Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 393-397
Received: 18-10-2020
Accepted: 16-12-2020

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Assessment of carbon sequestration under different age of bamboo plantation

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Abstract
The study in relation to "Assessment of carbon sequestration under different age of bamboo plantation" was conducted during the year 2019-20 at Agro-forestry farm, College of Agriculture, Nagpur. The carbon stock in the soil ranges between 13.52 to 22.97 Mg ha^{-1} (surface) and 12.44 to 22.34 Mg ha^{-1} (sub-surface), the soil carbon stock were highest in 1990 year of bamboo plantation and was found lowest in fallow land. The carbon sequestration potential increases in order to 2014, 2008, 1997, 1994, 1992 and 1990 year of bamboo plantation respectively. The carbon sequestration potential increases with the age of bamboo plantation, more the age of bamboo plantation higher value of carbon sequestration potential, whereas lower value of carbon sequestration potential was recorded in fallow land.

Keywords: Carbon sequestration, carbon stock, organic carbon and bamboo

Introduction

Carbon is the fundamental building block of life and important component of many chemical processes on the planet earth. Carbon is exchanged and cycled among earth's oceans, atmosphere, and ecosystem and geo-sphere. It is present in the atmosphere primarily as carbon dioxide (CO_2) now a day's there has been a consistence and continuous increase in the emission of greenhouse gases (GHGs) in to the atmosphere. Primarily due to the anthropogenic activities, burning of fossil fuels for energy, deforestation land use change, biomass burning and draining of peat and wetlands.

Sequestration can be defined as the capture and secure storage of carbon that would be emitted in the atmosphere. The idea is to first prevent carbon emissions produced by human activities from reaching the atmosphere by capturing and diverting them to secure storage, and second secure carbon from the atmosphere by various means and store in to the soil [10]. Soil organic carbon sequestration is process of transferring carbon dioxide from the atmosphere into the soil through crop residue and other organic solids and in the form that is not immediately reemitted Lal, (2004) [9]. It implies transferring atmospheric CO_2 into lived pools and storing it securely so that it is not immediately reemitted. In other words soil carbon sequestration mean increasing soil organic carbon and soil inorganic carbon stocks through judicious land use and recommended management practices. The soil organic matter, the seat of soil organic carbon, is the most complex, dynamic and reactive soil component. It contributes to plant growth and development through its effect on the chemical, biological, and physical properties of soil. Changes in soil C stocks may thus significantly influence the atmospheric carbon dioxide (CO_2) concentration. The SOC concentration is an indicator of soil fertility and strongly affects soil physical and biological properties.

India has abundant resources and species diversity of bamboo. About 25% of bamboo species of the world are found in India, distributed widely in almost all states. They are particularly abundant in the Western Ghats and the "Sister States" of North-east India [5] [12]. Bamboos occupy 13% of the total forest area of the country [19]. Bamboo has several advantages over tree species in terms of sustainability and carbon fixing capacity. Bamboo is one of the most productive and fastest growing plants on the planet. The fastest growing species among the bamboos may grow up to 1.2 m a day. This unique growing capacity makes bamboo a valuable sink for carbon storage. In our common thorny bamboo, *bambusa bamboos* the dry matter accumulation at the age of 4, 6 and 8 years has been reported to be 122, 225 and 286 t ha^{-1}, respectively and it is on par with the 10 years old fast growing *Casurina equiestifolia* (292.68 t ha^{-1}) or *Eucalyptus tereticornis* plantation (254.97 t ha^{-1}). The per hectare biomass accumulation by the *D. stictus*at the age of three years (Singh *et al.*, 2004) is very high compared to that of *Tectona grandis, Dalbergia sisoo* and *Acacia nilotica* of ten year age.

Total bamboo bearing area of the country is estimated as 1,60,037 sq km. There is an increase of 3,229 sq km in bamboo bearing area as compared to the estimate of ISFR 2017 [1]. In the present assessment, total carbon stock in forest is estimated as 7,124.6 million tonnes. There is an increase of 42.6 million tonnes in the carbon stock of the country as compared to the last assessment of 2017. The annual increase is 21.3 million tonnes, which is 78.1 million tonnes CO_2 eq. Soil Organic Carbon (SOC) represents the largest pool of carbon stock in forests, which has been estimated 4,004 million tonnes. The SOC contributes 56% to the total forest carbon stock of the country.

Materials and Methods

The study entitled "Assessment of carbon sequestration under different age of bamboo plantation" was carried out at Agro-forestry farm, College of Agriculture, Nagpur where the different bamboo plantations were done. Six different age series of bamboo plantation was selected. In order to study the physico-chemical properties and carbon stock, a soil samples were taken from 0-15 cm (surface) and 15-30 cm (subsurface) depth and one sample was taken from adjacent fallow land (control) for the comparison of the study from the Agro-forestry farm. The soil samples were collected from three different sites of six different age series of bamboo plantation. Total 42 soil sample were collected and was analyzed for various soil properties. The soil samples were dried in shade and gently grind with mortar and pestle and sieved through 2 mm sieve and for determination of organic carbon grind soil samples were passed through 0.5 mm sieve. The physico-chemical properties, carbon stock and carbon sequestration that are determined in the laboratory and method adopted are presented below.

Bulk Density: The bulk density was determined by clod coating method [6].

Saturated hydraulic conductivity: The Hydraulic conductivity of soil was determined by constant head method as described by Richard, 1954 [13].

Soil reaction: pH of 1:2.5 soil: water suspension was determined electrometrically using pH meter as per method described by Jackson (1973) [7].

Electrical conductivity: EC at 1:2.5 soil: water suspension was determine as per the method described by Jackson (1973) [7].

Calcium Carbonate: The calcium carbonate was estimate by rapid titration method as described by Piper (1966) [11].

Organic carbon: Available organic carbon was assessed by wet oxidation method given by Walkley and Black (1934) [21].

Carbon stock in soils (Mg ha^{-1})

The soil carbon stocks were estimated by mass, volume and density relationship [3]. The SOC pool (Mg ha^{-1} for a specific depth) was calculated by multiplying the SOC concentration (g kg^{-1}) with bulk density (Mg m^{-3}) and depth (m).

$$C\ Stock_{Depth} = TC(i) * BD(i) * TH(i) * 10^{-3}\ Mg\ kg^{-1} * 10^{4}\ m^2 ha^{-1}$$

Where,
C Stock (Depth) = Cumulative Soil Carbon Stock (Mg ha^{-1})
TC (i) = Total soil C concentration in the ith layer (g C kg^{-1})
BD (i) = Bulk density of the ith layer (Mg m^{-3})
TH (i) = thickness of ith layer (m)

Results and Discussion

Physical property of soil.

Bulk density of soil (Mg m^{-3})

Bulk density is the mass of soil per unit volume, including pore space. As the bulk density relates to combined volume of the solids and pore spaces, it serves as a guide to assess the soil compaction and porosity. It can be used as an indicator for root penetration and soil aeration.

The data in respect to bulk density of soil is presented in table-1. Bulk density of soil is an index of soil compactness. In the present study, the value of bulk density varied from 1.19 to 1.61 Mg m^{-3} (surface) and 1.23 to 1.64 Mg m^{-3} (sub-surface), the bulk density was high in fallow land and low in 1990 year of bamboo plantation due to high organic matter and bamboo plant residues. The lowest bulk density of soil was recorded 1.19 Mg m^{-3} (surface) and 1.23 Mg m^{-3} (sub-surface) in 1990 year of bamboo plantation whereas highest bulk density of soil was recorded 1.61 Mg m^{-3} (surface) and 1.64 Mg m^{-3} (sub-surface) in fallow land. In general bulk density showed increase from surface to sub-surface soil. High value of sub surface soil may be due to murrum layer [2] under very shallow soils Entisols. Difference in bulk density caused due to in land use or land cover affects the calculation of carbon stock by influencing the amount of soil sampled from the same depth [17].

Hydraulic conductivity of soil (cm hr^{-1})

The Hydraulic conductivity of soils is one of the important physical property which is associated to flux/movement of water in soil and tendency to measure the permeability of soil. In the present study, the results of hydraulic conductivity of soil exhibited difference between the various bamboo plantations. Increase in hydraulic conductivity of soil is associated with decrease in bulk density and organic sources (organic matter and plant residues) which influence on the amount of water and also air present in soil.

The data pertaining to hydraulic conductivity of soil is reflected in table- 1. The value of hydraulic conductivity of soil ranged between 0.89 to 1.94 cm hr^{-1} (surface) and 0.68 to 1.78 cm hr^{-1} (sub-surface) the hydraulic conductivity of soil was more in 1990 year of bamboo plantation and less in fallow land. The lowest value of hydraulic conductivity was recorded 0.89 cm hr^{-1} (surface) and 0.68 cm hr^{-1} (subsurface) in fallow land whereas highest hydraulic conductivity of soil was recorded 1.94 cm hr^{-1} (surface) and 1.78 cm hr^{-1} (sub-surface) in 1990 year of bamboo plantation. Increased in HC of soil is associated with decrease trend in bulk density and increased in pore space as reported by Singh (2010) [15].

Table 1: Bulk density and hydraulic conductivity of soil under different age of bamboo plantation

Sr. No	Year of bamboo plantation	Bulk density (Mg m^{-3})		Hydraulic conductivity (cm hr^{-1})	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	1990	1.19	1.23	1.94	1.78
2	1992	1.26	1.28	1.81	1.65
3	1994	1.33	1.38	1.70	1.41
4	1997	1.43	1.47	1.49	1.28
5	2008	1.47	1.52	1.20	0.98
6	2014	1.53	1.58	1.11	0.75
7	Fallow land	1.61	1.64	0.89	0.68

Chemical property of soil

Soil pH (Soil reaction)

Soil pH is an important intrinsic property of soil which usually does not change easily. The data in respect to pH of soil is presented in table-2.The value of soil pH varied from 7.53 to 8.09 (surface) and 7.59 to 8.30 (sub-surface) the soil pH was high in fallow land and low in 1990 year of bamboo plantation. The lowest soil pH was recorded 7.53 (surface) and 7.59 (sub-surface) in 1990 year of bamboo plantation, whereas highest soil pH was recorded 8.09 (surface) and 8.30 (sub-surface) in fallow land. Sihi *et al.* (2017) [14] observed that, soil pH was 0.5 unit lower in organic fields as compared to conventional fields and associated with the formation of humus and organic acids on decomposition.

Electrical conductivity (dS m^{-1})

The EC is also an important property of soil related to concentration of salt. In all locations, there was no much variation in EC of soil. The electrical conductivity of soils in all different age of bamboo plantation was under the safe limit (< 1.0 dSm^{-1}). The data of electrical conductivity of soil is presented in table 2. The values of electrical conductivity of soil ranged between 0.27 to 0.37 dS m^{-1} (surface) and 0.25 to 0.36 dS m^{-1} (sub-surface) under different age of bamboo plantation. The lowest EC of the soil was recorded 0.27 dS m^{-1} (surface) and 0.25 dS m^{-1} (sub-surface) in 1990 year of bamboo plantation. Irregular variation in EC could presently due to leaching of salt from surface to down level through the percolation of water, followed by accumulation at places during evapo-transpiration resulting in differential salt accumulation along the pedon. Similar findings were recorded by Vaidy *et al.* (2002) [18].

Table 2: pH and EC of soil under different age of bamboo plantation

Sr. No	Year of bamboo plantation	pH 1:2.5(soil : water)		EC (dS m^{-1})	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	1990	7.53	7.59	0.27	0.25
2	1992	7.57	7.61	0.37	0.34
3	1994	7.64	7.68	0.36	0.33
4	1997	7.72	7.78	0.33	0.36
5	2008	7.85	7.91	0.31	0.34
6	2014	7.95	8.02	0.36	0.32
7	Fallow land	8.09	8.30	0.31	0.33

Organic carbon (g kg^{-1})

Soil organic carbon plays a very important role in maintenance and improvement of soil properties as well as nutrient status of soil. The organic carbon concentration of the soil showed wide variation across the land use system. However, it was observed that the in bamboo plantation the soil contain much higher organic carbon. All these results associated with soil organic carbon contained clearly indicates that land use plays the dominant role in controlling organic carbon in the soils under a similar climatic condition.

The results obtained in respect to soil organic carbon under different age of bamboo plantation is presented in table 3, revealed that the soil organic carbon varied from 5.60 to 12.87 g kg^{-1} (surface) and 5.06 to 12.11 g kg^{-1} (sub-surface). The organic carbon was more in 1990 year of bamboo plantation and less in fallow land. The maximum OC was recorded 12.87 g kg^{-1} (surface) and 12.11 g kg^{-1} (sub-surface) in 1990 year of bamboo plantation, whereas lowest organic carbon was recorded 5.60 g kg^{-1} (surface) and 5.06 g kg^{-1} (sub-surface) under fallow land. The results are in agreement with the findings of Verma *et al.* (2011) [20].

Calcium carbonate (%)

The calcium carbonate is one of the important property of soil. The results of $CaCO_3$ content in soil are presented in table-3. The data shows that the values of $CaCO_3$ of soil ranged between 3.09 to 3.56 % (surface) and 3.49 to 3.93 % (sub-surface), the calcium carbonate was high in fallow land and low in 1990 year of bamboo plantation. The lowest calcium carbonate was recorded 3.09 % (surface) and 3.49 % (sub-surface) in 1990 year of bamboo plantation whereas highest calcium carbonate was recorded 3.56 % (surface) and 3.93 % (sub-surface) in fallow land. The value of calcium carbonate did not have much more difference in all the locations. Kharche (2013) [8] reported that, the significant reduction in free $CaCO_3$ could be attributed to considerable amount of biomass added to the soil due to long-term cultivation and organic matter applied through conjunctive use treatments. The reduction in $CaCO_3$ might be due to organic acids released during the decomposition of organic materials which react with $CaCO_3$ to release CO_2 thereby reducing $CaCO_3$ content of the soil.

Table 3: Organic carbon and $CaCO_3$ of soil under different age of bamboo plantation

Sr. No.	Year of bamboo plantation	OC (g kg^{-1})		$CaCO_3$ (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	1990	12.87	12.11	3.09	3.49
2	1992	11.79	11.07	3.15	3.64
3	1994	10.66	9.96	3.23	3.73
4	1997	9.27	8.49	3.33	3.74
5	2008	8.66	8.07	3.41	3.83
6	2014	8.06	7.59	3.49	3.89
7	Fallow land	5.60	5.06	3.56	3.93

Carbon stock and sequestration potential of soil.

Carbon stocks of soils (Mg ha^{-1})

There is change in soil organic carbon pools when natural ecosystem is converted into agro-ecosystem and or land use changed over time, the magnitude of changes depends on land use, management and ecological factors, such as, temperature, precipitation, soil types and native vegetation. Quantification of changes in the SOC pool as a result of agricultural land use provides a references point regarding sequestration potential of SOC stock estimation and comparing the C sequestration potential of various land use systems. Forest soils, being the least distributed by anthropogenic activities like agriculture.

The data in respect to carbon stock of soil is presented in table 4. The data shows that, the value carbon stock ranged between 13.52 to 22.97 Mg ha^{-1} (surface) and 12.44 to 22.34 Mg ha^{-1} (sub-surface) under different age of bamboo plantation. Carbon stock was recorded more in 1990 year of bamboo plantation and less was recorded in fallow land. The highest value of carbon stock was recorded 22.97 Mg ha^{-1} (surface) and 22.34 Mg ha^{-1} (sub-surface) under 1990 year of bamboo plantation whereas lowest carbon stock was recorded 13.52 Mg ha^{-1} (surface) and 12.44 Mg ha^{-1} (sub-surface) in fallow land.

Table 4: Carbon stock of soil under different age of bamboo plantation

Sr. No.	Year of bamboo plantation	Carbon stock (Mg ha^{-1})	
		0-15 cm	15-30 cm
1	1990	22.97	22.34
2	1992	22.28	21.25
3	1994	21.26	20.61
4	1997	19.88	18.72
5	2008	19.09	18.39
6	2014	18.49	17.98
7	Fallow land	13.52	12.44

The highest value of carbon stock was recorded in 1990 year of bamboo plantation fallowed by 1992 year of bamboo plantation and low value of carbon stock was recorded in fallow land.

Carbon sequestration potential

The capacity of a soil to sequester organic carbon is dependent mainly on climate, soil type and landscape, types of vegetation and soil management imposed by agriculture practices. Reduction in soil organic carbon (SOC) has commonly been attributes to traditional agriculture practices in cropping soils that have left the soil vulnerable to the effect of wind and water erosion.

The large potential of carbon sequestration is to soil, forestry and agro-forestry system has provides premising approach to reduces the atmospheric concentration of CO_2 for mitigation climate change. The global soil carbon stock of agriculture land use has deserved historically and continues to decline. There improved agronomic practices that could lead to reduced carbon losses or even increased soil carbon storage are highly desired.

The soil under 1990 year of bamboo plantation (Baseline or Reference level) and those under different age of bamboo plantation have similar soil substrate and pedo-climate, therefore; ideally the SOC stock obtained in 1990 year of bamboo plantation soils may also be attainable in the soils under different age of bamboo plantation. It is, in this context, the finding of the present work is extrapolated to quantify C-sequestration potential and also the priority areas.

The data presented in table 5. Revealed that, in (0-15 cm) surface soil as much as 22.97 Mg ha^{-1} organic carbon was sequestered in soil under 1990 year of bamboo plantation. Similarly, 22.28, 21.26, 19.88, 19.09, 18.49 and 13.52 Mg ha^{-1} of SOC were sequestered in 1992, 1994, 1997, 2008, 2014 and fallow land respectively. Whereas, in (15-30 cm) sub-surface soil as much as 22.34 Mg ha^{-1} organic carbon was sequestered in soil under 1990 year of bamboo plantation. Similarly, 21.25, 20.61, 18.72, 18.39, 17.98 and 12.44 Mg ha^{-1} of SOC were sequestered in 1992, 1994, 1997, 2008, 2014 and fallow land respectively.

Table 5: Carbon sequestration potential of soil under different age of bamboo plantation

Sr. No.	Year of bamboo plantation	Existing Carbon stock (Mg ha^{-1})		Carbon sequestration potential (Mg ha^{-1})	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	1990	22.97	22.34	Baseline	Baseline
2	1992	22.28	21.25	-0.69	-1.09
3	1994	21.26	20.61	-1.71	-1.73
4	1997	19.88	18.72	-3.09	-3.62
5	2008	19.09	18.39	-3.88	-3.95
6	2014	18.49	17.98	-4.48	-4.36
7	Fallow land	13.52	12.44	-9.45	-9.90

The result conclusively indicates that the soil under fallow land lost their SOC followed by 2014, 2008, 1997, 1994 and 1992 year of bamboo plantation. It means soil under fallow land have lowest carbon sequestration potential whereas soil under 1990 year of bamboo plantation recorded highest carbon sequestration potential.

From the above result, it can be concluded that the carbon sequestration potential increases in order to 2014, 2008, 1997, 1994, 1992 and 1990 year of bamboo plantation respectively.

Bhattacharyya *et al.,* (2009) observed that carbon sequestration is one of the important mitigation strategy to cope with the impacts of climate change by reducing the atmospheric concentration of carbon dioxide emissions. The Kyoto protocol brought the mechanism of trading carbon units as a global mechanism to address the issue of reducing the emissions by various countries to meet the mandatory requirements.

Conclusion

From the study it can be concluded that, the carbon stock in the soil ranges between 13.52 to 22.97 Mg ha^{-1} (surface) and 12.44 to 22.34 Mg ha^{-1} (sub-surface), the soil carbon stock were highest in 1990 year of bamboo plantation and was found lowest in fallow land. The carbon sequestration potential increases in order to 2014, 2008, 1997, 1994, 1992 and 1990 year of bamboo plantation respectively. The carbon sequestration potential increases with the age of bamboo plantation, more the age of bamboo plantation higher value of carbon sequestration potential, whereas lower value of carbon sequestration potential was recorded in fallow land.

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