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Soil organic carbon stocks in different agroforestry systems of south Gujarat

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Abstract
Soil organic carbon (SOC) content has influences on the sustainability and stability of any agroforestry system. In this present study, SOC and SOC stocks distribution in soil (0-30 cm) in five predominant agroforestry systems (agri-horticultural, agri-horti-silvicultural, agri-silvicultural, horti-pastoral and homegarden) practiced in Navsari, Gujarat were examined. The result revealed that homegarden system had low bulk density (1.36 Mg m^{-3}) and highest soil organic carbon content (0.78 %) as compared to other agroforestry systems. Overall, the soil organic carbon stocks (0-30 cm) in different agroforestry systems ranged from 23.75 to 29.58 Mg ha^{-1}. The top soil layer (0-15 cm) of homegarden system had the highest (15.82 Mg ha^{-1}) soil organic carbon stocks (SOCS), followed by agri-horti-silvicultural system (14.56 Mg ha^{-1}) and the agri-silvicultural system recorded the lowest SOCS of 12.32 Mg ha^{-1}. Overall, there was a decline of 8.57 % SOCS spatially from the top to the sub-soil layer.

Keywords: Agroforestry systems, Navsari, Soil bulk density, Soil organic carbon stock

Introduction

Organic matter content in the soil is the most important ecological factor that determines the productivity of terrestrial ecosystem as, it affects physical, chemical and biological properties of soil, thus considered a key attribute of soil fertility (Verma *et al*., 2010; Amundson, 2001). This adjudges land management issues to enable greater sequestration of carbon (Lal, 2004; Banerjee *et al.,* 2006). As far as food production system is concerned for a greater carbon stocking, agroforestry systems are prescribed (Leifeld and Kögel-Knabner, 2005; Nair, 2012). The ecological processes in agroforestry systems due to continuous addition of litter and decomposition activities make the system more efficient in terms of carbon stocking and nutrient cycling. The present study, therefore, aimed to explore the potentiality of different agroforestry systems in terms of carbon stocking to eventually help in enhancing the productivity of the systems.

Materials and Methods

***Selection of Agroforestry systems*:** The present investigation was carried out during 2015-16 in Navsari district of Gujarat by choosing five dominant agroforestry systems *viz*., agri-horticultural (mango + rice), agri-horti-silvicultural (okra + mango + teak), agri-silvicultural (sugarcane + teak), horti-pastoral (sapota + sorghum) and homegarden systems of this region. The selection of agroforestry system was done after a preliminary survey. The most common agricultural crop grown in AH system are *Oryza sativa*, *Dolichos lablab* and *Cicer arientinum*. Under homegarden system, farmers of this region mostly grow crops like *Cymbopogon spp, Ocimum spp, Allium sativum, Coriandrum sativum, Colocasia esculenta, Musa spp, Carica papaya, Capsicum annuum, Curcuma longa, Vigna unguiculata, Trigonella foenum-graecum, Cajanus cajan, Spinacia oleracea,* and *Cyamopsis tetragonoloba*. In AHS system farmers generally grow agricultural crops like *Abelmoschus esculentus*, *Solanum melongena* and *Solanum lycopersicum*. However, in AS and HP systems farmers preferred to grow *Saccharum officinarum* and *Sorghum spp*, respectively. The climate of the study site was characterized by a very hot summer, a moderately cold winter and a warm and humid monsoon. The mean annual rainfall was about 1431 mm, mostly concentrating in the months of July and August. The soils of this region were predominantly of clayey type.

***Soil sampling and analyses*:** Soil samples were collected at two depths (0-15, 15-30 cm) using power auger. Soil samples were collected throughout the year in seasonal basis *viz.,* summer (July - August), autumn (October-

November), winter (January-February) and spring (March-April). The six replicated soil samples collected from each site was pooled to have a composite soil sample for each system. The samples were air dried and used for determining organic carbon (Walkley and Black, 1934). Soil bulk density was measured by core method (Allen *et al*., 1974). Soil OC stock (Mg ha^{-1}) at different soil depths in different agroforestry systems were calculated using the formula given by Nelson and Sommers (1996):

SOC stock (Mg ha^{-1}) = SOC (%) × bulk density (Mg m^{-3}) × soil depth (m) × 100

***Statistical analysis*:** One way analysis of variance (ANOVA) was carried out in accordance with the procedure suggested by Gomez and Gomez (1984). Duncan's multiple range test (DMRT) and LSD at P <0.05 for comparison of significant differences between means, were performed using SPSS 17.0 (SPSS Inc., Chicago, USA) windows version package.

Results and Discussion

Soil bulk density: Soil bulk density was significantly different (P<0.05) amongst agroforestry systems studied (Table 1). The homegarden system produced the minimum (1.36 Mg m^{-3}) bulk density followed by horti-pastoral system (1.38 Mg m^{-3}). Agri-horticultural system however, recorded the greatest bulk density (1.41 Mg m^{-3}) Significant differences across soil layers were observed with upper soil depth (0-15 cm) had lesser bulk density than lower depth (15-30 cm). Bulk density increased with soil depth and lower value was observed under the homegarden system. Among the five agroforestry systems, the bulk density of the agri-horticultural system was the highest which might be attributed to less root biomass in this agroforestry site, and this was in conformity with Deb (2005).

Soil organic carbon: The data pertaining to soil organic carbon (SOC) content (%) in different soil depth under different agroforestry systems indicated significant differences (Table 1), registering a decrease of 16.17% SOC in 15-30 cm soil layer over 0-15 cm irrespective of systems. Amongst the systems, the top 0-15 cm soil layer in homegarden system registered the highest SOC (0.78%), followed by agri-horti-silvicultural system (0.70 %) and lowest value was recorded under agri-horticultural and horti-pastoral systems (0.65 %) SOC. In sub-surface layer (15-30 cm), the results showed similar trend as observed in upper soil depth (0-15 cm). It was also observed that top layer (0-15 cm) soil depth exhibited significantly higher SOC content than the bottom layer in all the system, except in agri-silvicultural and horti-pastoral systems. Variation in organic matter across the present study sites might be due to differences in plant species composition (Arunachalam and Arunachalam, 2000; Singh *et al*., 2018; Chaturvedi *et al*., 2016). For instance, the homegarden systems had greater species richness that might have resulted in diverse litter accumulation on the floor leading to higher SOM. Significant increase in SOC was also reported in grazed permanent pasture fields due to high return of leaf litter and animal dung (Milne and Haynes, 2004). On the other hand, low organic matter content in agri-horticultural system might be due to the fact that the less litters fall and consequently lower addition to the soil. SOC content also showed variation among the seasons being highest during autumn season and decreased with increasing depth. SOC content was maximum in homegarden system and minimum in agri-horticultural system (Fig 1). Higher accumulation of organic matter during autumn season was also observed by Singh *et al*. (2000) in their study in arid zone agroforestry system.

Table 1. Effect of different agroforestry systems on bulk density and soil organic carbon content in different soil depths (values are means of four seasons)

Agroforestry systems	Bulk density (Mg m^{-3})			SOC (%)		
	0-15	15-30	Between layers	0-15	15-30	Between layers
Agri-horticultural (AH)	1.41^{c}	1.53^{c}	*	0.65^{ab}	0.53^{a}	*
Agri-horti-silvicultural (AHS)	1.38^{b}	1.50^{c}	*	0.70^{b}	0.60^{b}	*
Agri-silvicultural (AS)	1.39^{b}	1.48^{b}	*	0.59^{a}	0.52^{a}	ns
Horti-pastoral (HP)	1.38^{b}	1.50^{c}	*	0.65^{ab}	0.58^{ab}	ns
Homegarden (HG)	1.36^{a}	1.43^{a}	*	0.78^{c}	0.64^{c}	*
General mean	**1.38**	**1.49**		**0.68**	**0.57**	

Values bearing different superscripts are significantly different at P<0.05 based on Duncan's multiple range test (DMRT). Significance between soil layers of same fruit crop at P<0.05, ns: non-significant.

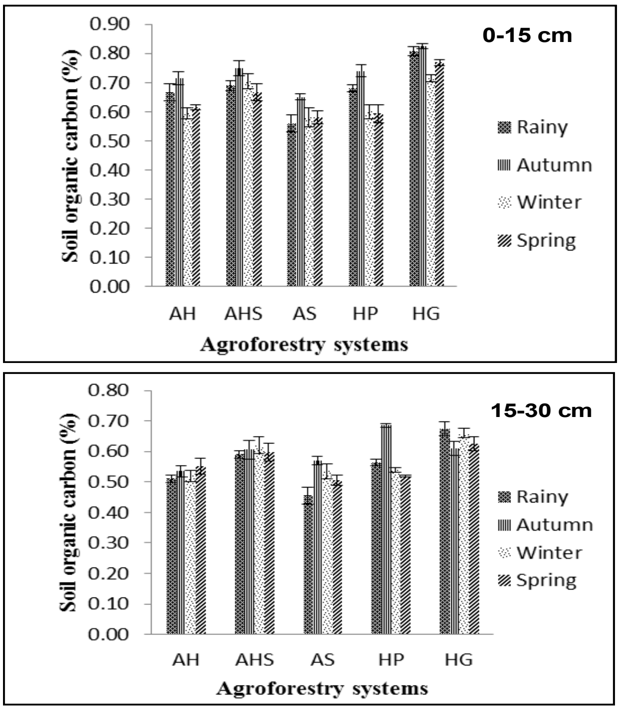

Fig 1. Seasonal variation of SOC in different agroforestry systems

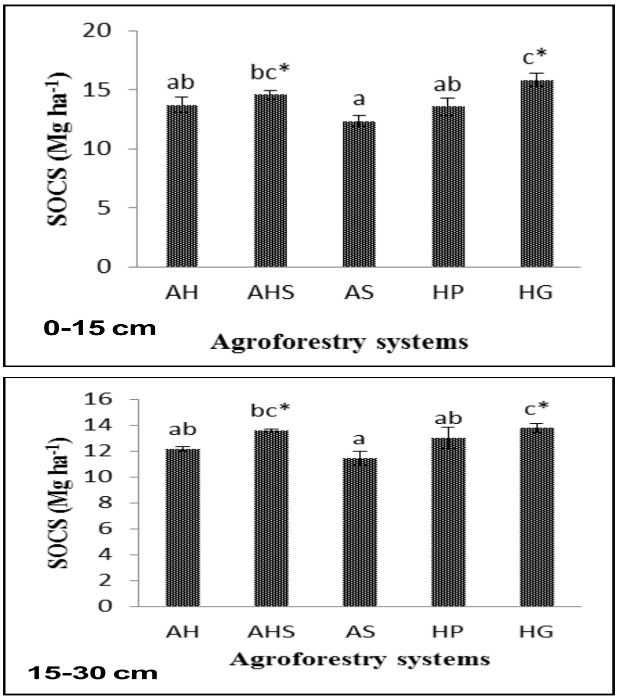

Fig 2. SOCS (Mg ha^{-1}) in soil at two depths of different agroforestry systems. Each bar represents the mean and standard error (n = 3). Means not sharing a letter in common differ significantly (P<0.05) between same soil layers of different systems. Means sharing '*' in common differ significantly (P<0.05) between soil layers of same system

Soil organic carbon stocks: The data pertaining to soil organic carbon stocks (SOCS) revealed that the SOCS storage (0-30 cm) in different agroforestry system ranged from 23.75 to 29.58 Mg ha^{-1}. The upper soil layer (0-15 cm) of homegarden system stored 15.82 Mg ha^{-1} SOCS, followed by agri - horti - silvicultural system (14.56 Mg ha^{-1}), and the agri-silvicultural system recorded the lowest value of 12.32 Mg ha^{-1} SOCS (Fig 1). It was also found that soil SOCS content showed significant (P<0.05) differences across soil depths in homegarden and agri-horti-silvicultural systems only. Structural composition of the different agroforestry system associated with their in-situ interaction with the environment influenced the carbon storage of the system (Samra and Singh, 2000; Saha *et al*., 2007). Due to higher species composition along with proper management in the homegarden system leads to higher concentration of SOCS. Significantly higher SOCS content was recorded in upper layer of soil than lower layer of soil (Fig 2). Overall, irrespective of different agroforestry systems there were a spatial decline of 8.57 % SOCS in the 15-30 cm soil layer as compared to the 0-15 cm depth. Similarly SOC, SOCS also showed variation among the season and highest being registered during autumn season since, SOC was mainly attributed to the building of SOCS.

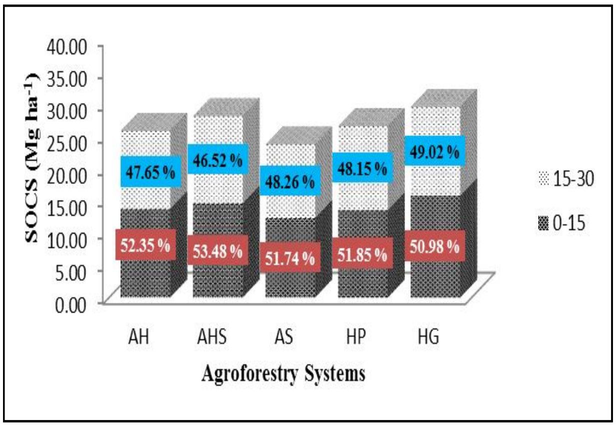

Fig 3. SOC stock (for 30 cm depth) and depth wise proportionate distribution in different agroforestry systems

Correlation between BD and SOC: Soil bulk density determines the compactness of the soil. The relationship between bulk density and soil organic carbon concentration was negative correlated indicating any improvement of bulk density that could enhances the soil organic content in the soil (Fig 4) and similar results was also reported earlier by Schrumpf *et al.* (2011) and Kalita *et al*. (2016). Generally land management level had a major impact on the bulk density, since continuous cultivation of soil would likely to destroy the soil aggregates and influenced the compactness of the soil.

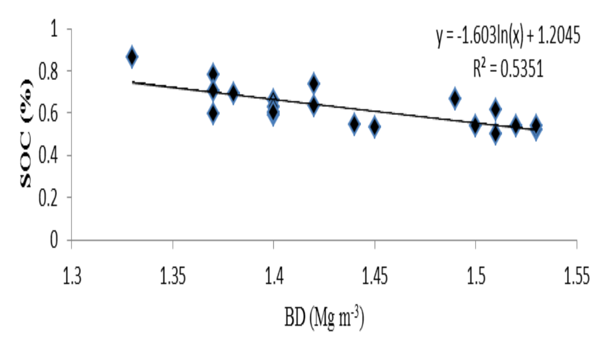

Fig 4. Relation between bulk density (BD) and soil organic carbon concentration (SOC%) under different agroforestry systems. Data for two soil depths were plotted and the regression equations were noted together with R^2 values (N= 20).

Conclusion

Variation in organic matter across the present study sites indicated the differences in plant species composition, level of diversity and management activities. Homegarden systems registered the maximum SOCS due to higher species diversity. This further reflects the ecological role of trees in farm lands. It could be said that adoption of agroforestry could help in mitigating the effects of climate change phenomenon on a long-term basis, by not only sequestering more carbon in its biomass, but also accumulating soil organic carbon through litter recycling.

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