Modelling farmers' choice of adaptation strategies towards climatic and weather variability:

Empirical evidence from Chikhwawa district, Southern Malawi

Authored by

Innocent Pangapanga Phiri[1]*

Abstract

This study analysed factors that influence household choice of adaptation strategies and examined the contribution of such strategies on crop production and household food security. The study collected data from 283 randomly selected households from 26 Villages of Chikhwawa district using a semi-structured questionnaire. Results show that irrigation farming, income-generating activities, crop diversification and shifting planting dates are some of the adaptation strategies in the study area. Empirical results from a Multinomial Probit Model indicate that flood, droughts, gender and education are important factors on influencing household choice of adaptation strategies. Climatic information, input markets and credit accessibility deterred households from adapting to climatic and weather variability. Based on the Normalized Translog Production and Tobit Models' results, irrigation farming increased crop production and household food security by 80% and 21% in the study area, respectively. On the other hand, shifting planting dates reduce crop production and household food security by 50% and 9% in the study area, respectively. The study concludes that adaptation strategies have significant contribution on crop production and household food security in the study area. The study therefore advocates that projects should mainstream barriers and choice of adaptation strategies in the farming system.

[1] Research Economist, Living Standards Measurement Study/Integrated Surveys on Agriculture, Poverty and Inequality, National Statistical System, National Statistical Office, P.O. Box 333, Zomba, Malawi. Call: +265-999-338-441/888-338-441. Mailto: phiriinnocent@gmail.com,

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1.0 Introduction

1.1 Background Information

Food production has globally increased from 850 million tonnes in 1960 to 2.35 billion tonnes in 2000s. Per capita food consumption has also increased from 2 300 kcal/day in 1960s to approximately 2 800 kcal/day in last decade (FAO, 2011). Major causes of increasing crop production are: intensified food farming systems; appropriate research; technological development; functioning institutions; and good policy guidelines. However, in the 21st century, per capita global food production slowed down by 7%. This is because of low soil productivity and other related factors (Rosenzweig and Parry, 1994). Southern Africa has experienced deteriorating food production letting down efforts to meet the United Nations Millennium Development Goals (MDGs) of reducing hunger by half by 2015. Poor and excessive precipitation has reduced food crop production by 30% and increased food insecure households from 160 million in 1996 to over a 200 million in the 2000s (Parry, 2007).

Besides, climatic and weather variability has increased the rate of extreme events such as droughts and floods that have adversely affected food security situation in Southern Africa (Aggarwa et al., 2010, Hassan and Nhemachena, 2008; Molua and Mlambi, 2008). Drought and floods have prolonged and increased frequency leading to crop failures and damages. In addition, high population in Southern Africa region has worsened the impacts of climatic change. This has exerted pressure on land leading to land fragmentation and continuous cultivation without traditional fallows (Ajayi et al., 2008).

In Malawi, like most countries in Sub Sahara Africa (SSA), climatic and weather variability has disrupted farming systems through crop failures and damages. This has resulted in shortfalls in food production, hunger and malnutrition (Action Aid, 2006). Droughts and floods impede poverty reduction efforts as stipulated in Malawi Growth and Development Strategic paper (GoM, 2006). Furthermore, extreme events such as droughts, pest and diseases and floods have also made Malawi look for external food aid to support her citizens during food deficits period (World Agroforestry Centre, 2005). Erratic precipitation and temperature drastically reduced household food production in 1991/92, 1994/1995 and 2001/2002 (FAO, 2011).

Chikhwawa, one of the districts in Southern Malawi, has experienced severe food shortfalls due to climate change and weather variability over the past decade (GOM, 2008). In Chikhwawa district, households experience about 60% annual reduction in food production and about 76% of the households become food insecure every year (NSO, 2012; Fewsnet, 2011). Households suffer from shortfalls in food production because of prolonged and recurrent floods, dry spell, pest and disease and other related factors (Fewsnet, 2011). Following the impacts of climatic and weather variability on household food production and food security, a number of interventions are promoted to help households contain climatic and weather variability related impacts in Chikhwawa district (EAD, 2006). These include irrigation farming, crop diversification, small-scale business and shifting crop-planting dates. Despite efforts to promote these interventions, the adoption of these technologies has remained very low such that households have continued to experienced food shortages, hunger and malnutrition (Action Aid, 2006). Using survey data from 283 randomly selected households from low[2] and highland areas of Chikhwawa district, this study explores factors that influence farmers' choice of adaptation strategies and examine the impacts of adopted adaptation strategies on household food production and food security and/or availability.

1.2 Rationale of the Study

Malawi, with a population of 14 million people and a gross domestic product of about US$5 billion, is one of the third world countries that is heavily dependent on agriculture (International Monetary Fund, 2011). However, presently, food productivity does not meet the food demand due to, in part, high population growth and deteriorating soil productivity that has been exasperated by climatic and weather variability (Action Aid, 2006). Unpredictable precipitation induces excessive soil erosion that has led to loss of soil fertility. In Malawi, improved food productivity is very critical to the country's socioeconomic development. As such, the government has developed a number of programs to help households adapt to changes in climate and other related factors (GoM, 2008).

Agriculture sector, of which 70% is dominated by subsistence farming, forms the foundation of the national economy and constitutes the primary source of livelihood for the overwhelming majority of the population. According to World Bank (2010), the sector employs 85% of the labour force and contributes about 35% to gross domestic product and 73% to total export revenues. In addition, approximately 85% of household food and nutritional security is derived from agricultural sector. Climatic and weather variability has worsened food production and food security scenarios in Malawi due to its exclusive dependence on precipitation. On the other hand, irrigated agriculture in Malawi was estimated at less than 1% of the country's total cultivated land (GoM, 2004). Thus, the amount and temporal distribution of precipitation, drought, floods and adaptation strategies are important for boosting crop production and household food security in Malawi (Action Aid, 2006; Tchale et al., 2004). Precipitation and other related factors have been major causes of fluctuating crop production. Malawi experienced a reduction in production by 3.1% in 1997/1998 and followed with 3.5% drop in 2000 and 2001 and another 10% decline in the middle of 2004 (GoM, 2004). In 2008, about 1.1 million people, on average 242,000 households, were food insecure due to extreme events such as droughts and floods.

Nationally, the impacts of climate change and what strategies households are using to adapt is widely recognized. However, little is known about what factors influence farmers' choice of adaptation strategies and what is the impact of such adaptation strategies on household food production and food security. Furthermore, few or no studies have addressed the question why farmers combine a number of strategies to adapt to climatic and weather variability effects (Gomani et al., 2008; Action Aid, 2006). Aggarwal et al (2010) observed that research on household adaptation strategies offers better policy options on how to integrate adaptation strategies in food security projects. This study therefore explores factors that influence households' choice of adaptation strategies to inform decision makers on better design or

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[2]Lowland areas have altitude below 80 meters and situated along $(16^0 16' 08.80'' S\ 34^0 58' 33.01'' E)$
While highland areas have altitude above 80 meters and situated along $(15^0 57' 14.06'' S\ 34^0 45' 53.92'' E$
(Google Earth, 2011).

implementation of climatic and weather variability adaptation programmes. The study further highlights adaptation strategies' economic impacts on crop production and household food security. The information is important for the design of effective climatic and food security related project in Chikhwawa district of Southern Malawi.

1.3 Study Objectives

1. To analyze factors that influence household choice of adaptation strategies to climatic and weather variability in Chikhwawa district.
2. To examine the contributions of various adaptation strategies to household food production and food security in Chikhwawa district.

1.4 Hypotheses

1. Household characteristics (age and education), climatic variables (rainfall, temperature) and climatic extreme events (droughts, floods, pests and diseases outbreaks) have significant influence on farmers' choice of various adaptation strategies in Chikhwawa district.
2. Climatic and weather variability adaptation strategies (irrigation farming, improved varieties, income generating activities and crop diversification), except shifting planting dates, have positive contribution on household food production and food security in Chikhwawa district, Southern Malawi.

1.5 Research Questions

1. What makes farmers choose various adaptation strategies to climatic and weather variability in highland and lowland Chikhwawa Districts?
2. Do climatic and weather variability adaptation strategies improve household food crop production and food security?

2.0 Literature Review

A number of studies have been conducted in Sub Sahara Africa on climatic and weather variability, adaptation, crop production and household food security. However, most studies have concentrated on the impacts of climatic variability on crop production and less on the factors that influence household choice of adaptation strategies (Aggarwal et al., 2010; Akpalu et al., 2008; Hassan and Nhemachena, 2008). Despite limited research on climatic and weather variability adaptation, most of the 21rst century food projects require information on how households would adapt to the effect of climatic and weather variability.

Maddison (2006) applied a Heckman model to determine factors that influence adoption of adaptation strategies towards climatic and weather variability in Africa. The study revealed that education, gender, extension and experience significantly influenced households in adapting towards climatic change. It was found that education and gender increased the probability of adoption of adaptation strategies by 0.03% and 6%, respectively. Study findings recommended that education and extension should be emphasised to appropriately adapt towards changes in climate. Furthermore, lack of appropriate seed, credit accessibility, security of tenure and market accessibility were some of the barriers to household adaptation.

In a similar study, Deressa (2006) employed a Heckman model to assess the determinants of household adaptation to climate change in Ethiopia. The study found that household size and gender, availability of credit and temperature had positive influence on household adaptation to climate change. For instance, credit accessibility and climatic information increased household likelihood of adopting adaptation strategies by 48% and 37%, respectively. Favourable temperature and precipitation increased the probability of household adoption of adaptation strategies by 18% and 12%, respectively. It recommended mainstreaming of credit accessibility in household farming projects.

Action Aid (2006) assessed farmers' adaptation towards climatic change and variability in Southern part of Malawi. It was found that most households in Malawi do not have sufficient capacity to cope with challenges posed by climatic change and variability. However, the study did not estimate the impacts of adaptation strategies on household food production and food security. Pauw et al, (2009) used a general equilibrium model to study the impacts of drought and floods on economy-wide in Malawi. Empirical results showed that droughts and floods were associated with loses of 1.7% in GDP. It was recommended that adaptation has to be intensified in order to counteract the adverse impacts of droughts and floods.

Studies conducted by Nangoma (2007) and EAD (2006) identified improved varieties, irrigation farming, shifting cropping dates and crop diversification as some of the household adaptation strategies to climatic and weather variability in the Southern Malawi. Langyintuo and Mekuria (2008) used a Tobit model to analyse the effects of household characteristics on adoption of improved varieties among Mozambican farmers. The study found a significant contribution of social networks to technology adoption. It was suggested that government should invest in farmers' associations to facilitate high technology adoption.

On the other hand, Akpalu et al (2008) investigated the impacts of climate change and weather variability on maize yield in the Limpopo Basin of South Africa using the Generalized Maximum Entropy Leuven Estimators. Results from the Maximum Entropy Leuven Estimator showed that precipitation increased maize yield by 42% while temperature enhanced maize yield by 38%. In addition, irrigation improved maize yield by 32%. Similarly, Kato et al (2009) studied the impacts of soil and water conservation on crop production using a Cobb-Douglas function in the low and high rainfall areas of Ethiopia. The results showed a significant contribution of soil and water conservation on household food production. For instance, it was found that soil and water conservation technologies increased production by 4% and 25% between the low and high rainfall area, respectively. Besides, it was reported that grass trip improved production by 32% and 15% between the low and high rainfall areas, respectively. Kato et al., 2009 also found that irrigation increased production by 4% among low rainfall areas while a 25% reduction in food production among highland households. These results suggest that soil and water technologies performed differently in different agro-ecological of Ethiopia. This underscored the importance of geographical targeting when promoting and scaling up soil and water conservation technologies.

Kurukulasuriya and Mendelsohn (2006) used a Structural Ricardian model using data from 11 Sub Sahara Africa countries to study the impacts of climatic change on farm level net revenues. The study results showed that an increase in temperature was associated with losses of US$23 billion for dryland and US$16 billion for all African cropland. Furthermore, an increase in precipitation and irrigation were associated with a gain of $97 billion and $1 billion per year in most African cropland. Furthermore, Mendelssohn and Dinar (2009) employed a ricardian model to assess the impact of adaptation on agricultural production in India and they found that adaptation strategies increased production by 15% to 23%. However, it was revealed that access to credit, extension and information on rainfall and temperature constrained household adaptation to climatic and weather variability.

Similarly, Molua and Mlambi (2008) applied a translog production function to assess the impact of climate change on crop farming activities in Cameroon. Empirical results revealed that a 2.5℃ and 5℃ increase in temperatures reduced farm level net revenues by $0.5 and $1.7 billion, respectively. It was also found that a 7% decrease in precipitation decreased net revenues by $1.96 billion. Net revenues were estimated to have risen by $2.9 billion in mild and wet climate from US$1 billion. The study concluded that precipitation and temperature remained the dominant determinants of cultivatable farming practices in Cameroon. Rowhani et al (2010) studied the impacts of precipitation on household crop yield in Tanzania. The study findings pointed that 20% increase in precipitation reduced agricultural yields by 3.6%, 8.9%, and 28.6% for maize, sorghum and rice, respectively. Benhin (2006) found similar results in South Africa where he assessed the economic impact of climatic change on crop farming. It was depicted that an increase in temperature reduced net revenue by U$2637 and U$880 between irrigated and dryland areas of South Africa, respectively. On the other hand, increase in precipitation improved net revenue of dryland areas by U$22 from US$10.

Most studies have proposed specific studies and technologies to address climatic change impacts and household adaptation in specific locations (Aggarwal et al., 2010; Kato et al., 2008; Deressa, 2006). This study employs a Multivariate Analysis to model factors that influence household choice of adaptation strategies in low and highland areas of Chikhwawa district. Studies conducted in Malawi have mainly assessed the impacts of climatic change on food production and food security (Action Aid, 2006, Goman et al., 2007). According to literature reviewed, no study has been conducted to assess roles of adaptation strategies on food production and food security in Malawi. This study applied the translog production and tobit models to examine the impacts of adaptation strategies on food production and food security in low and highland areas of Chikhwawa, respectively.

3.0 Methodology

3.1 Theoretical and Empirical Frameworks

3.1.1 Household Choice Model of Adaptation Strategies

The study has developed a theoretical framework following a random utility theoretical structure. A random utility model describes a choice decision in which an individual i has a set of alternative adaptation strategies j from which to choose (McFadden, 1978). It is assumed that each adaptation alternative has its attributes which also influence individual's choice over 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_{ij} manifest the underlying utilities.

In other words, preference indicator y_{ij} is observed and determines the utility that farmers derive in various choices they make. The utilities are functions of a set of explanatory variables Z_i, which describe the decision-maker i $(i = 1,2, \ldots, N)$ and the adaptation strategies alternatives $j(j = 1,2,..,J)$ and its attributes q_j. j is a vector that represents adaptation strategies. The study considered the following adaptation strategies (j): irrigation farming (IF); income generating activities (IGAs); shifting planting dates (SPD); crop diversification (CD), agroforestry (A), climatic information (CI) and improved varieties (IV).
It is found that on the ground, farmers choose more than one of these adaptation strategies to averse climatic change challenges and risks. The utility (U_{ij}) that an individual i derives from choosing strategy j, from a choice set (C) of alternatives can be described as:

$$U_{ij} = V_{ij}(Z, q, \varphi, \xi) + \psi_{ij} \qquad [1]$$

In expression 1, q is a vector of attributes of each adaptation strategy j $(j = 1,2,3, \ldots J)$ as chosen by an individual i Z is a vector of household specific characteristics. ψ_{ij} is the error term, φ and ξ are described as a vector of unknown parameters. An individual i jointly chooses adaptation strategy j from a set of alternative adaptation strategies. An adaptation strategy is assumed to be chosen from an overall set of strategies only if the expected utility U_{i2} is greater than the actual utility U_{i1} of all other bundle of adaptation strategies(C).

In most choice models, the random components of the utilities are assumed to be independent and identically distribution (IID) with a type I extreme value distribution and this assumption results in the MNL model. The MNL model has a simple and elegant closed form mathematical structure, making it easy to estimate and interpret. It is also saddled with independence of irrelevant alternatives' (IIA) property at the individual level (Ben-Akira & Leman, 1985). Hence, the multinomial logit imposes the restriction and its IIA assumption cannot capture the interactive choices that farmers make on the ground (Stopher et al., 1981; McFadden, 1980). The IIA assumption is relaxed by removing the IIA assumption on the random components of the utilities. In this study, the IIA assumption is removed by allowing the random component to correlate while maintaining the identically distributed assumption (Daly and Zachary, 1979). The probability density and the cumulative distribution functions of the random component for the j th alternative is illustrated as:

$$F_{ij}(.) = \int_0^{\psi_{ij}=N} f(\psi_{ij})\delta\psi_{ij} = e^{-e^{-\psi_{ij}/\theta_{ij}}} \qquad [2]$$

where $F_{ij}(.)$ is the probability density function. Indeed, households choose an alternative that gives the highest utility over the other alternatives. However, in practice, households choose more than one alternative/strategies. Mathematically, choice probabilities can be presented as follows:

$$P_{ij} = Prob(U_{i2} > U_{i1})$$

$$= \int_{-\infty}^{\psi_{ij}=\infty} \Pi_{j=i,j\in C} \Lambda\left[\frac{(U_{i2} > U_{i1})}{\theta_{i1}}\right]\frac{1}{\theta_{i2}}\lambda\left(\psi_{i2}/\theta_{i2}\right)\delta\psi_{ij} \qquad [3]$$

$\lambda(.)\ and\ \Lambda(.)$ are the probability density and cumulative distribution functions, respectively which are functions of the standard type I extreme value distribution. It can be specified as:

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

The random component has the density function $f(\psi_{in}) = f(\psi_{i1}, \psi_{i2}, \psi_{i3}, .. \psi_{iJ})$. The component has a zero mean and a covariance $Cov(\psi_{ij})$ matrix as portrayed by:

$$Cov(\psi_{ij}) = \begin{bmatrix} \sigma_{11}^2\sigma_{12}^2 \dots \dots \cdots \cdots \sigma_{1n}^2 \\ \sigma_{21}^2\sigma_{22}^2 \dots \cdots \cdots \cdots \sigma_{2n}^2 \\ \vdots \\ \vdots \\ \sigma_{m1}^2\sigma_{m2}^2 \dots \sigma_{mn}^2 \end{bmatrix} \qquad [5]$$

The choice probability of alternative strategy j can also be specified as:

$$P_{ij} = \int_{-\infty}^{\psi_{ij}=+\infty} \Pi_{j\neq i,j\in C} \Lambda\left[\frac{V_{i1} - V_{i2} + \psi_{ij}}{\theta_{ij}}\right]\lambda(w)dw \qquad [6]$$

If the choice probability, given in equation [6], adds up to one over all alternative strategies, then the variance of all adaptation strategies equals 1 and the probability of equation [6] collapse to a multinomial logit model. On the other hand, there are a number of models such as Nested Logit, Random Parametric Logit and Multivariate or Multinomial Probit which assume heteroskedasticity for the random component. However, the main drawback of MNP is that multivariate normal integrals must be evaluated to estimate the unknown parameters. Such models are estimated using a maximum likelihood estimator (McFadden, 1978).

According to Bhat (1995), the generalized models allow the utility of alternatives to differ in the amount of stochasticity and are flexible to allow differential cross elasticities. A small change in utility of an alternative adaptation strategy can be illustrated as:

$$\frac{dP_{iw}}{dV_{i1}} = \int_{-\infty}^{w=+\infty} -\frac{1}{\theta_{iw}} \exp\left[\frac{V_{i1}-V_{i2}+\theta_{iw}}{\theta_{iw}}\right] \Pi_{j\neq i, j\in C} \Lambda\left[\frac{V_{i1}-V_{i2}+\theta_{iw}}{\theta_{iw}}\right] \lambda(w)dw \qquad [7]$$

The cross elasticity for alternative V_{i1} with respect to a change in the ith alternative can be obtained as follows:

$$\eta_{V_{i1}}^{P_{ij}} = \left[\frac{\frac{dP_{ij}}{dV_{i1}}}{dP_{ij}}\right] * \beta * V_{i1}(.) \qquad [8]$$

where β is the vector of unknown parameters. The corresponding own elasticity for alternative j with respect to a change in V_{i2} can also be illustrated as follows:

$$\eta_{V_{i2}}^{P_{ij}} = \left[\frac{\frac{dP_{ij}}{dV_{i2}}}{dP_{ij}}\right] * \beta * V_{i2}(.) \qquad [9]$$

The model in equation [1] is associated with the following log likelihood function:

$$L = \sum_{j=1}^{J=N} \sum_{j\in C} y_{ij} \log\left\{\int\int_{-\infty}^{w=+\infty} -\frac{1}{\theta_{iw}} \exp\left[\frac{V_{i1}-V_{i2}+\theta_{iw}}{\theta_{iw}}\right] \Pi_{j\neq i, j\in C} \Lambda\left[\frac{V_{i1}-V_{i2}+\theta_{iw}}{\theta_{iw}}\right] \lambda(w)dw\right\} \qquad [10]$$

A theoretical framework discussed beforehand derives a choice model empirical framework for this study. Attributes of various adaptation strategies are assumed to have influence over the choice made by farmers. In this study, a multivariate analysis is adopted because it accommodates both correlations and heteroskedasticity that may exist in the model (Train, 2002 and Greene, 2003). A multivariate analysis (i.e. MNP) 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

$$U_{ij} = V_{ij}(.) + \psi_{ij} \qquad [11]$$

According to Greene (2003), the MNP model relaxes the IIA assumption:

$$[Var\psi_{ij}] = \sigma_i = 1.0 \qquad [12]$$

This study adopts a Multinomial Probit model (MNP) and is specified as follows:

$$y_{ij} = \varphi Z_i + \xi q_j + \psi_{ij} \qquad [13]$$

where y_{ij}=1 if individual i chooses adaptation alternative j and $y_{ij} = 0$ if otherwise. It should be known that y_{ij} takes on a multiple adaptation choices that farmers i adapt.

Z_i, q_j and ψ_{ij} are household characteristics, adaptation attributes and error term, respectively. ξ and ϕ are unknown parameters (Greene, 2003). Since we cannot observe attributes of each adaptation strategies as researchers, we specify our MNP equation to take the following form:

$$Prob(y_{ij} = 1/z) = \Phi(\varphi Z) = \varphi Z_i + \psi_{ij} \quad [14]$$

where y_{ij}, Z_i, q_j and ψ_{ij} denote 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 have the following asymptotic distribution:

$$n^{1/2}(\hat{\varphi} - \varphi) \xrightarrow{d} N\left(0, \left(E\left[\frac{\varphi^2(Z'\varphi)}{\Phi(Z'\varphi)(1 - \Phi(Z'\varphi))} ZZ'\right]\right)^{-1}\right) \quad [15]$$

Equation 14 can be cast in a joint log likelihood function as follows:

$$\ln L(\varphi) = \sum\left(y_i \ln \Phi(\varphi Z) + (1 - y_i) \ln\left(1 - \Phi(\varphi Z)\right)\right) \quad [16]$$

3.1.2 Contribution of Adaptation Strategies to Food Crop Production

Food production functions transform resources into output and is illustrated in a more general quantitative description over various technical production possibilities as follows.

$$W_r = f(G, \varsigma) + \gamma_r \quad [17]$$

where W_r is the yield per hectare, G_r is a vector of factor of production (land, labour and seeds), ς is a vector of unknown parameters to be estimated and γ_r is an error term. Production function can be estimated by either parametric stochastic frontier or non parametric methods (Farrell, 1957; Chavas & Cox, 1988). The stochastic approach is subject to prior decisions on the modelling of the underlying technology and is specified by adhering to theory as well as flexibility (Tchale and Sauer, 2006). Parametric analysis incorporates random errors and requires a parametric specification in order to be estimated. Following Aigner et al (1977), food production function takes on a truncated normal distributed error term. Parametric analysis is appropriate and allows for error term which includes factors that affect food production but are outside farmers' control (Bauer, 1990). Food production function model can be re-specified as follow:

$$W_r = f_r(G, \varsigma, D, \Gamma, \varrho) + \gamma_r \quad [18]$$

Where ς, Γ and ϱ denote vectors of unknown parameters to be estimated. D_r is a dummy variable for adaptation strategies to climatic and weather variability. $D_r = 1$ if the household adopt a specific strategy and $D_r = 0$ if otherwise. Strategies such as agroforetry and crop diversification interacted with plot to assess their combined effects on crop production. However, due to lack of agronomic or engineering assessment techniques, the study did not carry out an in-depth specific assessment of plot characteristics other than plot size.

Several studies employ Cobb Douglas, quadratic, square root and translog production functions to estimate the parameters of production factors. The choice of these production functions depends on the researcher, study objectives and others (Bravoureta & Reiger, 1991). In this study, a Ricardian model is chosen to estimate farm level production. The model is developed to explain the variation in land value per hectare. Generally, the impacts of climatic change is reflected by measuring a reduction in net revenue. Since the response is nonlinear, a quadratic functional form has widely been used and it uses both linear and a quadratic term for all climatic variables introduced (Aigner et al., 1977, Tchale & Saure, 2006). It also assumes that the expected impact of variables on farm net revenue is evaluated at the mean and is specified as follows:

$$W_r = \varrho + \varsigma G_r + \varsigma G_r^2 + \Gamma D_r + \gamma_r \quad [19]$$

where ς, Γ and ϱ are vectors of unknown parameters and other variables are as explained above. The quadratic function form has nevertheless received several criticisms over yield response plateauxity (Bravoureta & Reiger, 1991). In this study, a normalized translog form of the quadratic function is applied. A normalized translog model is widely used for describing the crop response to factors of production (Tchale and Saure, 2006).

Following Tchale and Sauer (2006), the choice of the translog production function is based on its flexibility and convenience. The following analysis uses a primal production function other than the dual profit function as the latter is conditioned on prices. However, a robust translog production function is used to give efficient and consistent estimates without endogeneity being a major problem. We specify our translog production function as follows:

$$lnW_r = \varrho + \varsigma lnG_r + \varsigma lnG_r D_r + \Gamma D_r + \gamma_r \quad [20]$$

From equation [20], all variables are normalized to the sample mean by dividing by the mean value. The marginal product of input r is obtained by multiplying the logarithmic marginal product with the average product of input r. Thus the monotonicity holds if equation (21) is true for all inputs.

$$\frac{dw}{dG_r} = \frac{wdlnw}{G_r\, dlnG_r} = \frac{w}{G_r}[\varrho + \varrho lnG_r] > 0 \quad [21]$$

By further adhering to the law of diminishing marginal productivities, marginal products should be decreasing in inputs.
This implies the fulfillment of the following equation:

$$\frac{d^2w}{dG_r{}^2} = f_r = \left(\frac{w}{G_r{}^2}\right)[(\varrho + \varrho lnG_r)(\varrho - 1 + \varrho lnG_r)] < 0; f_r = f_1, f_2, ..f_N \quad [22]$$

Quasi-concavity conditions are related to the fact that this property implies a convex input requirement set. With respect to the translog production function curvature depends on the specific input bundle G_r. The condition of negative semi-definiteness of the bordered Hessian (BH) is met only locally (Tchale et al., 2004). The respective BH is negative semi-definite if the determinants of its entire principal are alternate in sign. A corresponding BH for the M x N input case is presented as follows:

$$BH = \begin{bmatrix} 0 & \varsigma_1 & \varsigma_2 & \varsigma_3 \cdots\cdots\cdots \varsigma_n \\ \varsigma_1 & f_{11} & f_{12} & f_{13} \cdots\cdots\cdots f_{1n} \\ \varsigma_2 & f_{21} & f_{22} & f_{23} \ldots\ldots\ldots f_{2n} \\ \varsigma_3 & f_{31} & f_{32} & f_{33} \cdots\cdots\cdots f_{3n} \\ & & & \vdots \\ \varsigma_m & f_{m1} & f_{m2} & f_{m3} \cdots\cdots\cdots f_{mn} \end{bmatrix} \quad [23]$$

A household maximizes net revenue on food production by moving towards diversified cropping. As such, a farmer will choose different or the same factor levels for a particular production. W_r takes on net revenues from crops such as maize, millet and sorghum in the same year. A Normalized Translog Production Function is presented as follows:

$$lnpW_r = \varrho + \varsigma lnG_r + \varsigma lnG_r D_r + \Gamma D_r + \gamma_r \quad [24]$$

Where p is the price of each of the crops per kilogram, W_r is the yield per acre while ϱ, ς and Γ denote unknown parameters to be estimated. Since prices did not vary significantly, total crop yield were used as a dependent variable to determine the effect of climatic variables on food production. In this study, the translog production function was run on yield per acre of maize garden. This was due to that more than 90% of the respondents grew maize as main food crop (National Statistical Office, 2008).

3.1.3 Contribution of Adaptation Strategies on Household Food Security

Food security is a situation where all household members have adequate food throughout the year. In Malawi, households are considered food secure if each household member has at least 270 kg food per year (GoM, 2008). The study makes a number of assumptions. Firstly, it assumes that 275 kg per year person of the food crop produced is a threshold. Any household that has more or equal to 275 kg per person per year is food secure and not otherwise. This threshold assumption allows us to adopt a censored data-modelling criterion. A Tobit model which illustrates the relationship between non negative variable Q_l and independent variables H_l. In this study, Q_l and H_l denote quantity of available food and vector of household characteristics, respectively. This model assumes that there is a latent dependent variable. Practically, a household food security is not only achieved through own production but also through economic or market based food accessibility. Food security can be further defined as total food availability at household level. Total food availability at household is however affected by a number of household specific and other non-observable characteristics. Household characteristics range from economic to environmental. Mathematically, latent model is simplified as follows:

$$Q_l = f_l(H, M) + \kappa_l \quad [25]$$

Where Q_l is total food availability at household level (*l*) and is equal to zero if the household has total food available of less than 275 kg per person per year. Q_l equals the actual total food available amount if the household has food of more than or equal to 275 kg per person per year. M_l denotes a vector of adaptation strategies, respectively. $M_l = 1$ if the household adapt to changes in climate and $M_l = 0$ if otherwise. κ_l is a vector of non observable characteristics. Since equation [25] censors some data, we call it a Tobit model.

A Tobit Model has the characteristics of assessing the contribution of adaptation strategies towards food security. Let $\gtrsim 275$ kg/year/person be denoted by T.

Q_l is a censored dependent variable that is presented as follows:

$$\mathrm{E}[Q_l/H] = \Phi(\Delta)T + (1 - \Phi(\Delta))(\Delta H + \sigma\lambda(\varrho)) \quad [26]$$

where $\varrho = \frac{(\mathrm{T}-\Delta\mathrm{H})}{\sigma}, \lambda(\varrho) = \frac{\phi(\Delta\mathrm{H})}{(1-\Phi(\Delta\mathrm{H}))}$. $\Phi(.)$ and $\phi(.)$ are standard normal distribution and density functions, respectively (Greene, 2003). $\lambda(\varrho) = \frac{\phi(\Delta\mathrm{H})}{(1-\Phi(\Delta\mathrm{H}))}$ is called an inverse mills ratio. A mill ratio indicates how one unit change in exogenous variables alters the latent dependent variable. Marginal effects of a Tobit model are represented as follows:

$$\frac{dE[Q_l^{*}/H]}{dH} = \Delta\Phi((\Delta\mathrm{H} - \mathrm{T})/\sigma) = \Delta\left\{1 - \lambda(\varrho)\left[\frac{\Delta H}{\sigma}\right] + \lambda(\Delta\varrho)\right\} = \Delta \quad [27]$$

where T is a censoring point that has a numeraire of 275kg/person/year. For censored data, the marginal effects are as follows:

$$\frac{\mathrm{dE}(\mathrm{Q}_l)}{\mathrm{dH}} = \Phi\left(\frac{[\Delta H/\sigma]}{\Delta}\right) \quad [28]$$

Furthermore, we derive the log likelihood expression for the censored regression model as:

$$lnL = -\frac{1}{2}\sum\nolimits_{\gtrsim 275kg}(\ln(2\pi)) + \ln(\sigma^2) + \left((Q_l - \Delta H)^2\left({}^{1}/{}_{\sigma^2}\right)\right) + \sum\nolimits_{<275kg} ln\left(1 - \Phi\left(\frac{\Delta H}{\sigma}\right)\right) \quad [29]$$

Where $\sum(.)$ is a sum over the non censored and censored observations. From the theory above, we derive and illustrate our empirical model as follows:

$$Q_l = \mu H_l + \zeta M_l + \kappa_l \quad [30]$$

where μ and ζ are vectors of unknown parameters. Our censored Tobit model considers two categories. Firstly, there is information on both independent variables and dependent variable.

Secondly, it has limited information on dependent variable and is specified as follows:

$$Q_l(.) = \begin{cases} 0, & Q_l^* = Q_l = \mu H_l + \zeta M_l + \kappa_l < T \\ actual\ number, & Q_l^* = Q_l = \mu H_l + \zeta M_l + \kappa_l \gtrsim T \end{cases} \quad [31]$$

Where Q_l^* is equal to zero [0] if food available at the house is less that 275kg/person/year (T). On the other hand, Q_l^* is equal to the actual food quantity if food is at least 275 kg/person/year. Expression 31 can also be expressed as follows:

$$\mathrm{P(censored)} = \mathrm{P}(Q_l^* < T) = \Phi\left(\frac{\mathrm{T}-\Delta\mathrm{H}}{\sigma}\right) = 1 - \Phi\left(\frac{\mathrm{T}-\Delta\mathrm{H}}{\sigma}\right) \quad [32]$$

$$\mathrm{P(uncensored)} = 1 - \Phi\left(\frac{\Delta\mathrm{H}-\mathrm{T}}{\sigma}\right) = \Phi\left(\frac{\Delta\mathrm{H}-\mathrm{T}}{\sigma}\right) \quad [33]$$

Focus group discussions and key informants were conducted to deepen the understanding of the household questions from a community perspective. These focus group discussions were composed of 8 male and 7 female headed households while key informants were prominent local leaders and agricultural extension officers.

3.2 Study Area and Sample Size

Data used in this analysis was collected from a household survey conducted in Chikhwawa district. The district has been chosen because it is heavily prone to floods and droughts (Action Aid, 2006). Several organizations promote various adaptation strategies at household level in Chikhwawa (Action Aid, 2006). According to Aggarwa *et al.*, 2010, single size fit for all strategy does not apply to generalized the impact of climatic adaptation in Chikhwawa districts. In other words, Chikhwawa district is a unique district that demands its own study that would assess the effect of climatic adaptation on crop production as well as household food security.

Chikhwawa has a total farming household population of 90,000 of which 93% are farmers (NSO, 2008). A sample size was calculated using the formula $\left[n = \frac{z^2(1-p)p}{e^2}\right]$ (Edriss, 2003). In the sample size formula, n is the sample size, p is the prevalence rate, z is the critical value and e is the error term. According to NSO (2008), 93% [p= prevalence rate] of the population in Chikhwawa district depend on rain-fed agriculture. One hundred (100) households have been derived from a sample size formula. Nevertheless, the study has accounted for a design effect of 2.5 due to the multistage sampling implicit errors and 14% has also been considered for non-responses. The sample size has been inflated from 100 to 283 households. One hundred and ninety four (194) and 88 of low and highland areas, respectively, have been sampled from 26 villages from 6 Traditional Authorities of Chikhwawa district. Lowland households include part of TA Mgabu and Lundu while highland households are sampled from Kasisi, Mlilima, Katunga and Sub TA Maseye.

3.3 Sampling Design, Instruments and Data Needs

A Multi-Stage Sampling Method was used to randomly select 283 households from the sample frame list. Sample frame list was collected from Chikhwawa District Agricultural Office. Firstly, Chikhwawa district was stratified into low and highland households due to differences in topographical vulnerabilities. Secondly, six Traditional Authorities were sampled out. Thirdly, the study selected 26 villages from which it randomly sampled out 283 households. Lastly, a probability proportional sampling method was applied for a representative sample size. From 283 households, the study collected data using a household questionnaire and focus group discussions. Primary data included household characteristics, food production, food availability as well as climatic and weather variability. STATA, SPSS and Excel were used for different analyses in this study. The study defined variables considered to estimate the econometric modelling of this study as follows (Table 1):

Table 1: Definition of Variables used in this study

Variables	Measurements	Variables	Measurements
Gender	1=Female; 0=Male	Drought	1= Yes; 0=No
Education	Years	Floods	1= Yes; 0=No
Labour	Man-day	IGA-income	Malawi Kwacha
Land size	Acres	Irrigation farming	1= Yes; 0=No
Income	Malawi Kwacha	Planting dates	1= Yes; 0=No
Age	Years	Improved varieties	Kg/Acre
Extension	Number of visits	Local seeds	Kg/Acre
Rainfall	1=Increased; 0=Reduced	Crop diversification	1= Yes; 0=No
Temperature	1=Increased; 0=Reduced	Agroforestry	1= Yes; 0=No
Pest outbreak	1=Affected; 0=not affected	Climatic information	1= Yes; 0=No
Fertilizer	Kg/Acre	Yield	Kg/Acre

4.0 Results and Discussion

4.1 Descriptive Statistics

4.1.1 Households Characteristics

Household characteristics such as education, age, income and gender of the household head influence the level of understanding and application of any agricultural technology (Edris, 2003). Table 2 shows that females head about 41 % and 47 % of the households in both low and highland areas of Chikhwawa district, respectively. Conversely, Table 2 shows that males head 59% and 53% of the lowland and highland households. The mean age of household head in low and highland areas is 39 and 35, respectively. Accordingly, NSO (2008) found that household heads in Malawi are in the economically active group of 25 to 49 years. Table 2 show no substantial difference between low and highland household head level of education. Most household heads in the study area have reached primary school. Furthermore, Table 2 shows that 58% and 63% of the lowland and highland households have reached primary level. Besides, on average, a household in low and highland areas of Chikhwawa district has five members.

Table 2: Household Characteristics between Low and Highland Households

	Lowland			Highland			Pooled		
Variable	%	Std dev	Std error	%	Std dev	Std error	%	Std dev	Std error
HH_Head_Age	39.29	13.88	0.99	34.66	13.45	1.426	37.83	13.89	0.82
Gender_Female	41%	0.49	0.03	47%	0.50	0.053	43%	0.49	0.02
Male	59%	0.49	0.03	53%	0.50	0.053	57%	0.49	0.02
HH_Size	5.90	2.64	0.19	5.27	2.31	0.245	5.70	2.55	0.15
Labour	3.07	1.66	0.12	3.13	1.71	0.182	3.09	1.67	0.10
HHD_Education	3.78	3.62	0.26	4.65	3.60	0.382	4.05	3.63	0.22
NO_Education	28%	0.45	0.03	22%	0.42	0.044	27%	0.44	0.03
Primary Education	58%	0.49	0.03	63%	0.48	0.051	60%	0.49	0.03
Secondary_Education	12%	0.33	0.02	13%	0.34	0.036	13%	0.33	0.02
Tertiary Education	1%	0.10	0.01	1%	0.10	0.011	1%	0.10	0.01
Total Land (Acre)	1.70	0.95	0.07	1.42	0.92	0.098	1.61	0.95	0.057
Annual Income (MK)	46202	12054	3750	45468	14595	6684	45971	12886	3314

The study average household size is in line with NSO (2008) report that average household members in Chikhwawa are five. In addition, the results revealed that low and highland areas have, on average, 1.7 acres and 1.4 acres of land, respectively. The mean value of household annual income for lowland households is MK 46,202 (US $ 308) and for highland households is MK45, 466 (US$ 303).

4.1.2 Adaptation Strategies

The study found that almost all households adopted at least one of the adaptation strategies to improve food production and meet their food security needs. Focus group discussions reported that households adopted a number of strategies to adapt to climatic and weather variability. In addition, most strategies have been into practice over decades ago. Focus group discussions highlighted that the use of these strategies have been intensified in the recent decades due to prolonged droughts and floods' occurrences that have been exasperated by variability in climate and weather. Households adopted strategies such as irrigation farming, crop diversification, income generation activities, shifting planting dates and improved varieties.

Seventy two percent of the lowland household and 66% highland households grow improved varieties, respectively (Table 3). It was reported that households adopted improved varieties such as DK5083, locally known as *kanyani* (for maize) and *kapire* (for millets) that contain the effects of climatic and weather variability. It was further reported that such improved varieties had advantages over local varieties because some of them have the capacity to produce high yield in spite of droughts and floods.

Table 3: Households and Adaptation Strategies

	Lowland			Highland			Pooled			
Variables	%	Std dev	Std error	%	Std dev	Std error	%	Std dev	Std error	t-test
Irrigation	84%	0.43	0.03	47%	0.50	0.05	72%	0.46	0.03	6.79*
IGAs	9%	0.34	0.00	69%	0.09	0.29	28%	0.10	0.33	-13*
CC_Information	82%	0.44	0.03	62%	0.51	0.05	76%	0.47	0.03	3.87*
Improved Variety	69%	0.46	0.03	79%	0.41	0.04	72%	0.45	0.03	1.002
Crop_ Diversificatn	32%	0.46	0.03	9%	0.29	0.03	25%	0.43	0.03	4.26*
Planting Dates	32%	0.46	0.03	15%	0.36	0.04	26%	0.43	0.03	3.10*
Agroforestry	87%	0.47	0.03	6%	0.45	0.05	61%	0.50	0.03	20.3*

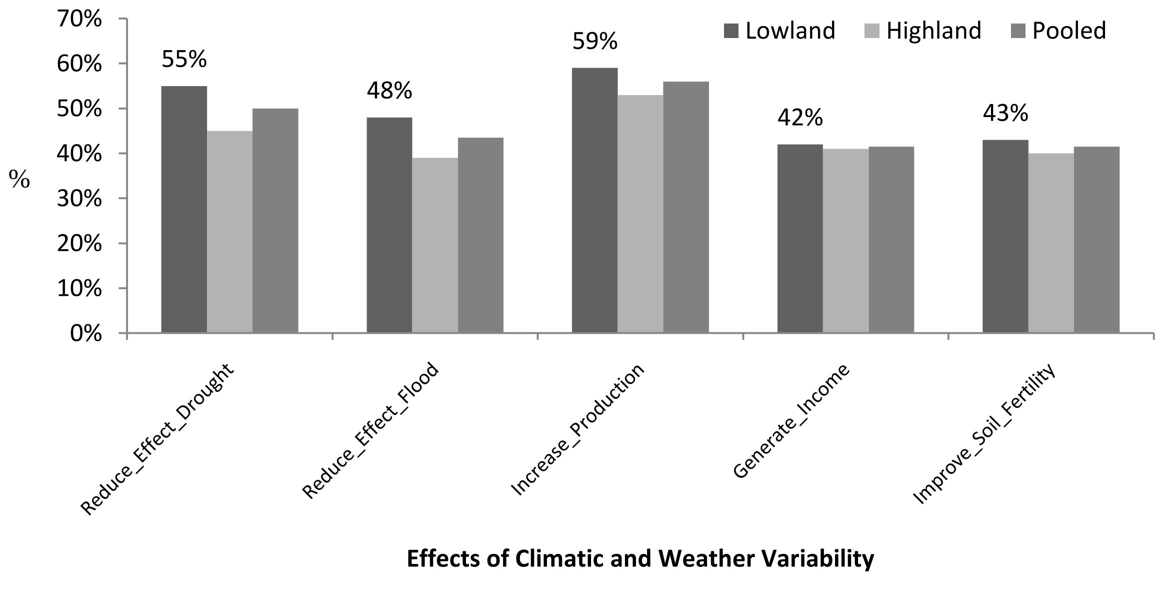
*,significant at 1%

Thirty two percent of the households in lowland and 9% of the highland household diversified their crops. Focus group discussions reported that households diversify their crops in order to spread the risks and challenges presented by climatic and weather viability. In addition, households grow other crops such as sorghum and millet other than maize to avoid the risk of food shortages during the lean.

Similarly, thirty two percent of the lowland and 15% of highland households shifted crop-planting dates due to erratic rainfall and unfavourable temperatures. Focus group discussions reported that crops were grown late encountered abrupt stoppage of rainfall and high temperature. This resulted into lack of adequate water for proper crop growth and maturity. Furthermore, a substantial ($p < 0.05$) disparity over irrigation farming is depicted between lowland and highland household. The study results depict that 84% of the lowland households practise irrigate farming whereas only 47% of the highland households irrigate their crops. Focus group discussions reported that low irrigation farming among highland households is due to lack of reliable water sources. Income generating activities is statistically different between low and highland areas ($p < 0.05$). Sixty-nine percent of the highland and 9% of the lowland households engaged in income generation activities as a source of income to purchase food during food shortages (see Table 3).

Fifty-four percent of the lowland and 45% of the highland households adapted to reduce the effects of droughts. On the other hand, 48% of the lowland and 39% of the highland households adapt to reduce the effects of floods. Moreover, 59% lowland and 53% highland households have adapted (i.e. growing of improved varieties, e.t.c.) to climatic and weather variability to increase food production (see Figure 1).

Figure 1: Reasons for Adapting towards Climatic and Weather Variability



4.1.3 Food Production and Household Food Security

The study found that 554 kg per capita food is available among lowland households. Similarly, 472 kg per capita food is available among highland households. An FGD reported that both own production and market access facilitate per capita food availability. Equally, Ellis (1992) indicated that food security depends on food production and accessibility. Data show that on average lowland areas produce about 318 kg/acre. In addition, two hundred and twenty two 222 kg/acre is produced by households in highlands. The study found no significant difference between food purchased by both low and highland areas.

Besides, a number of meals taken per day also measures food security. In Malawi, six (6) food groups consumed by households are indicated as a measure of food security nutritionally (GoM, 2001). Table 4 shows that 81% of the lowland households while 66% of highland households consume at least two (2) meals per day. A studentized t test shows a difference between meals eaten by low and highland areas (see Table 4).

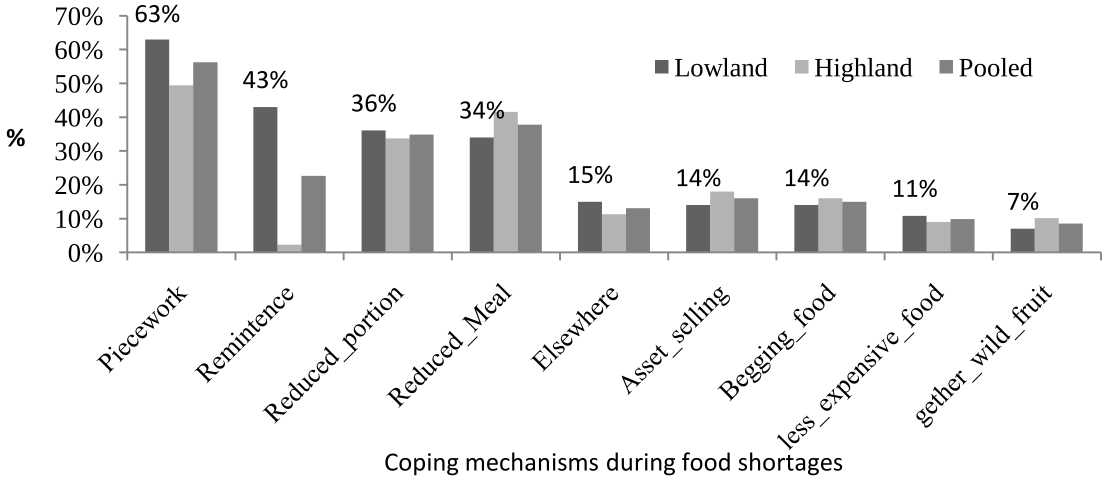
Table 4: Food Security (at least two meals per day)

	%	Std dev	Std error	t-test
Lowland Households	81%	0.49	0.04	3.76*
Highland Household	66%	0.50	0.05	
Pooled Sample	76%	0.50	0.03	

*: Significant at 1%

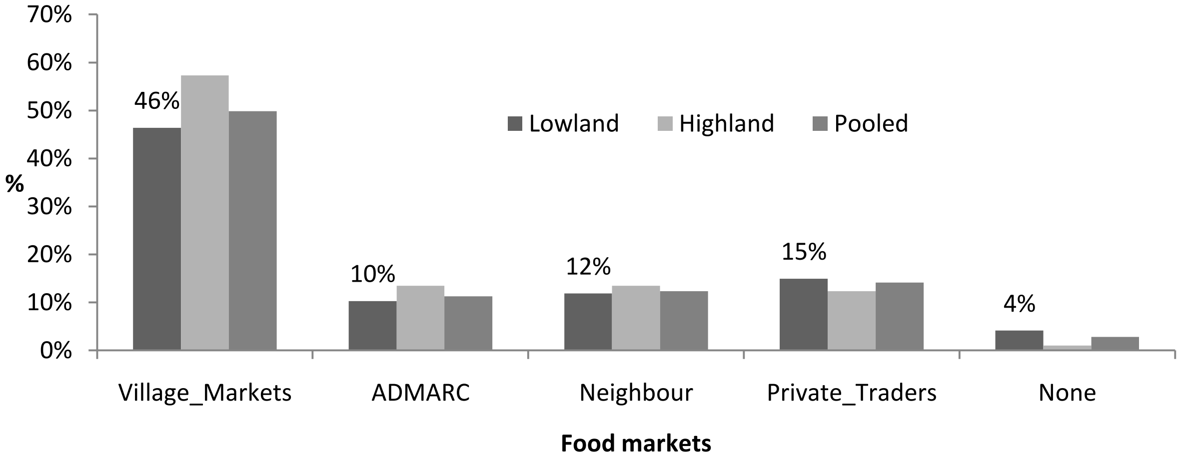
Figure 2 shows that 63% of the lowland and 49% of the highland household indulged in piecework during food shortages. Households used money earned from piecework to buy food at the local markets during food deficit periods. Four three percent of the lowland and 2% of the highland households benefited from free food. Food group discussions reported that World Food Programme and Evangelical Lutheran Development Services distribute food in times of food crisis. On the other hand, during food shortages, households access food through village markets. It was reported through focus group discussions that income from income generating activities was used to buy food at the market during food shortages times.

Figure 2: Coping mechanisms during food shortages



Fifty-nine percent of the highland and 53% of the lowland households buy food from local village markets. Fourteen percent (14%) of the lowland and 13% of the highland households purchased food from ADMARC (see Figure 3).

Figure 3: Food markets during food shortages



Discussions with farmers indicated that food is not usually purchased from ADMARC because it is locally accessed from village markets. Less than 5% of the households in the study did not access food markets during food shortages period. Interestingly, almost half of the households in low and highland areas purchased food from village markets (see Figure 3). Focus group discussions reported that food was easily accessed households because it was locally found and sold.

4.1.5 Farm Inputs and Sources of Seed Varieties

Food crop production depends on the input of production that households have employed in their gardens. In this study, farm inputs that are applied in crop farm and discussed below (see Table 5). On average, households applied nine kilograms and four kilograms per acre of improved and local seeds, respectively. Table 5 shows that households in lowland applied ten kilograms of improved varieties while highland households applied nine kilograms of improved varieties. Households in the study areas applied three bags of chemical fertilizer. In lowland, households applied three bags of chemical or inorganic fertilizer in their gardens while highland households applied just one bag of fertilizer in their field. Household applied four bags of organic manure. Discussions indicated that most households intensified use of organic fertilizer because of the increasing in prices of chemical fertilizer at the market. In addition, organic manure improved soil fertility over a longer period.

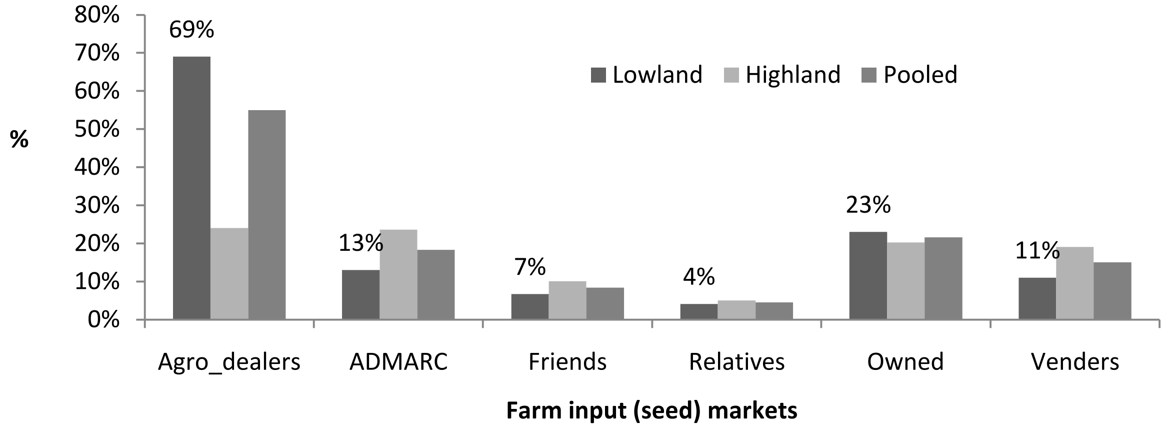
Table 5: Household farm inputs

	Lowland			Highland			Pooled			
	#	Std dev	Std error	#	Std dev	Std error	#	Std dev	Std error	t-test
Local_Variety (kg)	3.8	0.46	0.03	3.7	0.49	0.05	3.7	0.47	0.03	1.290
Hybrid_Variety (kg)	9.5	0.48	0.03	8.8	0.42	0.04	9.1	0.46	0.03	1.023
Chem_Fert (50 kg bags)	3.2	0.47	0.03	1.2	0.33	0.04	2.6	0.44	0.03	4.04*
Org_manure(50 kg bag)	6.6	0.47	0.03	0.7	0.25	0.03	4.0	0.50	0.03	4.06*

*, significant at 1%; #=number

A studentized t test depicts a substantial difference between lowland and highland household seed accessibility ($p < 0.05$). For example, 69% of the lowland and 22% of the highland households access new seeds from agro-dealers. Twenty-five percent highland households access seed from Agricultural Development Marketing and Cooperation (ADMARC) while only 13% lowland households have access to improved seed varieties from ADMARC. On average, 23% of the households in the study area planted seeds from own but previous harvest. In lowland, 24% of the households planted own maize seeds while in the highland, 20% of the households planted own seeds from previous harvest (see Figure 4).

Figure 4: Sources of farm (seeds) inputs



4.1.6 Climatic and weather variability effects and challenges

In order to assess the effect of climatic and weather variability, the study posed the following questions: a) what are the effects that are faced by households and b) what makes households adopt more than one adaptation strategies. Seventy seven percent (77%) of low and 84% highland households have their crops destroyed by floods and droughts (see Table 6).

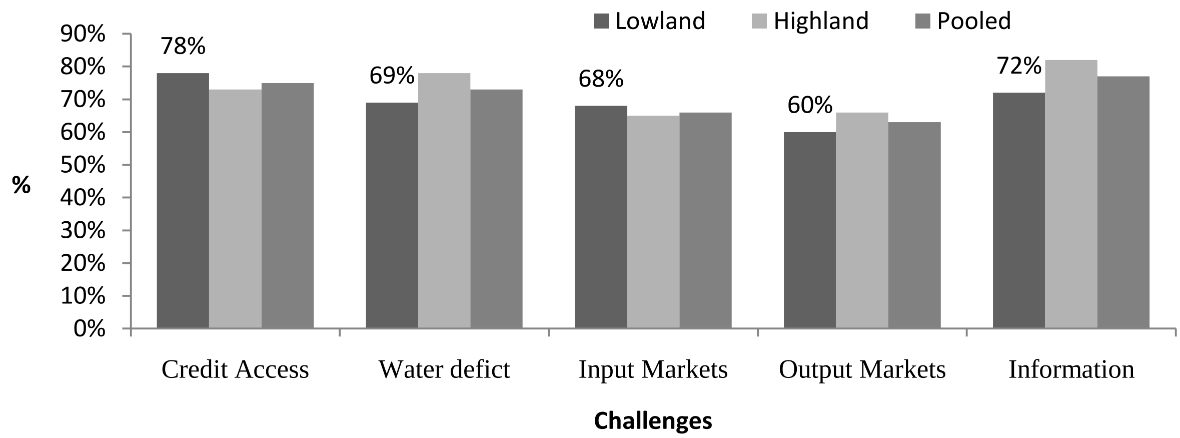
Table 6: Effects Encountered by households

	Lowland			Highland			Pooled			
Variables	%	Std dev	Std error	%	Std dev	Std error	%	Std dev	Std error	t-test
Crop_destruction	77%	0.42	0.03	84%	0.37	0.04	79%	0.41	0.02	-1.44
Crop_Failure	75%	0.43	0.03	85%	0.36	0.04	78%	0.41	0.02	-1.31
Reduced_Production	84%	0.37	0.03	74%	0.44	0.05	81%	0.40	0.02	1.49
Livestock_Death	67%	0.47	0.03	69%	0.47	0.05	67%	0.47	0.03	-0.25
Water_Deficit	66%	0.48	0.03	71%	0.46	0.05	67%	0.47	0.03	-0.79
Soil_Erosion	64%	0.48	0.03	63%	0.49	0.05	64%	0.48	0.03	0.25

Besides, 75% of low and 85% highland households experience reduction in production due to floods and droughts. Nevertheless, a studentized t tests show no substantial disparities between low and highland households over the effects of climatic change. The study shows that 78% of lowland and 73% of the highland households have no access to credit. Moreover, the results show that 68% of the lowland and 65% of the highland households have no access to input markets (see

Table 6). On the same note, no significant difference existed between challenges faced in the study area. Focus group discussions pointed that challenges became major barriers to climatic change adaptation (see Figure 5). It was hence suggested a need of external intervention that would empower households on how to overcome such challenges in adapting to climatic and weather variability.

Figure 5: Challenges to adapt to climatic and weather variability



4.1.8 Credit and Basic Facilities' Accessibility

Table 7 shows infrastructures and facilities accessed by lowland and highland households in the study area. In brief, these facilities included drinking water points, primary schools, tar mark road, village market and saving groups. The study illustrates that only 6% of the lowland and highland households have borrowed money/cash from localized lending institutions. On the other hand, it is shown that only 2% and 9% of the lowland and highland households lent cash to fellow farmers.

Table 7: Infrastructures and Facilities Accessed by the household

	Lowland			Highland			Pooled			
	%	Std dev	Std error	%	Std dev	Std error	%	Std dev	Std error	t-test
Drinking_Water	63%	0.47	0.03	69%	0.47	0.05	0.65	0.48	0.03	-0.9
Primary School	63%	0.47	0.03	69%	0.47	0.05	0.65	0.48	0.03	-0.9
Tarmark Road	62%	0.48	0.04	57%	0.50	0.05	0.59	0.49	0.03	0.81
Village_Market	57%	0.50	0.03	51%	0.50	0.05	0.61	0.49	0.03	0.92
Saving_group	55%	0.50	0.04	51%	0.50	0.05	0.54	0.50	0.03	0.02

The results show that households have access to drinking water points, elementary schools, tarmac road and village markets. It is shown that 63% of the lowland and 69% of the highland households have access to drinking water points. Alternatively, 57% percent of the lowland and 51% of the highland households have access to village markets. Focus group discussions reported that households that are close to basic infrastructures are likely to adapt towards climatic change. Focus group discussions reported that local markets helped both areas to access food economically. This is due to that households easily access farm inputs for farming activities and food during food shortage period. Besides, roads provide networks for transporting agricultural produce and IGAs products.

4.2 Empirical Estimations

4.2.1 Factors that Influence Household Choices of Adaptation Strategies

The study examines factors that influence household choice of various adaptation strategies at household level. Socioeconomic characteristics, climatic variables and extreme events are modelled to assess whether they have influence on household choices of adaptation strategies. The study assessed factors that influence choice of adaptation strategies in low and highland areas by employing a conditioned multinomial probit analysis. It considered adaptation strategies such as irrigation farming (IF), improved varieties (IV), income generating activities (IGA), shifting planting dates (SPD) and crop diversification (CD) as depended variables. Application of information on climatic and weather variability is a base outcome of the study multinomial probit analysis.

Before running the econometric models, the study carried a number of tests[3] to assess the presence of heteroskedasticity and multicollinearity. Through Breusch Pagan, White and Cameron and Triverd Decomposition tests, the study found varying variances (heteroskedasticities) over various dependent variables. The presence of heteroskedasticity is remedied by a multivariate analysis (i.e multinomial probit model) (Greene, 2003). On the other hand, the study found no multicollinearity among independent variables included in the models. Results from a Multinomial Probit are as discussed below and presented in Table 8. Log likelihood χ^2 showed that the multinomial probit model had strong goodness of fit on assessing household choice of adaptation strategies in low and highland areas of Chikhwawa.

The study found that household characteristics such as education and age have significant influence on low and highland household choice of growing improved varieties (see Table 8). Statistically, education increased the prospect of growing improved varieties by 89% in lowland area. Age (i.e. experience) of the of the household head increased the likelihood of growing improved varieties by 61% in lowland area while reduced the chances of growing improved varieties by 6% in highland areas. Discussions with farmers indicated that the more the number of years a household head adds, the more the level of experience on a kind of crop variety to grow. Household heads in the highland have noticed that local varieties do quite well in both circumstances of climatic and weather variability. Gender of household heads had a positive influence on household choices over growing improved varieties. In this, study women were found to have a positive response towards growing improved varieties in both low and highland households.

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[3] A Breusch-Pagan (BP), White and Cameron & Triverd Decomposition (CTD) tests are used to assess the presence of heteroskedasticity at 1% significant level. White's (χ^2 =185.74), BP (χ^2 =109.49) and CTD tests have confirmed that the data was heteroskedastic at $p < 0.01$. The study has remedied the problem of heteroskedasticity through a log transformation of variable within the model (Greene, 2003). Raw income values have been replaced by their predicted values. Besides, the study has also adopted a multivariate (Probit) analysis to overcome heteroskedasticity in the household choice modelling. Secondly, the study has also performed a multicollinearity test. A Variance Inflation Factor (VIF) ($6.19_{VIFcalculated} < 10.00_{VIFcritical}$)), Conditional Number Test (CNT) ($28.89_{calculated\ CNT} < 30_{Critical\ CNT}$) have been employed to test for multicollinearity. VIF and CNT have indicated that there is no substantial multicollinearity among variables in the model at $p < 0.05$. Pair wise analysis was done to determine correlation between number of plots and crop diversification and agroforestry and no significant correlation was found.

Droughts augmented the prospect of growing improved varieties by 26% and 2% in low and highland areas. Floods had a positive effect on influencing household choices to grow improved varieties. For instance, the probit results show that floods enhanced chances of growing improved varieties by 25% and 12% among low and highland households. Furthermore, it is depicted that pest outbreak substantially enhanced the chance of planting improved varieties by 50% and 16% among low and highland households, respectively.

A number of household characteristics at 5% significant level influence crop diversification. Statistically, age (i.e experience) of the household head increased household choice of diversifying their crops by 2% and 4% in low and highland areas. Education of the household head enhances the prospect of diversifying crops by 54% and 83% in low and highland households. Besides, the study found that rainfall improved household likelihood of diversifying maize to other crops by 2% and 5% in low and highland areas. Drought also increased household probability of diversifying crops by 83% and 59% in low and highland households. However, floods reduced the chance of diversifying ones crops by more than 50% in lowland while increased the prospect by 75% in the highland areas.

Household choice of shifting crop planting dates is influenced by factors such as age, education, income, rainfall, droughts and floods at 5% significant level. Education of household head had a positive influence on household choice over shifting planting dates. For example, the results show that education improved the probability of changing plating dates by 73% and 99% in low and highland areas. Gender of the household head significantly enhanced the prospect of shifting crop-planting dates by 79% and 38% in low and highland areas. In other words, women are likely to shift plating of crops when weather varies.

Rainfall increased the likelihood of shifting planting dates by 73% in high areas while reduced the same likelihood by 42% in lowland areas. Droughts positively influenced household choices by 37% in lowland areas. On the other hand, floods negatively influenced household choice over shifting planting dates by 79% in the lowland areas. In other words, household were more likely to shift their planting dates when there were droughts than when there were floods. According to focus group discussions, this was due to lowland households grew other crops such as rice that favoured water.

Table 8: Multinomial Probit Model Estimates

Improved Varieties

	Lowland dy/dx	Lowland Std. E.	Highland dy/dx	Highland Std. E.	Pooled dy/dx	Pooled Std. E.
Education (Yrs)	0.898*	0.363	0.749	0.766	0.22	0.264
Land (acre)	-0.092	0.254	-0.493	0.64	-0.1	0.188
Labour(manday)	0.011	0.147	-0.138	0.292	-0.1	0.104
Gender	0.534	0.512	0.521	0.962	0.405	0.341
Income (MK)	-0.216	0.214	0.886**	0.485	0.003	0.145
Age (Experience)	0.01*	0.002	-0.023*	0.004	0.014*	0.002
Extension	-0.974	0.755	0.723	0.011	-0.348	0.419
Rainfall	-0.386	0.709	0.791*	0.335	-0.531	0.561
Temperature	-0.197	0.569	-0.175	0.16	0.269	0.381
Pest	0.499*	0.162	0.984*	0.847	0.686**	0.4
Drought	0.263**	0.168	0.229*	0.252	0.102	0.491
Floods	0.246	0.562	0.120*	0.938	0.104	0.47

Shifting Crop-Planting Dates

	Lowland dy/dx	Lowland Std. E.	Highland dy/dx	Highland Std. E.	Pooled dy/dx	Pooled Std. E.
Education (Yrs)	0.725*	0.323	0.992	0.862	-0.291	0.26
Land (acre)	0.072	0.227	-0.462	0.689	-0.035	0.18
Labour(manday)	-0.103	0.15	0.037	0.324	-0.17*	0.111
Gender	0.789**	0.489	0.375	0.035	0.492	0.342
Income (MK)	0.232	0.203	-0.001	0.527	0.26**	0.148
Age (Experience)	0.012*	0.002	-0.030*	0.005	0.016*	0.002
Extension	-0.449	0.735	0.013	0.061	-0.249	0.422
Rainfall	-0.42*	0.689	0.73*	0.713	-0.724	0.564
Temperature	0.204	0.537	-0.436*	0.24	0.065	0.38
Pest	-0.168	0.6	0.49*	0.901	0.16	0.506
Drought	0.374**	0.779	-0.208	0.665	0.04**	0.588
Floods	-0.79**	0.53	0.530*	0.539	-0.05	0.479

Income Generating Activities

	Lowland dy/dx	Lowland Std. E.	Highland dy/dx	Highland Std. E.	Pooled dy/dx	Pooled Std. E.
Education (Yrs)	0.876*	0.344	0.191	0.762	0.489**	0.268
Land (acre)	0.17	0.234	-0.486	0.655	-0.007	0.182
Labour(manday)	0.093	0.149	0.399	0.307	0.244*	0.107
Gender	0.271*	0.489	0.178	0.975	0.588**	0.338
Income (MK)	0.094	0.197	0.910**	0.492	0.034	0.144
Age (Experience)	0.030*	0.003	-0.04*	0.006	0.032*	0.003
Extension	0.432**	0.724	0.977	0.03	-0.413	0.42
Rainfall	-0.46	0.662	0.085*	0.308	-0.713	0.543
Temperature	0.008**	0.561	0.825**	0.165	0.298	0.384
Pest	0.384	0.591	0.013*	0.897	0.334	0.496
Drought	0.656*	0.161	0.685	0.603	0.29	0.47
Floods	0.433	0.551	0.728*	0.47	0.552	0.456

Crop Diversification

	Lowland dy/dx	Lowland Std. E.	Highland dy/dx	Highland Std. E.	Pooled dy/dx	Pooled Std. E.
Education (Yrs)	0.539**	0.354	0.828	0.729	-0.147	0.265
Land (acre)	-0.139	0.257	-0.151	0.628	-0.086	0.187
Labour(manday)	-0.061	0.152	-0.271	0.288	-0.154	0.109
Gender	0.716	0.518	0.059	0.979	0.507	0.351
Income (MK)	-0.003	0.216	-0.647	0.492	0.106	0.153
Age (Experience)	0.012	0.002	0.035	0.005	0.016	0.002
Extension	-0.914	0.757	0.075	0.002	-0.162	0.437
Rainfall	0.054*	0.756	0.194*	0.577	0.708*	0.654
Temperature	0.174	0.157	-0.457	0.169	-0.248	0.389
Pest	0.362	0.603	0.942	0.869	0.347	0.506
Drought	0.830*	0.16	0.589*	0.586	0.37	0.525
Floods	-0.527	0.676	0.749*	0.539	-0.744	0.592

Irrigation Farming

	Lowland dy/dx	Lowland Std. E.	Highland dy/dx	Highland Std. E.	Pooled dy/dx	Pooled Std. E.
Education (Yrs)	0.339	0.313	0.996	0.773	0.003	0.251
Land (acre)	0.427**	0.239	0.682	0.674	0.369*	0.189
Labour(manday)	0.185**	0.103	0.759*	0.383	0.261*	0.104
Gender	0.809**	0.468	0.691	0.006	0.46	0.329
Income (MK)	-0.012	0.192	-0.881	0.502	0.028	0.141
Age (Experience)	0.016	0.002	0.002	0.004	0.012	0.002
Extension	-0.876	0.70*	0.047	0.059	-0.283	0.406
Rainfall	0.018**	0.634	0.927*	0.411	-0.586	0.537
Temperature	0.221	0.517	-0.543	0.197	0.076	0.37
Pest	0.468	0.549	0.082*	0.233	0.502	0.482
Drought	0.562*	0.16	-0.987	0.655	0.123	0.472
Floods	-0.178	0.521	0.652*	0.279	0.264	0.45

Multinomial Probit Statistics

	lowland	Highland	Pooled
LR	-279.8	-108.9	-442.9
Chi-square	90.72*	12.63*	83.54*

Base outcome: Climatic and weather variability information

*,** and *** shows significance at 1%, 5% and 10%, respectively.

In this study, it is revealed that labour, age and rainfall have significant influence on household choice of irrigation farming at 5% significant level (see Table 8). Labour increased the prospect of engaging in irrigation farming by 19% and 76% in low and highland areas, respectively. Age of the household head enhanced the likelihood of engaging in irrigation farming by 30% and 4% in low and highland areas, respectively. Age allowed household heads accumulate more experience over weather behaviour. In this study, household experience positively influenced choices over irrigation because it supplemented water for crop growth and development during drought times in both low and highland areas.

Rainfall had a positive influence on adoption of irrigation in the study area. It augmented the probability of irrigating crops by 2% and 93% in low and highland areas, respectively. Drought increased the chances of irrigating crop fields by 56% in lowland areas. Nonetheless, droughts negatively influenced household probability of irrigating crops by 99% in the highland areas. According to focus group discussions in the highland areas, this was due to lack of water to irrigate crops during drought times. However, households in the highland irrigated their crops during floods times by 65% due to presence of water.

Income generation activities adopted in the study area include *kanyenya, mandasi and kachasu.* The study found that household choice of income generating activities is influenced by factors such as age, rainfall and temperature. Age of the household head positively influenced choices of income generating activities. In this study, the more the number of years of household head, the more likely the household is to engage in income generating activities by 35% and 18% in low and highland areas. Education had a positive influence on household engagement in income generating activities. It enhanced the prospect of engaging in income generating activities by 88% and 19% in both low and highland households. According to focus group discussion, a household head is education is more likely to engage in income generating activities because it economically helped households in accessing food at the market during food shortage period.

Temperature increased the likelihood of income generating activities by 1% in lowland areas and reduced the likelihood of doing income-generating activities by 80% in highland areas. Rainfall reduced the prospect of engaging in off farm income-generating activities by 46% in lowland areas while increased the prospect of indulging in income-generating activities by 8% in highland areas. Both droughts and floods showed positive influence on household choices of engaging in income generating activities. Focus group discussions reported that households engaged in income generating activities to earn income that was used to acquire food when the on harvest food finishes. In addition, it was reported off farm activities provided income that was used to purchase inputs such as fertilizer.

4.2.2 Contribution of Adaptation Strategies at Households Food Production

The study further assessed contribution of adaptation strategies household food crop production using a Translog production function. Table 9 shows results on a normalized translog production analysis. It is shown that the Log likelihood tests are significant and depict strong goodness of fit on household food production. Area of crop field significantly influences food production. Table 9 shows that crop fields that are in the highland areas are likely to reduce food production by 24%. The study results show that characteristics such as labour, income and land had significant contribution on food crop production.

Irrigation farming, income-generating activities, improved varieties, agroforestry and shifting planting dates influenced household food production in both low and highland areas. Results indicate that irrigation farming improved food production in both directions. For instance, a household that irrigated crops increased food production by 8% in lowland areas and reduced food production by 6% in highland areas. According to focus group discussions, it was reported that households easily engage in irrigation farming because of water availability.

It is shown that improved varieties positively enhanced household food production by 20% and 24% in low and highland areas, respectively. Improved varieties that are adopted in the study areas are locally known as kanyani and kapire. On the other hand, households grew local varieties. Through focus group discussions, it was reported households grew local varieties because they survive during harsh climatic and weather effects. Shifting plating dates reduced food production by 24% and 38% in low and highland areas. Focus group discussions reported that shifting crop-planting dates shrunk food production because of water shortages for crop development, growth and maturity. It was further pointed that abrupt discontinuity of rainfall affects the growth of crops, as crops need enough amount of water for them to grow and mature.

Furthermore, results in Table 9 show that agroforestry significantly boosts household food production by 2% and 49% among lowland and highland households. Focus group discussions reported that households adopt agro forestry practices to improve soil fertility and retain soil moisture during unfavourable temperatures. Considering the whole sample size, agroforestry has a negative effect on food production. Focus group discussions reported that agroforestry did not automatically increase production in the first years. It was suggested that there is a need of incorporating inorganic fertilizers in the field especially during initial years of adopting agroforestry practices. Accordingly, Ajayi et al.(2008) pointed out that agroforestry technologies require two to three years time lag for them to contribute significantly. The study also found that crop diversification substantially improved household production by 25 % in lowland areas. Discussions with farming households indicated that diversified crops allow households harvest some food crop yield despite bad weather.

Table 9: Translog Production Function Results

	Lowland		Highland		Pooled sample	
	Coef	Std Err	Coef	Std Err	Coef	Std Err
Local seeds	0.146*	0.049	0.025	0.050	0.064**	0.037
Hybrid seeds (kg)	0.678	0.717	0.14*	0.018	0.621*	0.059
Fertilizer	0.498	0.183	0.393	0.040	0.984	0.175
Labour	0.469*	0.003	0.297	0.314	0.551**	0.260
Land	0.019*	0.000	0.799	1.148	0.071**	0.038
IGA-Income	0.633*	0.000	0.278*	0.113	0.581*	0.022
Irrigation farming	0.076*	0.004	0.061	0.237	0.804*	0.157
Planting dates	-0.242*	0.001	-0.37**	0.284	-0.50**	0.206
Improved varieties	0.195**	0.026	0.240**	0.066	0.126	0.200
Crop diversification	0.247*	0.002	-0.439	0.469	0.223**	0.130
Agroforestry	0.019*	0.001	0.486*	0.232	-0.54**	0.219
Climatic Information	0.169**	0.096	0.184*	0.089	0.386*	0.0659
CD_plot	0.134*	0.003	0.040	0.070	0.128*	0.003
Agroforestry_plot	0.038*	0.005	0.088*	0.028	0.006*	0.002
A1(IV-SPD)[4]	-0.449	0.262	-0.625	0.662	0.189	0.280
A2 (IV-IF)[5]	0.547**	0.262	0.063	0.335	0.146	0.239
A3 (IF-IGA)[6]	-0.276	0.262	-0.136	0.664	0.335*	0.105
A4 (CI-IV-IGA)[7]	0.266*	0.003	0.549*	0.252	-0.214	0.234
A 5(IV-IGA-IF)[8]	-0.238	0.262	0.610	0.688	-0.137	0.238
A6 (IV-IGA-CD)[9]	0.046	0.262	0.446*	0.043	0.551**	0.260
Area(Highland=1)					-0.24**	0.106
LR	139.16		-55.89		217.22	
Chi-Sq	496*		496*		118*	

Dependent variable: Crop yield (kg/acre)
*;** significant at 1% and 5%

The study shows that income-generating activities substantially improve food production. A household that engage in income generating activities increased food production by 63% and 28% in low and highland areas, respectively. Focus group discussions reported that households venture into IGAs to earn income that is used to buy improved varieties and pay hired labour for the next growing period. Consequently, households counterbalanced the effects droughts and floods through earnings from off farm income generating activities.

From Table 9, study results showed that irrigation of improved varieties (combination of improved varieties with irrigation farming) improved household food production. A household that grew improved varieties increased food production by 55% and 6% in low and highland areas, respectively. Focus group discussions pointed out that households are risk averse and combine a number of strategies in order to counteract the effects of climatic and weather variability. Furthermore, a mixture of IGAs with climatic information and improved varieties augmented household food production by 27% and 55% in low and highland areas, respectively. On the other hand, a combination of irrigation farming with income generating activities reduced household food production by 28% and 14% in low and highland areas, respectively due to competition over labour. Discussions with farmers revealed that farm inputs (i.e. labour) was divided between the irrigation and income generating activities.

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[4] Improved Varieties(IV) * Shifting Planting Dates (SPD)
[5] Improved Varieties * Irrigation Farming (IF)
[6] Irrigation Farming* Income Generating Activities (IGA)
[7] Climatic Information (CI) * Improved Varieties * Income Generating Activities
[8] Improved Varieties * Irrigation Farming * Income Generating Activities
[9] Improved Varieties * Income Generating Activities * Crop Diversification (CD)

4.2.3 Contributions of Adaptation Strategies on Household Food Security

The study analyzed the contribution of adaptation strategies on household food security and/or availability. A Normalized Tobit Model evaluated contributions of adaptation strategies on household food security. Table 10 presents results of a Normalized Tobit Model.

Table 10: Normalized Tobit Regression Estimates

	Lowland		Highland		Pooled Sample	
	dy/dx	Std. E.	dy/dx	Std. E.	dy/dx	Std. E.
Gender of HHD	0.136	0.356	0.042	0.551	0.139	0.306
Education of HHD	0.227	0.214	0.159	0.376	0.149	0.172
Labour	0.008	0.118	0.035	0.173	-0.051	0.100
Land holding size	0.078*	0.020	0.042**	0.027	0.057	0.168
IGA-income	0.239*	0.033	0.198*	0.028	0.237*	0.023
Irrigation farming	0.242*	0.090	0.185*	0.082	0.209*	0.070
Planting date	-0.206*	0.102	-0.104	0.084	-0.089	0.078
Improved varieties	0.235*	0.187	0.047	0.084	0.095	0.080
Crop diversification	0.264*	0.083	0.052	0.059	0.138*	0.066
Agroforestry	-0.479*	0.185	-0.151*	0.073	-0.246*	0.082
Climatic information	0.267*	0.103	0.179**	0.111	0.373*	0.074
CD_Plot	0.194*	0.006	0.006*	0.007	0.187*	0.005
Agroforestry_Plot	0.010	0.012	0.007	0.004	0.004	0.005
A1(IV-SPD)	-0.213	0.110	-0.123	0.105	-0.159	0.079
A2 (IV-IF)	0.204*	0.137	0.007	0.119	-0.171*	0.087
A3 (IR-IGA)	-0.209	0.213	-0.408**	0.255	0.185**	0.101
A4 (CI-IV-IGA)	0.487*	0.195	0.033	0.124	0.125	0.110
A5 (IV-IGA-IF)	-0.716*	0.220	-0.158*	0.028	0.290*	0.098
Area(Highland=1)					-0.331*	0.108*
LR	-1213.23		-570.06		-1803.93	
Chi-sq	27.45*		17.78*		-30.21*	

Dependent variable: Food availability (kg/person/year)
*;** siginificant at 1% and 5%.

Table 10 shows that land has significant influence on household food security. It is portrayed that there is a strong goodness of fit to capture the food security scenario at household level as indicated by the Chi-square. Area of crop field affected household food security by 33%. Land increased food availability/year/ person by 9% and 4% in low and highland areas. The study found that factors such as education and gender did not have substantial effect on household food security in both areas at any significant level. In this study, irrigation farming, crop diversification (CD) and income generating activities significantly influence household food security in both areas. Irrigation farming improved food availability by 24% and 19% in low and highland areas, respectively. Focus group discussions explained that households that engaged in irrigation farming had more produce, which translated into more food available to the household members.

Crop Diversification enhanced food availability by 26% and 5% in low and highland areas, respectively. According to focus group discussions, it was reported that crop diversification increased a number of food products of the households. Households that diversify their crops have advantage to harvest some food even when one crop failed to do better. In other words, when all crops do better, the household had an added advantage over the combine contribution of diversified production on food security. Similarly, income-generating activities positively boosted food availability. Households that engaged in off farm income generating activities increased food availability by 24% and 20% in low and highland areas, respectively. Focus group discussions pointed out that households supplemented own production with food purchased from the market. It was further elaborated that income from IGAs helped economically access food from the local markets.

On the other hand, shifting crop-planting dates reduced household food availability. Households that shifted their crop planting dates reduced food security by 21% and 10.4% in low and highland areas, respectively. Focus group discussions reported that reduced food availability at household level was because of reduced amount of food harvested from late-planted gardens because crops do not have the required amount of rainwater. Besides, agroforestry practices reduced household food security. Households that practised agroforestry technologies reduced food availability by 58% in the study areas. This is contrary to a study by Ajayi et al (2008) that found that agroforestry improved food availability by more than 2 times. However, Ajayi et al (2008) emphasized for an appropriate agroforestry environment for farmers to derive benefits from agroforestry. Focus group discussion cited that from experience agroforestry did not automatically translate into high food availability due to time lag involved. In other words, focus group discussions suggested for inorganic fertilizer incorporation in agroforestry practised farming activities.

On the ground, it is reported through focus group discussions that households simultaneously adopt alternative adaptation strategies to cushion themselves from food insecurity exasperated by climatic change. From Table 8, the study findings depicted that combination of irrigation farming with improved varieties increased food availability by 20% and 7% in low and highland areas, respectively. On the other hand, mixture of income generating activities with irrigation farming and improved varieties reduced food availability by 72% and 16% in low and highland areas, respectively. Focus group discussions reported that combination of some adaptation strategies resulted into reduced food availability because of resource diversion (labour, income) between the strategies.

5.0 Conclusion and Policy Implications

This study has analysed factors that influence household choice of adaptation strategies and examined the contributions of various adaptation strategies on food crop production and household food security in Chikhwawa district. The study employed a multinomial probit, normalized translog production and tobit functions on data of households from low and highland areas of Chikhwawa district.

5.1 Household Choice of Adaptation Strategies

The study found that households adopt a various adaptation strategies in order to cushion from the negative effects of climatic/weather variability and extreme events such as drought and floods. The study found that factors such as gender, education and age of the household head, rainfall and temperature, pest outbreak, floods as well as drought occurrence significantly affected household choice of adaptation strategies. Policy and decision makers would find these findings very important in making decision towards adaptation to changes in climate. The study results imply that climatic and weather variability projects should mainstream factors that affect household choice of adaptation strategies.

5.2 Household Food Production

Based on results from the translog production function, the study concludes that adaptation strategies such as crop diversification, irrigation farming, income generating activities and others have very significant contribution on household food production. For instance, growing of improved varieties increases household production by 20% and 24% in low and highland areas, respectively. Furthermore, combination of improved varieties and irrigation farming improved food production by 55% and 6% in low and highland areas, respectively. On the other hand, households that shift planting dates experience a reduction in food production by 24% and 37% among both low and highland areas, respectively. Besides, the study found that a mixture of irrigation farming and income-generating activities reduces household food production by 14% in the study area. Policy/decision makers should therefore consider adaptation strategies that would improve household food production. Otherwise, some adaptation strategies, when not carefully accounted, may result into reduced household food production. This implies that decision makers should simultaneously promote adaptation strategies that do not reduce food production.

5.3 Household Food Security and/or Availability

Empirical results from a normalized and censored tobit model establish that irrigation enhances food availability by 24% and 19% in low and highland areas, respectively. However, combination of irrigation farming with income generation activities shrunk food availability by 21% and 41% in low and highland areas, respectively. In addition, shifting planting dates reduces household food availability by 21% and 10% in both low and highland areas, respectively. The study therefore concludes that decisions on household food availability have to account for the different but substantial contributions that adaptation strategies play at household level. In other words, decision makers should take advantage of the positive contribution that adaptation strategies have at enhancing household food availability.

5.4 Policy Implications on Crop Production and Household Food Security

A number of factors influence household choice of adaptation strategies. Such factors include gender, education, land, labour, droughts, floods and others. Household adaptation is also constrained or limited by factors such as availability of information on droughts and floods, credit accessibility, water harvesting technologies as well as input/output markets. This therefore calls for policy/decision makers to consider integrating such factors in climatic adaptation interventions at household level. Furthermore, this study found a substantial contribution of household adaptation strategies on food production and food availability in both low and highland areas. Project implementers/decision makers should therefore understand, address and mainstream household choice of strategies in traditional farming systems for successful implementation of climatic adaptation interventions. There is also a need of promoting crop varieties that would significantly mature and produce optimally within short period i.e. when farmers grow their crops late. In addition, this study suggests that further research should be conducted to assess the profitability/feasibility of household adaptation strategies. This would help policy and decision makers as well as project promoters to introduce adaptation strategies that are economically feasible at household level.

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