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FOREST CARBON STOCKS, STOCK CHANGES AND IMPLICATION TO FOREST MANAGEMENT IN INDIA

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ABSTRACT

Forest management hitherto focussed attention on increasing the woody biomass and conserve biodiversity. However, in the light of climate change and the international negotiations the forest management needs to be reoriented to enhance the carbon stocks of the ecosystem and also conserve the biodiversity. The inter-relationship of the carbon stock in different pools, their changes with respect to different management treatments under different climate conditions throws open a vast field for research to understand carbon dynamics of the forest ecosystem. Preliminary analysis of the total carbon stock per hectare of different forest types in different canopy densities indicate that the carbon stock change is different for different forest type. The study of this may have practical forest management significance which is indicated here.

Key words: Climate change, Forest management, Carbon stocks, Forest types.

Introduction

Forests play an important role in mitigating the adverse effects of climate change by absorbing carbon dioxide from atmosphere. Deforestation and degradation, however, release carbon dioxide increasing its concentration in atmosphere. It is, therefore, the responsibility of all stake holders of forestry systems to prevent deforestation, and degradation and maximise carbon sequestration to mitigate the effects of climate change through various management options available. Knowledge of carbon stocks and their changes over time will, therefore, be one of the important forest management requirements under the climate change paradigm. Although wood / biomass oriented forest management is over a century old its association with carbon *per se* is of very recent origin. Many dimensions of carbon sequestration by different forest types under different silvicultural systems and management regimes are yet to be studied. These studies become important under REDD+ programs where not only carbon stocks are to be enhanced but the biodiversity conservation also is to be taken care of.

REDD+ requirements in International negotiations

The five finally agreed terms of international negotiations on climate change with respect to forestry are reduction of deforestation and degradation, sustainable forest management, conservation and enhancement of carbon stocks (UNFCCC/CP/2010). 'Conservation' in this context means the conservation of carbon stocks and also of the biodiversity essential for the livelihood of the local dependent communities. Under the REDD+ regime, therefore, the job of forest manager becomes a delicate balancing act and he/she will have to be better equipped with the knowledge of carbon stocks, the changes under different silvicultural systems and treatments.

Limitations in measurements of tropical forests

About two thirds of world forest resources are in the tropical regions. These tropical forests are characterised by the presence of a large number of species on every unit of forest area. Different species grow at different rates, attain different dimensions and generally have different wood densities. In the absence of rings in most of the species not age but the distribution of different species in different diameter classes is important. The management of such forests becomes a highly skilled job if we want to retain the original crop composition which the nature produced. This is because management practices generally tend to favour or disfavour one or the other species unless the management prescriptions are in tune with nature on every site. The growth, increment and the potential productivity of these forests have not been studied adequately probably because of the complex nature of the problem and long time required to reach any meaningful results.

The carbon stock measurements in India

In India FSI has been carrying out National Forest Inventory since 2002. The basic objective has been to collect the quantitative information of the forest resources of the country. Two 0.1 ha plots are laid out in a grid of 2.5'X2.5'. Growing stock information by species is

Preliminary analysis of the total carbon stock per hectare of different forest types in different canopy densities indicate that the carbon stock change is different for different forest type.

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Table 1 : Total carbon in tons per hectare for five forest types by three canopy densities in India

Canopy density	Mid-point of canopy density class	Tropical semi-evergreen	Tropical moist deciduous	Tropical dry deciduous	Montane and moist temperate	Subtropical pine
Very dense 0.7+ (VDF)	0.85	181.50	124.99	151.41	176.46	156.86
Moderately dense 0.4-0.7 (MDF)	0.55	117.73	95.39	136.26	139.75	104.53
Open forest 0.1-0.4 (OF)	0.25	75.32	65.25	48.30	88.86	77.61

compiled for which volumetric equations of different species in different regions have been evolved through the data collected during the inventory. For getting the carbon stock data of dead wood and leaf litter additional studies on assessing these were undertaken. For assessing the soil organic carbon, soil samples were collected and analysed in the laboratories. For the underground biomass default values as recommended by IPCC were used. It is, however, felt that adopting default values for below ground biomass may be replaced by actual values for different forest types by undertaking special studies in the next cycle of carbon stock assessment even if these studies are destructive in nature. The detailed methodology is given in the FSI report (FSI, 2013).

The data of sample plots falling in different forest types was analysed separately for the three forest canopy density classes (very dense forest-canopy density more than 0.7; moderately dense forest –canopy density 0.4-0.7; and open forest- canopy density 0.1 -0.4) for compiling the carbon stock information.

A forest type represents a definite crop composition within a range of environmental parameters. Reporting the carbon stock information for various forest types and canopy density classes, thus, has a better ecological sense than reporting the same by manmade district boundaries.

The figures reported in FSI report seem to have an important bearing on the management of forest ecosystems. They also imply that a variety of research activities are needed to better understand carbon sequestration by different pools under different soil, moisture, temperature and treatment conditions.

Carbon stock changes and the forest types

A few observations on the carbon stocks of five forest types occupying large extent of the area, under three crop canopy densities based on the data given in FSI report are presented in Table 1.

Following inferences are drawn from the above data and graph (Fig. 1).

1. The slopes of the lines depicting carbon stock change with canopy density are different for different forest types. The above lines show the change in the total of five carbon pools with canopy density, the above ground biomass being one of them. It can be seen that the Tropical dry deciduous forests gain most in terms of carbon stock when the canopy density increases from open to moderately dense category while the gain in carbon is minimum when in the same forest type the canopy density changes from moderately dense to very dense category. However, in case of subtropical pine forest and semi evergreen forests of western ghats the carbon stock builds up slowly as the canopy increases from open to moderately dense forest category but its growth is more when the canopy density increases from moderately dense to very dense category. These differences become important in deciding the restocking priorities of different forest types for immediate gain of carbon. The increase in carbon stock as the canopy density increases from open to moderately dense forest for the five forest types is given in the first row of the table 2. The increase in carbon stock as the canopy increases from moderately dense to very dense category is given in the second row of the Table 2.

Table 2 : Carbon stock change with canopy density for different forest types

Change in canopy density	Tropical semi-evergreen	Tropical moist deciduous	Tropical dry deciduous	Montane & moist temperate	Subtropical pine
Open to moderately dense forest	42.41 (5)	30.14 (7)	87.96 (1)	50.89 (4)	26.92 (9)
Moderately dense to very dense forest	63.77 (2)	29.6 (8)	15.15 (10)	36.71 (6)	52.33 (3)

(Changes in t/ha are given and the figures given in parentheses are suggested restocking priorities)

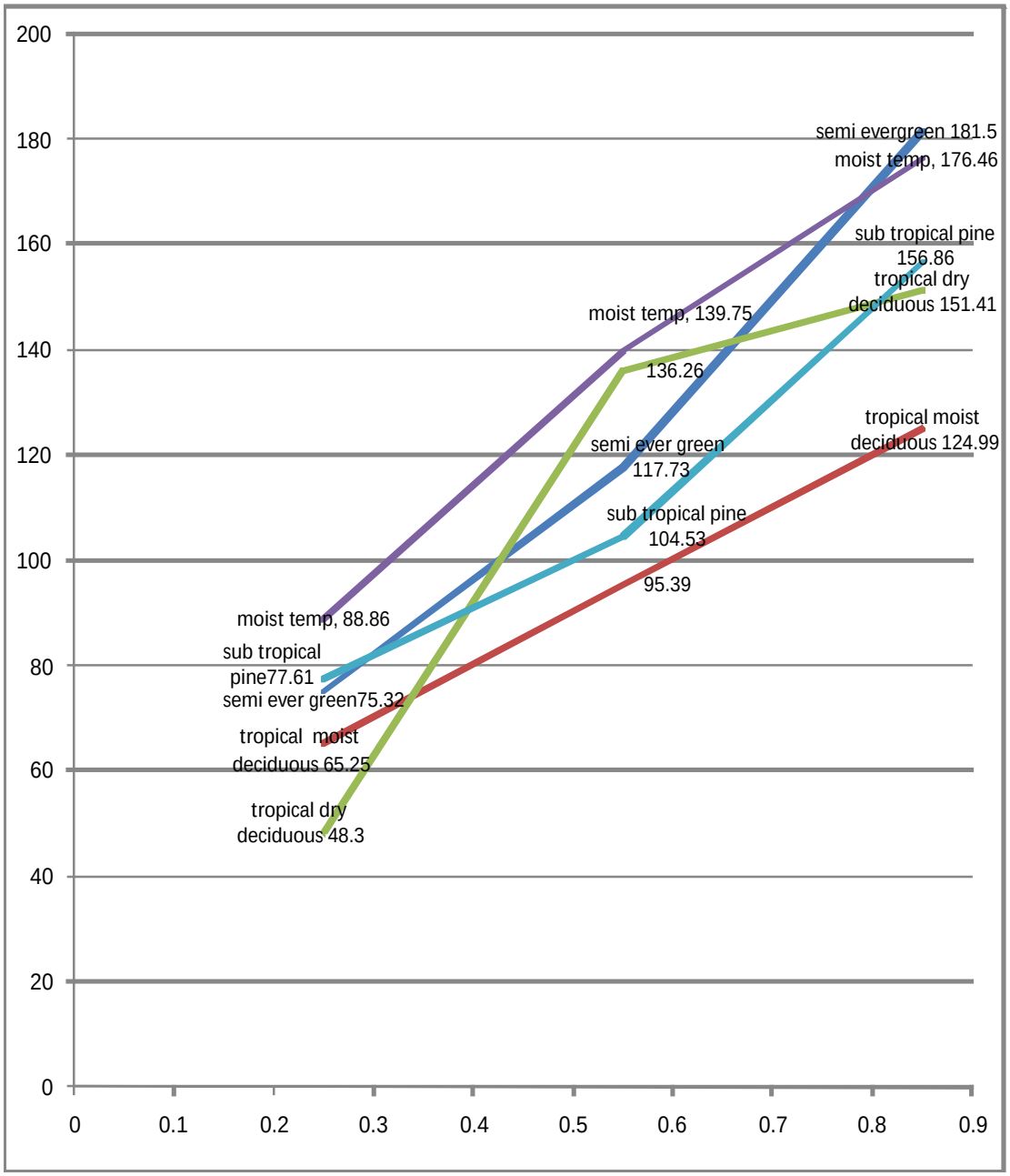

Fig. 1 : Carbon stock change with canopy density for five forest types in India (C stock in tons per ha on y axis and canopy density on x axis)

Restocking of open category of tropical dry deciduous forests is more important, for gain in carbon stock than restocking of open moist deciduous forests. These two forest types comprise about 42 and 19 per cent, respectively, of the total forest area of the country.

2. The difference in the growth of carbon stock of different forest types with canopy density may probably be due to, besides the different rates of growth of Above Ground Biomass of these forest types, drop in soil temperature which seems more pronounced in dry forests than in others. The rapid increase in carbon stock in going from moderately dense to very dense as in case of semi ever green forest may be due to interaction of soil moisture and reduced soil temperature at higher canopy density.

3. It may be noted that the above curves are drawn with canopy density on x axis and carbon stock on y axis. The time taken to reach different canopy densities may be different for different forest types (species composition) and cannot be read from these graphs. And to that extent the restocking priorities suggested above will undergo changes. Separate study may be required to do this.

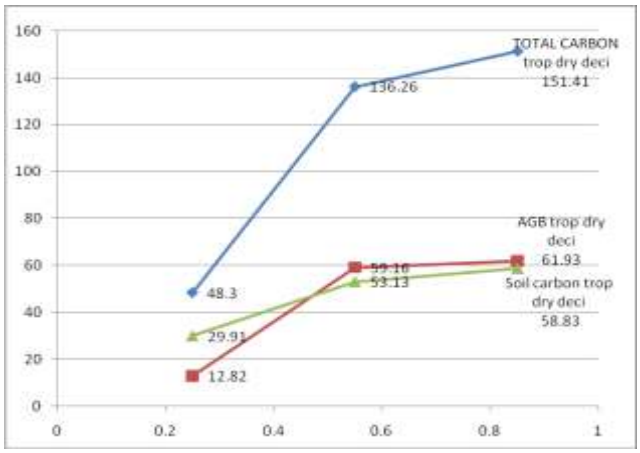

Fig. 2

The soil carbon content in all the forest types is substantial compared to the general perception of foresters. It is 40-70 per cent of the total carbon content and is as high as the carbon content of the above ground biomass. Within the same forest type the percentage of the soil carbon is more in the lower canopy density. This probably is because of the fact that the soil carbon changes are much slower compared to canopy density changes. The carbon stock changes more rapidly initially with canopy density in tropical dry deciduous forests than in the temperate forests but slows down after the crown closure.

It can be seen that soil carbon changes are slower than those of AGB. "Soils in equilibrium with a natural

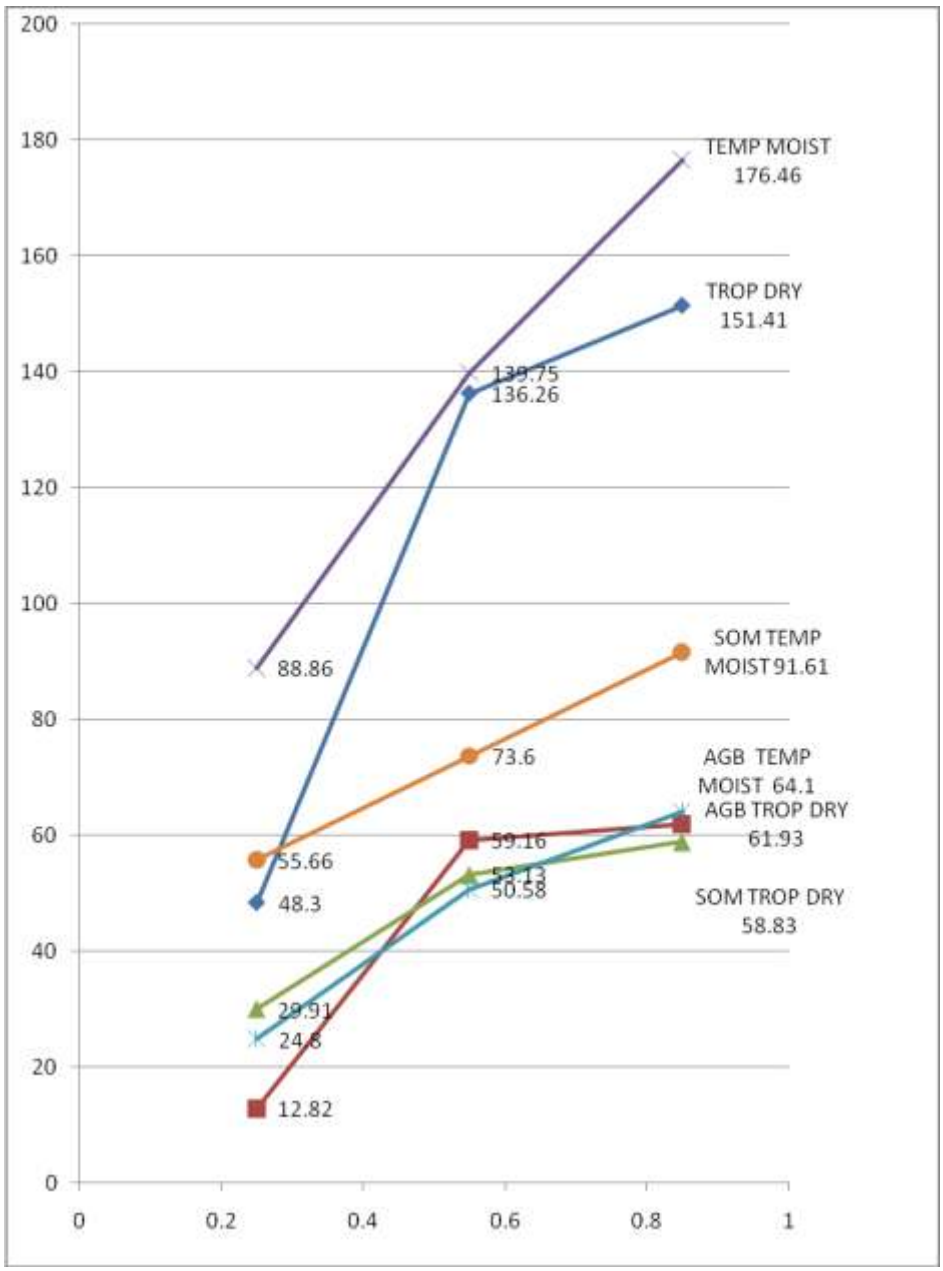

Fig. 3 : Changes in soil carbon, carbon in AGB and the total carbon with canopy density

Table 3 : Carbon stock changes in AGB and SOM in two forest types

Canopy Density of crop	Tropical dry deciduous	AGB t /ha	% of AGB to total	SOM	SOM % to total	Montane and moist temperate	AGB t /ha	% of AGB to total	SOM	SOM % to total
	(A)	(A)	(A)	(A)	(A)	(B)	(B)	(B)	(B)	(B)
VDF	151.41	61.93	40.9	58.83	38.8	176.46	64.1	36.3	91.61	51.9
MDF	136.26	59.16	43.4	53.12	39.0	139.75	50.58	36.2	73.6	52.7
OF	48.30	12.82	26.5	29.91	61.9	88.86	24.8	27.9	55.66	62.6

forest ecosystem have high carbon density.....Fire, natural or managed, is an important perturbation that can affect soil carbon stock for a long period after the event''(Lal, 2005)

The changes in soil carbon, carbon in AGB and the total carbon with respect to canopy density of two forest types are shown in Fig. 3.

Soil carbon content of temperate moist forest is always more than the AGB carbon.

It seems that the temperature plays important role in carbon loss of a forest.

Forest Management plans and the carbon stocks

Given the present climate-change scenario it appears certain that future forest management plans may require better understanding of carbon changes with different management treatments on the part of forest manager. The carbon stock of compartments, the smallest unit of management generally having uniform crop composition, and that of working circles will have to be monitored periodically at the time of every revision of the management plan. The FSI carbon stock data is good for estimation of the stock at national level. For more precise carbon stock information at the forest division level higher intensity of sampling may be required. Within the same forest type there may be lot of variation in the carbon stocking depending upon the site quality and other locality factors at different locations. ''The carbon storage capacity of the stable pool can be increased by increasing the productivity of the forest thereby increasing the Carbon input to the soil'' (Jandi *et al*., 2007).

In their submission to UNFCCC, Government of India has accepted that by 2017 the sub national level carbon stock information at State and District level will have ± 20% accuracy. This commitment calls for greater effort on capacity building of the state forestry personnel in updating their knowledge and skills with regard to carbon stock assessment and efforts to reorient management perspective.

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