Original Research Article

SOIL DYNAMICS FOR CARBON BUILDUP IN DIFFERENT LAND USE SYSTEMS IN SOUTH REGION OF GUJARAT, INDIA

Abstract: Soil dynamics for carbon buildup vary across different land use systems, reflecting how land is managed and used. Understanding the specific soil dynamics and management practices that contribute to carbon buildup in each land use system is essential for designing effective carbon sequestration strategies. Therefore, in a recent study, fifteen different land use systems were examined, including agriculture land use systems, tree plantation land use systems, and agroforestry systems land use systems.The study assessed the potential of these land use systems to store soil carbon based on the extent of tree components. Additionally, the study investigated various physical and chemical characteristics of the soil and their impact on soil carbon conservation. The results showed that as the number of tree components increased under the land use systems, the soil pH decreased from 6.10 to 5.55, and the bulk density of the soil decreased from 1.48 to 1.33 g/cm3. The tree plantation land use system had the highest available soil nitrogen, with *T.grandis* (TG), which was at par with plantation of *A.procera* (AP), *T.arjuna* (TA), and *D. latifolia* (DL) recording significantly higher levels compared to agriculture land use systems. The presence of soil moisture was higher in agriculture land followed by agroforestry land use systems and tree plantation land use systems respectively. In addition depth of soil increased the soil pH, bulk density, soil moisture etc. From the investigation of this research paper we concluded the tree components increased the soil carbon buildup compare to other land use systems but agroforestry land use systems where, both agriculture crop and tree plantation combination are better option to fulfill the requirement of human and environment balance.

Keywords: Soil dynamics, land use systems, agroforestry, soil carbon, pH, bulk density.

Introduction: Soil dynamics, or the physical, chemical, and biological processes that occur within the soil, can be significantly influenced by different land use systems. The consequences of soil dynamics in various land use systems are diverse and can have important implications for the environment, agriculture, and ecosystem sustainability andcarbon buildup refers to the accumulation and storage of carbon in various forms within ecosystems, particularly in the soil and

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vegetation. This process plays a crucial role in mitigating climate change by removing carbon dioxide (CO_2) from the atmosphere and storing it in long-term reservoirs. Carbon buildup is a key component of carbon sequestration, which involves capturing and storing carbon to reduce the concentration of greenhouse gases in the atmosphere. Some are the key aspects of carbon buildup like organic matter accumulation through plant residues where decomposed plant materials, such as leaves, branches and roots contribute to the organic matter content in the soil representing a significant pool of stored carbon as well as in microbial activity soil microorganisms break down organic matter, converting it into stable forms of carbon. This microbial activity plays a vital role in the buildup of soil carbon. Global climate change, considered to be one of the most serious threats to the environment, has been at the center of scientific and political debate in recent years. Climate change, more precisely global warming is reality but there are considerable uncertainty existing about the event of warming (1). Reduce the carbon emission or sequester are the plant biomass is option to minimize the rate of climate change but soils are also an effective sink for carbon. Scientists estimate that the global potential of soil carbon sequestration is 0.4 to1.2 Gt C/yr, or an amount equal to roughly 5 to 15 percent of total man-made CO_2 emissions (2). To be most effective, CO_2 must be fixed into long-lived pools (or "sinks"). The soil organic carbon sinks capacity depends on land use and its management. Soil management strategies for carbon sequestration include three approaches. First, management of soil to maintain higher than existing levels of soil organic matter. Secondly, to manage carbon degraded soils so as to restore soil organic matter levels. Third, enlarging soil organic carbon and micro-aggregation. Sub-soil organic carbon can be increased by growing deep rooted plants (trees/crops) and deep ploughing. Eco-friendly farming practices like organic farming, precision farming and agroforestry has a great potential to enrich soil with organic carbon through sequestrating carbon in soils. In order to exploit this vastly unrealized potential of C sequestration through agroforestry in both subsistence and commercial enterprises in the tropics and the temperate region, innovative policies, based on rigorous research results, have to be put in place. Research efforts are needed to quantify the carbon sequestration capacity of these practices. Adoption of a different land use systems by a farmer depends upon the economic return from the field and condition of market. From this objective that a comprehensive experiment was made to come out sustainable land use systems along with mitigating carbon.

Materials and methods:

Study site: Geographically, Navsari is situated at 20.95^o North latitude, 75.90^o East longitude and at an altitude of 12.0 meters above mean sea level (MSL). According to agro-climatic condition, Navsari is placed in South Gujarat heavy rainfall zone-I (Agro-ecological situation-III). The College instructional farm is located 12 km away in the east from the Arabian Seashore, Dandi. This region belongs to tropical climate characterized by fairly hot summer, moderately cold winter and more humid and warm monsoon with heavy rain. The average annual precipitation is 1355 mm. Monsoon commences mostly from the second week of June and lasts up to the first week of October. Most of the rainfall is received from south-west monsoon, concentrating in the months of July and August. Winter starts from November with mild cold and lasts up to February. December and January are the coldest months of the year. Summer commences from mid-February and ends in mid-June. April and May are the hottest months of the year. The soil of the experimental site is dark grayish brown type with flat topography. The soil is characterized by medium to poor drainage and good water holding capacity. The predominant clay mineral is montmorillonite.Fifteen different land use systems, in order of increasing tree component with sole agriculture and horticulture crops, representing agriculture field, paddy- *Oryza sativa* L. (OS), horticulture field sugarcane- *Saccharum officinarum* L. (SO) and banana- *Musa paradisiaca* L. (MP), tree plantation sapota- *Manilkara achras* L. (MA), Mango- *Mangifera indica* L.(MI), teak- *Tectona grandis*L.f. (TG), Killai- *Albizzia procera* (Roxb.)Benth. (AP), Eucalyptus- *Eucalyptus clones* (EC), Casuarina- *Casuarina equisetifolia*L.ex J.R.&C.Fraser (CE), Shisham- *Dalbergia latifolia*Roxb. (DL), Jatropha- *Jatropha curcas*L.,(JC) Arjun- *Terminalia arjuna* (Roxb.ex DC.) Wight & Arn. and three agroforestry land use systems order is Rice + Boundary plantation (*Tectona grandis* L.f.)(RTG), Sugarcane + Boundary Plantation (*Casuarina equisetifolia*L.ex J.R.&C.Fraser),(SCE) and Banana + Boundary plantation (*Tectona grandis*) (BTG) etc. were selected for comparison their carbon sequestration potential.**Table 1;** showed the detail of different land use systems with 15 treatments with 3 replication, number of tree/hectare, crop and plant space etc. were taken for observations.

Procedure of soil sample collection and preparation:

From the different land use system, soil were collected from different soil depth such as-0-10 cm, 10-20 cm, 20-30 cm in triplicates. The composite soil samples for each depth were obtained by mixing three samples. For analysis of soil physio-chemical, sample were air dried in shade, ground with wooden pestle, passed through 2 mm sieve and stored in cloth bags. Table 2: showed the different depth soil sample physio-chemical analysis methodology.

Table 1: Details of different land use systems.

S.no	Treatments (Land use systems	Tree spacing (m)	Crop spacing (cm)	Season of crop/Planting Year	No of trees (Per hectare)	Plot size m^2
1	**Agriculture land use systems (S_1)**					
a	*Oryza sativa* L. (OS)	---------	20 x 20	Kharif	-------	
b	*Saccharum officinarum* L. (SO)	----------	30 x 90	Kharif	---------	10 x 10
c	Banana- *Musa paradisiaca* L. (MP)	----------	1.8 x 1.8 (m)	Kharif	300	
2	**Tree plantation land use systems (S_2)**					
a	*Manilkara achras* L. (MA),	8 x8	------------	1994	156	
b	Mango- *Mangifera indica* L. (MI)	8 x8	------------	1990	156	
c	Teak- *Tectona grandis*L.f. (TG),	3 x3	------------	1990	1111	
d	Killai- *Albizzia procera* (Roxb.)Benth. (AP)	3 x3	------------	1995	1111	
e	Eucalyptus- *Eucalyptus clones* (EC),	2 x2	------------	2009	2500	
f	Casuarina- *Casuarina equisetifolia*L.ex J.R.&C.Fraser (CE),	2x 2	------------	2009	2500	
g	Shisham- *Dalbergia latifolia*Roxb. (DL),	3 x 3	------------	1991	1111	10 x 10
h	Jatropha- *Jatropha curcas* L.,(JC)	2 x 2	------------	2006	2500	
i	Arjun- *Terminalia arjuna* (Roxb.ex DC.) Wight & Arn. (TA)	4 x 4	------------	1990	400	
3	**Agroforestry land use systems (S_3)**					
a	Rice + Boundary plantation (*Tectona grandis* L.f.) (RTG),	5 x 5	20 x 20	1999	400	
b	Sugarcane + Boundary Plantation (*Casuarina equisetifolia*L.ex J.R.&C.Fraser), (SCE)	3 x 3	30 x 90	2006	1111	10 x 10

c	Banana + Boundary plantation (*Tectona grandis*) (BTG)	5 x 5	1.8 x 1.8 (m)	2002	400	

Table 2: Different methodology used for soil sample analysis.

Sr. No.	Parameters	Method employed
1.	Organic carbon (%)	(3)
2.	Available N (kg/ha)	Alkaline permanganate method (4)
3.	pH of soil	Potentiometric method (4)
4.	Bulk density (g/cm^3)	Core sample method (5)

Soil organic carbon stock expressed as tons per hectare were calculated by multiplying the organic car with eight of the soil for a particular depth. Soil organic carbon pool inventory (Mg/ha) for a specific depth was computed by multiplying the soil organic carbon expressed as g/kg with bulk density (g/cm^3) and depth of soil (cm) (6).

Data analysis: The experimental data were subjected to the statistical analysis as per the procedure suggested by (7). The treatment differences were tested by 'F' test of significance based on null hypothesis. The appropriate standard error (S.Em.±) was calculated in each case and critical difference (C.D.) at 5 percent level of probability was worked out to compare the treatment means, where the treatment effects were significant.

Results and Discussion: The soil pH was observed decrease in the land use systems where number of tree increased in sole tree plantation. In sole agriculture field paddy (OS) pH was 6.20 and tree plantation of *Albizziaprocera*(AP) had a pH 5.5 (Figure 1a). The reaction among soil in each land use systems, approached toward neutral as the soil depth increased. The decrease in soil pH with increase in the tree component land use systems is (AP) because land use systems plantation of *Albizzia procera*(AP) decomposition rate is higher compare to other plantation that's why the addition of more organic matter which results in production of organic acid during decomposition. As well as similarly extent of organic matter was more in surface layers and low in the deeper layer as a result the pH in deeper layer approached to neutral. The similar results found by (8), (9) and (10). (11) reported the low soil pH under tree plantation which is attributed to leaching of base and enhancement of weathering process giving rise to high A1 levels. In agriculture field paddy (OS) soil the mean value of bulk density was 1.48 g/cm^3 and it was least 1.33 g/cm^3 in soil of plantation of *Albizia process* (AP) (Fig. 1 b). The bulk density increased as the depth of soil sampling increased. Plantation of trees un different land use systems directly correlated to soil bulk density level decreasing due to the more organic matter which leads to better soil structure and hence more porosity of soil. (12), (13) also reported the bulk density inversely related to tillage intensity. (14) supported the finding of tree component increased the area for tillage decreases and decrease in bulk density with increase in soil depth.Soil moisture content was found higher in paddy (OS) field and least in tree plantation of *Casuarina equisetifolia*(CE). Soil moisture content also increased with the soil depth for all land use systems (Fig 1c). The soil moisture content was higher in paddy (OS) field is due to the management practices for rice cultivation. Increase in soil moisture content with increase in tree component in Fig 1c and its attributed to conservation of water by increase in organic matter and better soil structure. The least soil moisture content found in plantation of *Casuarina equisetifolia*(CE) due to the needle like leaf structure of plant not covered and conserved soil moisture as well as not practiced any management practices from long time. Plantation of other plant helps the conserve moisture by reducing the evaporation rate from the soil surface. (14) had reported that the if the increased one percent of soil organic carbon, can be stored 14.4 liters of extra available water in per square meter in top 30 cm of soil. The available nitrogen in the soil is influenced by different land use systems under the study. In agriculture land use systems available nitrogen in the soil varied from 237.52kg/ha to 287.78 kg/ha (Fig 1d). In soil nitrogen content decreased with increasing depth of soil up to 20 cm in all land use systems studied. Result shows that maximum available soil nitrogen in agriculture land use systems was in *S.officinarum*(SO; 287.78 kg/ha) which was at par with *M. paradisiaca* (MP; 255.40 kg/ha) and *O.sativa*(OS; 237.52 kg/ha), respectively. This may be ascribed to the fact that the crop was grown in organic soil field as well as application of gypsum and farm yard manure (FYM) was done. Application of gypsum and farm yard manure (FYM) seem to improve in air and water movement in amended soil, which might have increased the microbial activity and induced nitrogen availability in soil as compared to *O. sativa* crop due to intensity of the cultivation is very high in the field crops, as a result of which N is lost through removal of biomass, soil erosion and volatilization. Similar results were also reported by (15,16,17 18& 19).

The available soil nitrogen under tree plantation land use system recorded significantly maximum in *T.grandis* (TG; 315.65 kg/ha) which was at par with *A.procera* (AP;314.37kg/ha), *T.arjuna* (TA;310.47 kg/ha) and *D. latifolia* (DL; 305.40 kg/ha) while it was 293.85 kg/ha in Eucalyptus clones(EC). However, in plantation of *M.indica* (MI; 301.20 kg/ha), *J.curcas*(JC; 298.73 kg/ha) and *M. achras*(MA; 296 kg/ha) were in descending order as compared to *C. equisetifolia* (CE; 295.50 kg/ha).Significantly higher N status in tree plantations situated is deciduous in nature, which shed their leaves, during the winter months thereby continuously adding to the N status of the land. (20) also reported that the site of seven tree species *viz.,Bambusbambos, Cassia siamea, Casuarina equisetifolia, Eucalyptus tereticornis, Leucuenaleucocephale, Tectona grandis and Ceiba pentendra*were compared for soil fertility with a vegetation less site and a cultivated field. Under tree cover and agricultural soil nitrogen was registered to be significantly higher as compared to barren or uncultivated land. Similar variation have also been reported by (21).The combined crops and tree cultivation practices in same plot shows maximum available nitrogen in the soil when *O. sativa* is grown with *T. grandis* (RTG; 296 kg/ha) as compared to *M. paradisiaca* grown with *T. grandis* (MTG;295 kg/ha) and *S. officinarum* grown with *C. equisetifolia* (SCE;295 kg/ha), respectively.The probable reason is higher amount of tree leaf litter biomass returns to soil, combined with decay of roots contribute to the improvement of nitrogen status in soil as well as higher availability of cellulose and hemicelluloses in leaf litter, easy decay and release nutrient availability in soil as well in cropping *O. sativa* uptake of nitrogen may be lower as compared to *M. paradisiaca* and *S. officinarum.* Similar results were reported by (22) during experiment in Valsad, District, Gujarat.The mean data regarding variation in soil organic carbon under different land use systems are presented in Fig.1d. Soil organic carbon content of different soil samples (depth) collected from different land use system was compared in the study for the soil organic carbon was found to be highest in *S.officinarum*(SO ; 0.70%), which was followed by *M.paradisiaca* (MP; 0.51%) and least in *O.sativa* (OS; 0.50%), respectively. Soil organic carbon percentage found higher in surface layer of soil and lowest in deeper soil area.

Fig 1 Effect of soil physical and chemical characteristics under land use systems.

Fig-1 a: Soil pH characteristics under different land use systems

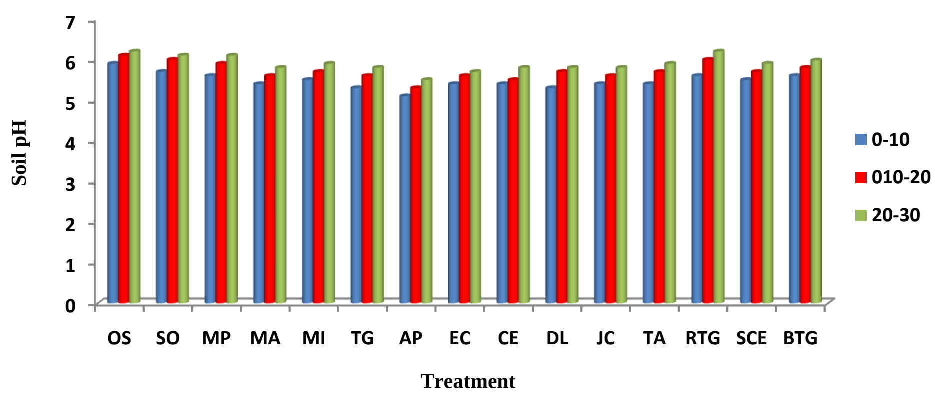


Fig 1b: Soil Bulk density (%) under different land use systems

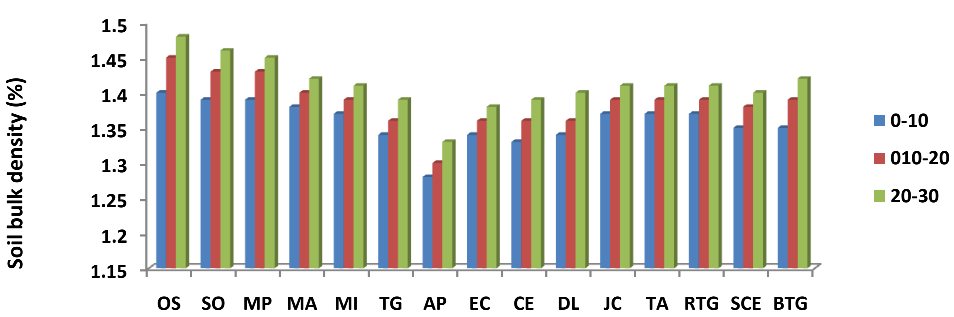


Fig 1c: Soil moisture under different land use systems

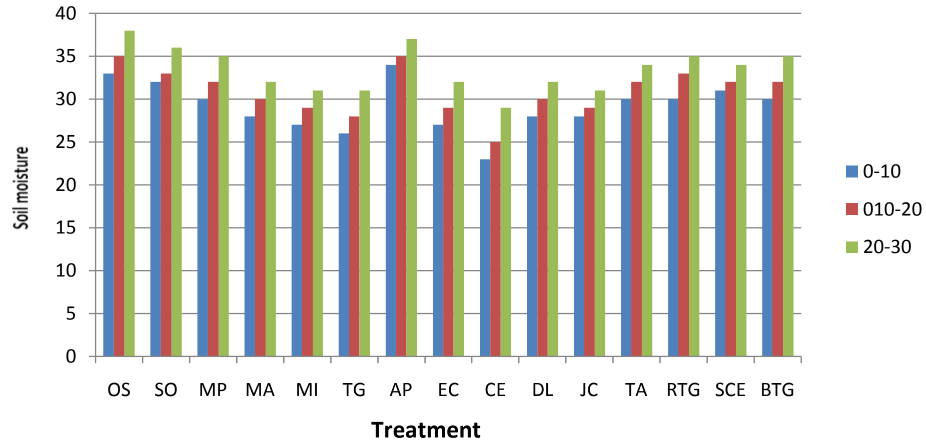


Fig-1d: Soil nitrogen properties under different land use systems

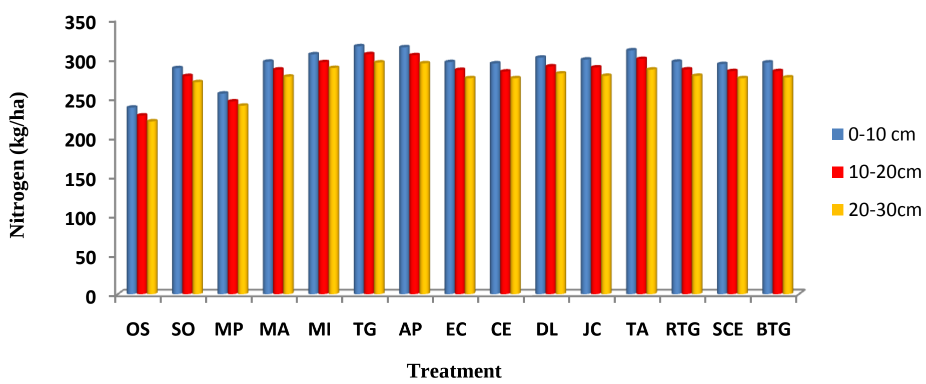
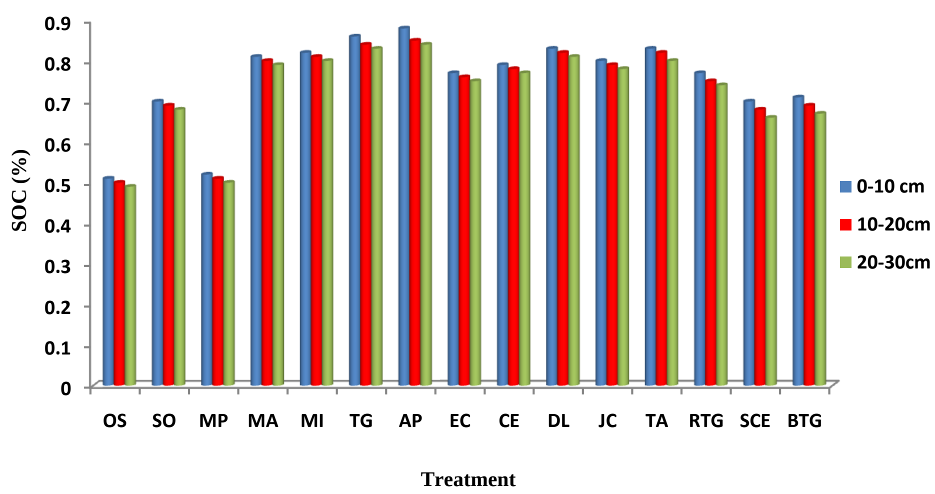


Fig-1e: Soil organic carbon properties under different land use systems



They could probably be due to increase in root biomass due to amendment as well as higher plant population. Similar, along with amendment, farm yard manure (FYM) was also added, which might have helped in increasing the organic carbon in soil and lowest soil organic carbon found due intensive cropping practices. Similar results were also reported by (15 16, 17& 18). Perusal of the plantation of trees data indicate that the available soil organic carbon was found highest (AP; 0.88%) in *A. procera*, which was at par with tree plantation of *T. grandis* (TG; 0.86%), *T. arjuna* (TA; 0.82%), *D. latifolia* (DL; 0.82%) and *M. indica* (MI; 0.81%), *M. achras* (MA; 0.80%). While it was lowest in Eucalyptus clones (EC; 0.77%) respectively (Fig 1e). This may happen because of enhanced stock of leaf litter in the tree based land use systems. The abundant leaf litter or pruned biomass returns to soil, combined with decay of roots contribute to the improvement of organic matter under complex land use systems (23).Our findings are also supported by (21). From the agroforestry land use system combined crops and trees practices shows that maximum (0.76%) available soil organic carbon in (RTG) *O.sativa* grown with *T.grandis*, which was at par with *M.paradisiaca* grown with *T.grandis* (BTG;0.70%) and *S.officinarum* grown with *C.equisetifolia* (SCE;0.69%), respectively. This may be due to abundant tree leaf litter biomass returns to soil, combined with decay of roots contribute to the improvement of organic matter. Similar observations were recorded by (24) in *Acacia nilotica* based agroforestry systems and opined that tree canopy contribute toward nutrient conservation, soil amelioration and nutrient availability. Soil carbon stocks in tons per hectare under different land use systems results showed the maximum in tree plantation land use systems, which was followed by agroforestry land use systems and least in agriculture land use systems respectively. Soil organic carbon stock decreased with increase in soil depth, signifying the importance of upper layer in storing soil organic carbon Table 3. Similarly the highest average soil carbon stock was 17.35 t/ha in tree plantation land use systems of *Albizzia procera*(AP), which was followed by tree plantation land use systems *Tectona grandis* (TG),*Terminalia arjuna* (TA), *Dalbergia latifolia* (DL) and least in paddy field (OS) 7.10 t/ha. Higher the soil organic carbon in tree plantation land use systems is due to the return of more organic matter to the soil in the form of leaves, bark, fruits and flowers. The study of different land use systems are conformity with the results obtained by (25) and (26) reported the soil organic carbon stocks differed significantly among tree species.

Table 3: Different land use systems and soil depth on soil organic carbon stock (t/ha).

S.no.	Treatments (Land use systems	Soil depth			Average
		(0-10 cm)	(10-20 cm)	(20-30 cm)	
1	**Agriculture land use systems (S_1)**				
a	*Oryza sativa* L. (OS)	7.95	7.10	6.25	7.10
b	*Saccharum officinarum* L. (SO)	8.20	7.58	6.99	7.59
c	Banana- *Musa paradisiaca* L. (MP)	8.00	7.50	6.80	7.43
2	**Tree plantation land use systems (S_2)**				
a	*Manilkara achras* L. (MA),	14.10	11.95	9.80	11.95
b	Mango- *Mangifera indica* L. (MI)	14.88	12.64	10.20	12.57
c	Teak- *Tectona grandis*L.f. (TG),	17.42	14.50	12.80	14.91
d	Killai- *Albizzia procera* (Roxb.)Benth. (AP)	18.5	17.20	16.35	17.35
e	Eucalyptus- *Eucalyptus clones* (EC),	11.50	10.45	9.20	10.38
f	Casuarina- *Casuarina equisetifolia*L.ex J.R.&C.Fraser (CE),	12.98	11.10	9.50	11.19
g	Shisham- *Dalbergia latifolia*Roxb. (DL),	15.95	13.60	11.20	13.58
h	Jatropha- *Jatropha curcas* L.,(JC)	13.50	11.40	10.10	11.67
i	Arjun- *Terminalia arjuna* (Roxb.ex DC.) Wight & Arn. (TA)	16.10	13.64	12.10	13.95
3	**Agroforestry land use systems (S_3)**				
a	Rice + Boundary plantation (*Tectona grandis* L.f.) (RTG),	13.45	11.25	10.10	11.60
b	Sugarcane + Boundary Plantation (*Casuarina equisetifolia*L.ex J.R.&C.Fraser), (SCE)	11.85	10.22	9.44	10.50
c	Banana + Boundary plantation (*Tectona grandis*) (BTG)	12.98	10.65	9.20	10.94
	Average	13.16	11.39	10.00	

Note: CD $_{(p=0.05)}$, land use-1.62, soil depth-0.65, interactions: land use x soil depth $_{1---n}$ -1.84, soil depth x land use $_{1---n}$ -2.24

Conclusion: Balancing global warming is a big problem in today's industrial age. There is a need to develop a special strategy for this. There is a need to adopt different land use methods which can meet the food needs of the increasing population while also maintaining a balance with the environment and maintain the buildup soil carbon. Fifteen land uses systems have been studied for this. In which it was seen that agricultural land use, which is a very good source of business along with food, but is unable to maintain environmental balance, whereas in another study, the environment can be balanced by planting trees, but the food requirement for country cannot fulfilled. Therefore, the need is to take a middle path, a land which can provide income and food and still has a capability of storing sufficient carbon. These are called agroforestry, in which trees are planted along with agricultural crops, which can balance the environment and also fulfill the need for food. Along with fullfill the purpose of carbon storage. Thus agroforestry land use system is the best option like Rice + Boundary plantation (*Tectona grandis*) Sugarcane + Boundary Plantation (*Casuarina equisetifolia*),(SCE) and Banana + Boundary plantation (*Tectona grandis*) (BTG) compare to sole tree plantation and sole cropping land use systems.

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