ENCOFOR

**Environment and community based framework for designing afforestation, reforestation and revegetation projects in the CDM:**

# WP1: Pre-Feasibility Report

# Chapare Case Study

## Bio-physical Characterization, Land Suitability and Project Scenario Analysis

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# WP1: CDM-AR Prefeasibility Report:

# Chapare, Bolivia

## Bio-physical Characterization, Land Suitability, and Project Scenario Analysis

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**Summary:** This report gives the results of a Prefeasibility Analysis for a proposed CDM-AR Project Development in the Chapare region of Bolivia, including the biophysical characterization, land suitability modeling, and project scenario analysis. An overview of the site characteristics and the CETEFOR Proposed CDM-AR project based on scenarios for three production components is reported. The biophysical characterization and land suitability analysis utilizes a set of spatial analyses to estimate the bio-physical limitations to growth, and to evaluate the potential for CDM-AR. Analysis of remote sensing data is combined with existing geospatial data, as well as relevant literature, and local expert sources, to model the project scenarios. The results of WP1 will be combined with WP0 and WP2 to produce the final comprehensive Prefeasibility Report for the Chapare Region Case Study.

Project results are reported, both in tabular form and as maps, for the three potential components, and also evaluated for the combined project, in order to give a brief, but comprehensive, overview of the potential for the CDM-AR activities on this site:

1.) Availablity of land for CDM-AR activities was estimated to be approx equal to the estimated size of the project, suggesting a high adoption rate will be necessary to meet the goals and projected income by the proposed project. However, scale and resolution used for remote sensing and mapping likely underestimated land availability by not accounting for smaller patches.

2.) Net Carbon (seqestration) for the “Entire Project” if implemented on 6000 ha is predicted to be approximately 100,000 tC.

3.) The net revenues for the entire project is predicted to approach $25,000,000. It is noted that project activities in these areas may still have non-monetary values associated with subsistence livelihood options.

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# WP1: CDM-AR Prefeasibility Report:

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# 1 Introduction

ENCOFOR is a framework for the design of sustainable CDM-AR projects. As a consequence, its activities are situated in the first two phases of a CDM project cycle (figure 1): (a) the Preparation and Review of the Project (called Prefeasibility Study in ENCOFOR) and (b) the Baseline Study and Monitoring plan (called Feasibility Study in ENCOFOR).

This report presents the results of the WP1-Prefeasibility Study for the Chapare region, in Bolivia. This report has been produced in association with CETEFOR, which is the ENCOFOR Country Partner for this Case Study. Results are based upon a land suitability evaluation, and a modeling of the project scenarios identified in the initial scoping (WorkPackage 0), within the ENCOFOR CDM-AR Land Suitabilty and Spatial Analysis Model (LSM). This report provides the results based upon the biophysical analysis of potential carbon sequestration and profitability under the project scenario, and provides the input into the final comprehensive Prefeasibility Report, which will combine this analysis with the socio-economic prespective, and will be an integration of the outcomes of WP1 and WP2. **The Final Prefeasibility Report will be executed as a common responsibility of WP1, WP2 and WP9**.

Much of the analysis presented in this prefeasibility report are results obtained using the ENCOFOR CDM-AR Land Suitability Model. Although a generalized overview of the methodology is given in the body of the report, a detailed presentation of the LSM methodology is outlined in Appendix 1. The activities and methods necessary to gather the data, and other inputs, needed to perform the land suitability evaluation required for this (prefeasibility) phase of the CDM project cycle was presented in the WP1 Field Manual (Zomer et al, 2004).

## 1.1 ENCOFOR WP1 Workflow and Methodology Overview

Projects (and their respective physical sites), selected through the WP0 process, are evaluated in WP1, in terms of their suitability and biophysical potential for CDM-AR projects. In addition, a simple calculation of net revenue is attempted for spatial evaluation modeling purposes. Both the site description (land suitability) and the proposed activities (project description) are used to determine the potential for biomass production, carbon sequestration and net revenue. Species based estimates of biomass accumulation rates are used to predict potential sequestration rates using a methodology based upon the average carbon stock accounting proposed by Schlamdinger et al (2004?), across a range of environmental variables, for potential site/project combinations.

WP1 output is conceived in such a way that the results include:

1.) a transferable, coherent set of protocols for Land Suitability Analysis for CDM-AR Project Design and Implementation;

2.) Land Suitability Analytical Model, implemented in a set of software tools;

3.) Geospatial Database and Information System (referred to below as the Geo-database) for each proposed project;

4.) a Land Suitability Modeling and Project Scenario Analysis for Prefeasibility Evaluation, completed for each proposed project, i.e. Encofor case study .

### 1.3. Building the Geodatabase:

The geo-database which was compiled in WP1, for the purposes of the prefeasibility analysis and report, forms the foundation and framework for a project specific geo-database (for the entire project). This database provides the core input and analytic environment for the combined ENCOFOR Case Study and the proposed CDM-AR Project. It is intended that eventually, the geo-database will become both a repository of project management information, and a platform for ongoing project monitoring, evaluation, and verification. By initiating this database building activity in an incremental, but planned approach from the beginning of the project, the geo-database evolves in tandem with the project, thus providing a powerful analytic and management tool that can be harnessed early in the process of evaluation (to allow for better pre-project decision making), as well as provide baselines for verification early in the project cycle. Additionally, this data forms the foundation data layers for the ENCOFOR Project Database and our research efforts.

### 1.3. Bio-Physical Characterization and Land Suitability Analysis

A spatial land suitability and project scenario analysis is performed within WP1 using available geospatial data, remote sensing analysis, the results from ground truthing / fieldwork activities, and input of expert knowledge. These results are combined with growth, biomass accumulation and baseline data to estimate potential carbon sequestration. At all stages, consultation with, and verification and evaluation by the Country Partners is required to get good results. This is especially important in this prefeasibility stage. The prefeasibility stage goal is to build as good an information base as possible, in order to make better decisions about investment, but also, to do that in a cost effective manner that minimizes the initial upfront investment (when the reality of the project is still in doubt). This requires expert knowledge (or best guess) approaches to the value of certain quantitative parameters required to complete the analysis, but not empirically available without substantial pre-project transaction costs. As a result, the prefeasibility stage relies on a body of local expert (in our case, ENCOFOR Country Partner) knowledge for “virtual” ground-truthing of intermediate and final results. This is based on a list of criteria that evaluates the quantitative analytic results with analysis based on in-depth local expert knowledge. During this stage of the prefeasibility report (analysis and results reporting) by WP1 Team, an on-line collaboration (using email, or other internet-based communication options) was established to facilitate an active role for Country Partners to provide input and feedback to the interpretation of remote sensing imagery, land use analysis and estimation of bio-physical parameters. ENCOFOR

Country Partners provide the essential source of expert knowledge for local site conditions, species adaptation, growth rates, and for project analysis.

The land suitability and spatial analysis was carried out by WP1 Team and included GIS data, knowledge and expertise from CETEFOR. National and local expertise and data has been primarily provided by the Country Partners. The results of the initial analyses will be evaluated and reviewed through consultation with the Country Partners. An iterative process will be followed to obtain the best results. It is possible that some rapid field validation may be required. Partners may also want to use the ENCOFOR Land Suitability Analysis Tool themselves to run various scenarios.

Site pre-selection at country level (scale level between 1:100000 and 1:1000000) was preformed in WP0, to come up with a shortlist of potential project sites. This was accomplished based upon a list of exclusion criteria within a national level spatial analysis using maps and descriptive statistics, and through stakeholder/expert consultation. In the partner countries (Bolivia, Ecuador, Uganda, Kenya) a rough site pre-selection took place in the first weeks of the ENCOFOR project or even before the project started. WP0 will have been used to (a) make the final pre-selection of two sites per country (only for countries where more than two pre-selected sites are still in the running) and (b) to check if the two pre-selected sites sufficiently meet the criteria of site pre-selection.

Within WP1, projects/sites in each country are evaluated using a spatial modeling methodology relying on existing and available secondary data sources, remote sensing analysis, and expert knowledge. The projects (and their respective physical sites) are characterized in terms of their biophysical suitability and potential for CDM-AR carbon sequestration projects. Initial preliminary estimates of site and regional baselines, carbon sequestration, and environmental impacts are extrapolated from this characterization, for a specific set of CDM-AR activities referred as the "project", using available data and expert knowledge, limited fieldwork and ground-truthing, and a "rule of thumb" approach. The results are used to develop the Prefeasibility Report, and may also be used to do a preliminary PCN (optional, at this stage).

# 2 Project Description

## *2.1 Project Area*

The Chapare project area is located at the foot of the Andes mountain range within the Amazon River basin (Figure 1). It ranges in elevation from 450 to 250 meters above sea level. In the early 1930s the area was given the designation of "multiple use area" and has since been colonized by migrants from the High Valley and the Altiplano regions of Bolivia. Currently there are 35,000 families that live within the 534,000 hectares of the Chapare region. Figure 2 provide a map of communities located within the project area. The project area is inhabited by 9,055 people (5092 male & 3963 female), living in a total of 2719 homesteads (1998).

As new settlers established they began by clearing the original primary forest to establish their small farms. The agricultural subsistence "slash and burn" farming, the poor logging practices and the past coca production have all resulted in a dramatic deforestation of both primary and secondary forests in the area. It is estimated that annually 10.000 - 15.000 hectares are deforested while cumulatively 300,000 ha of primary forests have been cut in the last twenty years. This level of deforestation is estimated to have generated emissions of 55 MtC (184t C/Ha) or 202 Mt $CO_2$ during the last 20 years.

When these recent migrants arrived they continued to use traditional land-use practices from their native regions that were not adapted to their new tropical setting where bioclimatic conditions differ completely. Until recently, many of these settlers did not appreciate the economic and ecological value of the native forests found on their parcels as a potentially sustainable source of income from timber and non-timber products, habitat for game and fishes, nor the relation of these forests to maintaining soil fertility and hydrological processes. (Stilma et al, 2000)

## *2.2 Detailed Project Description*

The project's objective is to work with farmers and farmer cooperatives to promote improved farming systems and forestry practices on farm parcels. The project will promote the establishment of plantations and improved forest – agriculture practices. As in other parts of the tropics, the nexus between sound agricultural practices and conserving native forests is fundamental. Likewise, it is vital that small farm families realize the benefits of both tangible and intangible benefits produced by their forest resources. In this context, the project strategy for achieving its objective is to design, promote and implement economically viable and labor-intensive land-use and forest resource management practices. Focusing efforts on training, technology transfer and monitoring, these practices will not only generated income and local employment for poor landowners from the sustainable harvesting of forest products, but provide a continuous revenue stream from carbon investments.

Basically an integrated farming system will be introduced. This farming system aims to improve the efficiency of land use on the whole farm, considering the current and future needs of the farmer family. Sustainable crop and forest production will generate income on short-, mid-, and long term and will also guarantee food security.
The project strategy to carbon fixation will be reached using three intervention approaches:

1. Management of secondary forests by enrichment planting with native species and application of silvicultural practices;
2. Reforestation in areas designated for that purpose within farmers' parcels.
3. Implementation of agroforestry systems,

The traditional agricultural practices of slash and burn will lose importance by introducing permanent agroforestry systems and nitrogen fixing species into the cultivation cycle. Land used for annual crops will have a reduced fallow period, because of the use of nitrogen fixing species (*Inga sp., Mucuna pruriens* and other leguminous species). Land fertility is recovered much faster by leguminous species than by species of natural fallow lands. Fallow land and secondary forests will be enriched with the aim to make these areas economically productive and stock a bigger amount of carbon.

The project hopes to achieve a system with a more intensive integrated land use system and overall producing a higher quantity of biomass. Additionally these activities will benefit the conservation of primary forest still left on their farms. Besides, these residual primary forests will be managed for wood and other forest products.

Tree species selection for specific sites will be based on site evaluations. Tree selection depends on proven suitability for the specific site conditions and purposes of the trees species in the (agro) forestry systems (timber production, shade, nitrogen fixing, etc). Principally native species will be used. The proposed species for this project are: *Guarea rugby, Schlizobium amazonicum, Centrolobium tomentosum, Terminalia amazonica, Swietenia macrophylla and one* exotic specie:*, Tectona grandis*.

Although these forests and (agro) forestry plantations will be harvested in the future, a forest management system will be introduced to minimize $CO_2$ emissions and maximize $CO_2$ sequestration. The application of a polycyclic harvesting system, in plantations and enriched secondary forests, will guarantee a relatively high average storing capacity in plantations as well in secondary forests.

The project will create a **Risk Management System (RMS)**, which will take actions to avoid $CO_2$ emissions produced by illegal lodging, forest fire or not controlled burn and slash activities, among others.
Also it will consider potential leakage through the implementation of the project activities, taking the necessary actions to minimized its impact.

The project will create a **Carbon mitigation Fund (CMF)** that will take into account $CO_2$ certificates from carbon pools which are additional to the pools already considered by the project, for instance from the logging residues recovery system or the accumulation of underground carbon, that are not included in the overall carbon accounting. Degradation of underground biomass resulting from inefficient agriculture activities will be measured, along with other ancillary improvements due to project investments. Also traditional pools will be taken into account, like reforestation activities which are exclusively developed for the CMF.

There will be established a **Contingency Fund (CF),** that will take into account a percentage, yet to be defined, of the project profits due to the $CO_2$ certificates commercialization,. The economic resources generated by this CF will be used to implement mitigation activities required by the RMS.

The proposed project is estimated as having the potential to reduce deforestation rates within project area by 69% from 2000 levels. The expected results of the project in terms of $CO_2$ emissions balance over 30 years on 75,000 ha are in the order of 17 Mt $CO_2$ reduced or sequestered. The reduction cost per ton of $CO_2$ in three scenarios of discount rate 12%, 18%, and 25% are respectively 3.27, 2.51 and 2.04 US$/ton $CO_2$.

## *2.3 Biophysical characterization of study area*

### Characterization of study area (WP1/WP2)

### a) Biophysically characterization / description:

From a biophysical perspective the study area is quite uniform; the terrain is relatively flat, the precipitation and temperature patterns do not fluctuate significantly and the soil texture and depth remain relatively homogeneous throughout. Figure 1 displays the topographic relief of the study area. The Andes mountains are located immediately south of the study area. The rivers flow in a north easterly direction down away from the mountains.

### i. Landcover / landuse

The study area however is comprised by a heterogeneous mix of different landuse and landcover types (Table 1). The average small scale farmer in this area possesses a parcel that typically is narrow but long in length (100 x 2000 meters). The average farm size ranges between 15 and 20 hectares.

A spatial delination of landuse classes is given in Figure 3, based upon the following source:

Miranda, F., M. Minto, J. Goítia, B. J, J. and A. Stilma (2002). *Informe Del Análisis Multitemporal De Imágenes Satelitales Para La Estimación De Perdida De Cobertura Forestal Primaria Y Evaluación Del Cambio De Uso De Suelo En El Bosque De Uso Múltiple Del Tropico De Cochabamba Años 1993 - 2001.* Cochabamba, FAO.

The most common agricultural landuses with in the area are:

- cattle grazing for beef and milk production,
- annual cropping (rice, maize, cassava),
- and perennial cropping (banana, palm heart, papaya, pineapple, citrus)

Each of these classes exhibit unique biomass accumulation curves through the course of their rotations, as agriculture crops shift within the landuse system. These biomass trends are discussed further in the baseline evaluation section.

### ii. Climatic conditions

There are three climate stations within the Chapare region, of which the La Jota station is being very close to the project area boundary (Figure 4). The area receives on average 4449 mm of rain annually, with most precipitation falling between the months of November and March (Figure 5a). The average annual temperature is 25.2°C (Figure 5b). Temperatures reach highs of 39°C and lows of 6°C. From May to September, temperature can drop down for days, due to cold winds that come up (called Surazos) from Patagonia.

### iii. Soil and terrain conditions

A detailed soil map for the Chapare project area is shown in Figure 6. The map delineates soil types using the Fertility Capability Classification (FCC) System. The FCC groups soils according to edaphic criteria that directly influence interactions between nutrient availability and plant growth.

The project area is composed almost entirely of loamy soils. Some areas to the north have a greater clay component, while the areas surrounding the central river bed contain a greater sand component. The FCC map indicates soil textures but also it indicates the deficiencies present in the soil (Montheith, 1993) Within this study area there are a number of factors influencing growth:

i. Aluminum toxicity: Within the entire study area aluminum toxicity pose a significant problem to plant growth.
ii. Gleying: Gleying and poor soil drainage is also a problem in the northeastern part of the study .
iii. Low cation exchange: The central area of the study has a low cation exchange capacity.
iv. Stoniness/ Rockiness: Some areas located along the southern border and along the rivers have a greater.

The terrain of the area is generally low evelavation and flat, excepting for some hilly topography along the Andean foothills (Figure 7). More than 75% of the project has a slope of less than 5% (Figure 8). Figure 9 gives various perspectives of the project area, including perspective of elevation, and a Landsat image draped over the DEM. Elevation data was derived from SRTM 90m DEM.

### iv. Landcover changes

Over the course of the past 30 years, the study area has dramatically changed. Settlers moved into the area to establish small farms, and as a result huge areas of primary forest were cut to make room for agricultural production *Millington et al. (2003*) observed that the main Cochabamba–Santa Cruz road moved eastwards from Villa Tunari during the 1980s and 1990s, facilitating an increasing cultivation density. Forest fragmentation, caused mainly by cultivation, increased rapidly from 1986 to 1993 but appears to recover after 1993. However, it is not possible to make this generalization for all of Chapare, as deforestation in many parts of the area continues to the present day. Rather, the increase in the tree component in some parts of the landscape is due to tree and bush crops (e.g. citrus, palmito and pimiento) which have been planted as alternatives to coca as part of aid programs.

Ivirgarsama (48,000 ha) to the west of Mariposas was occupied mainly by semi-directed colonists from the mid-1970s onwards and was extensively cleared by 1986. To the south of the main road, the area was mostly coca cultivation. For the area to the north of the main road, the improvement of a single-track mule trail to a gravel road improved access to the port at Puerto Villarroel. As the road was being constructed, workers observed spontaneous colonisation up to 300 m on either side of the road (Republica de Bolivia, 1972). However, the major clearance of this area came after this at the hands of directed colonists. Fragmentation of the woodlands to south of the road decreased in the 1990s as coca eradication and alternative development programmes were introduced. In this sector, the forest area was also more- or-less constant, again indicating a balance between clearances and maturing tree crop areas (Millington *et al.*, 2003).

These landcover changes, and a significant deforestation trend, are illustrated and visually readily apparent in comparison of satellite imagery for three dates, i.e. from 1974 to 1990 to 2000 (Figure 10). Primary forest showed a strong rate of decline from 1974 to 2000, with secondary forest and area devoted to crops increasing significantly over this time period (Figure 11). Satellite images used in the analysis of land cover, and for further analysis described below, include:

Landsat 5 TM - May 24th, 1990□
Landsat 7 +ETM - July 14th, 2000□
Landsat MSS - July 1st, 1974

### v. Tree cover

Tree canopy densities were calculated for two dates - 1990 (May 24th) and 2000 (July 14th) from Landsat imagery using the software program Forest Canopy Density (FCD) Mapper (ref). Both satellite images were acquired during the dry season. The FCD output maps spatially delineating tree cover density in 1990 (Figure 12a) and 2000 (Figure 12b). Almost 26,000 ha had a tree cover density greater than 50% in 1990, with little change in this estimate to the year 2000. However, within this category, the area with the highest canopy cover density (75-100%) declined significantly from 42% of the project area to 36%, indicating that in addition to actual deforestation, processes of ongoing forest degradation are also evident. Tree and forest canopy cover change was analyzed and spatially delineated based upon a change detection overlay analysis of the results from the two dates (Figure 13a).

A NDVI analysis of the landsat imagery was performed to observe vegetation (or biomass) change in the project are between 1990 and 2001 (Figure 13b). This map reflects differences in the Normalized Difference Vegetation Index (NDVI) between the two dates. The degree of change is emphasized in standard deviations: one standard deviation indicates a slight increase or decrease while two standard deviations reflects a greater degree of change. Also note this map shows all vegetation changes including changes occurring due to shifting agricultural cultivation practices areas, not just areas where deforestation, or reforestation, has taken place.

### vi. CDM eligibility

Based on CDM AR regulations eligible reforestation / afforestation projects can not be implemented on areas categorized as "forest" in either 1990 or 2000. Bolivia's definition identifies forest as having a canopy cover greater than 30%, i.e. areas either currently or historically (1989) with greater than 30% cover are ineligible for CDM-AR. Based upon the FCD analysis of Landsat data described above, land area available for CDM was delineated as the areas identified with less than 30% cover in both of the images, i.e. 1990 and 2000 (Figure 12c):

| | **Area (ha)** | |
|---|---|---|
| Not eligible | 22,657 | 56% |
| Eligible 1990 & Ineligible 2000 | 6,767 | 17% |
| Eligible 2000 & Ineligible 1990 | 5,945 | 15% |
| Eligible in both 1990 and 2000 | **5,239** | 13% |
| | 40,607 | |

Availability of land for CDM-AR activities was estimated to be approx equal to the estimated size of the project, suggesting a high adoption rate will be necessary to meet the goals and projected income by the proposed project. However, scale and resolution used for remote sensing and mapping likely underestimated land availability by not accounting for smaller patches.

## 3 Biodiversity

According to the biogeographical zonation of Bolivia the Cochabamba Tropics and Ichilo province belongs to:
Bio geographic province of Acre and Madre de Dios (South West Amazone), Sector bio geographic Amazon Andean foothill. District A.5. bio geographic district Amazon Chapare. Characterised by the following species: *Aspidosperma rigidum, Astorcaryum murumur, Attalea phalerata, Brosimum acutfolium, B. lactescens, Cariniana estrellensis, Cedrela odorata, Celtis schippi, Cetrolobium ochtryxylum, Clarisia biflora, C.racemosa, Coussapoa ovalifoloa. C. villosa, Erythrina poeppigiana, Guarea macrophylla, Iriartea detoidea, Leonia glycicarpa, Porcelia steinbachii, P. ponderosa, Poulsenia armata,*

*Pourouma cecropiifolia, Protium opacum, Pseudolmedia laevis, P. macrophylla, Ruizodendron ovale, Sloanea guianensis, Socratea exorhiza, Spaattosperma leucanthum, Swietenia macrophylla, Tabebuia serratifolia, Tapura acreana, Terminalia amazonica, T. oblonga, Trichilia pleeana, Thrihis caucana*. (Navarra, 2002)

### *3.1 Threatened Species*

**Rare endangered species**

The portfolio area contains a wide variety of fauna, including avifauna and aquafauna. Inhabitants of the region are reporting a decline in the number of animals and fish, due hunting ad fishing and destruction of their natural habitat.

The following mammal species are reported by people from the communities: jochi pintado (*Agouti paca*), jochi colorado o calucha (*Dasyprocta* sp.), chichilos (*Saimiri sciureus*), taitetú (*Tayassu tajacu*), parabas (*Ara spp*), loro cenizo (*Amazona farinosa*), venado o huaso (*Mazama americana*), tropero (*Tayassu pecari*), anta (*Tapirus terrestris*) y oso hormiguero (*Tamandua tetradactyla*). All of these species except the jochi pintado and the jochi Colorado are protected under CITES.

### *3.2 Conservation Measures*

Proposed project will use basically native tree species, leakage will be avoided and improved agricultural systems will slow down the pressure on the existing forest

## 4 Proposed Tree Species for the Project Area

The proposed species for this project are: *Guarea rugby, Schlizobium amazonicum, Centrolobium tomentosum, Terminalia amazonica, Swietenia macrophylla, and one exotic specie: Tectona grandis*. (Figure 14).

## 5 Land Suitability Assessment

The ENCOFOR Land Suitability Model (LSM) was used to derive ecological suitability maps for each prospective species, spatially modeling the performance of each respective species within the landscape. Species growth requirements and baselines estimates, based upon a review of literature specifically relevant to the Chapare regioin and the Bolivian Amazon, were combined with expert knowledge, to model land suitability for CDM-AR within the project area. The spatial model optimizes the species distribution within suitable areas, excludes non-suitable areas, and estimates site quality and growth potential, producing a set of "ecological suitability" maps (Figure 15). These maps represent a continuous gradient of suitability (30m grid cell resolution) integrating a set of environmental determinants of growth, which is to calibrate growth and biomass accumulation curves, and baseline carbon estimates.

For the Chapare region, only soils data was used to predict growth along a suitability gradient ranging from completely unsuitable to a hypothesized optimum site quality for CDM-AR. Growth response values were estimated using literature, expert knowledge and the assistance of project partners. An iterative approach was used to calibrate the model, and to test the sensitivity of the growth response to the various environmental parameters, within a range of expected biomass estimates. Growth response scores are designated to each environmental condition for each species. These scores are used to model the site-speficic and species-specific suitability of each 30m x 30m grid cell. The resulting ecological suitability maps indicates the potential growth response (i.e., site index) of each species, on a particular site. These growth response maps indicate how the environmental variables influence growth for that species on a per pixel basis. In general, results show that *S. amazonicum* did perform well on soils with high aluminium content and low potassium (LCaK), as the other species. All species present similar growth and productivity trends across the soil environmental gradient, however *T. amazonica* showed suitability scores consistently lower than the other species. The soil parameters excluded little area, only those areas that were classed as “river bed” based on remote sensing analysis. These layers were used to reduce growth potential using what was known of the trees’ physiology and environmental prerequisites. The resulting species-specific growth response maps indicate the degree by which optimal growth is reduced.

Ineligible areas, i.e., unsuitable for reforestation, were excluded from the analysis. Based upon the landuse map. Based on the canopy cover density map produced from our the remote sensing analysis, areas considered forest, i.e. with canopy cover greater than 30%, in either 1990 or 2000, were excluded and deemed unsuitable. This threshold is based on Bolivia’s UNFCCC forest canopy cover definition, and corresponds to the CDM-AR rules.

## 6 Project Scenario Analysis

The biomass production, wood volume, profitability, and carbon sequestration potential of a project is dependent upon a variety of factors including adoption rates, silvicultural activities, management regimes, and markets, among other factors. In this prefeasibiity analysis, three production schemes are modelled separately according to the intended project design, namely plantation, agroforestry, and silvo-pastoral activities. We then analyze the overall project as a whole, if it were designed included all three activities.

All three scenarios are based on on-farm tree planting and timber production and include various mixes of all five of the proposed tree species. It is anticipated that approx. 50% of the 2,400 farmers will participate in the project. The average farm size is 17 hectares, however, farms anticipated to participate in the project are approximately 20 hectares (100m x 2,000m).

- Pure plantations will be established using a 3m x 3m spacing (1111 trees/ha); 2,500 hectares of plantations will be established in the project area (approx. 12% of each participating farm). Results are given in Table 4 & 5. Species mix proposed for this component is given below:

| | |
|---|---|
| *Centrolobium tomentosum* | 15% |
| *Dipteryx odorata* | 15% |
| *Guarea rusby* | 25% |
| *Schlizobium amazonicum* | 40% |
| *Terminalia amazonica* | 5% |

| | |
|---|---|
| *Centrolobium tomentosum* | 30% |
| *Dipteryx odorata* | 20% |
| *Guarea rusby* | 10% |
| *Schlizobium amazonicum* | 25% |
| *Terminalia amazonica* | 15% |

- The agroforestry component will plant 550 trees/ha (50% of full stocking) between existing agricultural crops. It is proposed that 1,400 hectares will be converted to an agroforestry landuse system (this is approximately 7% of each participating farm). Results are given in Table 6 & 7. Species mix proposed for this component is given below:

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- In the silvopastoral component, 330 trees/ha will be planted (30% of full stocking), allowing enough space for cattle production to continue. Approximately 2,100 hectares of land will be dedicated to this project type (10% of each participating farm). Results are given in Table 8 & 9. Species mix proposed for this component is given below:

| | |
|---|---|
| *Centrolobium tomentosum* | 15% |
| *Dipteryx odorata* | 15% |
| *Guarea rusby* | 35% |
| *Schlizobium amazonicum* | 25% |
| *Terminalia amazonica* | 10% |

- When all three components of the project are taken together, a total of 6000 hectares will be planted, and on average encompass 30% of each participating farm. Results for the “Entire Project” are given in Table 10 & 11.

### *6.1 Growth and Average Carbon Stock Estimates*

Growth and yield estimates are modeled based upon the database of information complied from country partners and literature. Above ground biomass production and volume are calculated on a per pixel basis, based upon the species growth curves, modified by the environmental growth response surface. The anticipated growth and yield volumes are estimated as biomass, cubic meters of wood (Figure 16a) and the carbon accumulation rate (Figure 16b) in tons of carbon per hectare (tC/ha), for the prospective tree species, without any harvesting or thinning activities.

To estimate the carbon sequestration rate, wood volume from the growth and yield curves has been extrapolated, using specific wood density, the biomass expansion factor (based on guidelines) and the carbon fraction for each species, to get average carbon stock per hectare.

***Above Ground Biomass = VOB * WD * BEF*** (Brown, 1997)

*Where :*

*VOB = Volume over bark* ($m^3$*/ha)*
*WD = Wood density (volume weighted average wood density) (g/cm*$^3$ *or T/m*$^3$*)*
*BEF = Biomass expansion factor (ratio of above ground oven dried biomass of trees to oven dry biomass of inventoried volume)*

The equation for calculating carbon content from wood volume is given below:

***Total Aboveground Carbon = AGB * 0.5*** (Roy *et al.*, 2001)
*Where :*
*AGB = Above Ground Biomass (dry weight) in tons*

The aboveground carbon accumulated by each species (Figure 16b) has been modeled growth yield curves provide by CETEFOR, based upon their fieldwork in the region. Figures 17 describes the anticipated carbon accumulation trends for the five species, based upon the expected rotation and management regime, over a period of 100 years. No account is taken into consideration that successive yields will decrease, although this is likely without the input of added nutrients. Only above ground carbon estimates have been considered in this analysis.

## 7 Carbon Accounting

### *7.1 Total Project Carbon*

The total amount of carbon which is maintained on-site (i.e., on afforested/reforested areas), over the project duration, due to project activities, within the entire project area, is referred to as the “Total Project Carbon” (see Table 4 thru 11), and is given in tC. This project carbon is calculated using the average carbon stock method on a per pixel basis, i.e. on each grid cell. The estimate of average project carbon maintained on-site, on all pixels is then added together to arrive at the “Total Project Carbon” estimate.. All grid cells, or all grid cells with a particular species (e.g. Table 4, 6,8,10) or within a landuse type (e.g. Table 5,7,9,11) are averaged together to arrive at “Average Project Carbon” per ha, which is given in tC/ha.

### *7.2 Baseline*

Based upon literature, and expert knowledge, a carbon baseline has been estimated for each land use type, using a spreadsheet model based on the GORCAM carbon model (ref). This carbon stock baseline estimate, in combination with the environmental and edaphic factors, is used to derive a spatially disaggregated map of carbon baseline stock across the plantation area. The baseline calculation integrates specific knowledge of landuse and landuse trends, with the biophysical capacity of sites vegetation growth. The first step of the carbon trend modeling, was done using the ENCOFOR AR-DSS model (Joanneum-Research-Forschungsgesellschaft-mbH, 2005). This tool, designed to evaluate CDM-AR projects, allows the user to model carbon trends based on landuse dynamics, over a specified period of time. It models the changes in carbon through a landuse cycle, such as annual cropping, or shifting agriculture. Using expert knowledge, obtained in this case from the country partner, the landuse patterns, biomass and average carbon stock are quantified for each landuse category. The average carbon stock maintained in each landuse type, as estimated in the AR-DSS, is then used to parameterize the spatial modeling of baseline within the LSM spatial analysis.

In the first of the two part calculation, the carbon landuse dynamics were modeled in the AR-DSS (Table 3) and the average carbon stock for each landuse type was predicted and spatially delineated (Figure 18). The resulting output map spatially delineates the baseline carbon stocks within CDM-AR eligible areas, on a per pixel basis, based primarily upon landuse, integrating management practices, landuse trends, and the biophysical limitations imposed by climatic and environmental variables on vegetation growth. This calculation is difficult to model based on environmental parameters at fine resolutions, because the baseline condition encompasses many different vegetative species growing optimally under different conditions.

### *7.3 Net Carbon*

Based upon the carbon baseline, as estimated above, the "net carbon" stock is calculated for each grid cell by subtracting it from the total project carbon, or project average carbon stock estimate. This estimate is roughly equated with the amount of C that can be claimed as "sequestered" by the project, and the carbon credits for which the project will qualify.

Net Carbon for the "Entire Project" if implemented on 6000 ha is predicted to be approximately 100,000 tC (Table 10). Figures 19a, 20a, and 21a give the spatially delineated results for the net carbon estimation for the three respective components of this project.

## 8 Revenue Analysis

### *8.1 Biomass and Wood Volume*

Biomass and wood volume have been calculated using the equations described above. Only aboveground biomass is included in the calculation. A biomass expansion factor (BEF) is used to convert biomass to wood volume. Wood volume is defined as a measure of the volume of marketable wood by cubic meter at the first rotation. The revenue numbers expressed within these tables do reflect the differing rotation ages of the tree species, and no attempt has been made to discount the future value or calculate net present values (NPV). All results used in the revenue analysis are reported as being at the time of the first harvest, i.e. rotation period.

### *8.2 Net Revenue*

A rough calculation of gross revenues, based on wood volumes and market price, is made within the spatial analysis. By converting biomass to wood volume, we then use the current market price to estimate the gross returns at first harvest. The market price has been supplied by the country partner.

An “average plantation cost” is used to estimate costs. This estimate includes establishment and maintenance cost for the entire rotation period, as estimated by the country partner. Due to the difficulty of estimating the cost per ha of plantations in a heterogeneous environment, this estimate was used for all areas within the entire project site. In addition there are significant likely costs that are not included, particularly monitoring and verification costs, and interest on investment.

The net revenue is rather crudely calculated to allow the spatial scenario analysis to explore the spatial implications of the profitability dimensions of the project. The “total project cost” are simply subtracted from the “total revenue” to determine the “net revenue”. For a fuller accounting of the project financial analysis, these results should be further explored in the AR-DSS. Potential funds becoming available through the CDM , i.e., the selling of carbon credits, have not been calculated, nor into taken into account of in the net revenue analysis. Figures 19b, 20b, and 21b give the spatially delineated results for the net revenue estimation for the three respective components of this project.

Using this approach, the net revenues for the entire project (Table 10) is predicted to be almost $25,000,000. It is noted that project activities in these areas may still have non-monetary values associated with subsistence livelihood options, which are not taken into account here.

# 9 Literature Cited

FAO (2003). FAOCLIM 2: World-Wide Agroclimatic Data Base. Rome, Food and Agriculture Organization of the United Nations.

Frohn, R. C. (2002). Cultivos de Banano: Classificacíon sobre imagínes satelitales Landsat7 e Ikonos - Julio 2002, Departmento de Cochabamba, Proyecto Concade, USAID.

Frohn, R. C. (2002). Cultivos de Palmito: Classificacíon sobre imagínes satelitales Landsat7 e Ikonos - Julio 2002, Departmento de Cochabamba, Proyecto Concade, USAID.

Frohn, R. C. (2002). Cultivos de Pastos: Classificacíon sobre imagínes satelitales Landsat7 e Ikonos - Julio 2002, Departmento de Cochabamba, Proyecto Concade, USAID.

Frohn, R. C. (2002). Cultivos de Piña: Classificacíon sobre imagínes satelitales Landsat7 e Ikonos - Julio 2002, Departmento de Cochabamba, Proyecto Concade, USAID.

Miranda, F., M. Minto, J. Goítia, B. J, J. and A. Stilma (2002). INFORME DEL ANÁLISIS MULTITEMPORAL DE IMÁGENES SATELITALES PARA LA ESTIMACIÓN DE PERDIDA DE COBERTURA FORESTAL PRIMARIA Y EVALUACIÓN DEL CAMBIO DE USO DE SUELO EN EL BOSQUE DE USO MÚLTIPLE DEL TROPICO DE COCHABAMBA AÑOS 1993 - 2001. Cochabamba, FAO.

Montieth, S. and A. Quiroga (1993). Mapeo de Suelos del Chapare con Sistema FCC. Cochabamba, Development-Alternatives-Inc.