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Development Of An Agroforestry Sequestration Project In Khammam District Of India

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Abstract. Large potential for agroforestry as a mitigation option has given rise to scientific and policy questions. This paper addresses methodological issues in estimating carbon sequestration potential, baseline determination, additionality and leakage in Khammam district, Andhra Pradesh, southern part of India. Technical potential for afforestation was determined considering the various landuse options. For estimating the technical potential, culturable wastelands, fallow and marginal croplands were considered for Eucalyptus clonal plantations. Field studies for aboveground and below ground biomass, woody litter and soil organic carbon for baseline and project scenario were conducted to estimate the carbon sequestration potential. The baseline carbon stock was estimated to be 45.33 tC/ha. The additional carbon sequestration potential under the project scenario for 30 years is estimated to be 12.82 tC/ha/year inclusive of harvest regimes and carbon emissions due to biomass burning and fertilizer application. The project scenario though has a higher benefit cost ratio compared to baseline scenario, initial investment cost is high. Investment barrier exists for adopting agroforestry in the district.

Keywords: Agroforestry, mitigation, Eucalyptus, above ground biomass, soil organic carbon

1 Introduction

Globally forestry has taken central stage as one of the options to mitigate climate change. It is estimated that the total global technical potential for afforestation and reforestation activities for the period 1995-2050 is between 1.1–1.6 GtC/yr of which 70% will be in the tropics (IPCC, 2000). Agroforestry is an attractive option for carbon mitigation as (i) it sequesters carbon in vegetation and soil depending on the pre-conversion vegetation and soil carbon (ii) the wood products produced serve as substitute for similar products unsustainably harvested from natural forests and (iii) it increases income to farmers (Makundi and Sathaye, 2004). Approximately 1.2 billion people, making 20% of the world's population depend directly on agroforestry products and services in rural and urban areas of developing countries (Leakey and Sanchez, 1997).

The potential land area suitable for agroforestry in Africa, Asia and the Americas is 585-1215 Mha (Dixon, 1995). It is estimated that an additional 630 Mha of current croplands and grasslands could be converted into agroforestry, primarily in the tropics. Agroforestry activities could be of two types; converting fallow and marginal croplands to agroforestry and adopting agroforestry practices into existing cropping system.

A large potential for agroforestry has given rise to scientific and policy questions internationally and nationally from national governments, climate change negotiators, potential investors in greenhouse gas mitigation activities and local communities. The contentious issues are additional carbon that could be created, emissions reductions that can be achieved, cost effectiveness and total cost for implementation of agroforestry projects, institutional arrangements, etc. To research some of these issues, this paper addresses the following; considering agroforestry option in Khammam district, Andhra Pradesh, which is in the southern part of India. The main objectives are:

- Estimate carbon sequestration potential of farm forestry plantations promoted by industry
- Develop baselines for farm forestry plantation projects
- Establish additionality of carbon sequestration for farm forestry activity
- Measure carbon stock changes through stock change approach
- Assess leakage and measures to address leakage

2 Description of Project Location

The Khammam district lies in the north eastern part of the state of Andhra Pradesh, located between 17° 40’ N and 81° 00’ E and rises 100 m above mean sea level. Forest area constitutes 52% of the district geographic area and the forest types are tropical moist deciduous, tropical dry deciduous and tropical thorn. Soils in the region are of black cotton, red alluvial loam and red sandy type.

In Khammam district, the study was conducted in six mandals[1] namely Burgampahad, Kukunoor, Bhadrachalam, Kunavaram, Cherla and Velairpadu. The study area comprises 13.10% of the district area. The land use pattern in the mandals is given in Table 1. Forests dominate the land use accounting for 62% of the geographic area. Cultivated agricultural lands form the second most abundant landuse with a mean cropping area of 18%, followed by non-agricultural lands (8%). The rest of the area is covered by barren and uncultivated land (3.82%), fallow land (1%), land under tree crops (0.88%), pasturelands (0.4%) and cultivable waste (0.43%).

Land use pattern in selected mandals of Khammam district in Andhra Pradesh (ha)

TABLE 1

The croplands are variable in the mandals, but have identical management practices with regard to application of chemical fertilizers and irrigation practices. The cropping pattern in the six selected mandals in Khammam district is dominated by Rice (38.12%) except in Bhadrachalam and Kunnavaram mandals (Table 2). Cotton is the second largest crop with 16.15% of the cropping area, followed by chilli (9.26%) jowar (9.16%) and redgram (8.31%). The rest of the cropping area (19%) includes, green gram, sugarcane, maize, black gram, tobacco, groundnut and sesamum. Farm forestry accounts for only 10% of the cultivated area in these mandals. Eucalyptus and Luceana leucocephala clones form 90% and 3% of the area and the remaining plantations are raised by the Andhra Pradesh Forest Department (7%).

TABLE 2

Cropping pattern in the selected mandals (ha)

TABLE 2

3 Afforestation Rates – Past and Projected

It is necessary to take into consideration the past, current and projected rates of afforestation and reforestation (A&R) for projecting the "business as usual" or baseline scenario. The potential for farm forestry project activities in the selected mandals was estimated based on the rate of afforestation in the past, current and considering future land use and afforestation rates in the region. In this region, agroforestry is being promoted largely by ITC (a paper mill) and the rate of afforestation was about 54 ha/year during the period 1992-1999 (Table 3). The rates increased 5 folds to about 240 ha/year during 2000-2004 (Table 3). The company intends to plant 364 ha/year in the next 6 years (2005-2010) in these 6 mandals.

TABLE 3

Area afforested under farm forestry in selected mandals of Khammam district (ha)

TABLE 3

3.1 Technical Potential Of Land For Afforestation

The farmers are currently converting land under crops such as chilli, cotton and redgram to plantations. Though the yearly land use change pattern is not available, discussion with the farmers reveal the preference of farmers to shift from crop cultivation to Eucalyptus plantation. Just considering the uncultivated lands such as pasture land, uncultivated and cultivable and fallow land about 9658 ha is available, which is after deducting the projected afforestation rates for the period 2005-2010 by the ITC company. Considering conversion of marginal croplands, which is the current practice, the land potential for agroforestry is significant.

4 Additionality

A project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the project activity. Additionality is when conceptually it is possible to demonstrate environmental, technical and financial additionality. A project's environmental additionality is checked by the comparison of baseline and project GHG-benefits. The proposed project activities should result in increase of net carbon stocks, would it not have gone ahead (or not in their proposed form) in the absence of the project, do not result in increased deforestation (or decreased carbon removals) elsewhere. Further, the project should contribute to sustainable development, e.g. via local socio-economic benefits such as increased employment, income or access to non-timber forest products. Financial additionality include macro additionality factor, *i.e.* not financed with the help of Official Development Aid (ODA) and the micro additionality factor or investment additionality.

Considering the additionality tool as set by the UNFCCC, to demonstrate additionality, it is essential to demonstrate the following:

- *Identify likely alternative land use project activities* - The alternative to the project is dryland agriculture or status quo. Crops such as cotton, chilli and tobacco can be cultivated on these lands or can remain fallow.
- *Identify investment options* – The clonal eucalyptus plantation requires high establishment cost for the initial three years. The farmers have to invest Rs. 40,000/ha for raising Eucalyptus plantations. Financial institutions do not extend loans for plantations due to the risk factor. Also funding from international sources is lacking. The alternative to the project, agriculture is easier to adopt due to loan availability from banks and other financial organizations.
- *Analysis of barrier* – As mentioned above, finance is a barrier since loans cannot be secured from national and international markets for afforestation and the investment required is high.
- *Analysis of usual practice* – This step is to identify similar projects in terms of geographical area, technology, size and access to financing and differentiate them from the proposed project. In Khammam district, most of the rich farmers with large landholding plant part of their agricultural land with the Bhadrachalam Eucalyptus clones. The farmers pay upfront for the seedlings and other establishment costs. Under the project scenario, the small and marginal farmers with small landholding could be identified and planting done on their lands. The

impact of such a project in addition to environmental benefits could attract new investors.

5 Baseline Development

Under the Climate Convention, "the baseline for project activity is the scenario that reasonably represents anthropogenic emissions by sources of GHGs and removal by sinks that would occur in the absence of the proposed project activity". To determine additionality of a project, it is important to understand the business-as-usual emissions or sinks in the absence of the project. A structured project-specific approach to baseline development was adopted, which is based on reliable, site-specific information and comprehensive analysis and have the potential to credibly and accurately quantify additionality. Site-specific data was used to calculate the initial stock of carbon as climatic conditions, site conditions, species planted and site management can all significantly affect the carbon content of different management systems. Socio-economic indicators and land suitability were also examined while assessing the most likely land-use for a project site, as they are important determinants of what land-use is. These factors can also vary considerably from site to site. The general approach used to determine the baseline was to:

2. Identify current land-use/land-use trends and associated carbon stocks of the project site.
3. Assess likely future land use without intervention.
4. Quantification of carbon uptake and emissions of likely land use over project life.

   The following steps were undertaken to establish baseline (Ravindranath *et al*, 2004):
5. Define land use systems and their tenurial status
6. Define the project boundary and prepare a map
7. Select carbon pools and define methods for measurement
8. Develop sampling design and strategy for biomass and soil carbon estimation
9. Lay plots in different land use systems and measure identified parameters
10. Analyze data for aboveground biomass (AGB) carbon stock, below ground biomass, woody litter, dead wood and soil carbon

11. Assess past and current A&R ratesProject future land use and estimate potential area for the project activities
13. Estimate carbon stocks using area and per ha carbon stock data, for the project area.

5.1 Project Area And Legal Status

The project activity – afforestation is proposed on cultivable wastes, marginal crop and fallow lands in the 6 mandals of Khammam district. These lands are legally under private ownership of individual farmers.

Cultivable waste (long fallow) is such area available for cultivation, either not taken up for cultivation or taken up for cultivation once, but not cultivated during current year and last five years or more in succession. Such lands may be either fallow or covered with shrubs and jungles, which are not put to any use (NRSA, 1995).

Fallow lands are lands, which were taken for cultivation but are temporarily out of cultivation for a period of not less than one year and not more than five years. The reasons for keeping such lands fallow may be one of the following (i) poverty of cultivators (ii) inadequate supply of water (iii) silting of canal and rivers and (iv) non-remunerative nature of farming (NRSA, 1995).

5.2 Project Boundary

The project boundary needs to encompass all anthropogenic emissions by sources of GHGs and removals by sinks under the control of the project participants that are significant and reasonably attributable to the project activity. The project area consists of geographic domain with more than one discrete area of land, within which GHG emissions or removals and other attributes of a project are to be estimated and monitored. Thus the six mandal boundaries are the project areas. The project boundary includes discrete blocks of plantations on individual farmer's lands in the each of the mandals.

5.3. Sampling Strategy For Baseline

The carbon pools selected for baseline development are aboveground biomass, below ground biomass, and soil organic carbon. Dead wood was not included as this was not a major carbon pool under farm forestry. The definition of carbon pools are as defined by the IPCC (2003).

Aboveground biomass: This dominant carbon pool was estimated by the most commonly used plot method. Sampling on farmlands involved enumeration of all trees on individual farms i.e., whole farms. Sampling strategy for farm forestry involved randomly selecting 10 farmers who were open to farm forestry activity with Eucalyptus clones, out of which 5 were small farmers (<2 ha) and 5 were large (>2 ha). A total of 40 farmers were selected and interviewed for the cost and benefit of the present crop and area available for farm forestry. A total of 95 ha of fallow and culturable wasteland owned by them was sampled. All trees >1.5 m in height or >5 cm DBH (Diameter at Breast Height) were enumerated. In each tree plot, smaller plots (10m X 10m) were demarcated to enumerate shrubs and regenerating seedlings and record the species name, height and DBH (130 cm above ground) of each tree or sapling or shrub.

Species-specific or generic volume equations from FSI reports (1996) were used to convert DBH and height into volume (m^3/ha). The biomass estimate was obtained by using the density values of dry wood and the carbon value by using 0.45 of biomass as carbon content.

Below ground biomass: A default conversion factor of 0.26 of aboveground biomass was used to calculate the below ground biomass (IPCC, 2003).

Woody litter: The plots laid for shrub enumeration were used for estimating standing woody litter. All the woody litter was collected from these quadrats measuring 5m X 5m and fresh weight as well as dry weight estimated on per ha basis.

Soil carbon: To estimate soil organic carbon, soil samples at depths of 0-15 and 15-30 cm were collected. Bulk density was measured and soil organic carbon content was estimated in the laboratory using the Walkley-Black method. Soil samples from tree plots in marginal agricultural lands and other fallow lands representing baseline scenario were collected. A composite soil sample from multiple soil samples was prepared for different land categories.

5.4. Determination Of Baseline

Field measurements were made in the proposed project area for calculating carbon content of vegetation and soil. Direct field measurements will ensure the accuracy of the data.

The features of the project area are as follows:

- These lands have not been forests since 1990 and have either been croplands or fallow since 1990.
- The identified lands in the project area consist of cultivable wastes, fallow lands and marginal croplands.

Thus the current land use is either agriculture or fallow lands.

Biomass stock under baseline scenario: The aboveground biomass under baseline scenario is comprised of trees that are planted on bunds[2] of agricultural lands. In the sampled area of 95 ha of farm lands, the aboveground biomass varied from nil to 0.19 t/ha, with an average aboveground biomass of 0.02± 0.05 t/ha. Considering 0.26 as the conversion factor for estimating below ground biomass from aboveground biomass, 0.005 t//ha accounts for the belowground ground biomass. Thus the total biomass under baseline is 0.025 t/ha in the project area. There was negligible or no woody litter.

Soil organic carbon (SOC) under baseline scenario: Land use history has a strong impact on the SOC pool Ecosystem studies of soil carbon indicate large differences in soil carbon depending on soil type, topography, land-use history, and current land use and land cover (Marland, 2004). The SOC varies depending on agricultural systems and agricultural crops and on the inputs to production (e.g. fertilizers, irrigation and soil tillage). Therefore the SOC content of marginal cropland and fallow lands were determined in the proposed project area for depths of 0-15 cm and 15-30 cms.

In the proposed project area, the SOC for black and red soil under marginal croplands and fallow lands was determined. Black cotton soil was prevalent in the mandals of Bhadrachalam and Kunnavaram and red sandy and alluvial soil in Burgampahad and parts of Kukunoor mandal. The agricultural system and the inputs to production were similar with fertilizer application, irrigation and soil tillage by all the farmers. The average SOC at 0-30 cm depth of black soil was 46.98±15.87 t/ha and for red soil 37.07±16.95 t/ha. Further analyzing at different soil depths, the deviation was low at 0-15 cm layers than at 15-30 cm level (Table 4). If considering a regional baseline for Khammam district, aggregation of homogeneous land use systems provide a baseline SOC of 45.32±15.99 t/ha.

TABLE 4

Soil Organic Carbon (t/ha) under varying depths in different cropping systems and soil types in Khammam district based on field studies

TABLE 4

5.5 Carbon Stock Changes Under Baseline

The proposed A & R is on cultivated land, which are either fallow or marginal croplands. The carbon stocks in the baseline include aboveground biomass, below ground biomass and soil organic carbon. The aboveground biomass of 0.02 t/ha is due to a few big trees on the bunds, with an average DBH of >40 cm. Thus, the growth rate of trees is negligible with the few big trees having reached equilibrium state.

The soil C status under the pre-plantations land use is assumed to be in approximate equilibrium with inputs equals to outputs. If land has been cultivated for decades, the rapid soil-C changes with initial cultivation would have ceased, and either soil C is changing very slowly or has stabilized. Thus, the carbon stock change under baseline can be considered static. The C-stock under baseline is 45.33 t/ha, which could continue to remain so under the baseline scenario. For a project area of 8000 ha, the baseline C-stock would remain constant at 362 KtC.

6 Project Activities

6.1 Area For Project Activities

As explained earlier (Section 3.1), the potential land categories considered for afforestation are pasture & grassland, barren and uncultivated, cultivable waste and fallow land use in the 6 selected mandals is 10,687 ha. Currently 8000 ha is considered for A & R include cultivable waste, fallow lands and marginal croplands all on private farm land, through planting Bhadrachalam Eucalyptus clones at a rate of about 2000 ha/year.

6.2 Lifetime Of The Project

The lifetime of the project is defined by technical or economic considerations and is generally longer than the period during which the carbon credits can be legitimately generated (FA, 2005). The lifetime of the project is considered as 7-8 rotations or approximately 30 years, i.e. 2006-2035. The PRO-COMAP model is used to account for annual changes in carbon stock for the project period of 30 years. The accounting period is a determining factor for the volume of emission reductions that can be generated by a mitigation project.

6.3 Sampling Strategy For Project Scenario

Reporting changes in the stocks of all the five C-pools as mentioned earlier (Section 5.3) is desirable. For the present study, AGB, BGB, SOC and woody litter pools were selected for estimating carbon stock changes, since dead wood does not exist. The carbon stocks and growth rates for different pools are measured and estimated as input to PRO-COMAP model to project likely C-stocks for the project activities over a period of 30 years. The sites for sampling are largely from the same or neighbouring villages where similar plantations were raised earlier.

Aboveground biomass: AGB was determined by two-pronged strategy that included a) monitoring in permanent plots and b) direct AGB measurements by harvest.

a) Permanent plots. The Eucalyptus clones that represent the project scenario are being monitored in permanent plots for their annual increments in AGB by the paper mill company. The plots are measured twice a year for their height and girth (over bark). The compilation of yearly data over 9 years provided Current Annual Increment (CAI), Mean Annual Increment (MAI) and Eucalyptus-specific volume equations.

b) Harvest method. This is the most accurate of all the biomass estimation methods since it involves direct measurement of methodically harvested tree components. The usual inadequacies viz., non-availability of specific equations and the valid range of these equations for accurate results, variability in area of sampling and area measured in the equations, manual errors amongst others are overcome by quantification of the different tree parts.

The Biomass expansion factor was also calculated by the above procedure (excluding the BGB) at private farmlands where Eucalyptus was commercially harvested.

Below ground biomass: The below ground biomass is by far the most uncertain of the carbon pool biomass estimates, even though IPCC, 2003 provides for a conversion factor of 0.26 of the aboveground biomass. In the study, harvest method was used.

Woody litter: Four 10 X 10 m quadrats in all five-age classes were laid. All the woody litter was collected from these quadrats and fresh as well as dry weight estimated on per ha basis.

Soil carbon: To estimate SOC, soil samples at depths of 0-15 and 15-30 cm were collected. Composite samples from a plot from ploughed and unploughed sites were analyzed using the Walkley-Black method. SOC was determined for 0-30 cm depth on a per hectare basis.

The sampling of soil for determination of soil organic carbon was based on stratified sampling. The soil type was stratified into red and black soil. Further stratification was according to land use type or the crop type for the baseline scenario. For the project scenario, soil samples were collected from different age class and the adjacent land, which served as control. The difference of SOC was taken as the increment over the age class. For each of the age class, weighted average of SOC was calculated, which is a composite of soils from tilled and untilled region.

The Eucalyptus plantations are regularly tilled after rains every year using a one MB plough. Fertilizers such as urea, MOP and DAP are applied during all the years. To understand the annual increment in soil C due to these practices, the weighted average for various age classes was computed. The difference in increment in subsequent age class was considered as the annual increment. The SOC increment has been projected for the regional baseline scenario (Fig 1).

6.4 Carbon Accumulation In Various Pools

The PRO-COMAP model, (Sathaye *et al.,* 1995) a microsoft excel based spreadsheet, was used to analyze the mitigation potential as well as cost-effectiveness of mitigation activities. The model estimates the change is C-stock annually under the baseline and mitigation scenario. Adopting the C-stock change method to estimate the C-pool increment, mathematically, the change in carbon stocks attributable to a project (ΔCnet) at any given time can be expressed as:

$$\Delta Cnet = \sum_{i=1}^{n} [(\Delta Cproject - \Delta Cbaseline)_{time\ 1} + (\Delta Cproject - \Delta Cbaseline)_{time\ 2} + \ldots\ldots (\Delta Cproject - \Delta Cbaseline)_{time\ n}]$$

*Where, Δ**C**project and Δ**C**baseline are the measured changes in carbon stocks at periodic monitoring time over the period i, associated with the project and the respective baseline case.*

Aboveground biomass: Based on permanent experimental plots maintained by ITC Bhadrachalam paper mills, field measurements, the CAI of clonal Eucalyptus for pulpable wood (under bark) during year 1-4 is given in Table 5. Field studies were conducted to estimate the ratio of pulpable wood to the total above ground biomass. The biomass expansion factor ranged from 40.32-52.73% of the pulpable wood. Applying the biomass expansion factor and the moisture content, the dry weight of CAI values were estimated (Table 5). Thus, for a 4-year rotation cycle, the total AGB was 40.67 t/ha with a MAI of 10.17 t/ha/yr.

TABLE 5

Aboveground and below ground biomass growth rates of Eucalyptus clone for a 4-year rotation cycle in Khammam district

TABLE 5

***Below ground* biomass:** Although some roots may extend to great depths, the overwhelming proportion of the total root biomass is generally found within 30 cm of the soil surface. Measuring the amounts of biomass in roots and their turnover is an extremely costly exercise. Therefore, regression equations are often used to extrapolate aboveground biomass to whole-tree biomass (Kurz *et al*., 1996; Cairns *et al*., 1997). The problem with this approach is that deforestation and harvests (as well as changing environmental factors) may change the relationship between aboveground and below ground biomass. On the other hand, below ground carbon might still be assessed from a known history of aboveground vegetation. During the field studies, BGB through harvest method was estimated for 1-5 age class (Table 6). The BGB has been assumed to accumulate till the 8th year at the same ratio as that determined for the first rotation. The average of 26.85% of AGB based on field studies was considered as below ground biomass. For 5-8 years, the same proportional increase as that of the first rotation (4 years) has been assumed. The accumulation of below ground biomass has been assumed only up to 8th year after which there is no further increase in biomass or the annual increase is in equilibrium to the annual loss of root biomass.

TABLE 6

Below ground biomass as percent of above ground biomass and year-wise woody litter of Eucalyptus clone in Khammam district

TABLE 6

Woody litter: Based on field studies, the woody litter (dry wt) per year ranged from 0.009 t/ha/yr during year 1 to 0.137 t/ha/yr in year 4 (Table 6). There is a gradual increase in woody litter with age. After coppice during subsequent rotations, the woody litter is considered as that of year 1-4. Thus woody litter is not a major carbon pool in the project area.

Soil carbon stock: As Figure 1 demonstrates, a wide variation in changes in soil C is observed following afforestation in the project area. Based on field studies conducted in this region, the soil C is likely to be lost during the initial years of plantation establishment. The soil C under the pre-plantation land use is assumed to be in equilibrium with inputs equaling outputs. From year 1 to 4 there has been loss of SOC, while from age 5 to 9 there has been a steady increase in soil C. Thus, the calculations show an initial loss of soil C under plantations with inputs finally exceeding outputs to soil C beginning at year 5. This is in concurrence with results of Hansen (1993).

Figure 1.

Figure 1. Carbon stock change in the baseline and project scenario

6.5 Carbon Stock Change Under Project Scenario

Carbon stock change per ha: The carbons stock change for the project scenario is given in Fig 2. The stock change under the baseline scenario is nearly stable. The C-stock change in project scenario is inclusive of periodic harvest at every 4 years and carbon emissions due to biomass burning after harvest and annual fertilizer application. The carbon emissions due to biomass burning and fertilizer application are given in Table 7. In the initial 4 years, there is carbon emission from soil, after which there is a steady increase above pre-plantations levels from the 7th year (Table 8). The carbon stock reaches the maximum of 65.42 t/ha during 2013 providing a carbon increment of 20.19 t/ha, which is recurring successively every 4 years (Table 8).

TABLE 7

Carbon emissions (tC) due to project activity per rotation cycle

TABLE 7

TABLE 8

Carbon stock change under project scenario (per ha)

TABLE 8

C-stock change for project area: The carbon stock change in the project scenario is given in Fig 2. The mitigation potential for an area of 8000 ha is 3,077,819 tC at a rate of 384 tC/ha for the period 2006-2035, which is approximately 12.82 tC/ha/yr inclusive of harvest regimes and carbon emissions due to biomass burning and fertilizer application. Carbon pool-wise, during the first five years there is a loss in soil organic carbon, after which in the next 4 years there is a steady increase and then is a plateau. The other carbon pools of ABG, BGB and woody litter shows a steady rise and after a time period a plateau is reached (Fig 3). The carbon stock change under different scenarios – with and without wood products are given in Fig 3. In the project site, the Eucalyptus wood is used for making pulp, which is used for making paperboard. The product life is taken as 2 years. Considering the C-credit from harvested wood, an additional 45% carbon benefits can be accounted. Thus the policy decision to include wood products or not would make a considerable difference to C-calculations. One inevitable consequence is that, plantations come out as poor performers in the carbon-fixing stakes compared to no-harvest forests. The harvested products might be difficult to measure and monitor, adding possibly levels of uncertainty to project accounting procedures. But this is a debatable pool not to be ignored, as it might often be a large carbon-sink benefit for plantation projects (Leach, 2002).

Figure 2.

Figure 2. Carbon stock change in various carbon pools in project scenario

Figure 3.

Figure 3. Carbon stock change under various options under project scenario

7 Leakage Estimation

Leakage can be defined as the net change of anthropogenic emissions by sources of GHGs and removal by sinks, which occurs outside the project boundary, and which is measurable and attributable to the project activity (UNFCCC, 2002). It is the net change of anthropogenic emissions by sources of GHGs and removal by sinks, which occurs outside the project boundary, and which is measurable and attributable to the project activity. Leakage can be through shifting acforest conversion to cropland, since it is banned in the state. In this study, an attempt was made to estitivities from project site to another area (primary leakage). Secondary leakage also can occur where a project's outputs create incentives to increase GHG emissions elsewhere. Primary leakage in the project area can be due to shift in extraction or land use change. There will be no mate leakage through household survey where the quantity of fuelwood and poles/small timber currently extracted from forests, community grazing land and farmlands proposed for the project were quantified. Based on questionnaire method, interviews were conducted of farmers who currently have fallow lands and are willing to plant trees on their farmland and of farmers who have plantations. Their current dependence on lands proposed for plantations and forests for fuelwood, poles and other biomass needs were assessed. The 100% of farmers interviewed depended on natural forests for fuelwood and other biomass needs. Even those who had plantations depended on forests. In fact, there would be biomass available from plantations especially during harvest every 4 years. Further, the standing biomass on farmlands before project activity is negligible to displace the activity outside the project area. Thus, the survey indicates zero leakage from these marginal lands, since they supply no commodities that would displace the activity to other lands. If the project produces plantation products sold on market that displace plantations being planted elsewhere, then carbon benefit is reduced by that of the displacement. The new plantations will not lead to changes in market behaviour or area of plantation elsewhere, as these plantations are predominantly sold to ITC for pulp making due to good market price.

8 Estimates of Cost-effectiveness of Project Activities

Cost estimates are required to compare forestry projects and link to policies aimed at reducing greenhouse gas emissions. Cost estimates for forestry projects vary greatly according to the methodology employed. There are several levels at which cost of carbon-sequestration are being estimated. Some estimates of carbon sequestration take into account only the commercial component of the tree (or bole), while others include all vegetation. Still others include soil organic carbon (SOC), which can be enhanced through carbon-fixing roots and fallen and decaying branches and leaves, and deteriorated through erosion. The decision to include or exclude SOC alone can result in a vastly different estimate of carbon-uptake costs, since as much as two-thirds of the carbon stored in terrestrial ecosystems is in soils (Dudek and LeBlanc, 1990).

In this case study, the following approach is adopted:

- Financial method has been employed to determine costs of carbon sequestration
- The costs of carbon sequestration include establishment costs of plantations and yearly fertilizer application and other activities
- Costs for determination of baseline has been included
- Project monitoring is considered as a continuous assessment of the functioning of project activities, and as such the costs of monitoring are included in the implementation and management costs
- Transaction costs have been excluded.

The benefits include the market price offered to the farmers by ITC Bhadrachalam paper mill, which would be inclusive of harvest and transportation cost.

The costs and benefits of Eucalyptus plantations for a rotation cycle are given in Appendix 1. The investment cost is considered for the first three years, with the assumption that the community/farmer will meet the annual or operating cost of later rotations. Investors, donors or banks likely to be interested in funding or lending only the investment cost may be guided by these values. The present value of investment cost, extended over the first 3 years, is Rs 37,856/ha at a discount rate of 6%. The present value of initial cost is Rs. 98/tC.

Very often, funding only investment cost may not sustain a project and it becomes essential to consider annual or operating or maintenance costs as well. The lifecycle cost per ton of carbon is Rs.193 and per ha is Rs. 275 at a discount rate of 6%. The Net Present Value of Benefits, which the policy makers and the local community are interested, is positive and is Rs. 3/tC and Rs. 1042/ha, at 6% discount rate.

TABLE 9

Costs and benefits under baseline and project scenario for the period 2006-2035

TABLE 9

The cost benefit analysis of baseline and project scenario was done to estimate the net present value of benefits (Table 9). The best alternative to agroforestry or the dominant pre-plantations crop for which analysis has been done is chilli crop, which is also economically viable and most preferred in this region. The present value of costs, benefits and benefit cost ratio were estimated. The annual cost/ha for 2006-2035 worked out to Rs. 13,365 under baseline compared to Rs. 4,855 for Eucalyptus clones. The benefits accrued to the communities from the 4th year. The benefit cost ratio under baseline is 1.42, while under the project scenario is 2.18. Thus, there is a large financial incentive for the communities to take up afforestation. Though the project scenario is financially attractive compared to baseline scenario, the upfront costs of Rs 47,664/ha is an investment barrier especially to small and marginal farmers.

9 Discussion

Agroforestry systems or projects provide significant sustainable development benefits such as food security and secure land tenure in developing countries, increasing farm income, restoring and maintaining above-ground and below ground biodiversity, maintaining watershed hydrology, and soil conservation. Agroforestry also mitigates the demand for wood and reduces pressure on natural forests (Pandey, 2002). India is estimated to have between 14,224 million (Ravindranath and Hall, 1995) and 24,602 million (Prasad et al., 2000) trees outside forests, spread over an equivalent area of 17 million ha (GOI, 1999) supplying 49% of the 201 million tonnes of fuelwood and 48% of the 64 million cum of timber consumed annually (Rai and Chakrabarti, 2001). Forestry mitigation projects provide an opportunity to promote agroforestry in India.

The significance of agroforestry with regards to carbon sequestration and other CO_2 mitigating effects is being widely recognized, but there is still paucity of quantitative data. Thus this paper discusses the carbon storage potential of an industry promoted agroforestry system.

Several studies have shown that the inclusion of trees in the agricultural landscapes often improves the productivity of systems while providing opportunities to create carbon sinks (Winjum *et al*., 1993; Dixon, 1995). The amount of carbon sequestered largely depends on the agroforestry system, the structure and function, which are determined by environmental and socio-economic factors. Other factors influencing carbon storage in agroforestry systems include tree species and the way the system is managed. The Eucalyptus clones promoted by ITC Bhadrachalam in Khammam district, Andhra Pradesh has been successfully implemented as a major research and development project to improve productivity and profitability of plantations and making farm forestry an attractive land use option. The major emphasis has been on genetic improvement of planting stock and improvement in package of practices used by growers (Kulkarni, 2002). This provides an opportunity to study the carbon sequestration potential of agroforestry system, especially with regard to baseline and carbon mitigation scenario.

9.1 Carbon Inventory Techniques

Estimation of the 5 carbon pools – AGB, BGB, woody litter, dead wood and soil organic carbon periodically is essential to estimate the carbon sequestration potential of agroforestry systems.

Aboveground biomass: The variation in productivity can be high within complex agroforestry systems, and depends on several factors including the age, the structure and the way the system is managed (Albrecht *et al*, 2003). Especially with regard to clonal variety, apart from genetic quality of planting stock, site quality, adaptability of clones to specific sites, implementation of improved package of practices and effective protection of plantations from damage by pests and cattle are important factors, which determine the overall productivity of plantations. The clones given to the farmers are based on the site quality so as to ensure maximum productivity. The soil profile and analysis of soil samples is carried out to match adaptable clones to the plantation site. For pulp production, a uniform spacing of 3 X 2 m is adopted. Thus, the aboveground biomass in the region according to the clone can be obtained from the Clonal Multiplication Area or gene bank maintained by the company. A step further, CAI of plantations for various clone types is computed from experimental plots.

The productivities can be verified at the farm gate level, where the farmers harvest the plantations after 4 years. The MAI or CAI values for Bhadrachalam clones in farmlands can be estimated with minimum uncertainty. The survival percentage of majority of plantations is also reported to be more than 95% (Kulkarni and Lal, 1995). Thus the annual increments in aboveground biomass can be estimated without periodic field monitoring.

Below ground biomass: Biomass of structural roots of trees increases monotonically with that of aboveground biomass. According to the good practice guidance of IPCC, a default conversion factor of 0.26 of aboveground biomass can be used to calculate the below ground biomass (IPCC, 2003). A comprehensive literature review by Cairns *et al.* (1997) including more than 160 studies covering native tropical, temperate, and boreal forests, reported both below ground biomass and aboveground biomass. The average below ground to aboveground dry biomass ratios based on these studies was 0.26, with a range of 0.18 (lower 25% quartile) to 0.30 (upper 75% quartile). The Bhadrachalam clones have been root trained to produce quality planting stock and improved productivity. Therefore, BGB of clones were estimated through harvest method. The BGB of 1-5 yrs plantation ranged from 0.36 to 0.22 with an average of 0.26 (Table 6) confirming with global literature.

There is dearth of information concerning root dynamics of short-rotation systems. With harvest, the rate of BGB accumulation is not known and the ratio of BGB to AGB is skewed. Thus, more studies have to be conducted to understand the root dynamics of short rotation systems. To understand the accumulation of BGB after first harvest, secondary information was sought. According to Cannell and Smith (1980), the structural root biomass production is about 2-3 t/ha/yr for aboveground biomass productivity of 10-12 t/ha/yr in a short-rotation plantation thus constituting 20-25% of the AGB. Further studies are required to understand the root dynamics in short rotation plantations.

Woody litter: The Bhadrachalam clones are characterized by straightness of stem and narrow crown cover. The clones have a self-pruning mechanism and periodically thin shoots fall off. The extent of woody litter is very small and do not form a major carbon pool. The extent of woody litter even during the 4th year with peak productivity levels is 0.137 t/ha. The average woody litter is 0.069 t/ha/yr, which is 0.7% of the aboveground biomass. Thus, woody litter is not a major carbon pool in the Bhadrachalam eucalyptus clonal plantation.

Soil organic carbon: Following afforestation, changes in soil organic carbon occur in quality, quantity and spatial distribution. Abiotic factors such as site preparation, previous land use, climate, soil texture, site management and harvesting affect the extent of SOC after afforestation (Paul *et al*., 2002). The SOC change after afforestation for various age classes was determined by sampling an adjacent area with similar pre-project conditions. There was a loss of SOC during initial 4 years after afforestation especially from surface soil. These results are consistent with those observed on sites repeatedly measured over time. These studies also showed an initial loss of SOC followed by a gradual increase. In long-term studies, SOC is generally found to accumulate following afforestation. During the initial 3-4 years, there will be relatively little input of carbon from aboveground biomass due to low rate of litterfall (Wilde, 1964). The initial loss of SOC is due to decomposition overweighing gains in carbon from litter production. Subsequent accumulation of carbon indicates that annual inputs of carbon through primary production exceeded the amount lost by decomposition. Further, cultivation of soil by ploughing and other tillage methods also decreases SOC through enhanced mineralization of SOC and CO_2 release in the atmosphere (Reicosky *et al.,* 1999).

The plantations receive fertilizers annually through the rotations cycles to increase biomass productivity. The efficacy of fertilizer application in SOC sequestration is debatable. There are hidden carbon costs to the fertilizer input (Schlesinger, 2000). Nitrogenous fertilizers have hidden costs of 0.86 kg C/kg N (IPCC, 1996). This ratio has been used to calculate the C emissions in the project area. Similar to fertilizers, irrigation enhances aboveground and below ground biomass, which increases the return of BGB in soil and improve SOC concentration. From the 5th year after harvest, there has been an increase in SOC. One of the practices followed by the farmers is burning of the non-pulpable biomass or twigs, branches and leaves on-site after harvest. The process emits numerous gases immediately but also leaves charcoal as residual material. Charcoal is produced by incomplete combustion and may constitute upto 35% of the total SOC pool (Skjemstad *et al*., 2002). Charcoal is extremely resistant to combustion; it is not cycled like most organic matter and has a mean residence time of 10,000 years. Consequently they form a substantial proportion of the remaining organic carbon. Thus, on-site burning increases SOC in the soil by a large fraction, during the 5th year.

The resulting estimations in project site indicate a sharp initial loss of soil C in the plantation, with inputs finally exceeding outputs to soil C beginning at year 5. Based on literature, a new equilibrium state is usually reached by 10 years (Nigeria), 30 years (Congo) or 40-60 years in (Massachusetts). Based on literature, in the present case study, the accumulation of SOC is considered till the 8th year, which is a conservative estimate.

Thus, in a complex system with multiple practices such as tillage, fertilizer application, irrigation, the annual impact on SOC is rapid. Monitoring of SOC has to be done annually in such systems. Continuous observations of soil C under short rotation plantations and under adjacent land uses over entire rotations are required. The most accurate method to measure SOC change is to repeatedly sample the site over time and analyze consistently.

9.2 Additionality

Determination of the baseline accurately and efficiently is critical for additionality establishment. The environmental additionality is in terms of GHG reductions or carbon sequestration though plantations. The major reasoning to prove additionality is to conjecture what changes in land use of the area would have occurred if the sequestration project had not taken place. These are largely dependent on larger economic, social and legal context. Based on the national policies and regulations, it can be conjectured that no ODA money will be diverted, as the land tenure is private. The alternative to the project scenario is dryland agriculture with possibility of raising financial loans for marginal crops. The establishment cost of plantations is higher than the alternative land use. Assistance from national and international financial institutions is not feasible. Determining additionality is inherently difficult where the sponsor is a large commercial entity with good access to financing and information; the new technology is well understood and investment in the new technology yields a direct monetary return to the sponsor (Chomitz, 2002). But comparing the baseline to the project scenario, additionality can be proved.

9.3 Baseline Development

There are two approaches to baseline development – project-specific and benchmark approach. The project-specific baselines draw upon site-specific information and the comprehensive analyses has the theoretical potential to credibly and accurately quantify additionality. With benchmark baselines, credibility would be gauged in terms of the net impact of a benchmark across the entire region, which could be a district or a block within a district with similar geographic conditions. Benchmark approach would be practical as they could lower transaction costs and avoid the complexity of determining baselines for individual projects. Here we try and analyze if project-specific baseline can be analyzed for a benchmark approach. There are two components – the biomass and SOC, which determine the carbon stock of a baseline. The aboveground biomass in the baseline is negligible and SOC constitutes the dominant carbon pool. The SOC of farmlands depend on land use history. The SOC depends on the climate, soil type, crop type, nutrient management, tillage practices and irrigation type (Lal, 2004). The SOC according to soil type (red and black) varied with large standard deviation. A benchmark approach especially for SOC under a dynamic agricultural management system would lead to large uncertainty. Thus, benchmarking could be done for various soil type and management systems for an agro-climatic region based on soil types. This would require taking up an elaborate study to set a baseline.

Project-specific Baseline Vs Regional Baseline: Project specific baseline approach was adopted for the current study. Regional baselines are more beneficial as they reduce transaction costs of establishing baseline and monitoring plan. It also allows for quick, low-cost replication of the first project and also help in estimating GHG additionality. It also helps in identifying potential project sites/activities because regional baseline activity rates and locations are known and mapped. For example, ITC can target those lands according to land tenure i.e. low income farmers compared to richer farmers and also locations/pattern for adoption of clonal planting, that are unlikely to be planted under the projected baseline.

9.4 Leakage

In the study, leakage or displacement of activity was not an issue as carbon stock under baseline scenario is static. But the domain for monitoring project leakage, positive spillover and market transformation may be larger. Not all secondary impacts can be predicted. In fact, many secondary impacts occur unexpectedly and cannot be foreseen (Edward *et al*, 2001). For example, the project activity may lead to encroachment of forest areas for agriculture. Thus widening the system boundary may help in capturing secondary leakage if occurred. For small projects, the impact may be small or insignificant and the focus can be only on carbon stocks from the project, which will cut down monitoring costs.

9.5 Monitoring Of Carbon Stock Change

The measurement of carbon sequestration in a project necessitates monitoring using specialized methods based largely from experience with forest inventories and ecological research and based upon standard forestry approaches to biomass measurement and analysis, and apply commonly accepted principles of forest inventory, soil science and ecological surveys. The specific methods and procedures should be assembled on a project-specific basis (Vine *et al*, 2001). Monitoring can be based on (1) modeling, (2) remote sensing, and (3) field/site measurements, including biomass surveys, research studies, surveys, the monitoring of wood production and end products, forest inventories, and destructive sampling (MacDicken, 1998).

The most dynamic carbon pool is the SOC. The SOC changes due to land conversion from agriculture to plantation generally results in a build-up of soil C, although the process may be slow, often requiring from 10 to as many as 200 years (Post and Kwon, 2000). A more widely reported pattern is an initial decrease in soil C immediately after forest establishment followed by a long-term increase. Investigating patterns of old field succession, Zak *et al*. (1990) observed an initial loss of soil C for about 10 years after abandonment followed by a steady rise over the subsequent 50 years. It is therefore essential to study the soil organic carbon periodically, especially in the project area.

The AGB change is well researched and determination of the CAI may not be required in the project area. The pulpable wood that has sequestered carbon at the end of rotation period can be determined at the farm gate. The whole AGB can be determined from calculated biomass expansion factors. The default conversion factor can be used to determine the BGB from AGB values. Most importantly further research is required to estimate the BGB ratio to AGB with harvest regimes beyond the first rotation period.

Cost-effectiveness: The cost effectiveness analysis of project activity was done based on the investment required for establishment of plantations and the returns that accrue from them. Monitoring costs have been included every 4 years. As an economic activity, the project is viable. Further, the cost-effectiveness inclusive of transaction costs and the carbon price gives the correct picture of various financial parameters - costs and benefits per tC abated.

9.6 Socio-Economic Impacts

Agroforestry systems would be superior to other land-uses at the global, regional, watershed, and farm level because they provide synergy between increased food production, poverty alleviation and environmental conservation. The benefits of carbon sequestration and trading can reach the small and marginal farmers directly through agroforestry. The project activity will increase farm incomes compared to other alternative crops. It will also increase employment. Even in drought period, the farmers will be able to get revenue from the project activity compared to annual agricultural crops.

9.7 Environmental Impacts

Some of the adverse effects of climate change will be in developing countries, where populations are most vulnerable and least likely to adapt to climate change. Forestry mitigation projects not only act as carbon sinks but also aid in fulfilling sustainable development goals of the country. Increasing biodiversity is one the goals of a forestry mitigation project. Being a monoculture Bhadrachalam clone plantation, there is no enhancement of biodiversity. But the baseline scenario also has negligible trees. Thus there is no gain or loss of biodiversity due to the project. The project would improve soil organic carbon and fertility of the soil.

Appendix 1

Unit cost per hectare for raising and maintenance of 5 year old Eucalyptus clonal Plantation

Appendix table Table

Notes

[1] Mandal - Administrative unit below the district consisting of a group of Villages/Panchayats (in Andhra Pradesh blocks were sub-divided into mandals but retained the administrative and local government functions of blocks). (http://www.velugu.org/faq.html.)

[2] Earthen embankment constructed to retain water or for separating one farm from the other.

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TABLE 1: Land use pattern in selected mandals of Khammam district in Andhra Pradesh (ha)

Land uses	Burgampahad	Kukunoor	Bhadrachalam	Kunavaram	Cherla	Velairpadu	Total
Geographic Area	27390	28681	37669	20382	54337	41544	210003
Forest cover	14609	17067	25514	5435	37478	29471	129574
Total cropped area	7596	4835	9770	6089	6715	3184	38,189
Misc. tree crops	208	277	48	315	163	218	1,229
Non agriculture land	1311	1627	2015	4364	5446	2694	17,457
Pasture & grazing	284	297	0	19	0	236	836
Barren & uncultivated	624	902	159	2128	3499	709	8,021
Cultivable waste	28	166	0	139	63	500	896
Other fallow land	101	1056	54	0	264	612	2,087
Total	24761	26227	37560	18489	53628	37624	198289

TABLE 2: Cropping pattern in the selected mandals (ha)

Crops	Bhadrachalam	Burgampahad	Kunavaram	Kukunoor	Cherla	Velairpadu	Total
Paddy	2762	2569	1447	1812	3220	774	8590
Jowar	996	53	1942	56	0	0	3047
Maize	121	60	14	72	0	0	267
Greengram	190	266	404	150	692	227	1010
Blackgram	288	48	998	331	126	0	1665
Sugarcane	0	2	0	54	54	46	56
Redgram	1319	434	182	395	287	148	2330
Cotton	1157	3046	97	1008	0	67	5308
Tobacco	517	115	492	81	0	0	1205
Chillies	1955	273	377	348	7	120	2953
Groundnut	99	81	1	0	197	197	181
Sesamum	190	94	96	18	0	0	398
Total	9594	7041	6050	4325	4683	1578	27010

TABLE 3: Area afforested under farm forestry in selected mandals of Khammam district (ha)

Mandal	Bhadra-chalam	Burgham pahad	Kunav aram	Kukunoor	Cherla	Velair padu	Total
1992-1999	311.8	59.9	49	8.7	2.1	4.3	429.3
2000	76.3	17.2	36.2	6.4	10.18	2	136.1
2001	101.3	14.5	33.5	29.5	0.0	1.2	178.7
2002	126.2	83.1	74.5	54.1	0.0	0.0	337.8
2003	142.5	36.4	63.4	31.2	6.97	8.55	273.5
2004	154.4	54.2	51.2	12.2	0.0	0.0	272.0
Total	912.4	265.3	307.7	142.0	19.25	8.55	1627.4
Average planting rates (2000-2004)	120	41	52	27	3.43	2.35	240.0

TABLE 4

Soil Organic Carbon (t/ha) under varying depths in different cropping systems and soil types in Khammam district based on field studies

Management practice	Soil Organic Carbon (t/ha) at different depths		
	0-15 cm	15-30 cm	0-30 cm
Chilli (BS)	26.79±2.71	20.73±9.37	47.52±11.17
Cotton (BS)	27.86±8.04	20.07±14.89	47.94±20.10
Miscellaneous (BS)	20.99±5.42	18.27±9.21	39.26±3.80
Fallow (BS)	31.61±9.99	18.61±13.79	50.23±23.77
Average (BS)	27.16±6.86	19.82±11.59	46.98±15.87
Miscellaneous (RS)	16.62±4.34	20.45±13.28	37.07±16.95
Average (BS+RS)	25.40±7.57	19.92±11.46	45.32±15.99

BS – Black Soil (Vertisols); RS – Red Soil (Alfisols)

TABLE 5

Aboveground and below ground biomass growth rates of Eucalyptus clone for a 4-year rotation cycle in Khammam district

Parameters	Year 1	Year 2	Year 3	Year 4
Current annual increment of pulpable wood (cubic metres)[1]	12	18	48	24
Wood density	0.55	0.55	0.55	0.55
Annual increment of pulpable wood (t/ha)[2]	6.6	9.9	26.4	13.2
Biomass expansion factor (%)[3]	52.73	47.54	44.40	40.32
Wet weight of aboveground biomass (t)	10.08	14.61	38.12	18.52
Annual Increment of Above ground biomass (dry wt t/ha)[4]	5.04	7.30	19.06	9.26
Total standing biomass (dry wt t/ha)	5.04	12.34	31.40	40.67
Below ground biomass conversion factor (%)[5]	26.81	26.81	26.81	26.81
Below ground biomass (dry wt t/ha)	1.35	3.31	8.42	10.90
Total biomass increment (t/ha/yr) (AGB+BGB)	6.39	9.26	24.17	11.74
Total biomass accumulation (t/ha) (AGB+BGB)	6.39	15.65	39.82	51.57

1 – Pulpable wood is under bark - excluding branches, twigs, leaves and bark
2 – Calculated as CAI x wood density
3 – Ratio of branches, twigs, leaves, bark to the pulpable wood
4 – Moisture content is 50%
5 – Ratio of below ground biomass to above ground biomass based on harvest method

TABLE 6: Below ground biomass as percent of above ground biomass and year-wise woody litter of Eucalyptus clone in Khammam district

Age	Percent of aboveground biomass as belowground biomass	Age	Woody litter (dry wt t/ha/yr)
2	36.08	1	0.009±0.010
3	22.45	2	0.026±0.020
4	26.62	3	0.071±0.006
5	22.24	4	0.137±0.036
Average	26.85	Average	0.069±0.060

TABLE 7: Carbon emissions (tC) due to project activity per rotation cycle

Year	1	2	3	4
C emissions from on-site burning (ha)	0.00	0.00	0.00	4.94
C released from fertilizer application (ha)	0.02	0.09	0.09	0.14
Total C emissions for the project area	45	243	441	10618*

*The emissions for the year 5-30 years is 10618 tC

TABLE 8: Carbon stock change under project scenario (per ha)

	2006	2011	2016	2021	2026	2031	2035
Baseline	45.33	45.33	45.33	45.33	45.33	45.33	45.33
Project*	42.93	61.83	64.04	65.43	65.02	61.30	61.30
C Increment	-2.40	16.50	18.71	20.10	19.69	15.98	15.98

*The C-stock is estimated after deducting emissions from; biomass burning after harvest and fertilizer application

TABLE 8: Carbon stock change under project scenario (per ha)

	2006	2011	2016	2021	2026	2031	2035
Baseline	45.33	45.33	45.33	45.33	45.33	45.33	45.33
Project*	42.93	61.83	64.04	65.43	65.02	61.30	61.30
C Increment	-2.40	16.50	18.71	20.10	19.69	15.98	15.98

*The C-stock is estimated after deducting emissions from; biomass burning after harvest and fertilizer application

TABLE 9: Costs and benefits under baseline and project scenario for the period 2006-2035

	Baseline scenario*	Project scenario
PV of cost (Rs/ha)	13,364	4,855
PV of benefit (Rs/ha)	19,041	10,566
NPV of benefit (Rs/ha/yr)	5,677	8,011
Benefit cost ratio	1.42	2.18

*The best alternative to plantations – chilli crop has been considered for baseline scenario

APPENDIX 1: Unit cost per hectare for raising and maintenance of 5 year old Eucalyptus clonal Plantation

Operation	Years				Total
	1	2	3	4	
Ploughing	2400	2520	2646	2778	10344
Alignment/ Staking	150				150
Digging of Pits and planting	2499				2499
Weeding/Cleaning/ Soil working	1666	1749			3415
Cost of Fertilisers/Geen manure	2250	2363	2481	2605	9699
Cost of Anti-termite treatment	1600				1600
Provison for fencing/ Maintenance	2000	200	200	200	2600
Contingencies	628	342	266	279	1515
Cost of Plants	14000				14000
Insurance premium	340	430	499	573	1842
Total Cost per ha	27533	7604	6092	6435	47664

Figure 1. Carbon stock change in the baseline and project scenario

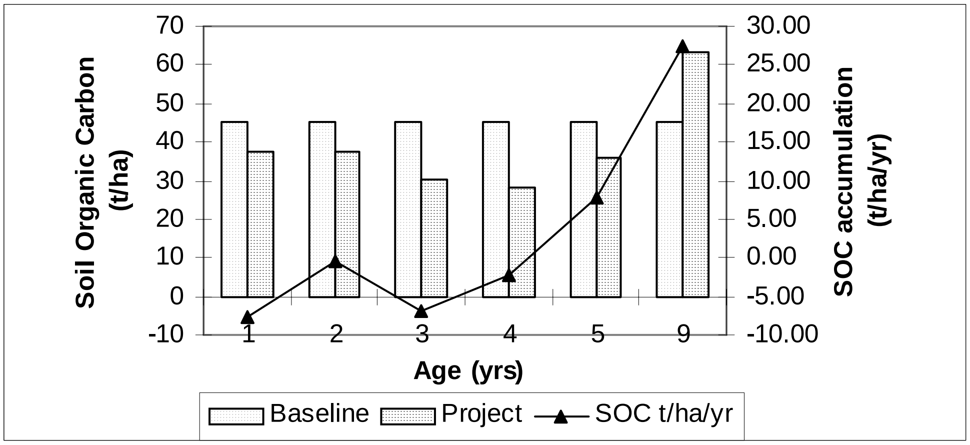

Figure 2. Carbon stock change in various carbon pools in project scenario

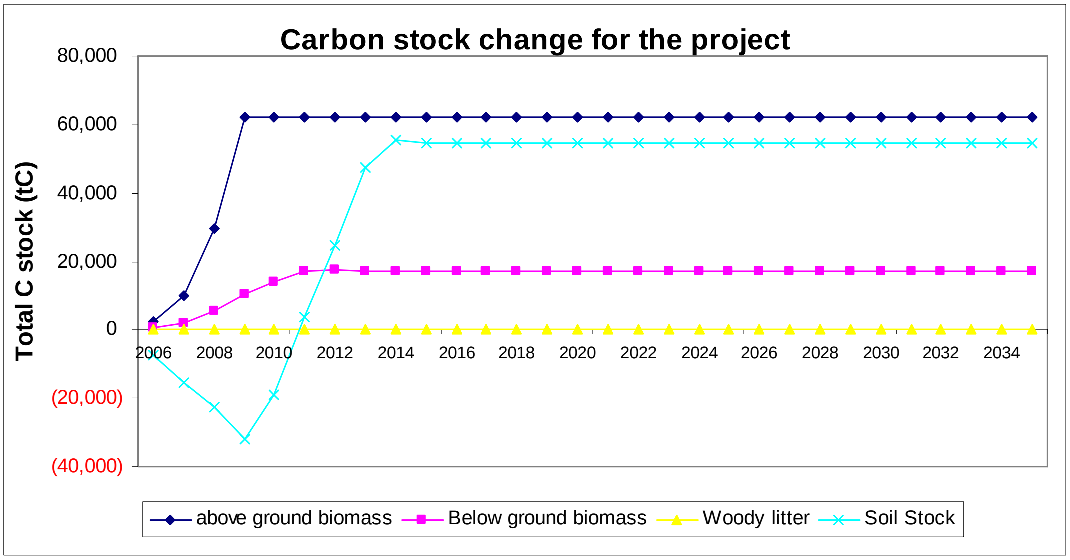

Figure 3. Carbon stock change under various options under project scenario