Original Research Article

Climate Change Adaptation Strategies for Agro-pastoralists in Tanzania

Abstract

Climate change is seriously impacting the well-being of rural agro-pastoralists whose main livelihoods depend on rainfed agriculture. This study examined the factors that influence farmers' decisions to climate change adaptation measures. The study sampled 411 agro-pastoralist farmers and used factor analysis to extract correlated and uncorrelated adjustment strategies. These strategies include; Crop diversification, livestock diversification, small scale irrigation, rain-water harvesting and off-farm activities were found to be the adaptation strategies extracted by factor analysis as dependent variables. Results obtained by the study show that the five coefficients of the variables identified were negative while three were positive, suggesting that the propensity (tendency) of adapting a practice is conditioned by whether or not a practice in the subset has been adapted. Moreover, it is clear that in central and northern zones of Tanzania, age and access to communication media are strongly determined the decisions to adaptation strategies to climate change among the agro-pastoralists. Therefore, the paper recommends for designing policies that reflect the differences in ecology among agro-pastoralists.

Keywords: Adaptation strategies, multivariate probit analysis, complementarity, substitutability, Tanzania.

1. Introduction

Climate change is impacting agriculture in many ways; one of them is directly impact on food production. In addition, almost all areas of agriculture (harvesting, livestock and fisheries) are weather and climate dependent and variable meant that farmers would implement a regular annual farming business plan risk of total bankruptcy due to climate change (IPCC, 2019).

In the face of climate change, policymakers have two choices: they may either accept the shift or allow their economies to partially adapt to it, or they can slow down the change and finally put an end to it (mitigate). A comprehensive plan to combat climate change should ideally incorporate both adaptation and mitigation. However, adaptation is a more urgent alternative for the majority of people whose livelihoods are already being impacted by the effects of climate change (IPCC, 2018). Due to this, smallholder farmers can strengthen their resilience and lessen their susceptibility. Therefore, adaptation has the ability to considerably reduce the detrimental effects of changes in the climate. Changes in temperature, rainfall, and rainfall variability have an impact on feed quantity in many livestock systems. Particularly in dryland settings, droughts and excessive rainfall variability can cause periods of acute feed scarcity, which can have catastrophic impacts on livestock herds (Kimaro *et al.*, 2018).

As a result, the pastoral lands of East Africa experienced droughts about once every five years. Despite these circumstances, it is typically still possible to maintain relatively constant herd sizes of cattle, but increases in drought frequency in such areas could make it more difficult to maintain such herd sizes (Awinia, 2020).

In many parts of the developing world, mixed crop-livestock systems are common. As climate change and shifting climate variability occur in the future, this interaction between crops and livestock in the landscape may change. Livestock may be a viable alternative to crop production in areas that will become increasingly unsuitable for it.

The response of individuals, groups and governments to these projected changes is known as climate change adaptation. The goal of adaptation is to increase resilience in a way that lessens both risks and vulnerabilities, and makes it possible to take advantage of opportunities brought on by climate change.

In other words, it involves programs and tactics to lessen the susceptibility of natural and human systems to present or anticipated stresses, such as those brought on by climate change. There are several different types of adaptation, including proactive and reactive, private and public, and autonomous and planned. Examples include replacing delicate plants and livestock with more temperature shock resistant ones.

Adaptation to climate change in Tanzania which depends greatly on agriculture, is vital for maintaining or continuing the rate of development. As Shemsanga *et al.* (2010) argue, smallholder farmers, particularly agro-pastoralists, are vulnerable to climate change due to poverty which is associated with high reliance on natural resources such as pasture, land, and water for livestock and crops which are already impacted by climate change. The government and other development partners facilitate agro-pastoralists in setting adaptation strategies by disseminating improved agricultural water management, diversification of land use, agricultural intensification and expansion and livelihood diversification technologies.

Therefore, by improving rural communities' capacity to adapt to climate change, farm level adaptation can significantly lower vulnerability to it through adoption of disseminated adaptation strategies. This suggests that agro-pastoralists must alter their methods in order to cope with and adapt to the continuously changing climate. Changing crops and livestock enterprises, using more or less inputs, putting new resource management techniques into effect, diversifying agricultural systems, and occasionally diversifying off-farm activities are all examples of adapting (Howden *et al.*, 2007). However, the determinants of agro-pastoralists' choices to adjustment strategies are not adequately known over space, local settings and time. Several studies (Gebrehiwot and van der Veen, 2013; Mwakaje, 2013; Below *et al.*, 2010; Lema and Majule, 2009) have been conducted on adaptation practices to climate change among farmers in Tanzania. These research placed a greater emphasis on the variables that influence adaptation to climatic variability and change while Sanga *et al.* (2013) and Komba and Muchapondwa (2012), studied farmers’ choice of particular farming adaptation strategies in Tanzania. These studies focused more on crop than livestock. Moreover, other studies (Sangeda and Malole, 2014; Goldman and Riosmena, 2013; Tumbo *et al.*, 2011; Lynn, 2010; Nassef *et al.*, 2009) have covered adaptive capacity and pastoralism, transition from pastoralism to agro-pastoralism. None of studies focused on adjustment strategies to climate change particular in agro-pastoral systems in Tanzania. Therefore, this paper examined the adaptation options and the main factors affecting agro-pastoralists' choices when faced with a bundle of adaptation options for both livestock and crop farming. A study of this kind can offer a framework for developing policies and directing research more effectively.

2. Materials and methods

2.1. **Data for the study**

A random sample of 411 agro pastoralists in northern and central Tanzania provided the study's primary data. A multi stage sampling technique was employed as follows. Stage one involved a selection of five regions on the basis of having farmers involved in farming crop and livestock keeping. Stage two involved a selection of one district from each region using the criteria of the importance of crop farming and herding animals. Stage three involved sampling which entailed the selection of 13 wards basing on the same criteria; and finally, stage four involved sampling of 22 villages. The last stage was on random selection of agro-pastoralists from village registers provided by Agricultural Field Officers of the selected villages in the sampled villages.

A sample size proportionate to the district's overall population was chosen for each study site. The sampling frame for each village was a numbered list of all households that was collected from the village government. Self-administered questionnaires were used to collect data in order to extract information about the adaption strategies. Data on demographic traits, asset endowment, economic activity, wealth, and income were all covered by the survey questionnaire.

2.2 Data processing and analysis

Data were coded, entered, in Statistical Package for Social Sciences (SPSS) software. Factor analysis was used to extract adaptation strategies and using Kaiser's criterion the number of strategies retained was determined. In order to ensure that variables are loaded maximum onto just one factor, the factor axes were rotated using the direct oblimin approach. Thereafter, the data were transferred to STATA version 12 for further analysis.
The estimation of probabilistic models includes variables (*Y*□*pj*) related with household characteristics (age, sex, years of education, marital status, size of land holding, and household size), access to markets and social services (extension agricultural extension or training, farmer to farmer extension and credit), level of wealth (index of access to communication media, Income from crops and number of livestock LU), climate change in the last 30 years (mean annual temperature in °C and mean annual precipitation in mm).

2.3. Analytical Framework

In economics, the basic approach to analyze individual decision-making under risk is expected utility (EU) theory based on the rationality assumptions (Neumann and Morgenstern, 1947). Thereafter, Simon’s theory of Bounded Rationality emerged. These theories are similar as they apply decision making processes. But there is a difference between these two theories in that bounded rationality identifies three elements that influence rational decision-making: cognitive ability, temporal restrictions, and incomplete knowledge. The expected utility theory considers how rational decision-making is possible when one is unsure of the results of their actions. In this paper, Bounded rationality theory was extended into rational choices of agro-pastoralists' strategies for adjusting to climatic fluctuation and change. It is assumed that an agro-pastoralist makes decision to adapt to climate change if and only if such options (mix of adaptation solutions) are readily available, practicable in light of the available resources, market inefficiencies, and technological limitations, and at the same time, offer the anticipated benefits (Zuluaga *et al.*, 2015). most popular analytical techniques for such situation include discrete choice regression models like binary probit or logit (Acquah de, 2011; Fosu-Mensah *et al*., 2010), multinomial probit (Komba and Muchapondwa, 2012) or logit (Sanga, *et al.*, 2013; Gebrehiwot and Van der Veen, 2013) and Principal Component Analysis (Below, *et al.*,2012).

According to what was previously mentioned, some farm households in the research areas made their selection from a variety of risk management and copping tactics. But given that the same unobserved farm household variables can have an impact on their decisions, these techniques might be connected. Because the error terms in this kind of circumstance could be interrelated, applying the usual univariate logit or probit models would result in inaccurate estimations (Greene, 2012). This possible issue was addressed using the multivariate probit (MVP) model. The MVP model simultaneously estimates several binary probit models using the maximum simulated likelihood technique. As a result of the MVP's recognition of the correlation in error terms, the variance-covariance matrix of the cross-equation error terms has values of 1 on the leading diagonal, and the off-diagonal components are correlations that need to be estimated. ($p_{ji} = p_{ij}$ and $p_{ii} = 1$, *for all* $i = 1..., m$).

Following Gebrehiwot and van der Veen (2013) and Lin *et al*. (2005). The multivariate probit econometric approach used for this study is characterised by a set of *m* binary dependent variables Y_{hpj} (with observation subscripts suppressed), such that:

$Y^*_{hpj} = X'_{hpj}\beta_j + u_{hpj}$ $j=1,2, ...m$ and

$Y_{hpj} = 1$ *if* $Y^*_{hpj} > 0$, *0 Otherwise*

Where:

$j=1, 2 \ldots m$ denotes the climate change adaptation strategies available,

X_{hpj} is a vector of explanatory variables,

β_j denotes the vector of parameter to be estimated, and

U_{hpj} are random error terms distributed as multivariate normal distribution with zero mean and unitary variance.

It is assumed that a rational □th agro-pastoralist has a latent variable, X^*_{hpj} which captures the unobserved preferences or demand associated with the j^{th} choice of adaptation strategy. The latent variable is a linear combination of reported household characteristics, additional features that have an impact on the adoption of adaptation strategies, and unobserved characteristics that are accounted for by the stochastic error term.

Given the latent nature of the variable Y^*_{hpj} the estimation is based on the observable variable Y^*_{hpj} which indicates whether or not a household adopted a specific climate change adaptation strategy. As several adaptation procedures may be used, the error terms in equation (1) are assumed to jointly follow a multivariate normal distribution, with a zero conditional mean and a variance normalized to unity. The unobserved correlation between the stochastic component of the j^{th} and m^{th} type of adaptation strategies is represented by the off-diagonal elements in the covariance matrix.

In order to identify the factors that affect a multinomial probability model was employed to assess the factors that affect agro-pastoralists' preferences for specific adaptation approaches to climate change. The dependent variable in this model was farmers' adaptation preferences, which included as many categories as there were climate change adaptation strategies accessible to the

sampled population. Thus, the model posits that farmer *i* maximizes his perceived utility of utilizing a particular adaptation strategy subject to given parameters when it comes to the selection of a particular adaptation strategy.
However before running the model, there is a need to identify the common adaptation strategies employed by agro-pastoralists. Therefore, an explanatory factor analysis was conducted whereby a set of adaptation strategies (y_1, y_2 …y_{12}) created a new set of variables that were orthogonal to each other and uncorrelated. The analysis therefore, identified and summarized the pattern of inter-correlation among variables.

3. Results and discussion

3.1 Socio-economic status of the agro-pastoralists

The socio-economic status of the sampled agro-pastoralists which were included in the model are as shown in Tables 1 and 2. The results show that heads of household had an average age of 48 years where the maximum age was 96 and the minimum ages being 16 years. In addition, the average household size was 5 persons. The results show further that respondents' education had an average of as low as 5 years of schooling. The sampled household heads' average years spent in school was 6 years with the maximum of 16 years and a minimum of 0 (i.e. no schooling at all). The average land size owned was 6.2 acres.

Table 1: Socio-economic status of the household heads

Explanatory variables	Mean	Std deviation	Max	Min
Household age	48.16	13.75	96	16
Years of schooling	6.68	2.56	16	0
Household size in number	5.59	1.97	13	1
Land size owned in acre	6.15	7.29	67	0.25
Income from crops in TZS	584 102	682 750	5 000 000	9600
Number of livestock owned in LU	6.23	9.93	111.46	0.2
Mean annual Temperature in ^{0}C	21.88	5.16	29.70	14
Mean annual Precipitation in mm	619.27	84.66	747.58	504.89

Table 2 shows that 7.5 % of the household heads sampled were women. This suggests that most of the sampled agro-pastoral household were headed by men. Moreover, the table shows that 21.9 % accessed warning information on climate variability/change but 78.1 % did not. This means that there is a small percentage of agro-pastoralists who access information regarding climatic fluctuation and change.

Table 2: Distribution of respondents (dummy variables) (n=411)

Explanatory variables	Response (%)	
	Yes	No
Women headed household	7.5	92.5
Marital status – Married	85.4	14.6
Connection to extension services	42.3	57.7
Farmer to farmer extension	75.7	24.3

Connection to credit services	20.9	79.1
Possess communication media devices	82.4	17.6

3.2 Adaptation strategies extracted by explanatory factor analysis

Utilizing oblique rotation, the factor analysis was performed on the 12 variables (direct oblimin). The Kaiser Meyer Olkin (KMO) criterion validates the suitability of factor analysis for the sample. The results show that the value of the KMO for the analysis was 0.614 which is considered to be average, and Bartlett's test of sphericity χ^2 (66) = 849.56, p< 0.01, showed that the correlations between the variables were high enough to allow for factor analysis. To produce eigenvalues for each component of the data, a preliminary analysis was carried out. In accordance with the Kaiser criterion for factor extraction, five components have eigenvalues greater than 1. Thus derived five components collectively explained 73.42% of the variance (Table 3).

Table 3: Total Variance Explained

	Total Variance Explained		
	initial Eigenvalues		
Adaptation strategies	**Total**	**% of Variance**	**Cumulative %**
Crop diversity	2.577	21.475	21.475
Water harvesting schemes	2.494	20.782	42.257
Livestock diversification	1.574	13.119	55.376
Irrigation	1.131	9.421	64.797
Find off-farm jobs	1.035	8.623	73.420
Livestock feed supplements	0.803	6.688	80.108
De-stocking	0.624	5.204	85.312
Migrate to other areas	0.514	4.285	89.597
Plant trees for shading	0.466	3.887	93.485
Use of Pesticides	0.332	2.768	96.253
Change from crop to livestock	0.242	2.013	98.266
Early Matured Crops	0.208	1.734	100.000

KMO= 0.61; Barteltt's test of sphericity =849.56; df = 66; significance level =0.000

3.3 Correlation of the dependent variables

Table 4 demonstrates that in eight of the 10 pair situations, the estimated correlation coefficients were statistically substantially different from zero, with five of the estimated correlation coefficients being negative while three were positive, indicating that whether or not a practice has been modified within the subgroup affects the likelihood (tendency) to adapt a practice. The sign of the coefficients supports the idea of interdependency between choi ces of various adaptation strategies to climate change, which may be attributed to complementarities or substitutability between the strategies, in addition to j ustifying the use of MVP in contrast to the constricting single equation approa ch.

Table 4: Correlation coefficients of the agro-pastoral adaptation strategies

Correlation	Crop diversity	Livestock diversity	Irrigation	RWH	Off-farm
Crop diversity	1.000				
Livestock diversity	0.047	1.000			
Irrigation	-0.109**	-0.109**	1.000		
RWH	-0.018	-0.018*	0.563***	1.000	
Off-farm activities	0.248***	0.119**	-0.131***	-0.150***	1.000

Note:,** and *** indicates the level of significance at 10%, 5% and 1% respectively*

3.4 Estimated results

Table 5 displays parameter estimates from the multivariate probit model. Significant joint correlations are revealed using a likelihood ratio test based on the log-likelihood values of the multivariate and univariate models $X^2(10)$ =142.184, Probability > X = 0.000) of the independence of the error terms of the different adaptation equations. This tells us that our model as a whole is statistically significant, that is, it fits the data better.

The MVP results shown in Table 5 demonstrate that separate decisions regarding the selection of various adaptation strategies were made. Additionally, the variables influencing each semi-arid agro-ecological zone's decision-making were different, suggesting the heterogeneity in climate change adaptation strategies among the two zones. Age of the head of the household was one of the significant factors that affected the overall choice of agro-pastoralists to climate change's adaptation strategies in both central and northern semi-arid agro-ecological zones. However, age affected positively the off-farm activities and irrigation adaptation among agro-pastoralists at $p<0.1$ significant level of central and northern semi-arid AEZs. These findings differ from those of a study by Hassan and Nhemachena (2008) who discovered that age had no bearing on the decision of a climate change adaptation strategy. Education of the head of the household was significant but negatively affecting the adaptation of livestock diversification among agro-pastoralists in the central semi-arid AEZ at $p<0.1$ significant level (Table 5). However, the variable was insignificant in the northern semi-arid AEZ. The results are at odds with those of a study by Asfaw et al. (2016), which discovered that the benefits of schooling are robust to other diversification techniques like diversifying livestock.

The head of the household's marital status i.e. being married, had negatively affected the uptake of irrigation and rain-water harvesting adaptation strategies in the central semi-arid AEZ (Table 5). This is contrary to the hypothesised signs. This finding may be due to the reason that large part of income of the married agro-pastoralists was spent on domestic consumption rather than in investing in irrigation and rain-water harvesting adaptation strategies which required a relative high initial investment.

According to the MVP findings, the likelihood of using crop diversification was negatively and significantly impacted by household size (at $p<0.1$) and off-farm activities (at $p<0.01$) in the central semi-arid AEZ and had positive influence in the central semi-arid AEZ at $p<0.05$ (Table 5). This means that a unit increase in the household size decreased the likelihood of using crop diversification and other income generating activities in the central semi-arid AEZ while a unit increase in the household size in the northern semi-arid AEZ increased the probability of livestock diversification.

From Table 5, it can be derived that the use of crop diversification and non-farm activities was more likely to be used as an adaptation strategy by households with less family members in the central semi-arid AEZ (Zuluaga *et al.,* 2015). The findings in the central semi-arid AEZ in contrast with those reported in a study by Ogunsola *at al.* (2015) and Mabuza *et al.* (2013) who found that households with big labour pools were inclined to adopt agricultural technology and use it actively because they did not experienced labour shortages during peak hours.

Table 5: Multivariate model results of CCA strategies

Predictor	Central Semi-arid AEZ					Northern Semi-arid AEZ				
	Crop diver	**Irrigation**	**RWH**	**Off-farm**	**Lives divers**	**Crop divers**	**Irrigation**	**RWH**	**Off-farm**	**Lives diver**
AgeHH	0.004	-0.004	-0.001	0.015*	-0.013	-0.001	0.003*	0.003	-0.002	-0.001
SeHH	-0.472	0.333	-0.119	0.32	-0.313	0.088	-0.022	-0.021	0.437	-0.089
EdlHH	0.013	-0.005	-0.012	0.022	-0.091*	-0.008	0.01	0.013	0.004	0.015
Marstatus	0.004	-0.888**	-0.221	-0.114	0.131	0.135	-0.099	-0.101	0.486	0.014
HHsize	-0.088*	-0.062	-0.059	-0.127***	0.07	0.021	0.007	0.005	-0.009	0.032**
Landsize	-0.015	0.002	-0.001	0.000	0.022	-0.007	0.013***	0.012***	-0.006	-0.003
Exte_serv	0.192	-0.007	-0.058	0.023	-0.207	-0.165**	0.011	0.026	-0.003	0.049
F2FExts	-0.284	0.172	-0.079	-0.253	0.049	0.076	0.331**	0.223**	-0.03	0.214***
Credi_Acce	-0.046	0.232	0.134	-0.144	0.015	0.049*	-0.032	0.005	0.053	-0.005
Access_Media	0.473*	0.407	0.639**	-0.437	-0.049	-0.169*	-0.106	-0.134**	-0.067	0.089
Yfrocfarm	-0.000*	0.000	0.000	0.000	0.000	0.000*	0.000***	0.000***	0.000***	0.000
LivesOwned	-0.015	0.004	0.015	-0.03**	0.714***	0.004	-0.001	-0.001	-0.000	0.134***
Aver_an Tem	0.002	-0.11***	-0.025	0.097***	0.153***	0.219	-0.237	-0.269***	-0.236	-0.175
Ave_an_Pre	-0.001	-.008***	0.002	0.004	0.011***	0.016	-0.011	-0.013***	-0.011	-0.013

*Note: ***, **, * Significant at 1%, 5% and 10% probability levels respectively.*

Table 5 shows that access to communication media as a measure of farmer's understanding of climate change information was negatively and significantly related to climate change adaptation strategies namely crop diversification ($p<0.1$) and rain water harvesting ($p<0.05$) in the central zone. However, access to communication media was positively related to the same techniques for adjusting to climate change and variability in the northern semi-arid AEZ. This suggests that in the central semi-arid AEZ, the agro-pastoralists did not utilize the communication media such as radio, television, newspapers and mobile phones for crop diversification and rain water harvesting as adaptation strategies.

The level of income gained from crop farming increased the probability among agro-pastoralists of engaging in crop diversification ($p<0.1$), irrigation (0.01), rain water harvesting ($p<0.01$) and off-farm activities ($p<0.01$) as adaptation tactics for the changing climate and its variability in the northern semi-arid AEZ. Nevertheless, income level gained from crop farming influenced crop diversification adaptation strategy among agro-pastoralists in the central semi-arid AEZ at $p<0.1$) as shown in Table 5. This means that as agro-pastoralists in the central AEZ did not utilize income gained from crops for expanding and diversifying crops but redirect the income to other activities to ensure that climate change and other risks do not affect all of their enterprises.

The number of livestock owned was found to be one of the fundamental resources and a crucial part of the agro-pastoral farming system as it influenced the livestock diversification positively in both semi-arid AEZs at $p<0.01$. This was due to the fact that agro-pastoralists who kept large herds normally tend to diversify. Conversely, the livestock owned was significant but negatively related to off-farm activities ($p<0.05$) in central semi-arid AEZ (Table 5).

4. Conclusions and policy implication

Using a multivariate probit model, this study investigated the factors that influence agro-pastoral households' decisions about various adaption options. Findings indicate that the main adaptation strategies were crop diversification, livestock diversification, and irrigation, rain-water harvesting and off-farm activities. Based on econometric estimation, there is some evidence that agro-pastoralists in the study area differ in making various options for coping with climate change and variability. Moreover, the socioeconomic and environmental aspects that influence how they choose to adapt to climate fluctuation and change do differ from one semi-arid AEZ to another. Meanwhile in the northern AEZ, household size, land size, farmer to farmer extension, access to credit, income from farm, and the number of livestock in livestock unit are important variables in making decision for climate change adaptation strategies. In both zones only age and access to communication media are operational factors in making rational decisions on adaptation to climate change and variability in the study areas. Therefore, the paper recommends for the designing of policies that reflect the differences in the ecology among agro-pastoralists.

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