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ADOPTION OF SOIL MANAGEMENT TECHNOLOGIES BY SMALLHOLDER FARMERS IN CENTRAL AND SOUTHERN MALAWI

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ABSTRACT

Due to growing concerns about the severity of land degradation in Malawi, the government has launched campaigns on soil and water conservation. This study determines a range of soil management technologies adopted by farmers and the incidence and determinants of adoption. The results indicated that the range of technologies adopted by individual households was low. However, the incidence of technology adoption was moderately high. Positive and significant determinants of technology adoption were the sex of the household head, being widowed, and extra hours needed to apply a given technology. Residing at the husband's village was significant, but negatively, affecting adoption. The results suggest that to further increase the incidence of technology adoption, the government's intensive campaigns on soil and water conservation should continue. Additionally, land resources management policies should emphasize on increasing land tenure security, especially in the patrilineal system. We also suggest transparent harmonization and joint implementation of agricultural and population policies.

Keywords: Land Degradation; Adoption of Technologies; Incidence and Determinants of Adoption

INTRODUCTION

Like most countries in the sub-Saharan Africa, Malawi's rapid population growth of 2.8% per annum (National Statistical Office, 2009) has been associated with a decline in farm size, degradation of the agricultural environment, and other strains on the natural resource base. In the last decade, the population of Malawi increased from 9.9 million in 1998 to 13.1 million in 2008. During the same period, the population density rose from 105 people per km^2 in 1998 to 139 people per km^2 in 2008. Correspondingly, the household size grew from 4.4 to 4.6 persons per household (National Statistical Office, 2009). Owing to population growth, the average landholding size per household registered a decline from 0.7 ha in 1987 to 0.6 ha by 1998, with the Southern region districts registering as low as 0.3 ha (Malawi Government, 1998; National Statistical Office, 2000). Reduced farmland impacts negatively on the socioeconomic status of smallholder farmers and poses serious challenges on the sustainable management of land resources and attainment of household food security (Maonga & Maharjan, 2003).

Land degradation caused by soil erosion and other processes, such as leaching and salinity, is a serious environmental threat to a sustainable agricultural production that has drawn a lot of attention from the international community. It is a serious problem in Malawi. Some of its indicators are soil erosion and declining soil fertility (Bishop, 1992; Mulenga, 2001). Severe erosion of soil has many ecological effects, including the loss of the soil nutrient capital (Freedman, 1995). Stoorvogel and Smaling (1990) estimated total nutrient loss at 30kgN and 20kgP per hectare of arable land each year in continuous cultivation and fragmentation of land. On average, Malawi has been losing 20 tons/ha/year of soil due to erosion and a corresponding yield loss of between 4% and 11.3% (Malawi Government, 1998). Increased land degradation threatens future food production potential (Shiferaw & Holden, 2000). Land degradation leads to deterioration of soil quality, reduction in land, and soil productivity thereby endangering sustainability of agriculture, environmental stability and quality, and producing adverse impacts on economic and social development. Without taking appropriate soil management measures, yields will persistently decline, which will affect the food security status of the entire country as well as export earnings from agricultural products, such as tobacco, tea, and coffee, which constitutes a large share of Malawi's agricultural export revenue.

In order to stop further land degradation and ensure increased food security for the smallholder households, the Government of Malawi intensified campaigns on soil and water conservation programs throughout the country in the mid-1990s. Spelt out in the land resources conservation policy, the government emphasized community participation to enhance continuity and cost-effectiveness of soil management programs.

Following the campaigns, farmers have adopted a range of soil management technologies, including planting vetiver grass (*Vetiveria zizanioides/Vetiveria nigritana*) and/or elephant grass, constructing contour bunds, contour and box ridges, making ridges, terraces, and adding manure into the soil. These technologies were chosen in the soil management program for their attributes. Vetiver grass is planted on contour lines or contour marker ridges to form a thin but dense hedge line. This controls runoff and improves moisture retention mainly through accurately marking the contour to guide crop ridges; it also slows down and disperses concentrated flows of runoff water (Malawi Government, 1995). Vetiver grass is one practical and probably powerful solution to soil erosion for many locations throughout the warmer parts of the world (National Research Council, 1993). Soil contour bunds are ridges and ditches made of soil, dug across the slope along the contour. They are used to prevent run-off and to conserve soil and water. When there is rainfall, contour bunds act as a barrier to the water flow and check the velocity. This reduces chances of soil erosion. Ridging especially when constructed on the contour is often used as the first line of defence against soil erosion. Contour cultivation reduces erosion on gentle slopes, helps conserve water and soil on cropland and enhances yields through more available moisture, a less eroded soil, productive soil, less washing out of seeds, and less burying of seedlings (Troeh, Frederick R., Arthur J. Hobbs & Roy L. Donahue, 1999). Box ridges or tied ridges are made across the furrows from one crop ridge to the next and slightly lower than ⅔ the height of the main crop ridges. Spaced approximately every 2 meters and staggered from one furrow to the next, box ridges help crop ridges hold back and infiltrate more water into the soil (Malawi Government, 1995). Box ridging brings two main types of benefits: water conservation (water harvesting) in dry areas and control/reduction of runoff and erosion particularly around depressions, anthills and other problem areas where crop ridges are not very close to the contour (Malawi Government, 1995; Troeh, et al., 1999). Crop ridges are constructed for planting of crops because they have the benefit of allowing easy root growth and conserving soil nutrients. Terraces help to control soil erosion and make sloped land convenient for agriculture. Manure (organic fertilizer) application improves soil structure by holding soil particles together; it also increases the organic matter content of the soil and enhances the ability of the soil to hold nutrients, thereby improving soil fertility (Maonga, 2005).

This paper determines a range of soil management technologies adopted by farmers by computing the composite index of adoption. It also determines the incidence of adoption using descriptive statistics (frequencies and percentages), and finally analyses the determinants of adoption using the probit model.

METHODOLOGY

Study area

The study was conducted in July 2007 covering six districts four of which (Thyolo, Zomba, Chiradzulu, Machinga) are in the Southern Region and two (Kasungu and Lilongwe) are in the Central Region of Malawi. The actual study sites are geographically characterised as hilly, some with steep slopes of more than 12%. Demographically, all these districts have high population densities which constituted one of the main factors leading to shortage of farmland and thus causing smallholder farmers to cultivate their crops on marginal land including sloped land. The Southern districts of Thyolo, Zomba (rural), Chiradzulu and Machinga had population densities of 342, 228, 376 and 130 people per km^2, respectively; on the other side, the Central region district of Kasungu had population density of 80 people per km^2 while Lilongwe (rural) had 216 people per km^2 (National Statistical Office, 2009). Despite the low population density in Kasungu district, much of the land is under large scale (estate) farming, and thus most smallholder farmers face shortages of farmland. It was because of the population-induced cultivation of steep slopes that the soil management technologies were introduced in Malawi.

Sampling procedure

A multi-stage (four stages) cluster sampling procedure involving a combination of purposeful and random sampling was used to draw the sample. The first three steps involved purposive selection of districts, traditional authorities and villages, respectively. The selected sites are some of the areas where the Government of Malawi had intensive campaigns on soil and water conservation. The fourth stage involved simple random sampling of households from the list of villages, ensuring that villages with a larger population have a proportionally greater chance of containing a selected household. To facilitate this final stage, lists of names of households in each selected village were obtained from the chiefs and village headmen in the study areas. The names were assigned numbers and using a table of random numbers, farming households to be interviewed were selected.

Sample size and data collection

A total of 1550 farming households was selected households and interviewed orally using a semi-structured questionnaire. This kind of questionnaire was used to collect both qualitative and quantitative data from the households because according to Fowler (1998) it is an effective tool for minimizing bias and random error. The type of data collected included application of soil management technologies by farmers, socioeconomic characteristics of the farming households, and plot/farm characteristics.

Conceptual framework

Based on the rational choice theory, the behaviour of human beings is motivated by the possibility of making gain. Farmers are rational consumers of new technologies and they will only adopt a technology if they anticipate it will result into increased productivity. Although profitability of the technology is a necessary prerequisite for technology adoption, there are several other factors that affect adoption. These include socioeconomic, technological and land related factors. When farmers fail to adopt soil management technologies, their farms become degraded through soil erosion and nutrient depletion. Consequently, the productivity of their land is jeopardized and crop yields decline considerably. The result is food insecurity and lack of marketable surplus at household level and reduction in the contribution of the agriculture sector to GDP at national level. In the long run, these impacts reinforce each other to keep farmers and the entire economy trapped in the vicious cycle of poverty.

Data analysis

Computing the composite index of adoption

According to Yila and Thapa (2008), the composite index of adoption reflects the range of technologies adopted but not the intensity of their use. Calculation of this index aids the understanding of the variation in technology adoption and its causes, thus contributing to the formulation of policies for effective implementation of land management programmes (Paudel and Thapa, 2004). The composite index of adoption (CIA) is computed as follows

$$CIA = \frac{\sum_{i=1}^{i=n}\left(\frac{T_{iA}}{T}\right)}{n}$$

Where;

T_{iA} denotes the total number of technologies adopted by the i^{th} household,

T denotes the total number of soil management technologies available for adoption,

n is the sample size, and

The expression (T_{iA}/T) represents the index of adoption for the i^{th} household.

Theoretical framework for analyzing adoption of technologies

The fundamental assumption of this study is that farmers' decisions on whether to adopt or not to adopt new technologies are based upon utility maximization (Rahm and Huffman, 1984). The expression $U\left(M_{ji}, A_{ji}\right)$ gives the non-observable underlying utility function, which ranks the preference of the i^{th} farmer for the j^{th} technology ($j = 1, 2: 1$ = traditional technology and 2 = Conventional technology). Thus, the utility derivable from the soil management technology depends on M, which is a vector of farm and farmer specific attributes of the adopter and A, which is a vector of the attributes associated with the technology. Although the utility function is unobserved, the relation between the utility derivable from a j^{th} technology is postulated to be a function of the vector of observed farm, farmer and technology specific characteristics and a disturbance term having a zero mean:

$$U_{ji} = \alpha_j F_i(M_i, A_i) + e_{ji} \quad j = 1, 2: 1, 2, \ldots, n \qquad (1)$$

As the utilities U_{ji} are random, the i^{th} farmer will select the alternative $j = 1$ if $U_{1i} > U_{2i}$ or if the non-observable (latent) random variable $y^* = U_{1i} - U_{2i} > 0$. The probability that Y_i equal one (i.e., that the farmer adopts soil management technology) is a function of the independent variables:

$$P_i = P_r(Y_i = 1) = P_r(U_{1i} > U_{2i})$$

$$= P_r[\alpha_1 F_i(M_i, A_i) + e_{1i} > \alpha_2 F_i(M_i, A_i) + e_{2i}$$

$$= P_r[e_{1i} - e_{2i} > F_i(M_i, A_i)(\alpha_2 - \alpha_1)]$$

$$= P_r(\mu_i > -F_i(M_i, A_i)\beta)$$

$$= F_i(X_i\beta) \qquad (2)$$

Where X is the n x k matrix of the explanatory variables and β is a k x 1 vector of parameters to be estimated, $Pr(.)$ is a probability function, μ_i is a random error term, and $F_i(X_i\beta)$ is the cumulative distribution function for μ_i evaluated at $X_i\beta$.

The probability that a farmer will adopt a technology is a function of the vector of explanatory variables and of the unknown parameters and error term. Equation (2) cannot be estimated directly without knowing the form of F. It is the distribution of μ_i that determines the distribution of F. The functional form of F can be specified with a probit model, where μ_i is an independently, normally distributed error term with zero mean and constant variance σ^2:

$Y_i = X_i\beta$ if $i^* = X_i\beta + \mu_i > T$ (Adoption)

0 if $i^* = X_i\beta + \mu_i \leq T$ (Non-Adoption) (3)

Where:

Y_i = probability of adoption of the technology

i^* = non-observed latent variable

T = non-observed threshold level

Specification of the probit model

Limited dependant variables models have been widely used in technology adoption studies. The said models are based on the assumption that, in adopting new agricultural technologies, the decision maker (farmer) is assumed to maximize expected utility (expected profit .i.e. yield increments) from using a new technology subject to some constraints (Feder *et al*, 1985). In the case of categorical dependent variables (binomial or multinomial) qualitative choice models of adoption such as the logit and Probit are usually specified. These models are commonly used to analyse situations where the choice problem is whether or not 0-1 value range to adopt a new technology. The Probit specification has advantages over logit models in small samples (Fufa and Hassan, 2006). This study therefore, employed a probit model to examine the farmers' decision to adopt or not to adopt soil management technologies. The dependent variable was whether or not a household had adopted at least one of the soil management technologies at the time of the study. This variable was measured by asking the selected households to list the soil management technologies they were using on their farms.

The probit model specification used in this study is given by

$$AF = F(\alpha + \beta x_i) = F(z_i) \quad (4)$$

Where, AF is the discrete adoption choice variable, F is the cumulative probability distribution function, β is the vector of parameters, x is the vector of explanatory variables and z is the Z-score of βx area under the normal curve.

The expected value of the discrete dependent variable in the probit model conditional on the explanatory variables is given by

$$E(y|x) = 0[1 - F(\beta' x)] + [F(\beta' x)] = F(\beta') \quad (5)$$

The parameters (β') are estimated by maximum likelihood and they are consistent, asymptotically normal and efficient. The joint log likelihood function is

$$ln\mathcal{L}(\beta) = \sum_{i=1}^{n}\left[y_i ln\Phi(x_i'\beta) + (1 - y_i)ln\left(1 - \Phi(x_i'\beta)\right)\right] \quad (6)$$

The marginal effect of each explanatory variable on the probability of adoption is:

$$\frac{\partial E(y/x)}{\partial x} = \emptyset(\beta' x) \qquad (7)$$

Where $\emptyset$(.) is the standard normal density function.

The marginal effect values after the probit regression model show the percentage change in the probability of adoption of soil management technologies for each unit change in the corresponding explanatory variable.

The dependent variable for the probit model is whether or not a household had adopted at least one of the soil management technologies that were disseminated to farmers through the Government campaigns on soil and water conservation. Definition and units of measurements of the independent variables are provided in **Table 1**.

Table 1: Determinants of adoption of soil management technologies

Independent variables	Description and units of measurements
Age	Number of years lived by the household head
Casual labour wages	Average daily wage of casual labour
Main occupation	Dummy variable (1 = Farming, 0 = otherwise; 1 = Business, 0 = otherwise; 1 = Casual labour, 0 = otherwise; 1 = Salaried work , 0 = otherwise)
Plot size	Hectares of total owned land
Marital status	Dummy variable (1 = married, 0 = otherwise; 1 = widowed, 0 = otherwise; 1 = separated or divorced, 0 = otherwise; 1 = single , 0 = otherwise)
Extra hours required	Extra hours required to apply a given soil management technology
Education	Number of school years completed by the household head
Plot slope	Dummy variable (1 = Steep slope, 0 = otherwise; 1= Slight slope, 0 = otherwise; 1 = Flat slope, 0 = otherwise)
Sex	Sex of household head (1= female, 0 = male)
Residence area	Dummy variable (1 = Wife's village, 0 = otherwise; 1 = Husband's village, 0 = otherwise; 1 = Neutral village, 0 = otherwise)

RESULTS AND DISCUSSION

Composite index of adoption

In this study, the composite index of adoption was found to be 0.120 (standard deviation = 0.112; minimum = 0; Maximum = 0.429). This index is low and highlights the fact that majority of the farming households have adopted very few technologies out of the seven technologies available to them. Indeed, some descriptive statistics generated revealed that only 18.7% of the surveyed households had adopted at least two technologies out of the seven technologies. The possible explanation to this is that, it may not be necessary for farmers to adopt all the seven technologies unless by design they are supposed to be adopted as a package. Besides, some technologies such as terraces, contour ridges and bunds may not be applicable on flat land.

Incidence of adoption

Table 2 shows the incidences of adoption as measured by the number of percentage of adopters. The adoption of soil management technologies in central and southern Malawi is relatively above average. Overall, about 64% of the respondents had adopted at least one of the soil management technologies highlighted in this study. Highest incidences of adoption were reported for Chiradzulu (77.7%), Thyolo (77.4%) and Zomba (73.6%) districts with box ridges, contour bunds and ridges being the most popular technologies in the three respective districts. Generally, technology specific adoption incidences were relatively highest for contour ridges, ridges, box ridges and contour bunds, particularly in Machinga (24.6%), Lilongwe (24.1%), Chiradzulu (35.3%) and Thyolo (25.0%), respectively. The high adoption rates of these technologies indicate that farmers do appreciate the seriousness of soil erosion problems in Malawi and the implications on land productivity.

Table 2: Percentage of adopters of soil management technologies in Malawi

Soil management technology	Overall sample N = 1550	Thyolo n = 208	Zomba n= 299	Chiradzulu n = 139	Machinga n = 112	Kasungu n= 365	Lilongwe n = 283	Pearson χ^2 (5)
Vetiver grass	6.61	9.62	1.00	8.63	0.00	11.23	6.01	39.895***
Contour bunds	16.36	25.00	22.41	13.67	21.43	10.41	10.60	38.48***
Contour ridges	28.53	18.62	11.11	5.11	24.62	12.01	23.68	76.804***
Box ridges	16.71	14.90	23.41	35.25	15.18	12.18	7.42	66.048***
Ridges	18.71	10.10	24.08	20.86	21.43	13.15	24.38	30.193***
Terraces	2.28	2.88	0.00	0.00	0.00	6.58	0.71	46.624***
Manure	2.77	4.33	2.34	4.32	0.00	3.01	2.12	7.016
Total	*63. 91*	*77.40*	*73.58*	*77.70*	*64.29*	*53.70*	*50.00*	*80.164****

Note: The *** indicate significance at 1%

The least adopted technologies were terraces and manure. The former had only been adopted in Thyolo, Kasungu and Lilongwe. The use of manure, though not a widely adopted technology, was reported in all districts except Machinga. Low adoption of terraces is mainly because the technology is relatively labour intensive and therefore not appropriate for the majority of smallholder households. The main reason for low adoption of manure is that it is required in large quantities in order to make significant impact on the farm and therefore farmers shun the technology; in addition, most smallholder farmers in Malawi do not own enough livestock herds to raise manure. Findings from the baseline survey on rural smallholder farming households in Malawi revealed that an average smallholder household owns 4 goats, 7 cattle, 4 pigs, 8 chickens, 4 guinea fowls and 3 ducks (Maonga, 2010). The few smallholder farmers who own livestock raise them on free range system. However, free-range system of livestock keeping precludes the collection of livestock manure for application on cropland (Ngugi, 2002).

Probit model results

The results of the probit regression analysis presented in **Table 3** revealed that sex of the household head was a significant determinant of adoption of soil management technologies (significant at 1% level). The probability of adopting soil management technologies by male headed households was 15% higher than for female headed households.

By implication, this could be because irrespective of security of land tenure and marriage system, most of the farming decisions in Malawi are made by men. Contrary to the expected, the number of extra hours needed to apply a given soil management technology had also a positive and significant effect (significant at 1% level) on the adoption. The probability of adoption was found to increase by 2.6% for each additional hour.

Table 3: Probit model coefficient estimates and marginal effects

Model	**Marginal effect**	**Standard error**	**z**	**P>|z|**	**Coefficient**
School years completed	0.001311	0.00392	0.33	0.738	0.003478
Age	-0.001145	0.00115	-0.99	0.321	-0.003038
Average daily wage of *casual labour*	0.000043	0.00006	0.72	0.473	0.000113
Extra hours required	0.025830	0.00838	3.08	0.002	0.068529
Plot size	-0.000002	0.00000	-1.06	0.287	-0.000004
Sex	0.151001	0.02639	5.72	0.000	0.411105
Marital status					
• Married	0.055292	0.05132	1.08	0.281	0.148523
• Widowed	0.148379	0.06988	2.12	0.034	0.431800
• Separated or divorced	0.036991	0.07559	0.49	0.625	0.099832
Main occupation					
• Farming	-0.005933	0.04890	-0.12	0.903	-0.015724
• Business	0.010660	0.07686	0.14	0.890	0.028410
• *casual labour*	0.016211	0.1168 0	0.14	0.890	0.043330
• Salaried work	0.035439	0.12393	0.29	0.775	0.095639
Residence area					
• Wife's village	0.014294	0.04441	0.32	0.748	0.037900
• Husband's village	-0.127056	0.04589	-2.77	0.006	-0.333168
Plot slope					
• Slight slope	-0.029845	0.02657	-1.12	0.261	-0.078936
• Steep slope	-0.078725	0.06024	-1.31	0.191	-0.203695
Pseudo R^2	0.043				
Log pseudolikelihood	-981.601				
Wald $chi^2(17)$	58.530				
Prob > χ^2	0.000				
Number of observations	1550				

Another positive and significant determinant of technology adoption was *being widowed* (significant at 5% level). The probability of adopting soil management technologies by widowed household heads was 14.8% higher than for household heads who had never married. This could be explained by the fact that in the former households, responsibility solely rests on the widow. It is therefore, not surprising that the widowed have to adopt productivity enhancing technologies so that they can sustainably meet the needs of the household. On the other hand, household heads who never married tend to have small household sizes and therefore low consumption levels. Thus, they do not feel the urgency to increase agricultural productivity (through technology adoption), especially if they intend to produce just for home consumption.

Other factors with a positive effect on the probability of adoption, despite being insignificant were: school years of formal education completed; daily average wage of casual labour; being married; being separated or divorced; residing at the wife's village; and owning a business or being involved in casual labour or having a salaried job as the main occupation.

On the negative side, the only factor found to significantly reduce the probability of adoption was residing at the husband's village (significant at 5%). The probability of adoption of soil management technologies by a household residing at the husband's villages was 12.7% lower than for a household residing at a neutral village. This could be explained by the fact that most of the households were from the Southern and Central regions of Malawi with predominantly matrilineal marriage system where land tenure is defined through women. As men do not own land in their villages, land tenure insecurity tends to be high and therefore with a consequent low adoption of farm technologies. Other factors that were likely to lower the probability of adoption of soil management technologies were age of the household head, plot size, practicing farming as the main occupation, and slight or steep slope on the plot in question. However, the impact of these factors was found to be statistically not significant.

CONCLUSION AND RECOMMENDATIONS

This paper has established that the range of soil management technologies adopted by individual farming households was low mainly because the technologies were not meant to be adopted as a total package. Farmers adopted only those technologies which were perceived to be most appropriate to them on their farms. Despite the low indices of adoption, the number of adopters (incidence of adoption) of soil management technologies was found to be moderately high. This is partly attributed to the intensive Government campaigns on soil and water conservation. The high incidence of adoption of the soil management technologies is also a manifestation of farmers' appreciation of the seriousness of soil erosion problems in the country and the implications on land productivity. The econometric analysis revealed that sex of the household head, being widowed and the number of extra hours needed to apply a given soil management technology, were the positive and significant determinants of adoption. Residing at the husband's village was also a significant determinant of adoption but with a negative effect.

This paper recommends that to further increase the incidence of adoption of soil management technologies, the Malawi Government should continue with the intensive campaigns on soil and water conservation. Additionally, the land resources management policies should emphasize on increasing land tenure security especially in the patrilineal system in order to encourage technology adoption by households residing at husbands' village. Considering that population growth contributes to the challenges of sustainable management of land and environmental resources, agricultural and population policies should be transparently harmonized and jointly implemented in order to reduce pressure on the use of land.

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REFERENCES

Feder, G., Just, R.E., & Zilberman, D. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, 33(2).

Fowler, T.J. (1998). Design and Evaluation of Survey Questions. In: L. Birkman & D.J. Rog (Eds.), *Handbook of Applied Social Research Methods,* (pp. 343-374). Thousand Oaks: Sage.

Freedman, B. (1995). *Environmental Ecology: The Ecological Effects of Pollution, Disturbance, and Other Stresses.* London, UK: Academic Press, 2nd Edition.

Malawi Government. (1995). *The Agricultural and Livestock Development Strategy and Action Plan.* Ministry of Agriculture and Livestock Development, Lilongwe, Malawi.

Malawi Government. (1998). *Status of the Environment Report 1998*. Retrieved on July 12, 2001 from: http://www.sdnp.org.mw/enviro/soe_report, 24 pages.

Maonga, Beston B. and Maharjan Keshav Lall (2003). An Alternative Cropping System of Smallholders in Malawi: Towards Improved Food Production in Sangadzi Area. *Journal of Rural Problems,* 39(3), pp. 30 – 41, Association for Regional Agricultural and Forestry Economics, Kyoto, Japan.

Maonga, B.B. (2005). *Sustainable Smallholder Land Resources Management and Food Security in Malawi: A Study on Indigenous Farming Practices in Mbwadzulu Extension Planning Area* (Unpublished doctoral dissertation). Hiroshima University, Japan.

Maonga, B.B. (2010). *Investigation of the potential of small scale biofuel production in employment and income generation, environmental rehabilitation and socioeconomic development in Malawi.* Unpublished Final Report on file at ARDEP, Small Scale Biofuels Project Office, Bunda College of Agriculture, Lilongwe, Malawi.

Mulenga, N.J. (2001). *Strategy for Promoting Vetiver Grass for Soil and Water Conservation,* Ministry of Agriculture and Irrigation, Land Resources Conservation Department, Promotion of Soil Conservation and Rural Production (PROSCARP), Lilongwe, Malawi.

National Research Council. (1993). *Vetiver Grass: A Thin Green Line Against Erosion.* Washington D.C., USA: National Academy Press.

National Statistical Office (NSO). (2009). *Population and Housing Census 2008,* Main Report, Zomba, Malawi.

National Statistical Office (NSO). (2000). *Final Results of the 1998 Population and Housing Census*, Zomba, Malawi.

Ngugi, D.N. (2002). Synthesis report on CTA-MAFE Agroforestry Tour of Malawi and Zambia: January 20 – 30, 2002. A report prepared for the Technical Center for Agricultural and Rural Cooperation. Relay Consultants and Associates, Kenya. Retrieved on December 15, 2002 from http://www.cta.int/pubs/agroforestry/synthesis report.pdf. pp. 1 – 22.

Rahm, M.R. & Huffman, W.E. (1984). The adoption of Reduced Tillage: The Role of Human Capital and Other Variables. *American Journal of Agricultural Economics,* 66, 405-413.

Shiferaw Bekele & Holden Stein T. (2000). Policy instruments for sustainable land management: the case of highland smallholders in Ethiopia, *Agricultural Economics,* 22, pp.217-232.

Troeh, Fredrick R., Hobbs Arthur J., & Donahue Roy L. (1999). *Soil and Water Conservation, Productivity and Environmental Protection,* Upper Saddle River, NJ, USA: Prentice Hall.

Yila, O.M. & Thapa, G.B. (2008). Adoption of agricultural land management technologies by smallholder farmers in Jos plateau, Nigeria. *Earthscan*.