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# Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia

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## Abstract

**Introduction:** This study is aimed at analyzing farmers' perception and adaptation to climate change in the Dabus watershed. It is based on analysis of data collected from 734 randomly selected farm household heads substantiated with Focus Group Discussions and field observations.

**Methods:** The study employed descriptive methods to assess farmers' perception of climate change, local indicators of climate change and types of adaptation measures exercised to cope up with the risk of the change in climate. The study also employed the Heckman sample selection model to analyze the two-step process of adaptation to climate change which initially requires farmers' perception that climate is changing prior to responding to the changes through adaptation measures.

**Results:** Based on the model result educational attainment, the age of the head of the household, the number of crop failures in the past, changes in temperature and precipitation significantly influenced farmers' perception of climate change in wet lowland parts of the study area. In dry lowland condition, farming experience, climate information, duration of food shortage, and the number of crop failures experienced determined farmers' perception of climate change. Farmers' adaptation decision in both the wet and dry lowland conditions is influenced by household size, the gender of household head, cultivated land size, education, farm experience, non-farm income, income from livestock, climate information, extension advice, farm-home distance and number of parcels. However, the direction of influence and significance level of most of the explanatory variables vary between the two parts of the study area.

**Conclusions:** In line with the results, any intervention that promotes the use of adaptation measures to climate change may account for location-specific factors that determine farmers' perception of climate change and adaptive responses thereof.

**Keywords:** Climate change, Perception, Adaptation, Heckman sample selection model

## Introduction

Agriculture is the most important sector in Sub-Saharan Africa, but it is predicted to be negatively impacted by climate change (Deressa 2006; Moussa and Amadou 2006; Jain 2006). It is clear that climate change will bring about substantial welfare losses especially for smallholders whose main source of livelihood derives from agriculture. Therefore, there is a need to neutralize the potential adverse effects of climate change if welfare losses to this vulnerable segment of the society are to be averted (Hassan and Nhemachena 2008; Molua and Lambi 2006; Mano and Nhemachena 2006). In Ethiopia, climate change features such as drought, flood, and soil degradation are among the major factors responsible for the low agricultural productivity (Asrat and Simane 2017c; Yirga 2007). These coupled with heavy reliance on traditional farming techniques and poor complementary services (such as extension, credit, marketing, etc.) reduce the adaptive capacity or increase the vulnerability of smallholder farmers to climate change, which in turn affects the performance of the already weak agriculture (Asrat and Simane 2017d).

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Climate variability and change also poses a huge threat to smallholder farmers in the Dabus watershed (the study area) due to overwhelming reliance on climate-sensitive small-scale agriculture, which could also be worsened by prevailing social and economic challenges in the watershed (Asrat and Simane 2017d). Agricultural production is apparently affected by climate-related shock in the area, which is usually manifested by the occurrence of pest and insect infestations as well as land degradation problems. In this regard, adaptation appears to be an efficient and friendly way for farmers to reduce these negative impacts of climate change (Füssel and Klein 2006).

Following IPCC (2007), adaptation to climate change refers to the adjustment in natural or human systems in response to actual or expected climatic stimuli or its effects, which moderates harm or exploits beneficial opportunities. Adaptation can be implemented by smallholder farmers themselves (autonomous adaptation) or by government policies aimed at promoting appropriate and effective adaptation measures (planned adaptation). However, in order to implement appropriate interventions, there is a need to understand location-specific opportunities, challenges, and the key drivers behind adaptation.

Adaptation can also be effected at different scales: individual/farm-level, national level, or international level. Although there is some autonomous adaptation at farm-level, it is usually inadequate and requires the intervention of different institutions (Simane et al. 2016; Semenza et al. 2008; Maddison 2007). Moreover, adaptation at national or international level entails an understanding of the process of location-specific autonomous adaptation at farm-level (Bryan et al. 2009).

Studies (Deresa et al. 2009; Mideksa 2009; Bryan et al. 2009) show that the use of improved crop varieties, agroforestry practices, soil conservation practices, irrigation practices, and adjusting planting dates are the most important adaptation strategies by smallholder farmers. However, adaptation decision is location-specific and influenced by key drivers such as socio-economic, environmental, and institutional factors. Based on Asrat and Simane (2017a) and Deresa et al. (2009), adaptation at farm-level involves two stages: perceiving a change in climate and deciding whether to adopt or not (including which adaptation strategy to use). Nevertheless, perception is not a sufficient condition for adaptation since farmers who have perceived the change in climate may not adapt or the nature of their adaptation response may vary as a result of a complex interplay among social, economic, environmental, and institutional factors (Maharjan et al. 2011; Mertz et al. 2009; Maddison 2007).

Thus, there is a need to understand location-specific drivers of perception and adaptation to climate change among smallholder farmers. This helps to design appropriate policy responses based on the vulnerability and sensitivity level of each location as well as the accessibility of the adaptation methods (Asrat and Simane 2017d; Simane et al. 2016). In this regard, there is a substantial deficit of location-specific information on the process of autonomous adaptation in the developing world including Ethiopia (Asrat and Simane 2017a; McSweeney et al. 2010). There are few research undertakings (Deresa et al. 2011; Di et al. 2011; Deresa et al. 2009), which focused mainly at a large scale (country level, region level, and basin level) and overlooked location-specific factors that drive perception and adaptation to climate change. The findings of these studies are highly aggregated and are of little help in addressing local peculiarities of perception and adaptation to climate change.

Understanding local perceptions and adaptive behavior provides better insights and information relevant to a policy that helps to address the challenge of sustainable agricultural development in the face of variable and uncertain environments (Simane et al. 2016). This study, therefore, will respond to a paucity of empirical information regarding the indicated gaps of knowledge addressing threefold purpose: (i) investigate farmers' perception and adaptation to climate change in the Dabus watershed, (ii) investigate location-specific social, economic, environmental and institutional factors that influence farmers' perception and adaptive decision, and (iii) compare the wet and dry lowland parts of the study area in terms of perception and adaptation to climate change.

## Methods

### Study area

Dabus watershed is part of the Blue Nile River basin and is situated in the North-West Ethiopia (Fig. 1). It has an area of 21,030 km$^2$ and its altitude ranges between 485 and 3150 m above mean sea level. The slope gradient of the study area varies from flat to steep slopes. According to MOA (1998), the area is characterized by two agro-climatic zones: dry lowland (hot to warm moist lowlands) and wet lowland (subhumid lowlands). Based on National meteorological service agency of Ethiopia (2016), the annual rainfall in the area varies between 970 and 1985 mm. The annual maximum and minimum temperature vary between 20–35 °C and 8–20 °C, respectively. The study area encompasses 20 districts with an estimated population size of 206,377 (CSA 2013; CSA 2008).

Agriculture is the main economic activity and source of livelihood in the study area. The farming system is characterized by a mixed crop-livestock production on a subsistence level. A considerable part of the area is cultivated and is dominated by maize-sorghum and maize-sorghum-perennial complex. The area is among the most vulnerable lowland agro-climatic zones to climate

**Fig. 1** Location map of the research area
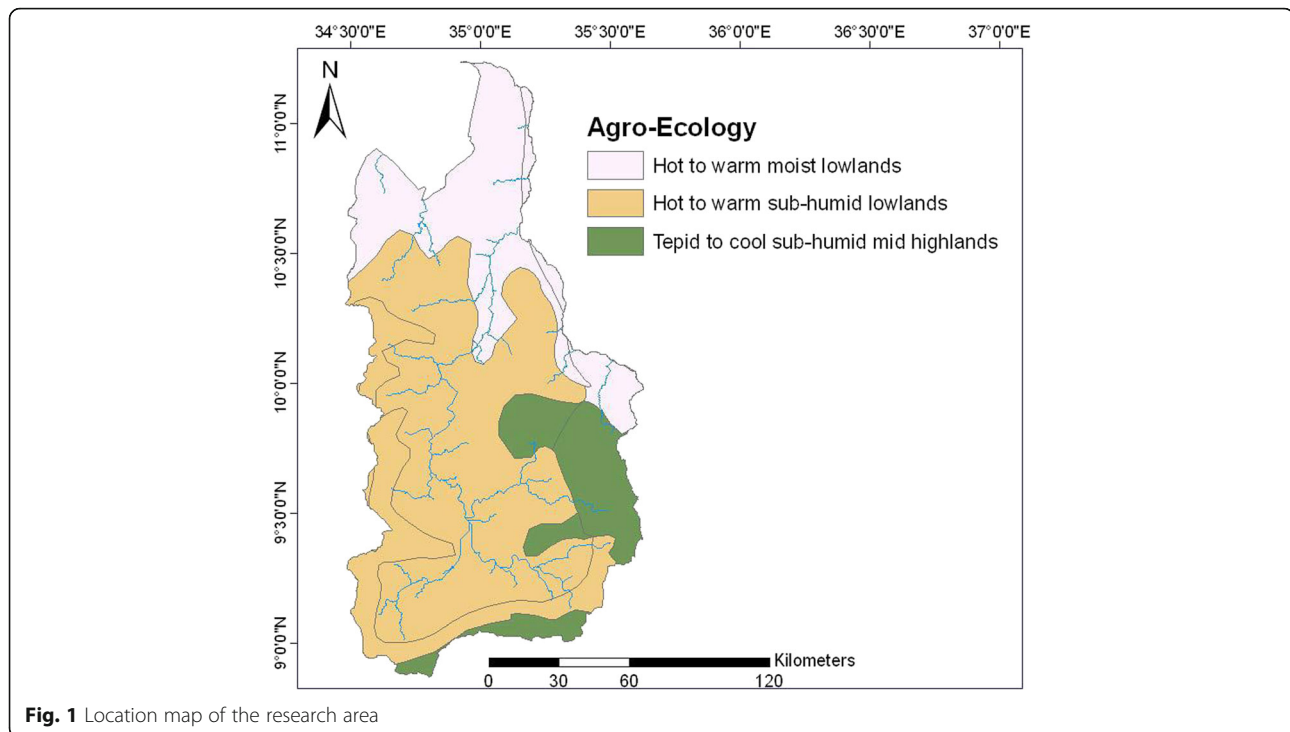
variability and change in Ethiopia (Asrat and Simane 2017d). Climate variability and change poses a huge threat to farmers in the area; the stressful problems being overwhelming reliance on small-scale agriculture, land degradation, and water shortages. The level of climate change impacts varies across the wet and dry lowland parts of the study area. However, the two parts have commonly caused multiple impacts that affect a wide array of ecosystem functions and services and hence possess a challenge on the adaptive capacity of smallholder farmers to climate hazards (BGNRS 2013).

### Data source and methods of data collection

The relevant data to this study were collected from both primary and secondary sources. The primary source is a cross-sectional survey data collected from 734 households in November and December 2016. The primary data majorly include demographic, socioeconomic, institutional, and biophysical attributes. The data also include information on farmers' perception of the patterns of temperature and rainfall over the past 20 years. Survey questionnaires, focus group discussion, and field observation were the data collection methods employed. Household-level data were collected through an open-and close-ended survey questionnaire. Six focus group discussions, each comprising ten persons, were also carried out to substantiate the responses acquired using the questionnaire. The primary data from the field survey were supplemented with data obtained from secondary sources.

### Sampling procedure

The Dabus watershed in the Blue Nile River basin was purposively selected, because this watershed, among others in the basin, is the most vulnerable to climate variability and change (Asrat and Simane 2017d). The households in the watershed were considered as the survey population, and the units of analysis were the heads of households. We followed Kothari (2004) to estimate the minimum sample size for the study from the study population. However, the sample size from this approach is valid only if simple random or systematic random sampling methods are applied. Multistage sampling requires a larger sample size to achieve the same precision. This study used a multistage sampling procedure, and hence, the calculated sample size is multiplied by a design effect based on Cochran (1977) and Daniel (1999). Previous studies of such type (Asrat and Simane 2017c; Daniel 1999) estimated the design effect in a range of 1.5–2. Based on this consideration and observations we made on the study population, a design effect of 1.5 is used.

In the first stage of our multistage sampling, 20 *Woredas* (districts) in the Dabus watershed were stratified into the two agro-climatic zones (wet lowland and dry lowland). In the second stage, four *Woredas* (Assosa and Bambasi from the wet lowland; Mengie and Shrkole from the dry lowland) were randomly selected to represent the agricultural production systems in the study area. From each selected *Woreda*, 3 *Kebeles* (the smallest administrative unit) were randomly selected, and hence, a total of 12 *Kebeles* were

included in the study. Finally, 734 farm households were randomly drawn from the selected *Kebeles* on the basis of probability proportional to size (PPS) sampling procedure.

## Method of data analysis

The data analysis was done by descriptive statistics and econometric model (Heckman's sample selection model) using STATA 12 and SPSS 19. The descriptive statistics were employed to describe farmers' perception of climate shocks, responses implemented to address the shocks, and the constraints faced in implementing the responses. The Heckman's sample selection model was employed to analyze the two-step processes of location-specific adaptation to climate change.

### Models specification

Based on Heckman (1976), when a farmer's decision process about the adoption of a new technology requires more than one step, models with two-step regressions, such as Heckman's sample selection, are appropriate to correct for selection bias generated during the decision-making processes. The Heckman's sample selection model is based on the farmer's utility or profit-maximizing behavior, and the assumption is that a farmer uses a new technology only when the perceived utility or profit from using the new technology is significantly greater than the traditional or the old method.

Similar to technology adoption, adaptation to climate change is a two-step process that involves perceiving that climate is changing and then responding to the change through adaptation measures (Asrat and Simane 2017a; Deresa et al. 2011). Therefore, the Heckman probit selection model is employed in this study to investigate the determinants of perception and adaptation to climate change. The first stage of the model (the selection model) considers whether a farmer perceived a change in the climate, and the second stage of the model (outcome model) explores whether the farmer adapted to climate change conditional on the first stage.

In the two-stage process, the second stage of adaptation is a sub-sample of the first. Thus, it is likely that the second stage sub-sample (those who responded to change) is non-random and necessarily different from the first (which included those who did not perceive climate change), and this creates a sample selection bias (Asrat and Simane 2017a; Deresa et al. 2011). Therefore, the Heckman two-step maximum likelihood procedure was used to correct for this selection bias. The underlying relationship in the Heckman's sample selection model consists of a latent equation given by:

$$y_j = x_j\beta + u_{1j} \tag{1}$$

Such that, we observe only the binary outcome given by the probit model as

$$y_i^{\text{probit}} = (y > 0) \tag{2}$$

The dependent variable is observed only if $j$ is observed in the selection equation

$$y_i^{\text{select}} = z_j\delta + u_{2j} > 0 \tag{3}$$

$$u_1 \sim N(0, 1)$$
$$u_2 \sim N(0, 1)$$
$$\text{corr}(u_1, u_2) = \rho$$

where $y_j^{\text{select}}$ is whether a farmer has perceived climate change or not, $z$ is an m vector of regressors, which include different factors hypothesized to affect perception; $\delta$ is the parameter estimate, $u_{2j}$ is an error term and $u_1$ and $u_2$ are error terms, which are normally distributed with mean zero and variance one. Thus, Eq. 3 is the first stage of Heckman's two-step model which represents the farmers' perception of changes in climate. Equation 1 is the outcome model which represents whether the farmer adapted to climate change, and is conditional upon the perception model.

When the error terms from the selection and the outcome equations are correlated ($\rho \neq 0$), the standard probit techniques yield biased results (Asrat and Simane 2017a; Deresa et al. 2011; Van de Ven and Van Praag 1981). Thus, the Heckman probit (heckprob) provides consistent and asymptotically efficient estimates for all parameters in such model.

The dependent variable for the selection equation is whether a farmer has or has not perceived climate change. The explanatory variables include socio-demographic, environmental, and institutional factors selected based on hypothesized relationships described in literature on factors affecting the awareness of farmers to climate change or their risk perceptions (Asrat and Simane 2017a; Deresa et al. 2011) and field observations made in the study area. In the case of the outcome model, the dependent variable is whether a farmer has adapted or not to climate change. The explanatory variables are chosen based on the climate change adaptation literature (Asrat and Simane 2017a; Deresa et al. 2011; Deresa et al. 2009; Hassan and Nhemachena 2008) and field observations made in the study locations. The hypothesized explanatory variables for the Heckman's two-step model used in this study are described in the section that presents the empirical model results.

**Table 1** Perception of climate change in the study area

| Perception | Wet lowland | | Dry lowland | | Total | | $\chi^2$ value | P value |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | | |
| Not perceived | 175 | 47.7 | 141 | 38.4 | 316 | 43.1 | 6.636*** | 0.006 |
| Perceived | 192 | 52.3 | 226 | 61.6 | 418 | 56.9 | | |
| Total | 367 | 100 | 367 | 100 | 734 | 100 | | |

***Values are significant at $P < 0.001$

**Table 3** Awareness of adaptation measures in the study area

| Exposure to adaptation | Wet lowland | | Dry lowland | | Total | | $\chi^2$ value | P value |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | | |
| No exposure | 139 | 38 | 191 | 52 | 330 | 45 | 14.659*** | 0.000 |
| Have exposure | 228 | 62 | 176 | 48 | 404 | 55 | | |
| Total | 367 | 100 | 367 | 100 | 734 | 100 | | |

***Values are significant at $P < 0.001$

## Results and discussion

### Descriptive results

#### Farmers' perception of climate change

The descriptive analysis indicated that about 52% of the respondents from the wet lowland and 62% from the dry lowland had perceived a change in climate (Table 1). This difference in perception of climate change between the two locations is statistically significant ($\chi^2 = 6.636$ with $P < 0.001$). The descriptive analysis also signified that more than 55% of the respondents perceived an increasing trend in temperature while 42 and 25%, respectively, perceived a stable and decreasing temperature. Regarding precipitation, about 64% of the respondents indicated a decreasing trend while 34% of them testified an increasing trend. Parallel to this, those farmers who inferred an increasing trend in temperature and a decreasing trend in precipitation specified the respective local indicators that make them deduce these trends (Table 2).

#### Farmers' adaptive responses

In the wet lowland condition, 62% of the respondents indicated that they know climate change adaptation measure and have implemented at least one in the past. In the dry lowland, only 48% the respondents reported having knowledge of adaptation options while 52% of them have no any past experience concerning the measures (Table 3). This difference in the exposure to adaptation measures is statistically significant ($\chi^2 = 14.659$ with $P < 0.001$), showing the existence of a verified difference between the two parts of the study area.

The respondents from the wet and dry lowland were also compared in terms of use of different adaptation strategies in their agricultural practices. The most used adaptation measures include soil and water conservation and agronomic practices such crop rotation, intercropping, adjusting planting dates, diversifying crop types, use of fertilizer, use of improved crop varieties, application of manure, and irrigation practices. Accordingly, about 47% of the respondents in the wet lowland and 44% in the dry lowland have used soil and water conservation practices (Table 4). However, the use of this practice is not statistically different between the wet and the dry lowland implying that the role of soil and water conservation in copping the hazards of climate change is evenly recognized in both areas.

**Table 2** Indicators that justify farmers' perception of increasing temperature and decreasing precipitation

| | N | Percent |
|---|---|---|
| Indicators of temperature change | | |
| Longest months with high day time temperature | 133 | 33.3 |
| Frequent occurrence of heat-induced crop disease | 119 | 29.3 |
| Switch to heat tolerant crop types/varieties (not previously adapted to the area) | 110 | 27.1 |
| Frequent occurrence of heat-induced livestock disease | 107 | 26.4 |
| Frequent occurrence of heat-induced human disease | 103 | 25.4 |
| Emergence of new plant species/invasive species in the form of weed | 82 | 20.2 |
| Quick disappearance of water sources/points due to high evaporation | 80 | 19.7 |
| Indicators of precipitation change | | |
| Shortened length of rainy season | 136 | 18.2 |
| Change in planting time/date to adjust to onset of rainfall | 123 | 16.8 |
| Early onset and early exit of rainy season | 114 | 15.5 |
| Erratic nature of rainfall/Increased volume of rainfall at a time | 100 | 13.6 |
| Late onset of rainy season | 99 | 13.5 |
| Crop failure due to water shortage | 98 | 13.4 |
| Switch to drought tolerant crop types/varieties (not previously adapted to the area) | 64 | 8.7 |

**Table 4** Adaptation through soil and water conservation measures

| Use of soil and water conservation practices | Wet lowland | | Dry lowland | | Total | | $\chi^2$ value | $P$ value |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | | |
| Non users of the practices | 196 | 53.4 | 207 | 56.4 | 403 | 54.9 | 0.714 | 0.415 |
| Users of the practice | 171 | 46.6 | 160 | 43.5 | 331 | 45.1 | | |
| Total | 367 | 100 | 367 | 100 | 734 | 100 | | |

Congruently, about 69% of the respondents from the wet lowland and 59% from the dry lowland have implemented agronomic practices as adaptation strategy (Table 5). The difference between the two areas in terms of use of agronomic practices is statistically significant ($\chi^2 = 8.497$ with $P < 0.01$). More use of agronomic measures in the wet lowland condition might be attributed to farmers' longer crop cultivation experience and better exposure to the practices compared to farmers in the dry lowland.

The proportion of respondents that have not used any of the adaptation practices is higher in the dry lowland as compared to the wet lowland. The non-users have pinpointed critical challenges for not responding to climate change through adaptation, lack of perception being a major bottleneck. Moreover, respondents who perceived climate change but failed to respond through the adaptation measures indicated lack of awareness on adaptation techniques, liquidity constraint (cash shortage), and lack of access to the adaptation measures as critical barriers.

## Empirical model results
### Determinants of perception and adaptation
Tables 6 and 7 portray descriptive summary of explanatory variables used in the Heckman probit selection and outcome models, respectively. As indicated in the tables, about 52% of the respondents in the wet lowland and 62% in the dry lowland perceived a change in climate. With regard to adaptation, about 52% of the respondents in the wet lowland and 44% in the dry lowland have used at least one of the major adaptation options.

The Heckman probit model was first tested for its suitability and explanatory power over the standard probit model. The test results indicated the presence of sample selection problem (dependence of the error terms from the outcome and selection models) justify the use of the model with rho significantly different from zero (Wald $\chi^2 = 10 \cdot 77$ with $P = 0 \cdot 001$). Moreover, the likelihood function of the Heckman probit model was significant (Wald $\chi^2 = 84.36$ with $P < 0 \cdot 001$), showing its strong explanatory power.

Results of the selection and outcome models are presented in Tables 8 and 9, for the wet lowland and the dry lowland, respectively. In both models, most of the explanatory variables and their respective marginal values are statistically significant in determining perception and adaptation in a direction that would be expected. The calculated marginal effects measure the expected changes in the probability of perception and adaptation with respect to a unit change in an explanatory variable.

Results of the selection model for the wet lowland condition (Table 8) indicate that education level of the household head, age of the household head, changes in temperature and precipitation, number of crop failures in the past, and frequency of drought in the past significantly increase the likelihood of farmers' perception of climate change ($P < 0.01$). Likewise, duration of food shortage faced in the past is statistically significant in enhancing farmer's perception of climate change ($P < 0.05$).

Results of the outcome model for the wet lowland condition are also portrayed in Table 8. Accordingly, income from livestock, the gender of the household head, extension advice, and knowledge of adaptation measures strongly influenced farmers' adaptation decision ($P < 0.001$). Moreover, education level of the household head, household size, age of the household head, non-farm income, land size, climate information, the proportion of non-fertile land, and farm-home distance are significant in determining farmers' adaptation decision ($P < 0.05$).

Unlike the wet lowland condition, change in temperature and precipitation and frequency of drought experienced in the past are less important in influencing farmers'

**Table 5** Adaptation through agronomic practices

| Use of agronomic practices | Wet lowland | | Dry lowland | | Total | | $\chi^2$ value | $P$ value |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | | |
| Non users of the practices | 112 | 31 | 151 | 41 | 263 | 36 | 8.497** | 0.004 |
| Users of the practice | 255 | 69 | 216 | 59 | 471 | 64 | | |
| Total | 367 | 100 | 367 | 100 | 734 | 100 | | |

**Values are significant at $P < 0.01$

**Table 6** Descriptive summary of model variables for Heckman probit selection model

| Dependent variable description | Farmers' perception status to climate change | | | |
|---|---|---|---|---|
| | Wet lowland | | Dry lowland | |
| | Perceived (%) | Not perceived (%) | Perceived (%) | Not perceived (%) |
| Perception (perceived = 1) | 52 | 48 | 62 | 38 |
| Independent variables | Mean | SD | Mean | SD |
| Education level of HH head (years) | 5.25 | 2.98 | 3.98 | 1.86 |
| HH head age (years) | 43.99 | 13.12 | 43.61 | 11.72 |
| Climate change information (yes = 1) | 0.6 | 0.5 | 0.4 | 0.5 |
| Frequency of drought (last 20 years) | 2.30 | 1.43 | 2.81 | 1.48 |
| Frequency of drought (last 10 years) | 2.37 | 2.16 | 2.23 | 1.11 |
| Number of crop failures (last 10 years) | 2.33 | 1.22 | 2.09 | 1.26 |
| Duration of food shortage (months) | 2.91 | 1.50 | 2.37 | 1.66 |
| Temperature (increasing = 1) | 0.7 | 0.3 | 0.65 | 0.3 |
| Precipitation (increasing = 1) | 0.3 | 0.7 | 0.4 | 0.6 |

perception of climate in the dry lowland. However, farming experience, climate information, duration of food shortage, and number of crop failures experienced in the past are statistically significant in determining farmers' perception of climate change (Table 9).

The outcome model result for the dry lowland condition (Table 9) revealed that education level of the household head, household size, the gender of the household head, farming experience, age, income from crop enterprise, climate information, slope of a plot, and

**Table 7** Descriptive summary of model variables for Heckman probit outcome model

| Dependent variable description | Farmers' adaptation status to climate change | | | |
|---|---|---|---|---|
| | Wet lowland | | Dry lowland | |
| | Adapted (%) | Not adapt (%) | Adapted (%) | Not adapted (%) |
| Adaptation (adapted = 1) | 52 | 48 | 44 | 56 |
| Independent variables | Mean | SD | Mean | SD |
| Education of HH head (years) | 5.25 | 2.98 | 3.98 | 1.86 |
| Household size (number) | 6.08 | 2.44 | 5.92 | 2.31 |
| HH head sex (male = 1) | 0.89 | 0.22 | 0.9 | 0.21 |
| Farming experience (years) | 22.68 | 11.47 | 14.71 | 7.27 |
| HH head age (years) | 43.99 | 13.12 | 43.61 | 11.72 |
| Crop income (Ethiopian currency) | 3352.23 | 3005.44 | 1332.64 | 952.61 |
| Livestock income (Ethiopian currency) | 3927.65 | 4916.84 | 3927.65 | 4916.84 |
| Non-farm income (Ethiopian currency) | 3393.89 | 3726.03 | 2566.24 | 1899.33 |
| Extension advice (yes = 1) | 0.7 | 0.3 | 0.4 | 0.3 |
| Climate change information (yes = 1) | 0.6 | 0.5 | 0.4 | 0.5 |
| Cultivated land size (hectares) | 2.23 | 1.69 | 3.85 | 1.08 |
| Plots with steep slope (%) | 0.5 | 0.5 | 0.2 | 0.11 |
| Plots with mixed slope (%) | 0.5 | 0.5 | 0.8 | 0.11 |
| Semi-fertile plots (%) | 0.4 | 0.3 | 0.4 | 0.33 |
| Non-fertile plots (%) | 0.5 | 0.5 | 0.4 | 0.4 |
| Shared out land (ha) | 0.64 | 0.46 | 1.15 | 0.73 |
| Farm-home distance (km) | 1.91 | 1.12 | 2.36 | 1.32 |
| Number of parcels | 2.08 | 0.93 | 1.85 | 0.85 |
| Past knowledge of adaptation (yes = 1) | 0.62 | 1.34 | 0.48 | 1.62 |

**Table 8** Results of the Heckman probit selection model for the wet lowland

| Explanatory variables | Outcome model | | | | Selection model | | | |
|---|---|---|---|---|---|---|---|---|
| | Regression | | Marginal effect | | Regression | | Marginal effect | |
| | Coefficients | P values | Coefficients | P values | Coefficients | P values | Coefficients | P values |
| Education of HH head | 0.082** | 0.022 | 0.016** | 0.012 | 0.033*** | 0.003 | 0.013*** | 0.002 |
| Household size | 0.044** | 0.012 | 0.014 ** | 0.043 | | | | |
| HH head sex | 0.580** | 0.010 | 0.177** | 0.012 | | | | |
| Farming experience | 0.072 | 0.133 | 0.023 | 0.131 | | | | |
| HH head age | 0.138** | 0.012 | 0.012** | 0.031 | 0.015*** | 0.000 | 0.008*** | 0.000 |
| Crop income | 0.001 | 0.142 | 0.031 | 0.531 | | | | |
| Livestock income | 0.829*** | 0.000 | 0.145*** | 0.000 | | | | |
| Non-farm income | 0.126** | 0.023 | 0.021** | 0.044 | | | | |
| Extension advice | 1.024*** | 0.000 | 0.303*** | 0.000 | | | | |
| Cultivated land size | − 0.565** | 0.034 | − 0.009** | 0.024 | | | | |
| Climate information | 0.255** | 0.021 | 0.074** | 0.023 | 0.034 | 0.131 | 0.031 | 0.113 |
| Temperature | | | | | 0.168*** | 0.000 | 0.044*** | 0.000 |
| Precipitation | | | | | − 0.013*** | 0.000 | − 0.03*** | 0.000 |
| Plots with steep slope | 2.62* | 0.054 | 0.263* | 0.041 | | | | |
| Plots with mixed slope | 2.62* | 0.054 | 0.263* | 0.043 | | | | |
| Semi-fertile plots | 0.056 | 0.113 | 0.012 | 0.110 | | | | |
| Non-fertile plots | 1.21** | 0.022 | 0.066** | 0.011 | | | | |
| Shared out land | − 0.025 | 0.310 | − 0.012 | 0.310 | | | | |
| Farm-home distance | − 0.122** | 0.011 | − 0.033** | 0.011 | | | | |
| Number of parcels | − 0.013** | 0.021 | − 0.011 | 0.012 | | | | |
| Number of crop failures | | | | | 1.418*** | 0.000 | 0.278*** | 0.000 |
| Frequency of drought in 20 years | | | | | 0.255** | 0.021 | 0.074** | 0.023 |
| Frequency of drought in 10 years | | | | | 0.83*** | 0.001 | 0.212 | 0.000 |
| Duration of food shortage | | | | | 0.011** | 0.028 | 0.003** | 0.035 |
| Past knowledge of adaptation | 0.476*** | 0.002 | 0.132*** | 0.001 | | | | |
| Constant | − 5.945*** | 0.003 | | | − 1.245*** | 0.000 | | |
| Total observations | 371 | | | | | | | |
| Censored | 77 | | | | | | | |
| Uncensored | 294 | | | | | | | |
| Wald chi-square (zero slopes) | 86.84 (P < 0·001) | | | | | | | |
| Wald chi square (independent equations) | 10.29 (P < 0·001) | | | | | | | |

***, ** and * indicate significance levels at 1%, 5% and 10%, respectively

knowledge of adaptation options are positively and significantly related to farmers' adaptation decision. Income from livestock and non-farm activities negatively affected adaptation decision showing that income from these sources may not be invested for adaptation in crop sector. Similarly, land size, size of shared-out land, and farm-home distance negatively influenced adaptation decision of smallholder farmers in the dry lowland.

Based on the model results, marginal effects of significant explanatory variables are compared between the wet and dry lowland parts of the study area. The computed marginal effect for education variable showed that one additional year in educational status of the household head increases the probability of adaptation by 14.4% in the dry lowland compared to 1.6% in the wet lowland. The probability of adaptation increases by 16.5% for each additional year of farming experience in the dry lowland while the marginal effect of farming experience on adaptation is negligible in the wet lowland. Likewise, the probability of adaptation increases by 31.9% as income from crop enterprise increases by one unit in the dry lowland.

**Table 9** Results of the Heckman probit selection model for the dry lowland

| Explanatory variables | Outcome model | | | | Selection model | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Regression | | Marginal effect | | Regression | | Marginal effect | |
| | Coefficients | P values | Coefficients | P values | Coefficients | P values | Coefficients | P values |
| Education of HH head | 0.505*** | 0.000 | 0.144*** | 0.000 | 0.272** | 0.014 | 0.070* | 0.049 |
| Household size | 0.056*** | 0.000 | 0.023*** | 0.000 | | | | |
| HH head sex | 0.016*** | 0.000 | 0.002*** | 0.000 | | | | |
| Farming experience | 0.580** | 0.010 | 0.165** | 0.012 | 0.061** | 0.017 | 0.019** | 0.017 |
| HH head age | 0.058* | 0.054 | 0.028* | 0.043 | | | | |
| Crop income | 1.022*** | 0.003 | 0.319 | 0.003 | | | | |
| Livestock income | − 0.140** | 0.011 | − 0.042* | 0.013 | | | | |
| Non-farm income | − 0.565** | 0.034 | − 0.019* | 0.042 | | | | |
| Extension advice | 0.015 | 0.143 | 0.045 | 0.141 | | | | |
| Cultivated land size | − 2.70** | 0.037 | 0.044* | 0.041 | | | | |
| Climate information | 0.203** | 0.011 | 0.057** | 0.023 | 0.155*** | 0.001 | 0.131*** | 0.002 |
| Temperature | | | | | 0.077 | 0.416 | 0.017 | 0.103 |
| Precipitation | | | | | − 1.121** | 0.031 | − 0.123** | 0.022 |
| Plots with steep slope | 0.543* | 0.050 | 0.021* | 0.056 | | | | |
| Plots with mixed slope | 0.956 | 0.419 | 0.026 | 0.337 | | | | |
| Semi-fertile plots | 0.139 | 0.124 | 0.003 | 0.124 | | | | |
| Non-fertile plots | − 1.50 | 0.204 | − 0.127 | 0.342 | | | | |
| Shared out land | − 0.54* | 0.071 | − 0.149* | 0.056 | | | | |
| Farm-home distance | − 2.626* | 0.046 | − 0.263* | 0.051 | | | | |
| Number of parcels | − 0.053 | 0.310 | − 0.016 | 0.310 | | | | |
| Number of crop failures | | | | | 4.414** | 0.017 | 0.278** | 0.021 |
| Frequency of drought in 20 years | | | | | 0.238** | 0.014 | 0.227** | 0.034 |
| Frequency of drought in 10 years | | | | | 0.323** | 0.032 | 0.044** | 0.013 |
| Duration of food shortage | | | | | 2.634*** | 0.000 | 0.212*** | 0.001 |
| Past knowledge of adaptation | 2.662** | 0.000 | 0.289*** | 0.000 | | | | |
| Constant | − 5.032*** | 0.001 | | | − 1.133*** | 0.000 | | |
| Total observations | 363 | | | | | | | |
| Censored | 75 | | | | | | | |
| Uncensored | 288 | | | | | | | |
| Wald chi-square (zero slopes) | 88.43, (*P* < 0.001) | | | | | | | |
| Wald chi-square (independent equations) | 10.86 (*P* < 0.001) | | | | | | | |

***, **, *Significance levels at 1, 5, and 10%, respectively

One unit additional income from livestock enterprise has increased the probability of adaptation by 14.5% for farmers in the wet lowland. However, additional income from livestock has decreased probability of adaptation by 4.2% in the dry lowland implying that income from this source may not be invested for adaptation in the crop sector. Likewise, one unit additional income from non-farm activities has increased the probability of adaptation by 2.1% in the wet lowland probably because it induces more investment in adaptation options. Nevertheless, non-farm income reduces the probability of adaptation by about 2% in the dry lowland showing that households who engage in non-farm activities are less dependent on crop farming and hence less motivated to invest for adaptation in the crop sector.

Owning farm plots with steep-slope increases the probability of adaptation to climate change by 26.3% in the wet lowland implying that farmers are more likely to invest on adaptation measures if their farm plots are steeper. Likewise, as the proportion of non-fertile land increases by one hectare, probability of adaptation increases by 6.6% in the wet lowland. However, in the

dry lowland, the probability of adaptation decreases by 12.7% as the size of non-fertile land increases showing that farmers may abandon a given farm plot if its fertility status significantly declines. This could be attributed to a relatively higher per capita landholding in the dry lowland which can possibly offset a decline in yield.

As the size of shared-out land increases by one hectare, probability of adaptation increases by 1.2% in the wet lowland and by 14.9% in the dry lowland. Increase in the farm-home distance by 1 km decreases the probability of adaptation by 26.3% in the dry low land compared to 3.3% in the wet low land. This is because farm size is relatively large in the dry lowland compared to the wet lowland, and hence, less attention is given to farm plots far away from doweling areas.

Extension advice increased the probability of adaptation by 3% in wet lowland suggesting that extension is instrumental for adaptation decision. Similarly, availability of climate information increases the probability of adaptation by 7.4% in the wet lowland and by 5.7% in the dry lowland.

The other variable of interest which affects the probability of farmers' adaptation decision is past knowledge of adaptation options (a proxy variable for awareness). The calculated marginal effect for this variable shows that the probability adaptation increases by 13.2% in the wet lowland and by 28.9% in the dry lowland showing that farmers' desire to try adaptation practices at own cost increases when they have prior exposure to the practices. This implies that the more a farmer is exposed to adaptation technologies, the more will be the willingness and trust to implement the techniques sustainably.

## Discussion

Climate change adaptation in smallholder agriculture is vital to reduce rural poverty and maintain ecosystem health. Besides, adaptation improves agricultural productivity and income of smallholder farmers (Asrat and Simane 2017c). As confirmed by the results of this study, adaptation to climate change is a two-step process which requires that farmers perceive climate change in the first step and respond to changes in the second step through adaptation. In the study locations, smallholder farmers well perceived the problem of climate change and make adaptive responses to minimize the negative effects that compromised their farm productivity and food security. However, different socio-economic, environmental, and institutional factors affect farmers' climate change perception and adaptive behavior.

The results of this study revealed that farmers living in the dry lowland area perceived more change in climate than farmers in the wet lowland. This could either be associated with the repeated drought events occurring in the area in recent years or could be linked to various environmental changes that cause reduced water availability

and agricultural yield in the dry lowland areas (Asrat and Simane 2017d; Deresa et al. 2011). With regard to adaptation, better awareness and use of adaptation measures is revealed in the wet lowland condition as compared to the dry lowland. This difference between the two locations may call for further heightening of intervention to facilitate the prospect for enhanced climate change perception and adaptation.

The relevance of different agronomic practices as adaptation measure is increasing over years in the study area to lessen the challenges of climate factors on agriculture. Some agronomic practices (such as adjusting planting date and early maturing crop varieties) are flattering in both parts of the study areas in response to change in the time of onset of rainy season, the incidence of terminal moisture stress, and early cease of rainfall. This is in line with the findings of Lobell et al. (2008) and Asrat and Simane (2017a) who signified adjusting planting date and use of early maturing varieties as key adaptive responses for to climate change in areas where rainfall is erratic.

Diversifying crop types is another agronomic practice emerging as adaptation strategy in the study locations attributed to farmers' risk aversion behavior. Moreover, diversifying crop types into high-value crops (such as horticultural crops) is a related new development as adaptation option aiming at intensifying the use of scarce farm resources (water and land) and maximizing returns thereof. This strategy is also further driven by improved access to market and growing experience of irrigation practices in the area. This result confirms the findings of previous studies that reported crop diversification as a contemporary practice in response to climate change (Asrat and Simane 2017c; Nkonya et al. 2011). However, it is contrary to Jones and Thornton (2010), who predicted that climate change would induce a shift from crop to livestock production.

Based on the results, farmers are more likely to implement soil conservation measures as adaptation strategy on parts of their agricultural land that are more susceptible (steep slopes) to climate change risks. This finding corroborates with the findings of Kassie et al. (2009) and Wossen et al. (2015). In the same line, a study by Asrat and Simane (2017b) implied that farmers invest in adaptation measures in plots where they expect more risk from climate hazards.

The study showed a significant positive role of access to training, extension service, and climate information in promoting farmers' investment on adaptation measures. Providing agricultural extension services helps to increase the implementation of the adaptation measures since farmers can able to acquire new skills and hence ensures sustainable use of the techniques. The knowledge gained through training can also capacitate farmers with the

technical know-how required for implementing adaptation measures in their agricultural production system and make them far-sighted to look for long-term benefits rather than immediate gains obtained at the expense land degradation. This is in agreement with the finding of Guteta and Abegaz (2015), Ketema and Bauer (2012) and Beshir et al. (2012) who reported that access to extension and training is instrumental for in promoting sustainable use of land-based climate change adaptation measures.

As expected, education is positively associated with farmers' climate change perception and adaptation decision suggesting that educated farmers tend to better recognize the risks associated with climate change. Education also more likely enhances the reasoning capability and awareness of farmers about new technologies and hence induces them to adopt. This is in the same line with the findings of Deresa et al. (2009) and Asrat et al. (2004).

Gender of the household head is positively and significantly related to farmers' adaptation decision in the study area showing that male-headed households better adapt to climate change. This can be associated with the fact that in rural Ethiopia, women-headed households are usually constrained by family labor because those women are responsible for both farming and household activities. Moreover, female-headed households have less access to resources, information, and other socio-economic opportunities and bear more burdens of household responsibilities than males. This finding concurs with other empirical findings (Asrat and Simane 2017b; Guteta and Abegaz 2015b; Deresa et al. 2011; Buyinza and Wambede 2008) who reported that male-headed households often have a higher probability of adopting new agricultural technologies.

Farm families are an important source of labor for any farm operation in smallholder agriculture. In line with this, household size increases the likelihood of farmers' climate change adaptation in the study area probably because large family size is normally associated with a better labor endowment. The result also suggests households that are endowed with family labor tend to use labor-intensive climate change adaptation measures. This result is in harmony with the findings of Kassie et al. (2009) who stated that the presence of more economically active household members favored adoption of labor-demanding agricultural technologies.

In the study area, the incidence of adaptation to climate change decreases with cultivated land size. This may reveal that adaptation is plot-specific and it is the specific characteristics of a plot that dictates the need for a specific adaptation rather than the size. In this regard, future research may account for plot level analysis to reveal the determinants of climate change adaptation at plot level. Previous studies (Asrat and Simane 2017a;

Deresa et al. 2011; Kurukulasuriya and Mendelsohn 2006) also reported similar findings.

Income from livestock and non-agricultural sources is positively and significantly associated with adaptation to climate change in the wet lowland parts of the study area. This could be attributed to the fact that income from these sources may provide farmers with additional capacity to finance adaptation measures. However, in the dry lowland, income from livestock enterprise and non-farm sources decreases the likelihood of adaptation. This may imply that as households engage more in livestock and non-farm activities, they become less dependent on crop farming and less motivated to invest for adaptation in the crop sector. This is in agreement with the findings of Simane et al. (2016) who reported a similar result for livestock-based farming systems in Ethiopia.

Size of non-fertile land is negatively and significantly associated with the likelihood of adaptation in the dry lowland showing that farmers may abandon a given farm plot if its fertility status significantly declines. This could be attributed to a relatively larger per capita land holding in the dry lowland which can possibly offset a decline in yield. In the same line, distant farmlands receive fewer adaptation measures in the dry lowland condition due to relatively large landholding size in the dry lowland compared to the wet lowland, and hence, less attention is given to farm plots far away from doweling areas. This result corroborates with the findings of Ketema and Bauer (2012) and Beshir et al. (2012).

Farmers' previous knowledge of climate change adaptation measures increases their adaptation decision in both the wet and dry lowland parts of the study locations. This shows that farmers' desire to implement adaptation measures at own cost increases when they have prior exposure to the practices. The more a farmer is exposed to the technologies of adaptation, the more will be the willingness and trust to implement the techniques sustainably. This is in agreement with previous empirical studies (Asrat and Simane 2017b; Simane et al. 2016; Asrat et al. 2004).

## Conclusions
Adaptation to climate change is a two-step process which requires that farmers first perceive climate change and then respond to the changes in the second step. This study employed the Heckman sample selection model to explore determinants of perception and adaptation to climate change in the Dabus Watershed, focusing on two agro-climatic zones (wet lowland and dry lowland). It is evidenced by the results that the farmers in the study area perceive the change in climate and have devised a means to survive through implementing different adaptation strategies. Smallholder farmers in the two parts of the study area are found to be similar

with respect some variables that affected perception and adaptation to climate change. They have also considerable differences in terms of the direction and effect of many of the explanatory variables that affect perception and adaptation.

Education of the household strongly and positively affected both perception and adaptation in the wet lowland area. It also strongly affected adaptation decision in the dry lowland area. Farming experience has a strong and positive effect on adaptation in the dry lowland, while it has no effect on adaptation in the wet lowland. Similarly, income from crop enterprise positively and strongly affected adaptation decision in the dry lowland, but it has shown no effect on adaptation decision in the wet lowland area.

Income from livestock enterprise positively and strongly affected farmers' adaptation decision in the wet lowland, while its effect is negative in the dry lowland condition. Likewise, income from off-farm activities has a positive influence on adaptation in the wet lowland area, while its effect is negative in the dry lowland. In the wet lowland condition, temperature is not statistically significant in affecting perception to climate change while the effect of precipitation is negative and significant. Slope and fertility status of farm plots positively and significantly affected adaptation decision in the wet lowland while these variables have no effect on adaptation in the dry lowland.

The study result generally reveals that farmers' climate change perception and adaptation in both locations are commonly affected by some similar types of variables, which necessitate joint policy intervention with regard to these variables. On the other hand, the two study locations are considerably different in terms of the direction and effect of some other variables. This difference dictates the need to have location-specific intervention to enhance smallholder farmers' perception and adaptation to climate change. Comparison of the two study location also revealed better awareness and use of the adaptation measures in the wet lowland condition as compared to the dry lowland. However, further heightening of awareness in both locations may facilitate the prospect for enhanced adaptation.

Most of the factors affecting farmers' perception and adaptation to climate change in the study areas are directly related to institutions, infrastructure, and technologies. Hence, there is a need for policy intervention aiming at enhancing institutional services, infrastructural facilities, and delivering effective adaptation technologies. The results of this study also show that lack of experience, lack of access to information on climate change and lack of education limit perception and adaptation decision of smallholder farmers. Hence, facilitating effective and reliable access to information and improving farmers' awareness of potential benefits of adaptation are found to be important policy intervention measures.

In line with the findings of this study, there is a need for location-specific readily available adaptation technologies that could help to reduce negative impacts of climate change on the already weak agriculture and on the livelihood of smallholder farmers. Policies must also aim at promoting farm-level adaptation through effective participation of farmers in developing and implementing relevant adaptation measures. Parallel to this, any intervention that promotes the implementation of climate change adaptation techniques should take in to account specific factors relevant to the nature of the practices. Since adaptation process is knowledge and resource intensive, it may not be implemented easily given the limited awareness and resource endowment of smallholder farmers. Therefore, enhancing perception and scaling up of climate change adaptation technologies require a shared vision of all potential stakeholders and public-private partnership.

### Authors' contributions
The first author (PA) generated the idea, designed the study, designed data collection instruments, carried out the data collection and analyzed the data, and wrote the manuscript. The second author (BS) participated in the study design, shaped the data collection instruments, coordinated the data collection process, technically supported the data analysis process, and revised the draft manuscript. Both authors read and approved the final manuscript.

### Competing interests
The authors declare that they have no competing interests.

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