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Status of soil carbon sequestration under different land use systems in *Terai* Zone of West Bengal

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Abstract: A study consisting seven land use systems fallow land, agriculture field, pure plantation of *Dalbergia sissoo*, tea garden, agri-horticulture agroforestry system, pure plantation of *Terminalia arjuna* and natural forest of *Shorea robusta* at four soil depths (0-10, 10-20, 20-30 and 30-40 cm) were studied to know the impact on carbon sequestration potential at Pundibari, West Bengal, India during September, 2004 to August 2006. It was found that the mean soil organic carbon (SOC) per cent was highest (1.46) in natural forest of *Shorea robusta,* which was significantly higher than rest of the land uses while mean SOC per cent in soil depth was highest in 0-10 cm depth. SOC stock was highest (17.69 t/ha) in natural Forest of *Shorea robusta*, followed by pure plantation of *Terminalia arjuna* (13.29 t/ha), agri-horticulture agroforestry system (12.14 t/ha), pure plantation of *Dalbergia sissoo* (10.66 t/ha), tea garden (10.45 t/ha), agricultural field (6.99 t/ha) and lowest amount of SOC stock was present in fallow land (10.05 t/ha). It was also observed that mean SOC stock was significantly higher (14.57 t/ha) in 0-10 cm depth and lowest (9.33 t/ha) in the 30-40 cm soil depth.

Keywords: Land-use, carbon sequestration, soil organic carbon, soil depth, *terai* zone

Introduction

In today's context of population explosion coupled with pollution, environmental degradation and climate change, increased concentration of CO_2 effecting climate and health of the global environment is a subject of intense scientific, social and political concern. Natural forests play an important role in reducing atmospheric CO_2. However, other land management systems also contribute in tapping CO_2. Carbon sequestration potential nevertheless, differs with the kind of land use. Soil is one of the main sinks of carbon on earth especially forest soil because these soils have normally higher soil organic matter (Jha *et al*., 2003). Soil organic carbon store has great importance to conserve carbon and restrict the carbon emission while quantification of soil carbon store is useful to know the total soil carbon sink and to formulate future strategies not only to conserve this sink but also to increase it by bringing more and more wasteland, degraded land and other unusable land under afforestation programme (Lal, $2004_{a,\ b}$ & 2005; Jose 2009). But due to increased population pressure as in India, immediate requirement is to provide food and in such situation much of the land cannot be spared for increasing forest cover. Moreover landholdings of most of the farmers in developing countries are less and they cannot spare land to permanent tree cover as it will not provide immediate benefit.

Status of carbon depends upon biomass production capacity and interaction between edaphic, climatic and topographic factors of an area. Hence results obtained at one place may not be applicable to another. In such circumstances, studies on the land use systems are crucial for determining storage of the carbon and computing the carbon cycling at a regional as well as global level. Therefore, region based potential of different land use needs to be worked out. Thus the present study was aimed at assessing the suitability of tree based land use systems as alternative to continuous cropping and permanent grasslands. The assessment is based on the system's ability to sequester and store carbon.

Study area

The study site is a *terai* zone of West Bengal which lies between 26^{o} 30$^{'}$ North and 26^{o} 56$^{'}$ North latitude and 88^{o} 7$^{'}$ East and 89^{o} 53$^{'}$ East Longitude at an elevation of 43 metres above mean sea level with annual rainfall of 250-300 cm from south-west monsoon of which 80 per cent is received from June to August. It covers an area of 12,015 sq. kms covering districts of Cooch Behar and Jalpaiguri. The land use pattern of this region can be classified into five broad categories. About 50 per cent of the land is net sown and 22 per cent is under non-agricultural uses. Forests occupy a little over 14 per cent mainly confined to the Jalpaiguri district and Siliguri sub-division of Darjeeling district. Orchards and plantation crops occupy about nine per cent of the land, tea being the most important commercial plantation crop dominantly grows in Jalpaiguri district. The area under barren land is about four percent and one per cent falls under fallow and cultivable waste. The climatic condition of terai zone is sub-tropical humid in nature.

Methodology

Seven land uses namely fallow land (FL), agriculture field (AF), tea garden (TG), agrihorticulture agroforestry (AHF) system, plantation of *Dalbergia sissoo* (PDS), plantation of *Terminalia arjuna* (PTA) and natural forest of *Shorea robusta* (NASR) at four soil depth (0-10, 10-20, 20-30 and 30-40 cm) were studied for comparing their carbon sequestration potentials. Plot size of 1 x 1 m for grasses and 10 x 10 m for tree based land use systems were taken for soil sampling. Composite soil samples were collected separately from 0-10, 10-20, 20-30 and 30-40 cm depth with the help of Dutch augur from all the plots with five replications. Samples were air dried in shade, grinded with wooden pestle, passed through 2 mm sieve and stored in cloth bags for further laboratory analysis. Walkley and Black's rapid titration method (Jackson, 1967) were fallowed for soil organic carbon estimation. Soil organic carbon stocks were calculated by multiplying the organic carbon with weight of the soil (bulk density and depth) for a particular depth and expressed as mega grams per ha^{-1} ($Mgha^{-1}$) as expressed by Joao Carlos *et al*. (2001). The data obtained was subjected to two way ANOVA statistical analysis following methods suggested by Gomez and Gomez (1984) using the package "INDOSTAT".

Results and Discussion

Soil Organic Carbon (SOC) Content

Among the land uses, mean SOC content was highest in NFSR (1.46 %) which was significantly higher then rest of the land uses studied (table 1). This was followed by PTA (1.0), AHF (0.89), PDS (0.76), TG (0.74), FL (0.65) and the lowest SOC content was recorded in AF (0.447 %). The organic carbon content in the soil also varied with its depth. Highest of 1.08 per cent was recorded on the top layer (0-10 cm) which then gradually decreased with increasing depth while the lowest of 0.67 per cent was recorded at the deepest layer studied (30-40 cm). The upper most soil layer was recorded with highest SOC because of litter presence on it. Natural forest always had highest SOC content due to the presence of vegetation that enhances the SOC content through its continuous production and decomposition of litter. Contrary to this, agricultural fields which had only herbal vegetation and also majority of it is removed by harvesting, contribute the lowest amount of crop residues to soil, resulting lowest SOC content in its soil. This is because SOC varies with the extent and type of vegetative cover on the land which was also reported by workers like Ravindranath and Somashekhar (1995), Jha *et al*. (2003), Sharrow and Ismail (2004) and Ladegaard *et al*. (2005).

Table 1 Effect of land-use and soil depth on SOC

Land use	SOC (%)				Mean
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	
FL	0.79	0.66	0.58	0.56	0.65
AF	0.56	0.50	0.44	0.40	0.48
TG	1.05	0.81	0.62	0.49	0.74
AHF	1.00	0.83	0.89	0.82	0.89
PDS	1.26	0.74	0.62	0.40	0.76
PTA	1.16	1.03	0.94	0.87	1.00
NFSR	1.77	1.53	1.38	1.16	1.46
Mean	1.08	0.87	0.78	0.67	

$CD_{(p=0.05)}$ Land use = 0.126; Soil depth = 0.053

Soil organic carbon stock

As was discussed above for the SOC content, SOC stock also exhibited the exact trend as SOC content with varying land use systems and soil depths (table 2). The highest average total SOC estimate of 17.69 $Mgha^{-1}$ up to 40 cm soil depth was recorded for NFSR which coincides with that reported for other tropical moist deciduous forests in India i.e. 8.9-176.1 $Mgha^{-1}$ of top 50 cm depth (Chhabra and

Dadhwal, 2005). However it was far lesser than the national average of SOC i.e. 182.94 $Mgha^{-1}$ (Jha *et al.*, 2003) which can be attributed to higher rates of decomposition due to high temperature. SOC store has great importance to conserve carbon and restrict the carbon emission. Temperate forests have unique feature to accumulate high quantity of soil organic matter and litter because of slow decomposition rate due to low temperature (Jha *et al*., 2003) and the reverse was true for the condition of the present study area which explains the lesser total SOC. Moreover as discussed earlier the organic carbon stock in the soil also varied with its depth. Highest of 14.57 $Mgha^{-1}$ was recorded on the top layer (0-10 cm) which then gradually decreased with increasing depth while the lowest of 9.33 $Mgha^{-1}$ was recorded at the deepest layer studied (30-40 cm). Carbon stock is intricately linked with site quality, nature of land use, choice of species and other management practices adopted (Swamy *et al*., 2003) which explains the varying carbon stock in different land use management and also at different soil depths. This in turn is due to the effect of differential litter addition in different land uses (Singh *et al*., 2004). Thus accumulation of SOC in different land uses through litter fall is different that might have regulated varying organic matter decomposition and the formation of stable and labile soil organic matter pool in these land uses studied (Vitousek and Sanford, 1986). Further the SOC concentration in most cultivated soils is less than 5 g/kg compared with 15 to 20 g/kg in uncultivated soils. Low SOC stock in the cultivated land uses of the present study can be attributed to plowing, removal of crop residue and other biosolids, and mining of soil fertility (Lal, $2004_{\mathbf{b}}$). Soil plays a key role in the global carbon budget and greenhouse effects (Jha et al., 2003). Soil accumulated greater amount of carbon as compared to forest litter as the target quantities of C is stored for longer period of time in the soil then in live component of terrestrial ecosystem (Schlesinger, 1977). It also influence the amount of biomass and carbon stored in vegetation (Anon, 2000). The conservation of natural forests to tree plantations and perennial crops reduce carbon density by at least 50 % when compared to natural forests (Lasco, 2002).

Table 2. Effect of land-use and soil depth on soil organic carbon stock

Land use	SOC stock ($Mgha^{-1}$)				Mean
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	
FL	11.96	10.15	9.11	8.92	10.05
AF	8.17	7.38	6.47	5.98	6.99
TG	14.44	11.27	8.89	7.16	10.45
AHF	13.47	11.27	12.36	11.45	12.14
PDS	17.52	10.42	8.84	5.79	10.66
PTA	15.17	13.64	12.53	11.80	13.29
NFSR	21.21	18.46	16.83	14.27	17.69
Mean	14.57	11.80	10.73	9.33	

$CD_{(p=0.05)}$ Land use = 1.55; Soil depth = 0.69

Conclusion

It can be concluded from the study that selecting better and efficient land use management is the best option to content the increasing level of atmospheric level of carbon dioxide. According to the Kyoto Protocol, land use, land use change and forestry (LULUCF) was recognized as serving the role of carbon sources and sink in relation to a change in land cover and carbon stock. Natural forest and pure plantations though sequester more carbon and hence are better options for reducing atmospheric carbon but they cannot be extended to large areas due to population pressure and high demand of land for agricultural purposes. Therefore, agroforestry systems seem to be the best alternative to minimize atmospheric carbon and simultaneously harness opportunity for biodiversity conservation and economic benefits to society. Associating nitrogen fixing trees in agroforestry systems will certainly help in improving the production and sustainability of the system. This is particularly necessary because more then 50 per cent of the country's land is degraded. Moreover the remaining natural forests need to be conserved for today and for the future generations.

Authors' contributions: D. N. Koul *(Student), For the master's thesis performed the experiments, recorded and analysed the data;* ***G. Shukla*** *(Fellow Student) contributed while executing the research work full time from taking data to analyzing it;* ***Dr. P. Panwar*** *(Assistant Professor) Project leader and contributed in experiment design;* ***Dr. S. Chakravarty*** *(Assistant Professor), co-investigator for the project, contributed in experiment design, preparation, wrote, final editing of the manuscript and corresponding author of manuscript.*

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