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Original Research Article

Effect of Organic Farming on Vertical Distribution of Soil Attributes, Carbon and Nitrogen Stocks

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A B S T R A C T

Agricultural soils are among the earth's largest terrestrial reservoirs of Carbon and soil organic-C pools play a vital role in the soil quality, availability of nutrients, environmental functions, and global carbon cycle. Organic farming may contribute substantially to future agriculture production worldwide by improving soil quality. In the present investigation, a field study was conducted to determine the vertical distribution of carbon, nitrogen and other soil properties in four representative soil profiles, one profile each from < 3 years, 3-6 years and > 6 years of fields with organic farming practice and one from conventional system under southern transitional zone of Karnataka, India during 2008-09. The results revealed that, the higher soil organic carbon concentrations were recorded in the first horizon (plough layer) in all the profiles irrespective of farming practice, ranging from 11.2 to 16.2 g kg^{-1}. Soil chemical and biochemical attributes, except bulk density, varied widely by period of organic farming practice and generally decreased with increasing depth. Under organic farming, plough layer in > 6 years of organics application, recorded significantly higher levels of both soil Total-C stock (239.66 Mg ha^{-1}) and Total –N stocks (10.85 Mg ha^{-1}).

Keywords

Organic Farming, Vertical distribution, Soil properties, Total-C & N stocks

Introduction

The effects of climate change are also greatly contributing to threatening food security in many regions of the globe. To this already scaring scenario we have to add the shortage of fossil fuels which, in the near future, will have a dramatic impact on the performances of intensive agriculture (Millennium Ecosystem Assessment, 2005). In this sense, organic agriculture represents an option that should be explored because it simultaneously aims to preserve soil fertility, biodiversity, and the landscape's ecological functionality.

Organic agriculture aims at maintaining the long term sustainability of the agroecosystem as a whole, preserving and improving soil quality, minimizing energy and water use, preserving biodiversity, guaranteeing good quality and safe food products to consumers. Soil organic matter, nutrients, and biological activity contribute to ecosystem-level process and are important for productivity, community structure, and fertility in terrestrial ecosystems (Stevenson, 1994).

Measurement of the soil enzymatic activities can be utilized as an indicator of the reestablishment of connections between the biota and restoration of function in degraded systems, they may also indicate the soil's potential to sustain microbiological activity (Paul and Clark, 1989). Information on organic C stocks in agricultural soils is important because of the effects of SOC on climate change and on crop production. The SOC stock at any time reflects the longterm balance between additions of organic C from different sources and its losses through different pathways. Following the adoption of large-scale intensive cropping, this long-term balance was modified since intensive cropping encourages oxidative losses of C due to continued soil disturbance, while it also leads to a large-scale addition of C to the soil through crop residues. This may cause either a net buildup or a net depletion of SOC stock (Cole *et al.*, 1993 and Rasmussen *et al.*, 1980).

The objective of the present study was to examine (i) the vertical variations in soil physical properties and nutrient availability; (ii) changes in microbial biomass C and N, soil enzyme activity depth wise and (iii) to measure the total C and N stocks in the pedons in organic farming practice over different periods (< 3years, 3-6years and > 6years) of continuous application of organic manures compared with one conventionally managed profile in a semiarid agro ecosystem.

Materials and Methods

Southern transition zone (Zone-7) comprises an area of 1.22 million hectares covering the districts of Hassan, Shimoga and parts of Mysore and Chickamangalore of Karnataka, India. The annual rainfall ranges from 612 to 1054 mm and more than 60% of this is received in *monsoon* season. The principal crops grown are rice, ragi, pulses, sorghum, coffee and tobacco.

A study was carried to identify the farmers who are practicing organic farming over different periods (*viz.*, 0-3 years, 3-6 years and over 6 years) in southern transition agroclimatic zone (Zone-7) of Karnataka. To draw comparisons, farmers practicing conventional farming identified adjacent to the organic systems for the study. The sites of soil sampling were fixed using Global Positioning System.

Four soil pedons representing the situation specified for the study, to a depth of 100 cm were exposed during February, 2008-09 soil samples from each diagnostic horizon were also collected. The soil samples analyzed for different physical, chemical and biochemical properties following the standard procedures. Soil microbial biomass was estimated by following the fumigation and extraction method as proposed by Carter *et al.*, (1999). The dehydrogenase activity was determined using procedure as given by Casida *et al*. (1964). The urease activity was determined by following the method outlined by Eivazi and Tabatabai (1977). Acid and alkaline phosphatase activities were estimated as per the procedure given by Tabatabai and Bremner (1969).

The quantity of carbon stock in each depth was calculated following the method described by Batjes (1996). All statistical analyses were performed with the program SPPS 11.0 for Windows (SPSS, 2001).

Results and Discussions

Pedon 1: Organic farming (0-3 yrs)

Pedon 1 was studied in a field cultivated to ginger-beans in organic farming system for the past two years. Bulk density of soil was 1.14 Mg m^{-3} for surface soil and in the subsoil layers it ranged from 1.19 to 1.25 Mg m^{-3} (Table 1). Soil reaction was moderately alkaline throughout the solum with pH increasing to lower layers. Available phosphorus content of the surface soil was 34.2 kg ha^{-1} and in subsoil ranged from 16.3 to 20.2 kg ha^{-1} . Potassium (K) content of the surface layer was 224 kg ha^{-1}.and declined to 144 in the subsoil.

Dehydrogenase activity in the surfaces soil layer was 894 which declined to 419 µg TPF g^{-1} h^{-1} in subsoil. Urease activity in surface soil was 84.8µg NH_4-N $g^{-1}h^{-2}$ but declined to 18.44 in subsoil. Acid phosphatase activity was 52.6µg p-NP g^{-1} h^{-1}in surface and in sub soil 29.03. Alkaline phosphatase activity in the surface soil was 44.92 and in subsoil layer 30.61µg p-NP g^{-1} h^{-1}.

Organic carbon content of the surface soil was 11.2 g kg^{-1}. In the subsoil layers it gradually decreased and reached the level of 4.8 in the lowest layer (Table 3). The soil microbial biomass carbon and nitrogen contents in the surface horizon of the studied pedon were 495 and 72.3 µg g^{-1} respectively and were decreased gradually with the depth. The total carbon stock in the surface soil horizon was 59.85 Mg ha^{-1} and a total carbon stock in the entire pedon was of the order 123.85 Mg ha^{-1}. Total nitrogen stock in the surface horizon was 2.96 Mg ha^{-1} and in the pedon (100cm) recorded 7.48 Mg ha^{-1}.

Pedon 2: Organic farming (3-6 yrs)

Pedon 2 was studied in a field cultivated to maize-potato-ginger-maize rotation for more than four years. Bulk density of the surface soil layer was 1.12 Mg m^{-3} and in subsoil the values ranged from 1.18 to 1.32 Mg m^{-3} (Table 1). Soil reaction was slightly acidic throughout the soil profile. The available phosphorus content of the surface soil was 36.8 kg ha^{-1} and in subsoil ranged from 3.3 to 23.3 kg ha^{-1}. Available Potassium (K) content of the surface layer was 242 kg ha^{-1}.and declined to 70 in subsoil. Acid phosphatase activity was 54 in surface horizon and in subsoil it was 15.9µg p-NP g^{-1} h^{-1}The SMB-C and SMB-N contents in the surface horizon of the studied pedon were 585 and 73.2 µg g^{-1} respectively and were decreased gradually with the depth (Table 2). Soil total carbon stocks in the surface horizon was 29.34 and was recorded total carbon stocks in the whole pedon to the tune of 143.43 Mg ha^{-1}. Soil total nitrogen stocks in the surface horizon was 1.6 and in the whole pedon (100cm) it was of 7.98 Mg ha^{-1}.

Pedon 3: Organic farming (>6 yrs)

Pedon 3 was studied in a field cultivated to organic coffee for over 8 years. Bulk density of the surface soil was 1.12 and increased to 1.15 Mg m^{-3} in the immediate subsoil horizon. In the lower subsoil horizons bulk density ranged from 1.18 to 1.21 Mg m^{-3}. Soil reaction was neutral in all the layers (6.4 to 7.1). Plant available phosphorus (P) content of the surface soil was 43.2 kg ha^{-1} and in subsoil ranged from 4.4 to 27.1 kg ha^{-1} .

Dehydrogenase activity in the surfaces soil layer was 1568 µg TPF g^{-1} h^{-1} and declined to 212 in subsoil. Urease activity in surface soil was 194.5 µg NH_4-N $g^{-1}h^{-2}$ and declined to 26.5 in subsoil. Acid phosphatase activity was 58.0 in surface soil and in subsoil it was 13.2 µg p-NP g^{-1} h^{-1}. Alkaline phosphatase activity in the surface soil was 60.3 and in subsoil layer it was 11.3 µg p-NP g^{-1} h^{-1}.

The organic carbon content of the surface soil was 16.2 g kg^{-1} (Table 2). In the subsoil horizons the organic carbon content ranged from 7.2 to 14.4 g kg^{-1}, gradually declining with depth. The soil microbial biomass carbon and nitrogen contents in the surface horizon of the studied pedon were 885 and 106.2 µg g^{-1} respectively and were decreased gradually with the depth.

Table.1 Physical, chemical and biochemical characteristics of pedons as influenced by organic farming

Horizon	Bulk Density (Mg m^{-3})	pH	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Dehydrogenase (µg TPF$g^{-1}h^{-1}$)	Urease (µg NH4$g^{-1}h^{-2}$)	Acid Phosphatase (µg p-NP g^{-1} h^{-1})	Alkaline Phosphatase (µg p-NP g^{-1} h^{-1})
Pedon -1: (Organic farming 0-3yrs)								
AP	1.14	7.9	34.2	224	894	84.8	52.6	44.9
BW1	1.19	8.0	20.2	189	778	52.3	48.1	38.3
BW2	1.25	8.1	16.3	144	419	18.4	29.0	30.6
Cr	Weathered parent material							
Pedon -2: (Organic farming 3-6 yrs)								
Ap	1.12	6.6	36.8	242	1160	112.3	54.3	55.0
BW1	1.18	6.5	23.3	196	837	98.4	44.5	51.7
BW2	1.22	5.8	8.8	84	539	64.2	38.4	19.2
BW3	1.32	6.5	3.3	70	372	42.3	15.9	17.4
Cr	Weathered parent material							
Pedon -3: (Organic farming >6yrs)								
Ap	1.1	6.8	43.2	320	1568	194.5	58.0	60.3
BW1	1.15	6.5	27.1	245	984	178.3	46.8	48.9
BW2	1.18	6.4	19.9	196	606	114.6	29.5	29.6
BW3	1.21	7.1	9.9	151	309	84.8	15.1	17.5
BW4	1.21	7.1	4.4	140	212	26.5	13.2	11.3
Pedon -4: (Conventional farming)								
Ap	1.12	4.9	22.7	193	388	52.5	45.2	17.4
BW1	1.16	4.8	18.8	168	286	43.3	33.1	15.3
BW2	1.33	5.2	7.2	98	209	15.4	21.0	12.7
BW3	1.33	5.5	2.7	46	68	8.8	17.5	10.7

Table.2 Carbon distribution in pedons as influenced by organic farming

Depth (cm)	Organic-C (g kg^{-1})	MB-C (μg g^{-1})	MB-N (μg g^{-1})	Tot-C (g kg^{-1})	Tot-N (g kg^{-1})	Tot-C Stocks (Mg ha^{-1})	Tot-N Stocks (Mg ha^{-1})
Pedon -1: (Organic farming 0-3yrs)							
0-25	11.2	495	72	21	1.04	59.85	2.96
25-55	7.4	362	55	16	0.96	39.5	3.42
55-75	4.8	159	39	9	0.44	24.5	1.10
75-10	Weathered parent material					**123.85**	**7.48**
Pedon -2: (Organic farming 3-6 yrs)							
0-10	12.6	585	73	26	1.44	29.34	1.61
10-20	11.2	428	55	21	0.94	25.25	1.01
20-54	9.2	268	41	14	0.82	60.59	3.40
54-75	6.6	155	36	10	0.71	28.25	1.96
75-100	Weathered parent material					**143.43**	**7.98**
Pedon -3: (Organic farming >6yrs)							
0-10	16.2	885	106	36	1.85	40.32	2.07
10-30	14.4	698	86	32	1.42	37.72	1.63
30-50	13.1	467	68	26	1.26	63.25	2.97
50-80	8.4	285	49	17	0.84	62.07	3.05
80-100	7.2	124	24	15	0.49	36.3	1.13
						239.66	**10.85**
Pedon -4: (Conventional farming)							
0-20	12.1	462	66	20	1.31	58.02	2.93
20-48	8.2	285	36	16	0.72	56.19	2.34
48-71	6	164	22	8	0.44	31.2	1.43
71-100	2.2	98	8	4	0.17	30.32	0.65
						157.73	**7.35**

The total carbon stock in the surface soil horizon was 40.32 Mg ha^{-1} and a total carbon stock in the entire pedon was of the order 239.6 Mg ha^{-1}. Total nitrogen stock in the surface horizon was 2.07 and in the entire pedon (100cm) it was 10.85 Mg ha^{-1}.

Pedon 4: Conventional farming

Pedon 4 was studied for evaluating properties of conventional farming system. Bulk density of soil was 1.12 Mg m^{-3} for surface soil and in the subsoil layers it ranged from 1.16 to 1.33 Mg m^{-3}. Soil reaction was moderately acidic in surface and immediate sub surface layers with pH decreasing to strongly acidic in lower layers. Phosphorus content of the surface soil was 22.7kg ha^{-1} and in subsoil ranged from 2.7 to 18.8 kg $ha^{-1.}$ Potassium (K) content of the surface layer was 193 and decreased to 46 kg ha^{-1} in the subsoil.

Dehydrogenase activity in the surfaces soil layer was 388µg TPF g^{-1} h^{-1} and declined to 68 in subsoil. Acid phosphatase activity was 45.2 and 17.5µg p-NP g^{-1} h^{-1}in surface and sub surface soil respectively. Alkaline phosphatase activity in the surface soil was 17.4 and in subsoil layer it was 10.7µg p-NP g^{-1} h^{-1}.

Organic carbon content of the surface soil was 12.1 g kg^{-1}. In the subsoil layers it gradually decreased and reached the level of 2.2 g kg^{-1} in the lowest layer (Table 2). The soil microbial biomass carbon and nitrogen contents in the surface horizon of the studied pedon were 462 and 66.2 µg g^{-1} respectively and were decreased gradually with the depth. Soil total carbon stocks in the surface horizon was 58.02 Mg ha^{-1} and was recorded total carbon stocks in the whole pedon was 157.73 Mg ha^{-1}. Soil total nitrogen stocks in the surface horizon was 2.93 Mg ha^{-1} and in the whole pedon (100cm) it was of 7.35 Mg ha^{-1}.

Higher values for nutrient and different enzyme activities were recorded in pedon 3 (ORG; >6years) followed by pedon 2 (ORG; 3-6 years). The values decreased with increase in depth in all the pedons. The higher organic carbon recorded in surface horizon of pedon 3 followed by pedon 2 . The pedon 1 (ORG; 0-3years) and pedon 4 which was representing conventional farming practice recorded almost equal values for measured parameters. Soil microbial biomass-C and N also followed similar trend. Except for bulk density, other parameters registered decreasing trend with increase in depth of the profiles irrespective of farming systems and periods of practice of organic or conventional farming under southern transition zone. Pedon 3 recoded higher total carbon and total nitrogen stocks followed by pedon 4, pedon 2. Relatively lower carbon and nitrogen stocks in the pedons 2 and 1 are attributed to the weathered parent material noticed from 75 cm onwards.

The enzyme activities (dehydrogenase and phosphatases) were consistently higher in the surface layer (Ap horizon) in all the four representative profiles studied. Activity of dehydrogenase and Phosphatases of soil increased significantly in the fields subjected to organic farming for three specified time periods irrespective of cropping systems evaluated over conventional farming, with maximum activity being in the profile where organic farming has been practiced for over six years. Soil enzyme activities may be increased by incorporation of organic materials in the soil (Nannipieri *et al.* 1990) and this increased activity has generally been attributed to increased microbial biomass resulting from organic matter enrichment in the soil. The activities of dehydrogenase, acid and alkaline phosphatase in our study decreased markedly with depth in organic as well as conventional farming systems. This decrease in dehydrogenase and phosphatase activities with depth was associated with decrease in organic matter content. The decrease in dehydrogenase and phosphatase activities with depth is of importance because dehydrogenase is considered to be an indicator of total microbial activity and phosphatases are the indicators of rate of hydrolysis of the organic P in the soil (Tarafdar 2001). In the present study, the activity of acid phosphatase was on an average twice that of alkaline phosphatase activity in conventional farming practice. In high pH soils, alkaline phosphatase activity generally exceeds acid phosphatase activity and *vice versa* (Kramer and Green 2000). According to Van Bruggen and Semenov 2000, a healthy soil is a stable system with resilience to stress, high biological diversity, and high levels of internal nutrient cycling and the increased microbial biomass and enzyme activity in organically managed soils in the present study expedited decomposition of organic manures, nutrient cycling, and formation of organic matter and soil structure. As a result, organic management increased soil quality, which is a necessary indicator of land sustainability and management.

In conclusion, the vertical distribution of nutrients and biochemical properties in soil profiles sourced from both systems under southern transitional zones recorded decreasing trend with depth. The enzyme activities were consistently higher in the surface layer (Ap horizon) in all the four representative profiles studied. Activity of dehydrogenase and Phosphatases of soil increased significantly in the fields subjected to organic farming for three specified time periods irrespective of cropping systems evaluated over conventional farming, with maximum activity being in the profile where organic farming has been practiced for over six years. The current results suggested that three years of organic management may be a minimum to significantly and consistently enhance microbial biomass and activities that support nutrient supply for crops in the varied climatic and soil conditions.

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