Nile Basin Initiative

Eastern Nile Technical Regional Office (ENTRO)

Documentation of EN Watershed Project Contribution to Climate Mitigation

Consultancy Service

By

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Final Report

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Acronyms and Abbreviations

AM	Approved Methodology
AR	Afforestation and Reforestation
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CO2	Carbon Dioxide
COP	Conference of the Parties
CRU	Climate Regional Unit- East Anglia University
DNA	Designated National Authority
DOE	Designated Operational entity
EB	Executive Board
EN	Eastern Nile
ENSAP	Eastern Nile Subsidiary Action Program
ENTRO	Eastern Nile Technical Regional Office
ENWSM	Eastern Nile watershed Management
GHG	Greenhouse Gases
IBIS	Integrated Biosphere Simulator
MOP	Meeting of Parties
NPP	Net Primary Production
PDD	Project Document
PFT	Plant Functional Type
PP	Participating Project
TRMM	Tropical Rainfall Monitoring Mission
UNFCC	United Nations Framework Convention on Climate
USD	U.S Dollar

EXECUTIVE SUMMARY

The objective of this study is to document the watershed project efforts in preservation of land cover over the region and in reducing the loss of vegetation cover. These past efforts should contribute to future mitigation of climate change. The methodology applied in this study consists of four steps: (i) Review of the past and future change in vegetation cover over the EN Watershed and documentations of the interventions by Eastern Nile Watershed Management (ENWSM) project; (ii) Selection and delivery of a modeling tool for estimation of the carbon emissions associated with natural vegetation in the EN; (iii) Application of the tool to estimate the carbon balance for degraded conditions as well as healthy managed conditions, in order to estimate effective reduction in emissions due to watershed management in the EN region;(iv) Definition of a road map for engagement of the CDM process.

Based on extensive review of the published literature, we document the followings: (i) The EN region experienced significant large-scale changes in land cover impacting all natural land cover types from forests and woodlands to shrub-lands and grasslands, e.g. the forests of Ethiopia now occupy less than 3% of the area of the country down from about 40% in the early years of the 20th century; (ii) The main drivers behind this change are population growth and the associated expansion of cultivated land, livestock population growth, overgrazing, and unsustainable land management practices; (iii) The change in land cover seems to be a reversible process. Whenever land cover protection and regeneration experiments were carried, or wherever the vegetation is relieved of the stress caused by human activity, natural vegetation tends to regenerate and recover to its original status.

Here, we conclude that the scale and severity of land cover changes due to land use changes are likely to dominate landscape of the region during the 21st century. Any future changes in land cover due to climate change are likely to be of secondary importance. The Integrated Biosphere Simulator (IBIS) is selected as the modeling tool suitable for simulating dynamics of the water and carbon balance at the land-atmosphere boundary and for estimation of the effective carbon emissions associated with natural vegetation in the EN. The (ENWSM) project focused on 4 regions in Ethiopia and Sudan: Tana-Beles in Ethiopia; Ingesana, Dinder, and Atbara river basin in Sudan, with objectives that promote adoption of sustainable land and water management practices. From within these broad regions, two locations are selected for application of IBIS to estimate the carbon balance under natural conditions: (i) The Chemoga catchment in the Tana region of Ethiopia; (ii) The southern Gedarif, in the Dinder region of Sudan. These two locations are representative of the two regions and lie within areas that are targeted by future investment activities planned by the ENWSM project.

Based on application of IBIS in the Tana region and in the Dinder region, we estimate that protection of natural vegetation with the objective of regeneration of the ecosystem should result in accumulated effective emission reduction of about 9.9 KgC/ m2 in the Tana region, and 7.4 KgC/ m2 in the Dinder region. Assuming a CER price of USD $ 1.3 per tonne of CO_2, and assuming an area of about 25 square kilometers at each site, we estimate that a project in the Tana region would result in 0.25 million tonnes of carbon sequestration and could receive CER credit of about $1.2M. A similar project in the Dinder region, with an estimate of 0.185 Million tons of carbon sequestration could receive CER credit of about $0.9M. These credits are proportional to the price of CER which varies significantly over time in response to trends in supply and demand, as well as uncertainty in regulation environment.

1.0 INTRODUCTION & BACKGROUND

The most significant observed trends in the global environment describe the evident changes in the chemical composition of the atmosphere, and the changes in global land cover. The change in atmospheric chemistry is caused by anthropogenic emissions of greenhouse gases and in particular of carbon dioxide which is a byproduct of fossil fuel combustion. These greenhouse gases represent the main forcing of the observed and predicted changes in global and regional climates. The main concern resulting from this global problem stems from the prediction that future climates which will shape future levels of rainfall, river flow, and surface temperature are likely to be significantly different from our current climate. This concern is particularly relevant to the planning and management of water resources projects such as hydropower plants and irrigation schemes. Traditionally such projects are planned and managed assuming that observed climate records of the past provide a sufficient characterization of the likely climate conditions in the future. The predictions of global and regional climate change question this assumption in a fundamental way.

In order for ENTRO to address the important issue of climate change in a systematic manner, an "Approach Paper" was developed in 2009 describing a comprehensive strategy on how to respond to the issue of climate change. The strategy consists of five pillars which constitute a systematic approach to climate change by ENTRO. A study on "Climate Smart/Proof ENSAP Projects" has been launched as a follow-up to the "Approach Paper" with a focus on how to address climate change issues within each of the ENSAP projects that are managed by ENTRO.

The objective of the Eastern Nile Watershed Management (ENWSM) Project, one of the ENSAP projects managed by ENTO, is to "improve standards of living of the population living within selected watersheds in the Eastern Nile region, decrease population pressures and increase land productivity so that sustainable livelihoods and land use practices can be secured for the target populations." This project emphasizes land productivity and advocates sustainable land use practices within the Eastern Nile countries. Change in land cover is one of the two processes driving global climate change. Hence, any efforts towards reducing the rates of change in land cover should also help in reducing effective emissions of carbon dioxide to the atmosphere. The climate change impacts that are most relevant to this project are changes in rainfall, river flow, temperature, and the associated distribution of vegetation. The Nile watershed is quite vulnerable to all these changes. There is an urgent need to document the extent of current and future changes of the Nile watershed including all these variables.

A Climate-Proofing report was developed in 2011 outlining a specific set of recommendations for streamlining climate change related activities within ENTRO. The report proposes a set of six special studies with the objective of climate change proofing of ENSAP projects. One of the proposed studies, relevant to ENWSM project, is: A special study to assess the impact of the activities of the watershed project related to preservation of vegetation cover and sustainable land use practices and their impact on carbon fluxes. In this report, we describe this study.

2.0 OBJECTIVE

The objective of this study is to document and quantify the watershed project efforts in preservation of land cover over the region and in reducing the loss of vegetation cover. These past efforts should contribute to future mitigation of climate change so that effective past efforts are used to guide future activities.

3.0 METHODOLOGY OF STUDY

The proposed methodology for this study consists of the following four steps:

Step 1: <u>Review of the past and future change in vegetation cover over the EN Watershed and documentations of the interventions by ENWSM project</u>

The first step in the proposed methodology will involve a literature review of all recent modeling and observational studies on:

(i) Past change in land cover over the EN watershed;

(ii) Potential impact of future climate change on vegetation and land cover over the Eastern Nile watershed.

The key findings will be summarized and general conclusions will be drawn. We will also devote a significant effort to estimation and communication of the level of uncertainty associated with future projected impacts.

We will study and document the past and planned interventions of ENWSM in Ethiopia and Sudan. Special attention will be devoted to describe specific scenarios proposed by ENWSM project for scaling-up of watershed management interventions in the EN watershed. These scenarios will serve as specific examples for potential future engagements with the CDM process. If this study is successful it should lay the groundwork for future engagements of the CDM process by watershed management activities.

Step 2: Selection and delivery of a modeling tool for estimation of the carbon emissions associated with natural vegetation in the EN.

The second step in the proposed methodology will involve selection of a specific modeling tool suitable for simulating dynamics of the water and carbon balance at the land-atmosphere boundary over the EN region. The criterion for selection of this tool includes:

(i) The modeling tool should have sound scientific basis as proven by scientific publication through the peer review process;

(ii) The modeling tool should have a track record of satisfactory simulations of ecosystem processes including the carbon cycle in Africa;

(iii) The modeling tool should be readily available (open-source) so that it can be packaged by the consultant and delivered for use by ENTRO.

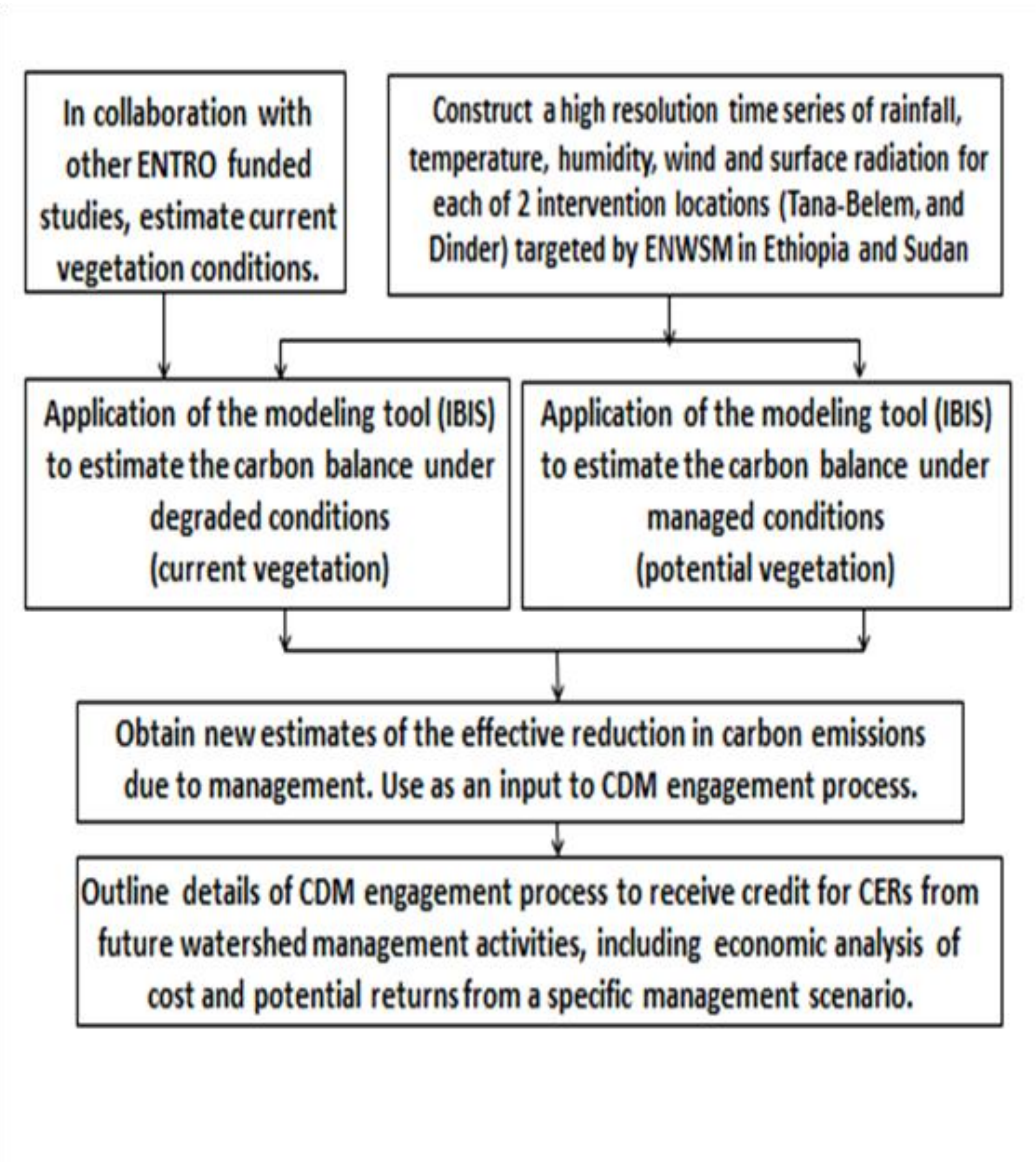

Figure 1: Methodology of the Study

Step 3: Application of the tool to estimate the carbon balance for degraded conditions as well as healthy managed conditions, in order to estimate effective reduction in emissions to watershed management in the EN region.

The analysis will focus on two of the intervention locations considered by ENWSM project: Tana-Beles, and Dinder. These two regions are selected since they offer the largest potential for effective reduction in carbon emission due to water shed management. The region near the Atbara river is located in a relatively dry area with insignificant carbon fluxes at the land-atmosphere boundary.

Analysis of observations will be carried to construct a high resolution time series of rainfall, temperature, humidity, wind and surface radiation for each of the 2 locations. We will consider several data sets including ECMWF, and ERA-Interim reanalysis products as well as TRMM satellite product and CRU stations-based data set.

Forcing of the selected modeling tool, using the constructed time series, will enable us to estimate the carbon fluxes and storage for degraded conditions as well as managed conditions, assuming current interventions or scaled-up management scenarios proposed by ENWSM project. The model of carbon cycle will be capable of simulating potential vegetation conditions under a managed scenario. The same model will be used to simulate storage of carbon over the ground and under the ground corresponding to the two vegetation conditions. The effective reduction in carbon flux is proportional to the estimated difference between the two carbon storages.

Step 4: Road map for engagement of the CDM process, economic analysis, and recommendations

The new estimates of the reduction in carbon emissions, due to watershed management activities will be used as important input to the process of engagement of the Clean Development Mechanism (CDM). The new estimates of the reduction in carbon emissions will be used to calibrate and recommend a specific road map. Economic analysis will be carried out to estimate the financial costs and potential returns for specific scenarios of scaling-up management practices promoted by the ENWSM project. The returns from any management activity will include many environmental and socioeconomic benefits that go beyond the return from the CERs. Here, our efforts will primarily focus on the financial returns from the CERs given current market conditions. We will conduct a preliminary evaluation on available financing opportunities to identify promising opportunities in both mitigation and adaptation funding mechanisms and outline a roadmap for the engagement processes.

4.0 APPLICATIONS OF METHODOLOGY

4.1 Review of the past and future change in vegetation cover

Table 1 describes an extensive review of studies on land cover change in the region. The findings of these studies can be summarized in the followings:

(i) The EN region experienced significant large-scale changes in land cover impacting all natural land cover types from forests and woodlands to shrub-lands and grasslands. For example the forests of Ethiopia now occupy less than 3% of the area of the country down from about 40% in the early years of the 20th century, Bewket (2002) and Edessa (1993). Forests, woodlands, and shrublands have been eliminated in many areas (e.g Zeleke and Hurni (2001); Garedew et al. (2009));

(ii) The main drivers behind this change are population growth and the associated expansion of cultivated land, livestock growth, overgrazing, and unsustainable land management practices. (Taddese (2001));

(iii) The change in land cover seems to be a reversible process. Whenever land cover protection and regeneration experiments were carried, or wherever the vegetation is relieved of the stress caused by human activity, natural vegetation cover tends to regenerate and recover to its original status. Darbyshire et al. (2003) conclude based on pollen records from Northern Ethiopia that "At about 500 BC, the forests were cleared and replaced by a secondary vegetation and grassland that persisted for 1800 years. Grasslands were dominant from about ad 1200 to 1400. Forest expanded from 1400 to 1700. Deforestation and soil erosion has again intensified during the last three centuries. Since forest regrowth was possible after 1800 years of human impact, northern Ethiopia should again be capable of supporting forest under appropriate land management."

This finding is important since reversibility of vegetation cover is a necessary requirement for any effort in reforestation or rehabilitation of land cover to succeed. In other regions of the world such as the Sahel of West Africa, this reversibility requirement is not necessarily satisfied.

Bewket (2002) point out that in the upper Blue Nile" Population growth and the associated demand for land and trees was the major driving force behind the (land cover) changes. This study shows that the deforestation trend was reduced and even partly reversed in the area because local people planted trees as a source of fuel and income. This trend ought to be encouraged through appropriate interventions-in particular by promoting planting of local species rather than eucalyptus-to increase not only economic but also ecological benefits. Indeed, the current state of land cover and its dynamics have environmental implications at the local scale and beyond. Hence, environmental management for sustainable development requires interregional and international cooperation."

Table 1: Land Cover Changes in the EN countries, Evidence from Literature

Location	Period	Nature, Extent, and Drivers of Change, Findings of Study	Method	Reference
Ethiopia, Two lakes in the highlands of northern Ethiopia	Last 3000 years	At about 500 BC, the forests were cleared and replaced by a secondary vegetation and grassland that persisted for 1800 years. Grasslands were dominant from about ad 1200 to 1400. Forest expanded from 1400 to 1700.	Pollen and charcoal analysis of sediment cores	Darbyshire et al. (2003)
Ethiopia	present	The major causes of land degradation in Ethiopia are the rapid population increase, severe soil loss, deforestation, low vegetative cover and unbalanced crop and livestock production.		Taddese (2001)
Ethiopia	present	Only the area of 3.6 % of Ethiopia remains with forest cover. Deforestation accounts 200,000 ha per year.		EDESSA (1993)

Chemoga Watershed, Blue Nile Basin, Ethiopia	1957-1998	The results show that during the last 41 years, forest cover increased at a rate of about 11 ha per annum in the 36,400-ha watershed. Woodlands and shrublands decreased between 1957 and 1982 but increased between 1982 and 1998, approximately to their previous levels. Farmland and settled areas gained from the other cover types (13% increase) in the first period but lost around 586 ha (2% decrease) in the second. Grassland and degraded land decreased, accounting for 4.8% of the total area of the watershed in 1982 and 3.5% in 1998, as against 9.6% in 1957. Riverine trees suffered the greatest destruction, shrinking by 79% over the 4 decades; much of this decline was due to cultivation. Forest cover in Ethiopia declined in the 20th century from 40% to 2-3%.	Two sets of aerial photographs (1957 and 1982) and a multispectral Spot image (1998) were used as inputs to produce 3 GIS-based land cover maps of the area.	Bewket (2002)
Upper Gilgel Abbay catchment, Blue Nile basin-Ethiopia	1973-2001	Results of the supervised land cover classification analysis indicated that 51% and 17% of the catchment area was covered by forest in 1973 and 2001, respectively. This significant decrease in forest cover is mainly due to expansion of agricultural land.	remote sensing based land cover data	Rientjes et al. (2011)
Koga watershed in a headwater of Blue Nile Basin	1957-2002	The watershed declined from 16% forest cover in 1957 to 1% by 1986.	observed hydrological data and community perception	Gebrehiwot et al. (2010)

Dembecha area, Gojam in the North-western high lands of Ethiopia	1957 to 1995	The results show that the natural forest cover declined from 27% in 1957 to 2% in 1982 and 0.3% in 1995. The total natural forest cleared between 1957 and 1995 amounts to 99% of the forest cover that existed in 1957. On the other hand, cultivated land increased from 39% in 1957 to 70% in 1982 and 77% in 1995.	aerial photography and Landsat TM imagery	Zeleke and Hurni (2001)
Wello, Ethiopia	1958-1986	Land cover changes in the Kalu District, Southern Wello, were most noticeable for shrub-lands, with a decrease of (51%)	two aerial photographs	Tekle and Hedlund (2000)
Northern Ethiopia	1868 and 2008	New eucalypt woodlands, introduced since the 1950s are visible and have provided a valuable alternative for house construction and fuel-wood, but more importantly there has also been locally important natural regeneration of indigenous trees and shrubs. Despite a ten-fold increase in population density, land rehabilitation has been accomplished over extensive areas by large-scale implementation of reforestation and terracing activities, especially in the last two decades. Overall there has been a remarkable recovery of vegetation and also improved soil protection over the last 140 years, thereby invalidating hypotheses of the irreversibility of land degradation in semi-arid areas.	A collection of photographs, taken during Great Britain's military expedition to Abyssinia in 1868, are the oldest landscape photographs from northern Ethiopia, and have been used to compare the status of vegetation and land management 140 years ago with that of contemporary times.	Nyssen et al. (2009)
WESTERN SHEWA,		The recovery of an economically more rewarding vegetation type may be achieved through providing alternative sources of fuel and	Vegetation data include cover-	ZERIHUN and

ETHIOPIA		construction and through prohibiting cultivation and grazing in the shrub-lands on the hillsides. Regeneration can be accelerated by actively introducing seedlings of tree species that do not need a heavy canopy cover for establishment and growth.	abundance values of vascular plant species.	Ingvar (1991)
Ghibe Valley, southwestern Ethiopia	1957-1993	Cropland expanded (1987-1993) at twice the corresponding speed for (1957-1973), but also contracted rapidly between 1973-1987. Rapid land-use/land cover change was caused by the combined effects of drought and migration, changes in settlement and land tenure policy, and changes in the severity of the livestock disease.	aerial photography and Landsat TM imagery	Reid et al (2000)
Central Rift Valley of Ethiopia	1973-2006	From 1973-2006, the area of cropland doubled at the expense of woodland and wooded-grassland in both of the study sites. Major deforestation and forest degradation took place from 1973-1986; woodland cover declined from 40% to 9% in one of the study sites, while the other lost all of its original 54% woodland cover.	Remote sensing and field data	Garedew et al. (2009)
Central Rift Valley , Ethiopia.	Last 30 years	The analysis revealed that in the last 30 years, water bodies, forest, and woodland decreased by 15.3, 66.3, and 69.2 per cent, respectively; intensive cultivation, mixed cultivation/ woodland, and degraded land increased by 34.5, 79.7, and 200.7 per cent.	Landsat data from 1973, 1985, and 2006 using Geographic Information Systems and remote sensing techniques	Meshesha, and Tsunekawa, (2012)
South-central Rift Valley of Ethiopia	20^{th} century	The findings indicate that the forest area declined from about 40% at the turn of the 19th century to less than 3% in the year 2000.	Field observations, satellite image and map analyses, interviews, and literature studies were employed.	Dessie, and Christiansson (2008)

Communal Grazing Lands in Tigray, Ethiopia	present	In this study, we investigated changes in ecosystem C stocks (ECS) after establishing exclosures on degraded communal grazing lands. We selected replicated (n = 3) 5-, 10-, 15-, and 20-yr-old exclosures and paired each exclosure with an adjacent communal grazing land. Differences in ECS between exclosures and grazing lands varied between 29 (+/- 4.9) and 61 (+/- 6.7) Mg C per ha and increased with exclosure duration.	Field data	Mekuria et al. (2011)
Highland of Tigray, Ethiopia	1964 to 2006	Results show that, for all periods, cultivated land constitutes the most prevalent (>60%) land-use type. Forest and woodland suffered more damage in both areas losing almost (100%) over four decades.	geographic information system and remote-sensing approaches	Gebresamuel et al. (2010)
Upper Agula watershed, Eastern Tigray (Ethiopia)	1965-2005	A significant portion of the watershed was continuously under intensively cultivated (tainted) land. The area under irrigation increased from 7 ha to 222.4 ha post-intervention. The area under dense forest increased from 32.4 ha to 98 ha.	Two sets of aerial photographs (taken in 1965 and 1994 at scale of 1:50,000) and Landsat ETM+ image (taken in 2000 with 30 m resolution)	Alemayehu et al. (2009)
Southern Gadarif region, Sudan	1972 - 2003	The land-cover of the southern Gadarif region has changed drastically since the introduction of mechanized rain-fed agriculture in the area. The average natural vegetation clearing rate was around 0.8% per year, and the most rapid clearing occurred during the seventies when conversion rates increased to about 4.5% per year. Recently, the conversion of natural vegetation to agricultural land has slowed because almost no	remote sensing imagery	Sulieman (2010)

		land was left for further expansion. In the period 1999 - 2003 significant natural re-vegetation on abandoned land was detected.		
Semi-arid Sudan	1900-2100	The soil organic carbon (SOC) over an area (262,000 square kilometers) (upper 20 cm) decrease from 1900 to 2000 was estimated to be 6.8 Mt and the maximum potential carbon sink (SOC increase) for the period 2000 to 2 100 was estimated to be 17 Mt. Cropland and grassland lost 293 and 152t SOC km(-2) respectively whereas the savannahs gained 76t SOC km(-2) from 1900 to 2000.	GIS and the CENTURY model	Ardo and Olsson(2003)
Kassala Province, Eastern Sudan	1972 and 1990	The study indicates increases in sand land, forest and cultivated areas, and a decrease in grassland.	Landsat Multi-Spectral Scanner (MSS) data	Larsson (2002)

The potential future changes in land cover over the EN region are quite uncertain. Here, we emphasize 3 observations:

(i) In relation to vegetation conditions and land cover, the most relevant predictions about the impact of future climate change on the region are changes in temperature and rainfall patterns. While most models agree that the average temperature levels will increase by a few degrees by the end of the 21st century, the same models disagree on the sign of the predicted change in rainfall amounts. Hence the resulting changes in vegetation cover are largely unknown at this point;

(ii) In the highlands of Ethiopia, a warming of temperature by a few degrees should result in an upward migration of vegetation zones by a few hundreds of meters. Given the uncertainty about the potential future changes in rainfall, cloudiness, and soil moisture conditions, it would be quite speculative to make any specific statements about the future change in vegetation cover due to climate change.

(iii) The studies reviewed in the above table paint a pattern of large-scale and intense change in land cover due to changes in land use. The scale and severity of land cover changes due to land use changes are likely to dominate landscape of the region during the 21st century. Any future changes in land cover due to climate change are likely to be of secondary importance. This conclusion highlights the fact that mismanagement of natural ecosystems leading to degradation and deterioration of ecosystem health may pose a more serious risk to society than the often emphasized risks from climate change.

4.2 Documentation of the interventions by ENWSM project

The ENWSM project focused on 4 areas in Ethiopia and Sudan: Tana-Beles in Ethiopia; Ingesana, Dinder, and Atbara river basin in Sudan.

In the Tana-beles watershed the ENSWM project supports livelihood improvement, natural resources management (soil and water conservation, afforestation, and agro-forestry), and institutional strengthening. Under the natural resource management activities, actions such as land closure on the steep and bad-lands, cutoff drains, check dams in steep watercourses, closing off gullies, stone faced bunds, etc. The project aims to establish and enforce community based rules and regulations for the existing forests.

In Sudan, the project development objectives are to increase the adoption of sustainable land and water management practices in selected micro-watersheds. These objectives are achieved through the following three components – Community Watershed Management, Knowledge for Cooperative Action and Project Management. Project-financed interventions are implemented in the following sub-watersheds in Sudan -- Lower Atbara, Bau (or Ingessana), Dinder, and Lau. The lower Atbara sub-watershed is a desert area with poor vegetation cover.

The Bau sub-watershed is located in the Bau (or Ingessana) area in the Blue Nile State. The area is in the savanna zone where the average annual rainfall is 600-800 mm. The main environmental issue in the Bau Sub-watershed is land degradation associated with deforestation. The main cause of deforestation is conversion of forests and woodlands into semi-mechanized farms. Most of these farms are now abandoned because poor soil and water management led to salinization and loss of soil fertility. From 1984 to 2003, about one-third of the forests and woodlands in the Bau area (about 420,000 ha) was lost to mechanized farming. The other major cause of deforestation is overexploitation of forests and woodlands for firewood and for making charcoal. About 27 villages in the Bau Sub-watershed would benefit from interventions in watershed rehabilitation and management.

Attachment: Location map of Easten Nile Fast Track Projects

Figure 2: Sites of The ENWSM Project Activities

The Dinder sub-watershed comprises the Dinder National Park and its adjacent communities. The Dinder National Park has a high level of biodiversity. It is also at the center of migration routes for several bird species among three continents –Africa, Europe, and Asia. The main environmental issues associated with land use in the Dinder area are overgrazing and the siltation of mayas. Addressing this problem requires a separate protected areas management operation. Siltation of the mayas in the park is the result of soil erosion in the Ethiopia Highlands. Sustainable land and water management interventions are planned to achieve watershed rehabilitation and management.

4.3 Selection of a modeling tool for estimation of the carbon emissions associated with natural vegetation in the EN.

The consultant selected the Integrated Biosphere Simulator (IBIS) of Foley et al. (1996) as the modeling tool suitable for simulating dynamics of the water and carbon balance at the land-atmosphere boundary over the EN region.

(i) IBIS is a well-known modeling tool in the scientific community. It has sound scientific basis as proven by the publication of Foley et al. (1996) through the peer review process, and the close to 500 citations that this paper received;

(ii) IBIS has a track record of satisfactory simulations of ecosystem processes including the carbon cycle in Africa. It has been tested over Africa and other tropical regions in many previous studies by MIT research group as well as other groups. This significant experience on use of the model under African conditions motivates our recommendation on the adoption of IBIS in the current study over the EN region.

(iii) IBIS is readily available (open-source) so that it can be packaged by the consultant and delivered for use by ENTRO at no cost.

Integrated Biosphere Simulator (IBIS) uses a hierarchical, modular structure to integrate a variety of terrestrial ecosystem phenomena. IBIS contains four modules, operating at different time steps, and includes a two-layer canopy with six soil layers. The four modules simulate processes associated with:

a. the land surface (surface energy, water, carbon dioxide and momentum balance),

b. vegetation phenology (winter-deciduous and drought-deciduous behavior of specific plant types in relation to seasonal climatic conditions),

c. carbon balance (annual carbon balance as a function of gross photosynthesis, maintenance respiration and growth respiration), and

d. vegetation dynamics (time-dependent changes in vegetation cover resulting from changes in net primary productivity, carbon allocation, biomass growth, mortality and biomass turnover for each plant functional type)

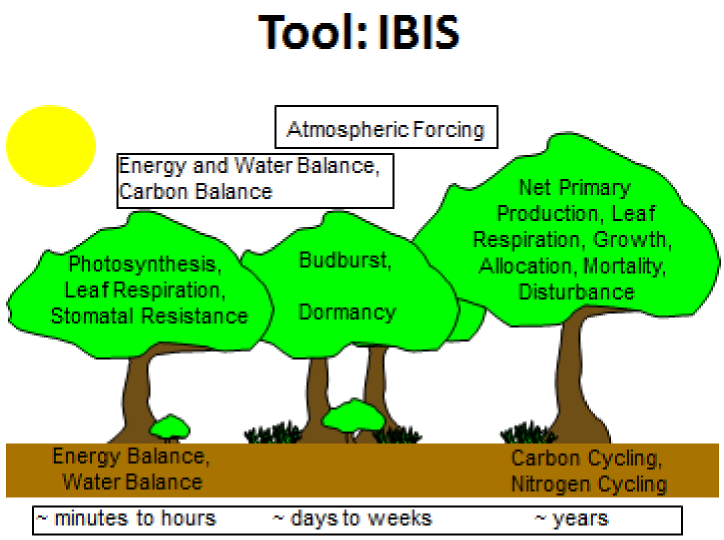

Figure 3: Integrated Biosphere Simulator (IBIS)

4.4 Application of the tool to estimate the carbon balance in the EN region:

4.4.1 Selection of Sites

The application of the modeling tool to estimate the carbon balance under natural and degraded conditions will focus on two locations:

(1) The Chemoga catchment in the Tana region of Ethiopia;

(2) The southern Gedarif in the Dinder region of Sudan.

The rational for selecting these two locations is the following

(i) Both areas are included in the investment projects for the ENWSM project (Profile I: Integrated Watershed Management – Abbay Sub-basin, Chemoga Catchment, Ethiopia: areas of High Agricultural Potential and Degrading Natural Resource Base; and Profile 13: Establishment of Transboundary Dinder-Rahad Park and Livelihoods Support, respectively)

(ii) The changes in vegetation cover in both of these areas were documented in two separate detailed studies using satellite remote sensing techniques (Bewket (2002) for Chemoga, and Sulieman (2010) for Gadarif). These studies describe the reference conditions for any future interventions.

(iii) The two sites are selected since, compared to other areas that were also foci of the ENWSM project activities, they offer a significant potential for effective reduction in carbon emission due to watershed management. The area near the Atbara river basin is located in a relatively dry area with insignificant carbon fluxes at the land-atmosphere boundary.

4.4.2 Chemoga Catchment:

The land cover conditions in the Chemoga catchment of the Abay river basin were studied extensively by Bewket (2002). Two sets of aerial photographs (1957 and 1982) and a multispectral Spot image (1998) were used as inputs to produce the land cover maps of the area, shown in the figure above. During a period of 41 years, forest cover increased at a rate of about 11 ha per annum in the 36,400-ha watershed. Woodlands and shrub-land decreased between 1957 and 1982 but increased between 1982 and 1998, approximately to their previous levels. Farmland and settled areas gained from the other cover types (13% increase) in the first period but lost around 586 ha (2% decrease) in the second. Grassland and degraded land decreased, accounting for 4.8% of the total area of the watershed in 1982 and 3.5% in 1998, as against 9.6% in 1957. Riverine trees suffered the greatest destruction, shrinking by 79% over the 4 decades; much of this decline was due to cultivation.

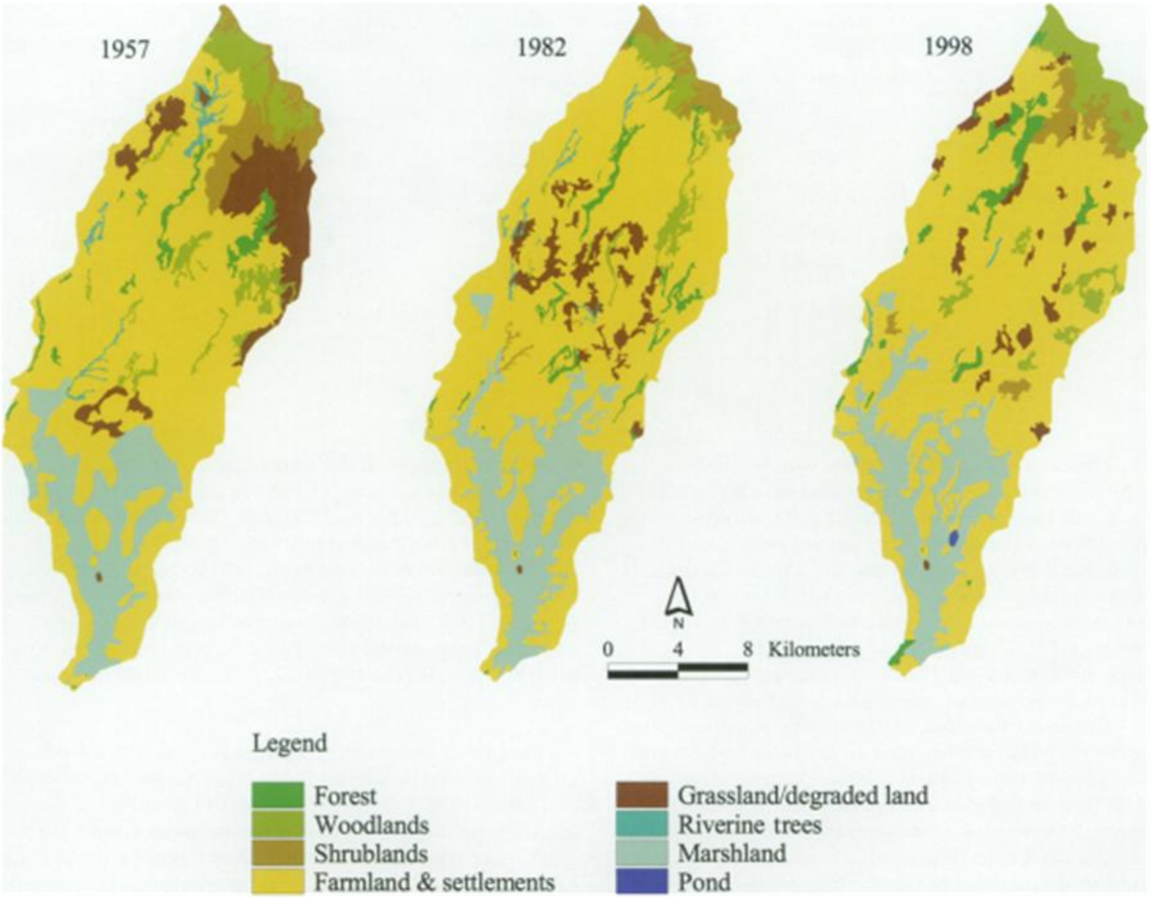

Figure 4: Land Cover Changes in Chemoga Catchment

Population growth and the associated demand for land and trees was the major driving force behind the changes. Deforestation trend was reduced and even partly reversed in the area because local people planted trees as a source of fuel and income. Bewket (2002) argues that this trend ought to be encouraged through appropriate interventions-in particular by promoting planting of local species rather than eucalyptus-to increase not only economic but also ecological benefits. He suggests that environmental management for sustainable development requires regional and international cooperation.

4.4.3 Southern Gedarif

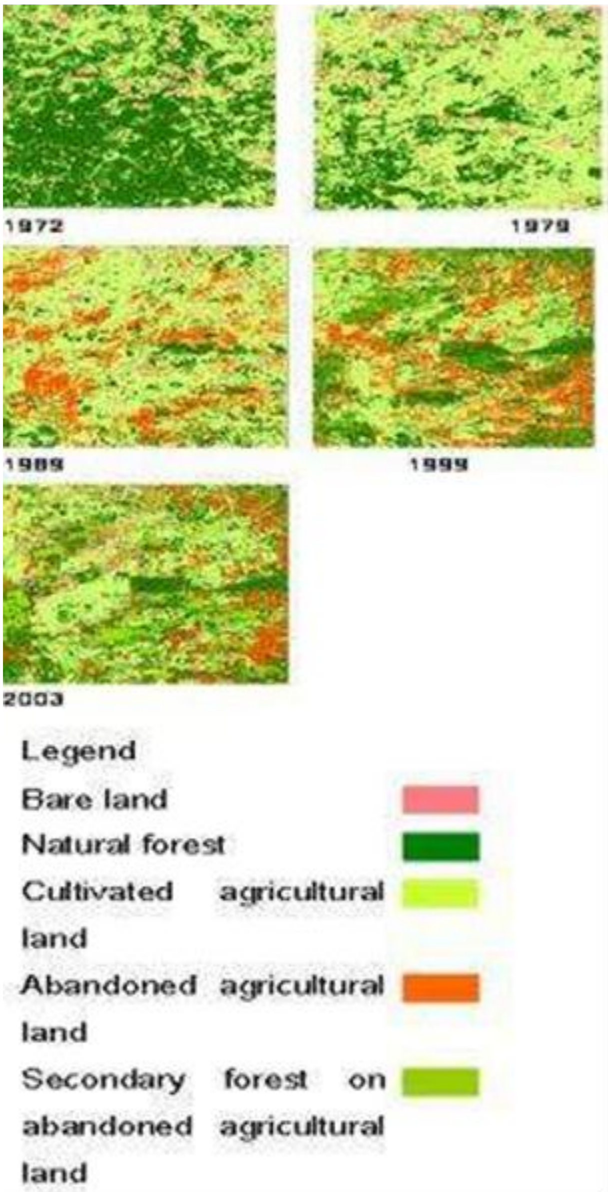

Figure 5: Land Cover Changes in Southern Gedaref Region

The study of Sulieman (2010) documented the rapid land-use/land-cover changes in southern Gadarif region, Sudan, for the period 1972 - 2003 using remote sensing images. Comparisons of images taken at different dates reveal that the land-cover of the southern Gadarif region has changed drastically since the introduction of mechanized rain-fed agriculture in the area. The agricultural expansion occurred at the expense of the natural vegetation cover. The average natural vegetation clearing rate was estimated to be about 0.8% per year, and the most rapid clearing occurred during the 1970s when clearing rates increased to about 4.5% per year. Sulieman (2010) point out that recently, the conversion of natural vegetation to agricultural land has slowed because almost no land was left for further expansion. In the period 1999 - 2003 significant natural re-vegetation on abandoned land was detected.

4.4.4 IBIS simulations

Analysis of extensive sets of observations was carried out with the objective of constructing a high resolution time series of rainfall, temperature, humidity, wind and surface radiation for each of the two locations in Chemoga (Tana) and Gedarif (Dinder). We used several data sets including ERA-Interim reanalysis products as well as TRMM satellite data set. IBIS was forced using the constructed time series, to estimate the carbon fluxes and storage for degraded conditions as well as managed conditions, assuming management scenarios consistent with the investment profiles proposed by ENWSM project. For each of the two sites, the IBIS was used for simulating potential vegetation conditions and the corresponding carbon cycle under a managed scenario. We assumed negligible storage of carbon corresponding to the current vegetation conditions. This assumption is motivated by the observations that indicate almost total destruction of vegetation cover. The effective reduction in carbon flux is proportional to the estimated difference between the two carbon storages.

In this section we discuss the inputs and results of the IBIS model using a representative year. The IBIS model was used over two locations: Tana (11.84 N, 37.61 E) and Dinder (12 N, 35 E), with data from a representative year, 2010. These examples are meant to demonstrate the capabilities of IBIS in estimating biomass and carbon fluxes. Ibis simulates natural vegetation regeneration by permitting a set of 12 plant functional types to compete for water and land (nutrients are not included). The plant functional types then grow and are translated to a carbon stock. We present the necessary forcing inputs so that IBIS runs may be repeated with a more detailed analysis in the context of CDM document preparation. We also provide the corresponding results to give a range of possible emissions reductions.

IBIS Inputs

The inputs into IBIS consist of invariant data to describe the initial soil and vegetation conditions and meteorological time series to describe the climatological forcing. These are summarized below in the tables below.

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Table 2: Invariant Forcing Data Used in IBIS

	Tana	Dinder
Latitude	11.84 N	12 N
Longitude	37.61 E	35 E
Elevation	1800 m	690 m
Initial vegetation Type	tropical broadleaf drought deciduous	tropical broadleaf drought deciduous

Table 3: Annual Average Summary of Meteorological Forcing Data Used in Ibis

	Tana	Dinder
TRMM Precipitation (mm)	1211	555
Temperature (deg C)	19.1	28.7
Wind Speed (m/s)	2	3.3
Relative Humidity (%)	61%	48%
Total Cloud Cover (%)	53%	33%

IBIS requires hourly inputs for meteorological data. The hourly time series data used as forcing are shown in the following Figures

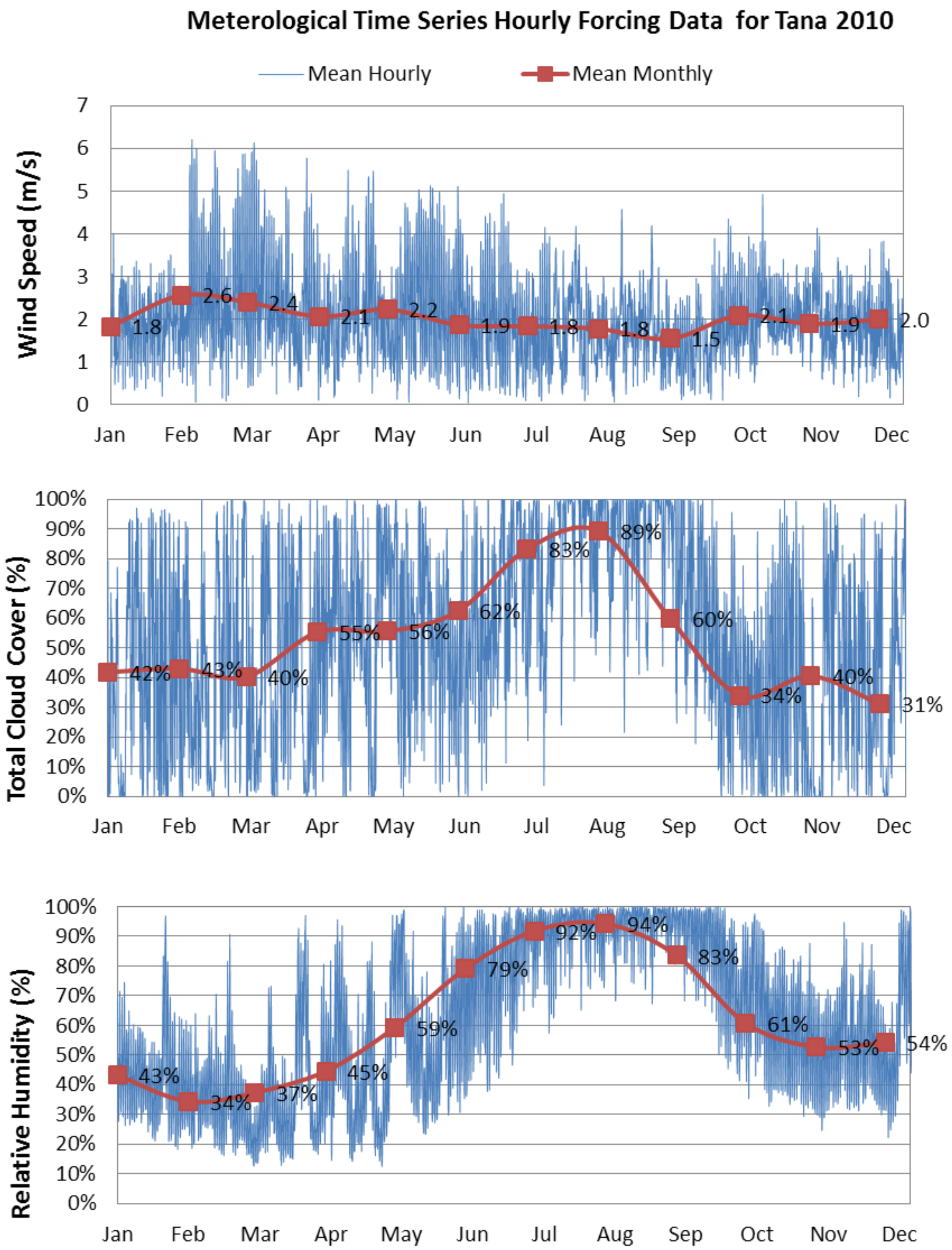

Figure 6: Hourly Windspeed, Cloud Cover and Relative Humidity in Tana 2010

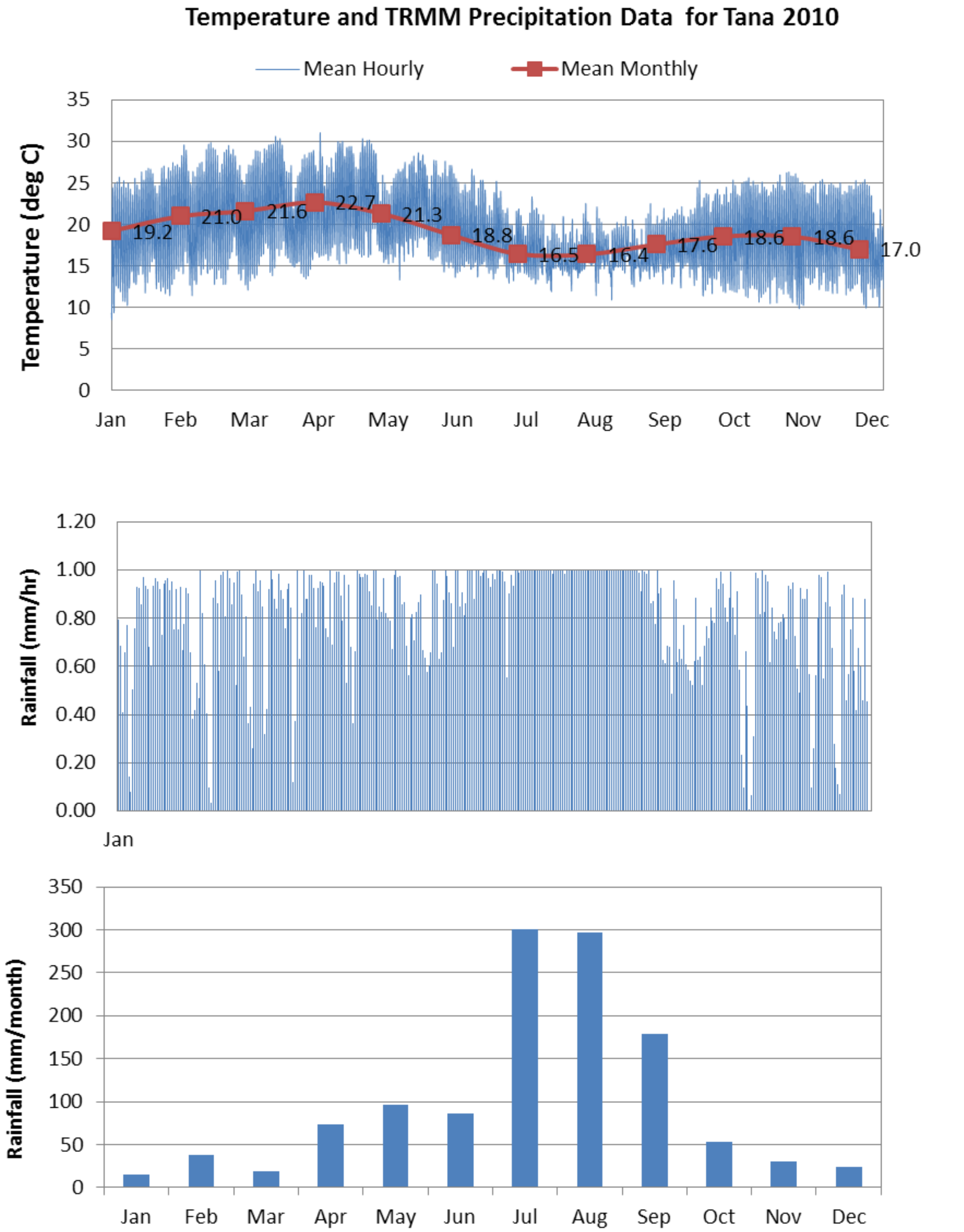

Figure 7: Hourly Temperature, Hourly Rainfall and Monthly Rainfall in Tana 2010

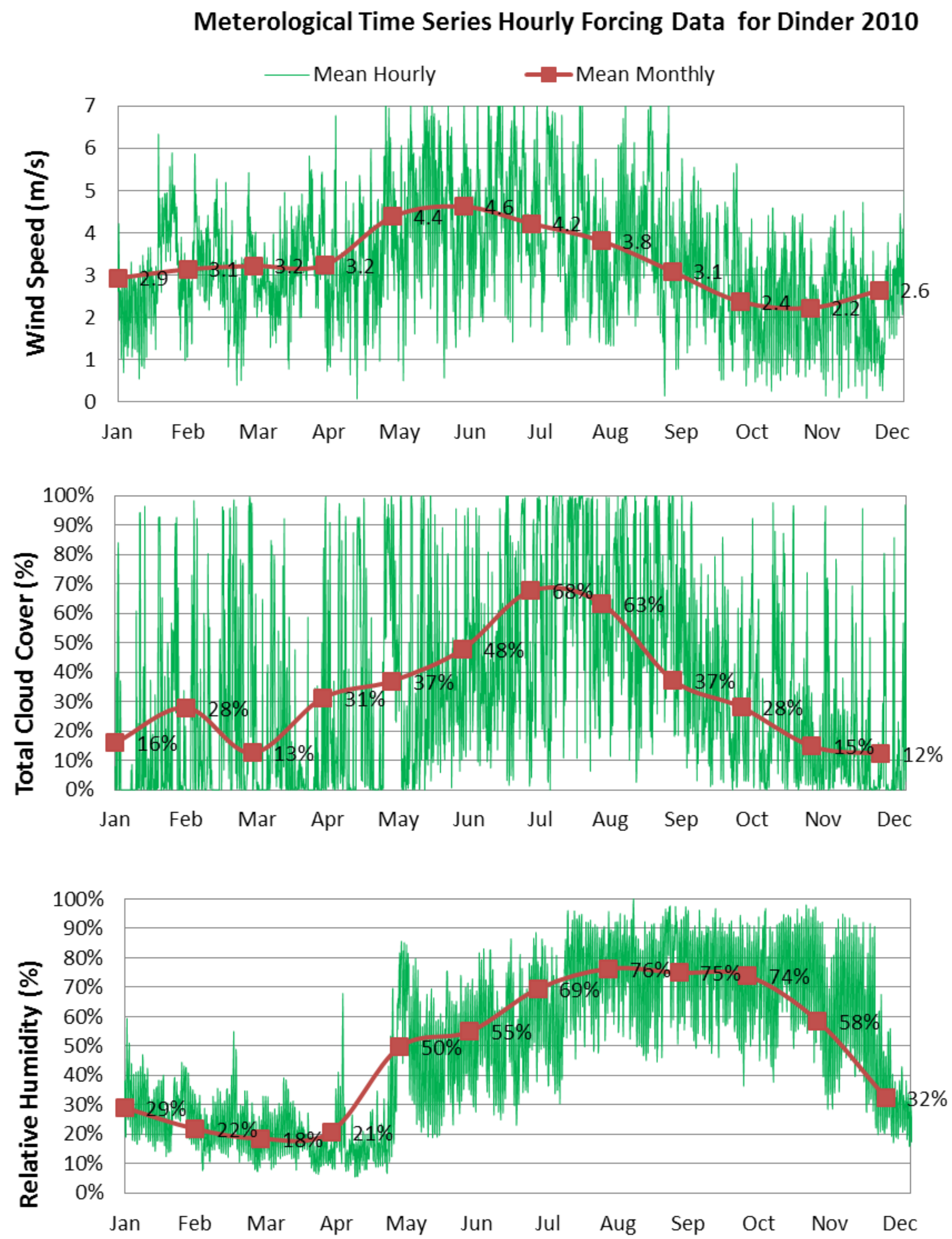

Figure 6: Hourly Windpseed, Total Cloud Cover and Relative Humidity in Dinder 2010

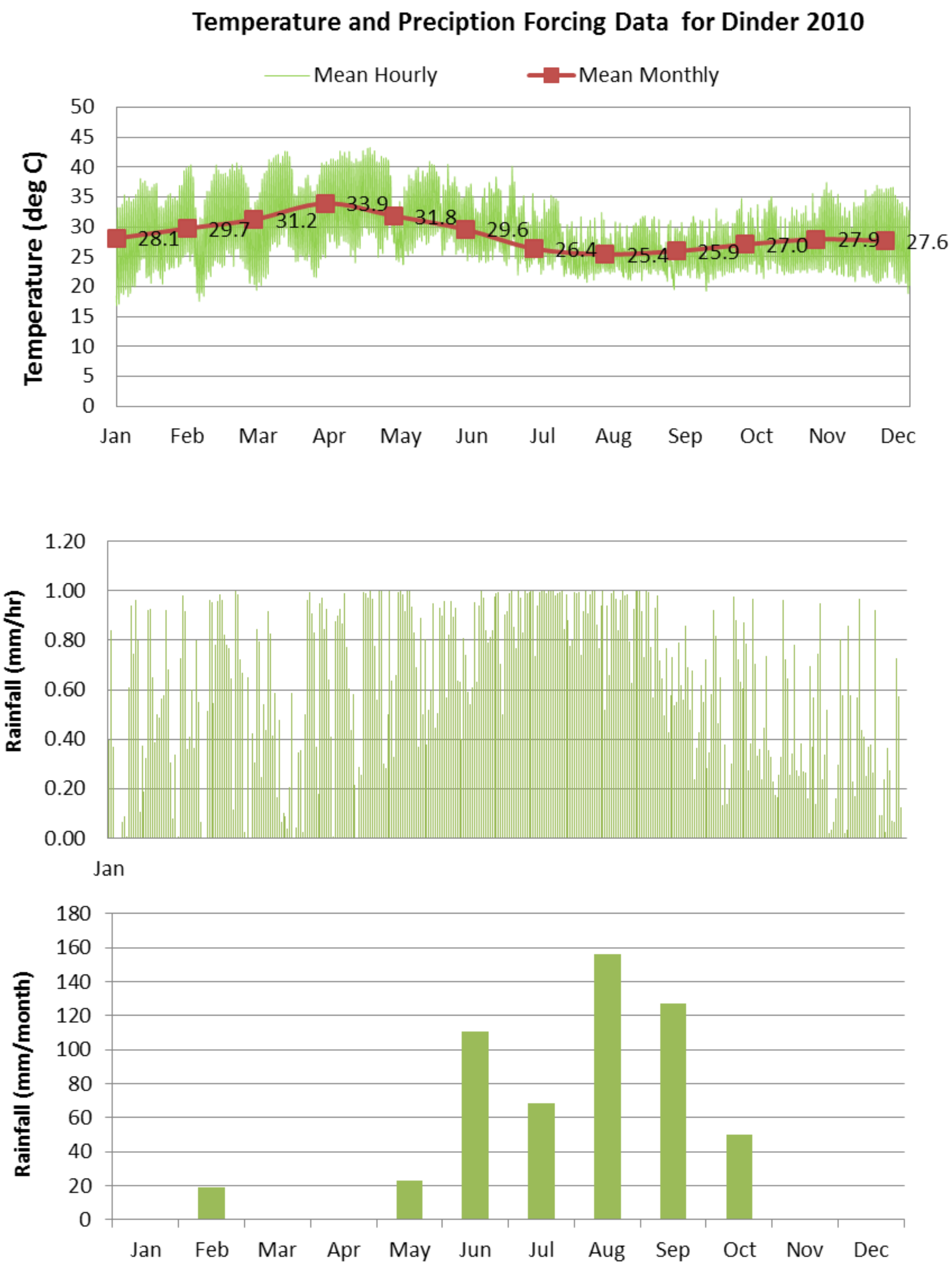

Figure 7: Hourly Temperature, Hourly and Monthly Rainfall in Dinder 2010

IBIS Results

We use the representative year of 2010 for the input data and then allowed the IBIS model to simulate 10 years. IBIS provides several output information at daily, monthly and yearly scales, but the parameters of interest are those related to vegetation and carbon stocks at the yearly scale:

biomass	**biomass of each PFT seperately**	**kg-C/m^2**
totbio	**annual biomass**	**kg-C/m^2**
npptot	**annual ecosystem net primary production**	**kg-C/m^2/yr**
npp	**net primary product of each PFT**	**kg-C/m^2/yr**

Net primary production is the rate at which all the plants in an ecosystem produce net useful chemical energy. It measures the net flux of carbon from the atmosphere into green plants per unit area per unit time. Biomass is the mass of living biological organisms. The biomass of the vegetation cover is converted to carbon and this allows us to estimate a carbon stock. Table 4 and Figure 9 show the resulting biomass per year at each location and the average biomass per plant functional type, respectively. The results suggest that in the last year of the simulation in which the area achieves equilibrium, the watershed restoration projects could sequester 7.41 kg carbon per square meter in Dinder. In a 25 square km area (25,000,000 square meter), this translates to a carbon stock of 0.185 million tons of carbon. Similarly, in Tana, we estimate 9.86 kg carbon sequestration per square meter. Which translates to 0.25 million tons of carbon per year.

Table 4: Simulated Biomass (kgC/m2) using IBIS for Dinder and Tana Locations

Simulated Biomass (kg C/m2)		
	Dinder	Tana
2010	9.90	9.91
2011	9.49	9.98
2012	9.16	10.05
2013	8.88	10.06
2014	8.61	10.04
2015	8.35	10.01
2016	8.11	9.97
2017	7.87	9.93
2018	7.63	9.89
2019	7.41	9.86
Yearly Avg.	8.54	9.97

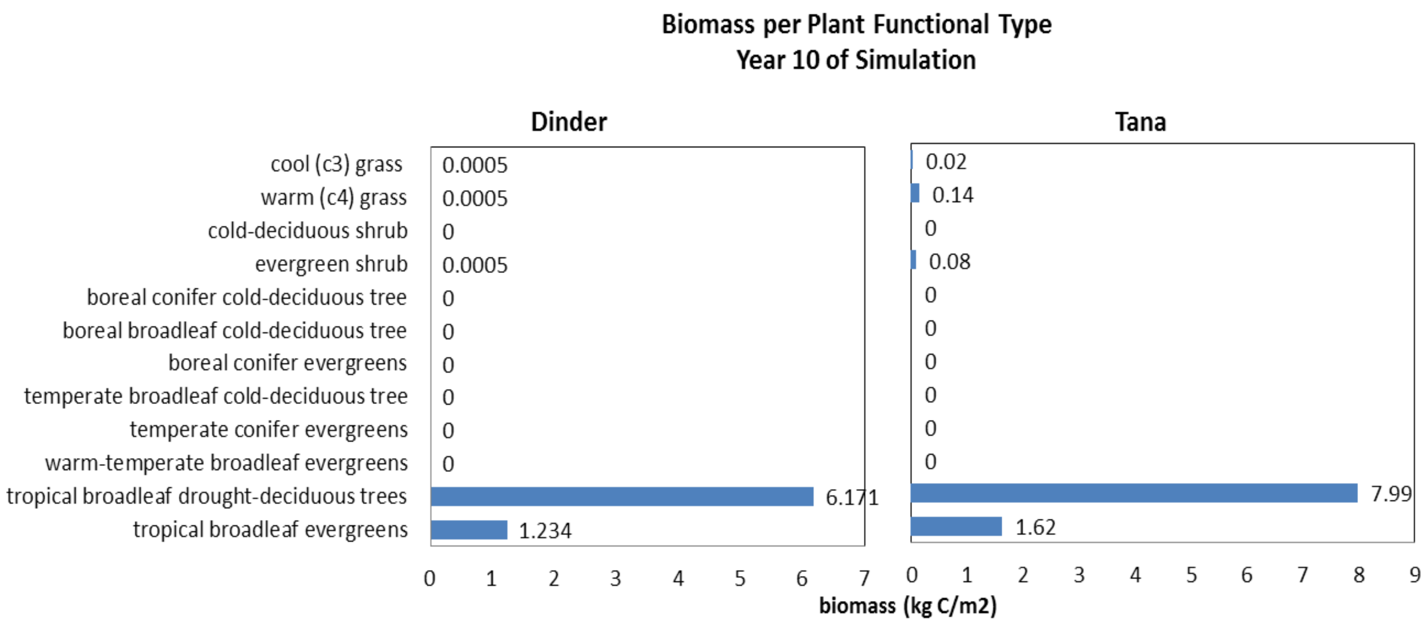

Figure 8: IBIS Simulated Biomass (kg C/m2) per PFT

In absence of the project, carbon stocks in the project areas are expected to decrease or due to the continued land degradation. Therefore, if the project does not occur, the baseline net greenhouse gas removals are expected to be negative due to ongoing degradation. We assume, conservatively, that the baseline carbon reductions are zero and, thus, all the carbon sequestration will count as an emission reduction: 0.25 x 3.67= 0.9 MT CO_2 in Tana and 0.185x 3.67 = 0.7 MT CO_2 in Dinder. (3.67 is the conversion factor between Kg of CO_2 and Kg C) This, however, does not account for leakage. The benefit received from the CDM process will depend highly on the price of the CER.

<u>4.4.5 IBIS simulations</u>

Assuming a CER price of USD $1 to $3 per tonne of CO_2. Assuming an area of about 25 square kilometers at each site. A project in the Tana region with an estimate of 0.25 Million Tons of carbon sequestration could receive CER credit between $0.9M to $2.7M. A similar project in the Dinder region, with an average 0.185 Million tons of carbon sequestration could receive CER credit between USD $0.7M and USD $2.1M.

4.5 Road map for engagement of the CDM process

Clean Development Mechanism (CDM)

The Clean Development Mechanism (CDM) was established under the Kyoto Protocol. It is defined in Article 12 of the Protocol, and allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to "effectively" implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO2, which can be counted towards meeting Kyoto targets. The CDM also allows approved projects in developing countries to earn Certified Emission Reductions (CERs) credits measured in tons of CO2. These CERs can then be sold to industrialized countries for use in accounting of their emission reduction targets. The CER's serve to make up the countries' opportunity cost of choosing a "green" option. Having the financial aid from CER lowers the perceived investment risk of the project and provides a steady income stream with a possible guaranteed fixed purchase price of CO2.

The specific steps for engagement of the CDM are (see Appendix A for additional details):

(i) A project participating in the CDM has to first be approved by a designated national authority as contributing to the country's sustainable development objectives;

(ii) Formal registration by the Executive Board of the CDM has to be secured;

(iii) The project has to establish a baseline scenario to determine baseline emissions levels

(iv) The project has to meet the "additionality" requirement which establishes that the planned reductions would not occur without the additional incentive provided by the (Certified Emission Reductions) CERs credits;

(v) The project has to be monitored over a pre-specified accounting period to determine the difference between actual emissions and the corresponding emissions under the baseline assumptions. This difference is then credited to the project as a CER.

In the CDM process, watershed management would fall under afforestation and reforestation (A/R) projects. Based on CDM rules "Annex 16, Procedures to define the eligibility of lands for afforestation and reforestation project activities ,"no forest can be present within the project boundaries between December 31, 1989, and the start of the project activity. Proof of forest absence could take the form of aerial photographs or satellite imagery from 1989 or before. Applications for AR CDMs require the use of the ": "Procedures to define the eligibility of lands for afforestation and reforestation project activities" approved by the CDM Executive Board2 to demonstrate land eligibility within the project boundary." Furthermore, the project must demonstrate additionality.

The UNFCC has a set of approved methodologies for calculating the emissions reductions associated with A/R projects shown in Table 5. The consultant deems AR-AM002 Restoration of degraded lands through afforestation/reforestation --- Version 3.0, as the most relevant and included in full in the Appendix. With AR-AM002, the ex-ante net GHG removals by sinks are estimated with empirical methods or peer reviewed carbon accounting models. Here we recommend that the model IBIS be used to assess the changes in carbon pools.

Table 5: Methodologies

Meth Number	Name
AR-AM0002	Restoration of degraded lands through afforestation/reforestation --- Version 3.0
AR-AM0004	Reforestation or afforestation of land currently under agricultural use --- Version 4.0
AR-AM0005	Afforestation and reforestation project activities implemented for industrial and/or commercial uses --- Version 4.0
AR-AM0007	Afforestation and Reforestation of Land Currently Under Agricultural or Pastoral Use --- Version 5.0
AR-AM0009	Afforestation or reforestation on degraded land allowing for silvopastoral activities --- Version 4.0
AR-AM0010	Afforestation and reforestation project activities implemented on unmanaged grassland in reserve/protected areas --- Version 4.0
AR-AM0011	Afforestation and reforestation of land subject to polyculture farming --- Version 1.0.1
AR-AM0012	Afforestation or reforestation of degraded or abandoned agricultural lands --- Version 1.0.1
AR-AM0013	Afforestation and reforestation of lands other than wetlands --- Version 1.0.0
AR-AM0014	Afforestation and reforestation of degraded mangrove habitats --- Version 1.0.0

Some examples of watershed projects that successfully received CDM credits include:

- The Guangxi Project designed to reforest 4,000 ha of multiple-use forests on seriously degraded and remote lands in in China with an estimated total amount of carbon to be sequestered of 0.77 Mt of CO2 equivalents (CO2e) over a 30-year crediting period (2006-2035). Developed in early 2005, the project became the world first registered CDM forest project in 2006.(World Bank)
- PROCUENCA-FAO (2007) the forestry project to restore the Chinchiná River watershed in Colombia which sought to restore 15% of the area of the Department of Caldas (112,675 ha) and estimated 4.4 M tons of CO2e during the first twenty-year accreditation period. (UNFCC 2012)
- Himachal Pradesh Reforestation Project – Improving Livelihoods and Watersheds (2011) The project seeks to implement A/R CDM activities on 4,000 ha of degraded lands in the watersheds of Mid-Himalayan region with an estimated 0.83 MtCO2-e during the 14 year crediting period and 10.34 tCO2-e per ha/year (excluding leakage).

The first step to engage in the CDM is to prepare a PDD. This report has attempted to provide some of the necessary information for the DOE to prepare a PDD. Particularly the consultant recommends the use of an alternate model for the calculation of emissions reductions within the context of an approved methodology and provides an example of the calculation and magnitude for emission reductions using the IBIS model.

<u>What is needed in the PDD?</u>

The PDD is one of 3 documents required to register along with a validation report from DOE and letter of approval from the designated national authority. It has the following components:

- A general description of the project.
- A baseline derived from an approved baseline methodology. (If there is no approved methodology to establish a baseline applicable to the project, a new methodology can be submitted for approval before the project as a whole can be

validated. The baseline the scenario that would most likely occur in the absence of the CDM project (i.e. what will happen under business-as-usual) Developing a baseline is critical for deciding whether a CDM project is additional. When assessing the PDD it is worthwhile checking whether all alternative scenarios have been considered. The PDD should have considered all realistic credible alternative scenarios, investment and barrier analysis to show the option is only financially attractive with carbon credit and that the carbon credit eliminates barriers/risk and has a common practice check.

• The estimated lifetime of the project and the crediting period

• A demonstration of how the project generates emission reductions that are additional to what would have occurred without the CDM. In A/R projects, the biggest concern is displacement of emissions, verification of emission reductions and leakage.

• An analysis of the environmental impacts

• A discussion of the stakeholder consultation process and how stakeholder comments were taken into account

• A monitoring and verification plan

The PDD should have considered all realistic credible baseline alternative scenarios, investment and barrier analysis to show the option is only financially attractive with carbon credit and that the carbon credit eliminates barriers/risk. After submitting a PDD, the DOE will officially engage in the CDM process.

6.0 CONCLUSIONS AND RECOMMENDATIONS

In seeking a viable project in the watershed management area that could qualify for CDM and receive CER credits, we conclude the following:

- The EN region experienced significant large-scale changes in land cover impacting all types from forests and woodlands to shrub-lands and grasslands.
- The main drivers behind this change are population growth, expansion of cultivated land, livestock growth, overgrazing, and unsustainable land management practices.
- The change in land cover seems to be a reversible process.

- The scale and severity of land cover changes due to land use changes are likely to dominate landscape of the region during the 21st century. Any future changes in land cover due to climate change are likely to be of secondary importance.
- The future changes in vegetation cover EN due to climate change are largely unknown at this point.
- In the Tana-Beles watershed the ENSWM project supported natural resources management (afforestation, and agro-forestry), including land closure on the steep and bad-lands. The project aims to establish and enforce community based rules and regulations for the existing forests.
- In Sudan, the project focused on increasing the adoption of sustainable land management practices in selected micro-watersheds. About 27 villages in the Bau Sub-watershed could have benefited from interventions in watershed rehabilitation and management. In the Dinder sub-watershed the project addressed the main land use issues associated overgrazing and the siltation of mayas, with plans for protected areas in order to achieve watershed rehabilitation and management.
- The Integrated Biosphere Simulator (IBIS) of Foley et al. (1996) is selected as the modeling tool suitable for simulating dynamics of the water and carbon balance at the land-atmosphere boundary over the EN region.
- IBIS is applied successfully to estimate potential carbon emission reductions due to protection projects with scales of about 25 square kilometers.
- We estimate that protection of natural vegetation with the objective of regeneration of the ecosystem should result emission reduction of about 9.9 KgC/ m2 in Tana region, and 7.4 KgC/ m2 in Dinder region. These estimates are consistent with estimates for similar successful CDM projects in other regions.
- Assuming a CER price of $ 1.3 per tonne of CO2, we estimate that a project in Tana region could receive CER credit of about $1.2M, and a similar project in Dinder region could receive CER credit of about $0.9M.
- As the first commitment period of the Kyoto Protocol comes to an end, the CDM process will be revamped, thus many improvements could occur for the next commitment period. (Bloomberg, 2012) We recommend that ENTRO stay informed on CDM changes as it may be able to offer opinions on how Africa can best engage in CDMs.

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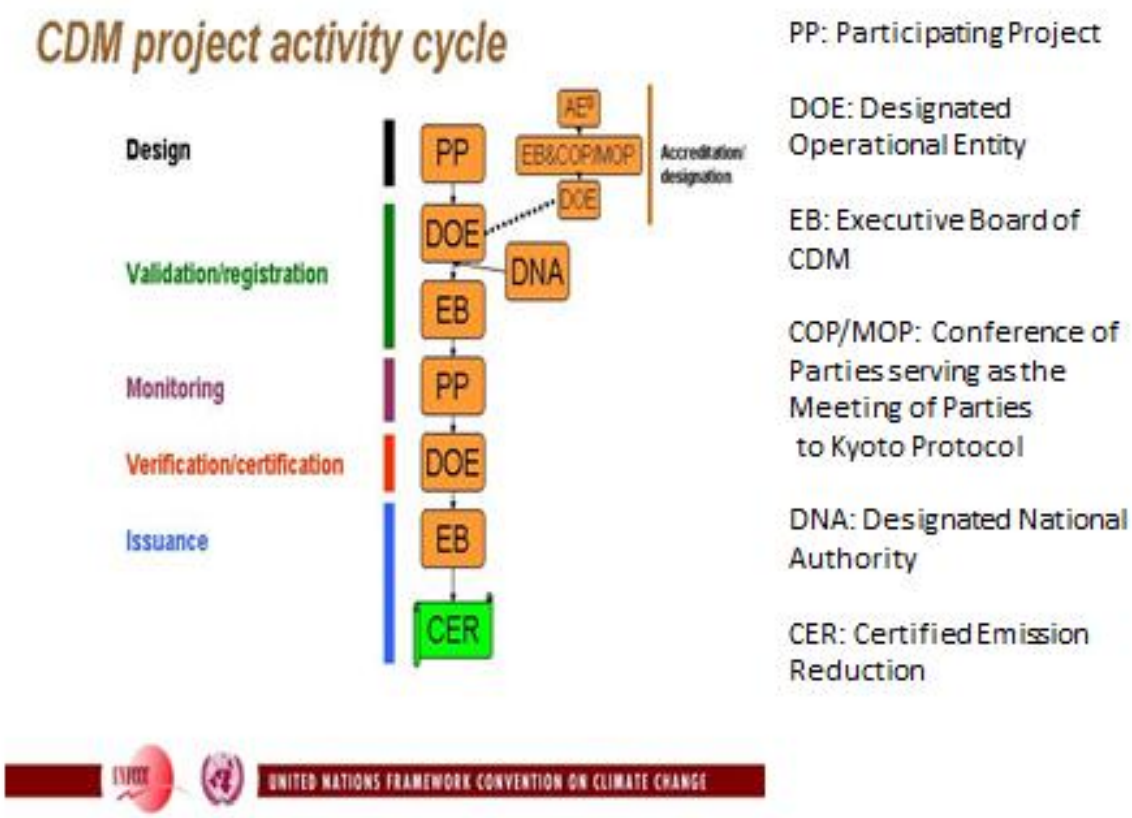
APPENDIX A: Roadmap for Engagement of the CDM process



APPENDIX B: Scope of Work (from TOR)

1. Provide an overview through literature search and desk studies of the impacts of climate change in the EN region particularly highlighting impacts of vegetation cover, biodiversity and land use.

2. Identify tools to quantify the associated carbon reductions of watershed projects

activities addressing climate change mitigation such as enhancing preservation of land cover and reducing loss of vegetation cover

3. Quantify the contribution of the pilot (and fast track) watershed projects in addressing climate change mitigation via enhancing preservation of land cover and reducing loss of vegetation cover, and the associated reduction in carbon flux.

4. Project future up-scaling scaling of watershed activities triggered by the current studies (CRAs identified a number of other projects and hot spots) and by other mechanisms and their possible associated reduction in carbon flux.

5. Conduct a preliminary Economic appraisal on the carbon emissions reduction

financing opportunities

6. Identify financing opportunities (in both mitigation and adaptation funding mechanisms) and outline a roadmap for the engagement processes.

APPENDIX C: AR-AM0002 Methodology

Approved afforestation and reforestation baseline methodology AR-AM0002

"Restoration of degraded lands through afforestation/reforestation"

(Version 03)

http://cdm.unfccc.int/methodologies/DB/6ZZXJUKK49WKLID7ZH8FG3BS9WTCCH