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Unravelling strategic choices towards droughts and floods' adaptation in Southern Malawi

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ABSTRACT

This paper examined factors that influence households' choice over climatic change (droughts and floods) adaptation strategies. The paper employs a multivariate probit analysis on 500 household survey data from low and highland of southern Malawi. Data reveals that households have adopted strategies such as irrigation farming, crop diversification, shifting planting dates, growing of improved varieties and income generating activities. Empirically, it is depicted that household characteristics such as education, land, income, labour and gender have significant influence on households' choice over droughts and floods related adaptation. Furthermore, climatic variables such as temperature and rainfall significantly affect households' choices over various adaptation strategies. The study advocates that climatic and weather related projects should mainstream factors that influence farmers' behaviours for successful adaptation.

1. Introduction

1.1. Study context

The climate is changing and mitigation efforts to reduce the sources or enhance the sinks of greenhouse gases will take time [42,31]. Climatic change is one of the predominant cross cutting issues in most developing countries. It plays a very important role in agriculture [35]. Like most countries in Southern Africa, in Malawi, climatic change and weather variability (CCV) exerts negative impacts on agriculture. Agriculture is the mainstay of the Malawi economy contributing approximately 40% to Gross Domestic Product (GDP) and 80% of the export earnings. CCV leads to crop failures and damages. This results into low food crop production, food shortages, malnutrition and hunger in most part of the country, especially in the Lower Shire, southern part of Malawi [14,41,49].

Although at national level, Malawi has been having surplus food crop production, there are chronic pockets of food insecurity in a number of farming households especially among disaster prone districts such as Chikhwawa, Salima, Karonga, Nsanje, Balaka and others. Some studies have shown that households, in Chikhwawa district, experience about a 60 to 70% reduction in food crop production due to floods and droughts [19,22,23,9,60]. This results into more than 56% of the households in Chikhwawa running out of food annually [1]. Besides that, low food production is also due to low adaptation capacity, however, this trend can be reversed effective adaptation.

Following the effects of climatic change and variability, different stakeholders such as public and private institutions, farmers and others have been developing programmes to help farmers to adapt towards climatic

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change and variability [1,15]. Through these programmes, farming households implement a number of adaptation strategies. In Chikhwawa district, some of the adaptation strategies being promoted include use of chemical fertilizer, composite manure, agro-forestry practices, improved crop varieties, irrigation farming, crop diversification and others [41]. However, adaptation still remains very low [1].

This paper examines factors that influence farmers' behaviour in choosing various adaptation strategies towards drought and floods at the household level in Chikhwawa district. A multi stage sampling procedure was employed to select 500 households from 26 villages of 6 Traditional Authorities in Chikhwawa. The study was conducted in Chikhwawa due to proneness to natural disasters and a number of climatic related initiatives in the district. In particular, this study answers the following researchable question (a) what factors influence farmers' behaviour in choosing various adaptation strategies towards droughts and floods.

1.2. Statement of the problem and rationale

Over the past decades, Malawi has experienced six major droughts (1978/79, 1981/82, 1991/92, 1993/1994, 2001/02 2004/05) [26]. These droughts resulted in frequent and increasingly long dry spells, and erratic onset and cessation of rainfall that negatively affect agricultural production [9]. Furthermore, it is noted that the 1991/92, 1994/1995, 2001/2002 and 2004/2005 droughts led to low national food production [17] and production has been dwindling over time for the past ten years. Floods have also severely disrupted food production in several districts such as Chikhwawa, Nsanje, Karonga, Phalombe, Mulanje, Salima and others. Above 54% of households, in Chikhwawa district, still experience food shortages despite surplus national food crop production and deliberate adaptation programmes at household level [20,19,18].

Action Aid [1] attributes food shortage in Chikhwawa district to, among others, the inability of farming households to adapt to droughts and floods. This is because they depend on rain-fed agriculture as a major source of livelihood [15,40]. On the other hand, it is indicated that adaptation may lead to more than 25% increase in food crop production (Brandshaw, et al. 2004). The effects of droughts and floods can only be contained if the information is well researched, documented and appropriately disseminated. However, in Malawi, natural disasters have not been comprehensively researched and documented. Most studies have focused on assessing the impacts of droughts and floods on crop production [16,49]. Conversely, literature reveals that little or less is reported on farmers' behaviours towards droughts and floods adaptation.

Lack of information is constraining farmers from adapting [24,51]. If effective research work on adaptation is compromised, crop production will continue to decline [2]. Nonetheless, studies show that adaptation is critical in cushioning food crop production [32,57,58]. Consequently, food security would be well achieved by most poor farmers [44,16,49,14,42].

This paper is of importance to the ongoing droughts and floods and variability related studies in Malawi [54,1,40]. The study derives intuition by addressing the following questions: what factors influence individual farmers in adapting towards changing climates and what are the characteristics of adaptation strategies that farmers adapt. We believe that the study lays a platform for better policy actions that can be embraced by concerned stakeholders. We assume that factors such as age, land holding size, labour and education and climatic variables such as drought, floods, pest infestation, erratic rainfall and temperature significantly influence farmers' behaviour towards droughts and floods' adaptation strategies.

2. Previous studies

There is a vast literature on climatic change and variability. Nhemachena and Hassan [42] define adaptation as any action that farmers adopt in order to adapt towards the effects of climatic and weather variability. Smith and Hitz [59] discuss two types of adaptation (autonomous and planned) towards climatic change in agricultural production. The first involves changes in management practices, such as shifting planting dates, increasing fertilizer use, introduction of new plant varieties and installation of irrigation systems to offset the effects of precipitation and higher temperatures on yields. Rosenzweig and Parry [50] included these adaptation options as exogenous factors in crop yield model. On the other hand, other studies did not include adaptation strategies as exogenous variables [12].

Adaptation is regarded as one of the second best solution to climatic change and variability in the short run. For example, in Zimbabwe, irrigation is one of the most important adaptation options to cushion rural households from climatic change and variability. Studies have shown that climatic variability had very negative impacts on crop productions from dry-land farms as compared to irrigated farms. Farmers with access to irrigation cushioned themselves from the effects of climatic variability. Nhemachena [43] reported that 68% of the farmers adapt towards climatic variability through different strategies such as early planting, planting short and drought resistant crop varieties and others. It is recommended that there is a need to conduct a behaviour analysis at micro-level on how farmers make decisions when choosing various adaptation options [42].

Maddison [35] used a Heckman's model to assess farmers' adaptation across 11 countries in Africa. His study found that the majority of farmers had made at least one adaptation toward droughts and floods and variability. In addition, the study noted that farmers who had perceived climate change, made some adaptations to their agricultural practices in the light of the changes in their production. This study further recommended that there is a need for both farmers and other stakeholders to play a major role in adapting towards the effects of climatic variability [35]. Furthermore, Maddison

[35] pointed out that there are many country specific differences in the propensity of individuals to adapt. This therefore requires further adaptation analysis to understand factors in specific locations and their contribution on food crop production.

Lema and Majure [34] conducted a study in Tanzania to understand local communities' perceptions on climate change and variability issues. The study found out that local people perceived changes in rainfall and temperature. The changes have affected crops and livestock in a number of ways resulting in reduced productivity. This study pointed out that a combination of strategies to adapt, such as proper timing of agricultural operations, crop diversification, use of different crop varieties, changing planting dates, increased use of water and soil conservation techniques and crop diversifying exist at household level. On the other hand, the study revealed that there are different wealth groups namely the rich, the middle and the poor who are differently vulnerable to climate change. However, the poor are adversely affected by climatic change and weather variability. The study concluded that knowledge on adaptation that should form a foundation for designing agricultural innovation systems to deal with impacts of climate change and variability.

Action Aid [1] conducted a study on assessing how farmers have adapted towards climatic change and variability in Southern part of Malawi. The study found out that most farming households in Malawi do not have sufficient capacity to cope with adverse impacts of climatic change and variability extreme events. Floods and droughts have resulted in acute crop failures and damages resulting into food shortages and hunger [41]. Besides, Paul et al, [47] using a general equilibrium model estimated that Malawi loses 1.7 per cent of its GDP on average every year due to the combined effects of droughts and floods. Alternatively, adaptation strategies such as improved varieties have positive impact on reducing the effects of floods and droughts in Malawi [47].

Most studies have employed a ricardian structural approach to study climatic change [42]. Bradshaw et al, [8] used a Ricardian Approach to estimate the impacts of adaptation strategies on agricultural production. Conversely, econometric approaches (multinomial logit or two step estimation) have been applied in assessing factors that affect farmers' choice in choosing various adaptation strategies across Southern Africa [43,42,35]. The multinomial logit model assumes homoscedasticity between alternatives [27]. It is because of the homoscedasticity assumption that in this study we adopt a generalised extreme value regression (multivariate analysis) [39] to assess factors that influence farmers in choosing various adaptation strategies in the lowland[1] and highlands of Chikhwawa district. Generalised models ably estimate relationships between adaptation strategies and other variables despite heteroskedasticity and correlations [61].

3. Theoretical and empirical framework

3.1. Household choices model over adaptation strategies

We develop our theoretical framework following Random Utility Theory. The random utility model (RUM) grounded in microeconomics of consumer theory was pioneered by Thurstone (1927), Marschak (1960), and Luce (1959). It later incorporated the manner of specifying utilities as developed by Lancaster (1966) and McFadden (1974). The RUM is appraised to represent theoretical paradigm to simulate a rational choice of a decision maker among a set of feasible alternatives [48,7,39,38].

Random Utility Model describes a choice occasion in which an individual n has a set of alternative adaptation strategies from which to choose. We assume that each adaptation alternative has its attributes which also influence individual n choice on another alternative. Random Utility Model helps us address how farmers make choices over alternative adaptation strategies. The model is based on the notion that an individual derives utility by choosing a number of alternatives. The utilities U_i are latent variables, and the observable preference indicators y_i are manifestations of the underlying utilities. In other words, we observe a preference indicator y_i to determine the utility that farmers derive in various choices they make. The utilities are assumed to be a function of a set of explanatory variables Z_i, which describe the decision-maker n nd the adaptation strategies alternatives i and its attributes q_i. Where i, which represents adaptation strategies, ranges from 1, 2, 3 to J; n, which denotes number of individual households, ranges from 1, 2, 3 to N. We make a very strong assumption that on the ground, farmers choose more than one adaptation strategies in order to mitigate to the effects of droughts and floods and variability.

The utility that an individual would randomly derive from choosing a particular adaptation strategy i, from a choice set C_n of adaptation alternatives, is described by a direct utility function:

$$U_{in} = V_i(q,Z,\emptyset) + \psi_i \quad (1)$$

where q_i is a vector of characteristics or attributes that are associated with each adaptation strategy i ($i=1,2,3,\ldots J$) as chosen by an individual n ($n=1,2,3,\ldots N$), Z_i is a vector of household specific characteristics, ψ_i is the error term and C_n is a vector of all adaptation strategies that are adopted by individual households. We also describe $\emptyset$ as a vector of unknown parameters which will be estimated by this study. We also assume that individual n will choose adaptation strategy i from a set of alternative adaptation strategies C, which are mutually exclusive alternatives. We assume that a bundle of adaptation strategies will be chosen from an overall set of strategies only if ($U_j > V_i$) the derived utility, U_j, is greater than the utility, U_i, of all other bundle of adaptation strategies. However, on the ground, farmers derive utilities from a combination of adaptation strategies that they employ in order to adapt

[1] Lowland households are those households that have gardens with altitude below 80 metres and situated along 16°16′ 08.80 S 34° 58′33.01E while highland households are those households with altitude above 80 metres and located along 15° 57′ 14.06′S 34° 45′ 53.92E.

towards droughts and floods. We consider utility function as a sum of observable $V_i(\cdot)$ and unobservable ψ_i characteristics of an adaptation strategy i and individual n. We can define the utility function as linear and additive over household characteristics and adaptation strategy attributes.

We assume that the random components have a location parameter equal to zero and scale parameter equal to θ_i for the ith alternative. Thus, we illustrate probability density function and the cumulative distribution function of the random error term for the ith alternative as:

$$f(\psi_i) = \frac{1}{\theta_i} e^{-\frac{\psi_i}{\theta_i}} e^{-e^{-\frac{\psi_i}{\theta_i}}} \text{ and } F_i(Z) = \int_{\psi_i=-\infty}^{\psi_i=Z} f(\psi_i) d\psi_i = e^{-e^{-\frac{\psi_i}{\theta_i}}} \quad (2)$$

A combination of expressions (1) and (2) and assumed independence among the random component of the alternatives [7] enable us to develop the probability that an individual will choose an alternative or combination of alternatives from set C of available alternative adaptation strategies. Mathematically, we can illustrate the choice probabilities as follows:

$$P_i = Prob(U_i > U_j),\ for\ all\ j \neq i, j \in C$$
$$= \int_{\psi_i=-\infty}^{\psi_i=Z} \Pi_{j\neq i, j\in C} \Lambda\left[\frac{V_i - V_J + \psi_i}{\theta_J}\right] \frac{1}{\theta_i} \lambda\left(\frac{\psi_i}{\theta_i}\right) d\psi_i \quad (3)$$

where $\lambda(.)$ and $\Lambda(.)$are the probability density function and cumulative distribution which are functions of the standard type I extreme value distribution, respectively. These distributions are given by

$$\lambda(.) = e^{-t} e^{-e^{-t}} \text{ and } \Lambda(.) = e^{-e^{-t}} \quad (4)$$

We also assume that the error term ahs the density function $f(\psi_{in}) = f(\psi_{i1}, \psi_{i2}, \psi_{i3}, \ldots \psi_{ij})$ where it has a zero mean and a variance-covariance ($cov(\psi_{in})$) matrix of

$$cov(\psi_{in}) = \begin{bmatrix} \sigma_{11}^2 & . & \sigma_{1n}^2 \\ . & . & . \\ \sigma_{m1}^2 & . & \sigma_{mn}^2 \end{bmatrix} \quad (5)$$

Following [7] substituting $w = (\psi/\theta)$ in expression 3, the probability of choosing alternative adaptation strategy i can be re-illustrated as:

$$P_i = \int_{\psi_i=-\infty}^{\psi_i=Z} \Pi_{j\neq i, j\in C} \Lambda\left[\frac{V_i - V_j + \psi_i}{\theta_j}\right] \lambda(w) dw \quad (6)$$

If the probability, given in Eq. (6), adds up to one over all alternative adaptation strategies, then the variance of all adaptation strategies become equal and the probability of Eq. (6) collapse to a Luce 1959, i.e. multinomial logit model [38]. In most choice models, the random components of the utilities of various alternatives are assumed to be independent and identically distribution (IID) with a type I extreme value distribution. This assumption results into a Luce 1959 model. The Luce 1959 model has a simple and elegant closed form mathematical structure, making it easy to estimate and interpret. However, the multinomial, Luce 1959, logit model is saddled with independence of irrelevant alternatives' (IIA) property at the individual level [6,48]. In short, the multinomial logit model imposes the restriction of equal cross elasticities due to a change in an attribute affecting only the utility of an alternative for all adaptation strategies [38,39]. The homoscedasticity assumption is unlikely to represent the actual choice in many situations [52,33,7,10].

On the other hand, there are a number of models which assume heteroskedasticity for the error terms. For example, models such as Random Logit model or Multinomial Probit accommodate a very general error structure although the flexibility of the random components, however, estimation of a MNP comes at the expense of introducing addition parameters in the covariance matrix [38]. In addition, a Multinomial Probit model specification for discrete choice models does not require the assumption of IIA [30]. However, the main drawback of MNP is the requirement that multivariate normal integrals must be evaluated to estimate the unknown parameters. However, with the use of sophisticated econometric softwares such as STATA, advance SPSS and others, the computation of MNP model has become easier and simplified. Another type of a model that relaxes the IIA is a nest logit which partially relax the assumption of independence among random components of alternatives [10]. This model has a closed form solution, is relatively simple to estimate and is more parsimonious than the Multinomial Probit model [33,7,38].

The Multinomial Probit Model avoids the pitfalls of the IIA property of the multinational logit model by allowing different scale parameters across alternatives. Intuitively, we can explain this by realising that the error term represents unobserved characteristics of an alternative. The variance of the error term represents the level of uncertainty. We assume that an effect of a small change in the systematic utility of an alternative on the probability of choosing alternative can be illustrated as:

$$\frac{dP_i}{dV_j} = \int_{w=-\infty}^{w=+\infty} -\frac{1}{\theta_j} \exp\left[\frac{V_i - V_J + \theta_{iw}}{\theta_J}\right] \Pi_{j\neq i, j\in C} \Lambda\left[\frac{V_i - V_J + \theta_{iw}}{\theta_J}\right] \lambda(w) dw \quad (7)$$

We also assume that there is a linear in parameter functional form for the systematic component of utility for all alternatives. The Heteroskedastic model developed in this study is estimated using the maximum likelihood technique [27]. We have assumed that the model is linear in parameters for utilities of all alternatives C_n subject to various household characteristics Z and adaptation strategies related attributes q as illustrated in Eq. (1) and its associated log likelihood function can be written as (Where y is the choice indicator):

$$L = \sum_{n=1}^{n=N} \sum_{i\in C_n} y_{ni} \log\left\{\frac{dP_i}{dV_j} = \int_{w=-\infty}^{w=+\infty} -\frac{1}{\theta_J} \exp\left[\frac{V_i - V_J + w_I}{\theta_j}\right] \Pi_{j\neq i, j\in C} \Lambda\left[\frac{V_i - V_j + \psi_I}{\theta_j}\right] \lambda(w) dw\right\} \quad (8)$$

From our theoretical framework above, we derive our choice model empirical framework. We firstly make our strong assumption that various adaptation strategies attributes influence the choice that farmers make on the other alternative adaptations. This assumption allows us to state that household's choice over one adaptation strategy is not independent from a choice they make over another or combination of adaptation strategies. From the aforementioned assumption, we relax the independence from irrelevant alternative assumption through a Multinomial Probit Model [56,27]. The Multinomial Probit model works quite well where we cannot specify the tree for the nested model. In addition, the model does not lose the characteristics of the random utility structures of

$$U_{ij} = V_{ij}(Z,Q) + \psi_{ij} \tag{9}$$

According to Greene [27], the Multivariate Probit model, one of the models that can be run where heteroskedasticity prevails relaxes the assumption of equal variance

$$Var\psi_{ij} = \sigma_i = 1.0 \tag{10}$$

Nevertheless, the model assumes unequal variance over all adaptation strategies

$$Var\psi_{ij} = \sigma_i \text{ and } \sigma_j \neq 1.0 \tag{11}$$

In this study, we generally illustrate the Multinomial Probit model (MNP) as follows:

$$y_{nij} = \varphi Z_i + \xi q + \psi_{ij} \tag{11}$$

where $y_{ni} = 1$ if individual n chooses adaptation alternative i and $y_{ni} = 0$if otherwise. It should be known that y_{ni} takes on a multiple adaptation choices that farmers n adapt which range from i $(i = 1,2,3,..J)$, $Z_,$ Q, $\psi_{ij}$are household characteristics, adaptation attributes and error term, respectively. ξ and φ are unknown parameters to be estimated by the model through a Maximum Likelihood Function [27]. It should be noted that this study will run both models in order to compare the estimates and for policy directions. Since we cannot observe attributes of each adaptation strategies, we specify our MNP equation to take the following form:

$$\Pr(y_i = 1/Z) = \Phi(\varphi Z) = \varphi Z_i + \psi_i \tag{12}$$

where $\underline{y}$, Z, Q,ψ_{ij} and φ are described as adaptation strategies chosen by a household, vector of household characteristics, error term and unknown parameter, respectively. $\Phi(.)$ is the cumulative distribution function of the standard normal distribution. The unknown parameters are typically estimated by maximum likelihood

$$\text{In } L(\varphi) = \sum \left(y_i \text{In}\Phi(\varphi Z) + (1-y_i)\text{In}(1-\Phi(\varphi Z))\right) \tag{13}$$

The asymptotic distribution of our unknown parameter is given by

$$n^{1/2}(\hat{\varphi} - \varphi) \xrightarrow{d} N\left(0, \left(E\left[\frac{\varphi^2(Z'\varphi)}{\Phi(Z'\varphi)(1-\Phi(Z'\varphi))}\right]\right)^{-1}\right) \tag{14}$$

We should note that the multivarite probit model is theoretically attractive but it has some practical because of a $(J+1)$ dimensional integral. This complexity not only makes the model difficult to estimate but also makes the likelihood infeasible. However recent advances in estimation make the multivariate probit estimation feasible for many alternatives [61]. We can also call the MNP model [30]. Conditional Probit Model. As other random utility model, the Conditional Probit offers highly desirable flexibility in subsituation among alternatives that its chief rival, multinomial logit, fails to possess. The unrestricted character of the variance matrix in the multivariate normal distribution that underlies probit cannot be produced by logit even in its generalised extreme value form.

The study undertook participatory rural appraisals (focus group discussions and key informants) to assess the typical situation of droughts and floods in Chikhwawa district. These discussions were carried out to confirm on the interviews adopted by households using a checklist of questions: What kind of adaptation strategies have the community been adopting? Who introduced and promoted such kind of strategies? How has the occurrence of droughts and floods been over time? What were the effects of droughts and floods? What should programs include to cushion households from the effects of droughts and floods? and how well should households adapt to climatic and weather variability? The focus group discussions were composed of 15 members: 7 men and 8 women. Key informants interviews included prominent people in the communities such as local leaders and agricultural extension workers.

4. Results and discussion

Our results cover two main components. We firstly consider description statistics of the interviewed households. Secondly, we present factors that determine farmers' choice over various adaptation strategies among lowland and highland farming households of 26 villages sampled from 23 group village headmen of 6 Traditional Authority of Chikhwawa district, Southern Malawi.

4.1. General household characteristics

Before we discuss the empirical results, we present the description of our study in the specified areas. In order to systematically compare household specific characteristics, we categorise our descriptions between Lowlands (Lower lands) and highlands (Upper lands) of Chikhwawa. From Table 1 above, firstly, we observe that 40 per cent and 47 per cent of the interviewed households were female headed from lower and upper lands, respectively. This is in accordance with the Integrated Household Survey Results that in Malawi most households are headed by male [26]. On the same note, the study reveals that 60 and 53 per cent are headed by male in lower and upper land, respectively. Secondly, the study shows that on average most households in both geographical divisions are in an economic productive age group as household head age average at 39 and 35 years, respectively.

Albeit, we note that the average group age is 37. However, there are households which are headed by a child aged 14 and very elderly aged 86 years. The list of household heads was obtained from agricultural district office, list from the farm input subsidy program. Thirdly, we note that on average most household head have reached standard 3 and 5 respectively. However, there are still other household heads that did not go to school

Table 1
Summary descriptive statistics.

Variable	Lowlands (69%)		Highlands (31%)	
	Mean	Std. dev.	Mean	Std. dev.
A. General household characteristics				
Gender (female=1)	0.407	0.492	0.471	0.502
Age (years)	39.293	13.881	34.662	13.449
Children (#)	4.383	2.587	3.356	2.267
Family size (number)	5.902	2.641	5.269	2.309
Labour (people > 15yrs)	3.09	1.663	3.136	1.709
Education (years)	3.783	3.621	4.651	3.603
Land (owned=1)	0.8917	0.311	0.898	0.303
Total land (acres)	1.435	0.911	0.904	0.726
Total income (MK)	4903	12054	5702	14595
Hybrid seeds (applied=1)	0.721	0.449	0.662	0.475
Local seeds (applied=1)	0.293	0.456	0.370	0.486
Manure (applied=1)	0.659	0.891	0.292	0.457
Chemical fertilizer (applied=1)	0.288	0.454	0.078	0.271
B. Adaptation strategies				
Improved varieties	0.721	0.449	0.662	0.475
Crop diversification	0.322	0.468	0.091	0.289
Changing planting dates	0.320	0.467	0.146	0.355
Irrigation farming	0.835	0.372	0.471	0.502
Climatic information	0.824	0.381	0.617	0.488
Income generating activities	0.087	0.283	0.685	0.466
Agro-forestry practices	0.865	0.341	0.325	1.213
Soil & Water conservation	0.865	0.341	0.314	0.466
C. Seed varieties and sources				
Hybrid Variety (kg/Acre)	9.440	9.169	7.685	7.621
Local Variety (kg/acre)	3.928	6.248	2.955	8.751
ADMARC	0.129	0.336	0.247	0.434
Agro dealers	0.686	0.465	0.225	0.419
Friends	0.072	0.259	0.112	0.318
Relatives	0.036	0.187	0.045	0.208
Own Source	0.232	0.423	0.213	0.412
D. Perceived effects of droughts and floods and variability				
Crop destructions	0.768	0.423	0.843	0.366
Crop failures	0.753	0.433	0.854	0.355
Reduced production	0.835	0.372	0.742	0.440
Death of livestock	0.670	0.471	0.685	0.467
Water deficits	0.660	0.475	0.708	0.457
Soil erosion	0.644	0.480	0.629	0.486
Soil Infertility	0.660	0.475	0.562	0.499

while others have gone up to secondary school. In addition, on average, most family in the study area have 5 household members. The study notes that each household in lower lands has, on average, a piece of land of 1.4 acres (0.523 hectares) and in the upper land, farming households have a 1 acre (0.4 hectare) of land holding size. Households have on average annual total income of 4903 Malawi Kwacha (32.68 US$) and 5703 Malawi Kwacha (38.02 US$) in lower and upper land, respectively. However, we observe that there are other households which have an annual income of 105,000 Malawi Kwacha (700 US$).

Households in Chikhwawa have adopted a number of adaptation strategies in order to boost production. In this study, we note that 72 and 66 per cent of the households, in lower and upper lands, respectively, grow hybrid varieties which are drought resistant, have early maturity and have high yield per hectares such as Kanyani (DK 8053) for maize and kapira for millet. In addition, manure and chemical fertilizer is applied by households in both lower (66% and 29%) and upper (29% and 8%) land, respectively. From Table 1, we note about 87 and 33 per cent of the households practise agro-forestry in lower and upper lands, respectively. On the other hand, 77 per cent of the households in lower lands practise soil and water conservation techniques compared with a 4 per cent application in upper lands.

Through focus group discussions and key informants, it was reported that most households indulged in various adaptation strategies because of several reasons. Some of these reasons are (a) to reduce effects of drought through improved varieties and shifting planting dates, (b) to regulate floods and run off through soil and water conservation techniques, (c) to increase food crop production, (d) generate income through income generating activities, (e) improve soil fertility through manure application, and (f) reduce soil erosion and diversify risks through crop diversification. These results confirms to earlier studies that indicated that agro-forestry and soil and conservation have

Table 2
Marginal effects of MPA and MLA.

Lowland households										
	Multivariate probit analysis (MPA)					**Multinomial logit analysis (MLA)**				
Depvar	IGA dy/dx	Irrigation dy/dx	SPD dy/dx	CD dy/dx	IV dy/dx	IGA dy/dx	Irrigation dy/dx	SPD dy/dx	CD dy/dx	IV dy/dx
Education	−0.02	0.1**	0.011	0.10*	−0.011	0.004	0.168*	0.018	0.066	0.002
Age	−0.01	0.003	−0.02	0.007	0.009	0.009	0.009	−0.019	0.021	0.04*
Family Size	0.24*	0.006	0.001	0.059	0.011	0.44**	0.079	0.096	0.136	0.177
Labour	0.275	−0.23	−0.06	−0.13	−0.02	−0.396	−0.158	−0.051	−0.051	−0.01
Gender	0.661	−0.13	0.484	0.603	0.687*	0.673	−1.69***	−1.077*	−1.25*	−1.4*
Land	0.62*	0.417	0.63*	0.6**	0.337	0.006	−0.371	−0.016	−0.168	−1.1*
Income	3E-05	6E-05	3E-04	4E-05	3E-05	0.83***	0.1176*	0.22*	0.12**	0.12*
Extension	-0.14	0.592	0.785	0.479	0.074	0.087	1.494*	1.723	1.071	1.33
Drought	0.733	0.559	2***	0.604	0.547	1.181	1.162	3.505***	1.258	1.69*
Flood	1.7***	−1.3**	0.576	1.07*	1.31**	0.354	−0.184	−1.347	−1.716	0.027
Pest Infest	0.228	0.622	−0.24	0.254	0.562	−0.921	−0.395	−1.306	−0.572	−0.4
Rainfall	1.4**	1.696	1.2**	1.4**	1.6***	1.152	1.746**	0.707	−1.215	2.5***
Temperature	0.493	0.9**	0.9**	0.582	0.256	−1.39*	2.098***	−2.043**	−1.756*	2.11*
External Assistance	−0.05	−0.22	−0.36	−0.51	−0.525	1.337*	1.014	0.78	0.24	0.471
		χ^2 (wald)=7.34*; LR= 1062.64					χ^2 (wald)=109.3***; LR= 264.83			
Highland households										
Education	0.012	−0.114	0.126	0.115	0.13	−0.475	0.282	0.271	0.073	0.13
Age	0.095	0.117	−0.037	0.133*	−0.043	0.074	0.038	−0.2*	0.033	−0.043
Family size	−0.346	−0.292	−0.56*	−0.051	0.403	0.343	0.74*	−0.14	0.125	0.403
Labour	1.82**	1.71**	2.6***	1.49**	−0.127	−1.39*	−0.68*	1.2**	−0.217	−0.127
Gender	0.274	0.316	0.657	0.504	2.2**	5.3**	2.9**	2.96*	2.57*	2.2**
Land	−0.138	0.677	−2.0***	−0.075	1.611	−2.794	1.549	−1.25	2.79*	1.611
Income	0.01**	0.01**	0.01**	0.01**	−0.3E-4*	6E-5	−0.001**	0.003	0.006	−0.3E-4*
Extension	0.207	0.204	−1.572	−0.389	−0.117	1.935	−0.277	−2.39	0.879	−0.117
Drought	0.654	2.855	0.437	17.0**	0.689	20**	20.8**	−0.13	21***	0.689
Flood	2.368	1.386	20***	−0.668	−0.892	−1.648	−3.301	23.5*	−3.93	−0.892
Pest infestation	−0.488	−1.074	−0.081	1.67**	−1.749	−24**	−2.875	−1.1	−2.625	−1.749
Rainfall	2.764	2.003	20***	1.392	2.968	−0.961	−6.69**	21**	−6.20*	2.968
Temperature	0.112	0.945	1.594	0.027	0.106	2.101	0.343	−1.89	−2.319	0.106
External assistance	12.4**	−14**	−12***	−12***	0.211	2.193	0.093	−0.74	−2.252	0.211
		χ^2 (wald)=6.63*; LR=418.65					χ^2 (wald)=193.5***; LR=91.22			

* Significant at 1%.
** Significant at 5%.
*** Significant at 10%.

been adopted in floods and drought prone areas to reduce erosion and improve soil fertility [1].

4.2. Empirical results

Table 2 illustrates the choices that famers make given a number of socioeconomic characteristics. Since farmers choose more than one adaptation strategies within the same season, this study presents the marginal effects of a multinomial logit estimates and Multinomial Probit estimates as shown in Table 2 respectively. These models are capable of jointly estimating the various adaptation strategies at household level.

4.2.1. Growing of improved varieties

Households grew improved varieties to offset the effects of both droughts and floods on food production. From Table 2, we note that education, age, family size, labour, land and income do not have significant influence on household choice over improved varieties in the lowlands. However, it is only gender of the household head that is statistically significant and positively influence farmers' choice over improved varieties among lowland households. In contrast, the study notes that factors such as education, age, income and land have significant influence on household choice over improved varieties among highland households. For example, Table 2 shows that education results into 0.49 percentage point increase in chances of choosing improved varieties among upland farmers. We get mixed results on the direction and significance of household characteristics as other similar studies [62,5]. In our study, we note that age of the household head increases the likelihood of growing improved varieties by 0.43 percentage points among low and highland households.

Our results further show that land holding size and income increase the prospect of growing improved varieties in the study area. Focus discussion groups revealed that farmers with more money are likely to purchase improved varieties on the markets. Through focus group discussion, our study noted that when a household has more land do not feel the impact of droughts on production. An increased in land dedicated to food crops by 1 acre reduces the chances of growing improved varieties by 1.06 percentage points. On the other hand, households which have gardens in the uplands have a 1.61 likelihood to grow improved varieties if land increase by 1acre. This is because farmers in the highland are vulnerable to droughts as compared to lowland households. Hence, upland household are likely to grow improved varieties to offset the effects of droughts, high temperature and erratic rainfalls.

4.2.2. *Crop diversification*

Households diversify their crops in order to spread the risks. Table 2 depicts that household income has statistically significant influence on crop diversification. This implied that an increase in income by MK1000 increases the likelihood of crop diversification by 0.11 percentage point in the study area. We further note that more upland households are likely to go into crop diversification by 0.01 percentage point. This is because upland household ably purchase/hire extra inputs that can be employed in crop diversification. This is again in accordance with the labour result which shows that upland households are likely to diversify their crop production by 1.49 when labour increases by one unit. Access to agricultural extension services also increase crop diversification by 12 percentage points. This is because agricultural extension ably provides households with information on the importance of crop diversification ([5,53] and [3]).

4.2.3. *Shifting/changing planting dates*

Participatory rural appraisals indicate that households shift planting dates because of floods and droughts [57]. In the study area, floods and droughts occurred in the month of January and February, respectively [18]. In order to respond to crops which were destroyed and burnt by floods and droughts, most farmers replanted their crops. From Table 1, our descriptive statistics indicates that 32 (15) per cent of the lower lands (upper) based households changed their planting dates due to floods (droughts) and other factors. Only gender and income have significant influence on farmers' choice over shifting of planting dates. In other words, income has a positive contribution on household choices. When income increases by MK1000 increases farmers' choice over changing planting dates by 0.12 percentage points among lowland based households. Age, labour, and gender also have significant effects on households' choices. Among highland based households, gender and labour have positive contributions on shifting planting dates. We note with interest that that when we increase labour by 1 unit (person), the upper land based household choice over shifting planting dates increases by 1.2 percentage points.

4.2.4. *Irrigation farming*

We note that household characteristics such as education, gender, income and extension play very significant influence on lower land based household choices over irrigation farming. It is expected indeed that education influenced irrigation choice positively. Our results show that households that have higher education are likely to adapt towards droughts and floods through irrigation farming by 16.8 percentage points. Correspondingly, extension and education plays a positive role on influencing farmers in choosing irrigation farming as an adaptation strategy ([25] and [11]). Our data reveals that when a household accesses extension by an extra unit (meeting day), the likelihood that the lower lands household will adapt through irrigation farming increases by 1.49 percentage points. It is also depicted that labour, gender and income significantly affect farmers' choice over irrigation farming among upper land based households. In this study, an increase in labour by 1 unit results into an increase in likelihood of upper land based farmers choosing irrigation farming by 0.68 percentage points. From focus group discussions, it was observed that households have access to gardens that can be easily irrigated through inheritance of farms that are close to the river. In other words, households that do not have gardens closer to a river do not have access to irrigation. In highlands, water from the rivers has been diverted to sugar plantations hence having limited access to water.

4.2.5. *Income generating activities*

Household food availability does not only depend on own production but it also depends on market (economic) access. In rural settings, our study note that households engage in income generating activities in order to source money that can be used to buy food in times of food shortages. Chikhwawa district, an area that is frequently affected by floods and droughts has developed strong income generating activities linkage to cushion itself from effects of climatic change and variability [41]. From Table 2, we note that factors such as labour, income and external assistance have a significant positive effect on household choice over income generating activities among lowland households. Interestingly, an increase of a unit in family labour, income and external assistance result into an increase in propensity of income generating activities by 0.44, 0.00083 and 1.34 percentage points as illustrated in Table 2. However, among highlands, we note that labour and gender have statistically positive influence on income generating activities. For example, any increase in labour (gender) unit among upper land based households increases the likelihood of indulging in income generating activities by 1.38 (5.288) percentage points. According to key informant interview, the study noted that household with more labour are likely to divide labour between households' labour competing activities. This has resulted members engaging in income generating activities while other members are indulging in other specific farm level activities.

4.2.6. *Role of drought and floods on adaptation strategies*

The study finds very interesting results on the effects of droughts and floods on the behaviours of farmers in choosing various strategies. In the study area, drought and floods have positive influence on most farmers' choices over irrigation, income generating activities and improved varieties. Focus group discussions pointed out that due to prolonged and frequent droughts and floods, farmers have undertaken actions to cushion themselves. It was further reported that even though droughts and floods have been happening in Chikhwawa district, their frequencies have been exasperated in the recent times. Hence forcing most households adopt at least one strategies.

5. Conclusion and policy implications

This study examined factors that influence farming households' behaviour over adaptation strategies by applying a multivariate probit and multinomial logit analysis on 500 household survey dataset in 26 villages sampled out from Chikhwawa district, Southern Malawi. Households have strategies such as growing of improved varieties, irrigation farming, crop diversification, shifting planting dates and income generating activities. It is found that age, gender, education, land and income are among factors that significantly influence households' behaviour over strategies in the study area. The study further revealed that drought and floods also significantly affect farmers' choice over adaptation strategies. In this paper, it is concluded that factors characterising farming household should be mainstreamed beforehand for successful adaptation towards droughts and floods in Malawi.

References

[1] Action Aid International. Droughts and floods and smalholder farmers in Malawi. Lilongwe, Malawi. 〈http://actionaid.org.uk/doc_lib/malawi_climate_change〉 [accessed May 2011]; 2006.
[2] Adger WN, Huq S, Brown K, Conway D, Hulme M. Adaptation to climate change in the developing world. Progress in Development Studies 2003;3:179–95.
[3] Anley Y, Bogale A, Haile-Gabriel A. Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district, Western Ethiopia. Land Degradation and Development 2007;18:289–302.
[5] Bekele W, Drake L. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. Ecol Econom 2003;46:437–51.
[6] Ben Akiva Lerman SR. Discrete choice analysis: Theory and application to travel demand. Cambridge: The MIT Press; 1985.
[7] Bhat CR. A heteroskedastic extreme value model of intensity travel mode choice. Transportation. Research B 1995;29(6):471–83.
[8] Bradshaw B, Dolan H, Smit B. Farm-level adaptation to climatic other weather variability and change: Crop diversification in the Canadian Prairies. Droughts and Floods 2004;67.
[9] Clay D, Reardon T, Kangasniemi J. Sustainable intensification in the highland tropics: Rwandan Farmers' investments in land conservation and soil fertility. Econ Develop Cult Change 2002;46(2):351–78.
[10] Daly A, Zachary S. Improved multiple choice model. London: Teakfield; 1979.
[11] Dolisca F, Carter RD, McDaniel JM, Shannon DA, Jolly CM. Factors influencing farmers' participation in forestry management programs: A case study from Haiti. Forest Ecology and Management 2006;236: 324–31.
[12] Darwin RF, Tsigas M, Lewandrowski J, Raneses A.World agriculture and climate change: Economic adaptations, Agricultural Economic Report no. 703, United States Department of Agriculture, Economic Research Service. Washington DC; 1995.
[14] Environmental Affairs Department (EAD). Lilongwe, Malawi: Malawi National Strategy for Sustainable Development (MSSD); 2005.
[15] Environmental Affairs Department. National adaptation programme for action. Lilongwe, Malawi: Ministry of Natural Resources and Environmental Affairs; 2006.
[16] FAO. Adaptation to droughts and floods in agriculture, forestry and fisheries: perspectives, frameworks and practices. Rome; 2007.
[17] FAO. FaoStat estimates on agricultural production. 〈www.faostat.fao.org〉; 2011.
[18] Famine early Warning Network-USAID. Malawi food updates. Lilongwe, Malawi; 2010.
[19] Famine early Warning Network-USAID. Malawi food updates. Lilongwe, Malawi; 2009.
[20] Famine early Warning Network-USAID. Malawi food updates. Lilongwe, Malawi; 2008.
[22] Famine early Warning Network-USAID. Malawi food updates. Lilongwe, Malawi; 2005.
[23] Famine early Warning Network-USAID. Malawi food updates. Lilongwe, Malawi; 2002.
[24] Gbetibouo G, Hassan R. Measuring the economic impact of climate change on major South African field crops: A Ricardian approach. Global and Planetary Change 2005;47(2–4):143–52.
[25] Glendinning A, Mahapatra J, Mitchell CP. Modes of communication and effectives of agroforestry extension in eastern India. Human Ecology 2001;29(3):283–305.
[26] Government of Malawi (GOM). Annual economic Report. Lilongwe, Malawi; 2008.
[27] Greene WH. Econometric analysis. 5th ed. Upper Saddle River: Prentice Hall; 2003.
[30] Hausman J, Wise D. A conditional probit model for qualitative choice: Discrete decisions recognizing interdependence and heterogeneous preferences. Econometrica 1978.
[31] Hulme M, Doherty RM, Ngara T, New MG, Lister D. African climate change: 1900–2100. Climate Research 2001;17:145–68.
[32] Kandlinkar M, Risbey J. Agricultural impacts of climate change: if adaptation is the answer, what is the question? Droughts and Floods 2000;45:529–39.
[33] Koppelman F, Hua wen C. Alternative nested logit models: structure, properties and estimation. Illinois, USA; 1997.
[34] Lema MA, Majure AE. Impacts of climate change, variability and adaptation strategies on agriculture in semi arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. African Journal of Environmental Science and Technology 2009;3(8): 206–18.
[35] Maddison D. The perception of and adaptation to climate change in Africa. CEEPA. Discussion Paper No. 10. University of Pretoria, Pretoria. South Africa; 2006.
[38] McFadden D. Modelling the choice of residential location. Spacial interaction theory and residential location. North Hollard, Amsterdam; 1978.
[39] McFadden D. Econometric models for probabilistic choice of product; A journal of business. Interference Between Marketing and Economics 1980:S13–29.
[40] MKwambisi D, Bie SW, Gomani M. Droughts and floods and rural livelihoods in Malawi.Lilongwe, Malawi: The Royal Norwegian Embassy; 2008.
[41] Nangoma E. National adaptation strategy to droughts and floods impacts: fighting droughts and floods: human solidarity in a divided world.Malawi: UNDP; 2007.
[42] Nhemachena C, Hassan R. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. IFPRI. Washington DC; 2007.
[43] Nhemachena C. Agriculture and future climate dynamics in Africa: impacts and adaptation options. University of Pretoria. Republic of South Africa; 2009.
[44] Nkomo JC, Nyong AO, Kulindwa K. The impacts of climate change in Africa, The stern review on the economics of climate change. 〈www.unep.org/pdf/ipcc/Ch09.pdf〉, [accessed May 2011]; 2005.
[47] Paul K, Thurlow J, Servester D. Drought and floods in Malawi: assessing the economy wide effects. IFPRI Discussion Paper 00962. Lilongwe, Malawi; 2009.
[48] Papola A. Some developments on the cross-nested logit model. Presented at the IX IATBR Conference Queensland. Australia; 2003.
[49] Richard M, Mustafa B, Sander B, Eduardo C, Tim C, Jae E,et al. Towards new scenarios for analysis of emissions, climate change, impacts and response strategies. Technical Summary. IPCC 2007 Expert Meeting. Geneva; 2008.
[50] Rosenzweig C, Parry M. Potential impacts of climate change on world food supply. Nature 1994;367:133.
[51] Stern N. Stern review on the economics of climate change. London: Her Majesty's Treasury; 2007.
[52] Stopher PR, Maybrug AH, Brog W. Travel behavior research: a perspective.Massachusetts: New Horizons in Travel Behavior Research. Lexington Books; 1981.
[53] Tizale CY. The dynamics of soil degradation and incentives for optimal management in the Central Highlands of Ethiopia. PhD

thesis. Department of Agricultural Economics, Extension and Rural Development, Faculty of Natural and Agricultural Sciences, South Africa: University of Pretoria; 2007.
[54] Tchale H, Bohn E, Armas E, Kambambe S. Malawi and Southern Africa: climatic variability and economic performance. Washington DC, USA 〈http://www.odi.org.uk/resources/details.asp?id=3658&title=malawi-climate-change〉; 2004.
[56] Train K. Structural logit model of auto ownership of choice model. Rev Econ Stud 2002;37(2):357–70.
[57] Kurukulasuriya P, Mendelsohn R. A Ricardian analysis of the impact of climate change on African cropland. African Journal of Agricultural Economics 2008;2:58–64.
[58] Seo SN, Mendelsohn R. Climatic change impacts and adaptations on animal husbandry in Africa. African Journal of Agricultural Economics 2008;2:100–4.
[59] Smith JB, Hitz S. Estimating global impacts from climate change, Background paper to OECD workshop on the benefits of climate policy: improving information for policy makers, 2002, 100 pp.
[60] Tchale H, Bohn E, Armas E, Kambambe S. Malawi and Southern Africa: Climatic Variability and Economic Performance, Washington DC, 2003.
[61] Wooldridge JM. Econometric Analysis of Cross Section. Cambridge, UK, 2002.
[62] Zhang D, Flick W. Sticks, carrots, and reforestation investment. Land Economics 2001;77(3):443–56.