A CROSS-REGION STUDY: CLIMATE CHANGE ADAPTATION IN MALAWI'S AGRO-BASED SYSTEMS

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Abstract

Agriculture in Malawi is vulnerable to the impacts of changing climate. Adaptation is identified as one of the options to abate the negative impacts of the changing climate. This study analyzed the factors influencing different climate change adaptation choices by smallholder farmers in Malawi. We sampled 900 farmers from all three regions of Malawi, using the multistage sampling procedure, study piloted in 2012. We analyzed smallholder farmers' climate change adaptation choices with Multinomial logit regression. Factors that enhance or hinder choice of climate adaptation options include age, gender, household size, land ownership, credit access, climate change training and extension visit. Policy thrust should focus on linking farmers to credit institutions, advocating for labour saving farm technologies and intensification of climate change trainings among smallholder farmers.

Key words: Climate change, adaptation, multinomial logit

1. Introduction

Climate change poses a great threat to agriculture sector, forestry and rural livelihoods which preconditions farmers to adopt strategies that can enhance their resilience to climate change impacts (Rosenzweig and Parry, 1993; Mendelsohn and Dinar, 2003; Gbetibouo and Hassan, 2005; Kurukulasuriya *et al.*, 2006). For the agriculture sector, climate change will have agronomic impacts on crop yields and also generate economic effects on agricultural prices, production, demand, trade, regional comparative advantage, and producer and consumer welfare. These agronomic and economic impacts will depend principally on firstly, the magnitude of climatic change, and secondly, the environment specific capacity to absorb the effect of climate change (Xiang et al., 2010).

Agricultural sector has always been an important component of the Republic of Malawi's economy. During the 2000s, agriculture accounted for as much as 35-40 percent of the Gross Domestic Product (GDP), 92 percent of overall employment, over 90 percent of the country's foreign exchange earnings, provided 64% of total income for rural people and contributed 33.6 percent to the economic growth. Agriculture supports the manufacturing industry by supplying

65 percent of the raw materials needed (GoM, 2007 and Damaliphetsa *et al*, 2007). The same sector is responsible for providing food to both rural and urban sectors.

The performance of this sector largely draws on crops grown which, in turn, depend on soil healthiness and climate variables (rainfall, humidity and temperature). The rain-fed dependency of Malawi's agriculture means that production is sensitive to fluctuations in precipitation (reduction in crop productivity is attributed to crop efficiency in fixing CO2 through the photosynthesis process) and lies in a region which endures from high heat (Kurukulasuriya and Mendelsohn; 2006; Sombroek and Gommes, 1996; Hay and Porter, 2006). Global circulation models also predict that global warming will lead to increased temperatures of about 4°C and cause variability of rainfall by up to 20% by the year 2100. From these predictions, the two extreme climate events that may adversely affect the agricultural sector are drought and flooding in both the arid and semi-arid areas and the high potential areas. What is clearly emerging from most scientific discourses is that the climate change phenomenon is inevitable and will exacerbate existing water stresses. The need for appropriate interventions to minimize impacts of climate change is no longer deniable.

The subject of this paper is not new in that there is already a flowing stream of studies on climate change and agriculture in Africa. Broad climate change adaptation strategies have been identified (Patt and Schroter, 2008; Below et al., 2010; IPCC, 2007). Some studies have attempted to analyze the impact of climate change and factors affecting the choice of adaptation methods in crop, livestock and mixed crop livestock production systems in Africa at regional level (Maddison, 2006; Kurukulasuriya and Mendelsohn, 2008; Seo and Mendelsohn, 2008; Hassan and Nhemachena, 2008). However, aggregated data remains vague to policy makers to use one size fits all key to enhance adaptive capacity of farmers. This requires country and, in turn, district specific adaptive strategies that can take care of given heterogeneity in agro-ecologies across countries.

Such variability with which to isolate area specific climate change adaptation responses is what this paper seeks to feed. There is literature deficiency as regards climate change and responses in Malawi. Climate adaptation strategies have been unpacked (Pangapanga et al., 2012; Magombo et al, 2011), however, findings have been established with spatial limitation as they only focused on Chikhwawa district which lies on demand end of food produced (supplied) by the study areas focused by this study. This is mostly a drought-prone area because of high rainfall variability. Nevertheless, drought can hit both drought-prone and non-drought prone areas of Malawi. Thus, results of earlier studies cannot be generalized over entire country. The findings of this study sorts out this limitation by employing a pool of data sampled from across all regions of Malawi.

For any given adaptation option, there exists a vector of socio-economic, institutional and environmental variables that may drive its adoption. The knowledge of these factors is essential for policy makers when they are faced with designing incentives to enhance private adaptation. Therefore, the thrust of this study is to analyze factors that affect adaptation decision for a given adaptation option by isolating a case of Malawian agriculture which, in turn, will guide policy makers in incentivizing climate adaptation in agriculture. Thus, future impacts of climate change on agriculture will have potential to be reduced as policy direction will be based on actual and country specific. The rest of the paper is organized as follows: the next section builds theoretical and empirical models, section 3 presents findings and discussion of model results, section 4 concludes the paper and provides policy implications.

2. Theoretical and Empirical Construct

A typical consumer derives utility from a good by disaggregating it into components or attributes that cannot be attained independently. A range of these attributes create choices from which a consumer can choose (Hanley, Mourato, and Wright, 2001). Lancaster (1966) developed a basis of modeling such choices for which ordering among choices has no meaning. These choices can be represented econometrically in consumer theory by using a multinomial logit to model random utility theory. In this study we use choice modeling to estimate the utility associated with the change in adaptation strategy as a result of climate change. It conforms to the economic notion that the value placed on a particular adaptation strategy is a reflection of its attributes (Lancaster, 1966). Choice modeling has been successfully used in situations where trade-offs between several attributes are being investigated (Blamey et al., 1999; Morrison et al., 1999; Bullock et al., 1998).

A farmer *n* chooses from a set of mutually exclusive adaptation strategies, $j = 1,\ldots\ldots, J$. The decision-maker obtains a certain level of utility U_{nj} from each alternative. The discrete choice model builds on the belief that a farmer chooses the outcome that maximizes utility. We do not observe farmer's utility, but observe some attributes of the farmer who is faced by a decision to choose an adaptation strategy. Hence, the utility is decomposed into deterministic V_{nj} and random part ε_{nj}:

1 $$U_{nj} = \psi_{nj} + \varepsilon_{nj}$$

The error term ε_{nj} is unobservable and makes the prediction of an individual's choice not to be exact. However, we derive the probability of any particular outcome. The stochastic part has a density $f(\varepsilon_{nj})$. The joint density for a vector of the stochastic portion is denoted as $f(\varepsilon_n)$. To map out individual *n*'s choice of alternative *i* on a range of *J* alternatives, we use probability;

2 $$P_{ni} = \Pr(U_{ni} > U_{nj} \forall_j \neq i)$$

$$P_{ni} = \Pr(U_{ni} + \varepsilon_{ni} > U_{nj} + \varepsilon_{nj} \forall_j \neq i)$$

$$P_{ni} = \int I(U_{ni} + \varepsilon_{ni} > U_{nj} + \varepsilon_{nj} \forall_j \neq i) f(\varepsilon_n) d\varepsilon_n$$

Where $I(.)$ is the indicator function, equalling 1 when the term in parenthesis is true and 0 otherwise. This is a multidimensional integral over the density of the unobserved portion of utility $f(\varepsilon_{nj})$ (Tutz, 2000).

The multinomial logit model assumes independency of irrelevant alternatives (IIA). However, this assumption is unrealistic in many circumstances. Train (1990) notes that an assumption of IIA in multinomial logit model is not as restrictive as it first sees. A variant of multinomial logit is nested logit model. In this study, all right hand side variables are individual characteristics, thus, nested logit model will in essence produce similar results as the multinomial model (Econometric Society, 1982**).** The density for each unobserved component of utility and the cumulative distribution are given, respectively, by (McFadden, 1974);

3 $$\lambda(\varepsilon_{nj}) = e^{-\varepsilon nj} e^{-e^{\varepsilon nj}}$$

$$\Lambda(\varepsilon_{nj}) = e^{-e^{-\varepsilon nj}}$$

The probability that farmer *n* chooses alternative *i* among the *J* alternatives of adaptation strategies is given by (McFadden, 1974);

4 $$P_{ni} = \Pr(\varepsilon_{nj} < V_{ni} - V_{nj} + \varepsilon_{ni} \forall_j \neq i)$$

$$= \int \prod_{j \neq i} \Lambda(V_{ni} - V_{nj} + \varepsilon_{ni}) \lambda(\varepsilon_{ni}) d\varepsilon_{ni}$$

Thus, the choice probability is the integral over all values of ε_{ni} weighted by its density $\lambda(.)$ as defined in (3).

It is hypothesized that an individual's choice of an attribute is determined by a vector of socio-economic characteristics. This relationship between vector of socio-economic characteristics and the dependent variable is established by estimation vector of parameters ϕ using log-likelihood method. Maximizing log-likelihood function for the parameter vector yields (Stern, 1997, McFadden, 1974);

5 $$\ln L(\phi) = \sum_{n=1}^{N} \sum_{j=1}^{J} y_{ni} \ln P_{nj}$$

In equation (3), y_{ni} is 1 when adaptation strategy *j* is chosen and 0 for all other strategies that are not chosen. Assuming each error term ε_{nj} for all alternatives *j* is identically and independently distributed, the logit probability $\psi_{nj} + x_n' \beta_j$ that an individual will choose alternative *j* will be;

6 $$P_{ni} = \frac{e(x_n' \beta_i)}{\sum_j e(x_n' \beta_j)}$$

Since MNL is a model where regressors do not vary over choices, coefficients are estimated for any choice. MNL requires identification: one of the choices, say *j*, is treated as the base category (correspondent β_j is constrained to equal 0). Use of improved seed variety is the base category.

This study is based on a cross-sectional survey data from agricultural households across 7 districts. The 7 districts (Rumphi, Dowa, Mchinji, Lilongwe, Balaka, Chikhwawa and Chiradzulu) were selected to capture representative farms across diverse agro-climatic conditions in all three regions of Malawi. In each district, survey was conducted in 2012 of randomly selected farms. Sampling was clustered in villages to reduce the cost of administering the survey. A total of 900 survey questionnaires were administered substantiated by focus group discussions and key informant interviews in all districts. From this, a total of 837 were usable for analyses in this study.

3. Empirical findings

3.1 Socio-economic characteristics of sample farmers

The mean age for the entire sampled households was 40 years. The variation does not change much across the districts. For the overall sample, the minimum age is 19 years and the maximum is 85 years. Household size has implications on labour availability but also the dependency burden. In this study, an average sampled household had a household size of 5.3 with a standard deviation of 2. More than half of the sample households were literate (62%). The dependency ratio for the study area is 1.3 implying that there are 0.3 more economically inactive persons for every economically active person.

Table 1: Descriptive statistics of sample households

Characteristic	Description	Mean
Gender of household head	1 = Male, 0=female	0.22
Age of household head	Years	40
Household size	Number of persons	5.2
Farming experience	Years in farming	15
Land ownership	1=yes, 0=no	94%
Access to credit	1=yes, 0=no	13%
Climate change training	1=yes, 0=no	28%
Climate change knowledge	1=yes, 0=no	92.5%
Extension visit	1=yes, 0=no	37%
Dependency burden		1.3
Literacy	Able to read and write	62%

In this study the general perception of the respondents to change in rainfall and temperature patterns was assessed through focus group discussions and household survey. The results showed that most of the communities were aware about the changing climate and its variables. Most of the communities revealed that the temperature is showing increasing trend and rainfall is showing decreasing trend. Household level data revealed that 92.5% of the sampled households are aware of the changing climate.

Though, some communities have poor knowledge on the technical matters of climate change, they have shown several evidences, which demonstrate that they have perceived, felt and experienced its effects. The amount and patterns of rainfall, the frequency and extent of droughts and trends of crop failure due to emergence of new crop diseases are some of the visible impacts. Communities reported that through the exercise of historical timeline, people have told stories transferred from one generation to another about the changes of climate and its impacts in local context. They sometimes have used the local knowledge on the basis of position of clouds, wind flows, position of stars, rainbow and with insects, pest and animal behaviour for the prediction of weather but such predictions could not be completely relied upon. People linked that these were due to climate change.

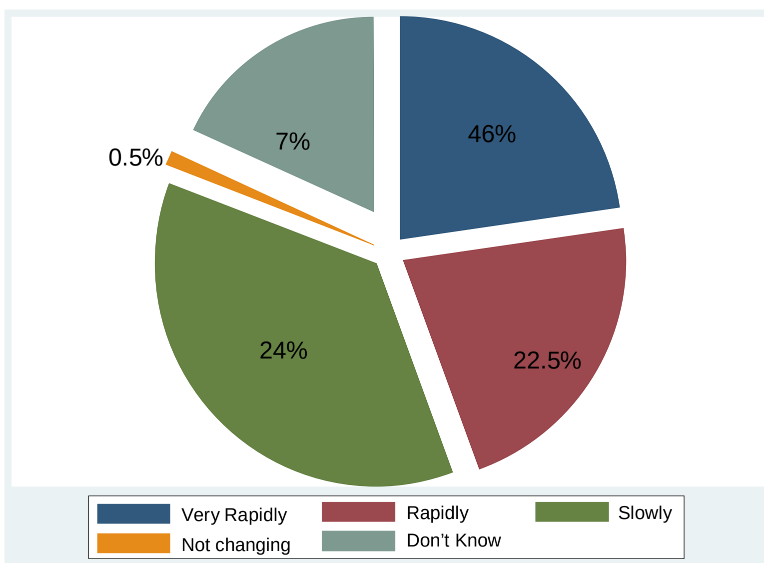

Figure 1: Perceptions on rate of climate change

The sampled households were also asked to rate the speed with which climate is changing on a scale of; very rapidly, rapidly, slowly, not changing and don't know. About 46% acknowledged that climate is changing rapidly. Those who said climate was changing rapidly and slowly were

22.5% and 24%, respectively. About 7% did not know whether climate was really changing while very few (0.5%) claimed that they never noticed any changes in climate (Figure 1).

3.2 Drivers of adaptation choices

We have presented the results of the multinomial logit model, which shows the drivers of adaptation choices, in Table 2 below. An important feature of the multinomial logit model is that it estimates *k-1* models, where *k* is the number of choices in the dependent variable. In this instance, we set "Improved Varieties" to be a referent group and we have estimated coefficients for the rest four climate change adaptation strategies which are "Irrigation", "Livestock", "Rain Water Harvesting" and "Off-farm Business" relative to the base category which is "Improved varieties".

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable: estimates do not represent actual magnitude of change or probabilities. Thus, the marginal effects from the MNL, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, are discussed. Table 3 presents the marginal effects along with the levels of statistical significance. We make some interpretations for each of the adaptive strategy with respect to the base category, but before which, we take space to comment on overall adequacy of the model in the preceding paragraph.

Table 2: Estimation results of the multinomial logit Model

Adaptive strategies	Coefficient	Std. Err.	p-value
Improved varieties (base outcome)			
Irrigation			
Gender of household head	0.6973*	0.3892	0.07
Age of household head	-0.2787***	0.1042	0.00
Household size	0.2839*	0.1941	0.06
Farming experience	0.0582	0.1360	0.66
Land ownership	0.1164	0.1718	0.11
Access to credit	1.3193***	0.1345	0.00
Climate change training	0.1074*	0.0551	0.05
Extension visit	0.6851***	0.0941	0.00
Constant	0.1721**	0.4266	0.01
Livestock			
Gender of household head	-3.3209**	1.5089	0.01

Adaptive strategies	Coefficient	Std. Err.	p-value
Age of household head	0.9611*	0.5114	0.06
Household size	-2.3032***	0.1874	0.00
Farming experience	3.1320*	1.4291	0.05
Land ownership	0.3514	0.5710	0.53
Access to credit	0.9124***	0.6322	0.00
Climate change training	2.7601***	0.3541	0.00
Extension visit	-0.8694	0.6801	0.20
Constant	-2.5024**	1.0479	0.01
Rain water harvesting			
Gender of household head	1.7199***	0.4671	0.00
Age of household head	-0.8900***	0.0964	0.00
Household size	3.1961***	1.1190	0.00
Farming experience	0.7543***	0.3002	0.00
Land ownership	-0.5991	0.5193	0.24
Access to credit	1.3933***	0.4500	0.00
Climate change training	1.1038	0.7857	0.16
Extension visit	-1.6348***	0.6342	0.00
Constant	-1.0454**	0.4652	0.02
Off-farm business			
Gender of household head	-1.3942**	0.6505	0.02
Age of household head	-0.3309	0.2012	0.10
Household size	-1.0490***	0.1445	0.00
Farming experience	0.5550***	0.1556	0.00
Land ownership	-0.1164	0.1718	0.11
Access to credit	2.5354**	1.0986	0.02
Climate change training	0.2980***	0.1156	0.00
Extension visit	0.5571	0.4855	0.25
Constant	1.285367	1.3132	0.32

LR χ^2 = 61, $p > \chi^2$ = 0.001, Wald χ^2 =1021, Pseudo R2 = 0.33

*means significant at 10%, **significant at 5% and ***significant at 1%

The chi-square (χ^2) distribution is used as the measure of overall significance of a model in Multinomial logit model estimation. The result of our Multinomial logit model shows that, the probability of the chi-square distributions less than the tabulated counterfactual is 0.001, which is less than 1%. So, we can conclude that, the variables included explaining choice of climate change adaptation strategies fits the multinomial logit model well. This implies that the joint null hypothesis of coefficients of all explanatory variables included in the model are zero is rejected at less than 1% level of significance.

Gender of a household head turned out to affect the probability choices for all the adaptation strategies as compared to the referent group. As can be seen in Table 3, being male increases the choice of irrigation and rain water harvesting unlike, the choice of livestock and off-farm business in relative to the choice of improved varieties. This is because irrigation and water harvesting need substantial labour and female headed households in Malawi are constrained with labour availability than male headed households. Being male headed household would result in a 2% and 6% increase in the probability of irrigation and rain water harvesting to adapt to climate change, respectively. On the other hand, being male headed farmer would result in a 9% and 5% decrease in the probability of Livestock and off-farm business to adapt to climate change.

Age of the household head was a determinant factor in climate adaptation choices except on the off-farm business. Age of the household head is tends to decrease the probability of choosing irrigation and rain water harvesting and increases the probability of livestock farming than the referent group (Improved verities). For example, a unit increase in a household age decreases the probability of using irrigation and rain water harvesting by 16% and 14% respectively, while it increases the probability of adopting livestock farming by 9%. Among the sample farmers, the average age, in years, was found to be 40. For the case of irrigation it implies that, as a farmer ages and draws closer to economically inactive age group (>64 years), he grows feeble and looses labour value required for irrigation farming.

Table 3: Discrete changes in predicted probabilities (marginal effects) of the multinomial logit model

	Improved varieties	**Irrigation**	**Livestock**	**Rain water harvesting**	**Off-farm business**
Gender of household head	0.02*	0.02*	-0.09**	0.06***	-0.05**
Age of household head	-0.08	-0.16***	0.09*	-0.14***	-0.02
Household size	0.03**	0.06*	-0.08***	0.11***	-0.07***
Farming experience	0.04*	0.03	0.03*	0.07***	0.09***
Land ownership	-0.14	0.03***	0.07	-0.08	-0.04
Access to credit	0.04***	0.05*	0.06***	0.05***	0.04**
Climate change training	0.04***	0.22***	0.04***	0.30	0.04***
Extension visit	0.12	0.17**	-0.03	-0.06***	0.06

*means significant at 10%, **significant at 5% and ***significant at 1%

Household size has also a significant impact on all climate change adaptation strategies. The result of our multinomial logit reveals that households that have large families have increased probability of choosing irrigation and rain water harvesting as compared to improved varieties.

On the other hand, it decreases the probability of off farm business. The marginal effects of our model show that, the probability of irrigation and rain water harvesting increases by 6% and 11%, respectively, as household size increases by a person. However, the same unit increases in household size results in 7% decrease in the probability of engaging in off farm activity as a climate change adaptation strategy. This is because rain water harvesting is practiced at the peak of rain season and needs intensive labour. Similarly, irrigation farming requires a lot of labour for both tilling the ground and watering hence, its probability lies proportional to household size.

Farm experience has a positive impact on the climate change adaptation options. A one year increase in farm experience of a farmer increases the probability of engaging in livestock farming, rain water harvesting and off farm activity by 3%, 7% and 9%, respectively. This indicates that households in Malawi have perceived the problem of climate change and are participating in different adaptation strategies over time. Interestingly, having training on climate change increases the probability of adopting Improved varieties, Irrigation, livestock and off farm business by 4%, 22%, 4% and 4%, respectively. On the other hand, extension visit has a positive and significant effect on irrigation while it has a negative and significant effect on rain water harvest. Having extension contact increases the probability of irrigation by 17% while it decreases the probability of rain water harvesting by 6%.

Land ownership is a proxy for land tenure security. Land ownership has a significant effect on the choice of irrigation only. The result of our multinomial logit model indicates that the probability increases by 3% for those who own farm land. This makes sense because irrigation facilities are normally built for some long period of time which most farmers would calculated the risk of losing these facilities to a land owner if using a rented land. Access to credit affects all the adaptation strategies. Credit access increases the probability of engaging in irrigation, livestock farming, rain water harvesting and off-farm income as climate adaptation strategies by 5%, 6%, 5% and 4%, respectively. On the contrary, it decreases the probability of improved varieties by 4%. Credit access would provide much needed start-up capital for irrigation, livestock farming, off farm business and structures for rain water harvesting.

4. Conclusion and Recommendation

This paper attempts to investigate the determinants of climate change adaptation strategies in Malawi. To achieve its objectives, this study utilizes a cross-sectional data from 900 randomly selected households across 7 districts in Malawi. The data were substantiated by focus group discussions and key informant interviews in all districts. Multinomial logit results have revealed that farmers adapted to climate change by using various methods. Access to credit, climate change training and household size had greater significant effect on the decisions of the farmers to adopt climate adaptive strategies. Therefore, it is recommended that policies from government and other stakeholders should ensure that farmers have access to sufficient credit to increase their ability and flexibility in adopting climate adaptation options. Secondly, adaptive options like irrigation have shown to depend much on of labour availability. It is therefore, recommended that government and other relevant stakeholders should advocate for use of labour saving technologies like use of improved irrigation systems, use of herbicides which enhance high adoption of levels for irrigation farming. The positive impact of climate change training sets a good signal to justify intensification of such trainings if agriculture sector is to enhance farmers' climate adaptive capacity.

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