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DECISION MAKING IMPLICATIONS OF NATURAL DISASTERS' ADAPTATION ON SMALLHOLDER CROP PRODUCTION IN MALAWI: USING A NORMALIZED TRANSLOG PRODUCTION FUNCTION

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ABSTRACT

This study selectively assessed the contribution of decision making over natural disasters adaptation on smallholder food crop production in Malawi. Data for this study was collected from randomly selected households from low and highland areas in Malawi using a semi-structured questionnaire. Data revealed that more than 60 % of households make household level policy decisions in engaging in irrigation farming, crop diversification and grow improved varieties to reduce the effects of natural disasters in Malawi. Based on empirical results, normalized Translog production reveals that irrigation farming increased food production by 8% and 6% in low and highland areas, respectively. On the other hand, shifting crop-planting dates reduced food production by 24% and 37% in low and highland areas, respectively. This study concluded that adaptation strategies have significant contribution on food production in both areas. However, decision makers at both household and project levels should understand and mainstream barriers related natural disasters' adaptation into farming systems to capture maximum contributions of overall climatic adaptation. Sustainable farming systems could only be assured if decision-making accounts for barriers that hinder effective choices and implementation of natural disasters adaptation. In other words, current farming systems may only save the needs of future generation when adaptation actions mainstream barriers faced by smallholder farming communities in Malawi.

Keywords: Normalized Translog production function, natural disasters adaptation and decision

INTRODUCTION

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 (IMF, 2011). Presently, food productivity does not meet the food demand due to, in part, high family size and deteriorating soil productivity that has been exasperated by natural disasters (Action Aid, 2006). Unpredictable precipitation has also induced soil erosion that lead to loss of soil fertility. This has made the farming system unsustainable in Malawi (Pangapanga et al, 2012), however, there is an urgent call for adaptation actions that would enhance sustainable farming production systems among smallholder farming communities. In order to maintain and improve the worsening food security situation, Malawi 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. In the other words, agriculture has a crucial role to play in sustainable development for Malawi. 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. Natural disasters have worsened food production and food security scenarios in Malawi due to its exclusive dependence on precipitation. On the other hand, irrigated agriculture was estimated at less than 1% of the country's total cultivated land (GoM, 2004; GoM, 2008). Thus, natural disaters' related adaptation strategies are important for boosting food production (Action Aid, 2006; Tchale et al., 2004). Natural disasters have been major causes of the country's fluctuating food 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.

At national level, the impacts of natural disasters on food production and what strategies households are using to adapt is widely recognized (Pangapanga and Thangalimodzi, 2012). However, little is known about what is the impact of these strategies on household food production and food security (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 natural disasters' projects. In other words, current farming systems may only save the needs of future generation when adaptation actions mainstream barriers faced by smallholder farming communities in Malawi. This study therefore highlights strategies that have greater economic impacts on household food production. It further asks researchable question of assessing reasons why farmers adapt at least one strategy in containing the effects of droughts and floods.

PREVIOUS STUDIES

A number of studies have been conducted in Sub Sahara Africa on natural disasters (droughts and floods), adaptation and food production. However, most studies have concentrated on the impacts of natural disasters on food production and less on the impacts of adaptation strategies (Aggarwal et al., 2010; Akpalu et al., 2008; Hassan and Nhemachena, 2008). Action Aid (2006) assessed farmers' adaptation towards natural disasters in Southern part of Malawi. It was found that most households in Malawi do not have sufficient capacity to cope with challenges posed by droughts and floods. 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 natural disasters were associated with loses of 1.7% in Gross Domestic Product. It was recommended that adaptation strategies have 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 natural disasters 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.

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.

Most studies have proposed specific studies and technologies to address natural disasters impacts and household adaptation in specific locations (Aggarwal et al., 2010; Kato et al., 2008; Deressa, 2006). Studies conducted in Malawi have mainly assessed the impacts of natural disasters 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 employs a translog production and tobit models to examine the impacts of adaptation strategies on food production and food security in low and highland of Chikhwawa, respectively.

METHODOLOGY

Theoretical and Empirical Frameworks

Contribution of Adaptation Strategies to Food Crop Production

Food production depends on a number of resources that can be transformed into output. It is illustrated in a more general quantitative description over various technical production possibilities as equation 1, 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 $\gamma_i$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). 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:

$$W_r = f_r(G, \varsigma, D, \Gamma, \varrho\ ) + \gamma_r \qquad [1]$$

Where ς, Γ and ϱ denote vectors of unknown parameters to be estimated. D_r is a dummy variable for adaptation strategies to droughts and floods.$D_r = 1$ if the household adopt a specific strategy and $D_r = 0$ if otherwise. Several production functions such as Cobb Douglas, Quadratic, Square Root and Translog have been used to estimate the parameters of factors of production. 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 droughts and floodsis 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:

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

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:

$$lnW_r = \varrho + \varsigma lnG_r + \varsigma lnG_r D_r + \Gamma D_r + \gamma_r \qquad [3]$$

From equation [3], 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.

$$\frac{dw}{dG_r} = \frac{wdlnw}{G_r dlnG_r} = \frac{w}{G_r}[\varrho + \varrho lnG_r] > 0 \qquad [4]$$

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:

$$\frac{d^2w}{dG_r{}^2} = f_r = \left(\frac{w}{G_r{}^2}\right)[(\varrho + \varrho lnG_r)(\varrho - 1 + \varrho lnG_r)] < 0; f_r = f_1, f_2, .. f_N \qquad [5]$$

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 semidefinite if the determinants of its entire principal are alternate in sign. A household maximizes net revenue on food production by moving towards diversified cropping. 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:

$$lnpW_r = \varrho + \varsigma lnG_r + \varsigma lnG_r D_r + \Gamma D_r + \gamma_r \quad [6]$$

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.

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

Household questionnaire was supported by participatory rural appraisals. Participatory rural appraisals were in the form of focus group discussions and key informants interview. Interviews included questions such as: what are the roles of adaptation on household food security and food production? Has the adoption of various strategies towards natural disasters been intensified? and what has changed in food production and food security compared to five years ago? The focus group discussions were composed of 8 male and 7 female household heads. Briefly, the study took place in the southern Malawi and map for the study area is shown below (figure 1):

Figure 1. Map of Chikwawa: the study area

RESULTS AND DISCUSSION

Descriptive Statistics

Households socioeconomic characteristics

Household characteristics such as education, 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 1 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.

Table 2: Household Characteristics between Low and Highland Households

Variable		**Lowlands**		**Highlands**		**Pooled Sample**		
		Mean	Std. E.	Mean	Std. E.	Mean	Std.E.	**t-test**
Gender	Female	41	0.035	47	0.053	43	0.029	*1.019*
	Male	59	0.035	53	0.053	57	0.029	
Household head Age		39.29	0.997	34.66	1.426	37.837	0.826	*1.315*
Family Size		5.902	0.190	5.269	0.245	5.703	0.152	*0.971*
Labour (People>15yrs)		3.073	0.120	3.136	0.182	3.0928	0.100	*-0.294*
HHD Education		3.784	0.260	4.652	0.382	4.057	0.216	*-1.483*
Educ. Levels	None (%)	28.35		22.47		26.50		
	Primary (%)	58.25		62.92		59.72		
	Secondary	12.37		13.48		12.72		
	Tertiary (%)	01.03		01.12		01.06		
Total Land (acres)		1.703	0.069	1.429	0.098	1.617	0.057	*1.122*
Annual Income (MK)		46202	3750	45468	6684	45971	3314	*0.103*

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. The study average household size is in line with NSO (2008) report that average household members in Chikhwawa are five. Additionally, the results revealed that low and highland areas have, on average, 1.7 acres (0.69 ha) and 1.4 acres (0.57 ha) of land, respectively. The mean value of household annual income for lowland households is MK 46,202 (US $ 308) and highland households have MK45, 466 (US$ 303). Nonetheless, the study found no difference between low and highland household annual income at any level of significance.

EMPIRICAL ESTIMATIONS

Contribution of Adaptation Strategies at Households Food Production

The study further assesses contribution of adaptation strategies household food crop production using a Translog production. The Study results based on Translog production function estimates are presented and discussed. Table 3 shows that the Log likelihood χ^2 tests are significant and depict strong goodness of fit on household food production.

Area of crop field significantly influences food production. Table 3 shows that crop fields that are in the highland areas are likely to reduce food production by 24%. The study results show that household characteristics such as labour, income and land had significant contribution on household food 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 by 8% in lowland areas and reduced food production by 6% in highland areas. A focus group discussion reported that lowland households easily engage in irrigation farming because of water availability in Shire River. Households in the lowlands have access to irrigation because most of their farms are located in the wetlands. While households in the highlands have lands located in the uplands. Its only those households that have gardens near a river which ably irrigate their crops. From Table 3 , it is shown that improved varieties enhanced household food production by 20% and 24% in low and highland areas, respectively. Shifting plating dates reduced food production by 24% and 38% in low and highland areas, respectively. Focus group discussions reported that shifting crop-planting dates shrunk food production because of water shortages for crop development, growth and maturity. Accordingly, Molua and Mlambi (2008) and EAD (2006) pointed that abrupt discontinuity of rainfall affects the growth of crops.

Table 3: Normalised 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
Fertilizer		0.4987	0.1834	0.3929	0.0404	0.9842	0.1751
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(IF)		0.076*	0.004	0.061	0.237	0.804*	0.157
Planting dates (SPD)		-0.242*	0.001	-0.37**	0.284	-0.50**	0.206
Improved varieties (IV)		0.195**	0.026	0.240**	0.066	0.126	0.200
Crop diversification(CD)		0.247*	0.002	-0.439	0.469	0.223**	0.130
Agroforestry(AG)		0.019*	0.001	0.486*	0.232	-0.54**	0.219
Climatic Information(CI)		0.169**	0.096	0.184*	0.089	0.386*	0.0659
Crop Diversification_Plot		134.3*	32.468	40.302	70.305	127.6*	29.388
Agroforesty_Plot		38.179	45.852	87.694	28.472	61.924	24.350
A1(IV-SPD)		-0.449	0.262	-0.625	0.662	0.189	0.280
A2 (IV-IF)		0.547**	0.262	0.063	0.335	0.146	0.239
A3 (IF-IGA)		-0.276	0.262	-0.136	0.664	0.335*	0.105
A4 (CI-IV-IGA)		0.266*	0.003	0.549*	0.252	-0.214	0.234
A 5(IV-IGA-IF)		-0.238	0.262	0.610	0.688	-0.137	0.238
A6 (IV-IGA-CD)		0.046	0.262	0.446*	0.043	0.551**	0.260
Area(Highland=1)						-0.24**	0.106
Statistics	LR	139.16		-55.89		217.22	
	χ^2	496*		496*		118*	

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

Furthermore, results in Table 3 show that agroforestry significantly boosts household food production by 54% in the study area. Focus group discussions reported that households adopt agro forestry practices to improve soil fertility and retain soil moisture during unfavourable temperatures. Besides, Agroforestry reduces soil erosion through controlling of excessive run off (Ajayi et al., 2008). The study also found that crop diversification substantially improved household production by 25 % in lowland areas. Off farm Income Generating Activities counterbalance the effects of natural disasters (EAD, 2006). The study findings show that income-generating activities substantially improve on 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. Households are risk averse and combine a number of strategies in order to counteract the effects of natural disasters (Nhemachena, 2009). From Table 3 , study results showed that irrigation of improved varieties (combination of improved varieties with irrigation farming) increased household food production by 55% and 6% in low and highland areas, respectively. 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. Climatic information provide a decision background for smallholder farmers to adopt actions that are sustainable not only in the short run but also future generations (Pangapanga et al, 2012). 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.

CONCLUSION AND POLICY IMPLICATIONS

This study has examined the contributions of natural related adaptation on household food production in Malawi. Based on results from the Translog production function, the study concludes that adaptation strategies such as crop diversification, irrigation farming and income generating activities have positive and 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. The study therefore concludes that decisions on household food production have to mainstream contributions that natural disasters' adaptation play at household level. Sustainable farming systems could only be assured if decision-making accounts for barriers that hinder effective choices and implementation of natural disasters adaptation. In other words, current farming systems may only save the needs of future generation when adaptation actions mainstream barriers faced by smallholder farming communities in Malawi.

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