Title

Comprehensive mitigation assessment process (COMAP) - Description and instruction manual

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Comprehensive Mitigation Assessment Process (COMAP) –
Description and Instruction Manual

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Part I: BACKGROUND

1.0 Introduction

In order to prepare policies and plans to reduce GHG emissions, national policy-makers need information on the costs and benefits of different mitigation options in addition to their carbon implications. Policy-makers must weigh the costs, benefits, and impacts of climate change mitigation and adaptation options, in the face of competition for limited resources. The policy goal for mitigation options in the land use sector is to identify which mix of options is likely to best achieve the desired forestry service and production objectives at the least cost, while attempting to maximize economic and social benefits, and minimize negative environmental and social impacts.

Improved national-level cost estimates of response options in the land use sector can be generated by estimating the costs and benefits of different forest management practices appropriate for specific country conditions which can be undertaken within the constraint of land availability and its opportunity cost. These cost and land use estimates can be combined to develop cost curves[1,2], which would assist policy-makers in constructing policies and programs to implement forest responses.

1.2 Previous approaches to Mitigation Assessment

The analyses of the costs, benefits, and economics of forest response options have varied in the extent and treatment of components, which should be included in the analysis of mitigation options. Table 1 summarizes the components arranged from those commonly included to those least addressed in the analyses.

Studies of the costs of mitigation options have evolved in complexity and specificity of data over the last few years. The initial studies[3,4,5] assumed a large programmatic goal and estimated land requirements and vegetation growth rates to meet it. These studies have largely been replaced by more detailed bottom-up studies[6,7,8,9,10]. The Bottom-up studies use economic and physical data at the project and mitigation option level and report results at the national, regional or global level. However, they do not capture the dynamics of the wood-product and land-use market explicitly. Dynamic studies[11] portray forest product markets, and include timber prices either exogenously or endogenously, and allow land to move between forests and other land uses in response to changes in price or land availability constraints. Such studies are more appropriate to industrialized countries where property rights are well defined and there exists functioning formal markets for wood-products and for land. Since these conditions only obtain at varying degrees in developing countries, the bottom-up approach as described in this paper would be more suited for mitigation analysis in the land use change and forestry sector.

Table 1. Components addressed in mitigation assessments

1.	Infrastructure and establishment costs
2.	Land and growing stock costs (opportunity)
3.	Monetary benefits (revenue)
4.	Non-monetizable costs and benefits
5.	Net present value of continuous rotations over a fixed (e.g., 50 years) or infinite period (perpetual)
6.	Capital requirements
7.	Project or regional economic impacts
8.	Macroeconomic impacts at national level
9.	Other environmental impacts (biodiversity, water quality)

The past approaches in analyzing mitigation options have been most useful in analyzing individual projects and/or programs in the land use sector. In order to achieve the policy goal of reducing GHG emissions while providing the desired goods and services from the sector at a minimum cost, one needs to use a comprehensive approach. The approach described here has been used in many country-level studies[12], and was specifically used in the UNEP study on Economics of GHG Limitation.

In part II of this paper, we briefly describe the framework of analysis, with specific attention on key concepts and terms used in mitigation analysis, and also on the description of the cost-effectiveness indicators needed to compare and rank different mitigation options. In part III we present the structure of the model used to undertake mitigation assessment, with a step by step description of two modules, one covering reforestation and the other dealing with forest protection. Also presented is a third module for balancing the demand and supply of biomass in the sector under different assumptions on baseline and mitigation projections. In the Appendix we describe and present solved examples of mitigation assessment of the reforestation and forest protection options with the corresponding biomass balance. A brief list of generic mitigation options in land use and forestry is also appended, and they are not restricted to the current list of included activities in the sector under the Kyoto Protocol[13].

Part II: THE FRAMEWORK OF ANALYSIS

2.0 Brief Description

The COMAP approach is mainly dependent on finding the least expensive way of providing forest products and services while reducing the most amount of carbon emitted from the land use sector. The approach consists of the following key steps:

(a) identification and categorization of the mitigation options appropriate for carbon sequestration for each country
(b) assessment of the current and future land area available for these mitigation options
(c) assessment of the current and future wood-product demand
(d) determination of the land area and wood production scenarios by mitigation option
(d) estimation of the carbon sequestration per unit area for major available land classes, by mitigation option
(e) estimation of the unit costs and benefits
(f) evaluation of cost-effectiveness indicators
(g) development of future carbon sequestration and cost scenarios
(h) exploration of the policies, institutional arrangements and incentives necessary for the implementation of options
(i) estimation of the national macro-economic effects of these scenarios (not reported in this paper)

The first step in the approach 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. Demand for wood products includes that for fuel wood, industrial wood products, construction timber, etc. Potentially surplus land in the future may be used solely for carbon sequestration or other environmental purposes. On the other hand, in many countries not enough land may be available, in which case some of the wood demand may have to be met through increased wood imports or through substitute fuel sources. Alternative combinations of future land use and wood product demand patterns will lead to different scenarios of the future. The most-likely-trend scenario 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 the costs and benefits per hectare of each mitigation option are determined. The carbon and cost and benefit information is used to establish the cost-effectiveness of each option, which yields its ranking among other options. In addition, the 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 payments, gross domestic product, capital investment, may be carried out using formal economic models or a simple assessment methodology.[14] For completeness of the mitigation assessment, one should identify and explore the policies, incentives and institutions necessary to implement each option, as well as the barriers that must be overcome.

2.1 Main Types of Mitigation Options in Forestry.

The main purpose of forestry mitigation options is terrestrial carbon storage, which would reduce atmospheric accumulation and thus delay its impact on global climate. Mitigation options may be classified into three basic types.[15] One option is to expand vegetation stocks and the pool of carbon in wood products. Expansion of stocks will capture carbon from the atmosphere and maintain it on land over decades. The second option is to maintain the existing stands of trees and the proportion of forest products currently in use. Maintenance of existing stands, whether achieved through reduced deforestation, forest protection, prolonged useful lifetime of products or through improved cook stoves, lengthens the duration the carbon stays trapped in terrestrial ecosystems and provides immediate carbon benefit. A third avenue to reduce carbon emissions is to substitute wood derived from renewable sources, e.g., plantations, for more GHG-intensive products, particularly fossil fuels[16]. Fossil fuel substitution with biomass derived from sustainably managed renewable sources delays the release of carbon from substituted fossil fuel indefinitely and may increase the standing stock of carbon on land if the biomass is from newly afforested/reforested areas. An expanded list of generic mitigation options in the sector is presented in Appendix 3.

2.2 Land Use and Wood-Product Demand:

The technical availability of land for the implementation of response options does not appear to be an important constraint to carbon sequestration in the tropics[17]. Dixon *et. al.* (1991) concluded that land technically available in the tropics for expanded management and agroforestry ranged from 620 million to 2 billion hectares[18]. A subsequent survey concluded that 950 million hectares might be available.[19] Whether technically available lands are ever used for biomass growth depends on economic, political, demographic, social, cultural, and other factors. Based on interviews with experts, Trexler *et. al.* (1991) reported that it was socio-economically feasible to utilize about 69% of the technically available land.[20]

2.3 Scenarios:

An important element of the approach is the development of scenarios of land use and wood products demand. These scenarios depict the amount of wood that would be demanded as well as the land area that could be consequently sequestering carbon over time. The amount of sequestered carbon that can be potentially stored, and the associated cost varies with the types of options that are included in the scenarios.

Although different types of scenarios can be envisioned, this approach encourages the use of two main scenarios, that is a baseline and a mitigation scenario. The baseline serves as a benchmark for determining the additionality in carbon stored through the mitigation policies.

A common method used to specify a baseline scenario is extrapolation of current trends of land use, tree planting and forest protection as well as consumption of forest products and services. A recommended method in this approach is to use end-use scenarios, which are mainly driven by the projections of the demand for wood products and for land in a country. The end-use approach has been used extensively to understand the magnitude of future demand for energy[21,22]. However, while it has been used routinely to determine the future demand for forest products[23], the use of this approach has not been reported in the climate change mitigation context.

End-use scenarios have the advantage that they take into consideration an end-user's needs for forest products and land. In tropical countries, where wood may be scarce and forests are used as sources of many non-timber products, planting trees for carbon storage alone may not be sustainable or politically justifiable. The trees will most likely be cut and used for their varied products. Thus, forestry mitigation options that provide multiple and adequate benefits, including carbon storage, to a diverse set of beneficiaries are more likely to be implemented and managed sustainably.[24] In order to satisfy our central assumption that tree stock should be maintained in perpetuity, it is important that all participants in an option be adequately compensated. An end-use based approach, which explicitly recognizes the needs of the participants, is likely to yield more plausible and sustainable future scenarios than other scenario construction approaches.

2.4 Key terms and Concepts used in COMAP

***(i) Carbon Flows in Land use sector*:**

The aforementioned mitigation options either maintain or expand the stock of carbon in biomass, soil and/or wood products. Two approaches have been used in the past to evaluate the value of stored carbon. The "plant and store" approach assumes that trees will be planted for the purpose of storing carbon and will not be harvested after they grow to maturity.[25] Hence, it suggests that carbon stock be estimated on the basis of the amount accumulated in forest biomass, soil, and litter over a period of time. The time period may be that of a single rotation or of multiple rotations. The "sustainable rotations" approach assumes that carbon will need to be stored for an indefinite period. In this approach, we estimate the amount of stored carbon on the basis of an average amount of carbon on-site over an indefinite number of rotations.[26] Harvested stock can be stored in pools (e.g., wood products) or substituted for fossil fuels at harvest or at the end of the products' useful lifetime.

A modified version of the second approach has been used by Swisher[27], which adjusts average stock for the biomass remaining at maturity. Swisher also includes the carbon in soil, litter and understory and wood products in estimating the total carbon storage. It should be noted that none of the mentioned methods for carbon flow estimation in the forest sector take into account the amount of carbon which may be removed from the site by natural processes like erosion and sequestered elsewhere like in water bodies or other ecosystems. Some anecdotal evidence from siltation rates indicates that this may be a significant amount in areas where there is substantial removal of topsoil by erosion.

The IPCC's 1996 revised methodology is based on the stock approach, with the emphasis being on estimating the change in carbon stocks over a given period[28]. This method was developed for the inventory of GHGs in the whole country, with a chapter dedicated to land use change and forestry sector. The methodology can not easily be adapted to mitigation assessment since it is a wide area approach, and uses long term approximations (up to 20 years for abandoned lands). Furthermore, some important aspects such as trade in forest products, emissions from bio-fuels, C-translocation from project site by natural processes and emissions from below-ground biomass, are not yet covered by the methodology.

(ii) Value of Stored Carbon[29]

Mitigation options store carbon and keep it from being released to the atmosphere for varying lengths of time. The economic value of storing carbon will depend on the damage being caused by atmospheric carbon at the time the carbon was stored and at the time it is released to the atmosphere. If the discounted economic damage being caused by atmospheric carbon is higher when the stored carbon is released, then a mitigation option would cause more economic damage and vice versa.[30]

However, there is great uncertainty regarding the rate at which damage, caused by higher greenhouse gas concentrations, might increase in the future.[31] The uncertainty about future damage is compounded by the possibility of catastrophic damages, and that of moving to a radically different new equilibrium state, which will, by definition, invalidate any prior assumptions on value of economic damage and discount rates. Given our limited knowledge regarding the rate at which the economic damage might increase, our approach assumes (i) that the damage will increase at the rate of discount, and (ii) that, everything else being equal, the expected economic damage will respectively influence the rate of discount. An important implication of this assumption is that the discounted economic value of damage caused by atmospheric carbon does not change over time. Therefore, the implied course of action would be to create a stock of carbon in the biosphere, which would last in perpetuity. This assumption about creating a perpetual stock of carbon has important implications for evaluating the carbon flows and the costs and benefits of options, which are discussed in the following section.

(iii) Incremental Carbon Storage

In order to evaluate the incremental carbon benefit of a mitigation option, it is necessary to estimate the carbon that might have been stored without the project. For forest protection, the amount of carbon stored may be estimated on the basis of that which would have been released in the absence of a protection measure, such as a physical barrier or relocation of forest users (Swisher, 1991). In the case of plantations or management of forests under rotation, the case is more complicated. We need to compare the incremental carbon, which would be sequestered in vegetation, soil, detritus and in products indefinitely. The carbon stored per unit area of a sustainably managed plantation or forest under rotations rotations can be shown to be equal to the sum of change in soil carbon storage and half of the maximum carbon stored in biomass per rotation[32]

(iv) ***Costs and Benefits***

In evaluating the costs and benefits of a project, it is important to draw a system boundary within which these would be evaluated, which is dictated by the objectives and the nature of each project. Costs are defined as the value of resources expended to implement a mitigation option, inclusive of the value of foregone benefits (opportunity cost). Benefits are defined as the value of all the outputs (goods and services) arising from a mitigation option. In order to be able to compare the stream of costs and benefits in project which occur in different years, the values are discounted to a common time frame, usually to yield a present value of costs and benefits.

Costs: The present value of project costs should include the initial cost of establishing the project, cost of silvicultural operations, management, extension services, protection, and cost of monitoring and evaluating the project's performance. Also, the present value of the opportunity cost is important since it captures the benefits derived from land use in the absence of a mitigation option. Opportunity cost may be evaluated using various methods, depending on the land in question and the likelihood of producing various goods and/or services if it is not used for the given option. These approaches include land rent, land market price and net benefits obtainable from an alternative land use. In all these cases, land values and benefits from alternative use should be adjusted to account for existing significant price distortions due to subsidies, zoning regulations etc. Deriving opportunity costs for many developing countries or countries with economies in transition is particularly difficult. Opportunity costs within a country may vary significantly with proximity to areas with rapid economic growth.[33]

In land use based mitigation options, some of the elements of costs do not have a market value, and a variety of methods are used to impute a value on them. Of specific importance here is land rental which vary significantly depending on land use policy and tenure as well as potential productivity and scarcity.

Benefits: In addition to carbon storage, the implementation of a mitigation option will result in other monetary and non-monetary benefits. These benefits may be classified into: (i) direct and indirect benefits depending on their role in, and level of, economic activity, and (ii) non-monetary intangible forest values. Direct benefits may include goods such as fuel wood and timber and services such as recreation. Indirect benefits may include such items as employment for local inhabitants, air pollution and microclimate control, watershed protection, and the development of social benefits, schools, roads, hospitals, etc. Various methods can be used to impute a monetary value on these indirect benefits. Forest value is derived from the stock in the forest as a resource, which has a recognized value in addition to the above benefits. This value may be influenced by concern for future generations, social status, etc.

Although carbon benefit may be a direct benefit, there is no consensus at present on the monetary value of reducing a unit of atmospheric carbon. Preliminary US fossil-fuel carbon tax estimates to stabilize climate change range between \$20 to \$200 per tC.[34,35] Estimates from some developing countries have shown that the unit cost estimates for forestry mitigation options fall well below this range, and for India they are also below the unit costs of the available energy efficiency options.[36],[37] Furthermore, when explicit evaluation of direct benefits such as wood products is incorporated, the benefits are sufficiently large to offset the life-cycle cost of many sink expansion options. In effect, carbon may be sequestered at a net benefit to society.

(v) Cost-Effectiveness Indicators:

Ideally, in determining the net benefit of a mitigation option, one would include the monetary benefit of storing carbon. However, as discussed above, it is not possible to assess the current and future economic damage that carbon might cause. Estimates of such damage for the United States have been controversial and cover a broad range.[38,39] However, to allow for a consistent evaluation and comparison of the various mitigation options across categories and with options in other sectors such as energy and agriculture, COMAP proposes to use a set of cost effectiveness indicators. Also, this will allow for an aggregation of the monetary and carbon implications across options. Different indicators of cost effectiveness of an option to store or avoid carbon emissions are:

(1). Initial cost per ha and per tC: This includes initial costs only, and does not include future discounted investments needed during the rotation period. The indicator would provide useful information on the amount of resources required at the beginning to establish the project.

Most cost studies[40,41,42] on GHG reduction projects/programs estimate this indicator. The other cost components and the option's benefits are often ignored. The studies take into consideration the carbon stored in live biomass and most account for soil carbon. Whereas very few studies use mean carbon stock to indicate the amount of carbon that would be stored by a mitigation option[43], most of the other studies report estimates of cost per tC although the method of carbon estimation used is unclear.

(2). Present value of cost per ha and per tC: This is the sum of initial cost and the discounted value of all future investment and recurring costs during the lifetime of the project. For rotation projects, it is assumed that the costs of second and subsequent rotations would be paid for by the revenues derived from the first rotation and thus would not be included in estimating the present value. This indicator is also referred to as endowment cost because it provides an estimate of present value of resources necessary to maintain the project for its duration.

A useful way to present the cost per ton of carbon or per hectare is to plot a *cost of conserved carbon (CCC) curve*.[44] The curve shows the amount of carbon that could be stored at increasingly higher per unit costs. Other indicators could also be used to plot similar curves.

(3). Net Present Value (NPV) per ha and per tC: This indicator provides the net discounted value of non-carbon benefits to be obtained from the project. For most plantation and managed forests this should be positive at a reasonable discount rate. For options such as forest protection, the NPV indicator is also positive if indirect benefits and forest value are included, both of which are subject to controversial evaluation. The formula for deriving this indicator for managed forests is given in Appendix 2.

(4). Benefit of Reducing Atmospheric Carbon (BRAC): This proposed indicator is an estimate of the benefit of reducing atmospheric carbon instead of reducing net emissions.[45] It expresses the NPV 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. The formulation of the indicator varies with the rate at which economic damage might increase. Appendix 2.d provides a formulation for deriving BRAC when the economic damage caused by atmospheric carbon increases at the real societal rate of discount.

A key shortcoming of the above indicators is their inability to provide a consistent ranking of mitigation options, which are finite, but of different duration or rotation. For example, establishment cost is usually the largest share of cost over a rotation and is incurred quite early in the project, while carbon sequestration occurs gradually over the biological rotation. Projects of varying rotations can not meaningfully be compared mid-stream since the timing of emission pulse e.g. harvesting, is different. To circumvent this shortcoming, an indicator based on annualization of the proposed indicators has been put forth.[46] Such an approach calculates the annual equivalence of a stream of costs and benefits and normalize this by the annual carbon-flow equivalence. However, the approach still does not resolve the issue related to the timing of the carbon emission or sequestration.

3.0 Flow chart of the Analytical Framework

COMAP is a framework of analysis which guides one to assess and evaluate a set of mitigation options in the land use sector for a country. The flow of the framework is graphically depicted in Figure 1 below.

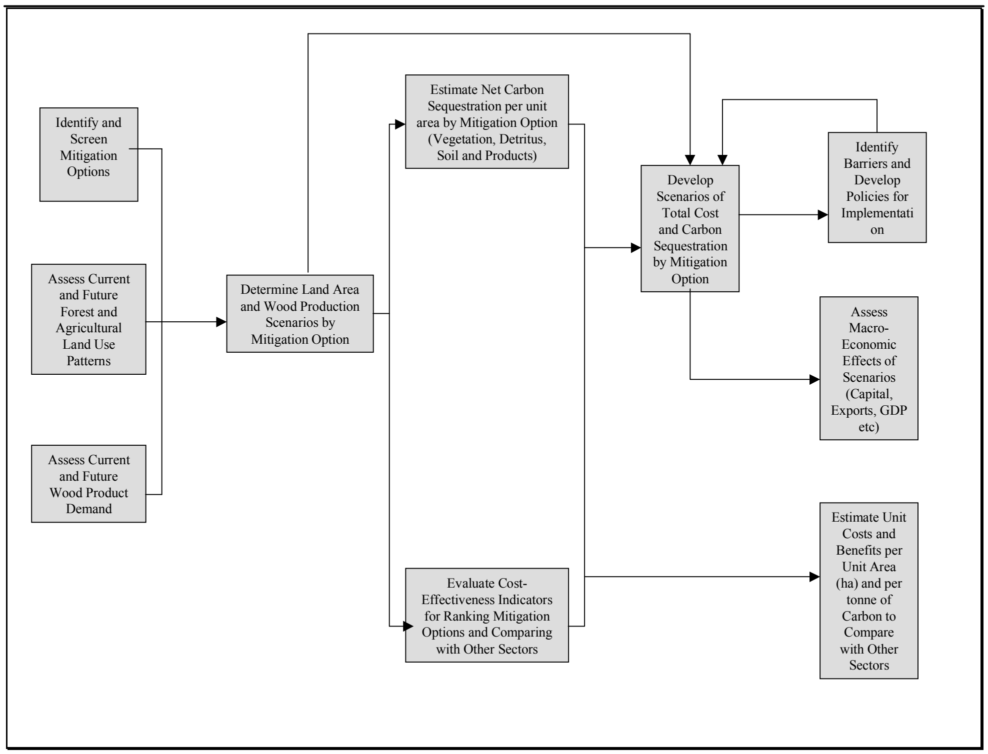

Figure 1: COMAP Flow Chart

3.1 Introduction of Modules

The COMAP framework as described above has been operationalized in a spreadsheet model in EXCEL with four main modules (Table 2). The first three modules correspond to the main types of mitigation options in forestry, and each has a set of sub-modules, which are used to analyze specific or similar options. For example, under the Reforestation module, there are sub-modules for natural regeneration (REFREGN), regeneration through reforestation (REGENDX) and reforestation by short rotation forestry (REFROTN). The fourth module (BIOMASS) balances the biomass in the sector by tracking the demand and supply of forest products and services under both baseline and mitigation scenarios. When analyzing individual projects, it may not be necessary to use the biomass balance module, but when evaluating state or national forest sector mitigation strategy, it is necessary to use this module.

Table 2: Main Module Types in COMAP

COMAP MODULES TYPES	DESCRIPTION
BIOENERGY	Bioenergy mitigation options e.g. biofuel electric generation substituting fossil fuels, efficient stoves and charcoal kilns, etc
PROTECTION	Forest protection and conservation options e.g. forest reserves, parks, sustainable harvesting, deforestation reduction measures, etc.
FORESTATION	Reforestation and regeneration options e.g. natural and enhanced regeneration, afforestation, urban forestry, non-forest tree plantations (rubber, oil palm etc.) and agroforestry.
BIOMASS	Biomass balance module for tracking demand and supply of forest products in the land use sector and the impact on biomass balance

3.2 FORESTATION OPTIONS.

This group of options include all projects and policies intended to re-inhabit an area with vegetation, ranging from natural reforestation, enhanced natural reforestation, afforestation, short rotation forestry, agroforestry, community and urban forestry, etc. If non-forest tree plantations such as rubber, oil palm and rattan are not included under agricultural sector mitigation assessment, then they can be analyzed under this module as afforestation/reforestation options. The majority of the potential C-abatement projects in the forestry sector are reforestation/afforestation projects. The REFOREST 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 as described in Part II above.

3.2.1 Steps and Data Requirements for REFOREST module

STEP 1: Define land use categories relevant to BASELINE as well as MITIGATION scenarios. Examples of the categories are natural forests (e.g. evergreen, dipterocarp, mangrove, etc), plantation forests, degraded land, rangelands and grasslands.

STEP 2: Specify area (ha) for the BASELINE under different land categories from a base year, for example 1990, to the desired horizon for the mitigation option. Due to long rotations for forestry projects, choose a horizon long enough to allow for at least one rotation so that there is a realistic turnover of the carbon stock into the intended sinks.

Data required for this step should be obtained from any existing projections on land use change for different vegetation types in the country. If no projections are available, it may be necessary to make projections using demographic, social, and economic factors. Normally, the degraded land area is taken to remain stable or increase over the years and forest area declines due to anthropogenic pressures in developing countries.

STEP 3: Specify area (ha) and define activities, which constitute MITIGATION scenario for the different categories of land identified in step 2.

The forestation options to be included in the mitigation assessment of the sector have to be decided in consultation with policy makers and forest planners, in concert with the long-term land resource management plans. The rates of reforestation depend on the availability of land, funding, infrastructure, and the organizational capacity of the Forest Department, industry and the community. Economic and technological factors will also influence the extent and the type of forestation activities.

Area to be reforested has to be entered for each year (or each period of implementation), from the base year to the end of planning horizon. It could be at constant or varying rates depending on the expected implementation of the project. Table 3 shows the outline of the three steps in the spreadsheet.

Table 3: Step 1, 2 and 3

REFORESTATION		1980	1990	1991	1992	1993	1994
>>> FROM STEPS 2 AND 3: LAND AREA (ha)							
>> Baseline Scenario							
> Wasteland							
>> Mitigation Scenario							
> Wasteland							
> Reforested Land							

STEP 4:1 Estimate C-storage in soil and vegetation under BASELINE scenario (t C/ha)

The data needed include C-densities of vegetation (above and below ground biomass) and soil carbon in tC/ha, to a specified depth e.g. 100 cm. The vegetation C-density is usually calculated from biomass and carbon content data (Table 4). Some C-density data are available in literature (published as well as unpublished) for vegetation as well as soil, though site specific measurements may be required to supplement the data, especially the soil C-data since it is not as abundantly available. Normally, C-densities are expected to decline under BASELINE scenario due to anthropogenic pressures. Soil C densities are likely to decline from year to year depending on the prevailing land use (agriculture, pasture, or abandoned wasteland), with agricultural conversion losing the most soil carbon, depending on the extent of tillage.

Table 4: Estimates of C-density in Baseline Scenario

>>> STEP 4.1: BASELINE SCENARIO – WASTELANDS							
			1980	1990	1991	1992	1993
>> Vegetation Carbon							
> Dry Weight (t/ha)							
> Carbon content (%)							
>> Soil Carbon							
> Amount of carbon stored in soil (tC/ha)							

STEP 4.2: Estimate C-sequestration and storage in soil, vegetation and products under MITIGATION scenario (t C/ha). As illustrated in Table 5, the data requirements fall under the following categories:

(i) Vegetation: C density is projected to increase annually due to natural regeneration and the additional biomass from reforestation and protection of the area. The rate of C accumulation depends on a number of factors such as; tree species, density, rainfall, nutrient supplements and rotation period. The rotation is different for various mitigation options depending on species, provenance and intended fate of the forest.

(ii) Soil The soil C density is normally low in degraded forests. Under reforestation options involving tree planting, soil C density increases due to new litter fall and decomposition. The rate of C accumulation is normally low and can be assumed to be constant over the duration of the project, lets say at a rate of 1-2 t C/ha/yr in the short to medium term, and tends towards equilibrium in the longer term.

(iii) Detritus The forest and/or plantation litter-fall consists of woody and non-woody plant biomass. The non-woody biomass decomposes in a relatively short period, e.g. 1-2 years depending on weather and biotic conditions. The woody litter stays on the forest floor for several years; at times beyond 10 years, also depending on the species and field conditions affecting microbial activity. The decomposing matter C density could vary from 5-25 t/ha, at different periods. This data is not readily available for specific sites and may have to be obtained from areas of similar conditions available in the literature.

(iv) Product Carbon: When/if harvested, the biomass has diverse end-uses, which lead to different C-emission streams. Potential biomass uses include wood fuel (where combustion leads to instant C- emissions), industrial wood for pulp and paper production (where emissions normally occur over 2 to 10 years or so), and structural wood for long-term use (timber for construction, housing, mining, etc); with emissions occurring in a few years or in 50 or more years depending on conditions and nature of product utilization.

STEP 4.3: Summarize carbon density (tC/ha) under BASELINE and MITIGATION scenarios.

In this step, the average carbon stock under both scenarios are summed up for each year, to be used in Step 6.1 to estimate the aggregate incremental carbon sequestered by implementing the reforestation program. Since the carbon density given is an average standing carbon over a rotation sequence, the actual amount on site may differ, especially in the pre-rotation age initial years. This does not cause a significant distortion of the indicators since the average is strictly correct after the rotation scheme gets in full swing.

Table 5: Carbon Pools for the Mitigation Scenario

>>>> STEP 4.2: MITIGATION SCENARIO – REFORESTATION							
				1990	1991	1992	1993
>> 1. Vegetation Carbon							
> Rotation Period (Years)							
> Annual Yield (t/year/ha)							
> Carbon density (%)							
>> 2. Soil Carbon							
> Rotation Period (Years)							
> Amount of carbon stored in soil (tC/ha)							
>> 3. Decomposing Matter Carbon							
> Decomposition Period (Years)							
> Amount of decomposing carbon (tC/ha)							
>> 4. Product Carbon							
> Average Age (Years)							
> Amount of carbon stored in product (tC/ha)							

STEP 5 Value of inputs, opportunity cost and benefits from the mitigation option.

STEP 5.1: Estimate cost of inputs for reforestation in current year outlays ($/ha) including establishment costs, recurring costs, monitoring costs and harvesting costs, depending on the pre-assumed system boundary. For example, if the concessionaire will be responsible for harvesting, then the only harvesting cost chargeable to the project are those necessary for pre-harvest preparations such as timber cruising, logging access roads, etc.

STEP 5.2: Estimate total direct benefit flows ($/ha) from all products, including timber and non-timber products. The value of indirect benefits such as multiplier effects and other positive externalities should not be bundled together with the direct benefits whose market value can be ascertained. These can be estimated separately and could be used to choose among closely ranked options or to assess the order of implementation depending on the magnitude and likely recipients of indirect benefits.

STEP 5.3: Specify discount rate with which the model computes the NPV ($/ha). For many land use change and forestry projects, we recommend use of the social discount rate rather than the private rate of discount which (the latter) is usually much higher. For the short duration options e.g. biofuel projects one could use the commercial discount rates since the projects can be compared to alternative investments in the economy.

STEP 6.1: For both BASELINE and MITIGATION scenarios the model estimates total C stock for the whole area, the net annual and cumulative carbon storage for the desired length of time (Table 6). This includes the carbon stored in soil, vegetation, detritus and in products.

Table 6: Total Carbon Pool

>>> STEP 6.1: TOTAL CARBON POOL (Tc)							
				1990	1991	1992	1993
>> Annual Incremental C Protected							
>> Baseline Scenario							
> Wasteland							
>> Mitigation Scenario							
> Wasteland							
> Reforested Land							

STEP 6.2: The model estimates total costs and benefits for the total reforested area. It also provides an estimate of incremental net benefit from mitigation compared to the baseline scenarios. These are compiled for each year for the duration of the project (Table 7).

Table 7: Total Costs and Benefits of Reforestation Project:

>>> STEP 6.2: TOTAL COSTS AND BENEFITS OF CSEQ ($)							
				1990	1991	1992	1993
>> Incremental Net Benefit							
>> Baseline Scenario Benefit							
> Cost							
> Benefit							
>> Mitigation Scenario Benefit							
> Cost							
> Benefit							

STEP 7: REFOREST module generates output on potential mitigation options, the cost-effectiveness of different options and net financial benefits. The cost-effectiveness indicators generated are:

Establishment cost ($/tC and $/ha)

Endowment cost ($/tC and $/ha)

NPV ($/tC and $/ha)

BRAC ($/tC-yr)

3.3. FOREST PROTECTION OPTIONS

Some of the low cost and most effective mitigation options involve protecting the forests from being deforested and/or degraded, leading to carbon emissions. There are a number of options as mentioned which call for halting deforestation of a given forest in a region or conversion of a threatened forest into a Protected Area. FORPROT module using data on area under relevant categories, biomass density, carbon stocks, C sequestration rates, and costs and benefits, provides estimates of the associated annual and cumulative changes in carbon stocks; and the cost effectiveness indicators for the mitigation policy. This is done for BASELINE and MITIGATION scenarios to obtain net reduction in carbon emissions

3.3.1 Steps and Data Requirements in FORPROT

STEP 1: Define land use categories. These consist of areas under different forest and other land categories relevant to mitigation analysis. Vulnerable forest areas and degraded land, which may need protection to recover, are crucial categories in forest protection module.

STEP 2: Baseline area under land use categories. Define BASELINE area under land use categories covering annual changes (ha) in forest area (clear-felled or converted to other uses) for the duration of the project. For the land categories selected give the base year area and projections for future years. In the absence of land use pattern projections, one can use factors such as demography, economic activity and technical parameters to estimate forecast future patterns under baseline scenario. At times simple projections can be made based on trends for a period prior to the base year. Forest areas converted to non-forest uses e.g. to degraded land, should be listed here.

STEP 3: Area protected under MITIGATION scenario (ha). Under mitigation scenario forest area, which would have been deforested or converted to other uses, will be protected and conserved. The area to be conserved will depend on forest policies, capacity and motivation of local and national forestry administration, community awareness, cost of protection, opportunity cost etc. Area that could be potentially conserved every year for the duration of the project has to be estimated. Since the mitigation scenario assumes that such a project would not have taken place under the business-as-usual situation, long term plans for these kind of mitigation policies/projects typically do not exist. To project the activity level under mitigation one may need to apply current and short-term data and extrapolate outwards.

STEP 4.1: Biomass density (t/ha). Data for this step need to be entered for both BASELINE MITIGATION scenarios. Biomass density data (aboveground woody biomass in t/ha) can be obtained from the Forest Department or from literature. Since this data is often recorded in terms of volume (m3/ha), it may need to be converted by applying a factor for converting volume to dry matter (t/ha), which depends on the species in the project area. Another conversion factor may be necessary to estimate total biomass including non-tree vegetation , litter and roots. Normally under BASELINE scenario, the biomass density is expected to decline annually due to conversion and other forest utilization activities. On the contrary, under MITIGATION scenario the biomass density may stabilize or increase.

STEP 4.2: Carbon density of wood (t C/ha). Enter the carbon content of wood. The default value is 0.5, but use site specific data if available. This coefficient will not vary significantly between BASELINE and MITIGATION scenarios in the early and middle years, but may change in the out years when pioneering vegetation is replaced by a climax vegetation.

STEP 4.3: Soil carbon density (tC/ha). Soil C density declines with removal of trees, forest clearing, and forest conversion. With protection soil C density is likely to increase gradually. Soil C data is available from literature for different forest types, but may need to be complemented by local soil C estimates.

STEP 4.4: **Total C-loading (tC/ha).** Estimate total C density for each year for the site, which is the sum of the vegetation, litter and soil carbon pools.

STEP 5.1.1: **Stream of protection costs ($/ha**). Annual cost of forest protection should be done for MITIGATION scenario. Data for costs can be obtained from forest protection section in the Forest Department, or can be estimated based on previous experience in other protection programs/projects in the country. The protection costs include the following elements:

(i) *Initial costs***:** Cost involved in initial years to enforce protection often referred to as establishment cost ($/ha) include such items like cadastral activities, gazetting, relocation of forest dwellers, and protection measures such as observation towers and fire lines.
(ii) *Recurring costs***:** These costs occur annually or at periodic intervals and may include labor for protection e.g., field patrols, boundary maintenance activities, fire line clearing, management and administration.
(iii) *Monitoring costs***:** This would involve monitoring of protection arrangements, biomass growth rates, soil C accumulation and possible product extraction.

STEP 5.2: **Benefits from land conversion. ($/ha/yr).** Estimate the value of goods and services, which are directly obtained from converting the area to other land uses in the BASELINE scenario. These may include wood products, agricultural land, pasture for cattle, etc. The market value of the outputs from the converted area is a good measure for benefits from conversion. In the absence of a market value for such products or services e.g. pasture, a value should be imputed using any one of methods which have been suggested for estimating non-market benefits of natural resources[47].

STEP 5.3: **Benefits or costs of providing alternative products ($/ha/yr).** Under MITIGATION scenario when the area is protected, we assume that some of the goods and services which were being obtained from the area before will be procured from other sources, either in true form or as substitutes. In some situations, in order to offset the loss of timber from the protected forests, a country may have to import. In rare cases where the same product can be obtained more cheaply from an alternative source e.g. imports, then the net savings will be considered negative opportunity cost (benefits) of the protection project.

STEP 5.4: **Benefits from Forest Protection ($/ha/yr).** Under MITIGATION scenario benefits from forests could include fuelwood from deadwood and lopes, non-timber forest products, eco-tourism, etc.

STEP 6.1: **Total and incremental carbon pool (tC).** Total carbon sequestered or conserved in soil and vegetation for the BASELINE as well as MITIGATION scenarios is used to calculate the annual incremental C protected due to implementation of the forest protection project.

STEP 6.2: **Incremental net cost** ($). This is calculated from difference between the BASELINE and MITIGATION scenarios, i.e. (protection costs +- opportunity costs) - (benefits from forests). The module computes this for every year and cumulatively for the whole period using a discount for values in different years.

STEP 7: **Cost-effectiveness indicators.** The model generates a number of cost-effectiveness indicators to enable comparison of mitigation options, some of which are also used to construct carbon reduction emission supply curves for a country.

(i) Net Present Value of Benefits - NPV in $/t C and NPV in $/ha

(ii) Initial Cost of forest protection - Cost in $/t C and cost in $/ha
(iii) Present Value Costs (Endowment cost) - PVC $/t C and $/ha
(iv) Benefits of Reduced Atmospheric Carbon -BRAC $/tC-yr

4.0 BIOMASS DEMAND AND SUPPLY (BIOMASS Module)

One of the main roles of the forestry sector in any country is to meet the current and projected biomass demands (fuelwood, industrial wood, sawnwood, etc.). 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. In many countries some of the mitigation options cannot 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 farm output. 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. This has to be followed by assessing the impact of the proposed mitigation option on biomass supply, with a goal to match it with the demand on biomass.

BIOMASS module is used to track the dynamics of land use patterns over time, including changes in biomass pools, product supply and demand. The steps involved in the BIOMASS module are listed below.

4.1 Steps involved in assessing biomass supply and demand

In the example used here, we assume that this mitigation project begins in 1990 and runs through 2030. In this module a periodic estimation of biomass balance is done every 10 years, for both BASELINE and MITIGATION scenarios. The module performs two separate biomass supply projections under the MITIGATION scenario, one covering biomass balance under unconstrained rate of extraction of wood products, and the other under sustainable rate of extraction, which constrains the model by extracting biomass which *does not exceed the gross mean annual increment.*

4.1.1 BASELINE scenario

STEP 1.0: Defining the land use categories relevant for the country.

STEP 1.1: Baseline land use categories (ha) for the whole period.

STEP 1.3: Biomass density for different land categories (t/ha)

STEP 2.1.1: Estimation of product supply 1990 (t/yr) by using baseline area under land categories at

- product rate of extraction
- sustainable rate of extraction

STEP 2.1.2: Estimation of biomass demand (t/yr) for year 1990

STEP 2.2.1: Estimation of biomass supply for year 2010 using baseline area under

- projected product rate of extraction
- sustainable rate of extraction

STEP 2.2.2: Estimation of projected product demand for year 2010

STEP 2.4.1: Estimation of projected biomass supply for the year 2030 under

- projected product extraction rate
- sustainable extraction rate

STEP 2.4.2: Estimation of projected biomass demand for the year 2030

4.1.2 MITIGATION scenario

STEP 1.2: Land area (ha) under different categories for 1990 and each year there after upto 2030.

STEP 1.4: Biomass density for different land categories (t/ha)

STEP 2.3: Estimation of biomass supply under MITIGATION scenario for the year 2010 at

- product rate of extraction
- sustainable rate of extraction

STEP 2.3.2: Projected biomass demand for the year 2010

STEP 2.5.1: Estimation of biomass supply for the year 2030 at

- projected product extraction rate and
- sustainable rate of extraction

STEP 2.5.2: Projected biomass demand for the year 2030

4.2 Data entry in BIOMASS module

4.2.1 BASELINE scenario

STEP 1: Defining land use categories relevant to the country

- broad categories: forests, cropland, pasture etc.
- specific categories:
  - * Forest types (dense/open forests, evergreen/ deciduous/montane)
  - * Cropland (annual/perennial)
- Data source: land use statistics for the country

STEP 1.1: Area under land categories

- Land categories defined in STEP 1.0 appears.

- Enter area under each category (ha) for the base year 1990.
- Enter potential areas for different categories annually from 1990 to 2030.
- If any projections made are available use those projected area data for the respective years.
- If no projections available, rates of changes during the period 1980 to 1990 could be used

for future years

STEP 1.3: Biomass density for land categories

- Enter biomass density (above ground standing biomass in dry t/ha) data for different categories
- Example: undisturbed evergreen forest = 300-600 t/ha
- Eucalyptus plantation (7 to 10 years) = 50-100 t/ha

STEP 2.1.1 Projected rates of extraction - 1990

- Enter current rates of extraction of wood from different categories of land.
- Examples: Protected Area = 0 t/ha/yr.
- Deciduous forest =2 - 25 t/ha/yr.
- Eucalyptus plantation = 5-50 t/ha/yr.
- Degraded forest/pasture = 0.5 t/ha/yr.

STEP 2.1.1, 2.2.1, & 2.4.1: Sustainable extraction rates for 1990, 2010 & 2030

- The current rates of extraction may not be sustainable.
- Need to estimate potential sustainable rates of extraction; for example evergreen forest 2 to 4 t/ha/yr. Plantations 4 to 10 t/ha/yr (depending on productivity), degraded lands; 0.1 t/ha/yr.

Table 8: 1990 Biomass Supply for Various Uses

>>>	STEP 2.1.1: 1990 SUPPLY								
>>>	1990 PRODUCT SUSTAINABLE RATE (t/ha)			Ag. Waste*	Fuel Wood*	Industrial	Agric.	Livestock	Other
>>>									
>>	Dense Forest								
>>	Plantation								
>>	Waste land								

STEP 2.2.2: Social, economic and demographic parameters

- To make future demand projections, one need estimates of parameters such as; growth rates of population, GDP growth rate, crop area and income, per capita base-year demand, growth of agricultural output.
- Using such data, the model projects biomass demand for 2010, 2030.

4.2.2 Data entry MITIGATION scenario

In the MITIGATION scenario data on land use pattern, biomass density and extraction rates will be different from BASELINE scenario, thus needs to be entered at appropriate locations in the module.

STEP 1.2: Land use pattern under MITIGATION scenario

- Enter data on area under different categories as defined in step 1.0.
- There is a need to develop the projected land use pattern for the MITIGATION scenario. This could be done using two approaches:
  - for a given region or location with a project (e.g. reforesting 2,000 ha in a region or converting a forest patch of say 5000 ha into a Protected Area)
  - for the whole forestry sector or as part of land use planning in the country
- Land areas for MITIGATION scenario need to be developed in collaboration with experts in forestry, agriculture, land use planning and policy makers in the country keeping in mind the pressures on land, land use policies, demand for forest land for food production and biomass supply.

STEP 1.4: Biomass density (t/ha)

- Under MITIGATION scenario the biomass density (for above ground woody biomass) could change with protection and management for many land categories such as forests, wastelands, plantations etc.
- Data may be obtained from literature and reports with comparable situations. For example, the biomass density in any undisturbed forest patch in the region could be estimated and used as input for the area to be brought under protection. Similarly for plantations, use biomass data from existing plantations or estimates from yield studies.

Step 2.3: Projected and sustainable rates of extraction for 2010 and 2030

- To estimate the projected biomass supply under MITIGATION scenario, it is necessary to estimate projected and sustainable rates of extraction
- Projected rate could be estimated taking area under the category supplying biomass given the requirements (example; industrial wood required and area under plantation forestry), assuming all biomass will be extracted from that source.

5. COMPARISON AND RANKING OF FORESTRY OPTIONS

Using REFOREST and FORPROT modules, output is generated giving the mitigation potential of different forestry options in terms of t C/ha sequestered or emissions avoided. The decision-maker or the funding agencies require information on cost-effectiveness of mitigation options in addition to the total mitigation potential. Not all the mitigation options could be implemented in full. Decision-makers and funding agencies and investors in the mitigation options in this sector are likely going to use different cost-effectiveness parameters in evaluating the options. It may be useful to convert the model outputs for different options into a table or a graph; to enable comparisons. Information to be presented in a summary table should include:

(i) Option name
(ii) Potential area available for the option
(iii) Per hectare and total mitigation potential (tC).
(iv) Investment or life cycle costs per hectare
(v) Investment or life cycle costs per t of C abated
(vi) Total cost for each mitigation option.
(vii) NPV and BRAC indicators for each mitigation option

Appendix 1: Solved Examples of Mitigation Options

In this Appendix we present numerical examples of two mitigation options (reforestation and protection) which were analyzed using the COMAP framework and also present the associated biomass balance spreadsheet.

Example 1: REFORESTATION OF WASTELANDS

The first example consists of a mitigation option to reforest a wasteland at a rate of 1000 hectares per year over a 40 year period. In the baseline scenario, this area would have remained as a wasteland with low vegetation biomass density (20 tB/ha), and a stable soil carbon density estimated at 70 tC/ha. This information is entered in steps 2, 3 and 4.1 as described above in Section 3.2.1.

Under a mitigation scenario, the wasteland will be reforested by fast growing species whose rotation age is 10 years, and will be managed in perpetual rotations. As described in Section 3.2.1 Step 4.2, the sequestered carbon will be stored in four pools, i.e.; (i) growing vegetation, (ii) decomposing biomass, (iii) soils and (iv) harvested wood products. In this example, it is assumed that soil carbon will accumulate at a rate of 2 tC/ha through the first rotation, and remain constant after that. It is estimated that the vegetation will store on average, half the maximum amount of carbon that could be sequestered per hectare by the vegetation if the trees would never have been harvested[48]. The amounts of carbon stored in detritus and that in wood products depend on the decomposition period and the product's lifetime respectively. On average, each will store half of the maximum accumulation in the respective pool since the pools are being replenished pursuant to the management of the rotational crop. The difference between the carbon stock under the mitigation and baseline scenarios, provide an estimate of incremental carbon pool arising from the reforestation project (see Step 4.3).

The costs per hectare under baseline scenario are minimal ($5/ha/yr), mainly from wasteland management such as fire protection. In the mitigation scenario, a large initial cost is incurred in the first three years for ground preparation, planting, weeding and beating-up. For the remainder of the rotation, there is a small but increasing maintenance and monitoring cost ($15 – $150/ha/yr) for activities such as pruning, thinning and protection. In this example, the costs are discounted at 10% discount rate to obtain input-based cost effectiveness indicators such as present value of initial costs, present value of all costs, and annualized value of costs.

The value of products obtained from the wastelands such as firewood and non-timber forest products is estimated at $20/ha/yr. Under mitigation these would increase to $75/ha/yr, but the largest benefit comes from the timber products which are valued at $1000/ha at harvest. At 10% discount rate, the reforestation program yields benefits whose present value is estimated at $ 4125/ha, or an annualized value of $ 423/ha/yr. The net present value is estimated at $1198/ha for the mitigation project.

The total carbon pool is estimated for both scenarios as well as the total costs and benefits for the program, and these are used as a basis for estimating the four cost effectiveness indicators. The reforestation project would result in a NPV of $4.75/tC or $266/ha of reforested land. This implies that the mitigation project can be economically be implemented, with the monetary benefits outweighing the cost. If benefits were to be ignored, the present value of costs add up to $13.87/tC sequestered or $777/ha. This indicator is useful for ranking projects which have no monetary benefits, or for budgeting purposes, since this is the present value of the resources which are going to be required to implement the project. The present value of initial cost is estimated at $8.5/tC or $476/ha, an amount which is critical for policy purposes, since the availability of such funds is necessary to initiate the project. The net cost of removing a ton of carbon from the atmosphere for a year (BRAC) was estimated at 3.6 cents (negative cost), assuming that the damage caused by its atmospheric residence increases at a rate equal to the societal rate of discount. In this example, we actually gain 3.6 cents (in 1990 value) per ton of carbon withdraw from the atmosphere by the reforestation project. The large NPV and positive BRAC can be attributed to the substantial stream of timber benefits from the project.

Example 2: FOREST PROTECTION

This example involves the protection of a closed dense forest which covered 15,000 ha in 1980 and by 1990 (base year) it had been reduced to 12,000 ha through conversion to agriculture. At this rate, the baseline scenario assumes that all the forest will have been converted to agricultural land by the year 2030. The proposed mitigation option involves protecting the forest through measures such as setting a new policy for the area, boundary demarcation, surveillance, enforcement, and provision of equivalent or better alternatives for the people who were converting the area to farm land.

To evaluate this mitigation option requires estimates of carbon densities under baseline and mitigation scenarios. Under baseline scenario, the vegetation carbon per unit area is expected to decline to about 7tC/ha by 2030, though the soil carbon is conservatively projected to remain unchanged. If the area is protected, both the vegetation and soil carbon are projected to increase significantly. The incremental carbon gain is projected to reach 114.5 tC/ha by the end of the program.

The cost of protection is minimal ($2/ha/year) under baseline scenario, mostly for reducing the acceleration of the process by influx of more farmers, and boundary fire protection to avoid burning of the remaining forest or its spread to other forested areas. However, the benefits accruing from the agricultural production are estimated at $50/ha/yr, which will be considered as an opportunity cost of protecting the area under the cost of the program. Furthermore, the annualized value of direct cost of protection under mitigation rises to $ 9.4/ha/yr.

Using the stream of monetary costs and benefits from the program, and dividing this by the carbon benefits which will accrue, the cost effectiveness indicators reveal that it will cost $0.70/tC or a total of $177.50/ha of protected forest. The value of the BRAC indicator implies that in 1990 dollars, it will cost 5 cents per ton of carbon withdrawn from the atmosphere per year, if the damage rate would rise at the same rate as the social rate of discount. The initial cost of protecting the forest is about 2 cents per ton of carbon or $ 5/ha, and it would require an endowment of $64.37/ha in the base year to ensure the protection of the forest, or 25 cents per ton of carbon.

These estimates are consistent with expectations since there are no products with monetary value which is obtained from the area under the mitigation scenario. However, as mentioned earlier, the cost per ton of carbon is still quite low compared to other mitigation options, especially in the fossil fuel sector.

Example 1: **REFORESTATION FOR ROTATION MANAGEMENT**

Year	**1980**	**1990**	**1991**	**1992**	**1993**	**……**	**2029**	**2030**
>>> FROM STEPS 2 AND 3: LAND AREA (ha)								
>> Baseline Scenario								
> Wasteland	40000	40000	40000	40000	40000	……	40000	40000
>> Mitigation Scenario								
> Wasteland		40000	39000	38000	37000		1000	0
> Reforested Land			1000	1000	1000		1000	1000
>>>> STEP 4: ESTIMATING CARBON POOL AND SEQUESTRATION								
>>> STEP 4.1: BASELINE SCENARIO -- WASTELANDS								
>> Standing Vegetation Carbon								
> Dry Weight (t/ha)			20	20	20	……	20	20
> Carbon density			0.45	0.45	0.45		0.45	0.45
>> Soil Carbon								
> Amount of carbon stored in soil (tC/ha)			70	70	70		70	70
>>> Carbon Pool (tC/ha)			79	79	79		79	79
>>> STEP 4.2: MITIGATION SCENARIO -- REFORESTATION								
>> 1. Vegetation Carbon Pool			30	30	30	……	30	30
> Rotation Period (Years)			10	10	10		10	10
> Mean Annual Increment (tB/year/ha)			12	12	12		12	12
> Carbon density			0.5	0.5	0.5		0.5	0.5
>> 2. Soil Carbon Pool			20	20	20		20	20
> Accumulation Period (Years)			10	10	10		10	10
> Amount of carbon stored in soil (tC/ha/yr)			2	2	2		2	2
>> 3. Decomposing Matter Carbon Pool			10.5	10.5	10.5		10.5	10.5
> Decomposition Period (Years)			6	6	6		6	6
> Amount of decomposing carbon (tC/ha/harvest)			21	21	21		21	21
>> 4. Product Carbon Pool			4.5	4.5	4.5		4.5	4.5
> Average Age (Years)			3	3	3		3	3
> Amount of carbon stored in product (tC/ha/harvest)			9	9	9		9	9
>>> Carbon Pool Created by Mitigation Option (tC/ha)			65	65	65		65	65
>>> Carbon Pool Including Baseline Soil Carbon (tC/ha)			135	135	135		135	135
>>> STEP 4.3: TOTAL CARBON DENSITY (tC/ha)								
>> Baseline Scenario								
> Wasteland			79	79	79		79	79
>> Mitigation Scenario								
> Wasteland			79	79	79		79	79
> Reforested Land			135	135	135		135	135

Year	**1980**	**1990**	**1991**	**1992**	**1993**	**……**	**2029**	**2030**
>>>> STEP 5: ESTIMATING COSTS AND BENEFITS								
>>> STEP 5.1: COSTS ($/ha/yr)								
>> Baseline Scenario (Wastelands)			5	5	5		5	5
>> Mitigation Scenario (Reforestation)			300	300	300		300	300
>>> STEP 5.1.1: STREAM OF COSTS ($/ha) OF REFORESTATION								
>> Initial Costs ($/ha/yr)			1000	800	500			
>> Recurrent (Maintenance etc.) Costs ($/ha/yr)			10	20	30		100	100
>> Monitoring Costs ($/ha/yr)			5	10	15		50	50
>> Establishment Costs ($/ha/yr)								
>> Total Costs ($/ha/yr)			1015	830	545		150	150
>> Present Value of Costs ($/ha)	**2927**							
>> Annualized Value of Costs ($/ha/yr)	**300**							
>> Present Value of Initial Cost	**1946**							
>>> STEP 5.2: BENEFITS ($/ha/yr)								
>> Baseline Scenario (Wastelands)			20	20	20		20	20
>> Mitigation Scenario (Reforestation)			423	423	423		423	423
>>> STEP 5.2.1: STREAM OF BENEFITS OF REFORESTATION PROGRAM								
>> Timber Product ($/ha/yr)			0	0	0		1000	1000
>> Non-timber benefits (fuel wood) ($/ha/yr)			5	10	15		50	50
>> Non-timber benefits (resin/honey/fruits) ($/ha/yr)		2.5	5	7.5		25	25	
>> Other benefits ($/ha/yr)								
>> Total Benefits ($/ha/yr)			7.5	15	22.5		1075	1075
>> Present Value of Benefits ($/ha)		**4125**						
>> Annualized Value of Benefits ($/ha/yr)		**423**						
>>> NET PRESENT VALUE OF BENEFITS ($/ha)		**1198**						

Year	**1990**	**1991**	**1992**	**1993**	**….**	**2029**	**2030**	**Total**
>>> STEP 6.1: TOTAL CARBON POOL (1000's tC)								
>> Annually Created Incremental C Pool		56	56	56		56	56	2240
>> Baseline Scenario								
> Wasteland		3160	3160	3160		3160	3160	
>> Mitigation Scenario		3216	3272	3328		5344	5400	
> Wasteland		3081	3002	2923		79	0	
> Reforested Land		135	270	405		5265	5400	
>>> STEP 6.2: TOTAL COSTS AND BENEFITS OF FORESTATION PROGRAM (1000's $/yr)								
		Present Value at 10% discount rate						
>> Incremental Net Benefit		1079	216	323	……	4204	4312	10644
>> Baseline Scenario Net Benefit		600	600	600		600	600	5867
> Cost		200	200	200		200	200	1956
> Benefit		800	800	800		800	800	7823
>> Mitigation Scenario Net Benefit		708	816	923		4804	4912	16511
Year	**1990**	**1991**	**1992**	**1993**	**….**	**2029**	**2030**	**Total**

> Annual Cost of Wasteland	195	190	185		5	0	1462
> Annualized Cost of Converted Land	300	600	900		11699	11998	29615
> Annual Benefit from Wasteland	780	760	740		20	0	5849
> Annualized Benefit from Converted Land	423	846	1268		16488	16910	41740
> Present Value of Initial Costs ($/ha)	1946	1946	1946	…..	1946	1946	19029

>>> STEP 7: COST-EFFECTIVENESS INDICATORS FOR THE 40 YEAR PROGRAM

>> Net Present Value of Benefits		
> $/tC		**4.75**
> $/ha.		**266**
>> Benefit of Reducing Atmospheric Carbon (BRAC)		
> $/tC-yr.		**0.036**
>> Initial Cost		
> $/tC		**8.5**
> $/ha.		**476**
>> Endowment (Present Value of Costs)		
> $/tC		**13.87**
> $/ha.	……	**777**

Example 2**: FOREST PROTECTION**

Year	1980	1990	1991	1992	1993	….	2029	2030
>>>> FROM STEPS 2 AND 3: LAND AREA (ha)								
>> Baseline Scenario	15000	12000	11725	11450	11175	….	1275	1000
> Land Converted from Forest			275	275	275		275	0
>> Mitigation Scenario	15000	12000	12000	12000	12000		12000	12000

>>>> STEP 4: ESTIMATING CARBON POOL AND SEQUESTRATION

>>> STEP 4.1: BIOMASS DENSITY (t/ha)

>> Baseline Scenario	200	160	158	157	155		108	107

>> Mitigation Scenario	200	160	162	163	165	236	238
>>> STEP 4.2: BIOMASS CARBON DENSITY (tC/ha)							
>> Baseline Scenario	100	80	79.2	78.4	77.6	54.1	53.5
>> Mitigation Scenario		80	80.8	81.6	82.4	117.9	119.1
>>> STEP 4.3: SOIL CARBON DENSITY (tC/ha)							
>> Baseline Scenario	100	100	100.0	100.0	100.0	100.0	100.0
>> Mitigation Scenario	100	100	101.0	102.0	103.0	147.4	148.9
>>> STEP 4.4: TOTAL CARBON DENSITY (tC/ha)							
>> Baseline Scenario	200	180	179.2	178.4	177.6	154.1	153.5
>> Mitigation Scenario		180	181.8	183.6	185.5	265.3	268.0
>>>> STEP 5: ESTIMATING COSTS AND BENEFITS							
>>> STEP 5.1: COST OF FOREST PROTECTION ($/ha/yr)							
>> Baseline Scenario	2	2	2	2	2	2	2
>> Mitigation Scenario		9.4	9.4	9.4	9.4	9.4	9.4
>>> STEP 5.1.1: STREAM OF COSTS AND PRESENT VALUE ($/ha.)							
>> Initial Costs		5					
>> Recurrent (Maintenance etc.) Costs			0.5	0.5	0.5	0.5	0.5
>> Monitoring Costs							
>> Total Costs			5.5	0.5	0.5	0.5	0.5
>> Present Value of Costs	**9.4**						
>>> STEP 5.2: BENEFIT FROM LAND CONVERSION ($/ha/yr)							
>> Baseline Scenario	50	50	50	50	50	50	50
>>> STEP 5.3: BENEFIT OR COST OF PROVIDING ALTERNATIVE PRODUCTS (1000's $/yr)							
>> Mitigation Scenario			-14	-29	-43	-563	-578
>>> STEP 5.4: BENEFIT FROM FOREST PROTECTION ($/ha/yr)							
>> Baseline Scenario	2	2	2	2	2	2	2
>> Mitigation Scenario		15	15	15	15	15	15

Year	1980	1990	1991	1992	1993	….	2029	2030	Total

>>> STEP 6.1: TOTAL CARBON POOL (1000's tC)

>> Annual Incremental C Protected			80	80	80		75	75	3062
>> Baseline Scenario C Pool	3000	2160	2101	2043	1985		196	154	
>> Mitigation Scenario C Pool		2160	2181	2203	2225		3184	3216	

>>> STEP 6.2: TOTAL COSTS AND BENEFITS OF FOREST PROTECTION (1000's $)

					<Present Value at 10% discount rate>			
>> Incremental Net Cost		-39	-10	18		1033	1061	2130
>> Baseline Scenario Benefit		14	28	41		536	550	136
> Cost		23	23	22		3	2	180
> Benefit from Conversion (Opportunity Cost)		14	28	41		536	550	136
> Benefit from Forest		23	23	22		3	2	180
>> Mitigation Scenario Benefit		52	38	23		-496	-511	-772
> Cost		113	113	113		113	113	1107
> Alternative Supply of Imported Products	14	29	43		563	578	1425	
> Benefit		180	180	180	….	180	180	1760

>>> STEP 7: COST-EFFECTIVENESS INDICATORS

>> Net Present Value of Benefits	
> $/tC	**-0.70**
> $/ha.	**-177.50**
>> Benefit of Reducing Atmospheric Carbon	
> $/tC-yr.	**-0.05**
>> Initial Cost of Forest Protection	
> $/tC	**0.02**
> $/ha.	**5.00**
>> Endowment (Net Present Value of Costs)	
> $/tC	**0.25**
> $/ha.	**64.37**

Appendix 1 C: 'LAND USE AND BIOMASS ALLOCATION MODULE
STEP 2.1: BASEYEAR 1990

PRODUCT SUPPLY AND DEMAND

>>> STEP 2.1.1: BASEYEAR SUPPLY

		Agric. Waste	**Fuel Wood**	**Indust. Wood**	**Agric. Product**	**Live-stock**	**Elect-ricity**	**Other**
Units		**‘000t**	**000’t**	**000’t**	**000’t**	**1000’s**	**GWh**	**---**
>>>	Forest Land							
>>	Dense Forest	100	0	1000	0	0	0	0
>>	10-40% Crown Cover	0	50	100	0	0	0	0
>>	<10% Crown Cover	0	0	0	0	0	0	0
>	Rangelands	0	0	0	0	5	0	0
>	Grasslands	0	0	0	0	10	0	0
>	Wastelands	0	0	0	0	10	0	0
>>	Other	0	0	0	0	0	0	0
>>>	Protected Land	0	0	0	0	0	0	0
>>	Wildlife Sanctuaries	0	0	0	0	0	0	0
>>	National Parks	0	20	0	40	0	0	0
>>	Other	0	0	0	0	0	0	0
>>>	Crop Land	0	0	0	0	0	0	0
>>	Perrenial	1000	0	0	1200	260	0	0
>>	Annual	495	0	0	1695	0	0	0
>>	Shifting	15	0	0	300	30	0	0
>>	Current Fallow	0	0	0	0	0	0	0
>>	Other	0	0	0	0	0	0	0
>>>	Other	0	0	0	0	0	0	0
>>	Urban	0	0	0	0	0	0	0
>>	Dams and Roads	0	0	0	0	0	45	0
>>	Mines	0	0	0	0	0	0	0
>>>	Not Classified above	0	0	0	0	0	0	0
>>	Additional Categories	0	0	0	0	0	0	0
>>	Imports/ (Exports)							

>>> STEP 2.1.2: BASEYEAR SUPPLY AND DEMAND

		Agric. Waste	Fuel Wood	Indust. Wood	Agric. Product	Live-stock	Elect-ricity	Other
Units		‘000t	000’t	000’t	000’t	1000’s	GWh	---
>>>	TOTAL SUPPLY OF PRODUCTS	1610	70	1100	3235	315	45	0
>>>	TOTAL DEMAND FOR PRODUCTS	1515	70	1100	3240	315	45	0

NOTE:

* Agricultural waste and fuel wood are treated as substitutes in the model. Their combined supply should be compared with total household cooking fuel demand.

>>>> 1990 PRODUCT EXTRACTION RATE (/ha)

Units		Agric. Waste t/ha	Fuel Wood t/ha	Indust. Wood t/ha	Agric. Product t/ha	Live-stock #/ha	Elect-ricity MWh/ha	Other
>>	Forest Land							
>	Dense Forest	1.00	0.00	10.00	0.00	0.00	0.00	0.00
>	10-40% Crown Cover (Woodlands) 0.00	1.00	2.00	0.00	0.00	0.00	0.00	
>	<10% Crown Cover							
>>	Rangelands	0.00	0.00	0.00	0.00	0.20	0.00	0.00
>>>	Grasslands	0.00	0.00	0.00	0.00	0.50	0.00	0.00
>>	Wastelands	0.00	0.00	0.00	0.00	0.25	0.00	0.00
>>	Other							
>>	Protected Land							
>>>	Wildlife Sanctuaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	National Parks	0.00	1.67	0.00	3.33	0.00	0.00	0.00
>>	Other							
>>	Crop Land							
>>	Perrenial	1.00	0.00	0.00	1.20	0.26	0.00	0.00
>>	Annual	0.33	0.00	0.00	1.13	0.00	0.00	0.00
>>>	Shifting	0.08	0.00	0.00	1.50	0.15	0.00	0.00
>>	Current Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Other							
>>>	Urban	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Dams and Roads	0.00	0.00	0.00	0.00	0.00	0.15	0.00
>>	Mines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Not Classified above	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Additional Categories	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Imports/ (Exports)							

>>>> 1990 SUSTAINABLE PRODUCT EXTRACTION RATE (/ha)

Units		Agric. Waste t/ha	Fuel Wood t/ha	Indust. Wood t/ha	Agric. Product t/ha	Live-stock #/ha	Elect-ricity MWh/ha	Other
>>>	Forest Land							
>	Dense Forest	0.00	0.00	10.00	0.00	0.00	0.00	0.00
>	10-40% Crown Cover (Woodlands) 0.00	1.00	2.00	0.00	0.00	0.00	0.00	
>	<10% Crown Cover							
>>	Rangelands	0.00	0.00	0.00	0.00	0.20	0.00	0.00
>>>	Grasslands	0.00	0.00	0.00	0.00	0.50	0.00	0.00
>>	Wastelands	0.00	0.00	0.00	0.00	0.25	0.00	0.00
>>	Other							
>>	Protected Land							
>>>	Wildlife Sanctuaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	National Parks	0.00	1.67	0.00	3.33	0.00	0.00	0.00
>>	Other							
>>	Crop Land							
>>	Perennial	1.00	0.00	0.00	1.20	0.26	0.00	0.00
>>	Annual	0.33	0.00	0.00	1.13	0.00	0.00	0.00
>>>	Shifting	0.08	0.00	0.00	1.50	0.15	0.00	0.00
>>	Current Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Other							

Agric.	Fuel	Indust.	Agric.	Live-	Elect-

		Waste	Wood	Wood	Product	stock	ricity	Other
Units		**t/ha**	**t/ha**	**t/ha**	**t/ha**	**#/ha**	**MWh/ha**	
>>>	Urban	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Dams and Roads	0.00	0.00	0.00	0.00	0.00	0.15	0.00
>>	Mines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Not Classified above	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Additional Categories	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>>>	Imports/ (Exports)							
>>	DATA FOR PROJECTING DEMAND			1990	2010	2030		
>	Population Growth Rate				0.02	0.015		
>	Rural Population Growth Rate				0.03	0.02		
	GDP Growth Rate				0.04	0.035		
	Agricultural Value Added Growth Rate				0.04	0.035		
	Industrial Value Added Growth Rate				0.04	0.035		

STEP 2.4: BASELINE SCENARIO:

PRODUCT SUPPLY AND DEMAND

STEP 2.4.1: PRODUCT SUPPLY 2030

Units		**Agric. Waste ‘000t**	**Fuel Wood 000’t**	**Indust. Wood 000’t**	**Agric. Product 000’t**	**Live-stock 1000’s**	**Elect-ricity GWh**	**Other ---**
>>	Forest Land							
>	Dense Forest	0	0	1000	0	0	0	0
>	10-40% Crown Cover (Woodlands) 0	50	100	0	0	0	0	
>	<10% Crown Cover	0	0	0	0	0	0	0
>>	Rangelands	0	3	0	0	8	0	0
>>>	Grasslands	0	0	0	0	12	0	0
>>	Wastelands	0	0	0	0	10	0	0
>>	Other	0	0	0	0	0	0	0
>>	Protected Land	0	0	0	0	0	0	0
>>>	Wildlife Sanctuaries	0	0	0	0	0	0	0
>>	National Parks	0	1	0	0	0	0	0
>>	Other	0	0	0	0	0	0	0
>>	Crop Land	0	0	0	0	0	0	0
>>	Perrenial	1000	0	0	2000	200	0	0
>>	Annual	2433	0	0	4896	378	0	0
>>>	Shifting	150	0	0	300	30	0	0
>>	Current Fallow	0	0	0	0	0	0	0
>>	Other	0	0	0	0	0	0	0
>>	Other	0	0	0	0	0	0	0
>>>	Urban	0	0	0	0	0	0	0
>>	Dams and Roads	0	0	0	0	0	99	0
>>	Mines	0	0	0	0	0	0	0
	Not Classified above	0	0	0	0	0	0	0
>>>	Additional Categories	0	0	0	0	0	0	0
	Imports/ (Exports)			0	773			
>>>								
>>>	STEP 2.4.2: PRODUCT DEMAND				2030			
	TOTAL SUPPLY OF PRODUCTS	3583	54	1100	7969	637	99	0
	TOTAL DEMAND FOR PRODUCTS	3372	156	1100	7969	628	104	0

>>>> BASELINE SCENARIO: PRODUCT EXTRACTION RATE (/ha) 2030

Units		Agric. Waste t/ha	Fuel Wood t/ha	Indust. Wood t/ha	Agric. Product t/ha	Live-stock #/ha	Elect-ricity MWh/ha	Other
>>	Forest Land							
>	Dense Forest	0.00	0.00	10.00	0.00	0.00	0.00	0.00
>	10-40% Crown Cover (Woodlands) 0.00	1.00	2.00	0.00	0.00	0.00	0.00	
>	<10% Crown Cover	0.00	8.00	2.00	0.00	0.00	0.00	0.00
>>	Rangelands	0.00	0.12	0.00	0.00	0.30	0.00	0.00
>>>	Grasslands	0.00	0.00	0.00	0.00	0.60	0.00	0.00
>>	Wastelands	0.00	0.00	0.00	0.00	0.25	0.00	0.00
>>	Other	0.00	0.00	0.00	0.00	0.25	0.00	0.00
>>	Protected Land							
>>>	Wildlife Sanctuaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	National Parks	0.00	0.85	0.00	0.00	0.00	0.00	0.00
>>	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Crop Land							
>>	Perrenial	1.00	0.00	0.00	2.00	0.20	0.00	0.00
>>	Annual	1.61	0.00	0.00	3.24	0.25	0.00	0.00
>>>	Shifting	0.75	0.00	0.00	1.50	0.15	0.00	0.00
>>	Current Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>>	Urban	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Dams and Roads	0.00	0.00	0.00	0.00	0.00	0.33	0.00
>>	Mines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Not Classified above							
>>>	Additional Categories	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>>	Imports/ (Exports)							

>>>>2030 BASELINE SCENARIO: SUSTAINABLE PRODUCT EXTRACTION RATE (/ha)

Units		Agric. Waste t/ha	Fuel Wood t/ha	Indust. Wood t/ha	Agric. Product t/ha	Live-stock #/ha	Elect-ricity MWh/ha	Other
>>	Forest Land							
>	Dense Forest	0.00	0.00	10.00	0.00	0.00	0.00	0.00
>	10-40% Crown Cover (Woodlands) 0.00	1.00	2.00	0.00	0.00	0.00	0.00	
>	<10% Crown Cover	0.00	0.50	1.00	0.00	0.00	0.00	0.00
>>	Rangelands	0.00	0.00	0.00	0.00	0.20	0.00	0.00
>>>	Grasslands	0.00	0.00	0.00	0.00	0.50	0.00	0.00
>>	Wastelands	0.00	0.00	0.00	0.00	0.25	0.00	0.00
>>	Other	0.00	0.00	0.00	0.00	0.25	0.00	0.00
>>	Protected Land							
>>>	Wildlife Sanctuaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	National Parks	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Crop Land							
>>	Perrenial	0.60	0.00	0.00	1.20	0.26	0.00	0.00
>>	Annual	0.57	0.00	0.00	1.13	0.00	0.00	0.00
>>>	Shifting	0.75	0.00	0.00	1.50	0.15	0.00	0.00
>>	Current Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>>	Urban	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Agric. Waste	**Fuel Wood**	**Indust. Wood**	**Agric. Product**	**Live-stock**	**Elect-ricity**	**Other**

Units		**t/ha**	**t/ha**	**t/ha**	**t/ha**	**#/ha**	**MWh/ha**	
>>	Dams and Roads	0.00	0.00	0.00	0.00	0.00	0.15	0.00
>>	Mines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Not Classified above							
	Additional Categories	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Imports/ (Exports)							

STEP 2.5: MITIGATION SCENARIO: 2030

PRODUCT SUPPLY AND DEMAND

STEP 2.5.1: PRODUCT SUPPLY 2030

		Agric. Waste	**Fuel Wood**	**Indust. Wood**	**Agric. Product**	**Live-stock**	**Elect-ricity**	**Other**
Units		**'000t**	**000't**	**000't**	**000't**	**1000's**	**GWh**	**---**
>>	Forest Land							
>	Dense Forest	0	0	2100	0	0	0	0
>	10-40% Crown Cover (Woodlands) 0	50	100	0	0	0	0	
>	<10% Crown Cover	0	0	0	0	0	0	0
>>	Rangelands	0	3	0	0	5	0	0
>>>	Grasslands	0	0	0	0	10	0	0
>>	Wastelands	0	0	0	0	0	0	0
>>	Other	0	0	0	0	0	0	0
>>	Protected Land	0	0	0	0	0	0	0
>>>	Wildlife Sanctuaries	0	0	0	0	0	0	0
>>	National Parks	0	0	0	0	0	0	0
>>	Other	0	0	0	0	0	0	0
>>	Crop Land	0	0	0	0	0	0	0
>>	Perrenial	1000	0	0	2000	200	0	0
>>	Annual	2436	0	0	4871	300	0	0
>>>	Shifting	150	0	0	300	30	0	0
>>	Current Fallow	0	0	0	0	0	0	0
>>>	Other	0	0	0	0	0	0	0
>>	Other	0	0	0	0	0	0	0
>>>	Urban	0	0	0	0	0	0	0
>>	Dams and Roads	0	0	0	0	0	100	0
>>	Mines	0	0	0	0	0	0	0
	Not Classified above	0	0	0	0	0	0	0
	Additional Categories	0	0	0	0	0	0	0
	Imports/ (Exports)			2261	798			
	TOTAL SUPPLY OF PRODUCTS	3586	53	4461	7969	545	100	0
	TOTAL DEMAND FOR PRODUCTS	3372	156	4461	7969	574	104	0

>>>> 2030 MITIGATION SCENARIO: PRODUCT EXTRACTION RATE (/ha)

Units		**Agric. Waste ‘000t**	**Fuel Wood 000’t**	**Indust. Wood 000’t**	**Agric. Product 000’t**	**Live-stock 1000’s**	**Elect-ricity GWh**	**Other ---**
>>	Forest Land							
>	Dense Forest	0.00	0.00	15.00	0.00	0.00	0.00	0.00
>	10-40% Crown Cover (Woodlands) 0.00	1.00	2.00	0.00	0.00	0.00	0.00	
>	<10% Crown Cover	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Rangelands	0.00	0.12	0.00	0.00	0.20	0.00	0.00
>>>	Grasslands	0.00	0.00	0.00	0.00	0.50	0.00	0.00
>>	Wastelands	0.00	0.00	0.00	0.00	0.50	0.00	0.00
>>	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Protected Land							
>>>	Wildlife Sanctuaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	National Parks	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Crop Land							
>>	Perennial	1.00	0.00	0.00	2.00	0.20	0.00	0.00
>>	Annual	1.62	0.00	0.00	3.25	0.20	0.00	0.00
>>>	Shifting	0.75	0.00	0.00	1.50	0.15	0.00	0.00
>>	Current Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>>	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Urban	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Dams and Roads	0.00	0.00	0.00	0.00	0.00	0.33	0.00
	Mines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Not Classified above	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Additional Categories	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Imports/ (Exports)							

>>>> 2030 MITIGATION SCENARIO: SUSTAINABLE PRODUCT EXTRACTION RATE (/ha)

>>>	Forest Land							
>	Dense Forest	0.00	0.00	15.00	0.00	0.00	0.00	0.00
>	10-40% Crown Cover (Woodlands) 0.00	1.00	2.00	0.00	0.00	0.00	0.00	
>	<10% Crown Cover							
>>	Rangelands	0.00	0.00	0.00	0.00	0.20	0.00	0.00
>>>	Grasslands	0.00	0.00	0.00	0.00	0.50	0.00	0.00
>>	Wastelands	0.00	0.00	0.00	0.00	0.25	0.00	0.00
>>	Other							
>>	Protected Land							
>>>	Wildlife Sanctuaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	National Parks	0.00	2.00	0.00	0.00	0.00	0.00	0.00
>>>	Crop Land							
>>	Perennial	1.02	1.00	0.00	1.20	0.26	0.00	0.00
>>	Annual	0.33	0.00	0.00	1.13	0.00	0.00	0.00
>>>	Shifting	0.08	0.00	0.00	1.50	0.15	0.00	0.00
>>	Current Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>>	Urban	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>>	Dams and Roads	0.00	0.00	0.00	0.00	0.00	0.15	0.00
>>	Mines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Not Classified above	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Additional Categories	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Imports/ (Exports)							

Appendix 2
Estimating Net Present Value of Forests
Managed in Perpetual Rotation

This note explains the computation of the net present value (NPV) for a plantation or forest, which is managed in perpetual rotation. We provide the formulas for computing the NPV for one rotation on a single plot, that for perpetual rotations on a single plot and finally for a mosaic of perpetual rotations on multiple plots. The NPVMP shown in the last equation should be used to calculate the NPV indicators shown in Item 4.

a. NPV per hectare for one rotation on one plot:

$$NPV = \sum_{0}^{T} (R_t - C_t) e^{-rt}$$

where;

R_t = Revenue per hectare in time t
C_t = Cost per hectare in time t
r = Rate of Discount
T = Rotation age in years
e = Natural logarithm base

b. NPV per hectare for perpetual rotations on one plot (NPVP):

$$NPVP = NPV(1 - e^{-rT})^{-1}$$

Note that for coppice plantations, a rotation should be taken to mean the length of time until replanting. The coppice harvest and costs should be treated as intermediate output and costs.

c. NPV per hectare of perpetual rotations on multiple plots (NPVMP):

$$NPVP = NPVP(1 - e^{-rT}) / T(1 - e^{-r})$$

d. Estimating the Benefit of Reducing Atmospheric Carbon (BRAC)

For the case where the economic damage caused by carbon increases at the rate of discount, we can estimate BRAC using the following formulation.

$$BRAC = NPV / (a^{-1} \sum_{0}^{Te} C_t)$$

where;

NPV = Net Present Value of Benefits
a = Decay Rate of Carbon
T_e = Time duration of carbon flows
C_t = Net carbon flow in time t

Appendix 3:
Mitigation options in Forestry

I. Maintain Existing Stocks:

(1) Forest Protection and Conservation –

Such measures, projects or policies are usually put in place for non-carbon resource management purposes, such as wildlife protection (national parks and game reserves), biological reserves, soil conservation, water catchment reserves, recreational areas, etc.

(2) Increased Efficiency in Forest Harvesting and Product Utilization.

These measures may include selective harvesting, harvesting for multiple end-uses, wood residue utilization for fuel, increased conversion efficiency (esp. in saw-milling and pulping) possibly involving technological intervention; salvage operations during conversion of forests to other landuses like hydropower development, etc.

(3) Bio-energy initiatives

-Efficient charcoal kilns and packaging of charcoal e.g. briquetting, more efficient woodfuel stoves, increased use of charcoal for industry like steel, use of sustainably grown woodfuel in the agricultural processing e.g. tobacco and tea curing, etc.

-Urban tree planting to reduce fossil fuel use for cooling and heating

II. Expanding Carbon Sinks.

Each one of the options under this category has to be separately identified and described depending on the end-use for which the new biomass is intended or the fate of the new land use. These would include: forest products such as woodfuel, timber, pulp and paper; forest services such like recreation, soil protection, emission reduction through fossil fuel substitution, etc. The fate of the biomass influences the carbon flows, cost and benefit streams, as well as the implementation possibilities of the specific mitigation option listed below:

(1) Afforestation - Planting forests in bare land, with biomass density commensurate to the objective of the project.

(2) Reforestation - Replanting and/or natural regeneration of deforested areas.

(3) Enhanced Regeneration - increasing the biomass density of existing degraded and under-stocked forests.

(4) Agroforestry - Some or all of the agroforestry forms listed below may be applicable to different suitable sites in the country. The most commonly practiced forms are:

- inter-cropping for agricultural and forest products.
- boundary and contour planting for wind and soil protection, as well agricultural and wood

products.
- taungya system which is applied in tandem with forest management.
- pastro-silviculture for forest and animal husbandry products
- non-timber tree farms for rubber, tannins, bamboo, rattan, etc.

(5) Urban and Community Forestry

- Include here is non-contiguous tree cover not elsewhere covered. This may include residential shade trees, roadside and demarcation trees.

III Substitution of GHG-intensive products

- The use of sustainably grown biomass for fossil fuels will delay the release of carbon from the fossil fuels for as long as the fossil fuels remain unused[49].

- Similarly, wood-derived from renewable sources if used as a substitute for wood obtained from depletable natural forests will also delay carbon release. Biomass products can also be used to replace emission-intensive products such as concrete, steel, plastics, etc.

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