MALAWI'S SECOND NATIONAL COMMUNICATION TO COP OF THE UNFCCC

Mitigation Analysis for the Forestry and Land Use Sector

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August 2008

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Preface

This mitigation analysis report for the Forestry and Land Use Sector has been prepared as an input into the mitigation analysis of climate change in Malawi, for the Second National Communication to the COP of the UNFCCC. Other mitigation reports cover the key sectors of Energy, Agriculture, and Industrial Processes and Waste Management. The scope, outline and format of this report follow the requirements of the Second National Communication of Malawi.

The Forest and Land Use Sector is a major player in carbon mitigation. Forests absorb carbon as they grow and therefore establishing new forest plantations and protecting existing ones is an attractive way of removing greenhouse gases from the atmosphere. However, projects of this nature come at a cost. This report, therefore, examines the costs, benefits and impact associated with different forest mitigation options.

The report analyses two mitigation options: forest protection and conservation, and reforetstaion/afforestation options. Under each option the report gives the associated carbon pool and flows, monetary costs and benefits, and cost-effective indictors. It is hoped that with this information, right decisions can be made regarding the appropriate mitigation options that should be advocated in the Forest and Land Use Sector. It is also hoped that this report will provide the anticipated input into the mitigation analysis of climate change in Malawi and useful information for Malawi's Second National Communication to the COP of the UNFCCC, and that the recommended climate change project identified in this report will not be ignored.

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Forward

Acronyms and Abbreviations

AGB	Above Ground Biomass
BEF	Biomass Expansion Factor
BGB	Below Ground Biomass
BRAC	Benefits of Reduced Atmospheric Carbon
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
COMAP	Comprehensive Mitigation Analysis Process
COP	Conference of Parties
DOF	Department of Forestry
DREA	Department of Research and Environmental Affairs
EAD	Environmental Affairs Department
FAO	Food and Agricultural Organisation of the United Nations
Gg	Gigagram
GHG	Greenhouse Gas
Ha	Hectare
m3	Cubic Metre
Mk	Malawi Kwacha
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
NPV	Net Present Value
NSO	National Statistical Office
SSC	Swidish Space Corporation
tC	Tonnes of Carbon
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollar

Acknowledgements

We would like to thank the leader of the Mitigation and Abatement Team Prof. John D. Kalenga Saka for his supervision and coordination during the production of this report. His comments, suggestions and accredited expertise are very much appreciated. We also thank Mr Girland Mnensa for coordinating some activities of our work. Furthermore, we would like to thank the Climate Change Project Office, the Project Manager Dr Alex Saka, and the Environmental Affairs Department, for the technical support that they provided throughout the course of this assignment, and for the training and stakeholders consultative workshops that were organised. The knowledge and information obtained at these workshops and from various reports availed to us, and the comments that were made on our draft reports helped to shape the report in its current form.

We also wish to acknowledge the support that we received from the Malawi Polytechnic, Chancellor College, the Forest Research Institute of Malawi, and Mzuzu University. The encouragement and support that we got from the mitigation analysis team and the entire technical team of the Malawi Second National Communication to the COP of UNFCCC is highly appreciated.

EXECUTIVE SUMMARY

Forests in Malawi play an important role in both social and economic development of the country. Among the environmental services provided by forests is carbon sequestration. Carbon sequestration is the uptake and storage of carbon on land which reduces atmospheric accumulation and thus delays its impact on global climate.

The destruction of forests through burning and decaying of woody biomass results directly to significant contribution of carbon to the atmosphere. However, the expansions of forests and maintenance of existing stands can capture carbon from the atmosphere and maintain it on land over decades. Thus, it is important for Malawi to identify mitigation options in the forest and land use sector that would reduce the atmospheric accumulation of carbon.

The major objective of this assessment is to analyse the costs, benefits and impact of mitigation options in the forest and land use sector. In particular we want to identify a mix of options that is likely to provide the desired forestry products and services at the least cost and minimum negative environmental and social impacts.

In this assessment, a model called the Comprehensive Mitigation Analysis Process (COMAP) has been used. This model aims at finding the least expensive way of providing forest products and services while reducing most of the amount of carbon emitted from the land use sector.

The first step of the assignment was to identify and categorize the mitigation options that are suitable for implementation in Malawi. The next step was to determine the land that might be available for forestry and other uses. Alternative combinations of future land use patterns led to different mitigation scenarios of the future. The most-likely-trend pattern was chosen as the baseline scenario, against which the others were compared. Thus, the baseline scenario predicted the level of forest loss in the absence of any intervention measures. Based on this information, the potential for carbon sequestration and costs and benefits per hectare of each mitigation option were determined. This information was used to establish the cost effectiveness of each option and its ranking among other options. Furthermore, this information, in

combination with land use scenarios, was used to estimate the total and average cost of carbon sequestration or emission reduction.

Forest mitigation options include maintaining existing stands of the trees through reduced deforestation, or forest protection; expanding the stand of trees and the pool of carbon in wood products through reforestation programmes; and providing wood fuels as a substitute for fossil fuels. Two mitigation options have been analysed for Malawi, namely forest protection and reforestation. In the forest protection option, we assumed that adequate steps are taken to ensure that 3,336,000 hectares of forest land is effectively protected until 2040. The reforestation option takes into account the Tree Planting for Carbon Sequestration and Other Ecosystem Services Programme, initiated by the Malawi Government in 2007. The programme is to reforest about 24,125 hectares of degraded land within five years at a cost of approximately US$14.6 million.

A comparison of the results of the baseline and mitigation scenarios shows that under the baseline scenario, carbon pool declines from 543,767,171 tC in 2000 to 277,327,087 tC in 2040 while under the forest protection option it increases to 755,801,768 tC by 2040. Furthermore, the net benefit of forest protection for the baseline scenario declines from US$3,417,000 in 2001 to US$2,773,500 by 2040 while the net benefit of protection for each year is around US$31,557,100.

Under the reforestation option, the total pool of carbon for the baseline scenario is fixed at 1,905,875 tC per year. However, for the mitigation scenario, this increases to 2, 477,638 tC in 2007, 4,192,925 tC in 2010, and stabilizes at 4,764,688 tC per year from 2011 onwards. The total costs and benefits of reforestation in the baseline scenario amount to US$120,625 and US$241,250 per year respectively, giving a net benefit of US$120,625 per year. In the mitigation scenario, the net benefit of the programme increases from -US$6,320,437 in 2007 to -US$25,643,624 in 2010 and stabilizes at around -US$32,084,700 from 2011 to 2040.

Results from the analysis show that forest protection can reduce carbon emissions in Malawi at lower cost per tonne (or cost per hectare) than reforestation under the Tree Planting for Carbon Sequestration and other Ecosystem Services Programme.

Although the reforestation option gives higher costs than the protection option, it still has greater potential as a mitigation option. What is needed is detailed information on the amount and type of degraded land that is available for forest expansion. Thus, Malawi needs to carry out a comprehensive assessment of degraded land that is available for tee-planting, defined across silvicultural (forestry) zones, because cost per tonne of carbon (or per hectare) varies across land type and tree species. With such information, a new reforestation programme could be analysed.

1. INTRODUCTION

1.1 Background

Forests in Malawi play an important role in both social and economic development of the country. Forests supply about 93 percent of the country's energy needs, provide timber and poles for construction and industrial use, supply non-timber forest products for food security and income, support wildlife and biodiversity, and provide recreational and environmental services. Among the environmental services provided by forests is carbon sequestration. Carbon sequestration is the uptake and storage of carbon on land which reduces atmospheric accumulation and thus delays its impact on global climate.

Despite the important role that forests play in Malawi, the forest resources are under threat. For instance, in 1975, 57 % of Malawi was classified as forest while in 2000 only 28 % was classified as forest. Other records show considerable reduction in forestland from 4.4 million hectares in 1972 to around 1.9 million in 1992 (EAD, 1998; 2001; 2008).

The major causes of deforestation and the general degradation of the environment in Malawi are attributed to agricultural expansion, high population growth, increased woodfuel demands, and forest fires. The rapid expansion of agriculture from the mid 1975 to late 1980s led to extensive deforestation. Estate land increased from 67, 000 hectares in 1967 to 850,000 hectares by 1998. It is estimated that 95 % of rural households have only a hectare or less as farmland. Hence, smallholder farmers migrate on to steep slopes, riverbanks and/or encroach upon forest reserves in search of farmland, thereby, causing further forest and land degradation. However, it is estimated that the rate of deforestation has been declining. During the period when estate land was increasing, deforestation was around 3.5 % per annum. Later this rate declined to 1.6 %, probably because of lack of more arable land to be deforested (DREA, 1994). Deforestation rate is now estimated at 2.8 % per annum, but is highest in the northern region where the rate is at around 3.4 % per annum (EAD, 2001).

Malawi's population now estimated at around 12 million people, with a growth rate of about 2 percent per annum, exerts more pressure on forest resources (NSO, 1998). The demand for woodfuel for instance, exceeds available sustainable supply and the deficit is increasing every year. In 1999 the deficit was 5.8 million cubic metres and it is estimated to grow to 10 million cubic meters by the year 2010 (NEC, 2000). Household use, tobacco leaf curing, brick burning, fish processing, tea processing and beer brewing, amongst others, cause the high woodfuel demand.

Wildfires burn and destroy considerable amounts of forest resources every year. For example, in 2001, 64 fire-devastating incidences were recorded nation-wide, damaging a total of 1,520.04 hectares. This represented a decrease in hectares burnt since in the years 1998, 1999, and 2000 the total area burnt were 5,026.1, 1,912.34 and 1,657.8 hectares, respectively (DOF, 2002).

The destruction of forests through burning and decaying of woody biomass results directly to significant contribution of carbon to the atmosphere. However, the expansions of forests and maintenance of existing stands can capture carbon from the atmosphere and maintain it on land over decades. Thus, it is important for Malawi to identify mitigation options in the forest and land use sector that would reduce the atmospheric accumulation of carbon thereby delaying its impact on global climate change.

1.2 Objectives

The major objective of this assessment is to analyse the costs, benefits and impact of mitigation options in the forest and land use sector. In particular we want to identify a mix of options that is likely to provide the desired forestry products and services at the least cost and minimum negative environmental and social impacts.

2. MATERIALS AND METHODS

In this section we start by describing the model that was used in the assessment. Then we outline the assumptions that were made in the development of baseline scenarios. Finally we discuss the mitigation options that were adopted.

2.1 Model Description

2.1.1 Introduction

There are a number of methods and models that are used in mitigation analysis. The models can be categorised into top-down and bottom-up models. Top-down models are most useful for studying broad macro-economic and fiscal policies for mitigation such as carbon. They are mostly applied on a regional or international level. On the other hand bottom-up models are most useful for studying options that have specific sectoral and technological implications. They are therefore mostly used at national level. In this assessment a bottom-up model specific to the forestry sector has been used. This model called the Comprehensive Mitigation Analysis Process (COMAP) was chosen because it meets the objectives of this assessment. Furthermore, the same model was used in the first assessment and as such it would be easy to compare the two results.

2.1.2 COMAP model

COMAP is intended to guide an analyst in undertaking a comprehensive assessment of the role of the forest sector in a country's climate change mitigation effort (Sathaye and Meyers, 1995). It mainly aims at finding the least expensive way of providing forest products and services while reducing the amount of carbon most emitted from the land use sector (Makundi and Sathaye, 1999). In using the model, the following specific steps are followed:

a) Identification of mitigation options appropriate for carbon sequestration for the country;

b) Assessment of the current and future land area available for those mitigation options;
c) Assessment of the current and future wood-product demand;
d) Determination of the land area and wood production scenarios by mitigation options;
e) Estimation of the carbon sequestration per unit area for major available land classes, by mitigation option;
f) Estimation of the unit costs and benefits;
g) Evaluation of cost-effectiveness indicators;
h) Development of future carbon sequestration and cost scenarios;
i) Exploration of the policies, institutional arrangements and incentives necessary for the implementation option and
j) Estimation of the national macro-economic effects of these scenarios.

As presented by Sathaye and Meyers (1995) and Makundi and Sathaye (1999), the first step is to identify and categorize the mitigation options that are suitable for implementation in a country. The next step is to determine the forest and agricultural land area that might be available to meet current and future demand, both domestic and foreign, for wood products and for land. The demand for wood products may include that for fuel wood, industrial wood products and construction timber. Surplus land in the future, if available, may be used solely for carbon sequestration or other environmental purposes. On the other hand, in a country where not enough land may be available, wood demand may have to be met through increased wood imports or through substitute fuel sources. Thus, alternative combinations of future land use and wood product demand patterns will lead to different scenarios of the future. But the most-likely-trend pattern is chosen as the baseline scenario, against which the others are compared.

The mitigation options are then matched with the types of future wood-products that will be demanded and with the type of land that will be available. This matching requires iterating between satisfying the demand for wood products and land availability considerations. Based on this information, the potential for carbon sequestration and costs and benefits per hectare of each mitigation option are determined. This information is used to establish the cost effectiveness of each option and its ranking among other options. Furthermore, this information, in combination with land use scenarios, is used to estimate the total and average cost of carbon sequestration or emission reduction.

Assessment of the macro-economic effects of each scenario, on employment, balance of payment, gross domestic product and capital investment, may be carried out using formal economic models or assessment methods used by the country. However, for completeness of the mitigation assessment, an exploration of the policies, incentives and institutions necessary to implement each option, as well as the barriers that must be overcome need to be undertaken.

The COMAP framework is a spreadsheet model that runs in EXCEL. It has four main modules, namely: Forestation, Protection, Bioenergy and Biomass. With the exception of the Biomass module, the rest correspond to the main types of mitigation options in forestry. Each module has a set of sub-modules, which are used to analyze specific options.

2.1.3 Forestation option

This option includes all projects and policies intended to re-plant an area, ranging from natural reforestation, enhanced natural reforestation, afforestation, short rotation forestry, agroforestry, community and urban forestry, etc. Where non-forest tree plantations, such as rubber, are not included under agricultural sector mitigation assessment, then they can be analysed under this module as afforestation/reforestation options. The sub-modules are run under different land use categories with input data for area (ha), carbon density, rates of growth of biomass and cost and benefits. All modules are run for both baseline and mitigation scenarios. The model then calculates the annual changes in carbon stocks and the cost-effectiveness indicators associated with the scenarios.

2.1.4 Protection option

Some of the low cost and most effective mitigation options involve protecting the forests from being deforested and/or degraded, leading to carbon emission. There are a number of options which call for halting deforestation of a given forest in a region or conversion of a threatened forest into a protected area. The forest protection module uses data on area under relevant categories, biomass density, carbon stocks, carbon sequestration rates, and costs and benefits, to estimate the associated annual and cumulative changes in carbon stocks and the cost effectiveness indicators for the mitigation policy. This is done for both baseline and mitigation scenarios so as to obtain net reduction in carbon emission.

2.1.5 Bioenergy option

The bioenergy mitigation option analyses the substitution of GHG-intensive products, such as the use of sustainably grown biomass (biofuel), substituting fossil fuels. This may delay the release of carbon from the fossil fuels for as long as the fossil fuels remain unused. Other examples include the use of efficient stoves and charcoal kilns, wood-derived from renewable sources when used as a substitute for wood obtained from depleted natural forests, and the use of biomass products to replace emission-intensive products such as concrete, steel, and plastics.

2.1.6 Biomass module

The biomass module is actually a biomass balance module aimed at tracking demand and supply of forest products in the sector. This is important since one of the main roles of the forestry sector in any country is to meet the current and projected biomass demand, such as fuelwood, industrial wood, and sawn wood. These demands can be supplemented by imports when necessary. When the demand on biomass exceeds the rate of growth, a decline in the size of the forest estate (deforestation) or degradation of the biomass density becomes evident. Indeed, in many countries some of the mitigation options can not be implemented without arrangements for meeting biomass demands, including imports to cover biomass deficits.

Given the population increase and declining land productivity in many developing countries, more and more forestland is being converted to agricultural land for food production and other crops. Furthermore, forestland is also converted to infrastructure and human settlements. Thus, it is necessary to analyze the current and projected changes in land use patterns and the resulting changes in biomass supply, with a goal to match it with the demand on biomass. The biomass module is used to track the dynamics of land use patterns over time, including changes in biomass pools, product supply and demand.

2.2 Baseline scenario

This section describes the key assumptions that were made in the development of our baseline or likely trends scenario and the nature of input data used. It gives the current trends of land use in Malawi and describes the existing land use distribution among and within sectors, the rate at which land is being converted from one use to another and identifies the factors that lead to such land conversion. This sets the background for identification of mitigation options.

The main source of data for this analysis has been the various reports produced by the Food and Agriculture Organisation (FAO) of the United Nations, such as the State of the World's Forest reports (FAO, 2003; 2005a; 2007), the Global Forest Assessment reports (FAO, 2001; 2006), and the Global Forest Resource Assessment 2005: Malawi Country Report (FAO, 2005b). Additional information was obtained from the Malawi forest resources mapping and biomass assessment, undertaken jointly by the Department of Forestry in the Ministry of Mines, Natural Resources and Environment, and the SSC Satellitbild of SSC Swedish Space Corporation in 1992/93 (DOF,1993). Results from the Greenhouse Gases Inventory of Land Use Change and Forestry of 1994 and 2000 (see Tables 1 and 2) provided rough estimates of the quantities of green house gases that may be removed by different mitigation options.

Table 1: Summary of national green house gases inventory on land use change and forestry (in Gg) for 1994

Land use change and forestry	**CO_2 emission**	**CO_2 removals**	**CH_4**	**CO**	**N_2O**	**NOx**
Changes in forest and other woody biomass	14 003.02					
Forest conversion	2183		0.02	0.02	0.01	0.04
Abandonment of managed lands		1016				
CO_2 emissions from soils	2 342					
Net CO_2 emissions	17 512.02					

Source: Kainja a*t. al*., 2007

Table 2: Summary of national greenhouse gases inventory on land use change and forestry (in Gg) for 2000

Land use change and forestry	CO_2 emission	CO_2 removals	CH_4	CO	N_2O	NOx
Changes in forest and other woody biomass	14 003.02					
Forest conversion	2 182.62					
Abandonment of managed lands		889.4				
CO_2 emissions from soils	2 342					
Net CO_2 emissions	17 638.24					

Source: Kainja a*t.* a*l.*, 2007

2.2.1 Land area change

In this assessment, land in Malawi has been classified into inland water bodies, forest land, and other land. Inland water bodies include land for all major rivers, lakes and water reservoirs. Forest land is all land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10%, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use. Other land includes all land that is not classified as "Forest". Thus, it includes all land that is under agricultural and urban land use. Some of this land may have some tree cover for agroforestry or urban forestry purposes and is sometimes sub-categorised as "Other land with tree cover".

The total land for Malawi is the sum of these three categories and is estimated at 11,848,000 hectares. Table 1 shows the changes in land area for these categories from 1990 to 2005. The table shows that other land has been increasing overtime while forest land has been declining. The figures indicate that, in general there is an annual loss of 33, 000 hectares of forest land representing 0.9% (FAO, 2007). This rate has been used to project change in forest land for the baseline scenario. It is estimated that at this rate, forest land will decline to 2,247,000 hectares by 2040. The figures suggest that the decline in forest land is mainly due to the conversion of land from forestry to agriculture and urban developments.

Table 3: Changes in land area: 1990 – 2005

Category	Area (1,000 hectares)		
	1990	2000	2005
Forest	3,896	3,567	3,402
Other land	5,512	5,841	6,006
Inland water bodies	2,440	2,440	2,440
Total	11,848	11,848	11,848

Source: FAO (2007; 2005b)

2.2.2 Forest area change

In this assessment, forest land has been classified into primary (natural) forest land, modified (disturbed) natural forest land, and productive plantation forest land. Primary forest land is the forest land of native species, where there are no clearly visible indications of human activities and where the ecological processes are not significantly disturbed. It, therefore, includes some land in game reserves and national parks. Modified natural forest land is that land of naturally regenerated native species where there are clearly visible indications of human activities. Productive plantation forest land is the land of native or introduced species, established through planting or seeding mainly for the provision of wood or non-wood goods. It, therefore, includes all land for private and public forest plantations in Malawi. Thus, total forest area for each year is equal to the sum of these three categories.

Although total forest area has been declining, plantation forest and modified natural forest areas have been increasing over time while primary forest land has been declining together with the decline in total forest land. This information is depicted in Table 4. The figures in Table 4 imply that the annual loss of primary forest land was 595,000 hectares between 1990 and 2005 (FAO, 2005b). At this rate and without any mitigation measures, the area for primary forest is projected to decline to 142,000 hectares in 2030 and to completely disappear by 2040. Thus, the fall in forest land can be traced to the disturbance and loss of primary (natural) forests due to human activities (Table 4).

Table 4: Changes in Forest Area: 1990 – 2000

Category	**Forest Area (1,000 hectares)**			**Total forest area change (1,000 hectares)**
	1990	2000	2005	
Primary Forests	1,727	1,330	1,132	-595
Modified Natural Forests	2,037	2,057	2,067	+30
Productive Plantation	132	180	204	+72
Total	3,896	3,567	3,402	-493

Source: (FAO, 2005b)

2.2.3 Forest growing stock and biomass

In this assessment forest growing stock has been defined as volume over bark (o.b.) of all living trees more than 5 cm in diameter at breast height. It includes the stem from ground level or stump height up to a top diameter of 2 cm, and also includes branches to a minimum diameter of 2 cm. The average volume used is 109.5 m^3/ha (FAO, 2005b). This volume is more applicable to natural forests and not to planted forests.

Biomass has been divided into above-ground biomass (AGB) and below-ground biomass (BGB). It does not include dead wood biomass. Above-ground biomass is all living biomass above the soil including stems, stumps, branches, bark, seeds and foliage. Below-ground biomass is all living biomass of live roots. Fine roots of less than 2 mm diameter are excluded because these often cannot be distinguished empirically from soil organic matter or litter. The calculation of biomass is based on growing stock and is given by:

AGB = Growing stock * wood density * BEF

BGB = AGB * 0.24

where wood density = 0.58 tonnes/m^3, and BEF (biomass expansion factor[1]) = 1.2. The factor 1.2 has been used considering that branches down to 2 cm were included in the growing stock figure (FAO, 2005b).

[1] A factor for converting volume (in cubic metres) to biomass (in tonnes)

2.3 Mitigation Options

Major mitigation options for the forestry sector can be classified into two basic types. The first type involves expanding the stand of trees and the pool of carbon in wood products, and the second type involves maintaining the existing stands of the trees and proportion of forest products currently in use. Expansion of tree stands withdraws carbon from the atmosphere and maintains it on land. Maintaining existing stands can be achieved through reduced deforestation, forest protection, or more efficient conversion and use of forest products. It, therefore, keeps the avoided carbon emissions from entering the atmosphere for the duration of the pool maintenance.

There is another way of reducing carbon emissions which involves the use of wood obtained from renewable sources like forest plantations as a substitute for non-renewable emission sources, such as fossil fuel. This substitution delays the release of carbon from the fossil fuel for as long as one continues to use wood from a renewable source instead of the fossil fuel. In the same way, wood derived from sustainable sources, can be used as a substitute for wood fuel derived from depletable natural forests. This also delays carbon release from the unsustainable sources (Sathaye and Meyers, 1995).

Based on the baseline scenario outlined above, it is apparent that Malawi needs two interventions in order to check forest depletion. The first intervention should involve maintaining existing stocks through forest protection and conservation and the second intervention should involve expanding carbon sinks through reforestation and afforestation. Afforestation is the planting of forests in bare land while reforestation is the replanting or natural regeneration of deforested land. The difference between the two terms depends on the period of time that land has remained bare.

It is hoped that mitigation options in the bio-energy field will be assessed under the energy sector. It is also expected that agroforestry as a mitigation option to expand carbon sinks will be dealt with in the agricultural sector.

2.3.1 Forest protection and conservation

From the baseline scenario, it has been established that Malawi loses an average of 33,000 hectares of forest land every year. It has further been noted that within the forest sector, an average of 39,600 hectares of primary forest land is being lost every year due to human encroachment. It, therefore, follows that one of the measures that the Malawi government need to undertake is to protect primary forests.

Thus, in the mitigation scenario, it is assumed that adequate steps are taken to ensure that the area is protected and that the 3,336,000 hectares of forest land projected for 2007 remains protected until 2040. In particular, we assume that improved forest protection can be attained by providing adequate financial resources to the departments involved in forest protection and management. With adequate financial resources, the departments will be able to improve their fire control measures, and law enforcement activities such as confiscating more illegal forest products like charcoal, firewood and timber, and arresting more encroachers. Thus, the departments will be able to effectively reduce forest fires, illegal cutting down of trees, charcoal burning, agricultural encroachments and other practices that degrade natural forests. In this way, protection will check the increase in carbon emissions entering the atmosphere.

2.3.2 Reforestation/afforestation option

The reforestation/afforestation mitigation option depends on the availability of suitable land for tree-planting. The question that is often asked is whether developing countries, such as Malawi, have enough land for climate mitigation activities. At a glance, the high population densities and low agricultural productivity may suggest that there might not be enough land to be used for forestation programmes. However, when an assessment of degraded land[2] is undertaken in a country, the results usually show large amounts of degraded land available for forestation (Makundi and Satahye, 2004; Sathaye *et al*., 2001, Nijnik, 2005). Assessments of this type may also provide information on the tree species that are suitable for land under a particular silvicultural (forestry) zone, and on estimated costs and benefits of afforestation for each spatial unit of the forest classification (Nijnik, 2005). Malawi is yet to carry out

[2] This is land that either originally contained forests or that has been left fallow and agriculture is no longer practiced for various social and economic reasons.

such a comprehensive assessment of degraded land that is available for tee-planting, defined across silvicultural zones.

This mitigation option has, nevertheless, been incorporated to account for the Tree Planting for Carbon Sequestration and Other Ecosystem Services Programme, initiated by the Malawi government in 2007. The overall objective of the programme is to increase the area under forest cover in Malawi in order to enhance carbon sequestration and other ecosystem services that contribute to the reduction of greenhouse gases, in particular carbon dioxide, in the atmosphere. The programme promotes tree planting and forest management by households and institutions. This programme will enable Malawi to contribute to the attainment of the objective of the United Nations Framework Convention on Climate Change (UNFCCC), which aims at promoting the stabilization of the emissions of man-made greenhouse gases into the atmosphere.

The programme is being implemented in all the 193 constituencies of the country. Individuals and farm families are provided with inputs and training so that they can create their own tree nurseries and tree plantations. Participants in this programme are required to devote some land to tree management for a period ranging from 15 to 30 years depending on the tree species planted. Fast growing indigenous and exotic tree species are being promoted such as *Khaya anthotheca* (mbawa) and *Eucalyptus* spp. (bluegum). Each constituency has an allocation of 5 farmers growing 3 to 5 hectares of trees, thereby creating a national wide maximum of 4,825 hectares of plantation annually and a total of 24,125 hectares in the initial five years. The estimated cost for the initial 5 years of the programme is about MK2 billion (approximately US$ 14.6 million[3]) (Malawi Government, 2006).

3. MITIGATION ANALYSIS RESULTS AND DISCUSSION

For simplicity, the mitigation analysis results are presented by option. Under each option we analyse and present carbon pool and flows, monetary costs and benefits of mitigation, and cost-effectiveness indicators. The scenarios are projected up to 2040

[3] At a rate of 1US$ = K137.

with 2000 as the base year. We start with the forest protection and conservation option.

3.1 Forest Protection and Conservation Option

In this scenario, it is assumed that adequate steps are taken to ensure that 3,336,000 hectares of forest land projected for 2007 remains protected until 2040. The protection intervention started in 2007 (Appendix 1).

3.1.1 Carbon sequestration

In order to determine the carbon pool and sequestration under the forest protection option, biomass density, soil carbon density and carbon content of biomass were used. In the baseline scenario, we started with a biomass density of 95 tonnes /hectare for the year 2005 (FAO, 2007). We assume that the biomass density declines at a rate of 2% per annum under the baseline scenario but that it increases at a rate of 2% per annum under the mitigation scenario. Thus, under the baseline scenario, biomass density declines to 47 tonnes per hectare in 2040 while under the mitigation scenario it rises to 175 tonnes per hectare.

Carbon density in living biomass is obtained by multiplying the biomass density by a carbon ratio (C%) for each scenario. The carbon ratio varies between 0.45 and 0.55 for most vegetation. In this analysis, we assume that the carbon ratio is 0.5 and that it is the same for both baseline and mitigation scenarios. Thus, biomass carbon declines from 52 tC/ha in 2000 to 23tC/ha in 2040 in the baseline scenario but increases to 88tC/ha in the mitigation scenario. We also assume that the soil carbon density remains unchanged at 100tC/ha in the baseline scenario but that it increases at a rate of 1% per year in the mitigation scenario, thereby reaching a level of 139tC/ha in 2040. Adding the biomass and soil carbon density gives the total carbon density for each year under each scenario. Total carbon density deceases from 152 tC/ha in 2000 to 123 tC/ha in 2040 for the baseline scenario but increases to 227tC/ha in the mitigation scenario.

Multiplying the total carbon density (tC/ha) by the land area (ha) under each scenario gives the pool (tC) of carbon for each year. Since the carbon density and the land area decline in the baseline scenario, carbon pool also declines from 544 million tC in 2000 to 277 million tC in 2040. In the mitigation scenario carbon pool increases to 756 million tC by 2040 (Figure 1).

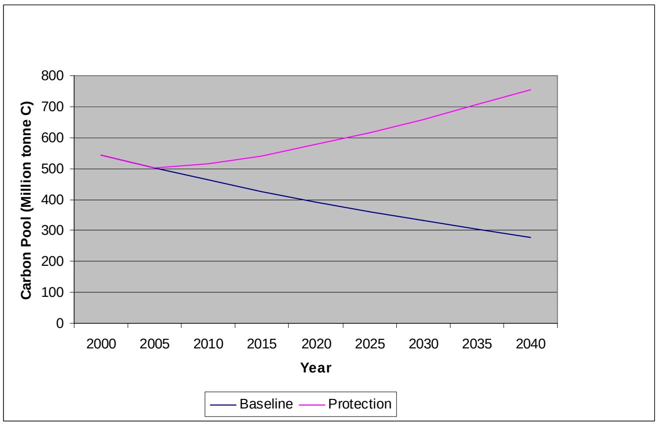

Figure 1: Carbon pool under forest protection option

3.1.2 Monetary costs and benefits

In the baseline scenario, the cost of forest protection is set to be US$1.5/ha/year. This has been estimated based on the actual budget expenditure of Viphya Plantations (DOF, 2001). It has been used on the assumption that forest areas in Malawi are poorly protected due to the insufficient funds actually spent for forest protection and management. In the mitigation scenario, the cost of forest protection increases to US$5/ha/year. This is based on the approved budget estimates for the Viphya Plantations (DOF, 2002) which we assume if actually disbursed could provide adequate protection to the area.

An average figure of US$50/ha/year has been used in the baseline scenario as the opportunity cost of land or the benefits from land conversion. This is based on the fact that some of the land is converted to commercial farming such as tobacco growing while some of it is used for subsistence farming. Thus, the land that is used for commercial farming will have conversion benefits that will be greater than

US$50/ha/year while those used for subsistence farming will have conversion benefits which will be less than US$50/ha/year. There is no opportunity cost of land under the mitigation scenario since no land conversion occurs under the forest protection option. For benefits of protection a default value of US$2/ha/year has been used in the baseline scenario but this has been increased to US$15/ha/year since mitigation reduces degradation of the vegetation in the protected areas.

Total costs and benefits are determined by aggregating the costs and benefits for the baseline and mitigation scenarios. Thus, the net benefit for the baseline scenario for each year is obtained by subtracting the total cost of protection from the sum of all benefits of land conversion and the benefits from forests. The net benefits for the baseline scenario decline from US$3,417,000 in 2001 to US$2,773,500 by 2040. The net benefit for the mitigation scenario for each year is obtained by subtracting the sum of all costs of protection including the opportunity cost of land from the total benefits of protection. The net benefit of protection for each year is US$31,557,089.

The present value of the stream of costs and benefits are computed using a discount rate of 10%. Although there is no agreement on the right discount rate to use, higher (commercial) rates are recommended for private investment projects and lower rates are recommended for social projects. In general, reducing the discount rate say to 5% makes the project more favourable while increasing the discount rate say to 15% makes it less favourable.

3.1.3 Cost-effectiveness indicators

COMAP model generates a number of cost-effectiveness indicators which can help us to compare and select from different mitigation options. These indicators include net present value (NPV) of benefits per hectare and per tonne of carbon, initial cost of forest protection per hectare and per tonne of carbon, present value costs (endowment cost) per hectare and per tonne of carbon, and the benefits of reduced atmospheric carbon (BRAC).

The NPV of benefits provide the net direct benefit to be obtained from a project or a mitigation scenario. In this mitigation scenario, the NPV of benefits is US$0.29/tC or

US$39/ha. It must be noted that our protection option includes indirect benefits of forest protection.

Initial cost of protection does not include future discounted investments costs needed during the implementation of the option. This indicator simply provides information on the amount of resources required to establish the project. The initial cost of protection is US$0.04/tC or US$5/ha.

The present value of costs is the sum of establishment costs and the discounted value of all future investment and recurring costs during the lifetime of the project. This indicator is useful because it provides the endowment necessary to maintain the project for its duration. The endowment requirements for the protection option is US$0.35/tC or US$47/ha.

The BRAC indicator expresses the net present value of a project in terms of the amount of atmospheric carbon reduced, taking into account the timing of emission reduction and the atmospheric residence of the emitted carbon. Thus, it estimates the benefit of reducing atmospheric carbon instead of reducing net emissions. The BRAC for the protection option is US$0.022/tC per year.

3.2 Reforestation/afforestation Option

Under this mitigation option, 4,825 hectares of land is to be reforested each year starting from 2007 to 2011 bringing in a total of 24,125 hectares of additional forest land by 2011 (Appendix 2). The carbon gains, costs and benefits and the cost-effectiveness indicators of this project are presented below.

3.2.1 Carbon sequestration

The information needed to estimate carbon pools for the reforestation option include biomass density, soil carbon density, and carbon content of biomass. In the baseline scenario, we assume that the biomass density remains fixed at 20 t/ha until 2040. We also assume a carbon ratio of 45% since the land is taken to be degraded. Thus, multiplying the biomass density by the carbon ratio gives the carbon density of 9 tC/ha per year. The soil carbon density is assumed to be 70 tC/ha, again since this is assumed to be degraded land with a lot of human disturbances like cultivation. Thus, in the baseline scenario, the carbon pool is estimated at 79 tC/ha.

Reforestation in the mitigation scenario has the potential to increase carbon density through increased carbon in vegetation, soil, decomposing matter and wood products. For vegetation carbon, we assume that the planted species has a rotation period of 15 years, a yield (mean annual increment) of 12 tonnes of biomass per hectare per year, and a carbon ratio of 0.5 (since this is under forestry). We also assume that soil carbon increases at 2 tC/ha over the rotation period of 15 years, and then remains fixed in the soil in perpetuity. Decomposition is equivalent to storing carbon. Thus, the decomposition of biomass on land also creates a stock of carbon. In this analysis we assume that the decomposition period is 6 years, and that the amount of decomposing carbon left behind is 6 tC/ha/year. If the forest products are renewed continually, they store a stock of carbon over an infinite period. The amount of carbon stored in the form of products will depend on the product life. The longer the product life the more carbon will be stored away. In this assessment, we assume that the average product life is 30 years, and the amount of carbon in the product is 30 tC/ha.

The total stored carbon by the mitigation option is the sum of carbon in vegetation, soil, decomposing matter and wood (forest) products. This amounts to 128 tC/ha. The pool of carbon for the reforestation scenario is the sum of carbon stored by the mitigation scenario and the baseline soil carbon. This gives a pool of 198 tC/ha.

Multiplying the total carbon density (tC/ha) by the land area (ha) under each scenario gives the total pool (tC) of carbon for each year. For the baseline scenario, this is fixed at 1,905,875 tC per year. However, for the mitigation scenario, this increases to 2, 477,638 tC in 2007, 4,192,925 tC in 2010, and stabilizes at 4,764,688 tC per year from 2011 to 2040 (Figure 2).

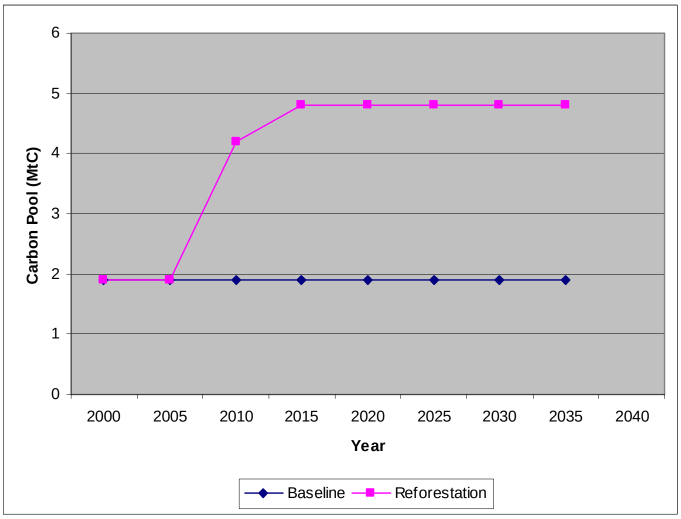

Figure 2: Carbon pool under reforestation option

3.2.2 Monetary costs and benefits

In the baseline scenario, the cost of reforestation has been assumed to be $5/ha/year. In the mitigation scenario, reforestation incurs initial (establishment), recurrent, and monitoring costs. These costs have been estimated from the Tree Planting for Carbon Sequestration and other Ecosystem Services Programme budget. According to the programme budget, the average establishment cost is about US$616/ha, recurrent cost is US$4/ha, and monitoring cost is US$8/ha (Malawi Government, 2006).

In the baseline scenario, the annual benefits obtained from working the degraded lands have been assumed to amount to US$10 /ha. For the mitigation scenario, the benefits are derived from the sale and utilisation of non-timber forest products such as firewood, honey, mushrooms, orchids, etc, management incentives, and carbon trade. It is assumed that there will be no timber production in this programme. A non-timber benefit of US$5/ha is assumed for 2007, and this increases overtime to a modest maximum of US$15/ha in 2015. According to the programme document, the government is to provide incentives to the participants of this programme. The incentives include a payment of US$234 per hectare in the first and second year for successful planting, managing and protecting the trees, and US$117 per hectare in years 3 to 5 for effective protection and management of the trees. It has been assumed that the sell of carbon will take place in the year 2012 after the establishment phase. A conservative price of US$6 per tonne of carbon has been used.

The total costs and benefits of the wastelands in the baseline scenario amount to US$120,625 and US$241,250 per year, respectively, giving a net benefit of US$120,625 per year. In the mitigation scenario, the present value of benefits is US$1,348/ha while the present value of costs is 1,468/ha, giving a net present value of benefits of -US$120 per hectare[4]. The negative value of the net present value of benefits could be as a result of the huge initial costs incurred during the establishment phase and the modest values of the non-timber forest products used. The net benefit of the reforestation programme per year is obtained by subtracting the sum of the annual cost of wasteland and the cumulative cost of converted land from the sum of the annual benefits from wasteland and the cumulative benefit from converted land. Thus, the net benefit of the programme increases from -US$6,320,437 in 2007 to -US$25,643,624 in 2010 and stabilizes at -US$32,084,686 from 2011 to 2040.

3.2.3 Cost-effectiveness indicators

The following are the cost-effectiveness indictors generated by the COMAP model. The NPV of benefits provided by the reforestation programme is -US$50.54/tC or -US$5,989/ha. This is not surprising considering that the programme has very high establishment costs averaging US$616/ha. The average cost of establishing a forest plantation, excluding the opportunity cost of land was estimated to range from US$230 to US$1000 per hectare with an average of US$400 per hectare (Sathaye and Meyers, 1995 cited from Sedjo and Solomon, 1988). The initial cost of reforestation is US$5.1/tC or US$601/ha. which is equally high compared to the protection option. The endowment requirements for the reforestation option is US$55.81/tC or US$6613/ha, and the benefit of reducing atmospheric carbon instead of reducing net emissions (BRAC) is -US$0.38/tC per year.

[4] The present values of stream of costs and benefits are computed using a discount rate of 10%.

4. SUMMARY AND RECOMMENDATIONS

The major objective of this assessment was to identify carbon mitigation options and analyse their costs, benefits and impact in the forest and land use sector in Malawi. In particular we wanted to identify a number of options that are likely to provide the desired forestry products and services at the least cost and minimum negative environmental and social impacts.

Forest mitigation options include maintaining existing stands of the trees through reduced deforestation, or forest protection; expanding the stand of trees and the pool of carbon in wood products through reforestation programmes; and providing wood fuels as a substitute for fossil fuels. Two mitigation options have been analysed for Malawi namely forest protection and reforestation. In the forest protection option, we assumed that adequate steps are taken to ensure that 3,336,000 hectares of forest land is effectively protected until 2030. The reforestation option takes into account the Tree Planting for Carbon Sequestration and Other Ecosystem Services Programme, initiated by the Malawi Government in 2007. The programme is to reforest about 24,125 hectares of degraded land within five years at a cost of approximately $14.6 million. These mitigation options have been analysed using the COMAP model.

Results from the analysis show that forest protection can reduce carbon emissions in Malawi at lower cost per tonne (or cost per hectare) than reforestation under the Tree Planting for Carbon Sequestration and other Ecosystem Services Programme. However, our approach assumes that the major factor contributing towards poor forest protection in Malawi is inadequate financial resources provided to protection agencies. Government funding to forestry, national parks and game reserves has been very low in most cases although there are some improvements. Thus, reversing the current trend in forest degradation will require a lot of resources and new commitments from the government, the private sector and non-governmental organisations. The resources will have to be used efficiently in improving human resources and providing the required facilities and equipment. But since resources could be just one factor, we recommend further investigation on non-monetary measures that could be undertaken to ensure that forests are effectively protected.

Although the reforestation option gives higher costs than the protection option, it has greater potential as a mitigation option. What is needed is detailed information on the amount and type of degraded land that is available for forest expansion. Thus, Malawi needs to carry out a comprehensive assessment of degraded land that is available for tee-planting, defined across silvicultural (forestry) zones, because cost per tonne of carbon (or per hectare) varies across land type and tree species (Appendix 3). With such information, a new reforestation programme could be analysed.

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APPENDICES

Apendix 1. Protection Option (Excel File attached)

Appendix 2. Reforestation Option (Excel File attached)

Appendix 3: Proposed Climate Change Project

Title: Comprehensive Assessment of Land Use in Malawi for Carbon Mitigation Programmes.

Background

Reforestation/afforestation option has great potential as a measure of mitigating climate change. However, this depends on the availability of suitable land for tree-planting. The question that is often asked is whether developing countries, such as Malawi, have enough land for climate mitigation activities. At a glance, the high population densities and low agricultural productivity may suggest that there might not be enough land to be used for forestation and other climate change mitigation programmes. Indeed, the world wide increase in the production of crops for bio-fuels has been named as one of the contributing factors to the current food crisis. However, when an assessment of land use is undertaken in a country, the results usually show large amounts of degraded land[5] available for forestation and other climate change mitigation programmes. Assessments of this type may also provide information on the tree species that are suitable for land under a particular silvicultural (forestry) zone, and on estimated costs and benefits of afforestation for each spatial unit of the forest classification.

In Malawi there is an increase in the number of activities that are being undertaken with the aim of mitigating climate change such as reforestation of degraded lands for carbon trade and establishment of Jatropha curcus plantations for bio-fuels. However, it is not known whether Malawi has adequate land to support these activities. What is urgently needed therefore is a comprehensive assessment of land use pattern in Malawi to act as a guide on how these mitigation programmes should be implemented.

[5] This is land that either originally contained forests or that has been left fallow and agriculture is no longer practiced for various social and economic reasons.

Objectives

The overall aim of this project is to provide detailed information on the scale and type of land that is available for forest expansion and other climate mitigation programmes, thereby updating Malawi's land use plans and silvicultural (forestry) zones.

In particular the project may among other things aim to:

- Determine the current land use pattern in Malawi
- Make projections on changes in land use patterns for Malawi
- Identify available land for tree-planting and other climate change programmes
- Specify silvicultural zones (type of land and associated species) for the forest land