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The Links between Poverty and the Environment in Malawi

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Abstract

Deforestation arising from conversion of forest areas into agriculture is a serious problem in Malawi. Cultivation of subsistence and cash crops is often cited as a major cause of this problem. This paper applies the von Thunen model to firstly, discuss competition for agricultural land and secondly, establish why the poor are closely associated with forests. Further, a regression analysis is conducted to examine the effects of changes in crop land use on changes in forest cover. Results indicate that cultivation of different crops has varying effects on deforestation. Cultivation of maize, primarily by the poor, appears to be the principal cause of deforestation while tobacco and pulses stand at second and third positions, respectively. Finally, a simple methodology is developed to estimate the extent of poverty-driven deforestation in Malawi.

Keywords

poverty
environment
agriculture
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JEL Codes

Q15; Q23

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INTRODUCTION

Reduction of extreme poverty and reversing loss of environmental resources are some of the key goals of many countries and international institutions including the United Nations. Current literature seems to converge towards the consensus that there exists a strong causal link between poverty and environmental degradation. For instance, a number of studies have shown that in many poor countries, slash-and-burn subsistence agriculture is having a toll on deforestation.

To a great extent, the issue of deforestation continues to be closely associated with poverty because a number of research findings indicate that many poor people live in or near forested areas. For instance, recently the patterns of association between poverty and forests were examined by Sunderlin *et al*. (2008) through their case studies on Malawi, Mozambique, Uganda, Indonesia, Brazil, Honduras and Vietnam. By applying the bivariate-spatial-autocorrelation approach via the Moran's *I* statistic[i] they found that there was a strong link between the location of the rural poor and forests. Similar findings have been registered by Zhou and Veeck (1999) regarding China; World Bank (2006), Shah and Guru (2004) regarding India; and Chomitz *et al*. (2007) regarding Nicaragua. While these studies provide very good information relating to where the poor are most likely to locate, they do not explain why the poor are closely associated with forests.

Furthermore, although a great deal of anecdotal evidence points towards a close relationship between poverty and deforestation through agriculture, country specific time series data on deforestation, especially in poor countries, is still a huge problem. In addition, many studies do not clearly specify how cultivation of which crops leads to how much deforestation. This has led to difficulties in designing and reviewing the effects of policies that are aimed at addressing concerns regarding poverty and deforestation.

The main aim of this paper is to examine the effects of changes in crop land use on changes in forest cover and develop a methodology that can be used to estimate the poverty driven deforestation, which to the best of our knowledge has not been adequately addressed. The paper starts by looking at classifications of forests and then applies the von Thunen (1826) model to firstly, discuss competition for agricultural land and secondly, establish why the poor are closely associated with forests in Malawi

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[i] In their paper, the Moran's *I* statistic is derived from the Anselin (1995: 98) formula as follows:

$I_i = Z_{xi} \sum_{j=1, j\neq i}^{N} W_{ij} Z_{yi}$ Where x and y are the two variables for district i and the neighbouring district j, Z_x and Z_y are the standardized z-scores of variables x and y, respectively. The special weight matrix W_{ij} is a binary contiguity matrix that defines the spatial structure for the locations that are included in the calculations of the local Moran's *I*. If observations share a common border $W_{ij} = 1$, otherwise $W_{ij} = 0$ (Sunderlin *et al.*: 4).

ASPECTS OF POVERTY-DEFORESTATION RELATIONSHIP

The causes of deforestation have traditionally been viewed from two perspectives, i.e., demographic and economic. The demographic pressures on forest lands were popularized by the classic Malthusian theory, which contended that an increase in population density would lead to deforestation (Walker 2004). It was therefore assumed that unless population growth was contained, the world forests were destined for an eventual disappearance.

From the economic perspective, two strands emerged. The first one put the blame for deforestation on the extraction of commercial timber and other wood products as experienced in Asia and South America. The second strand had much to do with agriculture where clearing of forest land for commercial farming was regarded as the most common cause of deforestation and this stemmed mainly from the von Thunen theory (Angelsen 2007). Both the demographic and the economic approaches can be said to be pessimistic in that they did not take into account issues of forest recovery.

Over time evidence started to indicate that the world was not necessarily doomed to deforestation. In the developed world, for instance, most lands that had been cleared started to show the resurgence of natural and planted trees and this phenomenon led to the birth of the forest transition theories (Mather 1992). Much as the forest transition theories uphold the demographic and economic causes of deforestation, they are seen to be optimistic in their approach. They postulate that with respect to time, forest lands tend to go through four stages. The first one is where the land is covered with indigenous (original) forest with low or no deforestation at all. The second stage involves rapid and high deforestation while the third stage indicates deceleration in deforestation evidenced by stabilization in forest cover. The final stage is where reforestation and natural resurgence take place and there is an increase in total forest.

From the above three theories, four classifications of forest land can be cited, namely the residual standing forest, the mature natural forest, the previously extracted but replenished forest and the forest that is in the region of agriculture (Hyde *et al*. 1996). However, there are some differences between forest lands that can be observed in the developed and poor countries. In the developed countries, while nearly all the four classifications can be observed, reforestation and natural resurgence have largely occurred.

On the other hand, in most poor countries such as Malawi, the classification of forest land can largely be broken into two: (1) the residual standing forest and (2) the forest land that is in the region of extensive agriculture. Forest lands that fall in category (1) are mostly government protected areas such as national parks and game reserves. The remaining forest land, category (2), is largely treated as common property owned by the general community.

The differences in observable forest classifications between the rich and poor countries are matched by the differences in attitude and concerns towards deforestation. In many developed countries, forested areas have not only stabilized but have also increased as such deforestation is no longer a major issue. This is due to strong institutions that have spearheaded education, property rights and awareness of the rule of law in these countries. In this part of the world, concerns about deforestation are expressed partly because the developed world views deforestation from poor tropical areas (e.g., from the Amazon basin) as having global negative externalities such as climate change (UNDP 2007). Others are concerned with the issue of deforestation because of their passion to maintain and protect forest biodiversity and other ecosystem benefits (Harris 2006). On the other hand, in poor countries, the apparent weak or lack of property rights and regulations in the category (2) forest land has led to extensive extraction of forest resources and deforestation.

However, even amongst the poor countries, causes of deforestation and their effects are also divergent. For instance in Latin America and Asia, deforestation is mainly due to logging and commercial agriculture and this is regarded as having impacts on global warming. In sub-Saharan Africa, deforestation is mostly associated with rural slash-and-burn subsistence agriculture and this has effects on poverty. Unfortunately, the relationship between poverty and deforestation has not been apparent in the aforementioned theories of deforestation as such for a long time poverty and deforestation have been researched upon as separate issues that required separate policy interventions.

The downside of looking at poverty and deforestation as separate issues is that a number of studies have tended to support policies which have had conflicting effects on the rural poor. For instance, the trade liberalization policies, which were mainly designed to foster trade and reduce income poverty, are on record to have led to deforestation in a number of developing countries (Lopez 2000). Today there is a general drift towards a consensus in which the two issues are being regarded as twin problems that require formulation of double-edged policies that are capable of addressing them simultaneously.

A number of studies have revealed that poverty can be both the source and result of deforestation (Perz 2003, Sunderlin *et al*. 2008). At the centre of this chicken-and-egg vicious circle is the general view that on the one hand, poverty leads to ecological degradation by causing the poor to depend on forest reserves for survival particularly with respect to firewood, farming, wildlife, water and fisheries. On the other hand, ecological degradation aggravates poverty, since the poor rely on the environment for their continued existence (Bojo 1999, Cleaver and Schreiber, 1994). This paper does not necessarily delve into the gist of the poverty-deforestation circle. In stead its emphasis is placed on the effects of poverty on deforestation mainly via agriculture.

With regards to agriculture, it is widely argued that in most poor countries, particularly in sub-Saharan Africa, the rural poor rely on low-productivity, subsistence agriculture for their living. This being the case, with no or very limited technological improvement, agricultural production can only be enhanced by converting forests into agricultural land (Coxhead and Jayasuriya 2004, Lufumpa, 2005). According to UNDP (2007), between 1990 and 2005, 3 percent of global forests were lost owing to conversion of forests into farmland in poor countries at the estimated rate of about 13 million hectares per annum.

POVERTY AND FORESTS: THE VON THUNEN MODEL

At the core of the von Thunen model is the argument that land is assigned to the use which yields the highest rent and that the rents of various land uses are determined by location. Today the von Thunen model has received much broader explanation and application in the literature. For instance, McCann (2001) succinctly applies the model to explain the spatial structure of the urban economy, i.e., how people and firms are distributed within the urban economy. On his part, Angelsen (2007) uses the model in conjunction with forest transition theories to analyse tropical deforestation and reforestation. This study uses the model to explain why the poor are usually located in or near forested areas with particular reference to Malawi. This will help to establish a threshold on which a theoretical model for estimating poverty driven deforestation is built. The analysis in this model closely follows the academic footprints of McCann (2001).

The construction of the von Thunen model is based on the assumption that there is a fixed supply of homogeneous land that is managed by an omnipotent planner and can only be used for agriculture and forestry. This land is allocated according to its most profitable use. To cultivate the land, it is assumed that a farmer pays rent, r per hectare, h. The agricultural output, q per hectare is assumed to be traded at a central market point at a given price, p. Apart from land, it is assumed that the agricultural production is also facilitated by two non-land production factor inputs, namely labour, l and capital, k, which are remunerated with w and i, respectively. It is also assumed that the agricultural goods incur a constant transport cost, c per kilometre whenever they are moved from their point of production to the central market point over a distance which is denoted by d. Based on these assumptions, the farmer's profit can be computed as follows:

$$\pi(d) = pq - wl - ik - rh - qcd \qquad (1)$$

From equation (1) the profit per unit of output can therefore be derived as follows:

$$\frac{\pi(d)}{q} = (p - cd) - w\frac{l}{q} - i\frac{k}{q} - r\frac{h}{q} \qquad (2)$$

The profit per unit of output from equation (2) can be interpreted as the difference between the price of goods and their costs of transport less production factor overheads per unit output. In order to calculate the maximum rent that a farmer could pay per unit of land area, profit per unit of output is set equal to zero, i.e., $\frac{\pi(d)}{q} = 0$. This transforms equation (2) into:

$$(p - cd)q - wl - ik - rh = 0 \qquad (3)$$

Equation (3) can be rearranged to make r the subject of the formula as follows:

$$r = \frac{(p - cd)q - wl - tk}{h} \tag{4}$$

The rent-distance relationship can therefore be calculated by differentiating equation (4) with respect to distance, d as follows:

$$\frac{\partial r}{\partial d} = -\frac{q}{h}\left(c + \frac{\partial c}{\partial d} d\right) \tag{5}$$

Given that transport cost, c is assumed to be constant, equation (5) can be simplified as follows:

$$\frac{\partial r}{\partial d} = -\frac{q}{h} c = -\frac{c}{h/q} \tag{6}$$

Basically, equation (6) stipulates that any increases in transport costs resulting from increases in distance are essentially compensated for by reducing the rent owed to the total land that is used to produce a unit of output. In other words, the price of land falls as the distance from the central market point increases.

So far it has been implicitly assumed that there is only one farmer producing one type of product. However, to see why different groups of people or firms locate at different places, the model is extended to include two farmers producing two competitive agricultural products, q and x from pieces of agricultural land of identical sizes. It is also assumed that the two farmers are faced with identical transport, land and non-land factor costs but different market prices, $p_q \neq p_x$.

Assuming that $p_x > p_q$, then the farmer producing product x will be more competitive. Given that payments to land are treated as a residual, the producer of x will consequently pay a higher rent than the producer of q and therefore by implication the producer of x will occupy land closest to the central market point. This trend would continue as more farmers and products are introduced into the model and the result will be several concentric zones with the most competitive bidder locating closest to the central market (McCann 2001).

From this analysis, it clearly follows that the less competitive farmers or households will be continuously pushed further away from the central market point into the outskirts (forested areas) where the cost of land is lowest. If it is therefore assumed that the cost of renting forests is zero (Angelsen 2007) then by implication, it must be the poor households that would locate in or near such places.

MALAWI’S LAND COMPETITION IN THE VON THUNEN MODEL

In Malawi, land is distinguished into three main categories, namely leased, customary and public land. Such categorisations can be traced as far back as 1891 when Britain declared Malawi, then Nyasaland, its protectorate. At that time, the white settlers obtained land through establishment of treaties with local chiefs for large-scale estate agriculture which were usually negotiated at a nominal price. The first acquired estates were mostly located in the Shire highlands in the south of the country and were mainly used for coffee production. However, with the collapse of the world coffee prices in the early 1900s, estate owners switched their interest to tea and tobacco (Mkandawire 1999).

During the entire colonial rule, much of Malawi’s best agricultural land was set aside for the white-owned tobacco and tea estates. In most cases, these estates were strategically developed close to the market points while in some cases trading centres eventually sprouted close to these estates. The poor black Africans were, by and large, forced to settle in the customary land, which was under the jurisdiction of traditional chiefs. This development led to shortage of customary land and ignited clashes over land between European estate owners and African smallholders. To solve the conflicts, a tenancy accord was designed whereby African smallholders were required to supply labour in return for a small piece of land within or close to the European-owned estates (Mkandawire 1999).

When Malawi became independent in 1964, it inherited the then existing land policies. The only change was that the public land was officially transferred from the colonial masters into the state ownership. By the end of 1969, some of the state-owned land and a better part of the customary land were leased to Africans, mostly government ministers, for the establishment of the tobacco estates especially in the central region. This worsened the problem of land scarcity, however, no one dared to complain or resist publicly given that such an act would not be condoned under the iron-fist rule of the first President of Malawi.

Leasing of the arable land to the politically connected and financially powerful elites continued until 1994 when the first multi-party, democratically elected government was ushered in. However, this did not necessarily affect the distribution of land amongst different groups in the country. Currently, through money votes, the best agricultural land is largely owned by the well-off households while the poor squat in the remote areas usually far away from the strategic market centres. This scenario is largely the same across the country but it is more pronounced in the south followed by the centre where most commercial farming of tea and tobacco takes place.

AGRICULTURAL PRODUCTION AND DEFORESTATION

A number of studies have been conducted on the causes of deforestation in Malawi. French (1986) attributed the problem of forest clearing to population pressure which was said to be forcing people to clear forest land for agriculture and fuel wood. The study was basically descriptive focusing on reviewing and interpreting the fuel wood prices and reforestation data estimates from the Department of Energy Studies Unit in the Ministry of Forestry and Natural Resources. He concluded that the problem of deforestation in Malawi was unstoppable and recommended that it was "necessary to abandon further talk of reversing deforestation" (ibid: 537).

However, contrary to French's recommendation, Hyde and Seve (1993) designed an econometric model to examine the attitude of smallholder farmers towards reforestation. On the demand side of the model were prices of wood products, income elasticity, the population growth rate, the growth rate of income per capita, and the rate of technical change as the main explanatory variables. The supply side was explained by the price elasticity of supply which comprised the stock of standing indigenous and planted forests. Their model projected that at some price, annual demand for and supply of forests would be equal and this would entail sustainability in the forest cover. Their simulation results indicated that the forestry sector in Malawi was extraordinarily resilient such that slight increases in wood prices would spark large increases in reforestation. They therefore predicted that while conversion of forests into agriculture was likely to continue, deforestation would cease to be an issue within a decade due to reforestation.

Another major study on deforestation was carried out by Place and Otsuka (2001) by employing aerial photos in conjunction with field studies conducted in 57 communities across the country. Their econometric results did not support the prediction of Hyde and Seve (1993) regarding the sustainability of forest cover as they found very little evidence of sustainable tree planting in Malawi. However, just like Hyde and Seve, they found that conversion of forests into agriculture was the major cause of deforestation. In the same year, Minde *et al*. (2001) investigated the causes of deforestation in Malawi through a household survey conducted in three study areas one from each region.

The survey was supported by a regression analysis based mainly on macroeconomic data which included producer prices, wages, population and the presence of refugees from Mozambique. Just like the other highlighted studies, Minde *et al*. (2001) concluded that conversion of forest land into agriculture was the front runner agent of deforestation. Most recent studies that reflect the conversion of forest land into agriculture as the major source of deforestation include that of Walker and Peters (2007) and Mwase *et al*. (2007) in which the former employed the remote sensing technique focusing on Zomba and Kasungu Districts while the latter used the field survey in six sites from the Shire highlands.

Studies on the causes of deforestation as reviewed above can therefore be summarized by the following equation:

$$Def = f(p_t, q_t, A, w, pop_j, y, fl) \tag{7}$$

where Def is deforestation, p_t denotes producer prices, q_t is non-labour input prices, A is technology level, w stands for real wages, pop_j is population growth and density, y is income per capita, and fl is fuel wood. The explanatory variables in equation (7) are by no means exhaustive; however, they capture most of the important variables that standard econometric models tend to incorporate. The first four variables deal with factors that are associated with the expansion of agricultural land while the remaining variables look at non-agricultural factors. Therefore equation (7) can be re-written as:

$$Def = f(\boldsymbol{Agr}, \boldsymbol{Nagr}) \tag{8}$$

where $\boldsymbol{Agr}$ is a vector of agricultural factors and $\boldsymbol{Nagr}$ is a vector of non-agricultural factors, with the former set of factors being the central cause. Traditionally, the vector $\boldsymbol{Agr}$ is explained from two approaches, namely the subsistence approach and the market approach.

The subsistence approach stands on the assumption that, as utility maximisers, poor households aim at satisfying their subsistence needs through the production of agricultural products using the available factors of production. It is further assumed that after reaching their expected subsistence level of consumption, households tend to prefer leisure to work (Angelsen 2007). This implies that the households' economic problem is to minimize production factor costs given a subsistence goal. The households' agricultural production function in period t is given as:

$$Q_t = A_t f(L_t, N_t, F_t) \tag{9}$$

where Q represents the physical units of the agricultural output, A denotes the level of technology, while L, N and F are the factors of production, namely labour, land and fertilizer, respectively. The production function is assumed to display positive but diminishing marginal factor productivity (Gbetnkom 2008). As indicated earlier, under the von Thunen model, the forest land is priced at zero therefore the conversion of forest into agriculture is carried out by whoever comes first. However, clearing of a forest land and transporting inputs and outputs come at a cost $n(N)$, therefore the total cost of labour can be specified as $w[L + n(N)]$. If we add the cost of input, i.e., fertilizer, then the total cost of production becomes:

$$w[L + n(N)] + qF \tag{10}$$

As stipulated above, it is assumed that households aim at minimizing their cost of production subject to subsistence consumption, $yPOP = pQ$, which acts as the constraint. Hence, the optimization problem becomes:

$$C(L, N, F) = w[L + n(N)] + qF - \lambda[pA_t f(L_t, N_t, F_t) - yPOP] \quad (11)$$

where, λ is the Lagrangian multiplier. Subsistence consumption, $yPOP$ is expressed as the product of income per capita, y (which is used as a proxy for subsistence consumption) and POP, which stands for total population. The rest of the variables are defined as above.

From the Lagrangian function (equation 11), the first order condition can be specified as:

$$C_1^{'} = w - \lambda pAf_L = 0; \ C_2^{'} = wn_N - \lambda pAf_N = 0; and \ C_3^{'} = q - \lambda pAf_F = 0 \quad (12)$$

Therefore, $\lambda pA = \frac{w}{f_L} = \frac{wn_N}{f_N} = \frac{q}{f_F}$ (13)

Just like the subsistence approach, the market approach assumes a production function as specified in equation (9). However, the difference arises from the fact that the latter assumes profit maximizing households and perfectly elastic labour supply which is employed at a predetermined wage rate. Hence the optimization problem becomes:

$$\pi(L, N, F) = p[A_t f(L_t, N_t, F_t)] - \lambda[wL + wn(N) + qF] \quad (14)$$

In this case the first order condition is specified as follows:

$$\pi_1^{'} = pAf_L - \lambda w = 0; \ \pi_2^{'} = pAf_N - \lambda wn_N = 0; and \ \pi_3^{'} = pAf_F - \lambda q = 0 \quad (15)$$

Therefore, $\frac{1}{\lambda} pA = \frac{w}{f_L} = \frac{wn_N}{f_N} = \frac{q}{f_F}$ (16)

Some differences between the two models can be cited. For instance, if we assume that the shadow price, λ is greater than 1 then households would appear to be more price elastic under the market approach than the subsistence approach. This is because under the market approach, the opportunity cost of responding to changes in prices is by far smaller ($\frac{1}{\lambda}$) than is the case under subsistence approach (λ). These differences can have major influences on the way econometric models respond to exogenous shocks and the way results are reported. This may explain the difference between the results of Hyde and Seve (1993) and Place and Otsuka (2001) regarding reforestation in Malawi. By assuming that smallholder farmers in Malawi were very responsive to changes in wood prices, the former can be said to have implicitly assumed that the decisions by these households to invest in agriculture were largely driven by profit maximization objective. This might have led to their optimistic conclusion that in Malawi, reforestation was on course to the extent that the trend would replenish the deforested areas within a decade.

On the other hand, Place and Otsuka (2001) appear to have implicitly considered Malawian smallholder farmers as being largely driven by subsistence consumption objective as indicated in their following argument: "Given the high degree of poverty among rural households and the poor remuneration from maize production, it is unlikely to be high profits from agricultural production that have driven the conversion process" (ibid: 29). This might explain why they found little evidence of reforestation amongst the smallholder farmers.

The other difference is that in the subsistence approach, population is exogenously determined while it is endogenously determined in the case of the market approach. This also can have fundamental effects on the way models respond to external shocks hence modelers need to be aware and take into account such differences when designing their models and interpreting results (Gbetnkom 2008). Irrespective of the cited differences, the two approaches are very similar in establishing the important economic factors that explain the demand function for the agricultural land expansion, D_{Agrt} which can be specified as follows:

$$D_{Agrt} = f(p, A, q, w) \tag{17}$$

From the findings of the above discussed studies, it is apparent that deforestation in Malawi is mainly explained by agricultural factors. This being the case, it can be stipulated that the deforestation function mimics the demand for agricultural land expansion function hence we can specify deforestation as:

$$Def \approx f(p, A, q, w) = f(\boldsymbol{Agr}) \tag{18}$$

The downside of equation (18) is that deforestation is explained indirectly via the factors that determine the demand for agricultural land expansion. For instance, it is usually assumed that the increase in prices of cash crops, such as tobacco and pulses, would lead to smallholder farmers converting more forest lands to grow the said cash crops. However, this might not always be the case because in most cases the poor that are engaged in growing cash crops tend to be those that are in the upper income quartile usually with sufficient land (Tobin and Knausenberger 1998) as such they may not necessarily need to deforest for agricultural expansion. On the other hand, those in the lower quartile usually with limited land tend to focus on subsistence agriculture and may deforest just for their sustainability. The other weakness of equation (18) is that it is very difficult to link specific crop production to deforestation. For instance, much as Minde *et al*. (2001) found out that extra land for agriculture was acquired from forests, they were unable to specifically link cultivation of individual crops, particularly maize and tobacco, to the acquisition of new land.

The above bottlenecks are our motivation. It is therefore hypothesized that much as in Malawi conversion of forest land into agriculture is the major cause of deforestation, cultivation of different crops has different effects on changes in forest cover. Unlike the studies reviewed above, this paper's contribution stands on the fact that changes in annual forest cover are used as a surrogate for deforestation, which is assumed to be explained by changes in crop land areas as explained below.

METHODOLOGY

It is assumed that the size of forest cover directly depends on agricultural land use; therefore, the model is specified as follows:

$$F = f(\boldsymbol{X}) \tag{19}$$

where, F is forest cover and $\boldsymbol{X}$ is a vector of crop land areas for maize, tobacco, cassava, pulses, millet, sorghum, rice, sugar, tea and wheat. The choice of crops has been influenced by two main reasons, namely their socio-economic importance and data availability. With regards to importance, Malawi's agriculture mainly revolves around two crops, namely maize and tobacco. Maize is the major food crop cultivated by 98 percent of the rural population (GoM 2005). Currently the crop covers nearly 65 percent of the country's arable land while tobacco, the major cash crop, constitutes about 15 percent and all other crops are catered for by the remaining 20 percent of the agricultural land. Another important phenomenon about farming in Malawi is the issue of inter-cropping. In most cases, legumes and other vegetables such as pumpkins are inter-cropped with maize as such they may not independently account for any land use.

Appendix 1 shows that crop land areas are generally non-linear. For instance, cassava production experienced a steep reduction in land use between 1987 and 1990 due to mealybugs that swiftly decimated the crop especially in the northern region of the country. During that time, most of the land for cassava was substituted for by other crops such as maize. However, cassava land use started to register a steady increase after the pestilence.

In the case of other crops such as maize, millet, sorghum and wheat, their erratic land use largely reflect drought patterns that have hit Malawi nearly every two to three years since 1990. However, land use for cash crops such as tobacco, sugar, tea and pulses appear to be relatively steadier than is the case with subsistence farming, implying that there are factors other than rainfall that explain land use for cash crops. These factors may include changes in international prices and the exchange rates. In general, with respect to time, land uses for most crops seem to be increasing much faster than the changes in time as such deforestation is specified as an exponential function as follows:

$$F = AX^{\beta_i}e^{\mu} \tag{20}$$

Taking the natural log of equation (20) and considering deforestation as change in annual forest cover, the following equation is generated:

$$Def = \Delta lnF = lnA + \beta_i \Delta \ln \mathbf{X} + \mu \quad (21)$$

where A is a constant, β_i stand for the respective coefficients of the explanatory variables, μ is the error term and Δ signifies change.

Generally, the β_i, which can be interpreted as elasticities[ii], are expected to be negative for most changes in crop land areas. In particular, changes in land areas for maize and tobacco are likely to have negative effects on the changes in forest cover. However, for some crops such as sorghum, cassava, pulses, millet and wheat, the β_i may have either positive or negative signs due to two reasons. Firstly, smallholder farmers may use part of the already cultivated land and fallows to grow these other crops. Secondly, even if growing these crops would require converting forest land into agriculture, crops such as millet, are grown on relatively small scale such that there impact on forest change may be negligible.

In Malawi, tea is almost entirely cultivated by the wealthy white farmers while sugar is grown by a corporate organization (Illovo Sugar Corporation) and in both cases high technology is employed. While the main focus of this study is on deforestation arising from agriculture as practiced by the poor farmers, including tea and sugar into the model partly helps to test the hypothesis of whether wealth driven agriculture has an effect on deforestation.

Rice, which acts as both cash and subsist crop, is mainly grown in the wetlands (*dambos*) and it may not have an immediate and direct impact on deforestation. However, its cultivation acts as a competitive substitute for maize crop that is cultivated in the *dambos* particularly during the dry seasons. The expansion of land for rice may therefore displace *dambo* maize crop. This would imply that farmers may decide to convert some forest land to grow more of the *rain-fed* maize crop as a replacement mechanism.

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ii These elasticities indicate the responsiveness of forest cover to changes in land use for a particular crop.

Sources of Data

Data on the crop land areas were compiled from the National Statistics yearbook (various issues) and the FAO (2005) both of which are on-line. Time series data on forest cover in Malawi are not readily available. So far, there are only three estimates on forest cover for the years 1990, 2000 and 2005 as provided by the World Bank (2008). Appendix 2 shows how annual data on forest cover was estimated for the rest of the years between 1985 and 2005.

Unit Root Tests

Before running our regressions unit root tests were carried out to determine whether the variables in the model were stationary or not. The problem of non-stationary variables is that they tend to lead to unauthentic regression results. For instance, the results might indicate statistically significant link between variables while, in reality, this is a mere reflection of simultaneous association. Therefore, the Augmented Dickey Fuller (ADF) tests were employed to investigate for the presence of unit root. Generally, the ADF model is formulated as:

$$\Delta y_t = \alpha + \rho y_{t-1} + \sum \delta_j \Delta y_{t-j} + \varepsilon_t \qquad (22)$$

where α is a constant, ρ and δ are coefficients, j is the lag order of the autoregressive process and ε is the error term. The test is conducted under the null hypothesis $\rho = 0$, i.e., that the variable, y_t has a unit root. Table 1 shows the results of the OLS unit root tests.

Table 1: Unit Root Tests Statistics

Variables		Augmented Dickey-Fuller test statistic
DLOG(MILLET)		-4.938213
DLOG(WHEAT)		-6.381960
DLOG(SUGAR)		-5.472643
DLOG(SORGHUM)		-4.443528
DLOG(PULSES)		-4.036264
DLOG(RICE)		-6.760443
DLOG(CASSAVA)		-3.836593
DLOG(TEA)		-10.09482
DLOG(TOBACCO)		-4.420237
DLOG(MAIZE)		-4.529299
Test critical values (MacKinnon, 1996):	1% level	-3.959148
	5% level	-3.081002
	10% level	-2.681330

When compared with the MacKinnon critical values, the results indicate that all the variables are stationary as such we had to carry on with the regression analysis. However, if a number of variables had proven to be non-stationary then the route of co-integration analysis would have been considered.

The OLS Regression Results

As pointed out above, the ordinary least square estimation technique was applied as provided by the econometric package, EViews and the results are as indicated in Table 2.

Table 2: OLS Regression Results

Dependent Variable: DLOG(FOREST)

Variables	Coefficient		t-Statistic
DLOG(MAIZE)	-0.107		-3.73*
DLOG(TOBACCO)	-0.025		-2.41**
DLOG(CASSAVA)	0.005		0.36
DLOG(MILLET)	0.012		1.06
DLOG(PULSES)	-0.027		-2.20**
DLOG(SORGHUM)	-0.005		-0.66
DLOG(RICE)	-0.003		-0.49
DLOG(SUGAR)	0.189		1.19
DLOG(TEA)	0.080		1.10
DLOG(WHEAT)	0.003		0.37
C	-0.003		-1.72***
R-squared	0.88	F-statistic	7.15
Adjusted R-squared	0.76	Durbin-Watson stat	2.43

The *, ** and *** indicate significance at 1, 5 and 10%, respectively.

The overall performance of the model can be described as good. The adjusted R-squared indicates that the variables in our model explain 76 percent of deforestation in Malawi. The F-statistic, which tests the hypothesis of how well the model fits, is statistically significant and so is the D-W statistic, which tests for serial correlation.

The results indicate that the effects of changes in land use for maize, tobacco and pulses are statistically significant at 1 percent for maize and 5 percent for the other two crops. The results imply that 1 percent increase in land for maize will lead to 0.10 percent decline in forest cover while 1 percent increase in land for either tobacco or pulses would lead to nearly 0.03 percent decline in forest cover. The rest of the crop land changes appear to have no effect on deforestation and are therefore not discussed except for tea and sugar.

The regression results have two important implications. Firstly, they confirm the findings of most previous studies that agricultural land expansion explains much of the deforestation phenomenon in Malawi. As envisaged by Minde *et al*. (2001), the results in this study have established that indeed maize and tobacco production are responsible for much of the deforestation in Malawi with the former being the prime agent. Secondly, this study has shown that in addition to cultivation of maize and tobacco, growing of pulses is also responsible for deforestation in Malawi. This is important because traditionally studies on agriculture-led deforestation have largely revolved around two main suspects, namely maize and tobacco production. However, our findings may act as an eye opener to the fact that cultivation of other crops that have usually been overlooked may have the potential to harm the environment through deforestation. The main strength of these findings is that it is now possible to estimate the rate of deforestation based on the changes in either agricultural land or output of specific crops such as maize, tobacco and pulses as indicated by the following two equations.

$$Def = \epsilon_F \Delta Y_L \quad (23)$$

$$Def = \epsilon_F \Delta \left[\frac{Y_O}{\gamma}\right] \quad (24)$$

where, ϵ_F is the elasticity, indicating the responsiveness of forest cover to changes in land use of a particular crop, ΔY_L. Y_O is the total output and γ is the yield per hectare of a specific crop.

The estimated coefficients of tea and sugar are both statistically insignificant implying that there is no correlation between production of these two crops and deforestation. However, what can be deduced from this is that by employing technologically intensive agricultural methods, producers of these two crops have been able to increase yields without necessarily increasing the crop land area. This phenomenon can be of great help to policy makers especially with regards to designing policies that are meant to address poverty and environmental degradation simultaneously. For instance, the fertilizer subsidy that the Malawi Government is currently providing to the rural poor to reduce hunger, can be paired with the promotion of hybrid maize which would lead to farmers producing more output using less agricultural land and this would reduce pressure on the forest land. Currently, the average maize yield of about 1 200 kilograms per hectare is way below the potential yields of up to 10 000 kilograms per hectare of hybrid maize (USAID 2007). By adopting improved farming practices and varieties, particularly the hybrids, Malawi can not only help reduce poverty and hunger amongst its people but it can also contain deforestation.

CONCLUSIONS

Like is the case with many poor sub-Saharan African countries, deforestation is a serious problem in Malawi. This is mainly caused by the need to produce enough food to feed the mostly poor households. In addition, the need to grow cash crops such as tobacco and pulses has a negative effect on deforestation as well. The empirical evidence from our study has shown that cultivation of different crops has different effects on changes in forest cover. Maize production can be said to be the primary causative agent of deforestation in Malawi while tobacco and pulses are rated at second and third positions, respectively.

The Government of Malawi, like many others in sub-Saharan Africa, is currently faced with the twin problems of poverty and deforestation. Being agricultural based most poverty reduction policies are streamlined along the agricultural sector. Unfortunately, some agricultural policies that have been designed to reduce income poverty have on the other hand harmed the environment through deforestation. An understating of how much cultivation of each crop contributes to how much deforestation is therefore very crucial in helping policy makers to come up with policies that can strike a balance between the two. For instance, there is need to consider adoption of modern farming techniques and technology to ensure that maize farmers are able to produce more output from less land areas. In addition, there is need to ensure that property rights and secure ownerships are promoted especially amongst the poor. This may help local smallholders to consider the issue of reforestation more seriously than is the case today.

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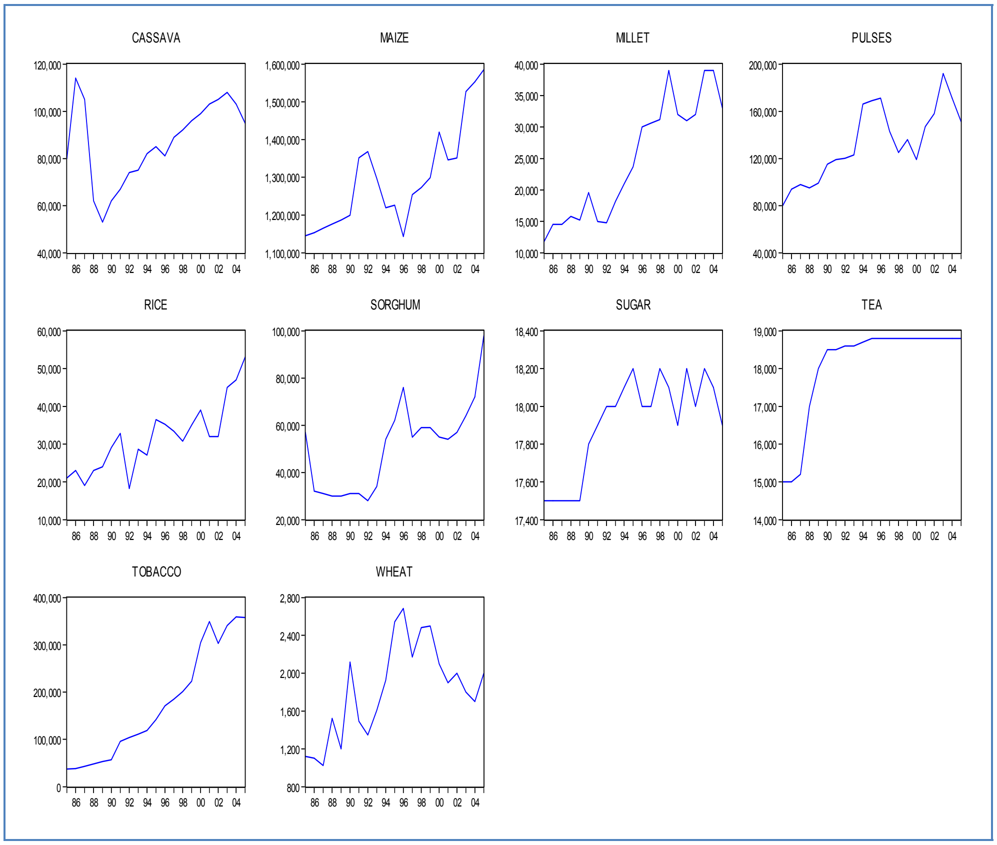
Appendix1: Figure 1: Agricultural Land Changes in Malawi

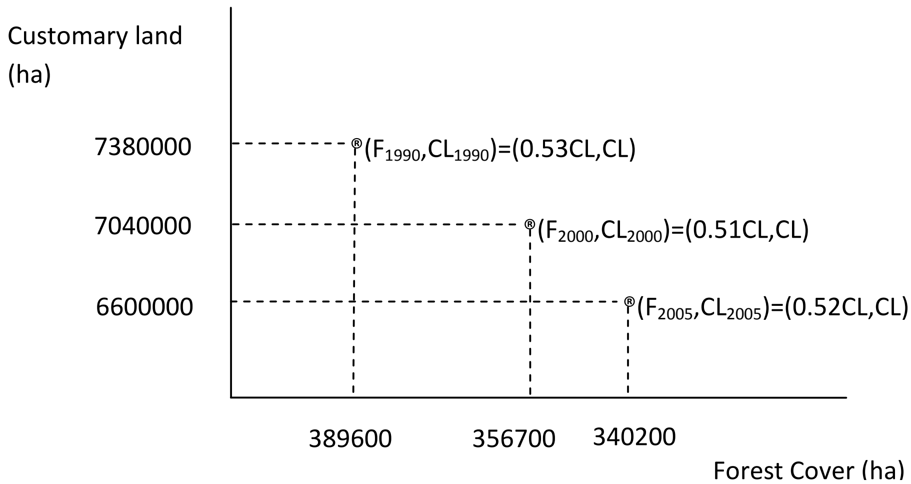


Appendix 2: Forest Cover Estimation Technique

For the purpose of this study, the forest change in Malawi is regarded as a geometric vector passing through three points $(F_{1990}, CL_{1990}), (F_{2000}, CL_{2000}) and (F_{2005}, CL_{2005})$. However, in Malawi forest cover is roughly half of the customary land (Mwase *et al*. 2007). This can be traced as far back as 1964 when land was demarcated into state-owned (public), leased and customary land in which nearly half of the customary land was forest cover. Over time, the size of the customary land has been decreasing.

Between 1964 and 1994, most of the customary land was converted into tobacco estate subsector under government directives. After 1994, chiefs and other local land owners started selling idle (forested) lands to mainly wealthy people who have usually turned these lands into agriculture. In addition, urbanization is said to have had its share of the customary land and deforestation, although this is debatable. In any cases, the reduction in customary land has largely been matched by the reduction in forest land area making the ratio of forest to customary land remain relatively stable as shown in Figure 2 below.

Figure 2: Customary Land and Forest Cover in Malawi



Sources: World Bank (2008) and GoM (NSO) (various)

From the above diagram it follows that if we have data on customary land then it is relatively easy to estimate the forest cover over the years. In this case, mid-point weighting was used to estimate forest covers between 1990 and 2005 while the forest cover data between 1985 and 1990 was estimated using the 1990 weight.