Factors affecting farm management adaptation strategies to climate change: The case of western Lake Tana and upper Beles watersheds, North West Ethiopia

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Abstract: Ethiopia is vulnerable to climate change and variability. This research investigates the factors that affect farm management adaptation strategies to climate change in west of Lake Tana and Beles river watersheds of Northwest Ethiopia. A survey was conducted collecting data from 338 households through a semi-structured interview schedule. To analyze the data, the multivariate probit model was used. The results indicated that market distance, frequency of extension services and oxen ownership have highly influenced the choice of crop management adaptation strategies to climate change. The likelihood of adopting short-mature crops, high yielding crop variety, and crop compost preparation was relatively higher (95%) as compared to the probability of adopting other strategies. The joint probabilities of success of the adaptation of the crop management adaptation strategies

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PUBLIC INTEREST STATEMENT

In Ethiopia, smallholder farmers are vulnerability to climate change and variability. It affects crop and livestock production and reduce yield potentials. Adaptations are required to mitigate the negative consequences of climate change. Hence, in the study area, choice of short matures crops, high yielding crop variety and crop compost preparation was relatively higher as compared to the probability of adopting other strategies in crop management adaptation strategies. Similarly, farmers choice of hay preparation, cut and carry system, herd size determination and rotational grazing were also relatively high in animal management adaptation strategies compared to the probability of adopting other strategies. It is clearly recommended that households need to use complementary and or integrated (package) farm management adaptation practices. Moreover, variables such as age, gender, market distance, crop income, extension service, education level, and oxen ownership are significantly affecting farm management adaptation strategies. Therefore, farm household and any development agents need to consider these factors during intervention.
were 15%. Hence, households are more likely to jointly adopt the crop management climate change strategies. Similarly, age of household head, market distance, and oxen ownership were important characteristics affecting the farmers’ choice of animal management as climate change adaptation strategy. The likelihood of adopting hay preparation (89.4%), cut and carry system (77.4%), herd size determination (69.6%) and rotational grazing (67%) were also relatively higher as compared to other strategies. The joint probabilities of adaptation of animal management as climate change adaptation strategy was more likely to be applicable if adoption of the technologies (16.8%) were made jointly compared to their failure to jointly adopt them. Therefore, promoting complementary farm management adaptation practices and considering the socioeconomic factors are crucial to mitigate climate change vulnerability in the study area.

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1. Introduction
Climate change and food security are challenges facing the Ethiopian agricultural system today. Currently, there exist serious and direct impacts of climate change on crops, livestock, and water as compared to other economic sectors in the country. Impacts of climate change on the crop sector are in terms of decreasing both productivity/yield and cultivable land due to high temperature and water deficiency (Nathnael & Hanna, 2017). One of the major reasons for the existing poverty is the dependence of the economy on agriculture, which has failed to meet the growing food demands of the population and left the nation dependent on food aid Moreover, the past trends of climate change and climate variability, which hinder agricultural production, are expected to sustain in the future (Deressa, Ringler, & Hassan, 2010). For example, over the last decades, the temperature in Ethiopia increased by about 0.2° C per decade. On one hand, the minimum temperature increased roughly by 0.4° C per decade. Precipitation, on the other hand, remained fairly stable over the last 50 years. A projection suggests that Ethiopia will experience a 1.7°C–2.1°C increase in the mean temperature by 2050 (Ethiopian Environmental Protection Agency [EPA], 2012). The Ethiopian average annual rainfall has recently shown a very high level of variability for the past 55 years. Some years have been characterized by dry conditions, resulting in drought and famine, whereas others are characterized by wet conditions (Deressa et al., 2010).

According to the IPPC report, approximately 20–30 percent of plant and animal species will be endangered if the global average temperature increases by more than 1.5–2.5°C (Intergovernmental Panel on Climate Change [IPCC], 2007).

Adaptation to climate change requires making anticipatory adjustments to prepare for expected climate variability and changing average climate conditions, in order to moderate harm and exploit beneficial opportunities (IPCC, 2007). According to Adger, Huq, Brown, Conway, and Hulme (2003), adaptation can be defined as the adjustment of a system to moderate the impacts of climate change or climatic stimuli.

Crop production is the dominant livelihood base of the people of the Amhara region like elsewhere in Ethiopia. Over 85% of the active population of the region is engaged in this sector. However, north and northeast parts of the region are more exposed to a shortage of rainfall with receiving less than 700 mm annually (Center for Disease Control and Prevention [CDCP], 2008) and face shortage of food throughout the year. Many surpluse-producing woredas (districts) before two decades in North and South Gondar, East Gojjam and North Shewa administrative zones have
already become highly vulnerable to food insecurity and poverty (Melesse, 2007; Misganaw, Enyew, & Temesgen, 2014).

Lake Tana and upper Beles watershed (the study area) is one of the ecologically sensitive areas in West Gojjam of the Amhara region, which the two watersheds desiccate towards Tana from the east side and towards Belese from the west side. Currently, it is a place where one of the great hydroelectric power generation plants is built (that is Tana Beles). Studying at the household (farm level) is very essential to know the micro-level farm and farmers’ characteristics in the local context. Its agro-ecology is characterized by hot temperatures and erratic rainfall. The area is also serious and successively affected by changing climatic conditions and extremes. To reduce their vulnerability to the negative effects of climate change, farmers adopt different adaptation mechanisms.

The study contributes to the growing literature on the issue of farming management adaptation strategies to climate change in the present worldwide agenda or scenario. The study also used a larger sample size of farm households in area coverage and also it considered, methodologically, the interdependence between different farm management adaptation practices. The study jointly analyzes the decision to adopt multiple climate change adaptation practices and answers the question whether farmers adopt technologies in piecemeal fashion or in package practices. This helps policymakers to design effective adaptation strategies in the agriculture sector. Moreover, the research focuses on identifying socioeconomic factors that are likely to influence farm management adaptive strategies development intervention in the study area. The study is specifically conducted in Lake Tana (the largest Lake in Ethiopia), and in bordered watershed areas in general.

2. Materials and methods
The study was conducted in west of Lake Tana i.e. from Lake Tana to Belese River comprising three kebeles; namely: Charmadusuman, Wombera eyes, and Kunzela zuria. In total, three of the villages have a sum of 2,703 households, of which 2,384 of them are male-headed households and the rest are female-headed households. The study area is bordered with the great Lake Tana and the farming system is both crop and livestock production. Besides, there are supplementary irrigation schemes from Lakes and rivers. The common type of crops grown in the area includes teff, maize, and figure millet. Moreover, growing animals like cattle, donkey, mule, sheep, and Goat (Figure 1).

The study employs a multistage sampling technique. First, the zone and the woreda were purposefully selected based on the ecological importance and sensitivity of the area as well as the access to research location. Both, household survey, focus group discussions and key informant interviews were used to collect data from primary and secondary sources. From the total population of households, a sample size of 338 was selected based on proportion to the population size of the kebele. Hence, the Charmadusman kebele holds 74, Wombera Eyesus kebele consists of 133 and Kunzela Zuria kebele also holds 131 households respectively. The data was collected from 338 sample households in the 2017/18 production year.

In this study, there are dependent variables (adaptation mechanisms) regressed against independent variables (age of household head, gender, education level, family size, farm experience, farm size, crop income, distance to market, frequency of extension and oxen ownership and credit access). The dependent variables were considered under the category of crop production management strategy and animal production management adaptation mechanisms of climate change (Table 1). The most common climate variability and climate change adaptation strategies in rural Ethiopia used by scholars include; Abirham (2017), Addisu, Fissha, Gediff, and Asmelas (2016), Elasha et al. (2006) and Wolka and Zeleke (2017).
2.1. Model specification

The climatic variability was analyzed through a combination of descriptive analysis and econometric models. The multivariate probit model is a generalization of the probit model used to estimate several correlated binary outcomes jointly developed by Chib and Greenbergx (2009). The difference between multivariate regression and multiple regression is that several dependent variables are jointly regressed on the same independent variables. Many researchers used the Heckman probit model and a multinomial logit (MNL) model to examine the determinants of adoption of climate change and variability (Gebetibou, 2009).

A farmer’s decision to use adaptation practice is discrete in nature and calls for qualitative choice models. Binary probit/Logit/ and Multinomial probit/Logit/models did not consider the possible interrelationships between the various adaptation strategies whereas a farmer may choice adaptation technology mixes and the decision to use one practice could be influenced by choice of decisions for other practice (Yu, Hurley, Kliebenstein, & Orazem, 2008). Since, univariate modeling excludes useful economic information about interdependent and simultaneous adoption technologies (Dorfman, 1996). However, the multivariate probit model considers the interdependencies and simultaneous choice decisions of various technologies (Arinloye et al., 2015; Degye, Belay, & Mengistu, 2013; Teklewold, Kassie, & shiferaw, 2013). It is observed that complementary use of new technologies can increase income and stimulate technology adoptions (Yu, Hurely, Kiebenstein, & Orazem, 2012). Therefore, to analyze socioeconomic factors that affect climate adaptation strategies, a multivariate probit model (MVP) is the appropriate model. The multivariate probit model for multiple-choice problem takes the general form as follows:

The selection of climate change strategy i by farmer j is Yij, defined as the choice of farmer j to adapt (mitigate) the technology in climate adaptation strategy i (Yij = 1) or not Yij = 0 is expressed as follows:
Where:

\[ Y_{ij} = \begin{cases} 1 \text{ if } y_{ij} = x_{ij}a_{ij} + e \geq 0 \\ 0 \text{ if } y_{ij} = x_{ij}a_{ij} + e < 0 \end{cases} \]  \hspace{1cm} (2)

Table 1. Dependent and independent variables that are likely to affect the choice of crop and animal adaptation strategy of farmers

| Dependent Variables | Measurement | Hypothesis |
|---------------------|-------------|------------|
| 1. Crop production management adaptation strategy | | |
| 1.1. Strip cropping (yes = 1, 0 = no) | | |
| 1.2. Mixed cropping (yes = 1, 0 = no) | | |
| 1.3. Crop rotation (yes = 1, 0 = no) | | |
| 1.4. Tree planting/wood lot (yes = 1, 0 = no) | | |
| 1.5. Agro-forestry (yes = 1, No = 0) | | |
| 1.6. Applying crop rotation (yes = 1, No = 0) | | |
| 1.7. Using high breed high yield varieties (yes = 1, No = 0) | | |
| 1.8. Small irrigation from river/spring (yes = 1, No = 0) | | |
| 1.9. Sowing short matures crops (yes = 1, No = 0) | | |
| 2. Animal production management adaptation strategy | | |
| 2.1. Rotation grazing (yes = 1, No = 0) | | |
| 2.2. Implement cut and carries system (yes = 1, No = 0) | | |
| 2.3. Using improved forage (yes = 1, No = 0) | | |
| 2.4. Herd size determination with carrying capacity (yes = 1, No = 0) | | |
| 2.5. Use improved breeds (yes = 1, No = 0) | | |
| 2.6. Hay preparation | | |
| 2.7. Care for communal grazing | | |

| Independent variables | Measurement | Hypothesis |
|-----------------------|-------------|------------|
| 1. Age of the household head | Number | Positive |
| (1) Sex of the household head | Dummy (1 = Male, 0 otherwise) | Positive or negative |
| 3. Education level | Level category | Positive |
| 4. Family size | Number | Positive |
| 5. Farm experience | Years | Positive |
| 6. Farm size | Hectar | Positive |
| 7. Distance to market | Kilometer | Negative |
| 8. Frequency of extension | Number | Positive |
| 9. Crop income | Birr | Positive |
| 10. Oxen ownership | Number | Positive |
| 11. Access to credit | Dummy (= 1 if yes) | Positive |

\[ C_j = X_1\beta_1 + e \]

\[ A_j = X_2\beta_2 + e \]  \hspace{1cm} (3)

Where \( C_j \) and \( A_j \) are binary variables taking values 1 when farmer \( j \) selects crop production, and animal production management, respectively, and 0 otherwise; \( X_1 \) to \( X_4 \) are vectors of variables; \( \beta_1 \) to \( \beta_4 \) a vector of parameters to be estimated and \( e \) is disturbance term.
In multivariate models, the choice of several adaptation strategies is possible; the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity, and the symmetric covariance matrix \( \Omega \) is given by:

\[
\Omega = \begin{bmatrix}
1 & \rho_{12} & \rho_{13} & \rho_{14} \\
\rho_{21} & 1 & \rho_{23} & \rho_{24} \\
\rho_{31} & \rho_{32} & 1 & \rho_{34} \\
\rho_{41} & \rho_{42} & \rho_{43} & 1
\end{bmatrix}
\]

Where \( \rho_{ij} \) represent the correlation between different types of adaptive strategies for climate change. If these correlations in the off-diagonal elements in the covariance matrix become non-zero, it justifies the application of a multivariate probit for each individual climate adaptation practice.

3. Results and discussion of the study

3.1. Descriptive analysis of the respondents

3.1.1. Age
Based on the ministry of Ethiopian Labour and Social Affair (MoLSA), the demographic age group can be classified based on four classes or cut points. The survey result indicated that about 81% of the sample households are between the age of 31 to 60 years old (prime and mature working age group), while about 10% of the sampled households were above 60 years old (elderly). This implies that the majority of the farmers sampled were adults who had vast experience in farming and had observed climate change over the years.

3.1.2. Gender
The survey showed that 94% of the sampled households were headed by male-headed and 6% were female-headed households. Most households can able to perceive adaptation strategies towards climate change, as it is explained by Asfaw and Admassie (2004).

3.1.3. Education level
Based on the Ethiopian ministry of education, an education level (years) can be classified based on four levels or years of education. The survey result revealed that 50% of the sample were illiterate (unable to read and write) and 35% were able to read and write (informal level of education, usually adult education and some traditional religious education) and 10% were between one and four years of education (formal education). The low level of years of education in the study area means farmers are less likely to be aware about the perception and adaptation strategies towards climate change.

3.1.4. Household size
Globally, average household size ranges from fewer than three persons per household to more than six (United Nation [UN], 2017). About 30% of the farmers have members of 6 to 7 person, which is over the national family size. The average household size observed in the country is 4.6 individuals per household (Central Statistical Agency [CSA] of Ethiopia and ICF, 2017). The household size is a proxy to labor availability that enables farmers to take labor adaptive measures on their farm.

3.1.5. Farm experience
The majority of the farmers have experience in farming practice in the study area. The more the farming experience, means that the better to perceive climate change adaptation strategies compare to farmers having less experience in farming practices in the study (Table 2).

3.1.6. Land size and oxen ownership
The majority of the farmers own land between 0.5 and 1 hectare, which consists of 30% of the sampled households. About 8% of households own less than 0.5 hectares and 21% of them own a land size...
### Table 2. Descriptive statistics of the farm households

| Descriptive statistics | Freq. | Percent (%) | Descriptive statistics | Freq. | Percent (%) |
|------------------------|-------|-------------|------------------------|-------|-------------|
| 1. The age of respondents |       |             | 7. Land size/ownership |       |             |
| 18–30 (early working age) | 30    | 8.88        | less than 0.5 ha | 27    | 8.49        |
| 31–60 (mature working age) | 272   | 80.47       | 0.5–1 ha | 97    | 30.5        |
| Above 60 (elderly) | 36    | 10.65       | 1.1–1.5 ha | 66    | 20.75       |
|                       |       |             | 1.5–2 ha | 60    | 18.87       |
|                       |       |             | Greater than 2 ha | 68    | 21.38       |
| Total                  | 338   | 100         | Total              | 318   | 100         |
| 2. Education level of HH |       |             | 8. Oxen number of HH |       |             |
| Illiterate (Unable to read & Write) | 170    | 50.3        | 1                    | 46    | 13.6        |
| Read and write (Adult & religious education) | 119    | 35.21       | 2                    | 186   | 54.9        |
| 1–4 years of education | 36    | 10.65       | 3                    | 52    | 15.3        |
| 5–8 years of education | 10    | 2.96        | 4                    | 36    | 10.6        |
| 9–10 years of education | 3     | 0.89        | 5                    | 9     | 2.7         |
| Total                  | 338   | 100         | Total              | 329   | 97.3        |
| 3. Gender of household |       |             | 9. Income of HH |       |             |
| Male                   | 317   | 93.79       | less than 5000 | 4     | 1.19        |
| Female                 | 21    | 6.21        | 5,000–10,000 | 61    | 18.1        |
| Total                  | 338   | 100         | 10,001–15,000 | 65    | 19.29       |
|                       |       |             | 15,001–20,000 | 51    | 15.13       |
| 4. Family size of HH   |       |             | 10. Do you get a credit service? |       |             |
| 1–3 (low)              | 34    | 10.06       | above 20,000 | 156   | 46.29       |
| 4–5 (average)          | 74    | 21.89       | Total              | 337   | 100        |
| 6–7 (large)            | 124   | 36.69       | Yes                | 197   | 58.28       |
| Greater than 7 (extended) | 106   | 31.36       | No                 | 141   | 41.72       |
| Total                  | 338   | 100         |                       |       |             |

(Continued)
Table 2. (Continued)

| Descriptive statistics | Freq. | Percent (%) | Descriptive statistics | Freq. | Percent (%) |
|------------------------|-------|-------------|------------------------|-------|-------------|
| **Total**              | 338   | 100         | **Total**              | 338   | 100         |
| 5. Farm experience of HH |       |             | 11. Extension visit of HH |       |             |
| Less than 10 years     | 7     | 2.07        | 1 to 4                 | 198   | 58.58       |
| 10-20 years           | 104   | 30.77       | 5 to 8                 | 110   | 32.55       |
| 21-30 years           | 115   | 34.02       | above 8                | 30    | 8.88        |
| 31-40 years           | 81    | 23.96       | Total                  | 338   | 100         |
| Above 40 years        | 31    | 9.17        |                        |       |             |
| Total                 | 338   | 100         | 12. Market Distance    |       |             |
| 6. Land size/ownership/|       |             | 1.1. Less 5 km         | 239   | 70.71       |
| 1.1 to 1.5 ha         | 66    | 20.75       | 5 to 10 km             | 66    | 19.53       |
| 1.5 to 2 ha           | 60    | 18.87       | 11 to 15 km            | 33    | 9.76        |
| Greater than 2 ha     | 68    | 21.38       | Total                  | 338   | 100         |
| Total                 | 318   | 100         |                        |       |             |

Source: field survey, 2018
between 1.1 to 1.5 hectares. The survey result shows that 54.8% of the sampled households own two oxen, 15.33% own three oxen and 10.6% own four oxen and about 13% own one ox only. Literature indicated that about 29% of Ethiopian farmers have no oxen, 34% have one, 29% have two and 8% have two or more (Melaku, 2011). With regard to the wealth or income status of the respondents, which is measured in terms of oxen ownership, 71% were rich (having two or more oxen) and 13% were poor (having one or no ox). Similarly, 40% of the respondents earn an income of greater than 20,000 ETB and 15% of them earn between 15,001–20,000 ETB income per year.

3.1.7. Credit and extension service
The sampled households were asked whether they obtain credit or not, 41% of them responded that they did not get any credit services; however, 58% got services from different sources like the Amhara credit institute (ACSI). The extension contact frequency was reported to be between 3 to 4 times a month for 33% of households and 1 to 2 times or 25% of the respondents. The majority of the respondents replied that the distance from the farmer training center (FTC) was found to be 5 km away for 46% of the respondents and between 5 to 7 km for 41% of the respondents. About 70% of the respondents mentioned that the market distance was less than 5 km (Table 2).

3.2. Farmers’ perceptions of climate change in the study area
The sample respondents were asked a dichotomous (“yes/no” response) question about whether or not they had experienced changes or perception levels in climate variabilities. About 74% of the respondents’ farmers argued that they have awareness about rainfall and temperature change in the study area as a result of climate change. The farmers replied that about 91% of them affirmed there are temperature distribution differences and rainfall irregularity distribution for the last 30 years’ time. The respondents also indicated that soil fertility, land productivity, forest resource, and rangeland status, has increased but soil erosion, land degradation, drought hazard impact has increased from the previous time. Moreover, crop pest infestation and animal disease hazards have decreased compared to the previous time. However, more than fifty percent of the respondents were indifferent about the questions they have answered (Table 3).

3.3. Econometric analysis
The decision to choose an adaptation strategy was determined by various demographic, socioeconomic and institutional factors. The Wald chi-square statistic was used to test the overall significance of variables. The result implied that the model was significant at the 1% level (Wald chi2 (81) = 319.38), and the explanatory power of the factors included within the model is satisfactory. The likelihood ratio test of the null hypothesis of independence of the adaptation strategy choice (ρij = 0) is significant at 1%. Therefore, the null hypothesis that all the ρ (Rhø) values are jointly equal to 0 is rejected, indicating the goodness of fit of the model and the decisions to choose different adaptation strategies were interdependent on each other. Several selected farmers’ adaptation strategies were applied to regress over the independent socio-economic factors of the model. These can include crop production management adaptation option strategies and animal management practices.

3.3.1. Factors affecting crop management climate change adaptation strategy
Of the seven socioeconomic variables listed, the age of the household head has no significant effect on crop management adaptation strategies. However, age influences compost preparation negatively, at the 10% level of significance. That means compost preparation is age-dependent. As age increases, there are fewer tendencies to apply or use compost preparation as a climate change adaptation strategy. Studies from Gebetibou (2009), explained that farmers with more than 30 years of experience are also less likely to claim no change in temperature and no change in rainfall variability.

Gender difference highly affects compost preparation positively and statistically at the 1% level of significance. However, the use of short mature crops and implementing irrigation practice is negatively determined by gender differences. It is statistically significant at 5% and 10%
| Questions                              | Total | Very decrease (%) | Decrease (%) | No change (%) | Increase (%) | Very increase (%) | Total |
|----------------------------------------|-------|-------------------|--------------|---------------|--------------|-------------------|-------|
| (1) Soil fertility trend               | 336   | 18%               | 57%          | 2%            | 22%          | 0%                | 100%  |
| (2) Soil erosion trend                 | 336   | 6%                | 38%          | 2%            | 52%          | 3%                | 100%  |
| (3) Land productivity trend           | 336   | 11%               | 52%          | 4%            | 33%          | 0%                | 100%  |
| (4) Land degradation trend            | 335   | 6%                | 38%          | 1%            | 53%          | 2%                | 100%  |
| (5) Forest resource status trend      | 336   | 22%               | 48%          | 1%            | 28%          | 0%                | 100%  |
| (6) Range land resource status trend  | 336   | 12%               | 82%          | 4%            | 3%           | 0%                | 100%  |
| (7) How do you perceive rainfall variation trend | 337   | 0%                | 0%           | 10%           | 89%          | 0%                | 100%  |
| (8) How do you perceive temperature variation trend | 337   | 0%                | 3%           | 6%            | 91%          | 0%                | 100%  |
| (9) Drought hazard impact on soil     | 268   | 11.6%             | 28.7%        | 24.3%         | 35.4%        | 0.0%              | 100.0%|
| (10) Flood hazard impact on soil      | 138   | 11.6%             | 31.2%        | 23.2%         | 24.6%        | 9.4%              | 100.0%|
| Questions                                                                 | Total | Very decrease (%) | Decrease (%) | No change (%) | Increase (%) | Very increase (%) | Total |
|--------------------------------------------------------------------------|-------|-------------------|--------------|--------------|--------------|-------------------|-------|
| (11) Crop pest infestation hazard impact on soil                         | 275   | 6.2%              | 34.2%        | 53.1%        | 6.5%         | 0.0%              | 100.0%|
| (12) Animal disease Infestation Hazard impact on soil                    | 245   | 7.3%              | 35.9%        | 54.7%        | 2.0%         | 0.0%              | 100.0%|

Source: field survey
respectively. The finding implies that males have a lower probability of changing crop varieties (may use of short mature crops) as an adaptation strategy to climate change than female farmers. The finding is consistent with Asfaw and Admassie (2004) and Deressa, Hassan, Ringler, Alemu, and Yesuf (2009). The education level of the household head is found to positively affect the use of short mature crops and the application of mix-cropping as an adaptation strategy for climate change. The result implies that farmers with higher levels of education are positively related to the choice of adaptation strategies of climate change technologies: farmers with more schooling are expected to adapt better to climatic changes and extreme climate events (Daberkow & McBride, 2003; Deressa et al., 2009; Maddison, 2006).

In this study, it is clearly indicated that farm size has no effect on farmers’ crop management adaptation strategies except crop rotation. It is indicated that crop rotation has a significant effect on farmers’ use of climate adaptation strategies positively. It is clear that farmers having larger farmland would be able to use rotational crop production so that it enables them to adapt climate variability over the location. This implies that farmers who have larger farm sizes have a higher probability to diversify crops for better adaptation options (Sahua & Diptimayee Mishrab, 2013).

Farmers’ income (or proxy crop income) has been influential in determining climate adaptation strategies. The study result showed that income has positively influenced with mixed crop strategy, is statistically significant positively (Sahua & Diptimayee Mishrab, 2013). However, it has a negative relationship with crop rotation climate adaptation strategy. This is consistent with the study by Mabe, Sienso1, and Donkoh (2014). This means that a farmer with more farm income expands his or her farm by using part of the income, that could increase the output from the farm so as to compensate for the decreased yield associated with climate change.

Market distance is one of the variables which affects farmers’ climate adaptation strategies. Farmers’ implementation of strip cropping as a climate change adaptation mechanism for crop management strategy is highly affected by market distance. Moreover, the implementation of irrigation and agroforestry practices as a climate change adaptation strategy was found to be positively affected. However, the effect of market distance towards the use of high yielding variety crops as an adaptation of climate change was negative and statistically significant. It was also hypothesized that the lesser the distance to markets, the more adaptation to climate change because the market serves as a means of exchanging information with other farmers (Maddison, 2006).

Frequency of extension service is positively and significantly affecting the choice of agroforestry, compost preparation, irrigation practices positively at a 1% level of significance. Moreover, extension services have also a positive effect on strip cropping and crop rotation practices as a climate adaptation strategy. Maddison (2006) and Nhemachena and Hassan (2007) showed that access to information through extension increases the chance of adapting to climate change. However, the use of mixed cropping as a climate change adaptation strategy is negatively related to extension services. The use of irrigation as a climate adaptation strategy is highly affected by extending the frequency positively and significantly. Similarly, farmers’ marketing distance from their residence was affecting climate change variability positively and significantly at the 10% level.

Farmers also used strip cropping as a climate change adaptation mechanism for crop management strategy. This is highly affected by market distance and frequency of extension positively and, significantly, at 1% and 5% level, respectively. However, the oxen number affected strip cropping negatively and significantly. According to the work of Marenya and Barrett (2007). Livestock had a positive significant influence on the adoption of technologies in Ethiopia and Kenya.
### Table 4. Factors affecting crop management, climate change adaptation strategy (MVProbit analysis)

| VARIABLES | Short mature crops | High yield variety | Crop rotation | Mixed cropping | Strip cropping | Agro-forestry | Compost preparation | Irrigation |
|-----------|--------------------|--------------------|---------------|----------------|----------------|---------------|--------------------|-----------|
| Age       | -0.6133            | -0.0857            | -0.5372       | 0.1069         | -0.0749        | 0.1644        | -0.6645*           | -0.2302   |
|           | (0.44)             | (0.2699)           | (0.4053)      | (0.2404)       | (0.2162)       | (0.2577)      | (0.3938)           | (0.2231)  |
| Gender    | -1.1587**          | -0.545             | -0.8652       | -0.438         | -0.2259        | -0.08         | 3.0053***          | -0.7508*  |
|           | (0.5849)           | (0.5613)           | (0.6059)      | (0.4727)       | (0.5052)       | (0.5221)      | (0.6075)           | (0.4444)  |
| Edu       | 0.5956***          | 0.1138             | 0.0656        | 0.1661*        | -0.1529*       | -0.0631       | 0.0465             | -0.0439   |
|           | (0.2157)           | (0.1353)           | (0.1401)      | (0.1002)       | (0.0929)       | (0.0957)      | (0.1386)           | (0.0947)  |
| Family size | -0.2545           | 0.038              | 0.1354        | -0.0502        | -0.0666        | -0.007        | 0.3549**           | -0.015    |
|           | (0.1804)           | (0.1384)           | (0.1434)      | (0.0959)       | (0.0921)       | (0.0951)      | (0.1707)           | (0.0885)  |
| Farmexperience | 0.1035             | 0.1528             | 0.4098***     | 0.0618         | 0.0243         | 0.1738*       | 0.134              | 0.0379    |
|           | (0.166)            | (0.1691)           | (0.1371)      | (0.0977)       | (0.0963)       | (0.0987)      | (0.1796)           | (0.0956)  |
| Farmsize  | 0.0298             | -0.0593            | -0.1259       | -0.0536        | -0.051         | -0.2237***    | -0.0153            | 0.057     |
|           | (0.1002)           | (0.1186)           | (0.0788)      | (0.0774)       | (0.072)        | (0.0709)      | (0.0915)           | (0.0684)  |
| Cropincome | -0.1075            | -0.0441            | -0.2661**     | 0.1306*        | -0.0285        | -0.0092       | -0.2610*           | 0.0581    |
|           | (0.1065)           | (0.1043)           | (0.129)       | (0.0688)       | (0.0708)       | (0.0689)      | (0.1431)           | (0.0652)  |
| Distancemkt | 0.15              | -0.3492**          | -0.1256       | 0.0437         | 0.3843***      | 0.2168*       | -0.2118            | 0.3079**  |
|           | (0.201)            | (0.1624)           | (0.1679)      | (0.1258)       | (0.1256)       | (0.1301)      | (0.1601)           | (0.1197)  |
| Frencencyextension | -0.0003         | 0.0029             | 0.2609**      | -0.1200*       | 0.1364**       | 0.1924***     | 0.3709***          | 0.1938*** |
|           | (0.1138)           | (0.1173)           | (0.1061)      | (0.0679)       | (0.0672)       | (0.0703)      | (0.1416)           | (0.0681)  |
Table 4. (Continued)

| VARIABLES          | Short mature crops | High yield variety | Crop rotation | Mixed cropping | Strip cropping | Agro-forestry    | Compost preparation | Irrigation |
|--------------------|--------------------|--------------------|---------------|----------------|----------------|-------------------|---------------------|------------|
| Oxaonership        | 0.5706**           | 0.3967*            | -0.1911       | 0.0012         | 0.2187         | 0.4790***         | -0.4408*          | -0.1537    |
| (0.2379)           | (0.2126)           | (0.1865)           | (0.1449)      | (0.1493)       | (0.1561)       | (0.2346)          | (0.1321)           |
| Constant           | 2.9096*            | 1.7165             | 3.4374***     | 0.5178         | -0.3582        | -2.0931**         | 0.0904             | 0.302      |
| (1.5888)           | (1.1278)           | (1.0306)           | (0.8561)      | (0.8359)       | (0.8725)       | (1.3456)          | (0.8189)           |
| Observations       | 312                | 312                | 312           | 312            | 312            | 312               | 312                 |            |

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho92 = rho52 = rho62 = rho72 = rho82 = rho43 = rho53 = rho63 = rho73 = rho83 = rho54 = rho64 = rho74 = rho84 = rho55 = rho65 = rho75 = rho85 = rho56 = rho66 = rho76 = rho86 = rho87 = 0: ch2(28) = 251.221 Prob > ch2 = 0.0000 Number of obs = 312 Wald ch2(80) = 718.39.

Log pseudolikelihood = -839.04434 Prob> ch2 = 0.0000

***, **, * are significant at P < 0.01, P < 0.05 and P < 0.1, respectively.
Oxen ownership has a positive and significant effect on farmers’ choice on the implementation of agroforestry adaptation strategies. It has also a positive effect on choice of short mature crops and application of high yield variety crops as a means of climate change adaptation strategy. However, it has a negative relationship on compost preparation to cope with climate change effects. Oxen number affected adaptation mechanism of farmers to climate change positively and significantly (Table 4).

The marginal success probability for each equation (adaptation decision) is reported (Table 5). The likelihood of adopting short matures crops, high yielding crop variety, crop composts preparation is relatively high (95%) as compared to the probability of adopting other strategies mixed cropping (76%), strip cropping (47%), agro-forestry (36.9%) and irrigation (51%).

The joint probabilities of success or failure of adaptation of the eight agricultural technologies suggest that households are more likely to jointly adopt the eight technologies. The likelihood of households to jointly adopt the eight strategies are about 15.5% compared to their failure to jointly adopt them (Table 6).

### 3.3.2. Factors affecting animal production management of climate change adaptation strategy of farmers

The second strategy farmers used for the climate change adaptation mechanism is animal production management strategy. The variables used by farmers were rotational grazing and the use of improved forage as a climate change adaptation mechanism. The socio-economic factors that affecting rotational grazing practices were the education level of the household, market distance from the residence and frequency of extension services. The result showed that the frequency of extension services and market distance affected negatively and significantly the animal production practice of climate change adaptation strategy of farmers. However, the education level of the household head has positively affected rotational grazing at 10% level of significance. Farmers in the study area have also used improved forage as a climate change adaptation mechanism strategy as an alternative. The variables affecting forage use were farm size of the households (negatively affecting) and both oxen number and market distance (positively affecting). Studies on the adoption of agricultural technologies indicated that farm size has both negative and positive effects on the adoption showing that the effect of farm size on technology adoption is inconclusive.

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**Table 5. The marginal success probability of crop, climate change adaptation strategy**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|----------|-----|------|-----------|-----|-----|
| Croppr1  | 312 | 0.953| 0.071     | 0.525| 1   |
| Croppr2  | 312 | 0.948| 0.047     | 0.662| 0.997|
| Croppr3  | 312 | 0.950| 0.059     | 0.546| 1.000|
| Croppr4  | 312 | 0.761| 0.080     | 0.408| 0.933|
| Croppr5  | 312 | 0.472| 0.129     | 0.197| 0.827|
| Croppr6  | 312 | 0.369| 0.155     | 0.061| 0.857|
| Croppr7  | 312 | 0.948| 0.069     | 0.493| 1   |
| Croppr8  | 312 | 0.511| 0.128     | 0.153| 0.851|

**Table 6. Joint probabilities of success or failure of crop, climate change adaptation strategy**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|----------|-----|------|-----------|-----|-----|
| croppr1s | 312 | 0.155| 0.095     | 0.006| 0.540|
| croppr0s | 312 | 0.000| 0.001     | 0.000| 0.004|
Table 7. Factors affecting Animal production management, climate change adaptation strategy (MVP probit analysis)

| Variables             | Rotational grazing | Herd size determination | Improved breeds | Improved forages | Cut and carry systems | Hay preparation | Communal grazing |
|-----------------------|--------------------|-------------------------|-----------------|------------------|-----------------------|----------------|------------------|
| Age                   | 0.1321             | −0.5586**               | 0.1354          | −0.4811**        | 0.0238                | 0.0823         | −0.2592          |
|                       | (0.2555)           | (0.2372)                | (0.2243)        | (0.2411)         | (0.2379)              | (0.2801)       | (0.2174)         |
| Gender                | −0.1588            | −0.7522**               | −0.0548         | −0.5771          | −0.356                | 1.9897***      | −0.6212          |
|                       | (0.4128)           | (0.3997)                | (0.3686)        | (0.4243)         | (0.4339)              | (0.4844)       | (0.4183)         |
| Education             | 0.1122             | −0.1065                 | −0.1647         | −0.1165          | 0.0902                | 0.0148         | −0.059           |
|                       | (0.0957)           | (0.0933)                | (0.1005)        | (0.0981)         | (0.1022)              | (0.1135)       | (0.0965)         |
| Family size           | −0.0242            | −0.1486                 | −0.0667         | −0.0959          | −0.0903               | −0.0327        | −0.3331***       |
|                       | (0.1012)           | (0.0932)                | (0.0864)        | (0.0955)         | (0.0947)              | (0.1209)       | (0.0875)         |
| Farm experience       | −0.0856            | 0.2627**                | −0.0426         | 0.1974*          | 0.0157                | −0.1243        | 0.08             |
|                       | (0.1075)           | (0.1034)                | (0.1013)        | (0.1048)         | (0.1032)              | (0.1175)       | (0.0955)         |
| Farm size             | −0.0501            | −0.0364                 | −0.0602         | −0.1553**        | 0.0368                | 0.1932*        | −0.0093          |
|                       | (0.0722)           | (0.0759)                | (0.0677)        | (0.0683)         | (0.0744)              | (0.0991)       | (0.0703)         |
| Crop income           | −0.0297            | −0.1740***              | 0.0684          | 0.1172*          | −0.0712               | −0.0568        | −0.0571          |
|                       | (0.0693)           | (0.0686)                | (0.0664)        | (0.0666)         | (0.0728)              | (0.0832)       | (0.0637)         |
| Market distance       | −0.3063**          | 0.0439                  | 0.3541***       | 0.3193***        | 0.0286                | −0.2905**      | 0.1246           |
|                       | (0.1224)           | (0.126)                 | (0.1249)        | (0.1213)         | (0.1274)              | (0.1419)       | (0.121)          |
| Frequency of extension| −0.3339***         | −0.0056                 | −0.0728         | −0.0049          | −0.1044               | 0.0672         | 0.0058           |

(Continued)
| Variables     | Rotational grazing | Herd size determination | Improved breeds | Improved forages | Cut and carry systems | Hay preparation | Communal grazing |
|---------------|--------------------|-------------------------|-----------------|-----------------|-----------------------|----------------|------------------|
|               | (0.0674)           | (0.0676)                | (0.0649)        | (0.067)         | (0.0702)              | (0.085)        | (0.0639)         |
| Oxen ownership| 0.2078             | 0.3484**                | 0.3469***       | 0.2812**        | 0.0145                | −0.1106        | 0.2119           |
|               | (0.1447)           | (0.1522)                | (0.1343)        | (0.1401)        | (0.1603)              | (0.1786)       | (0.1443)         |
| Constant      | 1.5964*            | 2.2975***               | −0.8977         | 0.2543          | 1.5144*               | −0.2771        | 2.0284***        |
|               | (0.881)            | (0.8096)                | (0.7614)        | (0.8233)        | (0.8696)              | (0.9341)       | (0.7756)         |
| Observations  | 312                | 312                     | 312             | 312             | 312                   | 312            | 312              |

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho62 = rho72 = rho43 = rho53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho76 = 0: chi2(21) = 310.232 Prob > chi2 = 0.0000.
Number of obs = 312 Wald chi2(70) = 286.80.
Log pseudolikelihood = −1061.9399 Prob > chi2 = 0.0000.
***, **, * are significant at P < 0.01, P < 0.05 and P < 0.1, respectively.
It is clear that oxen number and market distance were highly significant at a 1% significance level. Generally, the age of household head, market distance, and oxen ownership are the most important characteristics of farmers which affects animal management choice of adaptation strategies of climate change (Table 7).

The marginal success probability for each equation (adaptation decision) is reported below (Table 8). The likelihood of adopting hay preparation (89.4%), cut and carry system (77.4%), herd size determination (69.6%) and rotational grazing (67%) are relatively high as compared to the probability of adopting other strategies, use of improved breeds (43.5%), use of improved forages (43.6%) and care for communal lands (64.1%). This is good evidence to suggest that the availability of improved breeds and appropriate forage varieties is a challenge.

The joint probabilities of success or failure of adaptation of the seven agricultural technologies suggest that households are more likely to succeed to jointly adopt these technologies. The likelihood of households to jointly adopt these strategies are about 16.8% compared to their failure to jointly adopt them (Table 9).

4. Conclusion and recommendation

4.1. Conclusion
Farmers are aware of the change in climatic variability in the study area, about 91% of the respondents believe that there were temperature and rainfall variations in the last 30 years. As a result, farmers are taking steps to adjust their farming activities in crop and animal management adaptation practices. As a crop management adaptation strategy, farmers’ use of short mature crops is influenced by gender difference, education level, and farmer oxen ownership. Similarly, the use of high yield variety was affected by market distance and farmers’ oxen ownership. Crop rotation practice is influenced by the farmers’ experience, their income level of households and the extension services significantly. The use of mixed cropping and strip cropping is also determined by the farmers’ level of education, market distance, and frequency of extension services to the farmers. Agro-forestry is another practice used by farmers. This practice is also affected by the farmers’ experience, land size of the households and oxen ownership. Lastly, compost preparation depends more on age of the household head, sex of the household head,
family size, income level, extension service and oxen ownership. The likelihood of adopting short matures crops, high yielding crop variety, crop compost preparation is relatively high as compared to the probability of adopting other strategies like mixed cropping, strip cropping, agro-forestry a and irrigation. The joint probabilities of success or failure of adaptation of the crop management adaptation strategy were 15%. Hence, suggest that households are more likely to succeed to jointly adopt the eight management strategies.

As animal management adaptation strategy, rotational grazing is one of the technologies used by farmers. This technology is basically influenced by marketing distance and frequency of extension service significantly. Herd size determination is another adaptation mechanism used by the farmers and this is strictly determined by the level of age, farm experience, income level, and oxen ownership. Technology like the use of improved breeds is only determined by market distance and oxen ownership. Moreover, the use of improved forage is influenced by variables like age level, farm size, market distance, and oxen ownerships. Hay preparation and communal grazing are other options to adapt to climate change. On one hand, hey preparation is influenced by sex difference, farm size, and market distance. On the other hand, communal grazing practice is only influenced by family size of households. The likelihood of adopting hay preparation, cut and carry system, herd size determination and rotational grazing are relatively high as compared to the probability of adopting other strategies, i.e. use of improved breeds, use of improved forages and care of communal land. This indicates that the availability of improved breeds and appropriate forage varieties is, however, a challenge. Similarly, the joint probabilities of adaptation of the animal management, as a climate change adaptation strategy suggest that households are more likely to use if jointly adopt these technologies. The likelihood of households to jointly adopt these strategies was about 16.8% compared to their failure to jointly adopt them. Farmers need to use complementary/package/adaptation management practices or technology, where the adoption of a given technology is conditional on the adaptation of other farm management technology practices.

4.2. Recommendation
Farmers need to use crop and animal climatic adaptation strategies jointly (complementary or technology) than separately using a single technology in the area where crop and animal farming practices exist. These can be an effective adaptation strategy to cope up with climate change in the study area. Moreover, strengthening extension services, facilitating marketing infrastructure, and introducing alternative traction power (oxen), educating or training of farmers, and improving the income level of farm households are crucial for crop management adaptation strategies. Moreover, facilitating market infrastructure, improving the productivity of land, participating younger farmers and improving traction power ownership are important recommendations to apply in animal management adaptation strategies to climate change. Policies that support and consider the socioeconomic variables specific to crop and animal climate adaptation strategies should be implemented in the long run.

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Correction
This article has been republished with minor changes. These changes do not impact the academic content of the article.

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Note
1. The total sample size was determined by using Triola (2007) formula.

\[ n = \frac{NQ(Z)^2}{PQ(Z)^2 + (N-1)\alpha^2} \]

Where; \(N=\) Sampling frame= 2703. \(P=\) Sample proportion of success in a given sample frame (0.5). \(Q=1-P=\) Sample proportion of failure in a given sampling frame (0.5). \(Z=\) Score (critical value) in normal distribution at 95\% confidence level (1.96) and \(\alpha^2=\) Margin of error = 0.05.

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