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Determinants of ecosystem-based adaptation to drought in the central cattle corridor of Uganda

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Ecosystem-based Adaptation (EbA) is widely recognised as an important strategy for strengthening climate change resilience. Nevertheless, there is limited evidence on the factors that facilitate or impede EbA for ecosystem services, adaptation benefits and livelihood improvement. In this study, the determinants of EbA to drought were assessed. A mixed quantitative and qualitative cross-sectional survey among 183 farmer households was undertaken in the central cattle corridor of Uganda. The majority of the interviewed respondents were female (60.1%) who mainly carried out agro-pastoral farming (63.4%), a practice 83.2% of them learned through indigenous knowledge transfer. A multinomial logit (MNL) model based analysis was used to establish the determinants of EbA to drought. Ecosystem services, adaptation benefits and livelihood improvement were each made a base category thus yielding three MNL models. The significant (p<0.05) factors from all the three MNL models for EbA to drought were access to extension services, time (hours) spent daily on farm by farmers, land size under crop farming, type of major agricultural activity, average annual income, membership to farmer organisation and use of indigenous knowledge. These factors provide a vital knowledge base for fostering EbA policy formulation and implementation among agro-pastoral farmers to increase their resilience to drought. Climate change adaptation initiatives, institutions and governments should support education and information dissemination about EbA to farmers particularly in rangeland areas.

Key words: Determinants, drought, ecosystem-based adaptation, multinomial Logit model, Rangeland, Uganda.

INTRODUCTION

Natural resource dependent communities especially those found in developing countries are highly vulnerable to climate variability and change due to their dependence on ecosystems for livestock and crop production (Westerman et al., 2012; IPCC, 2012, Deressa et al., 2009). The impacts impose challenges such as forage and water scarcity, which are perceived drought impacts experienced by agro-pastoral farmers in west Africa (Ndamani and Watanabe, 2016). Climate variability and change impacts manifested through recurrent droughts for example, have resulted into reduction in farm productivity (Kgosikoma et al., 2018). Drought, a climate change hazard has heavily and negatively affected the livelihood of local people who depend on ecosystems and

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biodiversity (Phuong, 2011). It is projected that the livelihoods of the poorest communities in arid and semi-arid areas are more likely to be negatively affected by drought through effects like crop withering, increased pest and disease invasion (Adger et al., 2003; FAO, 2013, 2014; Hisali et al., 2011). Rangelands, which are characterised by arid or semi-arid conditions such as high evapotranspiration, make agro-pastoralism a risky economic activity (Phuong, 2011). It is therefore of paramount importance that the agro-pastoral farmers in rangeland regions develop appropriate adaptation strategies to respond to the projected climatic changes especially the recurrent droughts and irregular rainfall patterns (Mavhura et al., 2015).

The heavy dependence on ecosystems for livestock and crop farming in Uganda increases the agro-pastoral farmers' vulnerability to drought because of unpredictable access to water and pasture (Zake, 2015; Waiswa et al., 2019). This is further exacerbated by the weak policy environment and implementation portrayed through inaccessibility to land and climate change adaptation information, limited extension support, poor natural resource management and weak institutional arrangements (National Development Plan, 2010). Agro-pastoral farming communities try out various measures to enhance their adaptive capacity to drought impacts (Kgosikoma et al., 2018). It is currently well recognised that communities and households utilise ecosystem services and biodiversity as one of the comprehensive adaptation strategies. Ecosystem-based drought adaptation involves the use of biodiversity and ecosystem services to help people adapt to the adverse rainfall variability and drought effects (Scarano, 2017). Ecosystem-based Adaptation (EbA) not only entails utilisation of ecosystem services; it also includes the management, restoration and/or conservation of biodiversity, ecological functions and processes (Convention on Biological Diversity, 2009; Vignola et al., 2015; Scarano, 2017). The Convention on Biological Diversity (2009) reports that EbA should most importantly entail exploiting the potential of ecosystem services to improve the well-being of communities and households in the face of a changing climate.

Studies on EbA have proved it to be the most effectual and sustainable climate change adaptation strategy for agro-pastoral farmers (Vignola et al., 2015; Munang et al., 2014, 2013; Harvey et al., 2017). Results from these studies reveal the opportunities of EbA which include biodiversity conservation, improvement and/or maintenance of farm productivity, buffering of biophysical impacts of climate change, securing food and livelihood diversification. In light of these, it is noticeable that EbA is not only ecosystem based, but it is also a provider of climate change adaptation benefits and livelihood improvement of agro-pastoral farmers (Vignola et al., 2015). Despite EbA's significance, there is insufficient knowledge of what influences or affects agro-pastoral farmers' utilisation of EbA as a response to climate change in their farming systems during long dry spells (Vignola et al., 2009). This study therefore sought to fill this gap by analysing the determinants of EbA in the central cattle corridor of Uganda. More so, the study obtained these determinants using a multinomial logit (MNL) model where three categories (Ecosystem services, adaptation benefits to drought and livelihood improvement) comprised the dependent EbA variable and the characteristics of the agro-pastoral farmers comprised the independent variables. The knowledge of determinants of EbA is paramount in assisting policymakers during policy formulation and implementation of EbA among agro-pastoral farmers (Vignola et al., 2009). In addition, these determinants could be useful in climate change adaptation initiatives to enhance agro-pastoral famers' resilience to drought especially those found in semi-arid areas and other farming systems.

MATERIALS AND METHODS

Description of study area

The study was conducted in the central cattle corridor of Uganda where climate changes and variability have been reported (National Environment Management Authority, 2010). The central cattle corridor of Uganda which originally had two dry seasons annually is currently experiencing prolonged droughts due to varying rainfall patterns (Nimusiima et al., 2018). Furthermore, the fluctuating temperature patterns in the central cattle corridor have been associated with drought and consequent increase in cattle deaths (The Republic of Uganda, 2015). There is also low ground water supply in the central cattle corridor which is exacerbated by drought thus affecting agricultural production (Centre for Resource Analysis Limited, 2006). The population growth in the central cattle corridor leads to farm insecurity as people struggle for land as well as put pressure on the existing ecosystems thereby increasing their vulnerability to climate change and variability (Kiboga District Local Government, 2012). The cattle corridor is majorly a rangeland ecosystem with an assortment of habitats and land uses such as livestock forage, wildlife habitat, water, wood products, recreation and natural beauty (Rugadya, 2006). The cattle corridor is customarily a communal livestock grazing area characterised by varying intensity of pastoralism depending on the culture. There is a variety of socio-economic activities that have sprout up due to population increment and these have brought about some changes in the cattle corridor, such as opening up more land including marginal areas for crop farming thus increasing the fragility of the rangeland ecosystem with low, unreliable rainfall coupled with sparse vegetation cover (Rugadya, 2006). Crop diversification has been adopted as an adaptation strategy to climate change in the central cattle corridor (Nimusiima et al., 2018).

Ddwaniro and Lwamata sub counties located in a rural district called Kiboga (Figure 1), in the central cattle corridor of Uganda were purposively selected for the study. Firstly, because they were the mostly drought stricken areas at the time of the study. Secondly, they were predominantly occupied by livestock and crop farmers, respectively (FAO, 2016). Kiboga is originally a pastoral region but upon a reconnaissance study it was discovered that there were some crop farming activities dominating Lwamata. In the study area's pastoral production system, mobility in search of water

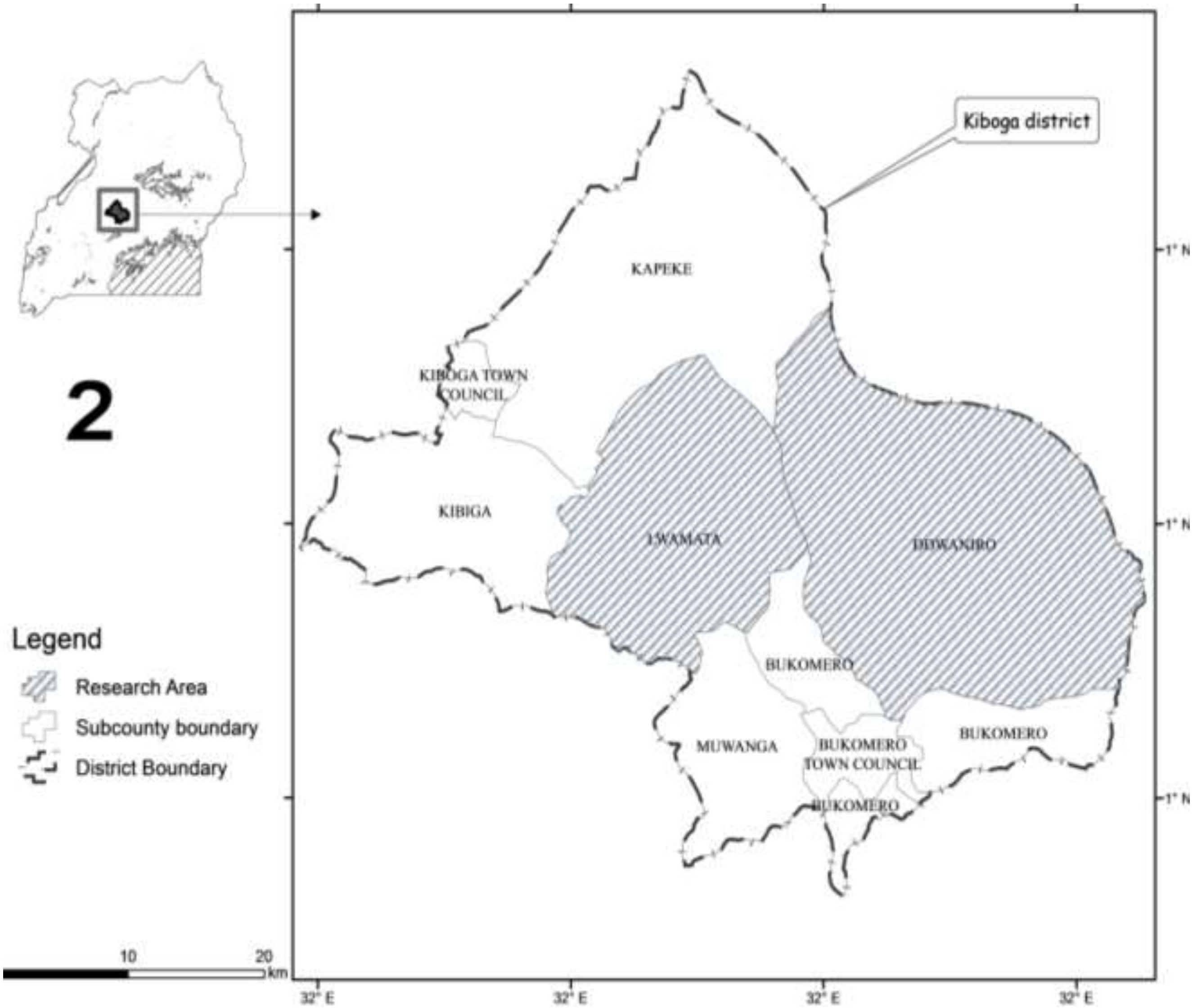

Figure 1. Map of Kiboga district showing the study area.

and fodder was initially an exclusive survival strategy for the farmers and their livestock (Ruhangawebare, 2010). However, most pastoralists have settled and started growing crops though livestock farming remains their major source of basic needs of milk, meat, income and savings. The agro-pastoral farmers not only graze their livestock on communal land in the rangeland but also give them crop residues. Nevertheless, they move the livestock in the dry season in search of fodder and water (Ruhangawebare, 2010). This history of agro-pastoralism reveals the relevance of ecosystems to such natural resource dependent communities. The study area's selection therefore was based on aforementioned farming predominance which would help to obtain information about the ecosystem-based drought adaptation from both livestock and crop farming.

Sampling and data collection

The study was based on a cross-sectional survey to collect data among randomly selected households using a semi-structured questionnaire. The survey covered a proportionate sample of 183 agro-pastoral farmer respondents (Roscoe, 1975). Since the cross-sectional survey was conducted among communities with very low literacy levels, guided and structured interviews using the questionnaire were undertaken to validate the questionnaire based responses (Morton, 2007). The use of semi-structured questionnaires allowed for some discretion about the order in which questions were asked, hence obtaining detailed information in a somewhat conversational style (Zake, 2015). Information on the agro-pastoral farmers' demographics, both on farm and off farm, was captured. The farmers' socio economic characteristics were important in examining the determinants of EbA to drought by agro-pastoral farmers. The respondents were interviewed from their randomly sampled homesteads so as not to interfere with their work. The household head was the major target of the interview although the spouse offered the immediate alternative in the event that the former was absent. The questionnaires were administered to the randomly selected households using the local language of the region. In case of language barrier, a field guide known in the area was used as an interpreter.

In addition, four focus group discussions were conducted to obtain broader context and understanding for interpretation of quantitative data from the questionnaire. The four focus group discussions were gender specific to allow free sharing of information, that is, two for females and two for males. For each sub county (Ddwaniro and Lwamata) there was a representative group for males and another for females. The membership to the focus group discussions was guided by the sub county veterinary (Ddwaniro) or agricultural (Lwamata) officer and comprised five to ten participants.

There were five key informants that were also interviewed. These were purposively selected basing on their farming expertise, on EbA and leadership position in Ddwaniro and Lwamata sub counties (Marshall, 1996). They included the Kiboga district environment officer, two local government council leaders (one from Ddwaniro and another from Lwamata), one veterinary officer from Ddwaniro and one agricultural officer from Lwamata.

Data analysis

The quantitative information collected through semi structured questionnaires during the survey was entered in SPSS software and then transferred to STATA software. Data on socio-economic characteristics was obtained and presented in Table 4. A multinomial logit model (MNL) was used to find out the degree of relationship between the dependent and independent variables to obtain the determinants of EbA to drought by agro-pastoral farmers in the central cattle corridor. The dependent variable comprises three categories, that is, ecosystem services, adaptation benefits to drought and livelihood improvement. The independent variables comprising majorly the characteristics of the agro-pastoral farmers were used to obtain the major determinants of EbA to drought. The qualitative information obtained through focus group discussions and key informant interviews was manually processed and used to complement the quantitative data in the analysis.

Estimation of the variables (dependent and independent) used to obtain determinants of EbA to drought by agro-pastoral farmers

The Multinomial logit (MNL) model used to obtain determinants of EbA by agro-pastoral farmers requires estimation of a relationship between a dependent variable and a set of independent variables. In this study, the dependent variable denotes EbA based on three EbA categories, that is, ecosystem services, adaptation benefits to drought and livelihood improvement. These aforementioned three categories are components of EbA as recommended by Vignola et al. (2015) that EbA should not only be based on ecosystem services and adaptation benefits but should also improve livelihoods of agro-pastoral farmers. In the MNL models run in STATA software during data analysis, these three categories (ecosystem services, adaptation benefits to drought and livelihood improvement) of this dependent variable was abbreviated as CAT_3. The three categories that make up CAT_3 were one at a time made a base category by the MNL analysis.

The agro-pastoral farmers' demographics provided a set of independent variables which were used in explaining the determinants of EbA to drought by agro-pastoral households. The choice of these independent variables was dictated by data availability, theoretical behavioural hypotheses and empirical literature. The variables considered in this study consist of socio-economic and institutional factors. Kgosikoma et al. (2018) report that resources, infrastructure institutions and household characteristics influence agro-pastoral farmers' ability to adapt to climate change. The independent variables that were used in this study have been summarised in Table 1.

Development of MNL model used to obtain determinants of EbA to drought by agro-pastoral farmers

Prior to the MNL analysis, the independent variables (from which the determinants of EbA were obtained) were tested for multicollinearity to ascertain that there were no two or more independent variables that are were highly correlated (Greene, 2000). Correction for possible multicollinearity problems between the independent variables in the MNL analysis was carried out using the estimated Variance Inflation Factors test (VIF). The VIF estimates (Table 2) were less than 10 for all the independent variables used in the MNL analysis of this study, thus indicating that the level of multicollinearity was not severe (Gujarati and Porter, 2009).

The MNL involved analysis of categorical placement on a dependent EbA variable (CAT_3) based on multiple independent variables (Table 1). The MNL analysis, provided calculations of choice probabilities expressed in analytical form with no need of multivariate integration (Tse, 1987; Deressa et al., 2009). The analysis also resulted in estimated binary logits for all comparisons among the three dependent categories of the EbA variable which are ecosystem services, adaptation benefits to drought and livelihood improvement (Long and Freese, 2001).

To describe the MNL model, let CAT_3 denote a nominal outcome representing EbA in any farming household and has three categories that is, based on ecosystem services E, adaptation benefits to drought, A and livelihood improvement, L. Each agro-pastoral farmer is assumed to face a set of discrete, mutually exclusive choices of EbA. EbA is assumed to depend on a number of factors (as explained in Table 2). Assume that there is a single independent variable ik measuring indigenous knowledge, examining the effect of ik on CAT_3 by estimating three binary logits:

$$\ln\left(p(L \mid x)\right) \middle| p(E \mid x)\right) = \beta 0, L \mid E + \beta 1, L \mid Eik$$
$$\ln\left(p(A \mid x)\right) | p(E \mid x)) = \beta 0, A \mid E + \beta 1, A \mid Eik$$
$$\ln\left(p(L \mid x)\right) | p(A \mid x)) = \beta 0, L \mid A + \beta 1, L \mid Aik$$

where the subscripts to the β's indicate which comparison is being made (e.g., $\beta 1, L \mid E$ is the coefficient for the first independent variable for the comparison of L and E).

The three binary logits include redundant information. Since ln x/y =ln x − ln y, the following equality must hold:

$$\ln(p(L \mid x)) | p(E \mid x)) - \ln(p(A \mid x)) | p(E \mid x)) = \ln(p(L \mid x)) | p(A \mid x))$$

This implies that:

$$\beta 0, L \mid E - \beta 0, A \mid E = \beta 0, L \mid A \qquad (1)$$
$$\beta 1, L \mid E - \beta 1, A \mid E = \beta 1, L \mid A$$

In general, with J outcomes, only $J - 1$ binary logits need to be estimated. Estimates for the remaining coefficients can be computed using equalities of the sort shown in Equation 1.

The MNL analysis, estimates binary logits of two categories while dropping the third (Long and Freese, 2001). For example if comparing ecosystem services, E and adaptation benefits to drought, A, then livelihood improvement, L is dropped. The dropped

Table 1. Description of independent variables as used in the MNL analysis.

Variable label	Variable name	Description	Measurement
Gender	Gender of farmer respondent	Discrete, dummy takes the value of 1 if male and 2 if female	1=Male, 2= Female
Agric	Major agricultural activity of the household	Discrete, Dummy takes the value 1= Crop farming, 2= Livestock farming, 3= Both crop and livestock farming	1= Crop farming, 2= Livestock farming, 3= Both crop and livestock farming
Extservices	Access to extension services	Discrete , Dummy takes the value 1 if yes and 0 if otherwise	1= Yes, 0= No
Policyaware	Awareness of policy related to farmers	Discrete, Dummy takes the value 1 if yes and 0 if otherwise	1= Yes, 0= No
HH_No	Household number	Continuous	People
farming_yrs	Number of farming years of farmer	Continuous	Years
Mgttime	Time (hours) spent on farm daily by the farmer	Continuous	Hours
Annualincom	Average annual Income of the farmer	Continuous	Uganda shillings converted to USD
Cropacreage	Acreage occupied by crops	Continuous	Acres
Livestkacre	Acreage occupied by livestock	Continuous	Acres
Familyonfarm	Number of family members working on farm	Continuous	People
Hiredlabour	Number of hired farm labourers	Continuous	People
farmer_org	Membership to farmer organisation	Discrete, Dummy takes the value 1 if yes and 0 if otherwise	1= Yes, 0= No
Ik	Use of Indigenous Knowledge as major source of farming knowledge	1= Yes 0= No	1= Yes, 0= No
Altincome	Having an alternative source of income	Continuous	Uganda shillings to USD

category, *L* becomes the base category and the comparison category. In such a scenario, the first comparison is made between coefficients from binary logit for *E* and *L*, then the second between *A* and *L*. In this study, three comparisons were made, that is, firstly ecosystem services, *E* and adaptation benefits to drought, *A* with livelihood improvement, *L* as base (comparison) category; secondly adaptation benefits to drought, *A* and livelihood improvement, *L* with ecosystem services, *E* as base category; thirdly ecosystem services, *E* and livelihood improvement, *L* with adaptation benefits to drought, *A* as the base category.

Formally, the MNL can be written as:

$$\ln\Omega_{m|b}(x) = ln\frac{P(y=m|x)}{P(y=b|x)} = x\,\beta_{m|b} \text{ for } m = 1 \text{ to } J$$

where *b* is the base category, which is also referred to as the comparison group. Since $\ln\Omega b|b\,(x) = \ln 1 = 0$, it must hold that $\beta\, b|b = 0$. That is, the log odds of an outcome compared to itself is always 0, and thus the effects of any independent variables must also be 0. These *J* equations can be solved to compute the predicted probabilities:

$$P\left(y=\frac{m}{x}\right)=\frac{\exp(x\,\beta m\,/b)}{[1+\sum_{h=1}^{j}[\exp(x\beta j/\,b)]} \quad (2)$$

The MNL assumes the independence of irrelevant alternatives (IIA) property. This IIA property, specifically, states that the probability of a given household using EbA basing on ecosystem services, adaptation benefits to drought or livelihood improvement should be independent of each other. This IIA property helps to minimize biases and ensures consistent parameter estimates of the MNL model in Equation 2.

The parameter estimates of the MNL model give only the direction of the effect of the independent variables on the dependent variable, but estimates do not represent either the actual degree of change nor probabilities (Deressa et al., 2009). For instance, if the estimated values of these independent variables are

Table 2. Table showing VIF test for multicollinearity among independent variables included in the MNL analysis.

Variable name	Variable label	VIF	1/VIF
Number of family members working on farm	Familyonfarm	2.08	0.481021
Household number	HH_No	2.04	0.489793
Major agricultural activity of the household	Agric	1.3	0.767428
Awareness of policy related to farmers	Policyaware	1.24	0.804505
Acreage occupied by livestock	Livestkacre	1.22	0.817132
Membership to farmer organisation	farmer_org	1.22	0.820623
Number of hired farm labourers	Hiredlabour	1.21	0.829168
Gender of respondent	Gender	1.19	0.843614
Acreage occupied by crops	Cropacreage	1.18	0.847886
Use of indigenous knowledge as major source of farming knowledge	Ik	1.18	0.848007
Number of farming years	farming_yrs	1.17	0.853763
Average annual income of the farmer	Annualincom	1.16	0.863615
Hours spent on farm daily by the farmer	Mgttime	1.12	0.895894
Access to extension services	Extservices	1.12	0.896243
Having an alternative income	Altincome	1.09	0.918699
	Mean VIF	1.3	-

positive and significant ($p< 0.05$), it infers that the farmers are more likely to use EbA. To determine the effect of a unit change in any of the variables in Table 2 on the probability that a given household will use EbA is given by the marginal effect equation (Greene, 2000):

$$\left(\frac{\partial Pj}{\partial Xk}\right) = Pj(\beta jk - \sum_{j-1}^{j-1} Pj\beta jk \qquad (3)$$

RESULTS

Socio-economic characteristics of agro-pastoral farmers

The results reveal that the majority of the interviewed respondents were female (60.1%) who mainly carried out both crop and livestock farming (63.4%), a practice 83.2% of them learned through indigenous knowledge transfer. On average, a household had 6.0 ± 3.3 persons with an average crop and livestock acreage of 3.63±8.51and 5 .91 ± 18.29, respectively (Table 3).

Determinants of EbA to drought by agro-pastoral farmers

Tables 4 to 6 present the significant coefficients at 5% of the estimated determinants obtained from the multinomial logit model. Three models were run which displayed three tables as each EbA category was one at a time made as a reference (base) category. In all the three models, access to extension services, average annual income of the farmer, the major agricultural activity of the household, acreage occupied by crops, spending more time on farm, use of indigenous knowledge and membership to farmer organisations were the most significant factors at 5%. The Chi-square results showed that the likelihood ratio statistics were highly significant (χ^2= 79.21, p=0.0000, pseudo R^2 =0.258) which suggested that the model was fit and had a strong explanatory power.

According to Model 1 (Table 4), the major agricultural activity, average annual income, and membership to farmer organisation were less likely to influence EbA based on ecosystem services compared to livelihood improvement whereas access to extension services had significant positive influence on EbA for the same. Acreage occupied by crops was less likely to influence EbA for adaptation benefits to drought compared to livelihood improvement.

With reference to Model 2 (Table 5), the hours spent on farm daily were more likely to influence EbA based on adaptation benefits compared to ecosystem services whereas acreage occupied by crops and use of indigenous knowledge as major source of farming knowledge were less likely to influence EbA for the same. Major agricultural activity, average annual income and membership to farmer organisation were more likely to influence EbA based on livelihood improvement compared to ecosystem services whereas access to extension services was less likely to influence EbA for the same.

In Model 3 (Table 6), acreage occupied by crops and use of indigenous knowledge as major source of farming knowledge were more likely to influence EbA based on ecosystem services compared to adaptation benefits to drought whereas the hours spent on farm daily were less likely to influence EbA based for the same. Acreage

Table 3. Socio-economic characteristics of agro-pastoral farmers.

Variable	Mean ± SD	Percentage
Gender of household head	-	Female 60.1% Male 39.9%
Major agricultural activity of household	-	Livestock farming only 2.7%, Crop farming only 33.9% Both crop and Livestock farming 63.4%
Use of indigenous knowledge as major source of farming knowledge	-	83.2
Alternative source of income		44.8
Access to extension services		21.3
Awareness of policy related to EbA		8.2
Membership to farmer organisation		24
Household number	6.02 ± 3.31	-
Number of farming years of household	25.37 ± 17.88	-
Time spent on farm daily by famers (hours)	4.69 ± 2.16	-
Average annual income of the farmer	*UG 1,445,658.39 ± 2,871,007.967	-
Land size under crop farming	3.63±8.51	-
Land size under livestock farming	5.91 ± 18.29	-
Number of family members working on farm	3.16 ± 2.836	-
Number of hired farm labourers	2.04 ± 1.18	-

***USD rate 3655 (USD 396 ± 786).

Table 4. Coefficients of significant determinants of MNL model run with livelihood improvement as the base outcome (Model 1).

Determinants	Based on ecosystem services (Coefficients)	Based on adaptation benefits to drought impacts (Coefficients)
Major agricultural activity	-0.7941351*	-0.3385913
Average annual income	-5.48E-07*	-4.42E-07
Access to extension services	1.058011*	-0.3815853
Membership to farmer organisation	-1.463593*	-0.7242587
Land size under crop farming	0.0377693	-0.4086709*
Constant	1.252623	-2.901506

Multinomial logistic regression, Number of obs = 183LR, $Chi^2(30)=79.21$, Prob > Chi^2 = 0.0000, Log likelihood = -113.88037, Pseudo R^2= 0.258. *indicate statistical significance at 5%.

occupied by crops was more likely to influence EbA based on livelihood improvement compared to drought adaptation benefits whereas the hours spent on farm daily were less likely to influence EbA for the same.

DISCUSSION

The socio-economic characteristics of the agro-pastoral farmers in the central cattle corridor reveal their vulnerability and adaptive capacity at household level. All the sampled households were highly dependent on farming. Despite the study area being an originally pastoral region, the majority of the agro-pastoral farmers practiced both crop and livestock farming mainly using indigenous knowledge transferred to them by their ancestors. This indicates that there has been a shift from pastoral to agro-pastoralism in the central cattle corridor of Uganda. The standard deviation of land size under livestock farming was very far from the mean which implies that the farmers have varying land sizes on which they keep their livestock. There could be a possibility of them diversifying the land into other activities like crop farming. Crop diversification plays a significant role in increasing household income and food security of pastoral farmers thus reducing their vulnerability to climate change including drought (Tiwari et al., 2014; Waiswa et al., 2019).

Table 5. Coefficients of significant determinants of MNL model run with Ecosystem services as the base outcome (Model 2).

Determinants	Based on adaptation benefits to drought (Coefficients)	Based on livelihood improvement (Coefficients)
Land size under crop farming	-0.4464402*	-0.0377693
Time spent daily on farm (hours)	0.6350912*	0.0910715
Use of Indigenous Knowledge as major source of farming knowledge	-2.309535*	-1.001454
Major agricultural activity	0.4555438	0.7941351*
Average annual income	1.06E-07	5.48E-07*
Access to extension services	-1.439596	-1.058011*
Membership to farmer organisation	0.7393346	1.463593*
Constant	-4.154129	-1.252623

Multinomial logistic regression, Number of obs = 183LR, $Chi^2(30)=79.21$, Prob > Chi^2 = 0.0000, Log likelihood = -113.88037, Pseudo R^2= 0.258. *indicate statistical significance at 5%.

Table 6. Coefficients of significant determinants of MNL model run with Adaptation benefits to drought as the base outcome (Model 3).

Determinants	Based on Ecosystem services (Coefficients)	Based on Livelihood improvement (Coefficients)
Land size under crop farming	0.4464402*	0.4086709*
Time spent daily on farm (hours)	-0.6350912*	-0.5440196*
Use of Indigenous Knowledge as major source of farming knowledge	2.309535*	1.308081
Constant	4.154129	2.901506

Multinomial logistic regression Number of obs = 183LR, $Chi^2(30)=79.21$, Prob > Chi^2 = 0.0000, Log likelihood = -113.88037, Pseudo R^2= 0.258. *indicate statistical significance at 5%.

There were more female respondents than males. This could be probably because the males have to traverse the cattle corridor in search for water for the livestock. As they camp near the water reservoirs (water dams) which could be far from their pastoral households, they establish dry thatched tents for shelter during their stay. The females that are left home to fend for the rest of the household members have to devise means to fend for their household members usually children. They therefore tend to establish kitchen gardens. Establishment of kitchen gardens is one of the climate change adaptation responses in the Uganda central cattle corridor (Mfitumukiza et al., 2017).

The MNL analysis showed different determinants of EbA to drought in the central cattle corridor of Uganda. The analysis used the socio-economic characteristics as the factors from which determinants of EbA to drought were obtained. The determinants were specific to each of the three EbA categories (ecosystem services, adaptation benefits to drought and livelihood improvement) in comparison with each other. The estimation involved normalising one category as the base category. Moreover, the most common factors which significantly influenced EbA during drought included access to extension services, average annual income of the farmer, the major agricultural activity of the household, land size under crop farming, time spent on farm daily (hours), use of indigenous knowledge and membership to farmer organisations.

The access to extension services had a significant positive influence on EbA to drought although the majority of the respondents were found to have had minimal access to the same. The results reveal that if the agro-pastoral farmers in the study area have access to extension services, then there is a greater likelihood of EbA to drought because of the ecosystem services that it offers to their farming systems. Access to extension services increases agro-pastoral farmers' knowledge and skills in regard to the ecosystem services derived from the existing ecosystems. This in turn enhances their likelihood to conserve the ecosystems in order to sustainably obtain services from them during long dry spells. A study by Bandyopadhyay et al. (2011) reveals that access to extension services increases the farmers' knowledge and information concerning sustainable utilisation of ecosystems which are a sole source of services that boost their agricultural productivity. A study by Harvey et al. (2017) estimated extension training to be an important determinant of some EbA measures that are knowledge intensive.

The use of indigenous knowledge as a major source of farming knowledge is more likely to influence EbA during long dry spells. The agro-pastoral farmers are more likely to use indigenous knowledge as a major source of farming knowledge during drought to derive ecosystem services from EbA strategy. The availability of ecosystem services in the central cattle corridor of Uganda is influenced by the use of locally available knowledge. Agro-pastoral farming depends on availability of ecosystem services such as pollination, water provision, nutrient recycling and biological pest control (Vignola et al., 2015). Agro-pastoral farmers in the central cattle corridor use drought resistant fodder crops to provide fodder for livestock and mulch for crops to maintain soil moisture during drought thus maintaining farm production. Elephant or Napier grass is the major fodder crop used by these farmers. Napier grass (*Pennisetum purpureum*) has low water and nutrient requirements therefore can easily survive uncultivated lands and long dry spells. Establishment of Napier grass is not only for fodder but also has the potential of attracting stem borer moths away from maize, a strategy that is more sustainably affordable for agro-pastoral farmers than insecticide (Khan et al., 2007). Indigenous knowledge has been depicted as simple, static and primitive yet it is essential for provision of ecosystem services and biodiversity (Nyong et al., 2007). According to a study done by Egeru (2012), in another agro-pastoral region of Uganda, indigenous knowledge plays a significant role in climate change adaptation through availing sustainable provisioning services. Since EbA entails sustainable management of biodiversity and ecological functions, the agro-pastoral farmers that possess and utilise traditional knowledge will more likely conserve those ecosystems on which they are traditionally dependent (Phuong, 2011).

Average annual income had a significant positive influence on EbA for the improvement of the agro-pastoral farmers' livelihoods. Increase in annual income potentially widens the opportunities for agro-pastoral farmers to opt for ecosystem based livelihood improvement options. For instance with increased income, the agro-pastoral farmers are able to diversify their agricultural systems to maintain food provision. In addition, with increased income still they could be able to restore riparian areas to ensure supply of water during long dry spells. On the other hand, with low average annual income the agro-pastoral farmers may not be able to meet the costs associated with sustainable establishment and maintenance of ecosystem based adaptation measures. A study by Mulwa et al. (2017) reveals that famers with higher income usually have off-farm income sources which allows them not to be fully reliant on agricultural income thus are less exposed to production risks. Therefore, with constrained income levels, the agro-pastoral farmers may find it difficult to adapt to drought effects using EbA even when provided with the right information.

Furthermore, the major agricultural activity of a household, land size under crop farming and membership to farmer organisations were found to have a positive influence on EbA to drought because of their ability to improve livelihoods. In the central cattle corridor of Uganda, the culture and economic status especially in Ddwaniro, is oriented towards livestock. Households depend on livestock for a significant part of their basic needs, typically characteristics of farmers in rangelands. Large herds guarantee subsistence, income, status and insurance against drought impacts on agriculture (Ruhangawebare, 2010). However, the initially pastoral famers that diversified their livestock herds with crops had a greater likelihood of coping with climate change risks like drought than those that did not (Mulwa et al., 2017). Crop diversification by farmers in the central cattle corridor regions such as those in the study area, increases food security and income during long dry spells (Nimusiima et al., 2018). Through discovery learning and sharing of experiences using existing ecosystems and biodiversity, the agro-pastoral farmers in Uganda's central cattle corridor learn crop diversification and other adaptation strategies in farmer organisations, commonly known as farmer field schools (Mfitumukiza et al., 2017). Establishment of kitchen gardens, use of water reservoirs and live fences are some of the ecosystem based adaptation measures that farmers learn in farmer field schools. Through such avenues, the uptake of EbA could be accelerated.

It was interesting to note that the amount of time (hours) the farmers in the central cattle corridor spent on farm daily was significantly less likely to increase availability of ecosystem services and improving their livelihoods during drought from EbA utilisation. This implies that the more time they spent on farm, the less possibility of obtaining available ecosystem services and having improved livelihoods, which are the cost-effective benefits arising from EbA. The reverse could be true; that sustainable supply of ecosystem services could promote spending less time on farm as well as have improved livelihoods. Therefore, there could be probable depletion of ecosystem services as a result of the drought. Considerably, insufficient knowledge about Ecosystem-based drought Adaptation could lead to increased time on farm so as to obtain enough produce for the household. Despite the drought, the agro-pastoral farmers in central cattle corridor have to continue providing for their households with basic needs from their farming activities. Agriculture in Uganda's central cattle corridor is constrained by the long dry spells. In addition, drought decreases ability of ecosystems to provide services sustainably. Therefore the agro-pastoral farmers have to spend more time working on their farms using the scarce ecosystem services in order to adapt to drought. The spending of more time on farm seems to contradict the benefits of EbA as it is supposed to decrease on farmers' workability which seems to be different in this case. EbA is aimed at reducing the considerable amount of time that agro-pastoral farmers spend on farm through continuous provision of ecosystem services even during periods of change in climate. This in turn will help to maintain or improve crop, animal or farm productivity, reduce the biophysical impacts of extreme drought events on crops, animals or farming systems and also reduce pest and disease outbreaks (Vignola et al., 2015).

Conclusion

In rural agro-pastoral farming communities, it is of paramount importance that their vulnerability to climate change is decreased and adaptive capacity to drought enhanced. The major determinants of EbA to drought in this study were access to extension services, time (hours) spent daily on farm by farmers, land size under crop farming, type of major agricultural activity, average annual income, membership to farmer organisation and use of indigenous knowledge. With this study, EbA not only improves the farmers' livelihoods but also increases their resilience to drought. Therefore, there is need to use the significant determinants of EbA in farmers' education and training, policy formulation and implementation to strengthen drought adaptation as well as improve the livelihoods of the agro-pastoral farmers. Access to extension services should be fostered, alternative income generating activities and crop diversification encouraged. Membership to farmer organisations like farmer field schools should be encouraged and supported by extension service providers. Indigenous knowledge use should be encouraged and incorporated in drought adaptation measures. The aforementioned recommendations will in turn minimise the time spent by agro-pastoralists on farm daily (hours) during drought. These determinants of EbA unveiled by this study could also be transformed into indicators of monitoring climate change adaptation in rangeland or semi-arid areas.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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