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EVALUATION OF TOBACCO BASED LAND USE SYSTEMS - EFFECTS ON SOIL ORGANIC CARBON DYNAMICS AND CARBON MANAGEMENT INDEX

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Six contrasting land use systems including Eucalyptus, Oil Palm, Sugarcane, Fallow – Tobacco, Paddy – Tobacco and Green manure (Sunnhemp) Tobacco were evaluated for their effects on soil carbon (C) storage, stratification, C fractions and carbon management index (CMI). The total organic carbon (TOC) content was significantly greater in surface soil layer (0.00-0.15 m) under all the land use systems and showed a decreasing trend with increase in soil depth. The TOC in 0.00-0.05 m soil layer was maximum under Oil Palm (8.52 g/kg) while it was minimum in Fallow- Tobacco system (3.54 g/kg). The highest and the lowest soil organic carbon storages were recorded by Eucalyptus system (34.77 Mg/ha) and the Fallow - Tobacco system (20.46 Mg/ha), respectively. The labile fraction of SOC also showed a decrease with increasing soil depth. The Oil Palm system that received organic manures showed relatively large quantity of labile carbon (CL) (480 mg/kg) in surface soil (0.00-0.05 m). The CMI, an index of soil quality, was the highest (71) under Eucalyptus system and the lowest (35) in Fallow-Tobacco system at surface layer as compared to the forest soil as reference having CMI value of 100. Stratification ratio of TOC for Green manure (sunnhemp) – Tobacco system has uniform values at all the depths, indicating that this system has maintained uniform TOC at all depths. The lowest SOC storage as well as CMI observed in Fallow – Tobacco may be attributed to the fact that entire plant biomass (leaves, stems and roots) is generally taken off the field. This study demonstrates that the monocropping (Fallow – Tobacco) of tobacco leads to a depletion of soil organic carbon and its quality, and hence calls for use of organics at liberal rates for sustaining the soil quality and production sustainability.

Key words: Carbon management index, Land use systems, Soil organic carbon, Tobacco

INTRODUCTION

Soil organic matter (SOM) plays an important role in maintaining the fertility and productivity of tropical soils because it provides energy and substrates, and promotes the biological diversity that helps to maintain soil quality and ecosystem functionality. SOM directly influences soil quality, due to its effects on soil properties (Wendling *et al.*, 2010). The concept of soil quality has recognized soil organic matter as an important attribute that has a great deal of control on many of the key soil functions (Doran and Parkin, 1994). However, soil organic matter generally increasing with higher crop residue inputs and cropping intensity (Franzlubbers *et al.*, 1998) with native vegetation compared with cultivated management (Burke *et al.*, 1989). There was an increased SOM content in the integrated coconut orchard soil due to the presence of cover crops as well as management of crop residues (Guimaraes *et al.*, 2013). The input of organic matter via below ground and above ground return of plant residues is the main source of soil C. Although the breakdown rate of SOM can be faster in tropics, regular inputs of organic amendments can promote a build up of SOM (Follett, 2001).

Due to the complexity of SOM compounds, the relationship between SOM characteristics and land use is poorly understood. Hence, knowledge of different pools of SOM under different land use systems should render the impact of soil quality. Total soil organic carbon (TOC) is commonly used to provide a measure of soil organic matter; however it is relatively insensitive to changes in soil organic matter because of the large pool of recalcitrant (non labile) C. This non labile C (C_{NL}), by its nature, changes very slowly. Labile C (C_L) is the fraction of soil organic carbon (SOC) with most rapid turnover times and its oxidation drives the flux of carbon dioxide (CO_2) between soil and atmosphere.

The soil organic C pool and the C lability directly influence soil physical, chemical and biological attributes as well as the self-organization capacity of soils. Integrating organic C pool and C lability into a C management index (CMI), originally proposed by Blair *et al.* (1995) can provide a useful parameter to assess the capacity of land use/ management systems into promote soil quality.

The stratification of SOC pools with depths in undisturbed soil (i.e natural vegetation) is a natural process governed by continuous input of C by litter at the soil surface and less input with soil depth (Prescott *et al.,* 1995; Franzlubbers, 2002). Franzlubbers (2002) defined SR as the ratio of parameter values in the soil surface with that at a lower depth, such as the bottom of the tillage layer. This lower depth is used to normalize the assessment and make valid comparisons among soils from different eco regions or land scape positions with inherent differences in soil capability. The SR of SOC among different land use and cropping systems such a comparison may be useful to determine changes in SR caused by different land use.

Stratification of soil organic matter pools with soil depth is common in many natural ecosystems (Prescott *et al.,* 1995) as well as when degraded crop land is restored with conservation tillage (Dick, 1983). The soil surface is the vital interface that receives much of the fertilizers and pesticides applied to crop land and receives the intense impact of rainfall and partition of the flux of gases into and out of soil.

A potential approach to mitigate rising CO_2 concentration quite apart from the development of energy as soil carbon storage is important phenomenon, tobacco soils are with very less carbon storage capacity and there is no addition of plant biomass in the form of residues to the soil, so soil carbon storage in the form of organic matter is very important for maintaining soil quality.

Most of the previous studies, In the northern light soils (NLS) of tobacco region of West Godavari, focused on fertility evaluation and crop yields in relation to soil, water and fertilizer management, but how the land use and cropping systems affect the pools of soil organic carbon is not well studied. Increasing the cultivation of tobacco in the same land has become a major cause of depletion of soil organic carbon pools and carbon stocks in comparison with other land use systems like eucalyptus, oil palm, sugarcane, paddy-tobacco, and green manure-tobacco cropping systems. Therefore, assessing soil quality of the northern light soils is of paramount importance in the NLS region.

The objectives of the present investigation are to assess changes in total soil organic carbon and its various pools in response to various land uses and depth wise distribution of various soil C fractions under different land use systems and to critically examine the impact of different land uses on soil quality in terms of Carbon Management Index (CMI). In spite of the existence of a large number of soil fertility experiments that can provide a lot of relevant data pertaining to soil management however, few studies are there that integrate the total soil organic C pool and the C lability into the CMI as the way to assess the capacity of management systems to promote soil quality. Labile fractions of organic matter can respond rapidly to changes in C supply and are considered to be important indicators of soil quality. However much less is known on the impact of different land use systems and depth on labile organic matter fractions.

MATERIALS AND METHODS

The work was conducted between April and August 2013 on NLS region of tobacco soils comprising West Godavari and East Godavari districts of Andhra Pradesh and Khammam district of Telangana state, India. The soil is sandy loam in texture and belongs to Alfisol. Six different and contrasting land use systems selected for the study (Table 1) were Eucalyptus (E), Oil Palm (O), Sugarcane (S) are plantation crops and Fallow-Tobacco (FT), Paddy- Tobacco (PT) and Green manure (sunnhemp) – Tobacco (GT) are different tobacco cropping systems. Forest system was selected for reference.

Table 1: History of land use systems selected for the study

Land Use	Location (Northern light soil) Region	Description
Eucalyptus	Buttayagudem, $17^0 12'$ N longitude $81^0 8'$ E latitude. West Godavari, Andhra Pradesh.	Tree litter, specially leaf litter is adding every year and there was no separate organic manures applied. Combination of potash, urea and super phosphate at the rate of 3 bags per acre applied twice in a year. Previously the land was not subjected to any cultivation
Oil Palm	Dippakayalapadu, $17^0 12'$ N longitude $81^0 8'$ E latitude. West Godavari, Andhra Pradesh.	This system is under practice for the past 14 years. Tree litter in the form of fronds is incorporating in to the soil. Vermicompost, farmyard manure at the rate of 20 kg was applied to each tree. Urea ½ kg, super phosphate and Boron 100 g were applied. Previously tobacco cultivation was practiced in this place.
Sugarcane	Dippakayalapadu, $17^0 12'$ N longitude $81^0 8'$ E latitude. West Godavari, Andhra Pradesh.	Complex fertilizer 17-17-17, urea 100 kg, MOP 150 kg, per acre. Farmer incorporating sugarcane trash every year in to the soil, Farm yard manure also applied. Since from beginning there was only sugarcane crop.
Fallow- Tobacco	Chinnayagudem, $17^0 12'$ N longitude $81^0 8'$ E latitude. West Godavari, Andhra Pradesh.	Continuous tobacco cultivation for the past 15 years. There is no addition of organic manures.
Paddy- Tobacco	Chinnayagudem, $17^0 12'$ N longitude $81^0 8'$ E latitude. West Godavari, Andhra Pradesh.	Fallow- Tobacco system changed to the Paddy-Tobacco from more than 15 years every year paddy stubbles are incorporated in to the soil.
Green manure - Tobacco	CTRI, RS, Jeelugumilli, $17^0 12'$ N longitude $81^0 8'$ E l atitude. West Godavari, Andhra Pradesh.	Fallow- Tobacco system changed to green manure (Sunnhemp) - Tobacco system. Sunnhemp as green manure crop is grown and biomass incorporated into the soil every year and is practiced for more than 10 years
Forest (Reference)	Jeelugumilli, $17^0 12'$ N longitude $81^0 8'$ E latitude. West Godavari, Andhra Pradesh.	Natural vegetation consisting of different kinds of trees, shrubs and plants.

Soil sample collection and preparation

The soil samples of four different depths (0.00 – 0.05, 0.05 – 0.15, 0.15 – 0.30, and 0.30 – 0.45 m) with 3 replicates were collected from the six different land use and cropping systems and forest soil as reference in May & June 2013. All chemical results are means of triplicate analysis. Soil samples were air dried and ground using pestle and mortar and subsequently sieved through a 2 mm sieve. The soil pH (1:2.5 soil water suspension) and electrical conductivity in soils were estimated (Jackson, 1973), Phosphorus was extracted with Olsen's reagent (0.5 M $NaHCO_3$) and potassium was by neutral normal ammonium acetate. The total organic carbon (TOC) was determined by combustion method, sub samples of air dried <2mm soil were further ground and passed through 1mm sieve for determination of TOC content using TOC analyzer. The organic carbon in soil was estimated (Walkley and Black, 1934) and the amount of carbon in soil which is oxidizable by 20 mM $KMnO_4$ is considered as Labile Carbon (LC) which was determined by following the procedure (Blair *et al.*, 1995) and modified by Weil *et al.* (2003). Soil samples of 3 g were placed in 50ml centrifuge tubes and 30 ml of 20 mM $KMnO_4$ were added. The suspensions were horizontally shaken for 15 min and centrifuged at 2000 rpm for 5 min. The supernatant solution was separated, diluted with distilled water at the proportion of 1:25 and then its absorbance at 565 nm was measured. The depletion of $KMnO_4$ concentration was directly related to the concentration of oxidizable C, namely of labile C, assuming that 1 mM MnO_4^- is consumed to oxidize 9 mg of C. In order to prevent $KMnO_4$ photo oxidation, care was taken to avoid the incidence of light on the solution and microbial biomass carbon (MBC) was estimated by fumigation extraction method (Jenkinson and Powlson, 1976). Separate samples from each site at each depth were collected and kept in oven at 60^0C for measuring Bulk density of the soil by core method.

Carbon management index

The CMI was obtained according to the mathematical procedure used by (Blair *et al.*, 1995), which are described below:

Carbon management index is the product of carbon pool index and carbon lability index size.
CMI = CPI x LI x 100

Where CPI is the carbon pool index and LI is the lability index.

The CPI and the LI are calculated as follows:

A. Carbon pool index (CPI): The loss C from a soil with a small C pool size is of greater consequence than the loss of same quantity of C loss from a soil with a large C pool size. To account for this, a CPI (ratio of total C pool in sample soil to total C pool in reference soil).

$$CPI = \frac{\text{C pool in sample}}{\text{C pool in reference}}$$

B. Carbon lability index (CLI): Loss of labile C is of greater consequence than the loss of non-labile C. To account for this, a CLI (ratio of carbon lability in sample soil to carbon lability in sample soil to carbon lability in reference soil) is calculated as

$$LI = \frac{\text{L in sample}}{\text{L in reference}}$$

Where L refers to the C lability, calculated as

$$L = \frac{\text{Content of labile C}}{\text{Content of non-labile C}}$$

Stratification ratio

The concept of SOM stratification is offered as an alternative soil quality assessment protocol to overcome their inherent differences in soil capability among environments. Stratification, in this context is defined as a soil property at the soil surface divided by the same soil property at the lower depth. The lower depth is used to normalize the assessment, so that soils from different eco regions or land use positions varying in inherent soil capability can be fairly compared (Franzluebbers, 2002). The SR of various parameters were calculated by dividing the concentration determined for each TOC in (0.00 – 0.05, 0.05 – 0.15, 0.15 – 0.30 m) layer with 0.30 – 0.45 m layer. The soil organic carbon storage was calculated by multiplying TOC with bulk density at each depth. Carbon and P stratification ratios (CSR and PSR) were calculated by dividing the SOC or extractable P concentration determined in each layer by the SOC or P concentration determined in each layer by the SOC or P concentration in the 17.5-20.0 cm layer of each sampled profile respectively (Diaz- Zorita, 2002).

Soil organic carbon storage

It is the sum of the product of bulk density and total organic carbon at all the four depths studied. Soil organic carbon storage in 0-0.05 m, 0.05-0.15 m, 0.15-0.30 m and 0.30-0.45 m depths was estimated on volume basis by taking into account the bulk density and TOC concentration in respective soil depths.

Statistical analysis

Analysis of variance was used to test for treatment effect, and means between land use systems were compared using t test at the 5% probability level.

RESULTS AND DISCUSSION

General characteristics of NLS soils collected from different land use system

General characteristics of the soil were calculated among all the land use systems (Table 2) Soil pH was in acidic range for all the tobacco based cropping systems while it was neutral or slightly alkaline for other systems. Higher soluble salts content (EC) was observed in all the land use systems in the surface layers. Higher accumulation of phosphorus was observed in the sub-surface layer (15-30 cm) among all the land use systems. An increase in content of potassium with increase in depth was observed among all the land use systems due to the problem of potassium leaching in this Northern Light Soils of tobacco.

Total organic carbon

The highest accumulation of TOC was observed in case of Oil Palm while Fallow- Tobacco showed the lowest value (Table 3). All the land use systems showed higher accumulation of soil organic carbon in the 0.00-0.05 m depth and then decreased with increasing depth (Fig. 1). The higher TOC content in the Oil Palm (8.52 g/kg) & Eucalyptus 7.52 g/kg) is due to large annual

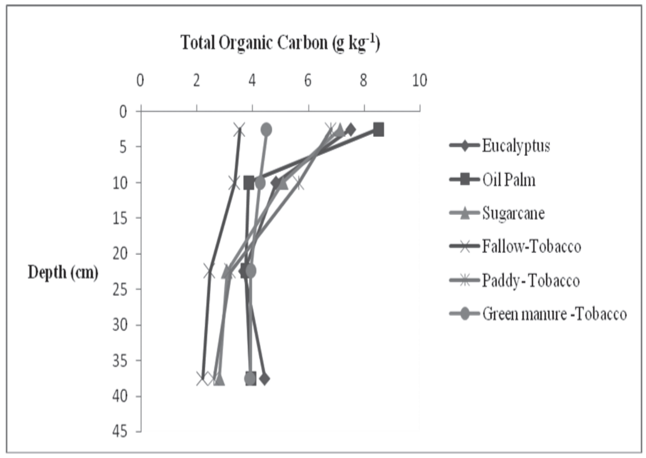

Figure 1: Total soil organic carbon (g/kg) under different land use systems

addition of organic matter in the form of leaf litter and fronds which remains in the soil due to the absence of any disturbance. A slower rate of SOM decomposition in these systems and its absence of annual tillage contribute to their accumulation (Haynes, 2005). Higher carbon content in the sugarcane in comparison with other tobacco cropping systems is due to addition of sugarcane trash and FYM application. In contrast, the low SOM content in all tobacco based cropping systems like Fallow- Tobacco, Green manure-Tobacco, Paddy- Tobacco may be due to that there is no addition of crop residues into the soil as the crop biomass is removed from the field. The lowest TOC in Fallow- Tobacco (3.54 g/kg) is due to neither or not cropping residues or other organic manures is adding to the soil. Green manuring tobacco has shown higher TOC compared with Fallow-Tobacco due to the residual effect of green manure crop that has enhanced the soil quality.

Table 2: Chemical characterization of soils under different land use and cropping systems

Land use and cropping systems	Depth (m)											
	0.00-0.15	0.15-0.30	0.30-0.45	0.00-0.15	0.15-0.30	0.30-0.45	0.00-0.15	0.15-0.30	0.30-0.45	0.00-0.15	0.15-0.30	0.30-0.45
	pH (1: 2.5 soil water)			EC (dS/m)			P (mg/kg)			K (mg/kg)		
Eucalyptus	6.64	6.57	6.54	0.14	0.02	0.01	7.50	17.17	11.45	67.50	155.00	201.00
Oil Palm	7.85	7.27	7.07	0.14	0.02	0.02	14.75	34.72	8.52	96.00	138.50	220.50
Sugarcane	6.21	5.40	4.77	0.19	0.01	0.01	43.00	73.92	55.28	225.50	139.00	192.00
Fallow- Tobacco	5.36	5.82	6.00	0.48	0.01	0.01	27.25	43.68	40.23	109.00	81.50	200.00
Paddy- Tobacco	6.30	6.58	6.76	0.46	0.01	0.04	19.25	26.88	16.61	88.50	94.50	126.50
Green manure -Tobacco	5.87	4.12	4.18	0.12	0.06	0.08	32.00	29.87	11.76	85.00	125.00	149.00
Reference soil (Forest)	6.84	6.82	6.76	0.15	0.10	0.09	2.00	2.25	4.75	97.00	102.50	105.00

Table 3: Soil total organic carbon (TOC), $KMnO_4$ oxidizable C (i.e., labile carbon LC), non labile carbon (NLC) under different land use systems.

Land use and Cropping systems	TOC (g/kg)				$KMnO_4$-C (mg/kg)				NLC (g/kg)			
	Depth (m)											
	0.00-0.05	0.05-0.15	0.15-0.30	0.30-0.45	0.00-0.05	0.05-0.15	0.15-0.30	0.30-0.45	0.00-0.05	0.05-0.15	0.15-0.30	0.30-0.45
Eucalyptus	7.52	4.85	3.69	4.44	390	263	128	113	7.13	4.59	3.56	4.33
Oil Palm	8.52	3.86	3.76	3.94	480	203	158	180	8.04	3.66	3.6	3.76
Sugarcane	7.14	5.09	3.08	2.81	330	255	143	113	6.81	4.84	2.94	2.7
Fallow-Tobacco	3.54	3.36	2.46	2.21	203	126	77	68	3.34	3.23	2.38	2.14
Paddy-Tobacco	6.81	5.66	3.21	2.62	263	225	135	68	6.55	5.44	3.08	2.55
Green manure –Tobacco	4.51	4.27	3.94	3.92	248	253	84	60	4.26	4.02	3.86	3.86
Mean	**6.34**	**4.52**	**3.36**	**3.32**	**319**	**221**	**147**	**100**	**6.02**	**4.29**	**3.24**	**3.22**
CD (P=0.05)	**1.15**	**1.39**	**0.87**	**0.7**	**75.1**	**NS**	**28.3**	**55.8**	**1.09**	**1.36**	**NS**	**0.71**
Reference soi l(Forest)	15.72	10.18	7.31	7.02	563	380	293	203	15.2	9.80	7.02	6.82

The Paddy-Tobacco system has recorded higher TOC due to incorporation of stubbles into the soil during crop rotation. Long term sustainability and overall productivity of cropping systems are directly relatively related to the maintenance of soil organic matter (Goswami, 1998). The highest organic carbon content in undisturbed forest and oil palm, eucalyptus systems which was attributed to the long term addition of carbon over more than 10 years in the soils coupled with minimum physical disturbance to surface soil as compared to tobacco cropping systems. Perennial vegetation with good management appeared to be the best land use as far as SOC pool and CMI are concerned, (Lakaria *et al.*, 2012). The total organic carbon content was the lowest under no manure and fully fertilizers addition followed by application of only recommended dose of fertilizer to Fallow-Tobacco cropping systems.

Labile carbon

The different land use systems revealed significant variations in the LC fractions. It ranged from 203 mg/kg in Fallow- Tobacco land to 480 mg/kg in Oil Palm land use (Table 3). Land use system which is receiving higher levels of organic manures contained significantly higher levels of LC values than no manure applied Fallow- Tobacco system. All the systems recorded a decrease in LC with increase in depth (Fig 2). LC values of all the depths were found to be higher in the oil palm system followed by Eucalyptus. Among the tobacco

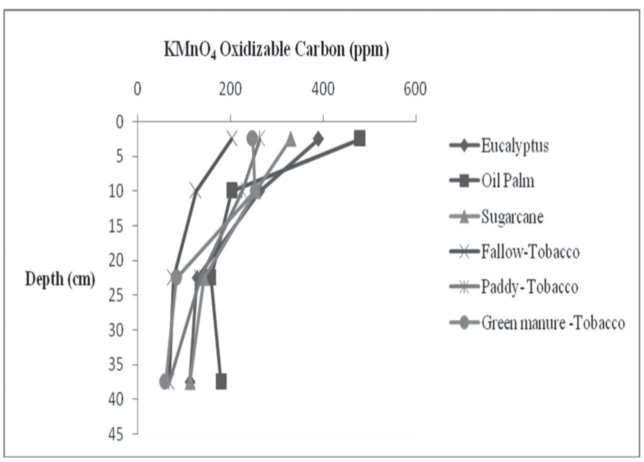

Figure 2: Profile distribution of $KMnO_4$ Oxidizable Carbon (ppm) under different land use systems

based cropping systems, the highest labile carbon was found in Green manure- Tobacco in all the depths compared with Fallow-Tobcco and Paddy-Tobacco. The labile carbon values under different land use systems are in the order of Oil palm> Eucalyptus> Sugarcane >Green manure- Tobacco >Paddy- Tobacco > Fallow-Tobcco. Labile pools of organic carbon are more readily influenced by management practices than the recalcitrant pools (Biederback *et al.*, 1994). Our results are in aggrement with earlier studies where agricultural practices promoting SOM accumulation have increased amounts of labile organic matter (Haynes, 2005; Mandal *et al.*, 2002). The labile carbon values ranged from 0.38 to 0.57% of TOC in the various land use systems in the surface layers under study. High organic matter additions and fertilizer treatments in multiple cropping systems significantly enhanced the root biomass yield which might be responsible for increased LC in soil. Nevertheless, roots are also reported to exude carbon compounds that are labile in nature (Contech *et al.*, 1997). The high levels of LC in forest system can be attributed to the constant supply of easily decomposable leaf litter throughout the year and high MBC values. The lower value of LC in the tobacco cropping systems is due to poor addition of organic manures and can be associated with aggregate disruption and greater organic matter oxidation in conventional agricultural systems based on ploughing and harrowing (Bayer *et al.*, 2006).

Non labile carbon

The greatest percentage of Non labile/ residual SOC observed among all the land use systems. Specially tobacco cropping systems has potential to significantly increase SOC in the soils through the integrated application of manure and fertilizers.

Soil microbial biomass carbon

Like TOC, the greatest accumulation of MBC was observed in Oil Palm while Fallow- Tobacco showed the lowest value (Fig. 3). The surface soil exhibited higher MBC compared to lower soil depths in all the land use systems primarily because of addition of leftover crop residues and root biomass in the soil. The higher MBC values

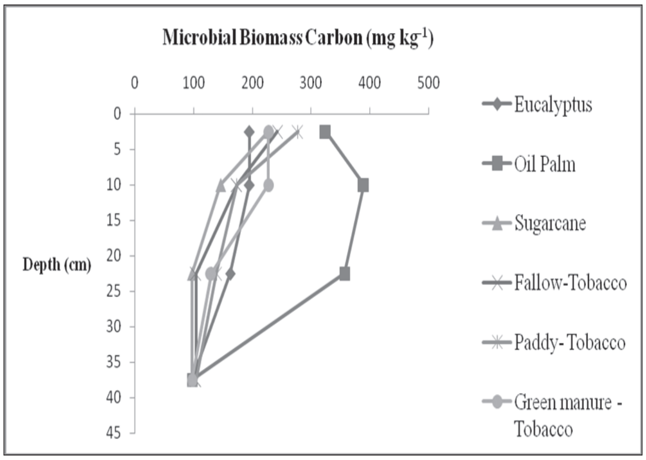

Figure 3: Soil microbial biomass carbon under different land use systems

observed in the Oil Palm & undisturbed forest can be attributed to the relatively continuous and more organic matter deposition in the form of fronds and leaf litter and to a lesser extent to less soil tillage management enhanced the microbial activity.

Stratification ratio (SR)

The soil organic carbon concentration decreased with increasing soil depth and had a differential distribution in the soil profile among treatments in the NLS region (Table 4). There was a different response of SR to Eucalyptus, Oil palm and Sugarcane to Tobacco cropping systems. In contrast to other tobacco systems green manure-tobacco systems showed uniform distribution of SOM in all the depths and hence there is no stratification. The stratification ratio was decreased with increasing depth in all land use systems.

Ecologically significant soil carbon stratification was observed in the upper soil layer (0.0- 7.5 cm) under chisel tillage and no-tillage management after 8 years or under Sod due to the surface accumulation of crop residues or organic residues in upper soil layer (Diaz- zontz, 2002).

Soil organic carbon storage

Eucalyptus recorded the highest soil organic carbon storage (34.77 Mg/ha) than Oil palm (32.06 Mg/ha), Among the tobacco cropping systems, Paddy- Tobacco and Green manure- Tobacco showed on a par soil organic carbon storage whereas Fallow-Tobacco showed the lowest soil organic carbon storage (20.46 Mg/ha) (Fig. 4). In the Eucalyptus system the highest soil organic carbon storage due to organic matter addition every year in the form of leaf litter and the soil is relatively undisturbed as the same reason has showed in the Oil palm system where carbon storage was recorded high due to inputs of organic matter in the form of FYM, Vermicompost, etc. All the tobacco cropping systems showed relatively less soil organic carbon storage due to the less addition of organic inputs neither or nor in the form of organic manures or crop residues is not adding to the soil.

Table 4: Stratification ratio for TOC under different land use systems

Land use and cropping systems	Ratio depth (m)		
	0.00-0.05 : 0.30-0.45	0.05-0.15 : 0.30-0.45	0.15-0.30 : 0.30-0.45
	Stratification ratio		
Eucalyptus	1.69	1.09	0.83
Oil Palm	2.16	0.98	0.95
Sugarcane	2.54	1.81	1.10
Fallow-Tobacco	1.60	1.52	1.11
Paddy-Tobacco	2.60	2.16	1.23
Green manure -Tobacco	1.15	1.09	1.01
Reference soil (Forest)	2.23	1.45	1.04

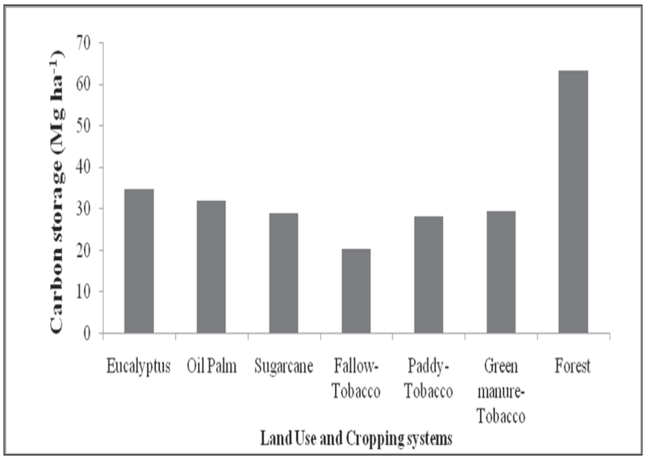

Figure 4: Effect of different land use systems on carbon storage (Mg/ha) in soil

Carbon management index

The CMI compares the changes that occur in total and labile C as a result of agricultural practices (Blair, 1995). All the land use systems have showed significant differences in CMI values as compared to the forest system (100). Significant differences were observed at all the depths (Table 5). The lowest CMI value for Fallow- Tobacco (35) indicates that continuous tobacco cultivation in the same field over years have resulted in less content of total organic carbon and labile organic carbon so there is an urgent need to rectify the problem by supplying organic inputs to the soil. CMI has helped in finding the system which is in degrading and aggrading condition. In the present study, the oil palm and eucalyptus systems have showed higher CMI as well as carbon storage values indicating that these systems have higher Carbon Sequestering potential when compared with other tobacco cropping systems.

The TOC and Labile organic carbon differed significantly between the land use systems, with Oil palm system showing highest TOC and LC values. Irrespective of the systems, total and labile fractions decreased with soil depth. Profile distribution of TOC clearly exhibited the stratification for all the land use systems except green manure- tobacco system, as evident from the stratification ratio. The carbon stock in the top 45 cm layer was found to be relatively higher for Oil Palm and Eucalyptus as compared to that observed in tobacco based systems. The CMI values differed significantly across land use systems, with Eucalyptus (0.71) and Fallow- Tobacco (0.35) being associated with the highest and the lowest CMI, respectively. All the Tobacco based systems with relatively lower CMI values indicated soil degradation. In contrast, the systems such as Eucalyptus and Oil palm with greater CMI showed the potential to maintain or improve soil quality.

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Table 5: Carbon Management index under different land use systems

Land use and cropping systems	**Depth (cm)**		
	0.00-0.15	**0.15-0.30**	**0.30-0.45**
Eucalyptus	71	43	55
Oil Palm	69	54	66
Sugarcane	65	49	56
Fallow-Tobacco	35	26	28
Paddy-Tobacco	54	46	33
Green manure -Tobacco	59	28	29
Mean	**58.83**	**41**	**44.5**
CD (P = 0.05)	**16.84**	**24.21**	**10.54**

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