the International Livestock Research Institute (ILRI), for hosting the CIRCLE Fellow, within the CGIAR Research Program for Climate Change, Agriculture and Food Security (CCAFS). In addition to that the authors would like to acknowledge Wondo Genet College of Forestry and Natural Resource, Hawassa University for the necessary support during the field work.

### Competing interests

The authors declare they have no competing interests.

### Consent for publication

The authors obtained permission from all participants in Arsi Negelle district, to publish their data.

### Ethical approval and consent to participate

Consent to participate was received from everyone interviewed in Arsi Negelle district, Ethiopia. A research committee from Ethiopia's Hawassa University and the International Livestock Research Institute (ILRI) was informed of the study.

### Funding

This project was funded by Department for International Development (DfID) and the Climate Impact Research Capacity and Leadership Enhancement (CIRCLE) programme.

Received: 13 April 2016 Accepted: 21 February 2017

### References

1. Stern NH. Stern review: the economics of climate change, vol. 30. London: HM Treasury; 2006.
2. Pachauri RK, Allen MR, Barros VR, Broome J, Cramer W, Christ R, Church JA, Clarke L, Dahe Q, Dasgupta P, Dubash NK, Edenhofer O, Elgizouli I, Field CB, Forster P, Friedlingstein P, Fuglestvedt J, Gomez-Echeverri L, Hallegatte S, Hegerl G, Howden M, Jiang K, Jimenez Cisneroz B, Kattsov V, Lee H, Mach KJ, Marotzke J, Mastrandrea MD, Meyer L, Minx J, Mulugetta Y, O'Brien K, Oppenheimer M, Pereira JJ, Pichs-Madruga R, Plattner GK, Pörtner HO, Power SB, Preston B, Ravindranath NH, Reisinger A, Riahi K, Rusticucci M, Scholes R, Seyboth K, Sokona Y, Stavins R, Stocker TF, Tschakert P, van Vuuren D, van Ypserle JP. Climate change 2014: synthesis report. In: Pachauri R, Meyer L, editors. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC; 2014. p. 151. ISBN:978-92-9169-143-2.
3. Dasgupta P, Morton JF, Dodman D, Karapinar B, Meza F, Rivera-Ferre MG, Toure Sarr A, Vincent KE. Rural areas. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL, editors. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge; 2014. p. 613–57.

4. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge; 2007. 996 pp.
5. Niang I, Ruppel OC, Abdrabo MA, Essel A, Lennard C, Padgham J, Urquhart P. Africa. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL, editors. Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge; 2014. p. 1199–265.
6. Bankoff G. A history of poverty: the politics of natural disasters in the Philippines, 1985–1995. Pac Rev. 1999;12(3):381–420.
7. Anderson S, Morton J, Toulmin C. Climate change for agrarian societies in drylands: implications and future pathways. In: Mearns R, Norton A, editors. Social dimensions of climate change: equity and vulnerability in a warming world. World Bank Publications; 2010. p. 199–230.
8. Amsalu A, Gebremichael D. An overview of climate change impacts and responses in Ethiopia in 2009. In: Forum for Environment: Addis Ababa, Ethiopia; 2010.
9. Boko M, Niang I, Nyong A, Vogel C, Githeko A, Medany M, Osman-Elasha B, Tabo R, Yanda P. Africa. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Climate change: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge; 2007. p. 433–67.
10. Otto FE, Boyd E, Jones RG, Cornforth RJ, James R, Parker HR, Allen MR. Attribution of extreme weather events in Africa: a preliminary exploration of the science and policy implications. Clim Change. 2015;132(4):531–43.
11. McCarthy N, Lipper L, Branca, G. Climate-smart agriculture: smallholder adoption and implications for climate change adaptation and mitigation. Mitigation of Climate Change in Agriculture Working Paper No. 3; 2011.
12. Adger WN, Huq S, Brown K, Conway D, Hulme M. Adaptation to climate change in the developing world. Prog Dev Stud. 2003;3:179–95.
13. Morton J. The impact of climate change on smallholder and subsistence agriculture. Proc Natl Acad Sci. 2007;104:19680–5.
14. Deressa TT, Hassan RM, Ringler C, Alemu T, Yusuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Change. 2009;19(2):248–55.
15. Hassan R, Nhemachena C. Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. Afr J Agric Resour Econ. 2008;2:83–104.
16. National Meteorological Services Agency (NMSA). Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia. NMSA, Ministry of Water Resources, Federal Democratic Republic of Ethiopia, Addis Ababa; 2007.
17. National Meteorological Services Agency (NMSA). Initial National Communication of Ethiopia to the UNFCCC. NMSA, Ministry of Water Resources, Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia; 2001.
18. Webb P, Von Braun J, Yohannes Y. Famine in Ethiopia: policy implications of coping failure at national and household levels, vol. 92. Washington DC: International Food Policy Research Institute; 1992.
19. Gizachew L, Shimelis A. Analysis and mapping of climate change risk and vulnerability in Central Rift Valley of Ethiopia. Afr Crop Sci J. 2014;22(Issue Supplement s4):807–18.
20. Belay A, Bekele T, Ewunetu, Z. Analysis of climate variability and its economic impact on agricultural crops: The case of Arsi Negelle District, Central Rift Valley of Ethiopia. Open Sci Repos Agric. 2013; e70081993. doi:10.7392/openaccess.70081993.
21. Kassie BT, Rötter RP, Hengsdijk H, Asseng S, Van Ittersum MK, Kahiluoto H, Van Keulen H. Climate variability and change in the Central Rift Valley of Ethiopia: challenges for rain-fed crop production. Climate Change & Agriculture Research Paper, Journal of Agricultural Science, Page 1 of 17. Cambridge University Press; 2013.
22. Bezabih E, Hadera G, Nigatu R. Impacts of improved seeds and agro-chemicals on food security and environment in the Rift Valley of Ethiopia: implications for the application of an African Green Revolution. Dry lands Coordination Group Report No. 56 02, 2010, DCG c/o, MiljøhusetG9. Oslo. Norway; 2010.
23. The Oromia Regional State Government (ORS). Socio Economic Profile of East Shoa Zone; 2004.
24. Central Statistical Agency (CSA). Report of population and housing census: Addis Ababa, Ethiopia; 2007.
25. Lema MA, Majule AE. Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: the case of Manyoni District in Singida Region, Tanzania. Afr J Environ Sci Technol. 2009;3(8):206–18.
26. Yanda PZ, Olson J, Moshy P. Climate change vulnerability impacts and adaptation in Tanzania. CLIP Working Paper, Institute of Research Assessment, University of Dares Salaam, Tanzania; 2009.
27. Neuman WL. Social research methods: quantitative and qualitative approaches, vol. 13. Boston: Allyn and Bacon; 2005.
28. Samuel B. How many subjects does it take to do regression analysis?. Washington: University of Kansas Agency; 1991.
29. Kurukulasuriya P, Mendelsohn R. Crop switching as a strategy for adapting to climate change. Afr J Agric Resour Econ. 2008;2(1):105–26.
30. Abid M, Scheffran J, Schneider UA, Ashfaq M. Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. Earth Syst Dyn. 2015;6(1):225–46.
31. Maddala GS. Limited-dependent and qualitative variables in econometrics (No 3). Cambridge: Cambridge University Press; 1986.
32. Wooldridge JM. Inverse probability weighted M-estimators for sample selection, attrition, and stratification. Port Econ J. 2002;1(2):117–39.
33. Deressa TT, Hassan RM, Ringler C. Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. J Agric Sci. 2011;149(01):23–31.
34. Gujarati D. Basic econometrics. 4th ed. New York: McGraw Hill; 2004.
35. Greene WH. Econometric analysis. 4th ed. New York: Prentice Hall International Inc; 2000.
36. Kandlinkar M, Risbey J. Agricultural impacts of climate change; if adaptation is the answer, what is the question? Clim Change. 2000;45:529–39.
37. Maddison D. The perception and adaptation to climate change in Africa. Centre for Environmental Economics and Policy in Africa (CEEPA) Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa; 2006.
38. Tsidu GM, Bayable E. Evidences of climate change signal at local scales in Ethiopia. In: Proceedings of the global conference on global warming. 11–14 July. Lisbon, Portugal; 2011.
39. Melka Y, Kassa H, Ketema M, Abebaw D, Schmiedel U. The effect of drought risk perception on local people coping decisions in the Central Rift Valley of Ethiopia. J Dev Agric Econ. 2015;7(9):292–302.
40. Mukheibir P, Ziervogel G. Developing a municipal adaptation plan (MAP) for climate change: the city of Cape Town. Environ Urban. 2007;19(1):143–58.
41. Di Falco S, Veronesi M, Yesuf M. Does adaptation to climate change provide food security micro perspective from Ethiopia? Am J Agric Econ. 2011;93(3):825–44.
42. Negash, M. Analysing the determinants of farmers' preference for adaptation strategies to climate change: evidence from north Shoa zone of Amhara region, Ethiopia. Doctoral dissertation; 2011.
43. Deressa T, Hassan RM, Alemu T, Yesuf M, Ringler C. Analyzing the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia. Washington DC: International Food Policy Research Institute; 2008.
44. Demetriades J, Esplen E. The gender dimensions of poverty and climate change adaptation. In: Mearns R, Norton A, editors. Social dimensions of climate change: equity and vulnerability in a warming world. Washington DC: World Bank; 2010. p. 133–144.
45. Gbetibouo GA. Understanding farmers' perceptions and adaptations to climate change and variability: the case of the Limpopo Basin, South Africa, vol. 849. Washington DC: International Food Policy Research Institute; 2009.
46. Advancing Capacity to Support Climate Change Adaptation (ACCCA). Improving decision-making capacity of smallholder farmers in response to climate risk adaptation in three drought prone districts of Tigray, northern Ethiopia. In: Farm level climate-change perception and adaptation in drought prone areas of Tigray, Northern Ethiopia. Project No. 093; 2010.

47. Nhemachena C. Agriculture and future climate dynamics in Africa: impacts and adaptation options. PhD dissertation, University of Pretoria, South Africa; 2009.
48. Kide, GT. Smallholder farmers' adaptation strategies to climate change in Ethiopia: evidence from Adwa Woreda of Tigray Region. PhD dissertation, Mekelle University; 2014.
49. Yesuf M, Di Falco S, Deressa T, Ringler C, Kohlin G. The impact of climate change and adaptation on food production in low-income countries: evidence from the Nile Basin. Ethiopia: International Food Policy Research Institute; 2008.