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Carbon Sequestration and Nutrient Storage in Soil under Different Agroforestry systems of Madhya Pradesh, India

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Abstract

The present study was focused on the analysis of physical and chemical properties of soil, under different agroforestry models**.** The study was conducted during 2016-2017 in the field of Indira Gandhi National Tribal University, Amarkantak, MP and during the study the soil sample was collected from different agroforestry model at the depth of 0-20 cm and 20-40 cm with the help of soil auger**.** Result reveals that the status of pH and EC ranged from 5.79 to 6.12 and 108.5µs to 233 µs, respectively, at 0-20 cm depth and at 20-40 cm depth, from all the Agroforestry Models. The Total Dissolving Salt (TDS) concentration ranged between 142 ppm to 166 ppm at 0-20 cm and 77.3 ppm to 162 ppm at 20-40 cm and salt concentration value varies from 57.1 ppm to 115 ppm in various Agroforestry Models.

The Nitrogen and Phosphorus contents was observed in Agroforestry Model I (D. Sisso + Aonla + Wheat) that is 420 and 22.5kg ha^{-1} at the depth of 0-20 cm and the highest Potassium was observed in Agroforestry Model II (Teak + Guava + Soybean) at the depth of 20-40 cm. The status of Nitrogen, Phosphorus and Potassium show mixed trends regarding the cultivation practices and depth of soil in case of model I and model II but in case of model III it was shows a significant difference between the model I and model II. The present study recommended that incorporation of at least one component belonging to leguminous family in agroforestry practices are highly preferable and beneficial which show better result regarding the health and fertility status of soil.

Keywords: Carbon Sequestration, Nutrient Storage, SOC, SOM, Agroforestry System.

Introduction

Agroforestry a term coined in 1977 denotes an age-old practice of having trees mixed in the agricultural landscape. It designates a holistic approach to land use in which woody perennials are deliberately grown on the same land management in spatial or temporal sequence. The objective of such combinations is to increase, sustain and diversify the production of land thereby to help in reducing economic and environmental risks. All agroforestry systems consist of at least two to three major groups of agroforestry components i.e. trees and shrubs (perennial), agricultural crops (annual or biennial) and pasture / livestock. There may be other components also, such as fish, honeybees, silk worms, lac insect etc. Agroforestry models play a very crucial and important role for the enhancement of soil fertility with efficient cycling of nutrients (Nair, 1984) through above- and below ground litter additions; retrieval behaviour of roots (Vogt et*al.,*1989; Young, 1991) and quality and quantity of added weed biomass.This advantage finds its root partially in studies of nutrient cycling in natural forest ecosystems (Golley*et al.,* 1975; Bernhard-Reversat, 1982; Jordan, 1982).

Review of Literature

In recent years attempts have been made to collect data on nutrient cycling in agroforestry systems as well. Among the major nutrients, nitrogen and phosphorus are the most important, especially in acid Alfisol is where nitrogen and phosphorus are most frequently limiting. In the case of Alfisols there is nearly always a substantial initial response to nitrogen fertilizer application. Phosphorus deficiency generally, appears after a few years of cultivation, when its initial quantity present in soil is depleted. In agroforestry systems there is some recovery of nutrients due to input of organic or inorganic materials by trees. However, little information is available on this aspect. The recovery of organic form of nitrogen by the crop is generally lower than that of inorganic N brought about by the application of nitrogen fertilizers during the course of cropping. Much of the nitrogen available from organic mulches not used by crops is incorporated into active and less active pools of soil organic matter (SOM), while much of the fertilizer nitrogen not used by crops is subject to leaching and denitrification losses. Agroforestry is a combined and sustainable land management system of intentionally growing agricultural crops along with woody perennials on farmlands to safe and sound both tangible and intangible benefits to the local people (Verma et al. 2017). The total area under Agroforestry in world is 1023 million hectare (FAO 2000). Out of this, the maximum area under Agroforestry, reported in South America followed by sub Saharan Africa. However the area under Agroforestry is increasing continuously, example in India, in 2007 it is reported 7.4 million hectare (Zomer *et al.* 2007) but in 2013 it reached up to 25.32 million hectare (Dhyani *et al*. 2013).

Aim of the study

Carbon and nutrients storage (NPK) is the basic element for plant growth the organic matter content of soil depends on the availability of carbon sequestration in soil under different land use systems. Soil organic carbon and soil organic matter are very important parameter of soil as they improves soil structure and soil health under various land use practices.

Materials and Methods

The study on **"**Analysis of carbon and nutrient storage in soil under different Agroforestry systems of Amarkantak**"** was carried in the Department of Environmental Science, Indira Gandhi National Tribal University, Amarkantak, Anuppur district of Madhya Pradesh, India during 2016-17.

Study Area

The present study was carried out in the premises of Indira Gandhi National Tribal University, Amarkantak, India. The IGNTU lays between 21° 15' to 22° 58' N latitude and 81°25' to 82° 5' E longitude. The study area was representing a dry tropical ecosystem in Amarkantak region, was selected for the analysis of Carbon and nutrient (N, P & K) storage in soil in different Agroforestry practices. The normal annual rainfall of the area is 1235.0 mm.The normal maximum temperatures recorded during the month of May is 41.3º C, and minimum during the month of December is 2.4º C. The normal annual means maximum and minimum temperatures of Anuppur district are 31.6º C and 18.2º C respectively.

Nutrient Analysis of Soil of Different Agroforestry Systems

Physical Properties

The physical properties of soil were determined with the help of given formulas and study revealed that the physical parameters i.e. pH, EC and TDS were measured.

Soil Sampling

The triplicate soil samples were randomly collected from the studied quadrates of different Agroforestry systems at soil depth of 0-20 cm and 20-40 cm with the help of soil auger. Soil samples of the same depth in a given sampling quadrate were thoroughly mixed and a composite sample was obtained. In all 30 soil samples (3 sample points x 5 quadrates x 2 depths) were collected and dried in shade and subjected to physico-chemical analysis. Soil pH is expressed in terms of pH and is a measure of the acidity or alkalinity of the analyzed soil.

Nutrient Analysis

The collected soil samples were chemically analyzed in triplicate for available N, P and K. Nitrogen was determined by Micro-Kjeldahl method (Jackson, 1967) by digesting 0.5 g of soil sample in 10 ml conc. H_2SO_4 and catalyst mixture of Na_2SO_4 and $CuSO_4$ (5:1 by wt.) followed by distillation and titration. The total phosphorous was determined by using spectrophotometer (Olsen *et al.,* 1954) and vando-molybdate yellow reagent procedure. In this procedure 0.5 gm soil sample was digested in 10 ml diacid (HNO_3 and $HClO_4$ 9:4) with yellow reagent (Ammonium molybdate+ ammonium meta-vandate+ nitric acid) and aliquots to take reading by spectrophotometer. Potassium was determined by flam-photometer method (Jackson, 1967). The organic carbon in soil was determined following Walkley and Black method (1934).The amounts of nutrients and C in soil were determined by multiplying soil volume, bulk density and respective concentrations of C and nutrient values for given soil depth corresponding to each forest type. These values converted into kg ha^{-1}. The determination of soil organic matter and soil organic carbon in various Agroforestry models has carried out.

Statistical Analysis

The significant difference between treatment means for all physical and chemical parameters of soil in various Agroforestry models were tested at $P < 0.05$ using least significant difference test (Gomez 1984).

Results and Discussions

The current study was focussed on the analysis of soil properties of different agroforestry models**.** During the study the soil sample was collected from different agroforestry model at the depth of 0-20 cm and 20-40 cm and the analysis of soil was carried out in the laboratory of Department of Environmental Sciences, Indira Gandhi National Tribal University, Amarkantak, and Madhya Pradesh**.** The outputs of current study are physiochemical properties of different agroforestry models, status of Nitrogen, Phosphorus, Potassium and organic carbon and organic material status in the soil of different agroforestry fields is depicted in Figure 1-4 and Table 1-3. Agroforestry provide diversified benefit to the people either directly or in the form of ecosystem services but still, there is great gap between research and extension in the field of Agroforestry (Kumar and Thakur 2017).

Physical Properties of Soil

The physical characteristics of the soil on different Agroforestry practices are presented in Table 1. The physical properties of soil viz; pH, EC, TDS and salt concentration were analysed**.** The physiochemical properties show approximate similar trends in case of pH mean while the EC, TDS and salt concentration show a significant result**.**

Table 1: Physical Properties of Soil in Different Agroforestry System

SN	**Agroforestry Models**	**pH**		**EC (µs)**		**TDS (ppm)**		**Salt conc.(ppm)**	
		0-20 cm	**20-40 cm**	**0-20 cm**	**20-40 cm**	**0-20 cm**	**20-40 cm**	**0-20 cm**	**20-40 cm**
1.	Agrihortisilvi cultural system	6.12	5.91	233	164.4	166	118	115	82.4
2.	Silvihorticultural system	6.02	5.90	198.8	232	142	162	98.6	109
3.	Agrihortisilvicultural system	5.98	5.79	218	108.5	155	77.3	107	57.1
	CD at 5%	0.41	0.48	0.091	0.11	0.57	0.46	0.23	0.31

The status of pH ranged from 5.98 to 6.12 at 0-20 cm depth and it was recorded 5.79 to 5.91 at 20-40 cm depth, from all the Agroforestry Models. The pH of Agroforestry Model I (Crop combination: Sissoo+ Aonla+ Wheat) was recorded highest 6.12 at the depth of 0-20 cm, followed by Agroforestry Model II (Crop combination: Teak+ Guava) was recorded 6.02 at 0-20 cm depth and lowest was recorded in Agroforestry Model III (Combination: Mahua+ Custard apple + wheat) that is 5.79 at the depth of 20-40 cm (Table 1). The trends of pH in different Agroforestry Model show the approximately neutral in nature which reflects the suitability of field condition for almost all crops is shown in Figure 1. EC values ranged from 108.5µs to 233 µs in three different Agroforestry Models. It was considerable difference in each Agroforestry Model. Maximum EC 233µs at 0-20 cm was observed in Agroforestry Model I, followed by 232µs in Agroforestry Model II at 20-40 cm depth and minimum 108.5µs was found in Agroforestry Model III (Figure 2). The Total Dissolving Salt (TDS) concentration ranged between 142 ppm to 166 ppm at 0-20 cm and 77.3 ppm to 162 ppm at 20-40 cm in all the Agroforestry Models, being higher in agroforestry model I 166 ppm at the depth of 0-20 cm and lowest was recorded in agroforestry model 77.3 ppm at the depth of 20-40 cm. (Table 1). The last parameter of same object was salt concentration and a salt concentration value varies from 57.1 ppm to 115 ppm (Table 1). The salt concentration values was recorded highest in Agroforestry Model I (D. sisso+ Aonla+ Wheat) 115ppm at the depth of 0-20 cm and lowest was recorded in Agroforestry Model III (Mahua+ Custard apple + wheat) 57.1 ppm at the depth of 20-40 cm among all the Agroforestry models Similarly studied were conducted by various researchers (Puri and Nair 2004; Pandey 2007; Singh and Gill, 2014).

The physiochemical properties of three Agroforestry model I viz., D.sissoo+ Aonla+ wheat, Agroforestry model II Teak + Guava + wheat and Agroforestry model III Mahua+ Custard apple + Wheat.The most favourable physiochemical properties of soil are found in Agroforestry model I followed by Agroforestry model II and III, respectively. The superiority of agroforestry model I regarding the physiochemical properties is outcome of tree component incorporated in the agroforestry practices. In the agroforestry model I, tree component incorporated are belong to leguminoseae family. In the agroforestry model II, the crop soybean which add nitrogen to field are grow with tree component Teak + Guava show more or less similar physiochemical properties in compare to agroforestry model I while agroforestry model III (Mahua+ Custard apple + Wheat) show poor result regarding the physiochemical condition of soil.

Figure 1: pH of Soil in Three Different Agroforestry Practices

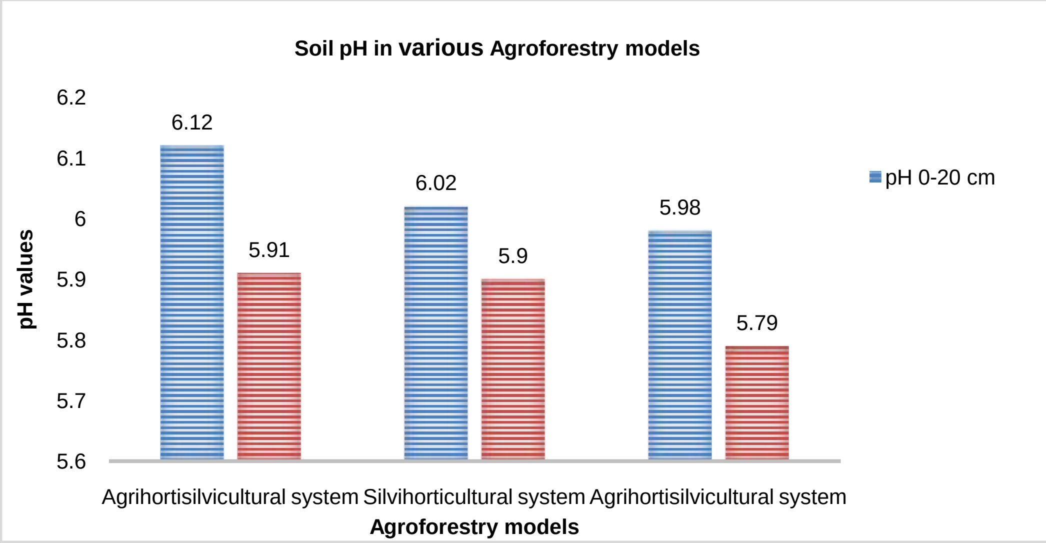
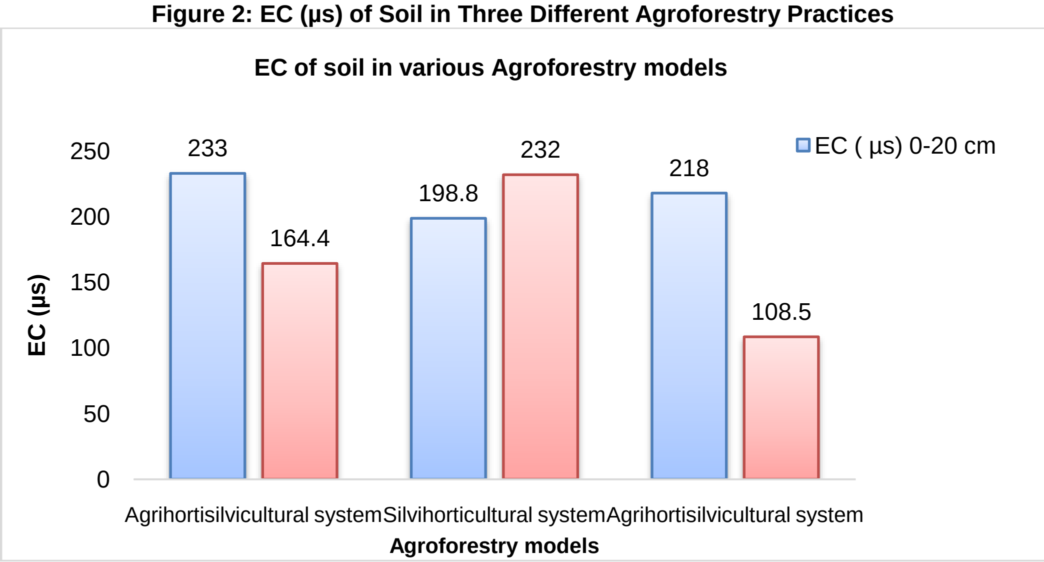


Figure 2: EC (μs) of Soil in Three Different Agroforestry Practices



Nutrient Status (NPK) of Soil in Three Different Agroforestry Models

N, P, and K are the key element for growth and development of plant. The status of these elements varied in soil according to cultivation practices, climatic condition, and depth of soil and locality of site. In the current study we observed the varying pattern of NPK in the soil. Present study indicated that the depth of soil and cultivation practices are varied which result the varying pattern of N, P, and K. The nutrient status of these three models is evaluated.

Total Nitrogen Content in Soil

Total nitrogen content in soil are presented in Table 2. The total nitrogen content varied from 400-420 kg ha^{-1} at 0-20 cm depth and 310-400 kg ha^{-1} at 20-40 cm depth in all three Agroforestry Models. The average total nitrogen content in both the depth of soil layers was recorded maximum 410 kg ha^{-1} in Agroforestry Model I (Crop combination: Sissoo+ Aonla+ Wheat) followed by in Agroforestry Model II (Crop combination: Teak+ Guava) and minimum 340 kg ha^{-1} was found in Agroforestry Model III (Combination: Mahua+ Custard apple + wheat). The analysis of variance indicated that the different between all the Models are significant at P>0.05. Similar results were done by various workers (Pandey et al. 2000, Verma et al. 2017).

Total Phosphorus Content in Soil

The total phosphorus content in soil ranged from 7.5 - 22.5 kg ha^{-1} at 0-20 cm depth and it was observed 13-15.5 kg ha^{-1} at 20-40 cm depth, from all the Models. The maximum phosphorus content in soil was recorded 22.5 kg ha^{-1} and 15.5 kg ha^{-1} in Agroforestry Model I at 0-20 cm depth and 20-40 cm depth, respectively. The minimum 13 kg ha^{-1} and 7.5 kg ha^{-1} in Agroforestry Model III of both 0-20 cm and 20-40 cm depth of soil layer. Analysis of variances showed significant (P>0.05) differences between all the Models (Table 2).

Total Potassium Content in Soil

The status of potassium content ranged from 125-250 kg ha^{-1} at 0-20 cm depth and it was observed 165-175 kg ha^{-1} ranged at 20-40 cm depth from all the Models. The potassium content was recorded maximum values 275 kg ha^{-1}Agroforestry Model II at 20-40 cm soil depth and minimum 165 kg ha^{-1} was found in Agroforestry Model III at 20-40 depth.

Total NPK Content (kg ha^{-1}) of Soil in Various Agroforestry Models

The highest quantities of Nitrogen and Phosphorus was observed in Agroforestry Model I (D. sisso+ Aonla+ Wheat) that is 420 and 22.5kg ha^{-1} at the depth of 0-20 cm and the highest Potassium was observed in Agroforestry Model II (Teak + Guava + Soybean) at the depth of 20-40 cm.

Table 2: NPK Quantities of Soil in Three Different Agroforestry Systems (kg ha^{-1})

S.N.	Agroforestry system	Nitrogen (kg ha^{-1})		Phosphorus kg ha^{-1})		Potassium (kg ha^{-1})	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1.	Agrihortisilvi cultural system	420	400	22.5	15.5	187	178
2.	Silvihorticultural system	405	320	18.5	14.5	255	275
3.	Agrihortisilvicultural system	400	310	7.5	13	250	165
	CD at 5%	0.097	0.087	0.093	0.13	0.21	0.26

The status of Nitrogen, Phosphorus and Potassium show mixed trends regarding the cultivation practices and depth of soil in case of model I and model II but in case of model III it was shows a significant difference with model I and model II. The NPK are the macro nutrient also called primary nutrients, required in large amount viz; more than 1 ppm. The agroforestry practices have significant beneficial compare to monoculture in improvement of soil fertility by adding nutrient in soil through tree component incorporated with it. The agroforestry practices have closed type of nutrient cycle which result more addition of nutrient compare to loss. in our study the highest quantity of nitrogen and phosphorus in soil is observed in agroforestry model I at the depth of 0-20 cm while potassium content is higher in agroforestry model II at the depth of 20-40 cm. The agroforestry model III found lowest trend regarding the NPK status of soil. The present studies revealed that leguminous component in field add nitrogen by fixing of soil nitrogen. While, other nutrients like phosphorus add through mycorrhizal association of tree component in the field. The study show the agroforestry model I having D. sissoo and Aonla as a tree component add more N_2 and phosphorus in the soil because D. sissoo belong to leguminous family and having mycorrhizal association with its root. The potassium was higher in Agroforestry model II which have Teak + Guava tree component. Guava is a good source of Potassium.

Determination of Soil Organic Carbon (SOC) and Soil Organic Matter (SOM) in Various Agroforestry Systems

Carbon acts as a building block for plant and soil in the nature. The quantity of carbon in soil represents the availability of organic matter in soil. The organic matter is a source of essential nutrient for plant in soil. It also facilitates the activity of beneficial microbes in soil. The carbon content of soil varied according the vegetation and climatic condition of particular area. The natural forest have richest source of carbon compare to other cultivation practices, however the agroforestry field also have considerable amount of carbon compare to sole agricultural field. The soil organic carbon and soil organic matter status of these three models are evaluated.

Soil Organic Carbon (SOC) and Soil Organic Matter (SOM) of Soil in Three Different Agroforestry System

The highest soil organic carbon and soil organic matter was recorded maximum in Agroforestry Model I (D. sisso+ Aonla+ Wheat) that is 1.87 % and 3.22 %, respectively at the depth of 0-20 cm followed by 1.05% and 2.06% in Agroforestry Model II (Crop combination: Teak+ Guava) at 20-40 cm and 20-40 cm depth. While, minimum concentration was recorded in Agroforestry Model III (Mahua+ Custard apple + wheat) that is 0.9 and 1.55 % respectively at the depth of 0-20 cm (Table 3). The details of soil organic carbon and soil organic matter were depicted in Figure 3 and 4.

Table 3: Soil Organic Carbon (SOC) and Soil Organic Matter (SOM) of Soil in Three Different Agroforestry Systems

Sl No.	Agroforestry system	SOC (%)		SOM (%)	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm
1.	Agrihortisilvi Cultural System	1.87	1.5	3.22	2.58
2.	Silvihorticultural System	1.05	1.2	1.81	2.06
3.	Agrihortisilvicultural System	0.9	1.5	1.55	2.58
	CD at 5%	0.023	0.028	0.12	0.18

Figure 3: Soil Organic Carbon (%) in Three Different Agroforestry Practices

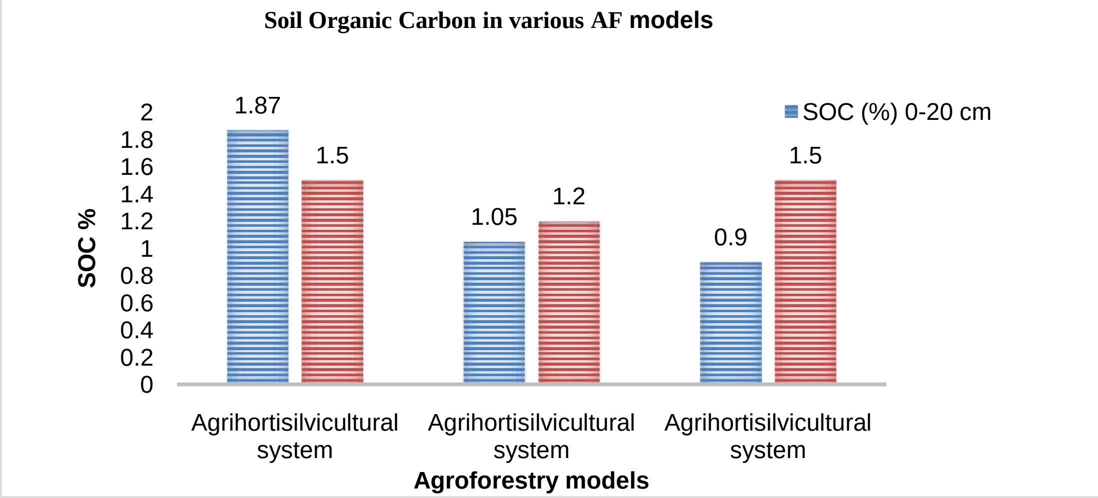
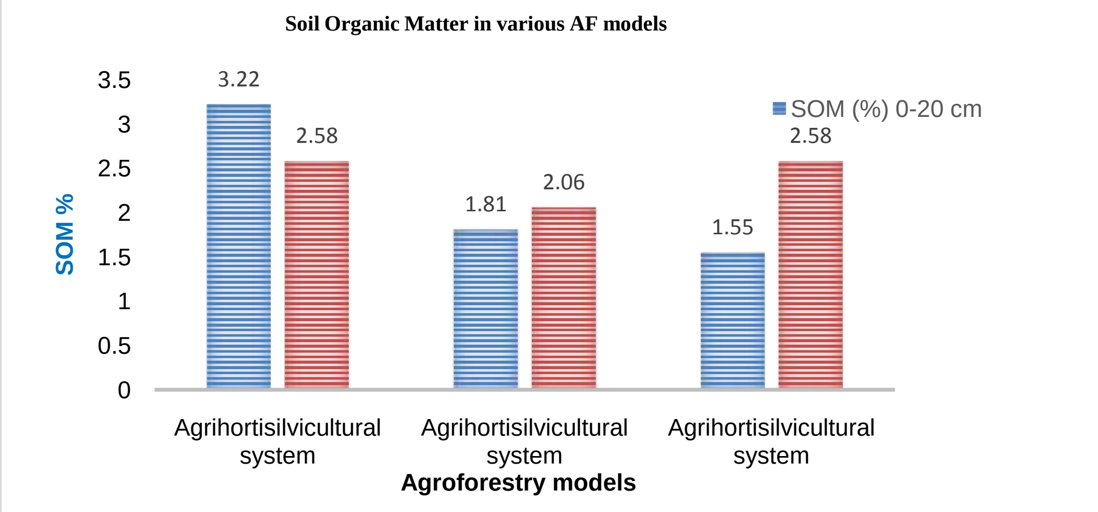


Figure 4: Soil Organic Matter (%) in Three Different Agroforestry Practices



The above shown data of these three tables revealed that the Agroforestry model I (D. sisso+ Aonla+ Wheat) was superior in case of soil properties compare to other Agroforestry models and the soil depth 0-20 cm are found superior or nutrient rich in all type of agroforestry systems. Carbon is the basic element for plant growth the organic matter content of soil depends on the availability of carbon in soil. Soil organic carbon and soil organic matter are very important parameter of soil as they improves soil structure, its drainage and aeration, water holding capacity, buffer and exchange capacity. soil organic carbon also important in controlling the available nitrogen in soil. During the present study we compare the soil organic carbon and organic matter in three different agroforestry practices and found the highest carbon and organic matter in the agroforestry model I at the depth of 0-20 cm. The surface soil has rich in organic carbon and organic matter due to the crop residues and plant detritus matter. The legume component add more organic carbon that result high content of organic matter. The organic matters in the field add 95% Nitrogen and 33% phosphorus in soil. This is another factor for high content of Nitrogen and Phosphorus in soil of Agroforestry model I. According to Bijalwan et al. 2017 t here are various neem based agroforestry systems are observed in India as under agri-silviculture, agri-silvi-horticulture, silvipastoral system and shelter belts/wind breaks etc. In traditional agri-silviculture system, retaining tree on farm land with agriculture crop is well known practice in all across the India.

Conclusion

The rapid growth in population, declining of size of land holding and irregular weather condition is increasing the pressure on sole agriculture crop. The farmers having small and marginal land holding are not able to fulfil their basic need from sole agriculture crop. To mitigate these harass situation several institutional approach, research activities and extension activities are carried out in state which inclined the farmers to accept sustainable land used practices and integrated farming practices viz; Agroforestry. The incorporation of trees/ Livestock within the farm, generating adequate income and employment for the small and marginal farmers. So, Agroforestry practices are more an important, efficient and viable option for small and marginal farmers in Madhya Pradesh. The Agrihortisilvicultural and silivihorticultural systems should be developed in natural open grasslands by planting MPTs and other palatable grasses to protect the forests from overgrazing and browsing. The rotational grazing practices should be adopted in regenerating grasslands. It is also suggested to practise alternative land management/ agri-silvicultural practices in marginal, degraded and agricultural lands, which are accurately under-utilized.

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