ETHIOPIAN FOREST RESOURCES:

CURRENT STATUS AND FUTURE MANAGEMENT OPTIONS

IN VIEW OF ACCESS TO CARBON FINANCES

LITERATURE REVIEW

PREPARED FOR THE

ETHIOPIAN CLIMATE RESEARCH AND NETWORKING

AND

THE UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)

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ACRONYMS

AGBC	Above Ground Biomass Carbon
A/R	Afforestation/Reforestation
BEF	Biomass Expansion Factor
CAI	Current Annual Increment
CBO	Community Based Organization
CDM	Clean Development Mechanism
EFAP	Ethiopian Forestry Action Program
FAO	Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility
FINIDA	Finish International Development Agency
FRA	Forest Resources Assessment
GHG	Greenhouse Gas
IPCC	Intergovernmental on Climate Change
JICA	Japanese International Cooperation Agency
MAI	Mean Annual Increment
NGO	Non-governmental Organization
NPV	Net Present Value
NTFP	Non-Timber Forest Product
PDD	Project Design Document
PFM	Participatory Forest Management
REDD	Reducing Emissions from Deforestation and Forest Degradation
R-PP	Readiness Preparation Proposal
SNNPR	Southern Nations, Nationalities and Peoples Region
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNSO	United Nations Sudano-Sahelian Office
WBISPP	Woody Biomass Inventory and Strategic Planning Project

EXECUTIVE SUMMARY

The main purpose of this review paper is to appraise current knowledge on forest resource base, forest resources management status, and to explore options for promoting multiple objectives forest management through the intermarriage of innovative forest management approaches and emerging carbon finances. The need for management of forest growth stocks for enhanced carbon sequestration will form the core of the review with emphasis on the need for paradigm shift from classical forest management focused on wood production to a new forest management approach for multiple objectives that includes carbon stock and carbon trading scenarios.

The key findings and recommendations are presented as follows:

The forests resources of Ethiopia store 2.76 billion tons of carbon (about 10 billion tons of CO_2) in the aboveground biomass, which will be released to the atmosphere in 50 years if the deforestation continues at the present rate of about 2%. The local consequences are shortage of wood products, substantial loss of foreign currency for importing wood, changes in local and regional climates, depletion of biological resources, further degradation of remaining vegetation and widespread land degradation. The current scenario of little investment in the forest management will result in substantial ecological (including carbon emissions from forest sector), social and economic costs for the country. Professional forest management intervention could have a significant impact on the socio-economic contribution of the forestry sector. For example, a *Eucalyptus* stand of one hectare could generate an additional value of 65,000 Ethiopian Birr in 30 years, if the stand were harvested following the criterion of maximum volume production rotation period of 19 years in typical Ethiopian condition, rather than waiting until the 30th year. This is an instance highlighting the need for change in attitude and appreciation to the contribution of professional management in the forestry sector.

At national and local level, the function of managed forest resources for creating a stable environment within which sustainable socio-economic development can be achieved is being recognized by policy and decision makers at various levels, including knock-on effects on the other sectors. For example, the rugged and sloppy terrain in the highlands, especially those without terraces, should command priority as the expected intense

rainfall associated with climate change on such exposed surfaces will result in increased sediment transport to reservoirs and dams. Financial instruments such as REDD+ and CDM could be utilized as a catalyst for promoting such programs. Cognizant of productive and protective functions of forests, Ethiopia has taken significant steps in the legal or policy arena for development, management and use of forest resources. The Ethiopian Government appreciates the fact that forest resources cannot be managed centrally by overstretched government staff. Following the federal structure, the Ethiopian constitution allows the devolution of power to Regional States for the management and use of natural resources including forests. Additionally, the forest policy and the environmental policy acknowledge participation of local communities in natural resource management. Such conditions as decentralization of power and participation of local communities are assumed to be effective in natural resource management, and are required to obtain climate related finances. In the context of drawing resources from the international community, Ethiopia has also developed and submitted Readiness Preparation Proposal (R-PP) for REDD negotiation. With such positive developments, there is a great prospect for Ethiopia to mitigate the ever declining and degrading forest resources.

By maximizing of access to such financial resources, the scene of Ethiopian forestry will gradually change. Ethiopia is endowed particularly with woodlands and shrublands which store more than five times higher carbon than that which exists in the natural high forests, and it is strongly suggested that the country brings these resources forward in REDD negotiations. In light of carbon finance prospects through CDM, most forest areas were deforested before the 1989 in Ethiopia, with large areas of land eligible for CDM projects through Afforestation/Reforestation (A/R).

Forest management is evolving from classical management targeting timber production to attaining objectives of environmental services and social demands. Carbon as a component is a new addition, with a potential to alter the economics of forest management, which has often constrained the capacity of the country for managing its forest resources. Future forest management should thus aim at diversifying outputs from forests by the principle of multiple objectives forest management. The major challenge Ethiopia faces in optimizing natural forest management for multiple objectives, including carbon forestry, is the high dependence of the country on biomass fuels for its energy. Over 90% of the energy consumed in the country is biomass fuel. Thus, alternative sources of energy, increased afforestation and efficient use of fuelwood should continue to receive attention.

The current forest development pilot activities including area enclosures, participatory forest management, biosphere reserves, pioneering forest carbon projects should be scaled-up to cover important natural forests and woodlands in the country. This should be possible with the potential technical and financial investments at least partly provided by the international community. Besides developing management plans for the remaining forests and woodlands, creating new forests should receive particular attention. To increase afforestation and reforestation, the relevant government institutions should support opening seed centers (and capacity building for managing the centers), provide technical and financial support to seed orchard development, and develop management tools (growth models for important tree species by research institutions) and guidelines for enhanced wood and carbon production, and for optimizing other ecological services.

There is a great hope that improved management of forest resources under the inter-marriage of innovative forest management approaches (PFM, community based area enclosures, soil and water conservation, etc.) and carbon finances will change the landscape of the forestry sector. This will enable the country to contribute more to climate change mitigation, while tackling national problems such as poverty and land degradation. However, despite progress in policies related to natural resources including forests, the weak implementation capacity, lack of a strong forest institution, and discrepancy among sectoral policies (investment/settlement vis-à-vis forestry) remain a challenge. Establishing a strong forestry institution and identifying conflicts in policy statements and taking measures should thus receive priority by the government.

1 INTRODUCTION

Managing forest resources has become one of the most important agenda in climate negotiations, which has resulted in proliferation of financial mechanisms such as CDM and REDD. The CDM was proposed by the Kyoto protocol as an instrument to reduce emissions with particular purpose of enhancing cooperation between developed and developing countries in mitigating climate change. The CDM assists developed countries implementing their emission reduction at low cost; and developing countries receive capital for environmentally acceptable and economically viable forest investments that contribute to sustainable development. Similarly, REDD opens an opportunity for the development of sustainable forest management and utilization in developing countries which have historically experienced high rates of deforestation and forest degradation due to financial and technical constraints. To access such financial resources and economic incentives, developing countries are expected, among others, to:

- Reduce deforestation and degradation of existing forests,
- Expanding the size of existing forest carbon stocks,

In this respect, the country's institutional capacity to generate and report accurate and consistent data that meet international standards and also to create favourable policy environment are most valid requirements to derive benefits from climate funds. More importantly various issues regarding carbon cycle in forests, periodic monitoring of changes in forest and carbon stocks and verifying the results and establishing empirical relationships are likely to be the subject of research and development undertakings.

In view of this, the UNDP-CDM Capacity Development Office has a long-term objective of supporting institutional capacity building for better economic returns, environmental management, and societal adaptive capacity to climate anomalies through promoting carbon projects in Eastern and Southern Africa. The Ethiopian Climate Change Research and Networking is established with a broad objective of providing scientific information on climate change related issues to development actors and policy makers in a useful and timely manner. In view of assisting the national efforts, the UNDP-CDM Office and the Ethiopian Climate Change Research and Networking held a series of discussions and agreed to conduct a review on current knowledge on the status of Ethiopian forest resources, their management and carbon stocks potentials and explore options for promoting multiple objectives forest management in light of climate change mitigation and adaptation. With this objective, UNDP-CDM Capacity Development Office has commissioned this review.

The review article consists of seven chapters. Chapter 1 provides background and purpose of the work and the contents of the review article. Chapter 2 broadly describes the extent of global forests resources and their special role in carbon cycle and climate. In Chaper3 and 4, the focus turns to forest resources in Ethiopia, and presents data on forest types, growth stocks, productivity and their carbon stocks. Chapter 5 provides an overview of the carbon finance prospects for Ethiopia, and reflects on the conditions required for realizing the potential. Chapter 6 discusses about the multiple objectives forest management. This Chapter presents forest management scenarios with illustrations, proposes better future forest management options, and identifies the challenges/conditions for implementing the multiple objectives forest management.
Overall conclusions and recommendations are presented in chapter 7. Finally, for interested readers, five annexes are attached at the end of the document.

2 THE POSITION OF FORESTS IN THE GLOBAL CARBON CYCLE

Human beings have become a component in the earth's system, driving and accelerating global warming through the rapid release of greenhouse gases (GHGs) into the atmosphere. Human beings alter the composition of the atmosphere through increasing the concentration of greenhouse gases (GHGs) in the atmosphere by ***fossil fuel*** burning which represents about two-third of the global emissions and by ***deforestation*** and ***land use changes*** representing about one-third. These are ***anthropogenic causes*** of climate change. There is no doubt that our climate is changing. This will pose huge challenges to nations, organizations, enterprises, cities, communities and individuals. Developing countries will suffer most from adverse consequences of climate change, and the highly vulnerable regions and people are already being affected.

Forests play an important role in the global carbon balance. As both carbon sources and sinks, they have the potential to form an important component in efforts to combat global climate change. FRA (2010) estimated that the world's forests store 289 Gt of carbon in their biomass alone (www. fao.org/forestry/fra/fra2010/en/). As sources of GHGs, deforestation accounts for approximately 20% of anthropogenic emissions (FAO

2006; Stern, 2006). Although deforestation is reported to represent about 20% of the global GHGs emissions, regionally the figure varies. About 70% GHGs emissions is caused by deforestation in Africa (Gibbs et al., 2007). For the world as a whole, carbon stocks in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010, mainly because of a reduction in the global forest area. On the other hand, the recent IPCC report estimated that the global forestry sector represents over 50% of global greenhouse mitigation potential (IPCC, 2007). Consequently, forestry became the focus of global climate change policy and is given a key position in international climate treaties. While sustainable management, planting and rehabilitation of forests can conserve or increase forest carbon stocks, deforestation, degradation and poor forest management reduce them.

When forests are transformed into agriculture, the subsequent land use systems implemented determine the amount of potential carbon restocking that takes place. Annual crop systems will on average contain only 3 tons C ha^{-1}, intensive tree crop plantations 30-60 tons carbon ha^{-1}, which is 1 and 10-25% of the forest biomass and carbon stock. The annual C sequestration rate (increment of standing stock) may be the same for these three of vegetation types (annual crop, tree plantation and forest) about 3 tons C ha^{-1} yr^{-1}, but the mean residence time differs from 1, 10 to 83 years. Changes in carbon stocks between vegetation and land use types relate primarily to this 'mean residence time' of the carbon in the biomass.

3 FORESTS AND FOREST GROWTH

3.1 Extent of world's forest resources

The definition of forest is still ambiguous. According to FAO (2006) forest is a minimum land area of 0.05-1 ha with tree crown cover more than 10-30% and tree height of 2-5m at maturity. FAO (2001) defined a forest as "land with a tree crown cover (or equivalent stocking level) of more than 10% and an area of more than 0.5 hectare; the trees should be able to reach a minimum height of 5 meter at maturity *in situ*".

A recent Forest Resources Assessment (FAO, 2010) estimated the global forest cover at just over 4 billion hectares, which is 31% of total land area of the world (see also www. fao.org/forestry/fra/fra2010/en/; Table 1), which corresponds to an average of 0.6 ha per capita. The five most forest-rich countries (the Russian Federation, Brazil, Canada, the United States of America and China) account for more than half of the total forest area. Ten countries or areas have no forest at all and an additional 54 have forest on less than 10 percent of their total land area. Concerning deforestation, mainly the conversion of tropical forests to agricultural land, the same report indicated signs of decreasing in several countries but continues at a high rate in others. Around 13 million hectares of forest were converted to other uses or lost through natural causes each year in the last decade compared to 16 million hectares per year in the 1990s. Both Brazil and Indonesia, which had the highest net loss of forest in the 1990s, have significantly reduced their rate of loss.

Table 1 Global forest resources

COUNTRY	TOTAL FOREST AREA (MILLION HA)
Russia	809.0
Brazil	520.0
Canada	310.0
USA	3040
China	207.0
DRC	154.0
Australia	149.0
Indonesia	94.0
Sudan	70.0
India	68.0
Others	1,347.6
World	4,033.6

Source: FAO, 2010

3.2 Forests and other land cover types in Ethiopia

Ethiopia's forest resources supply most of the wood products used within the country, as well as a large volume of diverse non-timber forest products (NTFPs), besides their ecological functions. Several authors and national or sub-national inventory projects have carried out assessments and documented the extent of forest resources and other land uses of Ethiopia. Among these, the following are worth mentioning: Chaffey (1982), ENEC-CESEN (1986), LUPRD-MOA/FAO (1985), and the World Bank-funded Woody Biomass Inventory and Strategic Planning Project (WBISPP) has reviewed these various reports.

A key source of information on forests and other land uses in Ethiopia is WBISPP. WPISPP (2005) classified the land cover types in Ethiopia into 9 major types (Table 2). In the recent forest proclamation (No. 542/2007), high forests, woodlands, bamboo forests are recognized as forests.

Based on WBISPP, the land use/land cover statistics in Ethiopia indicates that woody vegetations including high forests cover over 50% of the land (WBISPP, 2005). The definition of forest is ambiguous in the IPCC Good practices Guideline. Following the definition of FAO (2001) the vegetations of Ethiopia that may qualify as 'forests' are natural high forests, woodlands, plantations and bamboo forests, with an estimated area of 35.13 million ha. If the shrublands are added to this (considering the definition of IPCC for forest), the estimated cover is over 50% (61.62 million ha). The next largest land use type is cultivated land with 18.6% cover.

Table 2 The land-cover types of Ethiopia and their magnitude/proportion (WBISPP, 2005)

LAND COVER TYPE	AREA IN HECTARE	PERCENTAGE
Cultivated land	21,298,529	18.6
High forests	4,073,213	3.56
Plantations	501,522	0.4
Woodlands	29,549,016	25.8
Shrublands	26,403,048	23.1
Grasslands	14,620,707	12.8
Afro-alpine	245,326	0.21
Highland bamboo	31,003	0.027
Lowland bamboo	1,070,198[1]	0.97
Swamp	810,213	0.70
Water	828,277	0.72
Bare rock, soil, etc	15,359,409	13.4

Source: WBISPP, 2005 (p. 18)

On the other hand, the recent data on forest resources of Ethiopia reported in FAO (2010) puts Ethiopia among countries with forest cover of 10-30%. According to this

[1] LUSO-Consult, 1997

report Ethiopia's forest cover (FAO definition) is 12.2 million ha (11%), clearly underestimated compared to the IPCC definition. It further indicated that the forest cover shows a decline from 15.11million ha in 1990 to 12.2 million ha in 2010, during which 2.65% of the forest cover was deforested. The cover belonging to other wooded land remained constant in the same period. The FAO (2010) FRA data is based on a reclassification, calibration and linear extrapolation of data from WBISPP 2004.

3.3 Forest growth stocks and annual increments in Ethiopia

The growth of forest and other woody vegetations in Ethiopia is primarily determined by the amount of rainfall, modified by local topography and drainage properties. Chaffey (1982), EFAP (1994) and WBISPP (2005) presented estimates of forest growth stocks for Ethiopia. The estimates for forest growth stocks and annual increments presented in Table 3 are derived from data of WBISPP (2005).

Table 3 Mean growth stock and annual increments of forest categories of Ethiopia (m^3 ha^{-1})

FOREST CATEGORY	GROWTH STOCK/FREE-BOLE VOLUME/ (M^3 HA^{-1})	MAI (M^3 HA^{-1} YR^{-1})
High forest	131.5	5.65
Woodland	21.0	0.79
Plantation	178.8	12.5
Lowland bamboo	26.0	1.3
Highland bamboo	83.0	3.9
Shrubland	14.9	0.5

Source: WBISPP (2005) and Sisay et al. (2009). Growth stock and MAI calculated based on weighted averages of sub-categories of a main forest category.

The estimates presented here are very rough and probably also underestimated. For example, JICA calculated stand volumes for Belete Gera high forest at three strata, namely, closed, slightly disturbed and disturbed forests. The calculated merchantable stand volumes were 410.8, 282.8 and 174.8 m^3 ha^{-1}, respectively. The discrepancy calls for the need for carrying out forest growth stock assessments at least at ecosystem scale.

3.4 Carbon stocks of forests in Ethiopia

At a national level, forest inventories, woody biomass assessments, agricultural surveys, land registry information and scientific research can prove useful data for acquisition of forest carbon accounting. In this context WBISPP data is relevant source of information for Ethiopian forest carbon accounting. Thus, the national carbon stock presented in Table 4 was estimated based on WBISPP data.

From Table 4, it is clear that the largest store of carbon in the country is found in the woodlands (45.7%) and the shrublands (34.4%). However, despite their great potential in influencing carbon balance, these vegetation types are largely neglected in forest related discussions, including carbon negotiations.

Table 4 Mean aboveground carbon density and total carbon stocks in major forest categories of Ethiopia

FOREST CATEGORY[2]	FREE-BOLE BIOMASS (TONS HA^{-1}) (A)	BEF (TONS HA^{-1}) (B)	AGB C (TONS HA^{-1}) (A*B*0.5*)	AREA (MILLION HA)	TOTAL C STOCK (MILLION TONS)
High forest	131.5	2.74	106.68	4.07	434.19
Woodland	21.0	6.9	42.75	29.55	1,263.13
Plantation	178.8	2.33	123.0	0.50	61.52
Lowland bamboo	26.0	6.19	47.5	1.07	50.80
Highland bamboo	83.0	3.44	84.23	0.03	2.53
Shrubland	14.9	8.20	36.04	26.40	951.54
Total C					2,763.70

*Assuming the carbon content of green wood is approximately 50% of the biomass (WBISPP, 2005). C is calculated based on the formula developed by Brown, 1997. AGB = Aboveground biomass. BEF = Biomass expansion factor.

The national carbon stocks shown here largely agree with 2.5 billion tons in 2005 reported by Sisay et al. (2009). On the other hand, the carbon stocks estimates for

[2] All woody vegetations (referred to as forest category) are included in the estimation of the national carbon stocks.

Ethiopia based on biome-averaged values of 153 million tons by Houghton (1999) and 867 million tons by Gibbs and Brown, (2007a) are very low. See http://cdiac.ornl.gov/epubs/ndp/ndp0555/ndp05b.html.

Brown (1997) reported a carbon density of 101 tons ha^{-1} for high forests in Ethiopia, and agrees well with the estimate presented here. However, some case studies show even higher carbon density values of close 200 tons ha^{-1} than the estimates based on WBISPP for high forests in Bale Mountains (Temam, 2010; Tsegaye Tadesse, 2010). The discrepancy is due to the different methods and tools applied, regional variability in soil, topography, and forest type and the uncertainties associated with the methods used.

The WBISPP data has provided a broad base for estimating forest and carbon stocks at national level. However, for higher accuracy and increased utility at management level, it may be appropriate to use a finer scale of vegetation classification and make estimates at this scale. For instance, nine vegetation types are distinguished in Ethiopia: Afro-alpine and Sub-Afro-alpine, Dry Evergreen Montane Forest, Moist Evergreen Montane Forest, *Acacia-Commiphora* (Small Leaved) Woodland, *Combretum-Terminalia* (Broad Leaved) Woodland, Lowland Dry Forests, Wetland (swamps, lakes, rivers and riparian) Vegetation,, Evergreen Scrub Vegetation, and Lowland Semi-Desert and Desert Vegetation (Sebsebe, 1996; CSE, 1997; Zerihun, 2000; IBC, 2005). Data on growth stocks and increments and corresponding carbon stocks could be generated at least following this classification or even at finer resolutions (e.g., strata within a vegetation type based on level of degradation) for increasing its utility in management planning and REDD negotiations in the future. Therefore, research institutions and other relevant organizations should draw their attention to addressing this gap.

3.5 Carbon stocks in agroforestry systems (Trees outside forests)

Despite the fact that trees outside forests have a great potential for carbon storage, they are often not recognized by researchers and development organizations and the government, while discussing about carbon and climate change at large. Although assessing the extent of tree resources outside forests remains challenging, it is essential that these are not overlooked in carbon accounting.

Coffee agroforestry: Among the four coffee production systems in Ethiopia namely, forest coffee, semi-forest coffee, garden coffee, and plantation coffee (Woldetsadik and Kebede, 2000), the focus of this part is on garden coffee, to avoid double counting. Although the potential for carbon storage is high, the carbon stocks in garden coffee system have not been systematically documented. The Gedeo traditional coffee-*enset* agroforests, for example store 70 tons of carbon ha^{-1} (Yitebitu Moges, unpublished data). Dossa et al. (2008) reported a more or less similar value for carbon stock of 81 tons ha^{-1} in the shaded coffee system (*Coffea canephora*) in Togo.

Cultivated land: Open cereal fields lightly stocked with trees contain about 1.78, while moderately stocked fields have 2.47 tons of carbon ha^{-1}. The carbon stock value for irrigated fields is about 1.6 tons of carbon ha^{-1} (WBISPP, 2005).

3.6 Carbon emissions and sequestration in forestry sector in Ethiopia

Identification of the potential sources and sinks of GHGs is a major step in making emissions accounting at various levels for directing policy. In Ethiopia, the major sources of GHGs emission from Land Use Change and Forestry are use of biomass energy (charcoal, firewood, dung, residues, etc., and conversion of forests to agriculture. On the other hand, the forest and woody vegetations of Ethiopia play an important environmental role in sequestering carbon. Table 5 presents the emissions of GHGs from burning of biomass fuels and conversion of forests to agricultural lands and sequestration by the woody vegetation in Ethiopia.

The results presented indicate that the forest resources of Ethiopia sequester 44 times the amount of CO_2 that is being released by burning the woody biomass stocks as fuels and 478 times the CO_2 released from clearing forests for agriculture.

Table 5 GHG emissions from and C sequestration in forest resources of Ethiopia ('000 tons)

GHGS	EMISSION BY FOREST CLEARING FOR AGRICULTURE	EMISSION FROM BURNING OF BIOMASS FUELS(WOOD, DUNG, CROP RESIDUE)	SEQUESTRATION IN WOODY BIOMASS STOCK	BALANCE

C	1,203.1	12,416.8	74,496.4	-60867.5
CO_2	4,415.4	47,490.3	2,108401.6	-2056495.9
CO	0.144	1.7	68.9	-67.1
CH_4	0.029	943.8	13.8	+930.0
N_2O	0.017	0.2	8.0	-7.8
NOx	0.291	2.8	139.0	-135.9

Source: WBISPP (2005)

The large net carbon sequestered in woody biomass suggests that woody vegetations in Ethiopia are in a state of fast biomass accumulation. However, previous national inventories (e.g., see Table 9 for the negative balance between wood yield and consumption at national level) and the level of increasing degradation indicates just the opposite. Therefore, either the yield increment estimates reported by WBISPP is too high and/or the wood consumption at national level for fuel and construction is underestimated. Hence, the emission and sequestration balance made by WBISPP needs to be re-evaluated.

4 PLANTATION FORESTS IN ETHIOPIA

4.1 Background

Forest resources in Ethiopia have experienced so much pressure due to increasing need for wood products and conversion to agriculture. The trend in Ethiopia today is to protect the remaining natural forests for their various social, economic and environmental values. On the other hand, there is increasing demand for wood and wood products (see Table 9 in section 6.1.1). To strike the balance between the two interests, afforestation/reforestation (here after referred to as plantations) is very important. Plantations are even-aged forest stands deliberately established by humans on formerly non-forested lands or deforested lands. The purpose can be wood production or protection under the ownerships of the private sector, individual farmers, the community, or the state.

The size of plantations ranges from less than a hectare (e.g., *Eucalyptus* woodlots) to several hundred thousands of hectares of land (large scale plantations). Size of large scale state or community plantations depends on whether the plantation is integrated with a processing industry (and thus with its annual intake of wood), availability of market or the wood requirements of communities.

Ethiopia has a long history of tree planting activities. According to historical records, afforestation started in the early 1400s by the order of King Zera-Yakob (1434-1468). Modern tree planting using introduced tree species (mainly Australian *Eucalyptus*) started in 1895 when Emperor Menelik II (1888-1892) looked into solutions for alleviating shortage of firewood and construction wood in the capital, Addis Ababa. However, the historic rapid expansion of large scale and community plantations occurred during the Dergue regime, which resulted in the establishment of large scale plantations. Several fuelwood projects funded by UNSO, UNDP and FINNIDA spread over the country with marked concentrations around big cities such as Bahir Dar, Dessie, Gondar, Nazareth, Addis Ababa and Debre-Berhan (Breitenbach, 1962). These plantations have often been established for supplying the huge demand for wood products in Ethiopia.

Today, tree plantations cover approximately 500, 000 ha (WBISPP, 2005), out of which 133,041 ha were established as community plantations between 1978 and 1989. *Eucalyptus species* (58%) and *Cupressus* (29%) are the dominant plantation species. Other species include *Juniperus procera* (4%), *Pinus* species (2%) and the rest (7%).

4.2 Productivity of plantation forests: Growth stocks and increments

Productivity of plantations depends on site productivity (quality), seed sources (genetic potential), and management. Site productivity is primarily determined by rainfall, modified locally by topography and drainage pattern influencing water availability and length of growing season. However, moisture limitation in drier areas can be overcome by irrigation, which greatly increases productivity because of high level of radiation and good soils.

For productive plantations, selection of mother trees with superior quality is essential. Seed collection, processing and storage are also key considerations. Currently about 59 % of the demand for tree seeds are covered primarily by a government supplier at the Forestry Research Center (Abayneh Derero, 2004). Besides site quality and the genetic potential, management of plantations including nursery establishment, seedling production, silvicultural operations (timely weeding, thinning, and pruning), protection (diseases, pests, fire) and timely harvesting affect the productivity of plantations in a given area. However, most of the plantations are suffering from lack of proper management. The condition of plantations established by the state and communities across the country does not receive timely thinning, pruning or harvesting. This has a negative implication on the economic benefits that could be accrued from plantations (see Section 6.1.2 below).

Knowledge of forest growth, mean annual increment and rotation period are important for forest managers in order to indicate the amount of total harvest in a given year by a specific species. The mean annual increment (MAI) indicates the amount of wood that the plantation will produce annually. The rotation period is the period in which the forest plantation is allowed to grow. The rotation period informs the manager as to when the plantation has to be harvested depending on the intended purpose of management.

Growth stocks prediction

Growth models (graphs, tables and equations) are used for predicting growth and yields of plantations across a variety of sites. Without these tools, there are no means to evaluate which rotation length or thinning schedule would give the most favourable yield of various timber assortments. Proper management of plantations in Ethiopia has been neglected partly due to lack of suitable growth models and yield tables. The exceptions are yield tables were developed for *Eucalyptus globulus* (Pukkala and Pohjonen 1989) and *Cupressus lucitanica* (Pukkala and Pohjonen, 1993; Negash Mamo 2007), the major plantation species in Ethiopia (Figures 1 and 2). Figure 1 a-d predicts the volume and biomass growth *E. globulus* in central highlands of Ethiopia for four site classes. For example, in Figure 1 a, at 20 years of age, *E. globulus* plantations of seedling origin produce total volumes (or attain a dominant heights) of 873 (46.5 m), 580 (38.7m), 370 (31.0 m), and 178 m^3 ha^{-1} (23.2m) at Site Class I (good site), II, III and IV (poor site), respectively.

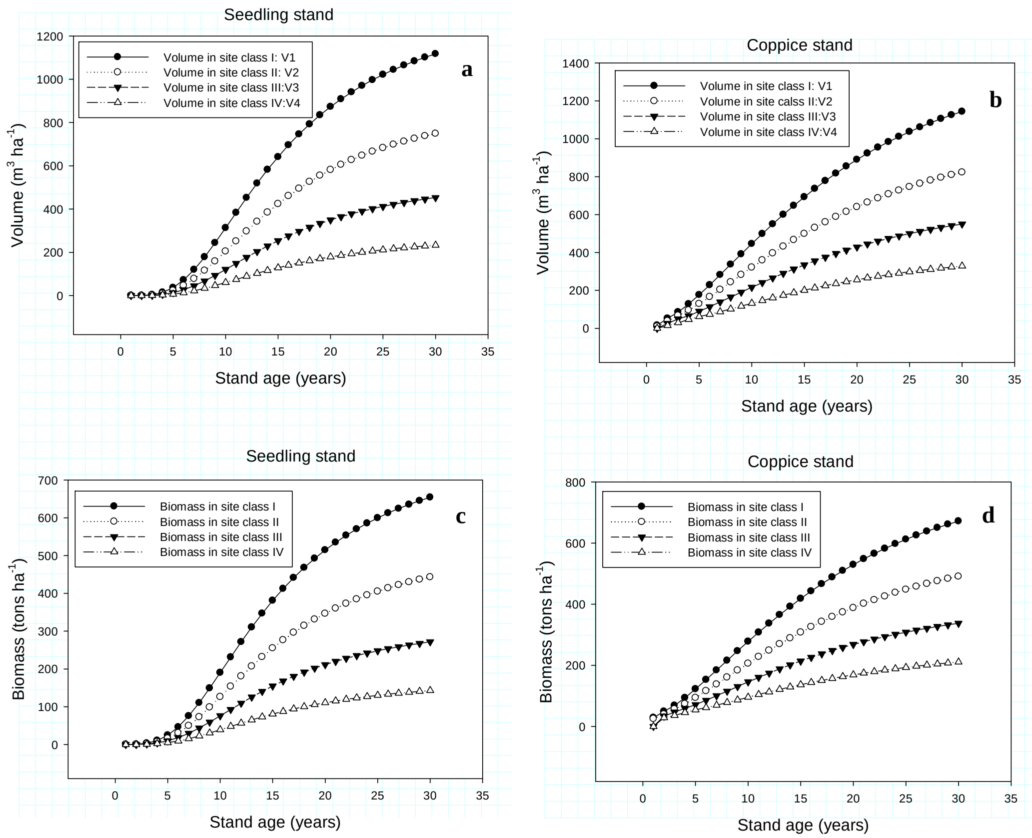

Figure 1 Growth curves predicting growth of *Eucalyptus. globulus* stands of different origins in central highlands of Ethiopia: (a) total volume production for stands originating from seedlings, (b) total volume production for stands originating from coppice, (c) biomass production for stands originating from seedlings, and (d) biomass production for stands originating from coppice.
Data source: Pukkala and Pohjonen, 1989.

Similarly, based on the yield tables developed by Negash Mamo (2007), the growth curves (volume and biomass) for *C. lucitanica* from 8 site indices are presented in Figures 2a and b.

The major limitation of site class/site index based productivity indicators developed by Pukkala and Pohjonen (1989), Pukkala and Pohjonen (1993) and Negash (2007) is that the biophysical setting (e.g., rainfall, temperature, soil fertility, soil depth, and soil type within which such classes exist is not defined. However, noting the fact that the major success factors (site, seed source and management) determining plantation productivity, there is a need for assessment of dominant heights versus age to assign site classes for the existing plantations (of the important species) in Ethiopia by research institutions for guiding the future investment in plantations. Generally, constructing a set of yield tables for different Ethiopian plantation growing sites for important species will provide forest managers with a more flexible tool for examining management options.

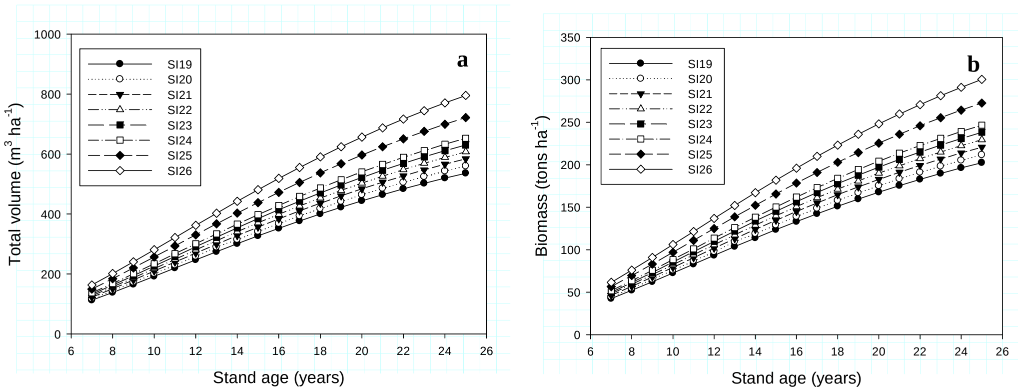

Figure 2 Growth curves predicting growth of Cupressus lucitanica stands at different sites (Site index 19-26) in Gambo-Shashemene, Ethiopia: (a) total volume, and (b) biomass.
Data source: Negash Mamo, 2007.

Mean annual increment

Pukkala and Pohjonen found a five-fold difference in mean annual increments (MAI) of *E. globulus* plantations (Table 6) at different locations in central highlands of Ethiopia. For *Eucalyptus globulus* in central highlands of Ethiopia the MAI ranges between 44 m^3 ha^{-1} at the Site Class I (most productive site) through 29.2 m^3 ha^{-1} at Site Class II, 17.5 m^3 ha^{-1} at Site Class III to 9 m^3 ha^{-1} in Site Class IV (the poorest site). However, most *Eucalyptus* fuelwood plantations in the 1980s were established on poorer sites, which produced 10 to 20 m^3 of wood $ha^{-1}yr^{-1}$ (Pohjonen and Pukkala, 1990). Negash Mamo (2007) has also found for *Cupressus lucitanica* plantations in Munessa area (within one traditional agro-ecology) at reference age 15 years maximum mean annual increments between 22 m^3 ha^{-1} yr^{-1}at site index 19 and 38 m^3 ha^{-1} yr^{-1} at site index 26. The results suggest that use of traditional agro-ecological zones for classification of forest productivity is too broad because highly variable site conditions are often encountered in a particular traditional agro-ecological zone.

Table 6 Productivity of major introduced tree species in Ethiopia at various site conditions

SPECIES	*SITE INDEX/ SITE CLASS*	*ROTATION LENGTH (YR)*	*MAI (M3 HA-1 YR-1) (STEM WOOD VOLUME)*	*BIOMASS (TONS HA^{-1})*
Cupressus lusitanica	M19	19	22.23	13.91
	M21	19	23.23	14.50
	M22	19	24.22	15.65
	M23	19	26.13	16.21
	M24	19	27.06	17.88

	M25	19	29.86	19.65
	M26	19	32.82	13.31
E. globulus (seedling stand)	Site class 1	19	43.90	26.29
	Site class 2	19	29.20	17.49
	Site class 3	19	17.50	10.48
	Site class 4	19	9.00	5.39
E. globulus (coppice stand)	Site class 1	14/15	46.20	27.67
	Site class 2	15	33.30	19.94
	Site class 3	14/15	22.30	13.35
	Site class 4	14	13.40	8.03
E. saligna		10	38.00	22.76
P. patula		12/13	25.00	14.97

Data source: Negash Mamo (2007) for *Cupressus lusitanica*; Pukkala and Pohjonen, 1989 for *Eucalyptus globulus*, and Orlander, 1986 for *Eucalyptus saligna*, and *Pinus patula*.

Information on growth stocks and yields of other important plantation species across sites remains still a gap, and should be addressed by research institutions.

Rotation period: Physical, financial, technical, maximum volume production

Four types of rotation period are distinguished. The rotation of maximum volume production uses the criterion of maximum MAI; and the plantation is harvested when the current annual increment (CAI) and MAI are equal. Technical rotation period uses the end use of the forest products (pole, timber, veneer) as a guide for harvesting. Financial rotation maximizes the positive cash flow from plantation. Physical rotation is determined by the ecological characteristics of the site (drier areas shorter rotation).

Similar to annual increments, lack of data on optimal rotation period for various plantation species hampers proper forest management in Ethiopia. Only few species in specific localities have been studied so far. For example, Pukkala and Pohjonen (1989) provided recommendation on rotation period for *E. globulus*. Based on maximum volume production, the rotation period for *E. globulus* plantations of 1500-2000 tees ha^{-1} which originated from seedlings is about 19 years (Table 6). For *Eucalyptus* woodlots planted at higher densities of 10,000 to 40,000 trees ha^{-1} and managed for pole production, the technical rotation period may be applied, which is 3-6 years (Evans, 1992).

The rotation period of maximum volume production for *C. lucitanica* is 19 years (Table 6; Negash, 2007). However, since the softwood plantations in Ethiopia are often managed for timber production (trees should be large enough for lumber) and thus require longer rotation period than 19 years as *Cupressus* trees will be still small for timber at 19 years of age. Therefore, longer rotation period is required for maximizing economic benefits. Either financial or technical rotations can be appropriate. Research should focus its attention on developing forest growth and yields models for important plantation species.

5 CARBON FINANCE PROSPECTS FOR ETHIOPIA

Climate change funding mechanisms available for financing forestry sector are CDM and REDD. Ethiopia has so far registered only one CDM project (Humbo, SNNPR, UNFCCC registration Dec. 2009, area of 2,728 ha). Concerning REDD, Ethiopia has prepared Readiness Preparation Proposal (R-PP) to the World Bank's Forest Carbon Partnership Facility (FCPF).

The prospect for access to carbon finances for Ethiopia is very great considering the following facts. Studies such as Ethiopian Forestry Action program (EFAP, 1994) indicate that about 35% of Ethiopia's land area or nearly 40 million ha might once have been covered by high forests. By the early 1950s the forest area cover declined to 16% of the total land area. In 1989, the land area covered by forests declined to 2.7% of the total land area. This shows that about 36 million ha of land in Ethiopia is eligible for CDM A/R (Table 7).

Table 7 Potential land area eligible for CDM in Ethiopia

YEAR	Total Land Area (ha)	Forest Cover (ha)	Land Potentially Eligible for A/R	Remarks
Pre- 1950	112,800,000	39,480,000		
1950	112,800,000	18,048,000	21,432,000	Afforestation
1989	112,800,000	3,045,6000	15,002,400	Reforestation
Total land that may be dedicated for CDM through A/R			36,434,400	

Source: Estimated by Sisay Nune in EPA (2010) based on data from EFAP (1994).

Actual areas under CDM are emerging on project basis. For example there are now three projects, in the Abote, Ada Berga, and Sodo areas, that are mentioned as potential CDM projects. An additional CDM project, covering an area 20,000 ha earmarked for afforestation/ reforestation in the Amhara National Regional State is under discussion.

With respect to REDD, the large amount of carbon stored in the different forest categories (Table 4) may continue to release CO_2 to the atmosphere through deforestation and forest degradation. If Ethiopia decides to protect these forest resources through carbon finances, it is possible to mitigate the release of 2.76 billion tons of carbon[3] into the atmosphere.

Similar to the CDM, REDD+ pilots are in preparatory stages in Ethiopia by various non-governmental organizations, such as FARM Africa/SOS Sahel in the Bale eco-region (500,000 ha) (which is expected to generate several millions of USD during the contract period of 21 years). The government of Ethiopia has started to take lessons from the experiences of the NGOs working in the area of CDM and REDD for example in the preparation of R-PP for REDD. On the basis of such experiences the government may refine some of the policy and other requirements that are expected under its domain. Clearly, the aforementioned prospects should provide sufficient incentives for the Government of Ethiopia to create enabling policy environment and over all readiness and the international community to provide required financial resources.

In order to fully utilize such financial opportunities while addressing global climate change, capacity building of the government institutions and the private sector dealing with forestry (for example in the preparation of PDD) should receive high priority. Despite the existence of good policies, there is still a gap in some areas that might hinder the implementation of carbon related projects such as absence of benefit sharing mechanism (e.g., how much for community and how much for the project developer, and how much for the government, etc) and absence participatory forest management in the forest policy of the country. Another limitation for carbon project development is the upfront cost. Therefore, to take advantage of the available opportunities:

[3] 1 ton carbon is equivalent to 3.6667 tons of CO_2.

- Identifying or re-organizing the right institution (s) to guide the process and implementation of carbon projects
- Building capacity of institutions and the private sector including communities
- Creating conducive policy environment for carbon and carbon related projects
- Facilitating access to bank loan for carbon and carbon related projects (e.g., upfront costs).

6 FUTURE FOREST MANAGEMENT OPTIONS : MULTIPLE OBJECTIVES MANAGEMENT

Forests have multiple functions in today's society, and the principles of multiple objectives management of different forest categories is expected to achieve such expectations. Addressing the problems of deforestation and forest degradation will enhance ecosystem services that have knock-on effect on other sectors such as energy, and agriculture. Additionally, the demand for wood and non-wood forest and tree products could be satisfied. Through appropriate management, the various objectives could be optimally achieved, including enhanced carbon sequestration in forest resources.

6.1 Forest management scenarios

6.1.1 Scenario 1: Status quo (Business as usual)

Forest resources have not so far been managed properly, with few exceptions by profit making enterprises (e.g., Oromyia Forest and Wildlife Enterprise) and forest managed temporarily by NGOs in PFM. Consequently, deforestation and forest degradation continued unabated (Table 8) at an annual rate of about 2%. At 2% deforestation, about 700,000 ha of 'forests' will be destroyed every year, releasing nearly 110 million CO_2 to the atmosphere. If this scenario is maintained, another important consequence is wood crisis (Table 9). Further, the country will be forced to import more wood, with a significant implication on foreign currency reserve.

Table 8 Annual deforestation rate estimates in Ethiopia

SOURCE	ANNUAL DEFORESTATION RATE	REMARKS
FAO, 2010	0.96	Forest decline between 1990-2010

WBISPP, 2005	2.08	Difference between forest cover estimates by CESEN in 1977 and WBISPP, 1991
WBISPP, 2005	1.66	For the three forested Regional States (Oromyia, SNNP, Gambella)
Reusing, 1998	5	For southwest high forests

The table presented above shows different figures on the rate of deforestation. The authors probably used different definitions of forest, different tools and methods. These figures are confusing for users including decision makers. Therefore, there must be one agreed rate of deforestation for Ethiopia that can be used by all stakeholders and forestry experts. Nevertheless, the WBISPP (2005, p.20) indicated the actual deforestation rate may be close to the oft-quoted rate of 2%.

On this demand-supply condition (Table 9), the remaining forest resources of the country will be further degraded and deforested, unless modern energy and construction materials are introduced. Additionally, the effort the Ethiopian Government is putting in order to benefit from the climate change related projects, particularly, REDD will be a futile exercise. Therefore, this scenario cannot be acceptable, and change is needed.

Table 9 Supply- consumption pattern of fuel wood in Ethiopia

SOURCE	ANNUAL WOOD SUPPLY	ANNUAL CONSUMPTION	DEFICIT OR SURPLUS
UNDP/World Bank, 1984	8.1 million tons (13.5 million m^3)	20.34 million tons (33.9 million m^3)	Consumption is 2.5 annual yield
ENEC/CESEN, 1986	63 million tons	24 million tons (40 million m^3)	Positive balance
EFAP, 1994	8.6 million tons (14.4 million m^3)	35 million tons (58.4 million m^3)	Consumption 4 times higher
UNDP/World, 1996	n.a.	31.5 million tons	Deficit indicated

		(52. million m3)	
WBISPP, 2005	50.1 million tons (84.9 million m^3)	53.6 million tons (89.4 million m^3)	Deficit of 3.5 million tons
EFAP 1994 projection for 2020	-	-	Deficit 87-121 million m^3

n.a. = data not available.

6.1.2 Scenario 2 : Managed forest

The experience in other countries shows that management intervention on natural forests increases wood production, carbon sequestration, besides its benefits in terms of biodiversity conservation and watershed protection. For example, the average accumulation rate of carbon dioxide in managed forests is around 5.5 tons ha^{-1} yr^{-1} in woodlands, and 21 in tropical rainforests, subtropical forests and lowland forests (www.communitycarbonforestry.org), while unmanaged tropical rainforests grow at a rate of about 0.5 tons ha^{-1} yr^{-1} (Lewis et al., 2009): about 40-fold increase in annual yields. Additionally, unmanaged forest is subject to further degradation.

Ethiopia has taken significant legal steps towards improved management of forests and may change the forest management regime in the country. The new forests policy and forest proclamation (542/2007) is one such step. In this proclamation, besides the definition of forest ownerships (primate and state) and purpose (protection and production), decentralized forest administration is recognized. Ethiopia has also gathered experiences on innovative forest management approaches including Participatory Forest Management and area enclosures (e.g., Tigray's experience) over the last two decades. Woodlots, agroforestry and public afforestation and reforestation are also increasing. Additionally, NGOs are pioneering special forest management strategies such as Biosphere Reserves, CDM and REDD carbon projects. The government has also introduced a national tree planting campaign every year all over the country in which every person is encouraged to plant trees, with significant influence on the attitude of the population on trees.

Given such developments, it can be expected that the gloomy situation in forest management will not continue. Up-scaling such strategic forest management approaches backed with proper forest management principles (which is not the case in most instances now) should be able to change the current forest management regime.

It is important to note that key aspects of proper forest management include the following, among others:

- Proper institutions for managing forest resources (skilled manpower, sufficient financial and material resources)
- Applying scientific forest management principles (e.g., sustainable yield principle where annual harvest equals annual yield)
- Adequate investment on required silvicultural operations and forest administration, and
- Proper utilization and marketing.

In this context, the Oromyia Forest and Wildlife Enterprise is pioneering implementation of these requirements.

Conventional forest management- Emphasis on wood production from plantations

The benefit of forest management guided by management plans is illustrated by Figure 3. In the past *E. globulus* plantations did not have management plans, except in a few cases, with respect to, among other things, when to harvest resulting in significant economic losses. In the Figure it can be shown that by applying a harvesting schedule recommended based on maximum wood production (optimal rotation period), about 160 m^3 ha^{-1} of additional wood can be produced in 30 years (indicated by green parenthesis). This is equivalent to at least a loss of 64,000 Ethiopian Birr at the current *Eucalyptus* wood prices (Table 10).

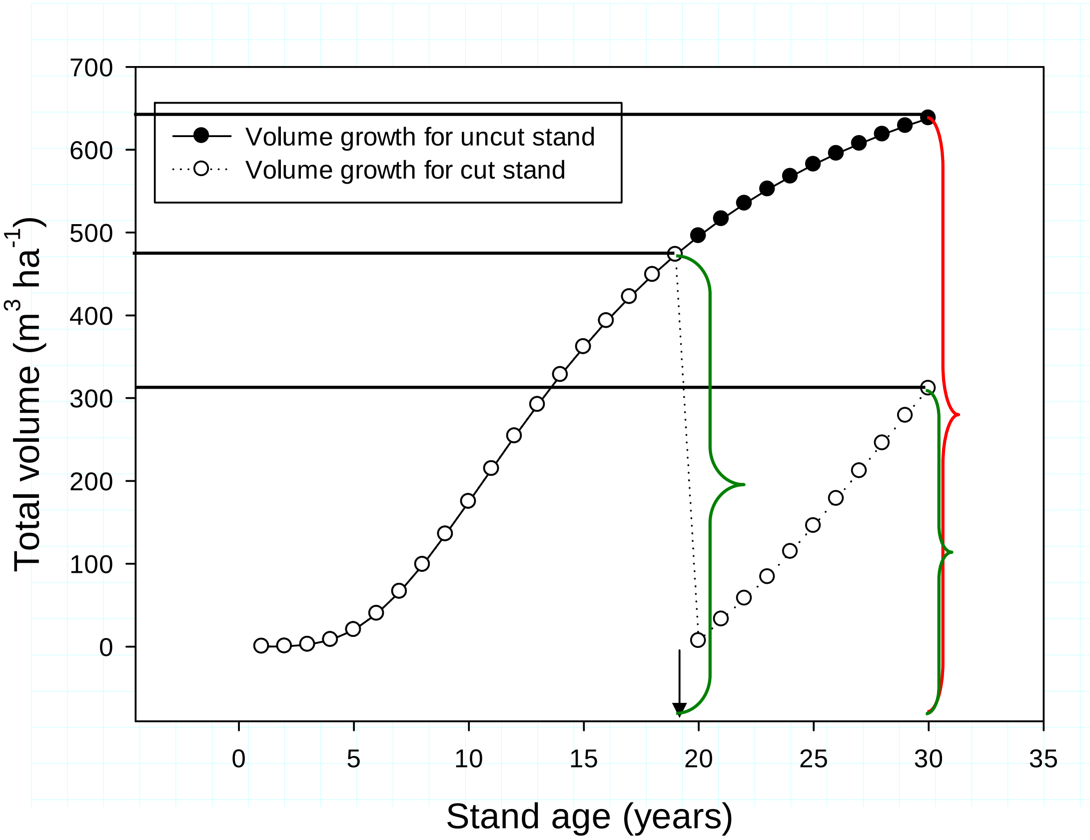

Figure 3 Total volume of wood produced in 30 years under unmanaged (red-current management) and managed by maximum volume production rotation (green-future management) *Eucalyptus globulus* stands in central highlands of Ethiopia.
Data source: Pukkala and Pohjonen, 1989.

However, the classical forest management for wood production may not be the best option in light of emerging demands on the forest resources in climate change mitigation and biodiversity conservation. Therefore, the principle of multiple objectives forest management including carbon as a non-wood product is a realistic and appropriate option for future forest management.

Table 10 Prices of wood products in Ethiopia

PRODUCT TYPE	*MARKET PLACE*	*DIAMETER (CM)*	*HEIGHT (M)*	*PRICE/UNIT PRODUCT (BIRR)*	*PRICE/M3 (BIRR)*
A. *Eucalyptus* wood	Addis Ababa				
1. *Chefeka*[4]		3.6	3.78	6	100
2. Small poles (*Mager*[5])		5.2	3.96	9	99
3. Medium size poles (*Quami*[6])		7.3	3.93	12	95
4. Large pole (*Woraji*[7])		9.4	8.3	15	102
5. Particle board wood					400
6. Split wood[8]					400
7. BLT[9]					
B. Timber (log)					
C. lucitanica	Goba	about 30 cm			611
C. lucitanica	Shambo	"			652
Pinus patula	Nekemt	"			710
P. patula	Illubabor	"			713
C. Charcoal	Addis Ababa				245*

Source: Oromiya Forest Enterprise and markets in Addis Ababa , September 2010.
*To produce 100 kg of charcoal, about 1 m^3 of wood is needed.

Multiple objectives management: Wood production and carbon forestry

In light of the national and global diverse interests on forest resources (wood products, climate change mitigation, watershed protection, biodiversity conservation etc.), future forest management in Ethiopia needs to adopt the principle of multiple objectives management. The aim of this section is to show the implications of multiple objectives forest management as applied on forest plantations on economic returns. We compared Net Present Value (NPV) of *E. globulus* and *C. lucitanica* stands managed only for wood, only for carbon and both for wood and carbon. We used the stem volume data from in Pukkala and Pohjonen (1989) for *E. globulus* stand site class I. For *C. lucitanica*, we drew the data from Negash Mamo (2007). In order to calculate the carbon from stem volume

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[4] *Chefeka*: Branches and attached leaves that are stripped from the trunks of *Eucalyptus* trees so that they are suitable as construction poles.
[5] *Mager* : A pole with about 4 m long and 4-4.5 cm (small) to 5-7 cm (large) diameter.
[6] *Quami* : A pole with about 3.5-4.0 m long and 5-8 cm (small) to 8-11 cm (large) diameter.
[7] *Woraji*: A pole about 8.0-8.5 m long and 4-6 cm (small) 9--11 cm (large diameter) diameter.
[8] Split wood: Poles, large branches and round wood that are split into size in length of about 0.5 m and thickness of 5-10 cm so that they are suitable directly as fuelwood.
[9] BLT: Small dead branches, leaves and twigs that fall to the ground as litter.

data, we applied the formula of Brown (1997). The current prices of firewood and saw logs were taken from Table 10. Forest management costs were also included in the analysis (SIDA, 1990). Using a discount rate of 10% and a conservative price of 4 USD/ ton of CO_2, the NPVs of *Eucalyptus* and *Cupressus* stands were calculated for wood, carbon and both wood and carbon scenarios. Accordingly, the NPVs for a hectare of *Eucalyptus globulus* stand managed at 21 years of rotation were 40,802 from wood only, 23,172 from carbon only and 77,177 Birr from wood and carbon. [It should be noted here that a *Eucalyptus* stand from the best site has been considered; and on poorer sites, lower NPVs are to be expected]. Similarly, from *Cupressus lucitanica* stand grown for 25 years (Site Index 23), the corresponding NPVs were 88,318, 10,348, and 106, 991 Birr per ha, respectively (for details see Annex 5). With same discount rate, the NPV for *C. lucitanica* calculated for wood only case closely agrees with the estimate of Pukkala and Pohjonen (1993).

NPV analyses show that the income from carbon trading for *C. lucitanica* and *E. globulus* has increased by 9% and 30%, respectively. These indicative analyses suggest that incorporating carbon as a component of multiple objectives management alters the economics of forest enterprises. Therefore, carbon payments should be considered as a catalyst and combined with sustainable utilization of wood and non-wood products to create sufficient economic incentive for forest plantation development. Considering the payments for other environmental services, such as reduced soil erosion and nutrient cycling, the benefits could be even higher.

6.2 Challenges and recommended actions for implementing best future forest management scenario

One challenge Ethiopia faces in light of managing forest resources for multiple purposes including carbon is that the national energy balance is dominated by fuelwood, which is the main source of energy to both urban and rural areas, accounting for over 90% of the primary total energy supply. The gap between demand and supply for fuelwood is increasing with time (Table 9). If Ethiopia is to bring significant change in forest resources degradation, alternative sources of energy should be a top priority at least in the medium term. Additionally, expansion of energy plantations which are eligible under CDM could also be taken as a strategy.

Additionally, despite significant progress in the policy arena, the main challenge is still weak implementation of the policies concerning land use planning, creating capacitated institutions at various levels, land use conflicts, illegal cutting of trees, benefit sharing mechanisms in participatory forest management, etc. Under the current forest administration and governance, the Natural Resources Directorate of Ministry of Agriculture and Rural Development are responsible for forestry development, conservation and utilization. The technical and financial capacity is very limited, and is understaffed. In the forestry research, the situation is not much different. Facilitating successful implementation of forest development strategies requires having adequate national institutional capacity, at federal and regional levels. In the REDD negotiations, the lack of a strong forestry institution in the country is raised as one of the challenges affecting the readiness of the country to access such emerging opportunities. The research institutions can handle the activities of carbon assessment and certification processes with adequate capacity building.

Policy discrepancies among sectors of the economy remain also a challenge. The implementation of investment and settlement policies without undertaking Environmental Impact Assessment and implementing the Social and Environmental Management Plan for resettlement program will be in conflict with forest conservation and development efforts.

Forest management plans are essential components of sustainable forest management, but the lack of up-to-date data on forest resources will constrain the development of such plans. Therefore, besides the use of available recent data, inventory efforts for carbon assessment and monitoring should also aim at generating data that can be used in developing forest management plans. The need to have an updated inventory data also underlines the necessity for an institution that conducts such inventory on a regular basis.

The role of CBOs and public institutions such as universities, hospitals and military barracks in forest development should not be overlooked. Indeed, some of these organizations consume considerable amount of wood, and thus could be encouraged to own their forests managed sustainably.

At the international level, active carbon finance available for forestry sector is CDM though A/R. However, as the experience show few forestry carbon projects have been approved so far, as creditors mainly support other carbon projects (e.g., energy efficient machines or apparatus). This challenge could be overcome by establishing a 'Forest-Credits' under CDM.

7 CONCULSIONS AND RECOMMENDATIONS

7.1 Conclusions

1. Global forests resources of just over 4 billion hectares now as a carbon pool hold about 40% of the carbon in the atmosphere. If the forests are converted to other land uses, the carbon in the atmosphere will increase from the current level of 760 Gt to 1,049 Gt, which in turn could result in unprecedented global warming. This means that the international community cannot keep the threshold of 2°C acceptable warming without taking adequate action on global forest resources with such a significant carbon pool. These forest resources are in a state of decline.
2. Following the FAO (2006) definition of a forest which includes woodlands, plantations, bamboo forests and scrublands, Ethiopia has a total forest cover of 61.62 million ha (53.8%). Nevertheless, there is ambiguity on the definition of forests which is reflected on forest statistics by various sources. Forests not only refer to high forests, which is the case in most communications, but they also include the aforementioned vegetation types. National experts, research institutions and development actors should have a common understanding of this definition. The Ethiopian Forestry professionals should come up with standardized definition on forests considering the current developments such as carbon forestry, rather than timber ptroduction.
3. The forest resources of Ethiopia store an estimated 2.76 billion tons of carbon, playing a significant role in the global carbon balance. The largest store of carbon in the country is found in the woodlands (46%) and the shrub lands (34%), while the high forests store about 16%. REDD negotiations and other carbon related policies and projects should not neglect the woodland and shrub land resources. Likewise, trees outside forests are often overlooked.

4. There is discrepancy among deforestation estimates made by several studies owing to differences in the methods and tools applied, forest definition used, period of assessment and the forest types considered. A comprehensive assessment on forest resources in the country is so far made by WBISPP, which estimated an approximate annual rate of 2%. However, information on the degree of degradation in forest resources is still a gap.
5. Data on forest growth stocks and increments in Ethiopia (except plantations) is aggregated without due considerations for the variations within the broad vegetation types (e.g., the nine vegetation types) mostly leading to underestimated values.
6. The plantation forests in the country, except a few cases, are not properly managed (no timely silvicultural operation and harvesting) with a significant negative consequence on economic returns. In order to fill the gap between demand and supply of wood, and reducing pressure on the remaining natural forest resources, expansion of plantation forests should be taken as an important strategy. The expansion can not only be shouldered by the government, but the private sector and public institutions such as education institutions and military barracks should also be encouraged to develop their own forests.
7. However, in order to support plantation expansion, responsible bodies at the federal and regional levels need to identify suitable land. Additionally, although some forest management tools (yield tables, growth models, etc) and plantation technologies (e.g., seed) have been developed on certain sites and plantation species, knowledge gaps on most species still remains a challenge, and research institutions need to address these gaps.
8. The prospect for Ethiopia in regard to access to carbon finances is high given the large area potentially eligible for CDM and the large forest resources of the country. However, limitations in institutional capacity, policy gaps, competing interests and weak implementation of polices, and absence of defined benefit sharing mechanisms may hinder the implementation of carbon projects.
9. The status quo forest management (little investment in applying proper management, limited plantation development, deforestation and degradation of existing forest resources) will cost the country economically, ecologically and socially. Alternative management scenario is necessary. In light of the national and global diverse interests on forest resources (wood products, climate change

mitigation, watershed protection, biodiversity conservation etc), future forest management in Ethiopia need to adopt the principle of multiple objectives management. Incorporating carbon as a component of multiple objectives management alters the economics of forest enterprises (up to 30% increase in revenue), and thus acts as a catalyst to create an economic incentive for forest plantation development.

10. To overcome some of the abovementioned discrepancies forest resource assessment statistics in general and in forest carbon accounting in particular, there is a need for developing standard manual-protocol for Ethiopia.

7.2 Recommendations

1. Cognizant of the importance of global forest resources in climate change mitigation and also in some cases their role in adaptation, there must be international commitment to take adequate action on protection of the remaining forest resources.
2. Ethiopia needs to have a mandated forestry institution that, among other things,:
    - Clarifies on the definition of forests and forest classification in the country in agreement with relevant experts.
    - Verifies forest statistics and reports in local, national and international communications.
    - Caries out periodic inventory of forest resources
    - Identifies suitable technologies and land for plantation development, and supports private and public sectors
3. Development and research agents need to give due attention to woodlands and shrub lands in the same status as high forests of the country. Additionally, REDD negotiations and other carbon related policies and projects should consider these resources as well as trees outside forests.
4. The country should have responsible, accountable and strong institutions at all levels equipped with sufficient skilled manpower, budget and physical resources for realizing optimal access to climate finances and implementing multiple objectives forest management. Historical instability of the Forestry Sector in Ethiopia and its consequences, justifications for upgrading the status of the Forestry Sector in Ethiopia in light of the emerging issues, experiences in other

countries and proposed management structure has been detailed in a separate document prepared by the Forestry Research Center at the Ethiopian Institute of Agricultural Research. This document provides a framework for further discussions which eventually lead to the establishment of the envisaged national forestry institution.

5. The country should have a standard forest resources and carbon assessment manual or protocol and reporting formats that is officially adopted and strictly followed by users.
6. An up-to-date inventory on forest growth and carbon monitoring should be conducted periodically based on systematically located geo-referenced sample plots located in the nine vegetation types and other land cover types.

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9 ANNEXES

9.1 ANNEX 1: GLOBAL FOREST SECTOR AND CLIMATE CHANGE

Climate change: causes, consequences, definitions of terms and concepts

Climate change is a change in the statistical distribution of weather over periods of time. There is no doubt that our climate is changing. This will pose huge challenges to nations, organizations, enterprises, cities, communities and individuals. Developing countries will suffer most from adverse consequences of climate change, and the highly vulnerable regions and people are already being affected.

Today, human beings have become a component in the earth's system, driving and accelerating global warming through the rapid release of greenhouse gases (GHGs) into the atmosphere. Human beings alter the composition of the atmosphere through increasing the concentration of greenhouse gases (GHGs) in the atmosphere by ***fossil fuel*** burning which represents about two-third of the global emissions and by deforestation and ***land use changes*** representing about one-third. These are ***anthropogenic causes*** of climate change.

Other forcing factors also exist that are beyond human kind's influence such as variations in solar radiation and volcanic activities, and fluctuations in the earth's axis and its orbit around the sun (***natural causes***). These are exogenous factors, partly responsible for the changes which have occurred between ice ages and the interglacial periods. They take place over a larger time frame (tens of thousands of years), and must be clearly differentiated from climate change that is induced by human beings. The latter can be prevented by taking adequate action. At the international level, knowledge of the consequences of human kind's behaviour on our climate system- presented for example in the latest IPCC assessment reports, is well founded and is adequate for policy makers.

Greenhouse effect: the earth's climate system is determined by many factors, processes and interactions at a global scale. One important phenomenon in the earth's atmosphere is the well known greenhouse effect. The ***greenhouse effect*** is a natural phenomenon that warms the planet to a temperature that allows the existence of all living beings. This natural effect is responsible for the comfortable living conditions on earth with a mean global temperature of 15 °C. Without an atmosphere, the mean temperature would be approximately 30 °C lower. However, that warming effect is increasing rapidly today – putting life at risk. Human activities such as the burning of fossil fuels result in the emissions of several GHGs, principally carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The table below presents the type of GHGs, and their warming power. The contribution of each of these gases to global warming in the next century based on the estimates of emissions of each is 63% by CO_2, 24% by CH_4, 10% by N_2O, and 3% by other GHGs (Hadley Centre, 2005). The principal gas, CO_2, will be responsible for almost two-thirds of the expected future global warming. For the scientific community and policy makers there are two main alternatives to try to improve this situation: (1) reduce the ***emissions*** of greenhouse gases into the atmosphere; and (2) remove these gases from the atmosphere once they are in place. The term '***carbon sequestration***' is the most commonly used term to talk about the removal of greenhouse gases from the atmosphere.

Greenhouse gases (GHGs) and their warming power

PARAMETERS	***CO_2***	***CH_4***	***N_2O***	***O_3***	***CFCS***
Concentration (1993)	362 $\mu l\ l^{-1}$	1,75 $\mu l\ l^{-1}$	313 $nl\ l^{-1}$	20 $nl\ l^{-1}$	0.6 $nl\ l^{-1}$
Concentration (1765)	280 $\mu l\ l^{-1}$	0.8 $\mu l\ l^{-1}$	288 $nl\ l^{-1}$	15 $nl\ l^{-1}$	-------
Current % yearly increase	0.45	0.95	0.25	0.5	5
Life time (years)	100	10	150	0.1	100
Warming potential per molecule	1x	21x	310x	2000x	15 500x
Current contribution to global warming	63	24	10	-	-

The two ***strategies*** necessary to reduce the risks of climate change are ***adaptation*** and ***mitigation***.

Adaptation: the latest IPCC assessment report gives the following definition: 'Adjustment in natural or human systems in response to actual or expected climatic stimuli o their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007b, WG II, p. 869).

Mitigation: The definition of mitigation is simple: 'It is just the reduction of greenhouse gases'. In mitigation, the primary purpose is to avoid the unmanageable – the causes of climate change are removed by reducing GHG emissions. Whereas in adaptation, the effects of climate change are dealt with by coping with their negative impacts: it is about managing the unavoidable. The two strategies are interlinked: the more successful the mitigation is, the less adaptation is required.

Political leaders around the world negotiate on the level of GHG emissions that can be allowed without affecting the integrity of the earth. There is increasing agreement that if temperatures rise by no more than 2 °C the earth's integrity can be preserved and many of the potentially grave consequences of climate change could be avoided. This threshold is associated with per capita emissions of approximately 2 tons of CO_2 equivalents each year. Developed countries, which currently have per capita emissions of about 16 tons per year, need to sharply reduce their missions (Kropp and Scholze, 2009).

Most important climate change related ***stimuli*** are:
Increased temperature (including seasonal changes), more intensive and frequent storms, sea level rise, more heat waves, more cold spells, more droughts, more flooding and more extreme floods, more extreme rain (including seasonal changes, change in annual and seasonal water availability, accelerated melting of glaciers, and melting of permafrost.

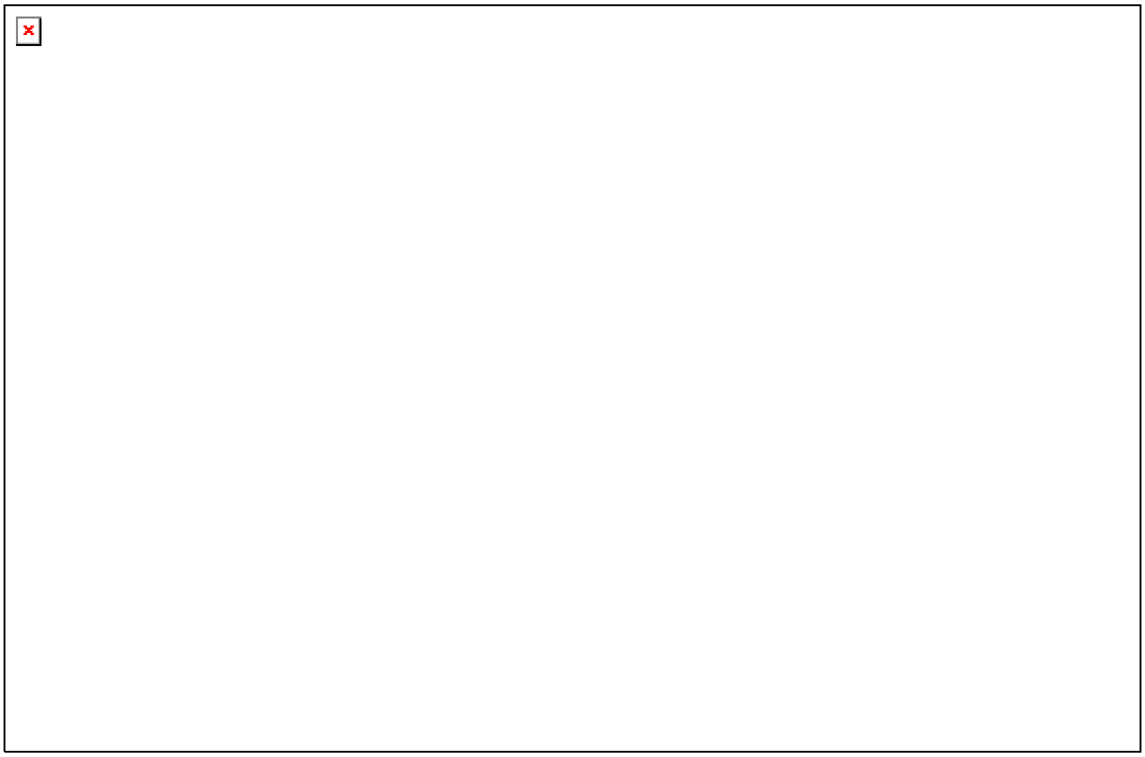
<u>Global carbon cycle</u>

The big picture

During geological history, the emergence of plants on earth has led to the conversion of carbon-dioxide (CO_2) that was in the atmosphere and oceans, into innumerable inorganic and organic compounds on land and in the sea. Natural exchange of carbon (C) compounds between the atmosphere, the oceans and terrestrial ecosystems is now being modified by human activities that release CO_2 from fossilized organic compounds ('fossil fuel') and through land use changes. The earth is returned to a less vegetated stage of its history, with more CO_2 in its atmosphere and a stronger greenhouse gas effect trapping solar energy.

The figure below shows the global C cycle between C-stocks and flows in the reservoirs and in the atmosphere. By far the greatest proportion of the planet's C is in the oceans; they contain 39000 Gt out of the 48000 Gt of C shown (1 Giga ton (Gt) = 10^9 t = 10^{15} g). The next largest stock, fossil C, accounts for only 6000 Gt. Furthermore, the terrestrial C stocks in all the forests, trees and soils of the world amount to only 2500 Gt, whilst the atmosphere contains only 800 Gt.

The use of fossil fuels (and cement) releases 6.3 Gt C yr^{-1}, of which 2.3 Gt C yr^{-1} is absorbed by the oceans, 0.7 Gt C yr^{-1} by terrestrial ecosystems, and the remaining 3.3 Gt C yr^{-1} is added to the atmospheric pool. Fossil organic C is being used up much faster than it is being formed, as only 0.2 Gt C yr^{-1} of organic C sediments into seas and oceans, as step towards fossilization. The net uptake by the oceans is small relative to the annual exchange between atmosphere and oceans: oceans at low latitudes (in the tropics) generally release CO_2 into the atmosphere, while at high latitudes (temperate zone and around polar circles) absorption is higher than release. Similarly, the net uptake by terrestrial ecosystems of 0.7 Gt C yr_{-1} is small relative to the flux: about 60 Gt C yr^{-1} is taken up by vegetation, but almost the same amount is released by respiration and fire.



The global C-cycle showing C-stocks in reservoirs (in Gt = 10^9 ton) and C-flows in Gt yr^{-1}) relevant to anthropogenic disturbance, as annual averages over the decade from 1989-1998 (Shimel et al., 1996)

Special roles of forest in global carbon cycle

Forests play an important role in the global carbon balance. As both carbon sources and sinks, they have the potential to form an important component in efforts to combat global climate change. FAO (2010) estimated that the world's forests store 289 Gt of carbon in their biomass alone (http://www.fao.org/forestry/fra/en/). While sustainable management, planting and rehabilitation of forests can conserve or increase forest carbon stocks, deforestation, degradation and poor forest management reduce them. For the world as a whole, carbon stocks in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010, mainly because of a reduction in the global forest area.

The vegetation of tropical forest is a large and globally significant storage of C, because tropical forest contains more C per unit area than any other land cover. About two-third of the global terrestrial C, exclusive of that sequestered in rocks and sediments, is sequestered in forest ecosystems (Sedjo, 2006). The main carbon pools in tropical forest ecosystems are the living biomass of trees and understorey vegetation and the dead mass of litter, woody debris and soil organic matter. About 50% of plant biomass consists of C. The carbon stored in the aboveground living biomass of trees is typically the largest pool and the most directly impacted by deforestation and degradation.

The recent IPCC report estimated that the global forestry sector represents over 50% of global greenhouse mitigation potential. On the other hand, the forest sector can also be a source of greenhouse gases. Consequently, global climate change policy focuses on the forest sector, and holds a key position in international climate treaties.

Deforestation and forest degradation represents about 17% of the global GHG emissions. Cutting down trees in the forest releases carbon to the atmosphere. Although selective logging may only remove a few big trees per ha (and damage surrounding ones), it can lead to a substantial decrease in total biomass and carbon stock. When forests (250 tons carbon ha^{-1}) are transformed into agriculture, the subsequent land use systems implemented determine the amount of potential carbon restocking that takes place. Annual crop systems will on average contain only 3 tons C ha^{-1}, intensive tree crop plantations 30-60 tons carbon ha^{-1}, which is 1 and 10-25% of the forest biomass and carbon stock. The annual C sequestration rate (increment of standing stock) may be the same for these three of vegetation types (annual crop, tree plantation and forest) about 3 tons carbon ha^{-1} yr^{-1}, but the mean residence time differs from 1, 10 to 83 years. Changes in carbon stock between vegetation and land use types relate primarily to this 'mean residence time'.

International climate agreements and climate finances

UNFCCC, Kyoto Protocol

A total of 192 countries of the world have joined an international treaty - the United Nations Framework Convention on Climate Change (UNFCCC) - to begin to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable. Most, but not all, nations have also approved an addition to the treaty: the Kyoto Protocol, which entered into force on 16 February 2005 and which has more powerful (and legally binding) measures, focused on the 'first commitment period' of 2008-2012.

The Convention places the heaviest burden for fighting climate change on industrialized nations, since they are the source of most past and current greenhouse gas emissions. For the most part, these developed nations, called "Annex I" countries (because they are listed in the first annex to the treaty) belong to the Organization for Economic Cooperation and Development (OECD). These advanced nations, as well as 12 "economies in transition" (countries in Central and Eastern Europe, including some states formerly belonging to the Soviet Union) were expected by the year 2000 to reduce emissions to 1990 levels.

Industrialized nations agreed under the Convention to support climate-change activities in developing countries by providing financial support above and beyond any financial assistance they already provide to these countries. Because economic development is vital for the world's poorer countries - and because such progress is difficult to achieve even without the complications added by climate change - the Convention accepts that the share of greenhouse gas emissions produced by developing nations will grow in the coming years. It nonetheless seeks to help such countries limit emissions in ways that will not hinder their economic progress. The Convention acknowledges the vulnerability of developing countries to climate change and calls for special efforts to ease the consequences. Developing countries have an obligation to report their emissions and C stocks to assist in the global book keeping of emissions and drivers of climate change. Developing countries that want to participate in other mechanisms of the Convention will need to provide such data, as part of global transparency.

To achieve required carbon reduction, carbon emissions are commoditized under a number of flexible mechanisms. The Kyoto protocol introduces three market-based mechanisms to allow Annex I countries to reduce emissions beyond their national boundaries yet include reductions in their national level target. The three mechanisms are: The International Emissions Trading, The Joint Implementation and the Clean Development Mechanism (CDM). International Emissions Trading (Article 17) allows Annex I countries to trade part of their assigned cap. Joint Implementation (Article 6) functions at sub-national level so that project activities can be sponsored and implemented in Annex I Party to meet reduction requirements in a second Party. The

Clean Development Mechanism (Article 12) allows the sponsorship and implementation of project activities in non-Annex I Parties.

The forest C sinks were included in the Kyoto Protocol as a mechanism to mitigate global climate change. According to the Protocol, the net sink of C arising from land use changes and forestry over the period of 2008-2012 can be credited and may substitute the reduction of GHG emissions and to fulfil the reporting requirements of international agreements of Annex I countries. Consequently, there has been a proliferation of climate-related financial mechanisms in the last few years.

Within the existing instruments of climate (and carbon) finance, the Clean Development Mechanism (CDM) and the Reduced Emissions from Deforestation in Developing Countries (REDD) are usually linked with efforts to mitigate the impacts of climate change. By creating a market for emission reductions, in effect paying people and business to reduce greenhouse gas emissions, they argue that the carbon market provides a financial incentive to invest in clean energy projects, in energy efficiency, in fuel-switching, in waste management and in forestry. The carbon market is estimated to be worth about $64 billion according to the World Bank.

The CDM was introduced for industrialized countries to achieve their emission reduction targets in a cost effective manner while contributing to sustainable development in developing countries (UNEP, 2002). However, CDM investments have been rather skewed with hardly any investments in the least developed countries (LCDs), particularly in Africa (Capoor and Ambrosi, 2006). The World Bank has attempted to improve the distribution of carbon investments in Africa through its Community Development Carbon Fund and BioCarbon Fund. However, all these investments in Africa still comprise less than 10% of the US$629 million worth of global carbon portfolio managed by the World Bank’s carbon finance unit. There is thus a need for other multilateral donors to push for more carbon investments in African countries.

An encouraging start in this regard is the creation of international funds that focus on carbon projects in poor countries. Examples include the International Union for Conservation of Nature (IUCN) Climate Fund and the Finnish CDM Program that are mandated to support carbon projects in Africa (UNEP and IETA, 2005). The UNDP’s

Millennium Development Goals Carbon initiative also seeks to redress this imbalance. Ethiopia will benefit from such initiatives.

The Bali Roadmap-RE(D)i+j

At the 13th Conference of Parties in Bali in December 2007 a "Bali Road Map' was agreed upon which includes efforts to include a new mechanism for Reducing Emissions from Deforestation and (forest) Degradation (REDD) in the agreements that are to define the successor of the Kyoto protocol, culminating in the 15th COP in Copenhagen, December 2009.

Earning carbon credits through avoided deforestation (REDD) could be particularly relevant for Africa, where many countries have very high deforestation rates. These high deforestation rates are often accompanied by rapid loss of species, reduction in land productivity and other adverse environmental impacts. Many African countries, however, lack adequate financial or technical means to conserve their forests. Carbon investments for emission reduction through avoided deforestation could therefore provide direct economic incentives for these countries to take up conservation. FAO (2007) estimates that the total carbon mitigation from avoided deforestation in Africa from 2003–2012 could be 615.8 million tons CO_2. A sale of even a small proportion of these carbon offsets to international investors will provide significant economic returns to local communities and to host governments in Africa to invest in forest conservation.

9.2 ANNEX 2: VALUES OF FOREST CARBON IN THE INTERNATIONAL MARKET AND COSTS OF CARBON FORESTRY

On the world market, carbon is currently valued at between $10 and $20 per ton. The forest management costs (that is, overheads incurred by the Forest Department) vary according to management activity but range from $1 per ha to $100, so at the lower end of the scale the management activities could in fact be financed entirely out of the carbon income. This does not however take into account the transaction costs (which include development of a CDM project proposal, creating the baseline, making the necessary carbon measurements of changes in vegetation on a periodic basis, reporting on these, etc). If such activities are carried out by experts there is likely to be little margin of gain to the communities themselves. As Landell- Mills and Porras (1999) have pointed out, it is the transaction costs that are likely to be the key factor in determining whether or not such forest management is financially feasible.

Unfortunately transaction costs for small projects which involve community groups under community based forest management (CBFM) are thought to be relatively higher than for industrial plantations which are more uniform in nature and under one owner, as well as having the advantage of economies of scale (Smith and Scherr, 2002). Chomitz concludes that the cost per ton of measuring carbon stored in biomass will be approximately inversely proportional to the size of the carbon sink (this follows from standard statistical theory). The cost for small, heterogeneous forest management projects could be exorbitant if done by fieldwork, especially if high levels of accuracy (e.g. 5% rather than 10% as in the case described above) are demanded. He suggests therefore that such projects might have to rely on standardized, benchmarked (so-called 'default') values (Chomitz, 2002).

9.3 ANNEX 3: CDM AND REDD ACTIVITIES IN ETHIOPIA

CDM supported reforestation projects in Ethiopia

There is one project registered under the Clean Development Mechanism (CDM) located in the Humbo area (UNFCCC registration Dec 2009, area of 2 728 ha); and there are three further projects, in the Abote, Ada Berga, and Sodo areas, that are mentioned as potential CDM projects (currently not registered at UNFCCC). An additional CDM project, covering an area 20,000 ha earmarked for afforestation/ reforestation in the Amhara National Regional State is under discussion.

These CDM projects are a key source of information when developing and implementing other CDM and REDD+ pilots. Experiences from the CDM projects on developing and innovating mechanisms for payment of environmental services, including benefit sharing mechanisms for community groups and MRV systems, contain valuable lessons. There is often criticism regarding the CDM projects. It included questions about the cost effectiveness of the projects, about challenges in cash flow systems, and about the complexity of the MRV systems. However, according to World Bank REDD+ consultants, these are the first projects in a new area of work, and so high initial costs are to be expected.

REDD+ Pilot Projects in Ethiopia

REDD+ pilots are in preparatory stages in Ethiopia, and they exist in the Bale ecoregion (500,000 ha) (which is expected to generate over 320 million USD during the contract period of 21 years), in the The Yayu and Gedo forests (190,000 ha), and in the Baro-Akobo area (7,610,300 ha), as well as in the south west of the country (Tsegaye Tadesse, 2010). These pilots are generally designed to feed into both PFM programmes and protected area programs that are developing PFM buffer zones. They are pioneering the development of REDD+ implementation in the country (developing carbon accounting, benefit sharing mechanisms), and will be essential sources of information for up-scaling of REDD+ projects in the country.

9.4 ANNEX 4: GLOSSARY

Above-ground biomass
The AGB carbon pool consists of all living vegetation above the soil, inclusive of stems, stumps, branches, bark, seeds and foliage.

Basal area
Basal are of a tree is the cross-sectional area of a tree at breast height.

Below-ground biomass
The BGB carbon pool consists of the biomass contained within live roots.

In some text books, the below-ground biomass comprises living and dead roots, soil fauna, and the microbial community.

Biomass
Biomass is a quantity of living matter in a given ecosystem expressed in terms of its mass. Alternative definition: The total mass of living organisms including plants and animals for a given area usually expressed as dry weight in g m^{-2} or kg ha^{-1}.

Broadly, forest biomass is organic matter expressed as oven-dry tons per unit area: it can be referred to as biomass density when expressed as mass per unit area.

Approximately 50% of dry forest biomass is carbon.

Carbon dioxide equivalent
A measure used to compare different greenhouse gases based on their contribution to radiative forcing. The UNFCCC currently (2005) uses global warming potentials (GWPs) as factors to calculate carbon dioxide equivalent.

Carbon pool
Carbon pools are major components of an ecosystem that can either accumulate or release carbon.

Carbon stocks
Total carbon stored (absolute quantity) in terrestrial ecosystems at specific time, as living or dead plant biomass (above and below-ground) and in the soil, along with usually negligible quantities as animal biomass. The unit is Mg ha^{-1}. The value expressed in terms of unit area is known as ***carbon density***, which is used to compare the potential of different land uses for carbon storage. Aboveground plant biomass comprises all

woody stems, branches, and leaves of living trees, creepers, climbers, and epiphytes as well as understorey plants and herbaceous growth.

Carbon stock accounting
Stock accounting assesses the magnitude of carbon stored in forest ecosystems at a single point in time.

Breast height diameter (DBH)
It is the thickness of the stem at 1.3 m above the ground level.

Emissions
The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.

Emission reductions accounting
Emission reductions accounting assesses the decrease in emissions from project or policy activities, often so that they can be traded.

Emissions accounting
Emissions accounting assesses the net greenhouse gas emissions to the atmosphere resulting from forests.

Forest
According to the IPCC forest is a minimum land area of 0.05-1 hectare with tree crown cover more than 10-30% and tree height of 2-5m at maturity.

Global Warming Potential (GWP)
Used to enable the comparison of the six common GHG, it is the cumulative radiative forcing effects of a unit mass of gas over a specified time horizon relative to CO2. It is expressed in terms of carbon dioxide equivalents (CO2e). Of relevance to forest carbon accounting: $GWPCO_2$ = 1, $GWPCH_4$ = 21, $GWPN_2O$ = 310.

Greenhouse Gas (GHG)
There are six recognised major greenhouse gases; CO_2 (carbon dioxide), CH_4 (methane), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), N_20 (nitrous oxide) and SF_6 (sulphur hexafluoride). Carbon accounting often refers to the accounting of all major GHGs using a carbon dioxide equivalent (CO_2e) that standardises these gases based on their global warming potential.

Sequestration
The process of increasing the content of a carbon pool other than the atmosphere.

Shrubland
Land supporting a stand of trees, usually not exceeding 6 m in height , with a canopy cover greater than 20 per cent. The ground cover is often poor as fire is very frequent, and there may exist scattered and rare trees.
Sink

Any process, activity or mechanism which removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere. Or a carbon sink is a carbon pool from which more carbon flows in than out: forests can act as sink through the process of tree growth and resultant biological carbon sequestration Notation in the final stages of reporting is the negative (-) sign.

Site index
Site index is a site quality indicator that uses dominant height of a stand at a certain age.

Source
Any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere. Or a carbon source is a carbon pool from which more carbon flows out than flows in: forests can often represent a net source of carbon due to the processes of decay, combustion and respiration Notation in the final stages of reporting is the positive (+) sign.

Stocking
A qualitative expression of the adequacy of woody plant cover on an area in terms of crown closure, number of woody plants, basal area or volume in relation to a pre-established norm.

Stock table
A summary table showing the volume of woody plants per unit area by species and diameter classes, for a stand, a forest type or land cover type.

Volume equation
It is a statistically derived expression of the relationship between volume and other woody plant or stand variables. It is used to estimate volume from easily measured variables such as diameter at breast height, woody plant or stand height and crown closure.

Weight (Biomass) table
A summary table showing the weight of woody plants per unit area by species and diameter classes, for a stand, a forest type ort land cover type.

Woodland
Lands dominated by trees, which are heavily branched and have a height of up to 20 m. The flat crowns do not form a closed canopy, but cover more than 20 per cent of the ground and are leafless during some parts of the year. The ground is covered with grasses, herbs and shrubs.

Yield table
A summary table showing characteristics at different ages or development stages for stands or land cover types of one or more species on sites of differing qualities. It shows the development of the most important stand characteristics, such as dominant height, average diameter, stocking, volume or weight (mass) per ha, and removal. It is the simplest tool for predicting the future development of a stand. Because site, tree species, rotation (seedling or coppice), thinnings, fertilization and other treatments affect growth and stand characteristics, there should be a separate yield table for each site class, species, rotation and for each treatment regime.

9.5 *ANNEX 5: Net Present Values (NPVs) FOR EUCALYPTUS AND CUPRESSUS STANDS*

A. Eucalyptus globulus: Site Class I (seedling origin)

Age	Stem volumeha^{-1}	Carbon (ton ha^{-})	CO_2 (ton ha^{-1})	Gross revenue from wood sale	Gross revenue from Carbon	Revenue from Wood and Carbon	Cost of production		Net revenue from wood	Net revenue from carbon	Net revenue from wood and carbon
							Mandays	Birr			
1	0.0	0.0	0.0	0.0		0.0	156.0	3900.0	-3900.0	-3900.0	-3900.0
2	0.5	0.3	1.2			0.0	6.4	160.0	-160.0	-160.0	-160.0
3	4.2	2.7	9.8			0.0	74.4	1860.0	-1860.0	-1860.0	-1860.0
4	14.9	9.5	34.8			0.0	0.0	0.0	0.0	0.0	0.0
5	36.9	23.5	86.1		5611.4	5611.4	0.0	0.0	0.0	5611.4	5611.4
6	72.2	45.9	168.4			0.0	0.0	0.0	0.0	0.0	0.0
7	120.1	76.4	280.1			0.0	0.0	0.0	0.0	0.0	0.0
8	178.4	113.5	416.1			0.0	0.0	0.0	0.0	0.0	0.0
9	243.8	155.1	568.6			0.0	0.0	0.0	0.0	0.0	0.0
10	313.0	199.1	730.0			0.0	10.0	250.0	-250.0	-250.0	-250.0
11	383.4	243.9	894.2			0.0	0.0	0.0	0.0	0.0	0.0
12	452.5	287.8	1055.4		63200.0	63200.0	0.0	0.0	0.0	63200.0	63200.0
13	519.1	330.2	1210.7			0.0	0.0	0.0	0.0	0.0	0.0
14	582.1	370.3	1357.7			0.0	58.8	1470.0	-1470.0	-1470.0	-1470.0
15	641.0	389.9	1429.7			0.0	0.0	0.0	0.0	0.0	0.0
16	695.7	417.6	1531.2			0.0	0.0	0.0	0.0	0.0	0.0
17	746.0	445.5	1633.6			0.0	0.0	0.0	0.0	0.0	0.0
18	792.2	473.5	1736.2			0.0	0.0	0.0	0.0	0.0	0.0
19	834.4	501.4	1838.6			0.0	0.0	0.0	0.0	0.0	0.0
20	873.1	529.2	1940.5			0.0	0.0	0.0	0.0	0.0	0.0
21	908.3	556.8	2041.5	363320.0	69906.3	433226.3	1907.4	47685.8	315634.3	22220.5	385540.5
			Total	363320.0	138717.6				0.2	0.3	0.3
									44702.5	27072.3	81077.5
								NPV	**40802.5**	**23172.3**	**77177.5**

B. Cupressus lucitanica Site Index 23											
Age	Stem volume (m^3 ha^{-1})	C (t)	Thinning removal (m^3 ha^{-1})	CO_2 ton (ha^{-1})	Gross revenue from wood (Birr)	Gross revenue from carbon (Birr)	Forest operation costs		Net revenue from wood (Birr)	Net revenue from carbon (Birr)	Net revenue from wood and carbon (Birr)
							Mandays	Birr			
7	132.1	58.2		213.3			333	8325	-8325	-8325	-8325.0
8	162.5	71.5		262.3				0	0	0	0
9	193.9	85.4		313.1				0	0	0	0
10	225.9	99.5		364.8				0	0	0	0
11	193.7	85.3	145.2	312.7	58097.3	20388.0	260	6500	51597.3	13888	65485.3
12	217.8	95.9		351.7				0	0	0	0
13	241.7	106.5		390.3				0	0	0	0
14	265.2	116.8		428.2				0	0	0	0
15	288.1	126.9		465.3				0	0	0	0
16	310.4	136.7		501.2				0	0	0	0
17	331.9	146.2		535.9				0	0	0	0
18	352.6	155.3		569.3				0	0	0	0
19	372.4	164.0		601.3				0	0	0	0
20	391.3	172.3		631.9				0	0	0	0
21	272.9	120.2	136.5	440.7	96884.8	28732.1	250	6250	90634.8	22482.1	113117.0
22	284.3	125.2		459.1				0	0	0	0
23	295.2	130.0		476.6				0	0	0	0
24	305.4	134.5		493.1				0	0	0	0
25	315.1	138.7		508.7	223689.1	33168.6	600	15000	208689	18168.6	226858.0
									96643.2	18673.7	115317.0
								NPV	**88318.2**	**10348.7**	**106992.0**