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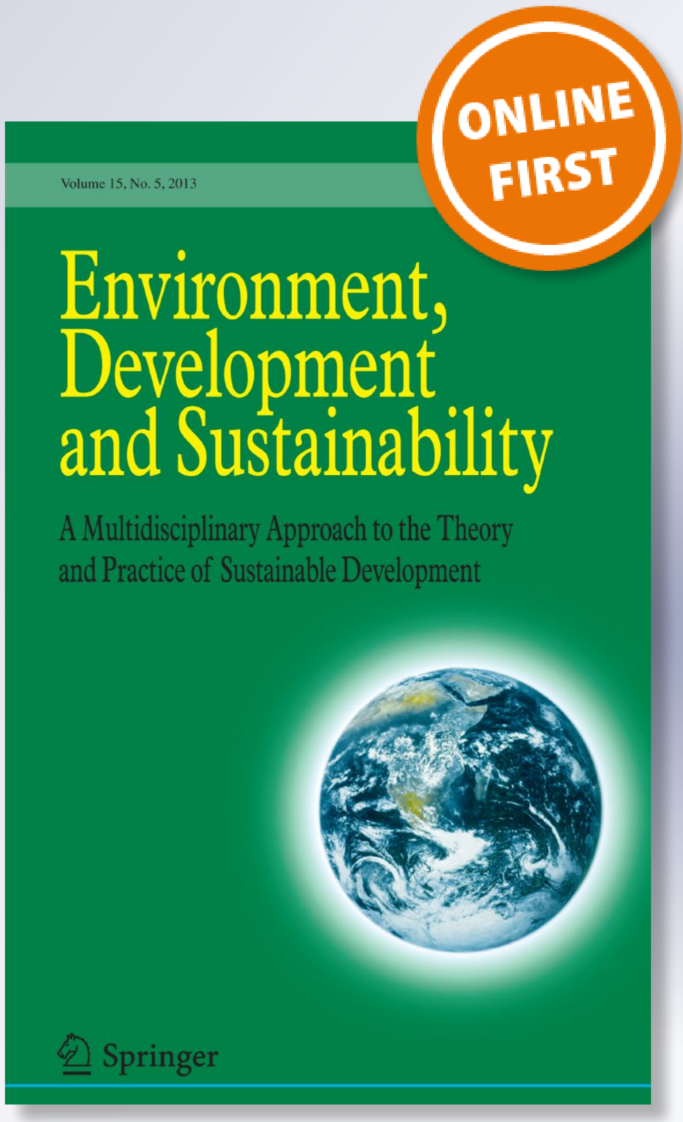

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Determinants in the adoption of climate change adaptation strategies: evidence from rainfed-dependent smallholder farmers in north-central Ethiopia (*Woleka* sub-basin)

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Abstract Smallholder rainfed agriculture, which is the mainstay of rural communities in Ethiopia, is negatively affected by climate change. Understanding the adaptations being practiced and factors which determine decision in adoption is vital in designing viable strategies. A cross-sectional survey research design was employed to collect data from 384 randomly selected smallholder farmers to identify adaptation measures being undertaken and to estimate the prominent determinants in the adoption of adaptations in drought-prone areas of north-central Ethiopia. Data were analyzed using percentage, weighted mean index, Chi-square test, *t* test and multinomial regression model and triangulated with thematic analysis. Around 96% of the respondents have perceived a change in climate and 65.4% employed adaptation measures. Stone/soil bund, changing the farming calendar and switching to short maturing varieties are the most widely practiced adaptations. Barriers inhibiting smallholder farmers from taking adaptation measures were financial constraint, lack of affordable technologies, lack of knowledge, limited access to early warning, uncertainty about the future, shortage of land and scarcity of water. The results from the multinomial discrete choice model revealed that age and educational level of the head, family

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size, herd size, access to training, access to microfinance, extension services, remittance and perceiving that climate change can be adapted influenced the selection of adaptations. Overcoming financial constraint, strengthening extension service, providing timely information and early warning, intensifying irrigation, integration of non-farm sources of livelihood in the farming system and land resource management would enable to enhance the adaptive capacity of smallholder farmers.

Keywords Climate change · Adaptation · Adaptive capacity · Coping strategies · Multinomial logit model · Smallholder agriculture

1 Introduction

1.1 Context of the Study

The evidences for climate change are certain, and its impacts are already being felt globally. The poorest countries are suffering more, and as a result, learning how to live with these impacts is becoming a priority for human development (Pelling 2011; Easterling 2011). As emphasized by Harley et al. (2008), building the adaptive capacity at local level plays a paramount role because adaptation offers opportunities to build resilience to climate change. Smallholder farmers, which are particularly vulnerable to climate change due to their weather-dependent livelihood systems, have no alternative but to adapt to climate change and variability (Easterling 2011; Badege et al. 2013; IPCC 2014). Adaptation, as explained by UNFCCC (2007) and IPCC (2007), is a process through which societies make themselves better able to cope with an uncertain future through taking the right measures to reduce the negative effects of climate change (or exploit the positive ones). Coping, on the other hand, refers to the ability to face and manage adverse conditions, emergencies or disasters. IPCC (2007) also underlined that 'focusing on mitigation alone will not address the inevitable impacts of currently observed climate change. Adaptation that is adjustments which moderate harm or exploit beneficial opportunities in response to actual or expected climatic stimuli or their effects is therefore imperative.'

According to IPCC (2007) and Pelling (2011), various types of adaptation can be distinguished. Anticipatory (proactive or planned) adaptation refers to the deliberate decisions made, based on foresight and planning, to prepare for the potential effects of climate change which are mainly undertaken before impacts of climate change are observed. Autonomous adaptation does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. On the other hand, reactive adaptations are measures taken as a response to the change. Any resilient adaptation, as explained by Ifejika Speranza (2010) and Easterling (2011), should seek to reduce vulnerability by addressing its drivers, building adaptive capacity and transforming the capacity into action. Options for adaptation include, inter alia, shifts toward crop and livestock varieties and breeds with greater drought tolerance, diversification of income-generating and livelihood activities, improvement in grain storage, change in cropping technique and calendar, strengthening community-based adaptation strategies, soil management and conservation, application of agroforestry and weather-related crop and livestock insurance (Deressa et al. 2009; Lasco et al. 2011; IPCC 2014).

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1.2 Models and drivers of climate change adaptation strategies: empirical literature

Three models, namely innovation diffusion, adoption perception and the economic constraints, are widely applied to explain the determinants and behavior of individuals when adopting a new technology/new idea including climate change adaptations (Wossink et al. 1997; Sarkar 1998). Innovation diffusion model follows the work of Rogers (1962) and contends that access to information about an innovation is the prominent factor determining adoption decision (Wejnert 2002). Since communication is influential in adoption, strengthening the role of extension, media and local opinion leaders or by the use of experiment station makes the processes easier (Adesina and Zinnah 1993). On the other hand, according to adoption perception model, the first step is the perception of the need to adopt. Such perception is dependent on individual characteristics such as education, experience and the human values of the potential adopter (Sarker et al. 2008). As disclosed by Wossink et al. (1997), Sarker et al. (2008) and Mcneeley and Lazrus (2014), the perception of climate change risk and vulnerability influences the feasibility and acceptability of climate adaptation. Therefore, farmers' perceptions regarding the severity of the problem matter in partaking adaptations (Kivlin and Fliegcl 1966). The economic constraints model argues factors of production such as access to credit, land, labor and other critical inputs conditioned technology adoption decisions and is driven by utility maximization (Kebede et al. 1990; Makokha et al. 1999).

People may not adapt, or adapt partially, for a variety of reasons. Leary and Kulkarni (2007) pointed out different possible reasons (socioeconomic, biophysical and institutional attributes) which conditioned people not to adapt to the impacts of climate change. Educated farmers are more likely to respond to climate change by making better adaptation option, have more knowledge and better ability to understand and respond to anticipated changes, have a better level of planning, are better able to forecast future scenarios and largely have relatively better access to information and opportunities than others which might encourage adaptation to climate change (Opiyo et al. 2015; Kumasi et al. 2017). Adaptation decisions are gender sensitive. (Some adaptation strategies are frequently implemented by males, while others are favored by females.) One major reason cited for this disparity is that much of the outdoor farming activities in developing countries are done by males while females are more involved in home chores which give male-headed households better opportunities in terms of farming experience and information on various adaptation strategies (Sarker et al. 2013; Nigussie et al. 2014; Elias et al. 2015). A study in Ethiopia confirmed that since women shoulder, almost all of the household chores, time left for adaptations and to engage in remunerative activities is minimal (Nigussie et al. 2014; Mare 2017). Besides, Aregu et al. (2010), Mare (2017) and Elias et al. (2015) disclosed that women in Ethiopia are constrained with access to credit, inputs, extension services and information which are very vital in undertaking adaptations.

The finding concerning the effect of age on the adoption of adaptations to climate change is mixed. For example, Atinkut and Mebrat (2016) reported that older farmers were more likely to adapt due to their better experience in weather forecasting. On the other hand, Ghosh et al. (2015) and Kusmana et al. (2016) argued that younger farmers are more energetic, risk takers, innovative, have better access to information which enabled them to implement different climate change adaptations, while older farmers prefer to continue their familiar practices. Both positive and negative effects of household family size have been reported for climate change adaptation. A larger family, particularly in productive

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age, may encourage the engagement of farmers in labor-intensive adaptations (Nyangena 2007). On the other hand, a larger family, particularly more dependents, might discourage participation in capital-intensive activities due to consumption pressure imposed by a large family (Taruvinga et al. 2016). A larger family might divert part of its labor into non-farm economic activities to generate additional income and to reduce consumption demands (Balew et al. 2014). Balew et al. (2014) had found that the likelihood of undertaking adaptations decreases when plot size increases mainly due to the possibility of producing sufficient productions from large farm size and/or large farms require greater levels of investment to implement adaptive strategies to climate change. Affluent farmers and those having surplus production from agricultural activities do have the ability to finance adaptation techniques and are more likely to adopt strategies which are capital intensive than are poor farmers (Taruvinga et al. 2016). Having income from non-farm sources significantly increases the likelihood of applying varied adaptation options (Deressa et al. 2014; Kumasi et al. 2017). Herd size is significantly and positively associated with integrated crop livestock-based diversification (Apata 2011) and the probability of using improved crop variety and soil/water conservation techniques (Tazeze et al. 2012). Access to climate-related information enhances farmers' awareness, which is crucial for adaptation decision making (Kusmana et al. 2016). Being a member of cooperatives and associations might increase the likelihood of participation of farmers in climate change adaptations. Katungi (2007) elaborated, as cited in Deressa et al. (2009), that informal institutions and social networks play triple prominent roles in adoption of different climate change adaptations by acting as a means for financial transfers that may overcome farmer's credit constraints, as a source of information about new technology and as a means to facilitate cooperation in collective action. As stated in Asnake and Mammo (2016), having access to extension services for farmers provides a vital source of information on agricultural production and management practices as well as on climate change. Smallholder farmers would take different adaptation strategies in response to risks and hazards mainly intensified or/and caused by climate variability and change. Noticing the change in the average rainfall and temperature enhances the chance of using different adaptation strategies (Atinkut and Mebrat 2016). Availability of credit services increases their financial resources and their ability to meet transaction costs associated with various adaptation options and allows farmers to purchase necessary inputs and irrigation facilities (Taruvinga et al. 2016; Kusmana et al. 2016). Better access to market enables farmers to buy new crop varieties, new soil and water conservation technologies and other important inputs (Opiyo et al. 2015). The difference in rainfall amount/variability and resources available based on agroecology has an impact on the types of adaptation strategies being implemented by smallholder farmers. Thus, people living in different agroecological settings employ different adaptation methods (Deressa et al. 2009; Tazeze et al. 2012).

1.3 Climate change and Ethiopian agriculture

Ethiopia is among the least developed and the most vulnerable countries to climate change (NMA 2007; World Bank 2010) due to its geographical location, low adaptive capacity and weather sensitive economy (NMA 2007). Rainfall is highly erratic and there is a high degree of variability in both time and space (NMA 2007; EPCC 2015). Since agriculture (which employs around 85% of the labor force, contributes more than 50% of the GDP and supplies 90% of export values) is climate sensitive, it is likely to remain the main engine of growth in the country, and climate-induced shocks will continue to be a threat to

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macroeconomic stability and could cause a remarkable loss in the total production unless strong remedial actions are put into action (MoFED 2010; EPCC 2015). Different national policies, programs and strategies that intend to address climate change have been designed by the Ethiopian government (see for example, MoFED 2006; NMA 2007; MoFED 2010; FDRE 2011; EPCC 2015; NPC 2016) which focused mainly on increasing the productivity of the agricultural sector so as to minimize the adverse impacts of climate change through strengthening the human resource capacity, using modern inputs, integrating watershed management, intensifying small-scale irrigation, diversify income-generating activities, expanding infrastructure, feed conservation and forage development, research on drought-resistant and early maturing crops, disease and pest control mechanism, providing early warning and proper utilization of meteorological information which are basic for the sector. Though such policies and strategies are designed and implemented, their effectiveness so far is not satisfactory (EPCC 2015) and more research, devotion and commitment is needed.

Different studies revealed that greater proportion of smallholder farmers even in developing countries do perceive a changing climate (Komba and Muchapondwa 2012; Uddin et al. 2014; Hameso 2017). But the proportion of farmers who have had undertaken measures in response to the changing climate is low (Komba and Muchapondwa 2012; Abid et al. 2015; Deressa et al. 2014). The perception implementation gap emphasizes the importance of identifying factors which hinder smallholder farmers to adapt. Different studies have been conducted (Deressa et al. 2009; Tazeze et al. 2012; Tesso et al. 2012b; Debalke 2014; Balew et al. 2014) to point out the factors which regulate adaptation to climate change based on agroecology. Moreover, results are not conclusive and there is no consistency in the outcomes of studies conducted so far in Ethiopia regarding the determinant factors, which suggests that a factor in a certain locality at a time might not be true in another locality. Based on the concept of 'one size does not fit all' in climate change adaptation discourse, the implication is, therefore, the need for conducting microlevel assessments. Furthermore, identifying the prominent factors which determine adaptations is the starting point in designing intervention measures to improve farmers' adaptive capacities. Since little has been studied regarding the responses to climate change and factors regulating the decision to adopt; and subsequently the study area is among the drought-prone areas of the country which is expected to be affected severely by the changing climate; pinpointing the determinant factors is timely and decisive so as to formulate policies which would enhance adaptive capacity. Furthermore, the findings of this study could enrich the literature on adaptation strategies being employed by subsistence farmers, particularly in developing countries. This study opted to answer the following basic questions. How do rainfed-dependent smallholder farmers respond to climate variability and change? What are major barriers inhibiting them to undertake adaptations? What factors determine the decision in the adoption of adaptations to climate change?

2 Materials and methods

2.1 Biophysical setting of the study area

Woleka sub-basin (in the north-central part of Ethiopia) is found between 10°15′-10°55′N and 38°25′-39°30′E (Fig. 1). It has an altitudinal range between 1070 and 4200 m above sea level and includes agroecology types ranging from hot to warm moist (*kolla*) to

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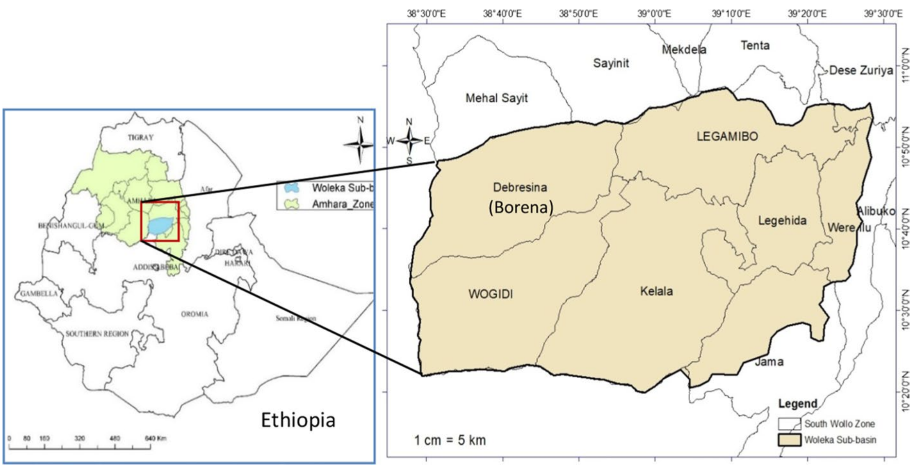

Fig. 1 Relative location of Woleka sub-basin (Debresina is currently named as Borena woreda)

sub-Afroalpine to Afroalpine (*dega and wurch*). The sub-basin has an annual rainfall ranging from 784 to 1899 mm with mean annual rainfall of 1151 mm; while the mean maximum, minimum and annual mean temperature are 24.5C, 9.96 and 17.2 °C, respectively. The distribution of rainfall mostly occurs from June to mid-September (main rainy season), locally known as *kiremt*; and February to May (*belg*) is the small rain season (Aster and Seleshi 2009; Rosell 2011). Thus, crop production follows a bimodal rainfall regime leading to two harvesting periods (Aster and Seleshi 2009), but the small rainy season is unreliable and experienced frequent failure which hampers *belg* harvesting (Rosell 2011; Ayalew et al. 2012). A study by Asfaw et al. (2018) revealed a declining trend of the main rainy season, increasing trend of meteorological drought episodes, highly variable *belg* rain and an increasing trend of temperature. Delayed onset and early cessation, erratic rainfall and poor *belg* performance affect both the farming system and production (Kahsay 2013). All these make the area as one of a drought-stricken and food deficit areas of the country where food aid is a major source of livelihood for most of the population (Desta et al. 2000; Bantider et al. 2011) while Cafer and Rikoon (2017) labeled the area as the 'famine belt of Ethiopia.'

2.2 Socioeconomic characteristic of the sub-basin

The sub-basin, based on 2017 estimate, has a total rural population of 950, 126 (50.4% male) which is around 91% of the total population of the sub-basin. With an estimated area of 6415 km^2, it has a rural population density of 148 person per km^2 which makes the area as among the most densely populated rural areas of the country (SWDoFED 2017). Rainfed crop production complemented with animal husbandry is the main economy of smallholder farmers (SWDoFED 2017; Asfaw et al. 2017) which are both at the mercy of nature. The sub-basin is intensively cultivated, and agriculture is constrained by poor soil fertility, small per capita landholding, soil degradation and erratic rainfall; as a result, most parts of the area are chronically food insecure (Bantider et al. 2011; Rosell 2011; Kahsay 2013; SWDoFED 2017). High population pressure and small per capita landholding lead to continuous cultivation and result in poor soil fertility. This low productivity is further

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Table 1 Total population, household heads and sample size. *Source*: SWDoFED (2017)

District	Agroecology	Total population	Household heads	Sample size
Borena and Legambo	*Dega*	93,413	19,461	130
	Woinadega	103,473	21,557	144
	Kolla	79,042	16,467	110
	Total	275,928	57,485	384

aggravated because agriculture production is reliant on the unreliable rainfall (Desta et al. 2000; Bantider et al. 2011; Kahsay 2013; SWDoFED 2017). Desta et al. (2000) and SWDoFED (2017) disclosed that greater proportions of farmers did not produce enough food and depended largely on food aid. Unless proper climate change adaptation strategies are designed and implemented, the fate of rainfed subsistence farmers would be challenging. Non-farm livelihood activities are not well developed (Bantider et al. 2011; Asfaw et al. 2017) due to limited access to infrastructure and low level of urban development, among others. As a result, rural people lack an alternative outlet for the increasing unemployed and underemployed workforce to relieve the ongoing pressure on land. To overcome land demand, farmers could convert marginal lands into agricultural land which in turn lead to further degradation of natural resources and accelerates soil erosion (Cafer and Rikoon 2017).

2.3 Sample frame and sampling techniques

The study area was selected due to its probable high vulnerability to adverse impacts of climate change. Legambo and Borena districts were purposively selected considering their heterogeneity in agroecology (*dega*, *woinadega* and *kolla*) and type of cropping seasons[1] (*belg*[2] dominated and *meher*[3] dominated). Target populations of rainfed-dependent smallholder farmers were selected using multistage stratified random sampling technique. *Kebelles* from each agroecology and household heads were selected randomly, and finally, 384 household heads were randomly and proportionately selected from the three agroecologies (see Table 1). In addition, five elders and twelve concerned bodies from the selected district agriculture offices were included for interview and key informant interview based on their lifelong experience and expertise. The sample size for survey study was computed based on Cochran (1977) and Kothari (2004) as:

$$n = \frac{Z^2 * N * p * q}{e^2(N-1) + Z^2 * p * q}$$

where 'n' is the desired sample size, 'N' is the total target population, 'Z' is the standardized normal deviation set at 1.96–95% confidence level, 'p' is the estimated proportion of an attribute that is present in the population (.5), 'q' is the estimated proportion of an

[1] Cropping season refers to the major source of rainfall for crop production. It has been included because agroecology alone does not capture the issue of heterogeneity in farming society.

[2] *Belg* (short rain season) which extends from (February–May).

[3] *Meher* or Kiremt (long rain season) which extends from June–September (NMA 2007:19).

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attribute that is not present in the population $(1-p)$ (.5), and 'e' is degree of accuracy required normally set at .05 alpha level.

2.4 Data: type, source and tools

A cross-sectional survey design (conducted from December 2015 to May 2016) was employed to collect primary data household heads using a pretested structured questionnaire with overall Cronbach alpha value of .82 (highly reliable). Surveys were carried out by well-trained data enumerators, while focus group discussion and key informant interview were carried out by the first author of this paper. Interview was conducted with elders and concerned experts at different levels coupled with field observation. The questionnaire particularly consisted of issues related to the socioeconomic characteristics of respondents and biophysical characteristic of the study area. Perception, coping strategies and adaptation measures were measured using a Likert scale. Specific strategies being employed in the study area were identified through consultation of experts from the agricultural office of the selected districts. Finally, respondents were asked to rate the strategies as per their extent of implementation. The index was computed based on the average weighted mean.

2.5 Data analysis techniques and model specification

After data were edited, coded and entered into SPSS 21, they were analyzed using thematic analysis, descriptive statistics, percentage, weighted average mean index, Chi-square and *t* test. Chi-square test and *t* test were applied to see associations and differences between adopters and non-adopters over different attributes. Determinants of adaptations were estimated using multinomial logistic regression (MNL) model. Coping strategy index[4] (CSI) was applied to point out the most frequently applied coping strategies in response to climate variability by smallholder farmers in the study area. The final index for coping strategies was computed based on the weighted average as: $\mathrm{CSI}=(\mathrm{CS_H}\times 3+\mathrm{CS_M}\times 2+\mathrm{CS_N}\times 1$), where CSI is coping strategy index, $\mathrm{CS_H}$ coping strategy implemented most frequently, $\mathrm{CS_M}$ coping strategy implemented often, and $\mathrm{CS_N}$ coping strategy not implemented.

Adaptation Strategy Index (*ASI*) identified the most frequently implemented adaptation strategies being carried out by smallholder farmers. ASI can be computed using a Likert scale and by assigning 3 for frequently implemented adaptation strategies, 2 for strategies which are implemented at medium scale, 1 for those strategies which are implemented at a low level and 0 for those strategies which were not implemented.

$$\mathrm{ASI} = \left(\mathrm{AS_H}\times 3 + \mathrm{AS_M}\times 2 + \mathrm{AS_L}\times 1 + \mathrm{AS_N}\times 0\right)$$

where ASI = adaptation strategy index, $\mathrm{AS_H}$ = highly implemented climate change adaptation strategy (frequently), $\mathrm{AS_M}$ = a strategy which is implemented at medium level (most often), $\mathrm{AS_L}$ = a strategy which is implemented at a low level (small extent), $\mathrm{AS_N}$ = a strategy which is not implemented at all (not at all).

[4] Average weight index method (for coping and adaptation strategy index) has been used based on Uddin et al. (2014).

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2.5.1 Multinomial logistic regression model specification

In order to identify factors that determine the selection of adaptations, discrete choice models like logistic regression (where there are only two options) and multinomial logit model, whenever the options are three or more, are widely used (see, for example, Hassan and Nhemachena 2008; Deressa et al. 2009; Balew et al. 2014; Shongwe et al. 2014). Likewise, MNL was employed in this research because it permits the analysis of decisions for more than two categories. MNL gives the choice probabilities of each alternative as a function of the systematic portion of the utility of all the alternatives. The multicollinearity problem among the explanatory variables was tested using variance inflation factor (VIF) test (Greene 2003). Overall model fitting and the validity of the assumption of independence of irrelevant alternative (IIA) tests were checked using the Hausman test before running the model. The IIA assumption requires that the probability of using a certain adaptation method by a given household is independent of the probability of choosing another adaptation method (that is, P_j/P_k is independent of the remaining probabilities). Respondents had selected only one category based on their major adaptation strategy.

The household decision of whether or not to undertake adaptation is considered under the general framework of utility or profit maximization. It is presumed that economic agents (like smallholder farmers) used adaptation options only when the perceived utility or net benefit from using a particular option is significantly greater than the benefit of the other strategy. In this circumstance, the utility of the economic agents is not observable, but the actions of the economic agents could be observed through the choices they made. Assuming that U_j and U_k represent households' utility for two choices, β_j and β_k, respectively, the linear random utility model could then be specified (Greene 2003) as:

$$U_j = \beta_j' X_i + \varepsilon_j \text{ and } U_k = \beta_k' X_i + \varepsilon_k \tag{1}$$

where U_j and U_k are perceived utilities of adaptation options j and k, respectively; X_i *is* the vector of explanatory variables which influence the perceived desirability of the option; j and k are the parameters to be estimated; and ε_j and ε_k are error terms assumed to be independently and identically distributed. For climate change adaptation[5] options, if a household prefers to use strategy j, then it follows that the perceived utility or benefit from strategy j is greater than the utility from other options (say, k) depicted as:

$$U_{ij}\left(\beta_j' X_i + \varepsilon_j\right) > U_{ik}\left(\beta_k' X_i + \varepsilon_k\right), \quad j \neq k \tag{2}$$

Based on the above relationship, it is possible to define the probability that a household will use option j from among a set of climate change adaptation options as follows:

$$P\left(A_i = 1/X\right) = P\left(U_{ij} > U_{ik}/X\right) \tag{3}$$

To describe the MNL model, the probability of smallholder farmer's choice (from a set of mutually exclusive options) of climate change adaptation strategies (A_i) was assumed to be a function of a number of attributes (X_i's) as presented in Eq. (4) where β_i is a vector

[5] Since it is difficult to differentiate development activities from adaptation actions (Ifejika Speranza 2010); actions undertaken by smallholder farmers which have contribution in building resilience and minimize the impacts of climate change-induced hazards were considered as a response to the changing climate, though it might not be necessarily true. The driving factors might be profit maximization, shortage of land or else.

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of coefficient on each of the independent variables, X_i's. The MNL model for adaptation choice, therefore, is carried out based on the relationship between the probability of choosing option A_i and the set of explanatory variables X as follows (Greene 2003):

$$\text{Prob}(A_i = j) = \frac{\exp \beta_j' x_i}{\sum_{k=0}^{J} \exp \beta_k' x_i}, \quad j = 0.1 \ldots J \tag{4}$$

Equation (4) is normalized to remove indeterminacy by assuming that the $\beta_0 = 0$ probability is estimated as:

$$\text{Prob}(A_i = j/x_i) = \frac{\exp \beta_j' x_i}{1 + \sum_{k=1}^{J} \exp \beta_k' x_i}, \quad j = 0, 2 \ldots J, \beta_0 = 0 \tag{5}$$

Maximum likelihood estimation of Eq. (5) yields the J log-odds ratios as:

$$\ln\left(\frac{P_{ij}}{P_{ik}}\right) = x_i'\left(\beta_j - \beta_k\right) = x_i'\beta_j, \quad \text{if}(K = 0) \tag{6}$$

The selection of different adaptation strategies is, therefore, the log of odds in relation to 'business as usual' strategy, which serves as the base alternative. According to Greene (2003), the parameter estimates of the MNL model are difficult to interpret (they only provide the direction of the effect of explanatory variables on the dependent variable, but the model estimates neither the actual size of change nor the probabilities), and associating the β_j with the jth outcome is tempting and misleading. Instead, the marginal effect measures the expected change in the probability of a given choice that has been made in relation to the unit change in the explanatory variable. As a result, the marginal effects are usually derived to estimate the effects of the independent variables on the dependent variables in terms of probabilities as:

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j\left[\beta_j - \sum_{k=0}^{J} P_k \beta_k\right] = P_j\left(\beta_j - \overline{\beta}\right) \tag{7}$$

The marginal effects measure the expected change in the likelihood of selection of a particular adaptation strategy with respect to a unit of change in the independent variable. The marginal effect for categorical variables shows how $P(Y = 1)$ changes as the categorical variable changes from 0 to 1, after controlling for the other variables (Williams 2012). The major responses (adaptive strategies) to climate change by smallholder farmers were categorized into six categories based on their similarity in character as land augmentation, land management practices, irrigation and water harvesting, changing cropping calendar or/and crop varieties, livelihood diversification and non-adaptors (as a reference group).

3 Results and discussion

3.1 Socioeconomic characteristic of respondents

The responses of 384 household heads (86.2% male-headed and 13.8% female-headed) who were mainly dependent on rainfed agriculture from three agroecologies were analyzed.

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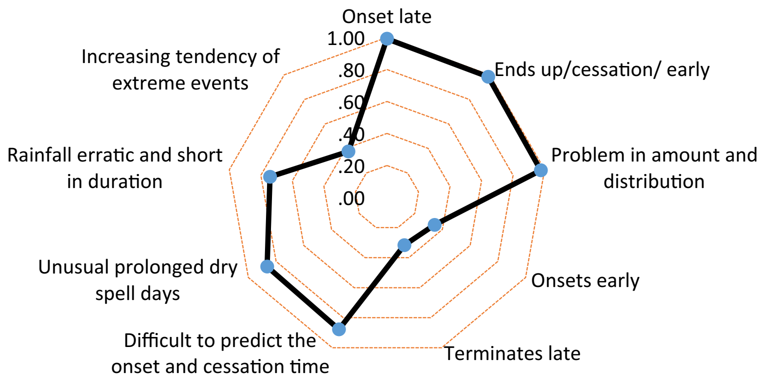

Fig. 2 Precipitation-related manifestations of climate change and variability

The average age was 48.9 years which implied that the majority were in the productive age group. The family size of the study area (5.57) was higher than the national rural average 5.13(t (383) = 6.19; $p < .05$) and the regional rural average 4.63(t (383) = 13.13; $p < .05$) (CSA 2014:13–20) which indicated the presence of high fertility rate. The average year of schooling was 2.92 years; implying that most farmers had not completed primary level which would have negative implication in adaptations. Around 48% had access to the credit market, the average distance to the nearby market was 1.92 h, and 31% of the respondents had reported a serious shortage of land for cultivation. The average total land holding per household was 0.72 ha (0.14 ha per capita) which is low compared with the average land holding of regional (1.22 ha) (t (383) = 31.6; $p < .05$) and national averages (1.17 ha) (t (383) = 28.4; $p < .05$). Small plot of land coupled with climate variability would make agriculture system in the study area more challenging. As a result, intensification and finding alternative sources of livelihood besides agriculture are vital. On average, surveyed households were food insecure for about 2.18 months in a year and it was higher than (t (383) = 9.5; $p < .05$) the national average of 1.2 months (Guush et al. 2013). Climate variability, frequent failure of *belg* harvest and low soil fertility would increase the number of food insecure month that farmers would face in the future unless feasible actions are put into action. Among the respondents, 65.4% undertook measures in response to the changing climate. The figure is similar to the findings of Komba and Muchapondwa (2012), Deressa et al. (2014) and Apata (2011). In the present study, agroecologically, adopters for *dega*, *woinadega* and *kolla* were found to be 28.7, 47.8 and 23.5% where more adopters were from *woinadega* agroecology. Such differences might be due variation in biophysical, socioeconomic assets and institutional arrangements which different localities had and implied for the need of designing different interventions for different geographical settings.

3.2 Perception of smallholder farmers on climate change

Around 96% of the respondents perceived a change in climate particularly an increasing trend in temperature and variability, late onset and early cessation of the rainy season, unusual prolonged dry spell as well as a decreasing trend of rainfall in their lifetime (see Fig. 2). The perception of respondents coincides with the empirical findings where erratic, high concentration, decreasing trend of rainfall as well as an increasing trend

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of temperature have disclosed (Rosell 2011; Asfaw et al. 2018). Almost all respondents (97.1%) responded that climate change has become a challenge for their farming system. The percentage of farmers who believed that climate change can be adapted was 72.4 and a gap between perception on climate change (95.8%), the perception of adaptability of the change (72.4%) and actual execution of adaptation strategies (65.4%) was found. Thus, the proportion of farmers who adapted to climate change was substantially less than of farmers who perceived the incidence of a changing climate which may be associated with various constraints. More individuals who believed that the changing climate can be adapted had taken at least one adaptation strategy (χ^2 (1) = 9.1; $p < .05$). Having early warning information also affected the extent of adoption. Those who had early warning information on the rainfall situation were found more likely to undertake at least one adaptation (χ^2 (1) = 36.98; $p < .01$). The result implied that perceiving a changing climate and believing on the adaptability of climate change are among the determinant factors in undertaking adaptations. Regarding the cause behind the change in climate, more respondents (68.8%) stated anthropogenic processes as the major factor while the natural process and God's wrath for wrong-doings of human beings were rated by 16.4 and 3.1%, respectively. Furthermore, 11.7% of respondents did not know the reason behind the changing climate. Though the majority of respondents had knowledge of the root cause of climate variability, more awareness creation programs should be launched because knowing the cause is among the major steps to take remedial action.

3.3 Coping and adaptation strategies to climate change and variability

Responding to risks and shocks is normal and has been practiced by communities for centuries. Actions might be employed prior to the impact (ex ante response-called adaptation) or in the aftermath or during the time of the impact (ex-post response-called coping). The first five coping strategies being employed in the study area (Table 2), according to their rank, included selling of assets or/and livestock, reducing expenses of health/clothes, depending on food aid/safety net program, borrowing from relatives/neighbors and reducing consumption (quantity, quality and timing). Though the overall figure seems like this, disparities in the type of coping strategies have been observed when agroecology and type of cropping season are taken into account.

Most of the coping strategies employed by smallholder farmers in the study area have a perpetuating effect where it further worsens the incidence and severity of poverty. Climate change either causes loss of assets or leads to selling to cope with impacts, thereby expanding poverty traps and reducing the number of households escaping poverty every year. Poor people might not be able to recover from and eventually will be trapped by a vicious circle of poverty whenever they sell their assets, mortgaging their farmland and borrow money for consumption smoothening in times of hazards. A study in Ethiopia by Dercon (2004) confirmed that it took an average of 10 years for asset-poor households to bring livestock holdings back to their pre-famine levels after the 1984/85 famine. Similarly, Tesso et al. (2012a) in Ethiopia found that households who had liquidated their productive assets during a shock were 17.8% less likely of moving to the next-better wealth category compared to those that did not liquidate assets. Wisner et al. (2004) underscored that vulnerable people in most instances suffer multiple, mutually reinforcing, repeated, and sometimes simultaneous shocks to their families and their livelihoods which adversely affect whatever attempts have been made to accumulate resources and savings. Likewise, some coping strategies would have an adverse impact on health and knowledge capitals.

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Table 2 Major types of coping strategies. *Source*: (Own survey, 2015/16)

Coping strategies	Mean	Agroecology						*Cropping season* (*dega*)			
		Dega		W/*dega*		*kolla*		*Belg*		Meher	
		F	*R*	*F*	*R*	*F*	*R*	*F*	*R*	*F*	*R*
Seasonal migration for causal work	1.48	70		37		78		32		38	
Selling of firewood or/and charcoal	1.33	40		25		60		13		27	
Food aid/safety net program	2.00	156	2	70		157	2	81	1	75	4
Borrowing from relatives/microfinance	1.99	153	3	74	4	153	3	74	5	79	2
Taking loan from money lenders	1.61	92		32		110		33		59	
Selling assets or/and livestock	2.22	166	1	136	1	166	1	78	3	88	1
Reducing consumption (quantity, quality and timing)	1.99	141		100	3	137		72		69	
Consuming seed stocks	1.61	65		54	5	115		33		32	
Selling farmland (or mortgaging) for sake of food or cash	1.61	81		42		112		34		47	
Collecting wild food	1.3	22		21		74		7		15	
Taking children out of school	1.37	37		36		67		10		27	
Reducing expenses of health/clothes	2.04	151	5	106	2	141	4	79	2	72	5
Borrowing grain from relatives or neighbors	1.95	152	4	71		141	5	75	4	77	3

[Cronbach alpha = .928; index (not at all * 1) + (sometimes * 2) + (frequently * 3)]. '*F*' and '*R*' stand for frequency and rank, respectively

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In short, coping strategies which individuals pursued to meet their short-term needs might render households to be more vulnerable in the long-run. This implied that timely support given for the victims will enable them not to liquidate their assets, and interventions are needed to reduce the exposure and vulnerability of the poor while increasing their capacity to adapt to shocks. An interviewer stated that it was common for farmers to sell their livestock whenever there is a failure in crop production and that restocking normally takes a longer period which perpetuates the incidence of poverty. An expert from Borena district agricultural office confirmed that efforts, mainly food aid and safety net programmes, were put into effect to minimize liquidation of assets, but such programmes were not as such sufficient.

The most widely practiced land management strategy carried out at household level or/and through community mobilization in both agroecologies was stone/soil bund. Cut and carry (zero grazing) method was also practiced in *woinadega* and *belg* growing areas, while agroforestry was undertaken in *dega* and *meher* dominated areas. Mulching, either using grass or crop residues, was little practiced (Table 3). Key informants confirmed that crop residues, which were left on the agricultural land after harvesting in the past to increase soil fertility, have not been carried out recently because the residues are used for fuel or/and forage. One major problem which was observed during field observation was that little attempt has been given in integrating physical structures with biological techniques. Though limited in scope, communities have started to use area closures (though they are limited) both as a source of forage and for apiculture activities. A key informant had confirmed that, though not with an expected degree, area closures have been used as a source of livelihood for landless and unemployed youths who have engaged in animal fattening and apiculture. Changing the farming calendar, switching to short maturing varieties, growing drought-resistant varieties and reducing the number of domestic animals were identified as the dominant important agronomic adaptation strategies. The result revealed that most adaptation strategies are driven by the immediate change in the climatic situation where planned measures like irrigation and non-farm livelihood diversification were not well developed. A similar finding was reported by Gadédjisso-Tossou (2015) in Togo and by Taruvinga et al. (2016) in South Africa where planting short maturing varieties and changing planting dates were identified as the major responses undertaken by rainfed smallholder farmers to climate change.

From technology-related adaptation strategies, application of fertilizer has been used as a land-augmenting strategy in both areas, while herbicides and pesticides are more applied in *kolla* and *woinadega* agroecologies. Intensification of crop diseases, insects and pests in these agroecologies, which are expected to increase with warming, make application of herbicides and pesticides more common. Using water resources (irrigation and water harvesting) has been better implemented in *dega* and *woinadega* areas. The major barriers for smallholder farmers to adapt to changing climate were financial constraint, lack of affordable technologies, lack of knowledge, limited access of reliable information and early warning, high costs for agricultural inputs, uncertainty about the future, labor constraint, shortage of land and scarcity of water. Experts from respective agricultural offices agreed that anticipatory adaptation strategies like irrigation and non-farm activities are not well developed, and the support and capacity building activities being executed so far are insufficient and need the commitment of practitioners at different levels.

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Table 3 Major adaptation strategies to climate variability and change. *Source*: (Own survey, 2015/16)

Adaptation Strategies	Mean	Agroecology						*Dega* (*Belg*/meher)			
		Dega		W/*dega*		*kolla*		*Belg*		Meher	
		F	*R*	*F*	*R*	*F*	*R*	*F*	*R*	*F*	*R*
Land/water management related adaptation strategies											
Terracing on the slope land (stone/bund)	2.72	226	1	217	1	215	1	109	1	117	1
Planting trees (agroforestry)/planting along the contour	2.14	131	3	175		129	3	55		76	3
Mulching technology	1.42	10		110		41		9		1	
Cut and carry method (Zero grazing)	2.05	113		202	3	87		77	3	36	
Watershed management	2.44	169	2	205	2	179	2	82	2	87	2
Agricultural practice related adaptation strategies (agronomic)											
Changing farming calendar	2.73	232	1	193	1	239	1	96	1	136	1
Planting in rows/selected seeds	1.71	48		159		66		22		26	
Draining of vertisols (cutoff drain)	1.71	53		115		103		11		42	
Reducing the number of domestic animals	2.03	115	4	139		140	4	67		48	4
Growing drought-resistant crop varieties	2.36	166	3	167	4	185	3	78	3	88	2
Switching to short maturing crops	2.42	174	2	182	3	189	2	88	2	86	3
Multiple cropping/Intercropping/planting in rows/crop diversification	1.69	57		129		80		36		21	
Crop rotation or conservation tillage	1.96	87		185	2	97		76	4	11	
Technology application related adaptation strategies											
Application of organic compost/manure	2.58	210	1	154	3	240	1	77	3	133	1
Application of inorganic fertilizer	2.75	178	2	288	1	204	2	82	2	96	2
Application of herbicides/insecticides	1.76	51		147		94	3	31		20	
Using irrigation of any type	1.66	103		87		62		38		65	3
Using energy efficient stoves	2.10	144	3	215	2	63		92	1	52	

[Cronbach alpha = .84); adaptation strategy index = [(not implemented at all*0) + (implemented in small extent * 1) + (implemented most of the time * 2) + (implemented regularly*3)]. '*F*' and '*R*' stand for frequency and rank, respectively

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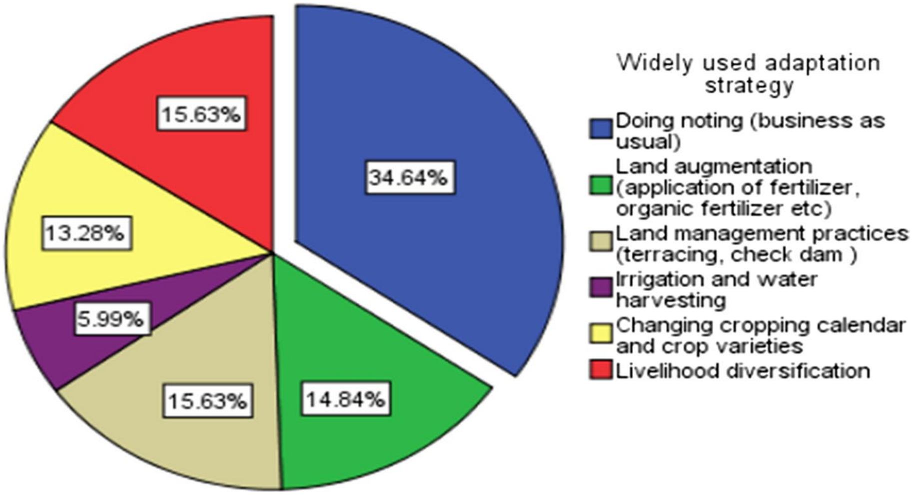

Fig. 3 Proportion of major adaptation measures (in percentage)

3.4 Major adaptation strategies to climate change and determinants

Overall, 65.4% of the respondents had undertaken adaptation measures in response to the changing climate. When we categorize the most commonly applied adaptations (based on their first choice) separately,[6] the figure resembles: land augmentation (14.8%), land management (15.6%), irrigation and water harvesting (6%), agronomic like changing planting calendar and planting early maturing crop varieties (13.3%) and engaging in beyond farm activities (15.6%). The remaining 34.6% of respondents conducted their activities as usual (see Fig. 3). When we examine the proportion of adopters in terms of the attributes of respondents, disparities were observed and the Chi-square and *t* test results confirmed statistically significant associations and differences between adopters and non-adopters based on different attributes. Adopters were younger, had better years of schooling, used more fertilizer per hectare, produced more production per hectare, had more livestock assets in TLU, cultivated more numbers of crops in one harvesting season, had more supplementary income from non-farm sources and were exposed to less numbers of food deficit months per year as compared with non-adopters (see Table 4). Policy makers and practitioners have to take such factors into account while designing adaptation interventions.

MNL regression analysis was employed to estimate the factors which influenced households' choice of adaptation strategies to reduce adverse effects of climate change. The estimation of the MNL model was made by normalizing one category (no adaptation), which is normally referred to as the base category. The validity of the IIA assumptions failed to reject the null hypothesis of independence of the climate change adaptation options suggesting that the MNL specification is appropriate to model determinants of climate change adaptation practices of smallholder farmers. VIF for all variables were less than 2 and the tolerance values were above .5; which indicates that multicollinearity in the data set did

[6] Multiple responses were not entertained. The percentage was calculated based on the major adaptation strategy which was identified as their first choice.

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Table 4 Comparison of adaptors and non-adopters of climate change adaptation strategies. *Source*: (Own survey, 2015/16)

Variables	Adopters	Non-adopters	X^2	Effect size[a]
Headship type (%)				
Male-headed	68.9	31.1	13.1***	.185***
Female-headed	43.4	56.6		
Agroecology (%)				
Dega	55.4	44.6	32.94***	.293***
Woina*dega*	83.3	16.7		
Kolla	53.6	46.4		
Wealth Status of the HHH (%)				
Poor	46.9	53.1	50.1***	.361***
Medium	67.5	32.5		
Rich	100	0		
Training on climate change (%)				
Yes	89.5	10.5	41.63***	.33***
No	55.2	44.8		
Training on small-scale business				
Yes	91.1	8.9	40.06***	.323***
No	56.2	43.8		
Training on farm management (%)				
Yes	72	28	15.99***	.204***
No	51.2	48.8		
Having radio (%)				
Yes	81.6	18.4	37.5***	.313***
No	51.7	48.3		
Having mobile phone (%)				
Yes	86	14	63.3***	.41***
No	47.3	52.7		
Having access to microfinance (%)				
Yes	84.2	15.8	55.6***	.38***
No	48	52		
Having saving account (%)				
Yes	96.4	3.6	93.7***	.497***
No	47.5	52.5		
Being member of cooperatives (%)				
Yes	83.7	16.3	28.9***	.274***
No	56.1	43.9		
Having early warning access (%)				
Yes	79.4	20.6	36.98***	.31***
No	49.7	50.3		
Climate change can be adapted (%)				
Yes	69.6	30.4	5.27**	.12**
No	58	42		
Information on climate change (%)				
Yes	80	20	60.9**	.39**
No	40.8	59.2		

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Table 4 (continued)

Variables	Adopters	Non-adopters	*t* test
Mean age of the HHH in years	47.29 (9.7)	52.02 (8.9)	4.69***
Mean year of schooling of the HHH	3.93 (4.1)	1.02 (2.5)	7.4***
Mean total house hold size (number)	5.5 (1.5)	5.69 (1.2)	1.3
Average total land size in hectare	.72 (.34)	.73 (.24)	.45
Mean fertilizer used in kg	118.22 (56.9)	79.26 (32.1)	5.39***
Average production per capita (in Qnt.)	2.5 (1.5)	1.4 (.7)	7..87***
Livestock asset in TLU	4.2 (2.7)	3.4 (2.1)	3.19***
Average time to nearest road	1.15 (1.5)	1.89 (1.24)	.881
Average time to nearest market	1.88 (1.32)	2.01 (1.09)	1.01
Crops cultivated in one season	4.05 (1.3)	3.17 (.8)	7.01***
Average annual income from non-farm sources	4544.6	897.3	3.72***
Average food deficit months per year	1.73 (2.1)	3.02 (1.5)	6.3***

**, ***Statistically significant at .05 and .001 alpha level, respectively

[a]Effect size for Chi-square test is interpreted as: < .1 weak, .11–.3 modest, .31–.5 moderate, .51–.8 strong and > .81 very strong (*source*: Cohen et al. 2007)

not pose a serious problem. Moreover, the contingency correlation result evidenced the absence of strong association among the categorical variables except for TRNING11 and TRNING12 where the former was omitted from analysis. The maximum likelihood method was employed to estimate the parameter estimation of the MNL model and statistically significant variables were identified in order to measure their relative importance on the farmers' decision to choose adaptation strategies. The likelihood test ratio output indicated by the χ^2 statistics was highly significant ($p < .001$), suggesting that all the explanatory variables included were jointly important in explaining the dependent variable and have strong explanatory power. From the regression result, we obtained pseudo R-square value of .5118 which implied that 51.18% of the model was explained by the included explanatory variables. The estimated coefficients of the MNL model and their levels of significance as well as the marginal effect results are presented in Table 5. Only those variables whose coefficients were statistically significant at 5% alpha levels or less are discussed further.

3.4.1 Land augmentation

Different types of measures which could increase land productivity were categorized under this strategy and were selected by 14.8% of respondents as their primary choice. The coefficient of family size was negative which depicted inverse relationship ($p < .05$). A unit increase in family size decreased the likelihood of using land-augmenting technologies by about 2.3%. This implied that households with more family size need high expense to satisfy their family, and due to this, they would tend to rely on labor-intensive techniques of increasing land productivity rather than applying capital-intensive ones. The result agrees with the findings revealed by Taruvinga et al. (2016) and Asnake and Mammo (2016). Contrary to our expectation, having more livestock (in TLU) decreased the likelihood of using modern land-augmenting inputs. A

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Table 5 MNL parameter estimates on determinates of adaptation strategies to climate change

Variables	Land augmentation		Land management practices		Irrigation		Changing calendar/crop varieties		Livelihood diversification	
	Coef. (SE)	dy/d*x*	Coef. (SE)	dy/d*x*	Coef. (SE)	dy/d*x*	Coef. (SE)	dy/d*x*	Coef. (SE)	dy/d*x*
HHHEAD	.275 (1.035)	.041	− 1.23 (1.049)	− .04	− 1.783(1.12)	− .142	.006 (.92)	.081	− .66 (1.02)	− .052
HHHAGE1	.0213 (.0333)	.001	.0446 (.035)	.001	.039 (.0419)	.002	.051 (.031)	.012	− .07 (.04)	− .011
HHHEDUCTN	− .0251 (099)	− .009	.0503 (.098)	− .001	.107 (.109)	.002	.187** (.088)	.026	.18** (.09)	.014
THHStotal	− .4415** (.207)	− .023	.4094 (.231)	.007	− .339 (.265)	− .008	− .268 (.192)	− .026	− .24 (.24)	− .009
WEALTH2	.3921 (.6993)	.023	− .372 (.812)	− .017	.664 (.919)	.026	.445 (.645)	.088	− .37 (.73)	− .071
LANDHA	1.3433 (1.318)	.119	.306 (1.465)	.010	2.059 (1.48)	.109	− .34 (1.28)	− .092	− 1.15 (1.39)	− .154
TLU	− .398** (.192)	− .024	− .477** (.19)	− .011	.102 (.194)	.011	− .237 (.147)	− .034	.04 (.15)	.011
TRNING12	1.488 (1.2952)	.073	4.55*** (1.56)	.087	.504 (1.344)	.006	.142 (1.23)	− .071	1.009 (1.23)	.069
TRNING18	1.664** (.815)	.079	3.284*** (.79)	.157	1.696 (.92)	.049	.98 (.69)	.026	.62 (.77)	.032
INFORMRD	− .4156 (.7313)	− .015	.753 (.766)	.032	.359 (.99)	.031	− .926 (.639)	− .191	.134 (.69)	.049
INFORMMB	.675 (.745)	.031	1.395 (.817)	.036	− .236 (.913)	− .028	.231 (.684)	.024	1.09 (.74)	.108
DISTMRKT	− .0053 (.434)	− .009	− .705 (.449)	− .025	.729 (.584)	.033	.139 (.34)	.011	.34 (.39)	.032
MCROFN	.337 (.627)	− .013	.449 (.659)	− .001	2.014** (.87)	.088	.734 (.56)	.067	.89 (.63)	.053
ASSOCTN	.459 (.670)	.056	.865 (.714)	.037	.583 (.821)	.042	− .69 (.69)	− .145	− .46 (.71)	− .042
ERLARWR	− .256 (.678)	− .019	− .374 (.751)	− .011	− .548 (.784)	− .027	.026 (.57)	.017	.16 (.66)	.026
INFOVCC1	2.083*** (.732)	.107	2.321** (.82)	.044	1.135 (.903)	.023	1.18** (.59)	.135	.39 (.73)	.034
DEGA	− .121 (1.544)	− .008	2.731 (1.59)	.069	.838 (1.412)	.049	.59 (1.026)	.181	− 1.46 (1.18)	− .159
W/*DEGA*	3.433** (1.572)	.333	− 1.152 (1.68)	− .046	1.264 (1.424)	.017	1.58 (1.15)	.180	− 1.29 (1.26)	− .215
CONEXT2	4.429*** (.815)	.228	4.07*** (.841)	.067	2.24** (.87)	.025	2.61*** (.62)	.218	2.23*** (.68)	.063
DISTROAD	− .058 (.428)	− .012	− .339 (.426)	− .013	− .371 (.53)	− .024	.43 (.28)	.099	− .055 (.304)	− .018
ILLNESS1	− 2.45*** (.846	− .066	− 6.11*** (1.57)	− .097	− 2.89*** (1.09)	− .052	− 2.56*** (.67)	− .236	− 3.16*** (.78)	− .156
RMTTNCE	.282 (.793)	− .021	.684 (.787)	.004	.181 (.89)	− .017	1.16 (.66)	.199	.76 (.72)	.029
CLVARLTY	− .252 (.735)	− .044	1.613 (.827)	.081	.82 (1.063)	.028	.78 (.68)	.141	.65 (.81)	.052
PROBAGRLND	− .087 (.759)	− .023	.483 (.764)	.0095	.433 (.79)	.013	.50 (.60)	.094	.05 (.64)	.019

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Table 5 (continued)

Variables	Land augmentation		Land management practices		Irrigation		Changing calendar/crop varieties		Livelihood diversification	
	Coef. (SE)	dy/d*x*	Coef. (SE)	dy/d*x*	Coef. (SE)	dy/d*x*	Coef. (SE)	dy/d*x*	Coef. (SE)	dy/d*x*
CROPFLR1	1.373** (.607)	.088	1.02 (.83	.020	1.11 (.98)	.039	.49 (.76)	.034	.14 (.81)	.030

Number of obs. (372); LR $\chi^2(125) = 633.57$; Prob > $\chi^2 = .0000$; pseudo-$R^2 = .5118$; log likelihood = − 302.20198

Base category business as usual (no adaptation)

HHHEAD, headship type; HHHAGE1, household head age in years; HHHEDUCTN, maximum class attended by the household head; THHStotal, total family size; WEALTH2, wealth status based on PSNP; LANDHA, total land size in hectare; TLU, livestock asset in TLU; TRNING12, training on land management; TRNING18, training on small-scale business; INFORMRD, radio ownership; INFORMMB, mobile ownership; DISTMRKT, distance to nearest market; MCROFN, access to microfinance services; ASSOCTN, membership with cooperatives; ERLARWR, having early warning on climate change; INFOVCC1, information on climate change; AGROELGYdummy1, *dega* agroecology; AGROELGYdummy2, woina*dega* agroecology; CONEXT2dummy3, contact with extension workers; DISTROAD, distance to all weather road; ILLNESS1, having a family member who needs daily care; RMTTNCE, having income from remittance; CLVARLTY, perception of adaptability of climate variability; PROBAGRLND, shortage of land as a problem; CROPFLR1, crop failure

**, ***Statistically significant at .05 and .001 alpha level, respectively

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unit increase in herd size decreased the propensity of using this strategy by about 2.4% ($p < .05$). The possible reasons might be households with more herds could use manure to increase the productivity of their agricultural land/or tend to livestock management practices rather than crop production. A similar result was reported by Deressa et al. (2014).

The probability of adopting land-augmenting strategy was 0.079 times ($p < .05$) more likely for those households having a training. The possible reason might be, in addition to the knowledge gained from the training, those who have trained and engaged in small-scale business would have the capital required to purchase agricultural inputs. Shongwe et al. (2014) reported similar findings. Besides, households having access to information about climate variability and its adverse impact were found to be 0.11 times ($p < .01$) more likely to apply land-augmenting technologies than their counterparts. The result is in line with the findings reported by Deressa et al. (2014) and Opiyo et al. (2015). This inferred that providing short-term training and access to information play paramount role in enhancing the adaptive capacity of smallholder farmers. Smallholder farmers who have had frequent contact with extension workers were 0.23 times ($p < .01$) more likely to adopt land-augmenting technologies. Since extension workers are the major sources of information and channel for knowledge spillover for agrarian communities particularly in developing countries where other means of information is very limited, strengthening their role and capacitating the skill of DAs would play overriding importance in the adoption of varied climate change adaptation measures. Studies by Tesso et al. (2012b), Ghosh et al. (2015) and Taruvinga et al. (2016) revealed similar result. In terms of agroecological setting, the likelihood of using modern land-augmenting agricultural inputs was 33.3% higher in *woinadega* as compared with others ($p < .05$). This might be due to, among other factors, small land size as compared with other agroecologies. It was found that land size per household for *woinadega* (0.63 ha) was lower than *dega* (0.77 ha) and *kolla* (0.80 ha) agroecologies (F (2383) = 12.53; $p < .05$). Since their farm size in *woinadega* is smaller, farmers tend to augment their land by applying inputs. Having a family member who needs the support of others (due to age, disability or/and health problem) might share the labor and capital to be invested in adaptation. As expected, households who had such dependents were less likely to apply modern land-augmenting inputs. Keeping other factors at their mean, households having such problem were .07 times less likely to adopt this strategy ($p < .001$).

Encountering a challenge might force individuals to adapt. In our study encountering problem of crop failure had a reinforcing and significant impact in adopting land augmentation strategy. Households who had experienced a crop failure due to rainfall variability were 8.8% more likely to undertake this strategy ($p < .05$). One possible reason might be the temptation of compensating the loss in productivity due to failure in rainfall through applying modern inputs. The econometrics outcome contradicts from the interview result obtained from elders. Informants from *kolla* and lower *woinadega* agroecologies asserted that using fertilizer whenever the rainfall is uncertain did not benefit to increase productivity. Since sufficient amount of rainfall is needed to use chemical fertilizer, farmers become reluctant to apply more amount of fertilizer in erratic and variable rainfall situation. A similar scenario was disclosed by Solomon et al. (2014) in Malawi where high variability in rainfall reduced the tendency of using inputs like inorganic fertilizer whose risk reduction benefits are uncertain. Though the estimates were not statistically significant, the coefficient for gender, mobile phone ownership, age, wealth status, having training in land management, access to microfinance, being

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a member of associations and having remittance were positive which would probably enhance smallholder farmers' ability to adopt land-augmenting strategies.

3.4.2 Land management practices

Practices like stone/soil bund, check dam and related physical and biological land management strategies were considered under this strategy. Household having a large size of herds tend to focus on livestock management rather than on land management adaptations. Whenever the size of the herd in TLU increased by one unit, the propensity of applying these strategies decreased by 1.1% ($p < .05$) taking all other factors at their constant. The finding agrees with the report of Deressa et al. (2014). Farmers who have got a training in land management and small-scale business were 8.7 and 15.7% more likely ($p < .01$) in choosing land management practices than their counterparts, respectively. Having information about climate change and its impact is widely stated as a prerequisite in undertaking adaptations (Debalke 2014). In our finding, concurrent with our expectation, those households who received information about climate variability took land management practices more likely (4.4%) than their counterparts ($p < .05$).

Land management practices have been influenced by access to extension services. Households who had better access to extension services carried out land management practices by 6.7% ($p < .01$) as compared with farmers with limited access to it. The result is in line with the findings of Tesso et al. (2012b) and Taruvinga et al. (2016). It was also confirmed during an interview that farmers in *woinadega* and relatively in the *dega* were better in employing land management related and agronomic adaptation strategies. Families who had more economically dependent members and required the daily care of other family members were .097 times less likely to adopt this adaptation strategy ($p < .01$). Recognizing the possibility of adapting a changing climate is among the influencing factors which govern adoption of different climate change adaptation measures (Shongwe et al. 2014). Though the result was not significant, farmers residing in *dega* areas, having more family size and who perceived the availability of possible adaptation measures to climate change were better in practicing land management options.

3.4.3 Water resource management

Water resource management of any type (river diversion, rainwater harvesting, using springs/ponds, small-scale dams and related) was classified under this adaptation strategy and it was selected as their primary measure only by 6% of respondents. Having access to reliable microfinance services was among the factors which influenced adoption of irrigation positively. Households who have microfinance access were 8.8% more likely to engage in irrigation activities ($p < .05$). Farmers having training in small-scale business and access to microfinance might have better knowledge and income which could alleviate financial constraints to get different irrigation technologies and agricultural inputs. Deressa et al. (2009) revealed farmers in the Nile basin did not invest in irrigation due to financial constraints. A study by Asnake and Mammo (2016) and Taruvinga et al. (2016) reported a positive association between access to credit and irrigation practices. This implied that providing smallholder farmers with affordable microfinance services would enhance their adaptive capacity. The frequency of contact with extension workers was found to be a factor influencing the engagement of smallholder farmers in irrigation activities positively ($p < .05$). Having better access to extension services could increase the probability

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of undertaking irrigation activities by about 2.5% because extension services provide better opportunity to identify viable adaptation strategies. A similar finding was disclosed by Asnake and Mammo (2016).

The probability of households with a dependent member who needs the support of other active family members in participating in irrigation schemes was less (5.2%) as compared with their counterparts ($p<.01$). Since irrigation is both labor demanding and capital intensive, the tendency of households with such a problem to practice irrigation as adaptation strategy is expected to be very low. Since rainfed agriculture is highly susceptible to climate variability, it is highly advisable to work with utmost effort to intensify irrigation practices of all possibilities. As confirmed by an expert from Borena district agricultural office and district administrator, there is a large potential for irrigation in the district, and some initiatives have been started to support the rainfed agriculture which has been frequently affected by rainfall variability. Besides, the traditional irrigation practices being implemented are not water efficient and needs reconsideration of shifting to technologies which would enable to save the scarce water. On the other hand, an elder from Legambo district confirmed that due to shortage of water during the dry season, implementing irrigation through river diversion becomes challenging unless supported by small-scale dams or night storage.

3.4.4 Changing planting calendar and crop varieties (agronomic)

Changing the planting dates and crop varieties (categorized under the agronomic adaptation strategies) were implemented as the primary adaptation by 13.3% of respondents. As evidenced in different empirical literature, educational level of the household head influenced the adoption of these strategies. The positive β coefficient for education suggested that a unit increase in grade level completed by the head increased the probability of changing cropping calendar and crop varieties by 2.6% ($p<.05$). Educated farmers had better knowledge of climate change and adaptation options, were better in accepting new ideas and technologies and were better in anticipating changes which would enhance their likelihood of adopting different adaptation strategies. The result coincides with the findings disclosed by Deressa et al. (2009), Balew et al. (2014) and Abid et al. (2015). Having information about the climatic situation would encourage smallholder farmers to adjust the planting data and to diversify crop varieties. It was found that, households having prior information about the climatic state were more likely (13.5%) to adjust the planting calendar ($p<.05$) than those who did not have such information. The empirical finding by Balew et al. (2014) and Kusmana et al. (2016) disclosed similar result. Access to extension services plays a vital role in climate change adaptation and farm management practices. The beta coefficient for the frequency of contact with extension workers was positive and significant ($p<.01$).The implication here is that, farmers who have better support from DAs were more likely (21.8%) to change the cropping calendar and crop varieties in response to the change. Similar finding was disclosed by (Ghosh et al. 2015; Taruvinga et al. 2016). Providing timely information and frequent support of extension services should be strengthened so as to enable farmers to adjust their agricultural calendar and crop varieties. The adoption of this strategy was also constrained by the presence of family member who needs the support of others. The likelihood of adopting this strategy dropped by 23.6% ($p<.01$) whenever there is such problem in the family.

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3.4.5 Livelihood diversification

Having source of income besides farming was carried out by 15.6% of the respondents as their principal adaptation choice. Agreeing with our prior expectation, the β coefficient of educational level of the household head was found positive which implied that livelihood diversification is positively and significantly influenced by education. Educated farmers tend to earn their source of livelihood from different sources so as to share risks. When the year of schooling increased by one grade level, the likelihood of diversifying livelihood increased by about 1.4% ($p<.05$), holding other covariates at their mean. Deressa et al. (2014) and Kusmana et al. (2016) had found a similar result. Access to extension services was among the factors which had a strong positive effect on livelihood diversification. Having such services had increased the likelihood of household to diversify their livelihood by 6.3% ($p<.01$). By the same token, Asnake and Mammo (2016) had found strong and significant impact on extension service with livelihood diversification. Having economically dependent family member did affect the adoption of this strategy negatively and significantly at 1% level of significant. Households with such problem were 15.6% less likely to earn their substance from diversified sources of income.

4 Conclusion and policy implications

The study area is among the critically affected regions by climate variability and extreme events, and further climate change could be a major development challenge for smallholder farmers. It is important to understand the nature of climate change impacts, the perception of the affected communities and adaptation practices at local levels in order to identify and implement feasible adaptation strategies at microlevels. This study intended to address these issues by taking *Woleka* sub-basin (in drought-prone parts of north-central Ethiopia) as a case study. Smallholder farmers were aware of climate change but not all of them responded by adapting to the changing climate due to different constraints mainly due to financial constraint, lack of knowledge and limited early warning information and scarcity of water. Climate change has been affecting the agrarian communities in different ways particularly confusion on planting dates due to unpredictable nature of the rainfall, forced to cease irrigation activities due to a shortage of water, reduction in crop yield, forced to travel along distance in search of water and reduction in the productivity of domestic animals. The prominent strategies being employed by smallholder farmers include stone/soil bund, changing the farming calendar, switching to earlier maturing varieties, growing drought-resistant varieties and reducing the number of domestic animals. Using water resource was better implemented in *dega* and *woinadega* areas. Since rainfall has been becoming more variable, rainfed agriculture will no longer enable to achieve food security and should be supported by irrigation practices. Non-farm livelihood diversification as climate change adaptation strategies was not well developed. The overwhelming majority smallholder farmers are still relying on age-old technologies and agricultural management practices that invariably result in low productivity and production. As a result, transforming the agricultural sector and affording water-efficient irrigation technologies would enable both to improve their current levels of production and will also build their livelihoods to be climate resilient.

The MNL regression model outcome reveals that different factors determine the selection and application of different adaptation strategies: age and education level of the head,

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family size, herd size, having a training, access to information, microfinance as well as extension services, agroecology, having a family member who needs daily care, perceiving that climate change can be adapted and experienced crop failure were found to be the determinants factors. As a result, it is imperative to consider these factors while designing adaptation measures. Adopters on average were found to be younger, had better years of schooling, had more livestock assets, had more income from non-farm sources and were exposed to fewer numbers of food deficit months. The study further evidenced that institutional factors and skill development such as agriculture extension service, training, access to information on climate change and access to credit enhanced the adaptive capacity of smallholder farmers to climate change. Thus, overcoming financial constraint, reliable extension service, providing timely early warning information, providing farm and non-farm-related training and better educational attainment would enable to enhance the adaptive capacity of rainfed-dependent smallholder farmers. One major problem faced by smallholders is the unpredictability of rainy season. As a result, disseminating timely weather and agricultural extension information to enable farmers to help them revise their climate change adaptation decisions for a specific time and specific agricultural activity is very essential. In nutshell, though farmers have employed varied types of autonomous and *ex-post* adaptive responses, farming activities and achieving food security have increasingly been constrained by climate change. This implied the need for planned interventions like the promotion of water-efficient irrigation system, affording improved and suitable crop varieties and expansion of non-farm economic activities. Since the duration of the rainy season has becoming shorter in the study area, research works have to focus on introducing short maturing and water efficient but high yielding crop varieties. The ongoing discussion evidenced that both adoption models (innovation diffusion, adoption perception and the economic constraints models) should be considered while estimating determinants of adoption which could improve the explanatory power of the model than using a single paradigm.

Our findings have several policy implications: supporting smallholder farmers through training on climate change adaptation options; targeting female-headed and poor farmers can have significant positive impacts for increasing the implementation of adaptation measures. Besides, there is a need to support research, development, and diffusion of appropriate and affordable technologies to help farmers adapt to changes in climatic conditions. Climate change impacts, constraints and livelihood assets varied at different scales and levels. Thus, microlevel studies enable to identify locality level constraints which are essential to design appropriate adaptation strategies based on the actual circumstances. The sub-basin is among the intensively cultivated and highly degraded areas of the country where productivity is constrained both by low fertility. Climate change would further exacerbate the existing low productivity unless viable adaptations are put into action. As a result, addressing both the drivers of vulnerability and enhancing the adaptive capacity of smallholders would have win–win output. In doing so, selecting strategies that would enable to increase land productivity and withstand the effects of changing climate is imperative. We recommend expansion of non-farm sources of livelihoods, integrated watershed management and implementation of irrigation schemes as feasible adaptations. Adaptation strategies which are feasible today might not be viable tomorrow. As a result, continuous follow-up and evaluation of interventions should be undertaken and supported by research findings.

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Appendix

See Tables 6, 7 and 8.

Table 6 Hausman specification test result for IIA assumption. *Source*: Own survey result (2015/2016)

Adaptation strategy restricted/omitted	χ^2	*df*	$p>\chi^2$	Evidence
Land augmentation	1.418	84	.982	For Ho
Land resource management	1.689	84	1.000	For Ho
Water resource (irrigation)	7.258	84	1.000	For Ho
Changing cropping calendar	11.867	84	.956	For Ho
Livelihood diversification	3.863	84	1.000	For Ho

A significant test output is evidence against Ho

Table 7 Multicollinearity diagnosis for continuous variables. *Source*: Own survey result (2015/2016)

Continuous variables	Collinearity statistics	
	Tolerance	VIF
HHHAGE1	.695	1.439
HHHEDUCTN	.678	1.476
THHStotal	.916	1.092
LANDHA	.638	1.567
TLU	.579	1.728
DISTROAD	.519	1.925
DISTMRKT	.555	1.802

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Table 8 Contingency coefficient table for categorical variables. *Source*: Own survey result (2015/2016)

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	HHHEAD																
2	WEALTH2	.26															
3	TRNING12	.17	.29														
4	TRNING18	.11	.11	.27													
5	INFORMRD	.23	.38	.34	.19												
6	INFORMMB	.14	.33	.26	.27	.46											
7	MCROFN	.17	.19	.16	.12	.33	.32										
8	ASSOCTN	.13	.09	.06	.27	.14	.17	.13									
9	ERLARWR	.19	.15	.22	.25	.24	.12	.15	.19								
10	NFOVCC1	.32	.26	.31	.22	.45	.31	.23	.18	.33							
11	W/*DEGA*	−.03	.16	−.13	.012	.04	.26	.12	.19	.09	−02						
12	CONEXT2	.24	.27	.34	.29	.38	.31	.26	.22	.43	.37	−.002					
13	ILLNESS1	−.19	−.25	−.13	−.22	−.27	−.34	−.32	−.15	−.26	−.25	−.28	−.39				
14	RMTTNCE	.10	.32	.19	.04	.32	.33	.27	.11	.16	.29	.05	.21	−.18			
15	CLVARLTY	.18	.29	.23	−.01	.31	.07	.22	−.05	.31	.39	−.14	.19	−.05	.18		
16	PROBAGRLND	.11	−.01	.05	.13	.04	−.07	.02	−.03	.13	.09	−.08	.11	−.01	−.03	.15	
17	CROPFLR1	−.05	−.02	−.21	−08	−.12	.07	.09	.06	.01	−.08	.47	−.09	−.15	.02	−.17	−.08

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