Mitig Adapt Strat Glob Change (2007) 12:1051–1075
DOI 10.1007/s11027-006-9064-3

ORIGINAL PAPER

Development of regional climate mitigation baseline for a dominant agro-ecological zone of Karnataka, India

P. Sudha · D. Subhashree · H. Khan · G. T. Hedge
I. K. Murthy · V. Shreedhara · N. H. Ravindranath

Published online: 5 December 2006

Abstract Setting a baseline for carbon stock changes in forest and land use sector mitigation projects is an essential step for assessing additionality of the project. There are two approaches for setting baselines namely, project-specific and regional baseline. This paper presents the methodology adopted for estimating the land available for mitigation, for developing a regional baseline, transaction cost involved and a comparison of project-specific and regional baseline. The study showed that it is possible to estimate the potential land and its suitability for afforestation and reforestation mitigation projects, using existing maps and data, in the dry zone of Karnataka, southern India. The study adopted a three-step approach for developing a regional baseline, namely: (i) identification of likely baseline options for land use, (ii) estimation of baseline rates of land-use change, and (iii) quantification of baseline carbon profile over time. The analysis showed that carbon stock estimates made for wastelands and fallow lands for project-specific as well as the regional baseline are comparable. The ratio of wasteland Carbon stocks of a project to regional baseline is 1.02, and that of fallow lands in the project to regional baseline is 0.97. The cost of conducting field studies for determination of regional baseline is about a quarter of the cost of developing a project-specific baseline on a per hectare basis. The study has shown the reliability, feasibility and cost-effectiveness of adopting regional baseline for forestry sector mitigation projects.

Keywords Regional baseline · Project-specific baseline · Mitigation projects · Transaction cost · Carbon stocks · India

P. Sudha · D. Subhashree · H. Khan · G. T. Hedge · I. K. Murthy · N. H. Ravindranath (✉)
Indian Institute of Science, Bangalore 560 012 Karnataka, India
e-mail: ravi@ces.iisc.ernet.in

V. Shreedhara
Karnataka State Remote Sensing Application Centre, Bangalore, Karnataka, India

1 Introduction

Climate change mitigation projects that reduce greenhouse gas (GHG) emissions are at various stages of implementation in the agriculture, land use change and forestry sector. An important issue for forestry mitigation projects is to determine the potential area for mitigation or for afforestation and reforestation (A&R). Various estimates from different sources estimating the technical potential are available. But it is essential to determine the actual land available, as there are several constraints for any mitigation activity. These constraints could be physical, social and economic. Thus, considering these issues, an attempt has been made to determine the technical and the actual or feasible potential of land available for forestry mitigation project for one agro-climatic zone of the 10 different zones in Karnataka, a state in south India.

Setting a baseline for carbon stock changes in forest and land use sector projects is essential for assessing additionality[1] of the project. The baseline for a project activity is the scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity. A baseline needs to cover emissions from all gases, sectors and source categories within the project boundary (UNFCCC 2002). There are two general approaches for setting baselines namely, project-specific and regional baseline. The project-specific baseline is a bottom-up approach, wherein each project has a baseline based on circumstances of the project. This is a commonly used approach by project developers for forestry mitigation projects. The regional baseline approach is the top-down approach, which is an aggregate at the sector, regional or national level based on information at that scale and is the likely baseline for any project in the region. This approach is also known as a performance standard (WRI/WBSCSD 2003, if an emission rate is chosen to determine project additionality), benchmarking (Hargrave et al. 1998) or regional baseline (Sommer et al. 2004).

The additionality estimates of carbon sequestration or mitigation projects rely on establishing an accurate baseline. Baselines are meant to be a plausible reference case to which the carbon reductions from a project can be compared after implementation. Project specific baselines are determined in most mitigation projects. But many projects have adopted computerized models to estimate expected carbon stock changes, which includes the projection of baseline carbon stocks. For example, Land Use and Carbon Sequestration (LUCS) model used by WRI (1999), CO2FIX (Nabuurs et al. 2001; Masera et al. 2001) and PROCOMAP (a modified version of COMAP model developed by Sathaye et al. 1995).

In the forest sector setting baselines could be at the level of a country, region, state or district. The scale is dependent on the heterogeneity of land and water resources of the region. A country with homogeneous climate, soil and vegetation type can have an aggregate country level baseline, while a country with varied physiographic/agro-climatic/agro-ecological zones can have varied regional baselines dependent on region's condition. Currently baseline methods are emerging but there are very few examples of regional baselines used in project development (Sathaye and Andrasko, this issue, review several). Here an attempt is made to develop a

[1] 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 (UNFCCC 2002). Further, institutional and financial additionality need to be established under the rules of the Clean Development Mechanism CDM.

regional baseline at an agro-ecological or agro-climatic zone level encompassing three districts of Karnataka, India.

The study consists of two parts; firstly, an attempt is made to identify and estimate the land suitable for afforestation and reforestation, based on GIS analysis of land suitability indicators for the three districts of the selected agro-climatic zone of Karnataka. Secondly, for the same districts, using the GIS-based database, an attempt is made to develop a regional baseline.

This paper presents the (i) methodology adopted for estimating the land available for mitigation, (ii) approach and methodology for developing a regional baseline (iii) transaction cost involved, (iv) uncertainty involved in developing a regional baseline, and (v) comparison of project-specific and regional baseline.

2 Project location and boundary

Karnataka has about 2 Mha under wastelands accounting for 11% of the total geographic area (NRSA 2004). Thus, there is a large potential for forestry mitigation projects. Based on agro-climatic criteria, Karnataka has 10 agro-climatic zones based on (i) rainfall pattern (both quantum and distribution), (ii) soil type including texture, depth and physio-chemical properties, (iii) elevation and topography and (iv) major crops and vegetation.

The dry zone of southern part of India is characterized by monsoon rainfall with twin peaks during May and August. The study location is characterized by relatively low rainfall with erratic distribution and is further sub-divided into five zones mainly based on soils and cropping pattern. Of them, two agro-climatic zones—the eastern dry zone and the central dry zone—have been selected for the study (Fig. 1). The mean annual rainfall in the selected zones ranges between 450 and 890 mm.

The districts selected for the study are Chitradurga, Tumkur and Kolar, with a total geographical area of 2.73 Mha, accounts for 17% of the total geographical area of the state (Fig. 1). Most part of area has clayey, clayey mixed and clayey skeletal soil. Loamy soil is found in some parts of Chitradurga and Tumkur while loamy skeletal soil occurs in certain parts of Kolar district. These districts fall under the agro-ecological sub-zone 4 of India[2] characterized as Karnataka Plateau with hot moist semiarid conditions with 150–180 days of LGP (length of growing period). The criteria for selection of these districts are maximum wastelands in district, contiguity of selected districts and large potential for A&R in the region.

3 GIS based approach to determination of technical potential area for afforestation and reforestation

Determination of technical potential area for A&R involves evaluation of land[3] suitable for the proposed activity. Also, adequate information on present and future

[2] The agro-ecological zones of India are based on physiography, soils, bio-climate and length of growing period (Sehgal et al. 1992).

[3] Land evaluation is formally defined as 'the assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation' (FAO 1976).

Fig. 1 Map showing location of regional and project baseline studies

land uses including management is a pre-requisite for elaborating policies and plans that would bring about specific desirable changes on these lands. Thus, plans and policies for plantation activities on these lands were assessed based on working plans[4] for the three districts.

Based on the land use/land cover maps and the definition for A&R[5] by the Climate Convention, wastelands and fallow lands are considered as lands suitable for reforestation. The technical potential area for reforestation of the study area—Chitradurga, Tumkur and Kolar—was assessed from the land use/land cover GIS maps and conduct of field studies. The schematic representation of methodol-

[4] Working plans are prepared for a forest division for 10 years.

[5] *Afforestation* is defined as ''the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources'' and *Reforestation* is defined as ''the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land''.

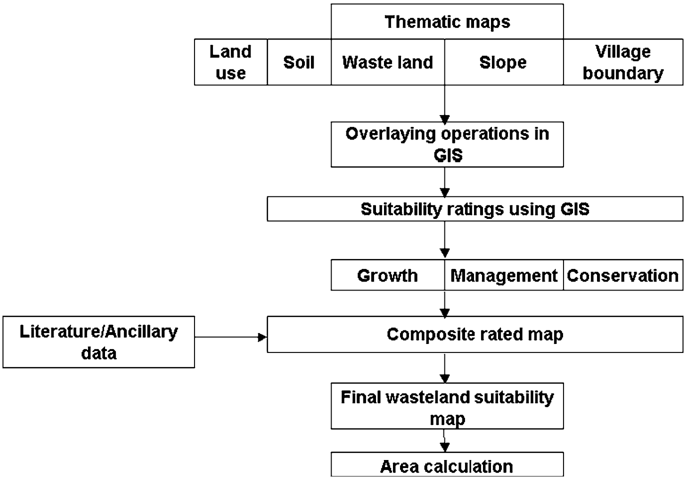

Fig. 2 Schematic representation of steps involved in determining potential land for forestry activities in an agro-ecological zone. Explanation for growth, management and conservation is provided in Table 2

ogy to assess the potential technical and actual feasible area for reforestation is shown in Fig. 2.

Data sets for the project area were procured from the Karnataka State Remote Sensing Agency and the following thematic maps for the districts Chitradurga, Tumkur and Kolar were used in the present study:

- Agro-ecological zone map of Karnataka
- Land-use type map for the districts
- Wasteland map for the districts
- Slope Map of the districts
- Soil Map/land capability map of the districts
- District/Village map of the districts.

The entire dataset was prepared at a scale of 1: 50,000. The land-use, wasteland, and soil maps were derived from PAN+LISS III (final resolution of 5.8 m) merged data from IRS 1C/ ID satellite images of 2000–2001. Slope maps were generated using contours from the Survey of India topographic sheets, while village boundary maps were derived from cadastral base maps. Thematic layers were generated through visual as well as digital classification. The GIS portion of the project was performed using ESRI product (Arc GIS 8). Analysis for the current study was done on a GIS platform. Composite maps of the study area were prepared for each theme, which was carried out by aggregating the district level database.

Land Use Pattern: The land use pattern of the study area was determined from the land-use/land cover GIS layers. Agricultural land is the dominant land use accounting for 76% of geographic area. Fallow lands account for 24,945 ha or 1.1% of the agriculture land and 0.91% of total geographic area. Fallow lands are defined as cultivable areas 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 (NRSA 1995). Forests[6] account for 8% of the geographic area dominated by moist and dry deciduous forest type. This estimate is identical to the estimate of 7.2% reported by the Directorate of Economics and Statistics, which is not based on remote sensing analysis.

Wastelands[7]: Maps of year 2001 were digitized separately for the different districts. The total area under wastelands in the three districts is 298,262 ha accounting for 11% of the total geographic area of these districts. This area is considered as potential area for A&R in the study. Area under different wasteland categories is given in Table 1. Sixteen wasteland categories have been identified according to the wasteland map and degraded forest dominated by scrub accounts for 38% of the wasteland area followed by area under scrub accounting for 34% of the area. Scrub forests are those with canopy cover less than 10% and hence are eligible for reforestation according to the definition of Climate Change Convention.

Of the 16 categories of wastelands, the categories—degraded land under plantation and saline/alkaline-strong—are not considered suitable for reforestation as the former is already under plantation crops and the saline/alkaline nature of the latter makes it unfit for planting activities. Thus, excluding these two land categories, the total available area for forestry activities is 297,120 ha.

3.1 Determination of feasible area for afforestation and reforestation based on ecological, management and social considerations using GIS approach

The technical potential area for reforestation for the study area is 297,120 ha. However, not all lands are suitable or available for forestry activities. It is essential to determine the feasible area for reforestation. The selected land categories were evaluated for suitability based on soil characteristics and terrain. Land suitability here is defined as fitness of a given type of land for a specified kind of land use, i.e, A&R. Conceptually, land evaluation requires matching the ecological and management requirements of relevant kinds of land use with land qualities[8], whilst taking local economic and social conditions into account. An attempt has been made in this study to consider these issues to arrive at land suitability classification (FAO 1984). The land suitability classes (FAO 1976) considered for the study are given in Table 2. To assess land suitability, the land use requirement necessary for the operation, i.e. A&R activity, has to be identified. The land use requirement are the conditions of the land necessary or desirable for the successful and sustained practice of a given land utilization type (Table 2).

[6] Forests, according to the Forest Survey of India is defined as ''all lands, more than one hectare in area, with a tree canopy density of more than 10%''. This is under the control of the state forest departments.

[7] Wastelands are marginal or degraded lands largely publicly owned but however could include marginal private lands also. National Remote Sensing Agency defines wastelands as ''degraded land which can be brought under vegetative cover with reasonable effort, and which is currently under utilized and/or which is deteriorating for lack of appropriate water and soil management or on account of natural causes''.

[8] A land quality is a complex attribute of land that acts in a distinct manner in its influence on the suitability of land for a specific use. Examples are moisture availability, erosion resistance, flooding hazard, nutritive value of pastures, accessibility.

Table 1 Wasteland categories (ha) for the selected districts

Wasteland description	Chitradurga	Tumkur	Kolar	Total
Agriculture land inside notified forest	2,180	6,188	4,357	12,726
Barren Rocky/Stony waste area	5,019	16,714	11,703	33,437
Degraded forest-scrub dominated	57,068	36,726	18,581	112,376
Degraded pastures/grazing land	1,988	–	–	1,988
Degraded land under plantation	–	49	1,062	1,112
Gullied and/or ravinous-Deep	–	2	–	2
Gullied and/or ravinous-Medium	624	350	906	1,881
Gullied and/or ravinous-Shallow	44	76	167	287
Land with Scrub	46,698	35,459	20,559	102,717
Land Without Scrub	2,858	404	1,337	4,599
Mining wastelands	776	1,460	720	2,957
Industrial wasteland	–	–	247	247
Saline/Alkaline-Moderate	1,152	1,334	17	2,504
Saline/Alkaline-Slight	919	846	–	1,766
Saline/Alkaline-Strong	30	–	–	30
Sands (tank/river bed)	3,423	150	16,055	19,629
Total Wastelands	122,783	99,763	75,716	298,262

Table 2 Land suitability classes, land use requirements and requirement parameters considered for the study

Suitability	Feature	Land use requirements
Highly suitable (S1)	No significant limitations or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level	- *Growth requirements:* Land conditions necessary for successful survival and growth of trees; climate and soil characters such as drainage (related to depth of water table), rooting conditions by soil depth and stoniness, salinity and toxicity by soil reaction.
Moderately suitable (S2)	Limitations which in aggregate are moderately severe; will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use is appreciably inferior to that expected on S1 land	- *Management requirements:* Land quality that influences management such as terrain factor affecting mechanized operations; characterized by slope angle, rockiness and microtopography
Marginally suitable (S3)	With limitations which in aggregate are severe and will so reduce productivity or benefits or increase required inputs that expenditure will only be marginally justified	- *Conservation requirements:* Land quality that affects conservation is erosion hazard, which is determined by characteristics such as slight, moderate and severe erosion
Not suitable (NS)	With limitations so severe as to prelude any possibilities of successful sustained application of the given land utilization type	

The study area being a uniform agro-ecological or agro-climatic zone (dry zone), parameters such as radiation, temperature and moisture qualities have been omitted. Based on the above-mentioned criteria, land evaluation was directly based on land characteristics. These land characteristics were given factor rating, which is a set of critical values, which show how well one particular land use requirement is satisfied

Table 3 Factor rating assigned to wasteland categories based on soil characteristics

Suitability class	Factor rating	Drainage	Depth (cm)	Texture	Slope	Erosion
S1	1	Well drained	>75	Loamy	0–5%	No erosion (5%)
S2	2	Moderately well drained	25–50	Clayey	5–10%	Slight (10%)
S3	3	Somewhat excessively drained	10–25	Cracking clay	10–15%	Moderate/Severe >15%)
NS	4	Excessively drained	Rocky	–	>15%	–

S1: Highly suitable; S2: Moderately suitable; S3: Marginally suitable; NS: Not suitable

by a condition of the corresponding diagnostic factor. Factor ratings were given from 1–4. The best condition is ranked 1 and the least 4. The factor ratings are set for each selected land quality in turn. For simplicity only one parameter for each class has been identified. They are as follows:

- Soil depth has been assigned for growth;
- Slope has been assigned for management and
- Soil erosion has been assigned for conservation.

The factor ratings for the various land characteristics are given in the Table 3.

3.1.1 Land suitability ratings

After the factor ratings were set for each land quality, they were compared with corresponding conditions of the land unit or wastelands. A set of component suitability or land suitability ratings was derived as shown in Table 3. These are suitability of land based on one particular requirement alone, i.e. if the wastelands has soil with an effective depth of >75 cm, the land suitability would be S1 or highly suitable for growth. A slope angle of >15% is considered not suitable for A&R and thus labeled as NS in Table 4. Erosion has only three factor ratings from 1 to 3 and can be taken up for A&R irrespective of severity of erosion, with varying soil and water conservation measures. These land suitability class were fixed based on field experience. The Karnataka Forest Department officials were consulted to assign the land suitability ratings, based on their field experience in the dry zone of Karnataka.

The land suitability ratings for growth, management and conservation as explained in Table 2 were then combined to obtain an overall land suitability classification (Table 4). Rated maps were prepared for each of the themes with corresponding land suitability ratings accorded to each attribute. A singular theme with descriptions and ratings of layers of wasteland, slope and soil of the

Table 4 Overall suitability class of wastelands for A&R activities

Suitability class	Area	% Area
S1 (Highly suitable)	46,811	15.8
S2 (Moderately suitable)	11,268	3.8
S3 (Marginally suitable)	129,671	43.7
Not Suitable (NS)	109,243	36.8
Total	296,994	100.0

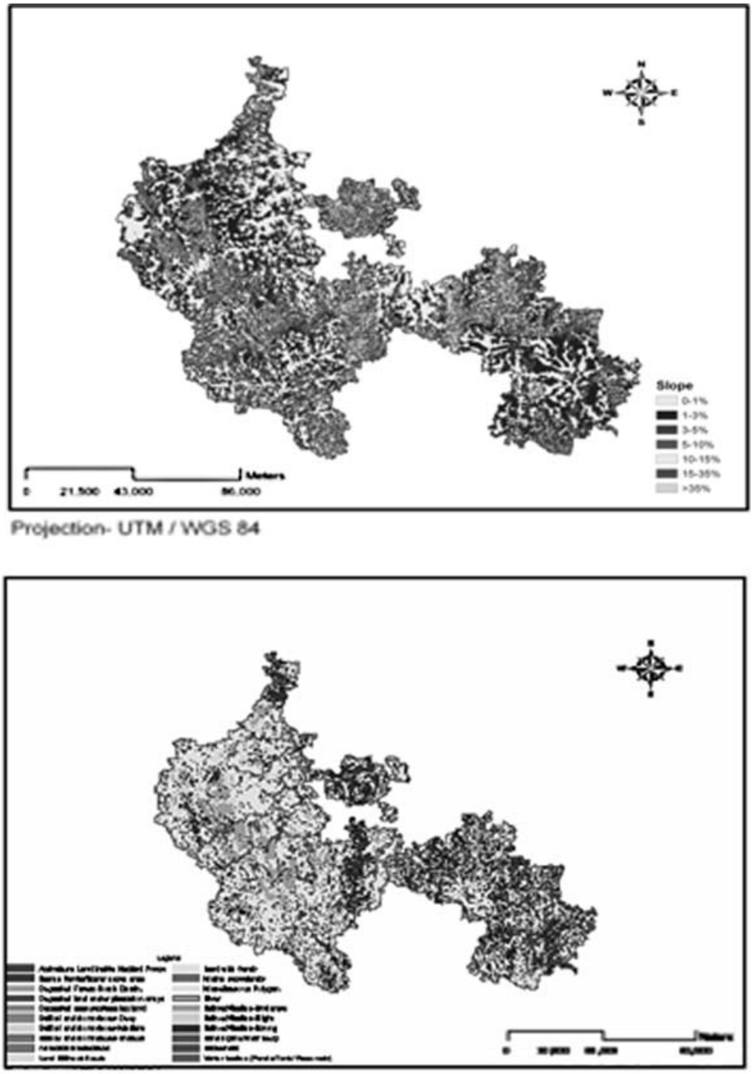

Fig. 3 Wasteland and slope maps of Chitradurga, Tumkur and Kolar districts

study area was generated using overlaying operations in GIS and projected to Universal Transverse Mercator with datum WGS 84, Zone 44 (Figs. 3, 4). Different combinations of ratings were generated for each category of wasteland. Land suitability was assigned based upon effective growth, management and conservation factors. Key constraints were identified in different combinations in the form of 17 land categories and final reclassification of wastelands was performed (Table 4).

The area of wastelands under different land suitability ratings was deduced. About 37% of wastelands are not suitable for A&R due to constraints of depth and slope (Table 4 and Fig. 5). About 16% of the area or 46,811 ha of wastelands (Table 4) are highly suitable for A&R.

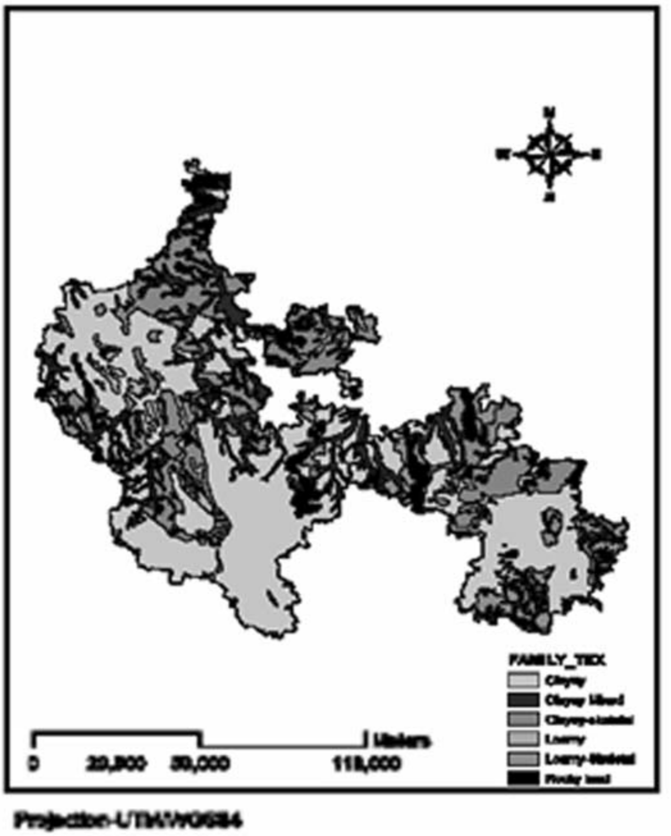

Fig. 4 Soil texture map of Chitradurga, Tumkur and Kolar districts

3.1.2 Economic and social analysis for forestry activity

The central function of land evaluation is to assess the potential of land for A&R. But land evaluation for forestry (A&R activity) is incomplete without economic and social analysis as it brings direct benefits to communities such as wood products, NTFPs, grazing use, etc. Economic considerations are required to assess the relative effects of physical limitation for an activity. The physical characteristics of land will influence production costs. The purpose of economic analysis is to compare the performance of land utilizations types on different kinds of land, which have been provisionally assessed as suitable. To make this comparison, it is essential to compute inputs and outputs into costs and benefits and the calculations of one or more measures of economic value. Consideration of need for inputs such as labour, material and capital for each combination of wasteland category and land characteristics will determine the input cost. The output costs are benefits received from wood and NTFPs. Since the consideration is A&R for climate change mitigation and meeting of sustainable development goals, economic analysis is limited to costs. The land use change to A&R has consequences for other national and local objectives such as employment generation, flow of NTFPs, meeting fuelwood needs of the

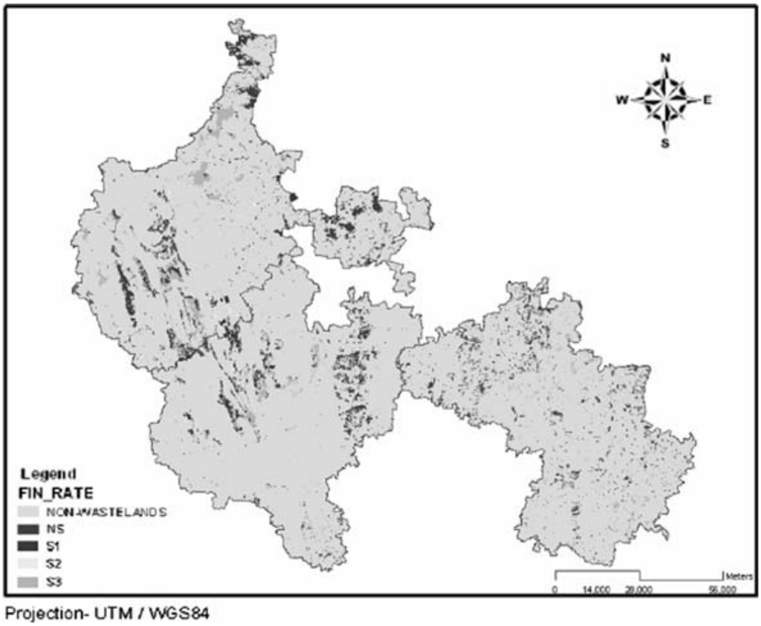

Fig. 5 Overall land suitability rating for A&R in Chitradurga, Tumkur and Kolar districts

village, etc. Thus, the initial costs of establishment are considered to evaluate economic suitability of lands for A&R.

The input costs for A&R activity was obtained from Karnataka Forest Department (Table 5). Tumkur Forest Department officials were consulted to obtain information about the A&R type and initial cost for establishment for the wasteland categories and land characteristics.

Various models suitable to different wasteland categories are adopted in the region. The establishment costs for initial three years ranges from US$ 493 to US$1042/ha based on the model (Table 5). Based on soil characteristics—depth, slope and erosion, soil and moisture conservation (SMC) measures are done, the cost of SMC measures, account for 0–50% of initial costs. Additional 5% of plantation cost is spent on fire protection. Thus, considering the maximum investment cost for each model, the costs for plantations varies from Rs. 34,000 to 72,000/ha. In this study, costs are not considered a constraint for A&R activity on wastelands based on the criteria set in Table 6.

Social analysis is an essential part of land evaluation. Unless the local communities are involved in the inception, evaluation and decisions on land use, mere technical and economic analysis is insufficient and is liable to fail. Here consideration of plantation type or model is governed by the technical knowledge of the forest department. Choice of species for plantation will be by the local community in association with the Forest Department, considering physical suitability, economic viability, socially acceptability, freedom from significant adverse environmental impacts and manageable implementation constraints.

Participatory Rural Appraisal (PRA) was conducted at the village level in sample villages to seek the opinion of various stakeholders to solicit their views on the extent of wastelands they were willing to dedicate to A&R. Based on the stake-

Table 5 Establishment costs of plantation models in dry agro-ecological zone of Karnataka in Rupies and Dollars

Model	Year 1	Year 2	Year 3	Total	Administrative costs	Total
Natural regeneration	17500	500	500	18500	3700	22200
	388	**11**	**11**	**411**	**82**	**493**
Eucalyptus plantation	15200	1700	1700	18600	3720	22320
	337	**37.7**	**37.7**	**413**	**82**	**495**
Mechanized plantation	**766**	3800	1670	39970	7994	47964
	34500	**84**	**37**	**887**	**177**	**1065**
Trench mound and pit	23520	9900	5700	39120	7824	46944
	522	**220**	**126**	**868**	**174**	**1042**
Irrigated Bamboo and Teak	29100	3600	3600	36300	7260	43560
	646	**80**	**80**	**806**	**161**	**967**

Source: Records of Tumkur Forest Department, Tumkur District, Karnataka

Note: Bolded figures are in US$; 1 US$ = Rs. 45

Table 6 Economic suitability for plantation activity

Suitability class	Ratings	Investment cost/ha	
Highly suitable-S1	1	<25,000	US$ 555
Moderately suitable-S2	2	25,000–50,000	US$ 555–US$1110
Marginally suitable-S3	3	50,000–75,000	US$ 1110–US$ 1665
Not Suitable-NS	4	>75,000	>US$ 1665

holders view, the extent of wastelands in the agro-ecological zone that would be suitable for A&R was determined. For farm forestry, large, medium and small farmers were interviewed to determine the extent of fallow land available with them and the area they were willing to dedicate for A&R. When community lands are considered, on an average the local community was willing to allocate only 50% of land for A&R, the main reason being land requirement for grazing. However, when the private fallow lands are considered, the farmers are willing to allocate 100% of lands for A&R activity. Incorporating economic and social analysis in land evaluation, the total wasteland area that can be taken up for A&R activity is 93,875 ha. Thus:

- Of the total wastelands of 296,994 ha, 187,750 ha is technically feasible for A&R accounting for 63.21% of total wastelands
- On economic and social analysis, only 93,875 ha is suitable for A&R, which is about 50% of technical potential and 31.6% of total wastelands of dry agro-climatic zone (Table 7).
- Considering fallow lands, 24,945 ha of fallow lands exist in the 3 districts of Chitradurga, Tumkur and Kolar, of which 100% could be considered for A&R activity.
- Thus overall, 118,820 ha of lands can be considered as feasible for A&R after considering technical, economic and social analysis, which is 36.9% of area (wastelands + fallow lands) (Table 7).

The land available for A&R would depend on the opportunity cost and the expected returns from the proposed A&R activity. Higher returns in the form of

Table 7 Availability of land for A&R based on various scenarios

Description	Area (ha)	% area to the total
Wastelands		
Total wastelands	296,994	100
Technical suitability of lands for A&R[a]	187,750	63
Overall wastelands for A&R considering economic and social analysis[b]	**93,875**	**32**
Fallow lands		
Total fallow lands	249,45	100.00
Social suitability of lands for A&R	**249,45**	**100.00**
Total area for A&R (wastelands+fallow lands)	**118,820**	**36.9**

[a] Technical suitability is after considering physical constraints

[b] Social analysis is based on community preference for land allocation for A&R

carbon revenue may provide incentive to farmers and communities to allocate more land for mitigation projects.

4 Approaches for baseline development

Under the UNFCC's Clean Development Mechanism (CDM), 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". According to the Milan Accord (UNFCCC 2002), three options for baseline methodology under the CDM are suggested. They include: (i) the natural emissions and removals that would otherwise occur; or (ii) the net greenhouse gas removals by sinks due to use of the land that represents an economically attractive course of action, taking into account barriers to investment or other barriers; or (iii) the most likely prospective land use at the time the project starts, which may include for example, agriculture (pasture or crops), natural regeneration, or forestry.

The three options give freedom to either choose regional baseline or project-specific baseline. The three main steps involved in setting a regional baseline are (Sommer et al. 2004):

i. Identify likely baseline options for land use,
ii. Estimate baseline rates of land-use change, and
iii. Quantify the baseline carbon profile over time.

The schematic representation to steps adopted in determining a regional baseline is given in Fig. 6.

4.1 (i) Likely baseline options

The land use categories considered for A&R in this case are wastelands and fallow lands. The likely options of land use for wastelands are conversion to croplands, plantation or remain as wastelands. In case of fallow lands, the likely options are croplands, conversion to forestry or continue to remain as fallow lands.

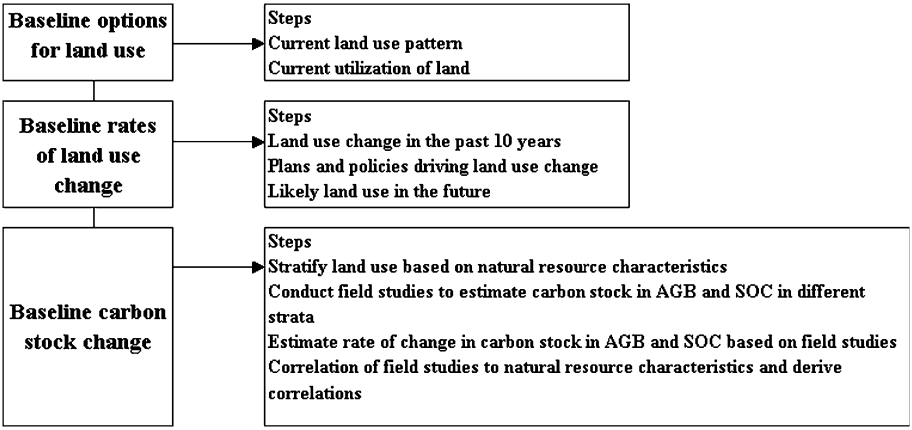

Fig. 6 Schematic representation for determination of regional baseline

4.2 (ii) Land use change

The carbon profile under baseline is based on the land use option. Future anthropogenic land-use changes are not perfectly predictable, nor are land-use changes purely random (Paladina and Pontius 2004). Anthropogenic changes can be predicted based upon a combination of cultural forces, biophysical factors, transportation networks, market accessibility and agro-climatic suitability (Kaimowitz and Angelsen 1998). Any prediction of land use has a level of uncertainty associated with it and a prediction further into the future should have a greater level of uncertainty than a prediction to the near future. Land use-change modelers have expressed the need for statistical methods to validate models and to state the uncertainty in land-change predictions (Lambin et al. 1999).

In the current study, to determine the likely land use change in the absence of project or baseline scenario of these lands, an assessment of the recent land use change in the region and the plans and policies for land use were considered. The major land use in these districts is agricultural land, which accounts for 47% of the geographic area. The area under agriculture has nearly remained stable since 1980 (Table 8). According to the perspective land use plan for Karnataka, increasing population pressure, demand for food and raw material for industries, the need for crop diversification for sustainable use of land and other natural resources will be the major challenge for the planners. The projected population and the demand for major food and commercial crops may double by 2025. However, the land available for cultivation has reached its optimum, and according to planners extension of cultivated area is ruled out (KSLUB 2001). The increase in food production is planned to be met by increasing crop productivity, through new technologies and their adoption and by expanding area under irrigation.

The other possible land conversion option under the baseline is conversion to forest plantation activities. The A&R rates in the past and the planned activities in the districts were considered. Plantations are raised on forest and non-forest lands. These are primarily firewood plantations of *Eucalyptus and Acacia auriculiformis*. Some of these are monoculture plantations of either *Eucalyptus* or *Acacia auriculiformis*. During 1990–2002, 50,000 ha were afforested in the three districts at a

Table 8 Land use statistics for Chitradurga, Tumkur and Kolar districts (ha)

Year	1985–86	1990–91	1995–96	2000–01	2001–02	2002–03
Forest	188,857	189,027	189,027	189,027	189,220	189,220
Land put to non agricultural use	198,273	201,232	206,997	208,424	208,774	208,848
Barren and uncultivated land	157,012	156,121	156,111	156,114	156,114	156,114
Cultivable wasteland	109,655	101,245	100,636	96,836	96,797	96,797
Permanent pasture & grazing land	342,551	326,958	307,774	273,907	269,554	269,554
Land under trees and groves	55,225	49,258	47,170	44,949	44,949	44,949
Current fallow	225,432	148,544	188,491	197,800	224,936	320,438
Other fallow lands	92,053	93,530	82,101	71,260	90,545	92,923
Net area sown	1,245,780	1,349,009	1336,617	1376,607	1334,035	1236,081
Total geographic area	2,614,924	2,614,924	2,614,924	2,614,924	2,614,924	2,614,924

Source: Directorate of Economics and Statistics, Bangalore

rate of 4,000 ha/annum. The rotation period of these species is 8–10 years. In all the three districts, most of the plantations have not been harvested so far. For the years 2001–2011 in Chitradurga district, 10,534 hectares of scattered, under-stocked plantations with a survival rate of under 30% will be replanted (Working Plan, Chitradurga) at a rate of 1,000 ha/annum. In Tumkur, as the majority of the plantations are of *Eucalyptus* species and have not been extracted regularly, coppicing will be allowed on all of them. Therefore the extent of new area to be planted will be small (Working plan, Tumkur, 2001–02). In Kolar, the extent of area that is proposed for planting for the years 2002–2011 is 6,200 ha. Thus under the baseline the plantation activity is confined to replanting, coppicing for Eucalyptus plantations, replanting in non-coppicing plantations such as Acacia, Casuarina, etc.

Considering other land use changes, Table 8 shows that in the past 18 years from 1985 to 2003, there has been a major decrease in pasture land, tree groves and cultivable wasteland, which has led to an increase in fallow lands and non-agricultural land use or infrastructure. Though the land use change matrix cannot be deduced from this numerical information, the trends in land use change can be deciphered. On an average in the last 18 years, a reduction of 8,000 ha of pastureland, 1,500 ha of cultivable wasteland and 1,000 ha of land under agriculture and trees and groves have been recorded. The mean increase in fallow lands is around 10,000 ha/yr, which means farmers are not finding rainfed cropping profitable.

Crop cultivation being the dominant land use, the correlation between annual change in crop area to other land use was assessed (Table 9). The Pearson correlation shows a strong negative correlation to current fallow followed by other fallow lands and pastureland. The conversion of other land use to cropland was not significant.

Land conversion to other land types is of lesser consequence. Therefore the baseline options considered for the area are wastelands remaining wastelands, and fallow lands continuing to be fallow lands. In fact if agro-forestry is economically attractive under the climate mitigation process much of the marginal croplands especially in this dry region could get converted to farm forestry through A&R.

4.3 (iii) Carbon stock under baseline

The baseline carbon stock of the land categories (wastelands and fallow lands) was determined based on field studies. Areas under each wasteland category were calculated at the village level, and villages with the largest areas under wastelands were selected for field studies to estimate biomass and soil carbon stock. Sample villages in each district for the different homogenous zones for A&R, with special emphasis on community and fallow lands, were selected. To determine the carbon stock under the baseline for community lands, 36 villages were selected from the three districts. Figure 1 shows the villages selected for estimating the carbon stocks in wastelands and fallow lands.

Details of land including historical information of time since abandonment (for aboveground biomass growth rates and soil organic carbon accumulation) were gathered to understand trends in changes in parameters. The plot method was adopted to estimate aboveground biomass in community lands. Replicates of 50 × 50 m plots were laid to study the vegetation. Whole fallow lands in each village belonging to small, medium and large farmers were sampled for aboveground biomass and soil organic carbon. In each village, 10 farmers were selected for the study. They were also interviewed to understand the past land practices, which could impact soil organic carbon. Interviews were also held with village elders/village forest committee presidents.

Field data was compiled and basal area estimated using DBH and height data. 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 0.5 of biomass as carbon content.

To estimate soil organic carbon, soil samples at a depth of 0–30 cm were collected. Bulk density was estimated and soil organic carbon content was estimated in the laboratory using the Walkley-Black method. Soil samples from wastelands and fallow lands representing baseline scenario were collected.

The average aboveground biomass for wastelands was 0.6 ± 0.7 dry t/ha, while soil organic carbon was 38.4 ± 5.7 t/ha (Table 10). The average soil organic carbon of fallow lands was 34.6 ± 10.8 t/ha and aboveground biomass was 0.01 ± 0.1 t/ha (Table 10). The average carbon stock for wastelands is 39.0 t/ha and for fallow lands is 34.6 t/ha. Soil organic carbon constitutes 98% of the carbon stock under the baseline. Hence, an attempt is made to determine soil organic carbon based on other soil characteristics.

Table 9 Pearson correlation of annual change of net sown area with other land categories for the period 1985–2003

Year	Pearson correlation	2-tailed significance level*
Forest	0.16	0.69
Land put to non agricultural use	0.17	0.65
Barren and uncultivated land	–0.40	0.28
Cultivable wasteland	–0.37	0.33
Permanent Pasture and Grazing land	–0.60	0.09
Land under trees and groves	–0.45	0.25
Current fallow	–0.99	0.00**
Other fallow lands	–0.60	0.09

*significant at 0.05 level; **significant at 0.01 level

Table 10 Baseline land characteristics of land considered for afforestation and reforestation activity in sampled areas of dry zone of Karnataka

Wastelands (n = 47)		Fallow lands (n = 240)	
Soil organic carbon (t/ha)	38.4 ± 5.7	Soil organic carbon (t/ha)	34.6 ± 10.8
Stand biomass (t/ha)	0.55 ± 0.7	Standing biomass (t/ha)	0.014 ± 0.1
Other features			
Soil depth (cms)	35.1 ± 27.2	No. of fallow years (yrs)	12.1 ± 9.8
Drainage	2.6 ± 1.4		
Erosion (t/ha/yr)	20.4 ± 17.4		

4.4 (iv) Factors determining SOC

For a given soil, in a minimally disturbed ecosystem such as wastelands and fallow lands, the maximum carbon sequestration potential is not known in part because soil takes more time to reach equilibrium than vegetation. Regional and global distribution of soil carbon stocks have been estimated by Eswaran et al. (1995), Kern et al. (1998), Kimble et al. (1991), etc. But it is difficult to relate spatial variation to the factors that determine soil carbon stocks. A GIS soils data layer permits analysis of the spatial distribution of stock of soil carbon and related edaphic parameters that are thought to affect soil carbon stock. An attempt has been made to use the soil characteristics and relate it to field information for the points using the GIS approach where field data was collected. Once the soil organic carbon content of soil and aboveground biomass of sample sites were computed, they were correlated to other soil parameters spatially using GIS, including soil depth, drainage and erosion for wastelands. The database comes from soil mapping efforts that take into account the field experience of soil surveyors, who integrate topography, microclimate, geology and other soil forming factors to delineate the distribution of soils on the landscape. Thus keeping soil organic carbon as the dependent variable, its correlation to other parameters was computed. For wastelands, soil organic carbon is positively correlated to soil depth and biomass and negatively to drainage and erosion (Table 11).

The factor rating given in Table 3 was followed for drainage, wherein the best option gets ranking 1 and the least 4. For erosion, the midpoint of actual erosion rates (t/ha/yr) range was given. The actual values for soil depth (Table 3) and biomass were considered. Nearly half of the variation is SOC can be attributed to drainage class, followed by aboveground biomass. This is in accordance with the study done in Kansas and Montana, wherein SOC is negatively correlated to drainage class (Davidson 1995).

Table 11 Pearson correlation of soil organic carbon to other soil characteristics

Wastelands (n = 47)		Fallow lands (n = 240)	
Soil organic carbon	1.00	Soil organic carbon	1.00
Log biomass	0.46	No. of fallow years	0.76
Soil depth	0.29	Soil depth	0.03
Drainage	–0.57	Drainage	–
Erosion	–0.36	Erosion	0.03

1. well drained; 2. moderately well drained; 3. somewhat excessively drained; 4. excessively drained

Table 12 Regression output for estimation of soil organic carbon in wastelands for regional baseline

	Unstandardized coefficients		t	Significance
	B	Standard error		
Constant	38.843	2.859	13.587	0.000
Soil depth	0.135	0.050	2.708	0.010
Drainage	–2.747	0.664	–4.135	0.000
Erosion	0.182	0.089	2.054	0.046
Log of standing biomass	1.151	0.896	1.284	0.206

R^2 = 0.51

Multiple linear regression analysis using the parameters to predict SOC in wastelands is given as follows:

$$\mathrm{SOC} = 38.43 + 1.151 \log \mathrm{B} + 0.1335\mathrm{SD} - 2.747\,\mathrm{D} + 0.182\,\mathrm{E}; \mathrm{R}^2 = 0.507$$

where logB = log of biomass; SD = soil depth; D = drainage and E = erosion

The dependence of SOC with other parameters has a strong coefficient of correlation with a R^2 value of 0.507 and a standard error of estimate of 4.25 (Table 12).

In case of fallow lands, the SOC at a given time is a function of the previous land history of additions of organic matter relative to losses through decomposition, transformation and erosion. The rate of change of SOC content associated with changes in management is influenced by the previous management and prevailing environmental conditions (Post et al. 2001). The parameters considered were years since fallow, soil depth, drainage and erosion (Table 13). The SOC content correlates positively to number of years of fallow period and soil depth and negatively to erosion (Table 13).

Multiple linear regression analysis using the parameters to predict SOC for fallow lands is given as follows with a standard error of the estimate of 6.87.

$$\mathrm{SOC} = 20.394 + 0.86\mathrm{FY} + 0.10\mathrm{SD} - 0.38\,\mathrm{E}; \mathrm{R}^2 = 0.59$$

where FY = number of years since land is fallow; SD = soil depth and E = erosion

These results show that soil maps can be used effectively as a tool to calculate the regional stock of SOC and to study the spatial distribution of SOC and relative edaphic parameters. As layers in GIS database, preparation of SOC maps could also provide a useful basis for modeling the effects of changes in land use and climate on storage of carbon in terrestrial ecosystems (Davidson 1995).

4.5 (v) Rate of change of carbon stocks in soils

From field studies, based on time series data available for SOC at different length of fallow period, the trajectory of SOC was assessed. The average temporal change in soil C was calculated as a mean value weighted for time. The weighted-average change in soil C, and the percentage change in soil C compared to the initial C content was calculated as:

Table 13 Regression outputs for estimation of soil organic carbon in fallow farmlands for regional baseline

	Unstandardized coefficients		*t*	Significance
	B	Standard error		
Constant	20.39	1.76	11.59	0.00
No. of fallow years	0.86	0.05	18.58	0.00
Depth	0.10	0.03	3.17	0.00
Erosion	–0.38	0.11	–3.40	0.00

Weighted-average change in C (tC/ha per year) =

$$\frac{\Delta C_1 + \Delta C_2 + \Delta C_3 + \Delta C_4 + \cdots}{\text{age}_1 + \text{age}_2 + \text{age}_3 + \text{age}_4 + \cdots}$$

where $\Delta C_1 + \Delta C_2 + \Delta C_3 + \Delta C_4 + ...$represent the sum of the change in soil C for the various data sets as indicated with subscripts and $\text{age}_1 + \text{age}_2 + \text{age}_3 + \text{age}_4$ ...representing the age of fallow years for the various data sets as indicated with subscripts (Paul et al. 2002). Accordingly, the annual increase in SOC of fallow lands is 1.34 t/ha/yr. The yearly increase in SOC with years left fallow is shown in Fig. 7. As can be seen from Fig. 7, the SOC appears to reach equilibrium after 30 years of fallow period. In the absence of ploughing and disturbance of top soil, the fallow lands accumulate SOC initially and after about 30 years may reach a peak concentration of soil organic matter. The average SOC of a one-year-old fallow land is 15.4, which reaches 50.6 t/ha by 45th year.

5 Projected baseline carbon stocks

The annual change in projected baseline carbon stocks was determined using the PROCOMAP model based using the field information for wasteland lands and fallow lands, for a period of 30 years. Among the five carbon pools of aboveground and belowground biomass, litter, deadwood and soil, only aboveground biomass and SOC are included. Under the baseline scenario, in the wastelands and fallow lands, litter and deadwood pools are absent due to its frequent removal for fuelwood

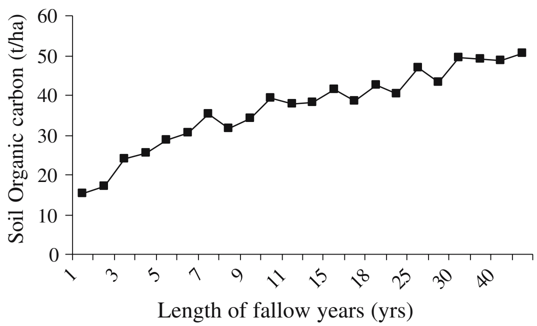

Fig. 7 Relationship between the length of fallow period and soil organic carbon from field data in dry agro-climatic zone of Karnataka

purposes by the local communities. Belowground biomass is not considered due to very low aboveground biomass stocks, an indication of low belowground biomass. The projections are based on assumptions given below:

- The aboveground biomass in wastelands and fallow lands will not alter significantly. The aboveground biomass was low at 0.55 t/ha for wastelands and 0.014 t/ha for fallow lands. Thus, changes in aboveground biomass in wastelands and fallow lands over time are insignificant.
- The SOC of wastelands is assumed as having reached an equilibrium. These lands have been wastelands for long periods and are not likely to undergo disturbances or change in land use pattern. Thus the SOC of the wasteland is assumed to be 38.5 t/ha.
- In case of fallow lands, the SOC is positively impacted most by the length of fallow period. The extent of area under different lengths of fallow period is not known. From the sample studies, the average length of fallow period is 12 years (Table 3) and is assumed the same for the study area.
- The increment in SOC is taken as 1.34 t/ha/yr based on field studies, until it reaches a steady state.
- The accumulation period is taken as 30 years as determined from field studies (Fig. 7), by which period, the SOC reaches equilibrium state at 55 t/ha/yr.

Based on above assumptions, the PROCOMAP was run for assessing the regional baseline for wastelands and fallow lands for a period of 30 years (Fig. 8). The regional baseline for wastelands is a steady carbon stock at 38.7 t/ha. The wastelands have very little aboveground tree biomass and are subjected to extensive grazing and extraction of biomass, leading to no addition of organic matter to the soil. The soils of the wastelands are also not subjected to disturbance. Thus, SOC in wastelands is likely to be stable.

In case of fallow lands, the increment in SOC is 1.34 t/ha/yr. The SOC in fallow lands is expected to increase due to the following reasons: (i) fallow lands are owned by farmers and are protected, (ii) are less subjected to biomass removal or grazing, and (iii) top soil is not subjected to disturbance. The average SOC stock in fallow lands from field studies is 34.6 t/ha and the maximum SOC of fallow lands is

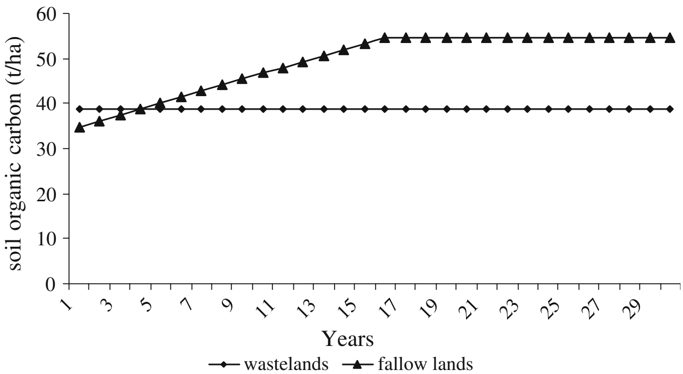

Fig. 8 Baseline projection of soil organic carbon in wastelands and fallow lands for dry zone of Karnataka

recorded to be 54.7 t/ha. Thus, at an increment of 1.34 tC/ha/yr, the maximum SOC of 54.7 t/ha will be reached by the 16th year, as shown in Fig. 4.

6 Uncertainty in determining regional baseline

Uncertainty of carbon stock and flow estimates from biological systems is considered to be high. Uncertainty in determination of regional baseline could be at two levels:

- First, uncertainties related to assumptions of the baseline situation or defining baselines that allow calculation of reliable and verifiable additional effects of the project. Baseline determination requires judgment of past, present and future set of carbon stocks.
- Second, uncertainty associated with estimating the carbon stock and annual changes.Carbon stock variation in the future cannot be determined directly and has to be estimated from carbon stock measured at one time. Wastelands biomass and SOC values are assumed to have stabilized. The uncertainty of carbon stock was estimated using simple error propagation through the root of the sum of the squares of the component errors. Here the plot results of biomass and SOC were averaged to give mean and 95% confidence intervals (CIs) for the stratum. The total CIs are calculated as follows:

$$\text{Total 95\% CI} = \sqrt{95\%\ \text{CI}_{\text{veg}}^2 + 95\%\ \text{CI}_{\text{soil}}^2}$$

$$\text{Total 95\% CI} = \sqrt{(0.209)^2 + (1.623)^2}$$

Total 95% CI = 1.63
The baseline carbon stock for the wastelands is 39.0 ± 1.6 t/ha
For fallow lands

$$\text{Total 95\% CI} = \sqrt{(0.006)^2 + (1.33)^2}$$

Total 95% CI = 1.33
The baseline carbon stock for the fallow lands is 34.6 ± 1.3.

Uncertainty of the carbon stock measured at one time extended to the future needs to be estimated. According to a study by de Jong (2001), the uncertainties of up to 74% in the offset calculations were observed among the three baseline assumptions. Even though carbon pools can be estimated within reasonably narrow confidence intervals, the uncertainties associated with the definition of the baseline make calculation of reliable and verifiable additional effects of the project. Baseline setting depends not just on methodology, but also on a set of criteria and indicators that keep the methodology critical and honest (Chomitz 1998). Appropriate guidelines should set standards for baseline definitions that are acceptable and based on international agreements. Though these guidelines may not necessarily guarantee precision of measurements, they will avoid systematic miscalculations (de Jong 2001).

7 Transaction costs for developing regional baseline

Implementation of climate mitigation projects entails considerable costs of baseline development, verification and certification. The profitability of a mitigation project will be limited if transaction costs become too high or procedures too bureaucratic. Development and adoption of regional baselines, in principle, should reduce the transaction costs. Transaction cost was assessed for the regional baseline developed for the agro-climatic region of Karnataka. There are two cost components to the study —GIS and computation component and that of field studies.

The GIS component involved:

- collaborate with Karnataka State Remote Sensing Agency (KSRSAC),
- overlay thematic maps to determine the soil characteristics,
- rank the soil characteristics and identify the polygons with different soil characteristics,
- group the land use based on soil characteristics and determine the area.

Thematic maps are available at district level in India. In this study, GIS maps were used to correlate SOC to soil characteristics. The transaction cost consideration is limited to analysis of the data for land use pattern, scoring soil characteristics and determining suitability classes.

Field studies involved:

- selection of field sites based on GIS data,
- conduct of field studies to assess carbon stock in biomass and soil organic carbon
- laboratory analysis for SOC and biomass.
- conduct of PRA and interviews with farmers, forest department officials and collection of secondary information,
- synthesis of information and construction of regional baseline.

The cost for conduct of field studies for determination of regional baseline for wastelands and fallow lands was Rs. 224,600 (US$ 4,985) for an area of 118,280 ha, which is about Rs. 1.90/ha (<US$ 1/ha) of land. The project-specific cost of developing the baseline for community and farm forestry in Kolar district was Rs. 125,400 (US$ 2,783) for an area of 14,000 ha, which is about Rs. 9/ha (<US$ 1/ha). Benitez et al (2001) report a transaction cost of US$ 0.5/ha/year for reforestation and natural regeneration projects in NW Ecuador and Patagonia, Argentina.

8 Testing the regional baseline for project-specific mitigation project

Project specific baseline was estimated for community and farm forestry in Kolar district, Karnataka, situated in the dry agro-climatic region and compared to the regional baseline. This is a test to determine if pre-existing natural resource data sets can be used to develop regional baselines in place of project-specific baseline. Applying the t-test of two-sample equal variance, the project-specific baseline carbon stock and the regional baseline carbon stock was compared (Table 14).

As can be seen from Table 14, the carbon stock for the project specific baseline was 39.9 and 33.6 t/ha for wastelands and fallow lands respectively, which correlates to 39.0

Table 14 *T*-Test of two—sample—regional versus project-specific carbon stock baselines in the dry agro-climatic zone of Karnataka, assuming equal variances

	Wastelands		Fallow lands	
	Regional baseline	Project specific baseline	Regional baseline	Project specific baseline
Mean	38.97	39.95	34.63	33.64
Variance	36.09	33.29	36.08	13.83
Observations	48	14	48	2
Pooled Variance		35.48		35.62
Df		60		48
t Stat		–0.46		1.27
t Critical two-tail		2.00		2.01
Ratio of project to regional baseline	1.02		0.97	

and 34.6 t/ha under the regional baseline. Thus the two means are from samples with equal variance. In other words, the means of the samples are highly correlated, where t = –0.46 and 1.27 for wastelands and fallow lands respectively, which is statistically highly significant, as it is far lesser than the t-critical two tail (Table 14). Thus, it can be safely assumed that the regional baseline can be applied to determine a project-specific baseline. The ratio of wasteland carbon stocks of project baseline to regional baseline is 1.02 and similarly the ratio of fallow lands in project to regional baseline is 0.97. Thus, the regional and project baselines are comparable.

Although the regional baseline is cost effective, it has the potential to over- or under-estimate carbon stocks at a given project location within a region.

9 Conclusions

Baselines, especially project-specific, will always be problematic for three reasons. Firstly, it is inherently difficult to predict what would have happened in the future. Secondly, both buyers and sellers of carbon credits have strong incentives to overstate the baseline level of emissions, since this increases revenues for the seller and in aggregate may reduce the price of offsets for buyers. Thirdly, baseline setting requires some assumptions about national policies (Chomitz 1998). Finally, project-specific baselines have high transaction costs. The project-specific approach can be easily monitored and verified. However, it is limited by high cost and inconsistent methods adopted across projects (Sommer et al. 2004).

Regional baselines could be one option to overcome some of these limitations. Regional baselines enhance the transparency of methods, facilitate ease of review of methods and reduce the uncertainty with respect to methods and subjective judgments. Regional baselines can be considered baseline standardization for a larger reference area, and would prevent high or low project-specific baselines. As can be seen from the study, for a large agro-ecological zone the variation of soil organic carbon stock for an agro-ecological zone is low. Thus, a regional approach to setting baseline can be adopted.

The present study has extensively used satellite imageries of the land use systems and overlaid the following thematic maps for the districts; (i) agro-ecological zone map, (ii) land-use type map, (iii) wasteland map, (iv) slope map, (v) soil map/land capability map, and (vi) district/village map of the districts. The study has further demonstrated that existing satellite imagery and the various thematic maps can be used in developing a regional baseline by identifying potential homogeneous zones. The ratio of wasteland carbon stocks of project baseline to regional baseline is 1.02 and similarly the ratio of fallow lands in project to regional baseline is 0.97, indicating regional and project baselines are comparable. This high level of comparability may result from the limited data available, preponderance of carbon in soils with comparable update rates, and relative biophysical and socioeconomic homogeneity of the district tested. Thus additional tests of the regional baseline concept are needed to support this early conclusion.

Transaction cost has been a contentious issue for mitigation projects, and efforts should be made to reduce the transaction costs. Standardization for development of regional baseline should be attempted, which would reduce transaction costs, though significant up-front work is required. Forest department, research organizations and state remote sensing agencies should develop standards for baseline accounting and measuring incremental carbon stocks. Guidelines and procedures must be efficient to keep the transaction costs low and avoid duplication of estimation and reporting.

It is feasible to measure the current carbon stocks at a project site, however predicting the future carbon stock if the project is not implemented involves uncertainty. This gives wide scope or flexibility to define a baseline with several trajectories. Thus, a regional baseline compared to project-specific baseline can standardize the approach to the construction of baseline. As shown for the energy sector (Parkinson et al. 2001), lifetime of the baseline is an issue for forestry mitigation projects. Shortening the lifetime reduces the uncertainty associated with the baseline.

A comparison of regional and project specific baseline in the present study has shown the reliability, feasibility and cost-effectiveness of adopting regional baseline for forestry sector mitigation projects. The initial cost for setting a national baseline and creating monitoring and verification systems may be higher than the project-by-project method (Hargrave et al. 1998) depending on the institutional arrangements. Over time, costs for estimating carbon stock changes using a regional baseline would be lower than for a project-by project method and should decrease in monitoring and verification costs.

The present study has demonstrated the utility of using existing GIS data for estimating land availability and suitability for A&R as well as for developing the regional baseline effectively.

Acknowledgements This work was supported by the U.S. Environmental Protection Agency, Office of Atmospheric Programs through the U.S. Department of Energy under Contract No. DE-AC02–05CH11231. Disclaimer: The views and opinions of the authors herein do not necessarily state or reflect those of the United States Government or the Environmental Protection Agency. The authors would also like to thank the Ministry of Environment and Forests for supporting and encouraging the research activities on climate change at the Indian Institute of Science. We also thank Jayant Sathaye and Ken Andrasko for their contribution at various stages of development of this study. This project was conducted under the USEPA-Ministry of Environment and Forests support.

References

Benitez P, Olschewski R et al (2001) Analisis costobeneficio de usos del suelo y fijacion de carbono en sistemas forestales de Ecuador noroccidental, Eschborn

Chomitz KM (1998) Baselines for greenhouse gas reductions: Problems, precedents, solutions, Report prepared for the Carbon Offsets Unit, World Bank, Development Research Group, World Bank

Davidson EA (1995) Spatial covariation of soil organic carbon, clay content, and drainage class at a regional scale. Landsc Ecol 10(6):349–362

de Jong Ben HJ (2001) Uncertainties in estimating the potential for carbon mitigation of forest management. For Ecol Manage 154:85–104

Eswaran H, Van den Berg E et al (1995) Global soil carbon resources. In: Lal R, Kimble JM et al. (eds), Advances in soil science: soils and global change, 1995. Lewis Publishers, CRC Press, Boca Raton, FL

FAO (1976) A framework for land evaluation. FAO Soils Bulletin 32

FAO (1984) Land evaluation for forestry. FAO forestry paper 48. Food and Agriculture Organization of the United Nations, FAO, Rome

FSI (1996) Volume equations for forests of India, Nepal and Bhutan, Forest Survey of India MoEaF, Government of India, 1996

Hargrave T, Helme N et al (1998) Options for simplifying baseline setting for joint implementation and clean development mechanism projects, Center for Clean Air Policy

Kaimowitz D, Angelsen A (1998) Economic models of tropical deforestation: a review, Center for International Forestry Research. Bogor, Indonesia

Kern JS, Turner DP et al (1998) Spatial patterns in soil organic carbon pool size in the Northwestern United States. In: Lal R, Kimbal JM et al (eds) Soil processes and the carbon cycle. CRC Press,Boca Raton, Florida

Kimble JM, Eswaran H et al (1991) Organic carbon on a volume basis in tropical and temperate soils. In trans. Int. Congr. Soil Sci. 14th, Soc soil Science. 1991. Kyoto, Japan, Vol. 5: pp 248–253

KSLUB (2001) Perspective land use plan for Karnataka – 2025 In. Karnataka State Land Use Board, Bangalore, Karnataka

Lambin EF, Baulies X et al (1999) Land-use and land-cover change implementation strategy In. Royal Swedish Academy of Sciences, Stockholm, Sweden

Masera O, Garza-Caligaris JF et al (2001) Modeling carbon sequestration in afforestation and forest management projects: The CO2fix V.2 Approach. Ecol Model 164(2003):177–199

Nabuurs GJ, Garza-Caligaris JF et al (2001) CO2FIX V2.0—Manual of a model for quantifying carbon sequestration in forest ecosystems and wood products. ALTERRA Report. Wageningen The Netherlands

NRSA (1995) Report on area statistics of land use/land cover generated using remote sensing techniques, National Remote Sensing Agency, Department of Space. Hyderabad

NRSA (2004) Atlas of wastelands map of India, National Remote Sensing Agency, Department of Space. Hyderabad

Paladina L, Pontius GR Jr (2004) Accuracy assessment and uncertainty in baseline projections for land-use change and forestry projects. http://www.clarku.edu/~rpontius/paladino_pontius_2004_ties.pdf

Parkinson S, Begg K et al (2001) Accounting for flexibility against uncertain baselines: lessons from case studies in the eastern European energy sector. Climate policy 1:55–73

Paul KI, Polglase PJ et al (2002) Change in soil carbon following afforestation. For Ecol Manage 168:241–257

Post WM, Izaurralde RC et al (2001) Monitoring and verifying changes for organic carbon in soil. Clim Chang 51:73–99

Sathaye JA, Meyers S et al (1995) Greenhouse gas mitigation assessment: A guidebook. Kluwer Academic Publishers

Sehgal J, Mandal DK et al (1992) Agro-ecological regions of India (2nd ed.) In Tech.Bull. NBSS Publ., 24. Oxford & IBH Publication Co. Pvt. Ltd. New Delhi and NBSS&LUP, Nagpur. 130

Sommer A, Murray B et al (2004) Project specific or performance-standard baseline? Testing the alternatives for a forest carbon sequestration project. In the 3rd DOE carbon sequestration conference, May 3–6, 2004. 2004. Alexandria, Virginia

UNFCCC (2002) Methodological issues land use, land-use change and forestry: Definitions and modalities for including afforestation and reforestation activities under article 12 of the Kyoto Protocol in the first commitment period: Options paper on modalities for addressing baselines, additionality and leakage. 2002

WRI/WBCSD (2003) The greenhouse gas protocol: Project quantification standard, in Road test draft (September 2003). 2003

World Resources Institute WRI, Mitigating climate change through forest and land use activities, 1999. http://www.wri.org/climate/mitigate.html