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International Journal of Current Research
Vol. 9, Issue, 12, pp.62233-62242, December, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

EFFECTS OF SEASONS ON SOIL ORGANIC CARBON AND NITROGEN POOL DYNAMICS IN DIFFERENT LAND USES OF DELHI NCR REGION OF INDIA

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ARTICLE INFO

Article History:
Received 20th September, 2017
Received in revised form
03rd October, 2017
Accepted 15th November, 2017
Published online 27th December, 2017

Key words:
Soil Organic Carbon,
Soil Inorganic Carbon,
Soil Carbon Sequestration.

ABSTRACT

Four different Land uses were sampled in Delhi NCR region of India to evaluate the effects of seasons on soil organic carbon (SOC), total nitrogen (TN), soil inorganic nitrogen (SIC), Soil pH, Soil EC and soil C/N ratio. A study was carried out in the Protected forest (PF) and Unprotected forest (UPF) of the South Central Ridge of Aravallis (28°32′00″N 77°10′40″E) near Vasant Kunj and Mehrauli in Delhi, as well as in the Organic Farming (OF) and Chemical Farming (CF) fields located in Bulandsahar (Uttar Pradesh state in northern India having coordinates $28^0$26'N 77^0 50; E), Ghaziabad, UP of India. Soil samples were collected in the summer (March), monsoon (July) and winter (December) seasons of the year 2015 from various depths 0-5, 5-10, 10-15, 15- 20 & 20-30cm. A significant difference ($P<0.05$) was observed in sampling depth in SOC, TN, pH and EC in the all four selected land use, but only PF has shown significant differences in SIC across the depth and CF in C/N ratio. But no significant differences were observed across the three seasons (summer, monsoon and winter) in the SOC, TN and C/N ratio in all the four selected land use. Statistically significant ($P<0.05$) were observed across the season in soil pH and soil EC. In all the land use pH was observed highest in monsoon while lowest in summer seasons. Soil EC was observed highest in summer season while almost same in monsoon and winter seasons.

Citation: Poonam Kumari and Prof. Arvind Kumar Nema, 2017. "Effects of seasons on soil organic carbon and nitrogen pool dynamics in different land uses of Delhi NCR region of India", *International Journal of Current Research*, 9, (12), 62233-62242.

INTRODUCTION

Carbon (C) and nitrogen (N) levels specify soil richer and considerably impact on global climate change. Their oxides (–CO_2 and N_2O–) are the chief components of greenhouse gases. Thus, the rotation of C and N in different ecosystems has become of gradually grave concern to the general public.Soil is the largest earthly C pool, comprising2157–2293 Pg C (1 Pg = 10^{15} g) in the 0–100 cm layer alone, 1462–1548 Pg C of which isorganic; It is four times the atmospheric C pool and considerably affectsthe settlements of aerial CO_2 (Batjes, 1996). C resulting from soil respiration is 10 times that comes out fromfossil fuel; thus, a minor change in soil C noticeably affects aerial CO_2 concentration (Guan, *et al*., 2015). Most terrestrial N is also stockpiled in soils (Schlesinger, 1997), with up to 133–140 Pg N inthe 0–100 cm layer (Batjes, 1996) thus, a minor change in soil N can probably affect the worldwidebiogeochemical cycle (Tian, 2006). The C cycle is closely related to the Ncycle in forest systems, and their vibrant balance directly affects soil richness and soilproductivity. Therefore, the C and N cycles influence both food productivity as well as the global environment. Soil C and N are often influenced by the variation of seasons. Thus, the seasonal influences inC equilibrium must be understood to properly estimate the susceptibility of the terrestrial C poolin upcoming climate change (Tang *et al*., 2013). Different ecosystems such has the temperate urban forest (Xie et.al, 2015), tea forest (Lötter *et al*., 2014), grasslands swamps (Mello, 2015) agricultural cultivation area (Wuest, 2014; Wuest, 2015) have the variation in C and N pool due to seasonal changes. Various factors, soildepths (Zhou, 2013), capacity of photosynthesis (Medvigy, 2013), ecosystem productivity (Farrell, 2011) precipitation and temperature variations (Xie *et al*., 2015; Lötter *et al*., 2014) and wind direction (Arndt, 2015) drives the seasonal variation leading to changes in soil C and N fluxes. Whether an ecosystem would be a source or sink of carbon is determined by season (Gao, 2012; Schneising, 2014). In this paper, the temporal variation of soil properties and the main environmental factors in four types of land use were investigated. It is aimed to characterize the variation across the depth as well as seasonal variation of soil organic carbon (SOC), soil total Nitrogen (TN), C/N ratio, Soil pH and Soil EC and to provide basic data in the Delhi NCR land for national and global carbon cycle researchers. It

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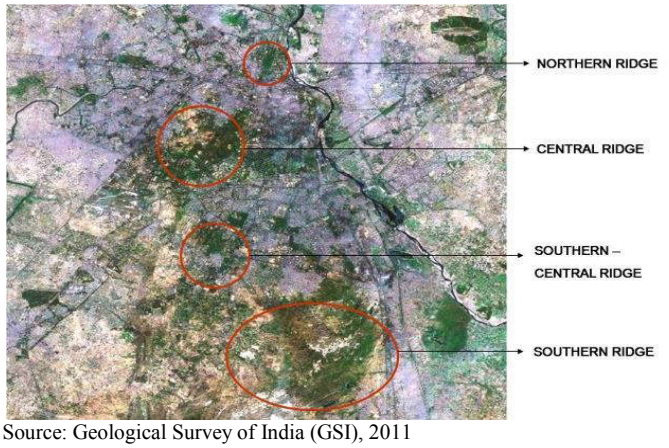
is hoped that the study will provide useful knowledge in the future.

MATERIAL AND METHODS

Study Area

Present study covers the four land use sites of Delhi NCR, the Protected forest (PF) and Unprotected forest (UPF) of theSouth Central Ridge of Aravallis (28°32′00″N 77°10′40″E) near Vasant Kunj and Mehrauli in Delhi, India, it encompasses to an area 633 hectares (Figure-1) and the Organic Farming (OF) and Chemical Farming (CF) fields located in Bulandsahar (Uttar Pradesh state in northern India having coordinates $28^0$26'N 77^0 50;E), Ghaziabad, UP (Figure-2). All the four land use sites are selected under the same weather condition (Table-1) and have almost same soil characteristics(Table-2) so that the other factors influencing the soil organic carbon retaining capacity would be same and only land use variable exists.



Source: Geological Survey of India (GSI), 2011

Figure 1. Location of the study area of protected forest (PF) and unprotected forest (UPF)

Figure 2. Location of study area of organic farming (OF) and chemical farming field (CF)

Climate

Delhi NCR region lies in the Northern Plains of the Indian Subcontinents. It experiences extreme hot and cold weather due to the vicinity of the Himalayas and the Thar Desert. Summer, rainy, winter and spring, the five distinct seasons run in one complete year. Summers begins in early April and peak in May, with average temperatures near 32 °C although unfrequented heat waves can result in highs close to 45 °C (114 °F) on some days. The monsoon begins in late June and lasts until mid-September, with about 797.3 mm (31.5 inches) of rain. The average temperatures are around 29 °C (85 °F), although they can vary from around 25 °C (78 °F) on rainy days to 32 °C (99 °F) during dry spells. The monsoons subside in late September, and the post-monsoon season continues till late October, with average temperatures sliding from 29 °C (85 °F) to 21 °C (71 °F).

Soil Sampling and Analysis

Soil samples were collected in the summer (March), monsoon (July) and winter (December) seasons of year 2015 from various depth 0-5, 5-10, 10-15, 15- 20 & 20-30cm from the protected forest (PF) and unprotected forest (UPF) of South Central Delhi Ridge of Aravallis (28°32′00″N 77°10′40″E) near Vasant Kunj and Mehrauli in Delhi as well as from the Organic Farming (OF) and Chemical Farming (CF) fields from village Bihta, located in Bulandsahar district (Uttar Pradesh state in northern India having coordinates $28^0$26'N 77^0 50;E), Ghaziabad, UP. The soil sample was taken from the center of each quadrate by driving a core sampler up to 30 cm depth. The soils were collected by soil recovery probe (1/2In*40IN) made in the USA. Each of the soil samples consisted of 4 subsamples and then mixed thoroughly to obtain composite samples. The collected soil samples were kept in polythene bags so that they remain in the field moist condition and mixed to obtain a composite sample needed for analysis. After transportation to the laboratory, the soil samples were air-dried at room temperature, ground to pass through a 2 mm sieve and analyzed for pH, electrical conductivity (EC), bulk density (BD), Total Nitrogen (TN), Soil Organic Carbon (SOC) and Soil Inorganic Carbon (SIC) were calculated. Soil pH and EC were measured by using a soil water suspension ratio of 1:2 (Sparks *et al*., 1996) by pH meter (model pH-538) WTW (Germany) and by Systronic conductivity meter (model 306) respectively. Soil Organic and inorganic carbon percentage of were determined in percentage by a dry combustion method using Shimadzu solid sample module, Model: SSM-5000A.To determine the soil bulk density, three additional sampling points (replicates) were done in each land use using a soil auger equipped with a stainless-steel cylinder (5.5 cm in diameter and 4.2 cm in height) to sample intact soil cores and are analyzed by the standard method. The total Kjeldahl N concentration (TN) was determined using the by TKN analyzer.

RESULTS AND DISCUSSION

Effect of Seasons on SOC Stock in different land use

Significant differences ($P<0.05$) in soil organic carbon (SOC) were observed among the sampling depth in all three seasons (summer, monsoon, and winter) in all the studied (OF, CF, PF, UPF) Land use (Fig-3). SOC decreased down the profile of all the studied land use in all three seasons (Table-3). This may be due to the decrease in the no of soil microorganism responsible for decomposition. This assessment was reinforced by Olojugba (2010) who was in agreement that both decreases in microbial population, as well as the decrease of soil, air/porosity, may be responsible for the decrease of SOC down the profile. The average value of SOC (0-30cm depth) in OF in summer, monsoon, and winter, were found at 1.63±0.04, 1.68±0.04,1.46±0.03 respectively, in CF were found as 0.97±0.05, 1.06±0.07, 0.86±0.06 respectively, in PF were found as 2.30±0.1, 2.48±0.18, 2.28±0.28 respectively and in UPF were found as 1.81±0.13, 1.74±0.14, 1.74±0.13 respectively.

Table 1. Average monthly air temperature, monthly rainfall, and evaporation in the year 2015 in the study area of Delhi NCR

Months	Average Max. Temperature	Average Mean Temperature	Average Min. Temperature	Precipitation (mm)	Potential Evapotranspiration (mm)	Open Pan data
Jan.	18 °C	13 °C	8 °C	13.97	4.45	5.93
Feb	26 °C	19 °C	12 °C	2.03	5.22	6.96
March	28 °C	22 °C	15 °C	59.68	6.41	8.55
April	35 °C	28 °C	21 °C	13.2	7.91	10.54
May	41 °C	33 °C	25 °C	2.79	8.62	11.49
Jun	38 °C	32 °C	26 °C	24.14	8.10	10.80
July	34 °C	30 °C	26 °C	133.08	6.64	8.85
Aug.	35 °C	31 °C	26 °C	141.21	5.85	7.81
Sept.	36 °C	31 °C	26 °C	2.28	6.30	8.40
Oct.	34 °C	27 °C	21 °C	0.51	6.67	8.90
Nov.	28 °C	21 °C	14 °C	1.02	5.81	7.74
Dec.	23 °C	16 °C	9 °C	0	4.70	6.27

Table 2. Soil Characteristics of four selected land use sites of Delhi NCR

Parameter	Organic Farming Land	Chemical Farming Land	Protected Forest	Unprotected Forest
Bulk Density(gm/cm^3)	1.37	1.39	1.37	1.38
Soil Texture	Loamy	Loamy	Loamy	Loamy
Sand	40%	41%	43%	44%
Silt	35%	36%	31%	31%
Clay	25%	23%	26%	25%

Table 3. Seasonal variation in SOC(%) in different Land Use

Depth	Summer			Monsoon			Winter		
	Avg.±SD		SE	Avg.±SD		SE	Avg.±SD		SE
				OF					
0-5 cm	2.1	±0.06	0.04	2.23	±0.03	0.02	1.89	±0.04	0.02
5-10 cm	2.0	±0.05	0.03	2.12	±0.04	0.02	1.66	±0.03	0.01
10-15 cm	1.9	±0.03	0.02	1.60	±0.03	0.02	1.63	±0.01	0.01
15-20 cm	1.1	±0.03	0.02	1.35	±0.05	0.03	1.07	±0.02	0.01
20-30 cm	1.1	±0.04	0.02	1.09	±0.04	0.02	1.06	±0.04	0.02
Avg.(0-30cm)	1.63	±0.04	0.02	1.68	±0.04	0.02	1.46	±0.03	0.02
				CF					
0-5 cm	1.75	±0.09	0.05	1.95	±0.06	0.04	1.44	±0.05	0.03
5-10 cm	1.12	±0.08	0.04	1.12	±0.04	0.02	1.21	±0.07	0.04
10-15 cm	0.79	±0.05	0.03	0.99	±0.06	0.04	0.67	±0.05	0.03
15-20 cm	0.59	±0.04	0.02	0.75	±0.04	0.02	0.50	±0.08	0.05
20-30 cm	0.58	±0.03	0.02	0.50	±0.06	0.04	0.47	±0.04	0.02
Avg.(0-30cm)	0.97	±.05	0.03	1.06	±0.07	0.03	0.86	±0.06	0.03
				PF					
0-5 cm	3.48	±0.14	0.08	3.88	±0.25	0.14	3.37	±0.67	0.33
5-10 cm	3.35	±0.12	0.07	3.55	±0.16	0.09	2.94	±0.25	0.14
10-15 cm	2.13	±0.09	0.05	2.33	±0.12	0.07	2.44	±0.12	0.09
15-20 cm	1.58	±0.09	0.05	1.53	±0.27	0.15	1.53	±0.34	0.20
20-30 cm	0.98	±0.08	0.05	1.11	±0.10	0.06	1.12	±0.07	0.04
Avg.(0-30cm)	2.30	±0.1	0.06	2.48	±0.18	0.10	2.28	±0.28	0.16
				UPF					
0-5 cm	2.78	±0.22	0.12	2.48	±0.11	0.06	2.57	±0.1	0.06
5-10 cm	2.61	±0.12	0.07	2.31	±0.23	0.13	2.10	±0.23	0.14
10-15 cm	1.84	±0.26	0.15	1.68	±0.22	0.13	1.79	±0.14	0.08
15-20 cm	0.98	±0.03	0.02	1.16	±0.10	0.06	1.15	±0.1	0.06
20-30 cm	0.82	±0.05	0.03	1.07	±0.02	0.01	1.08	±0.07	0.04
Avg.(0-30cm)	1.81	±0.13	0.08	1.74	±0.14	0.08	1.74	±0.13	0.07

Except for UPF, in all the other three land use SOC was observed higher in monsoon and least in winter. In UPF SOC were found highest in summer and almost same in monsoon and winter seasons. But in all the four land use the differences in SOC in the summer monsoon and winter season were not statistically ($P>0.05$) significant, as per Anova: Two-Factor without Replication analysis. Presence of highest SOC in monsoon season and least in winter season may be due to high decomposition of organic matter due to rain in the monsoon season and less decomposition of organic matter in winter as soil micro-organisms responsible for decomposition become prominent in monsoon season and becomes inactive or less active in winter seasons leads to high accumulation of SOC in rainy and less in winter season. As in UPF due to the high interference of anthropogenic activity, these effects are not observed.

Effect of Seasons on SIC Stock in different land use

Among the four selected land use Only PF has shown the significant difference in SIC across the depth and in OF, CF, and UPF no significant difference in SIC were observed across the depth of soil (Fig-4). SIC increases down the profile in PF in summer and winter seasons only, but remains almost same in across the depth in winter seasons. The average value of SIC in 0-30 cm depth in summer, monsoon and winter seasons in OF are 0.10±0.003, 0.103±0.003, 0.11±0.005 respectively in CF were found at 0.10±0.002, 0.10±0.003, 0.10±0.004 respectively, in PF were observed as 0.22±0.03, 0.22±0.03, 0.22±0.03 respectively, in UPF were found as 0.15±0.02 in all the three seasons (Table-4). As per the present study, no significant differences were observed in SIC in all the three seasons.

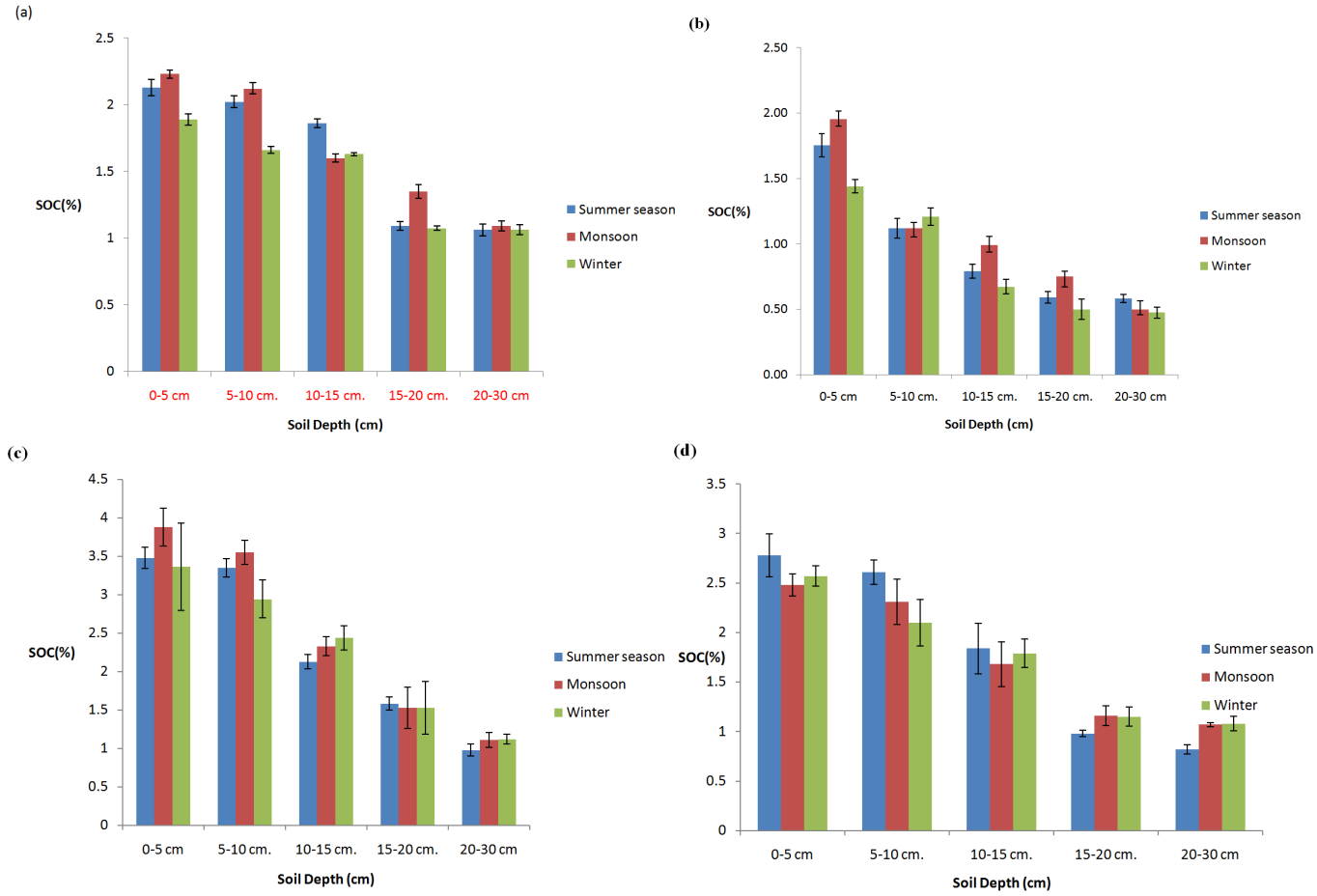


Fig. 3. Seasonal variation in SOC in the differentLand use in different soil depth. (a) Organic Farming (OF) (b) Chemical Farming (CF) (c) Protected Forest (PF) (d) Unprotected Forest (UPF). Error bars represent standard deviation. Each value refers to mean +/- SD(n=3)

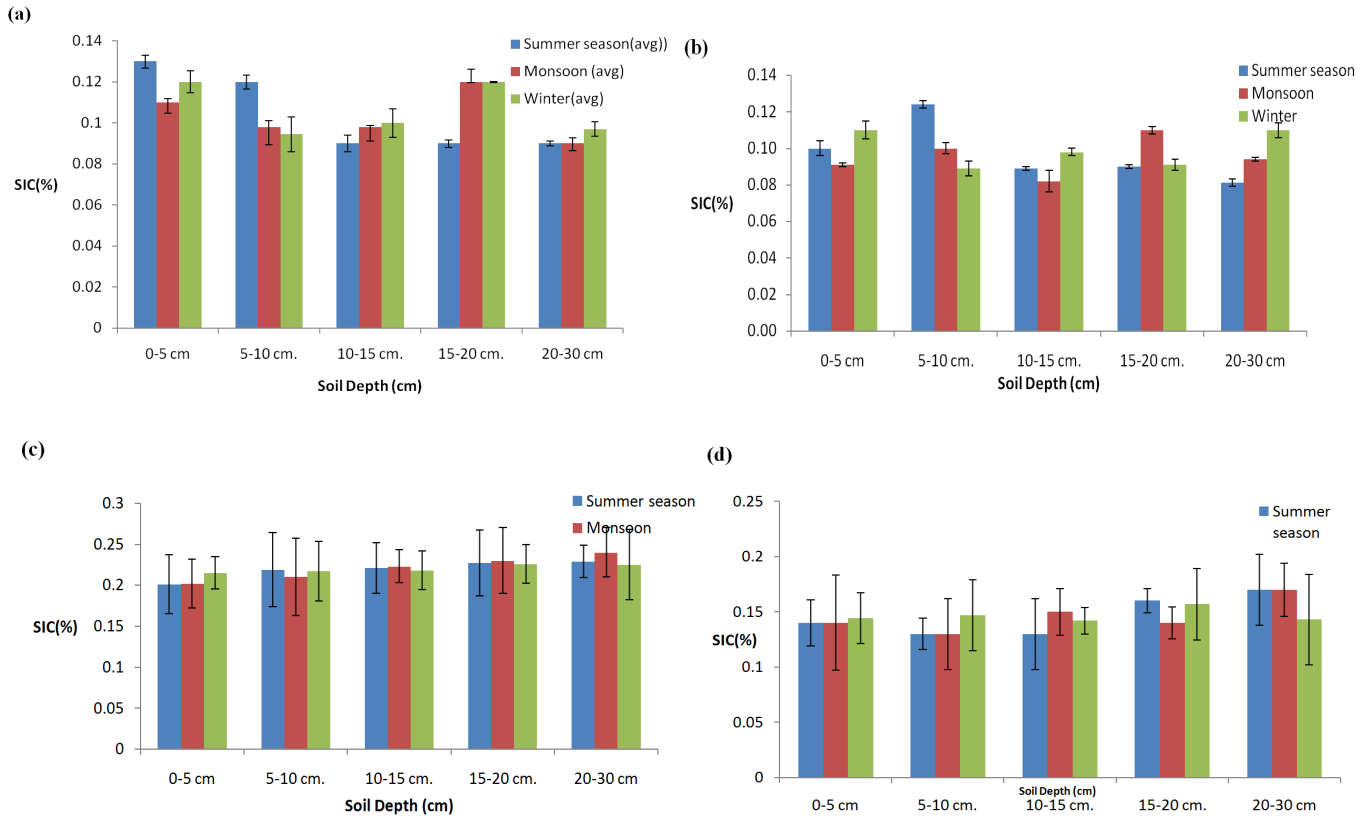


Fig.4. Seasonal variation in SIC in the differentLand use in different soil depth. (a) Organic Farming (OF) (b) Chemical Farming (CF) (c) Protected Forest (PF) (d) Unprotected Forest (UPF). Error bars represent standard deviation. Each value refers to mean +/- SD(n=3)

Table 4. Seasonal variation in SIC (%) in different Land Use SIC

Depth	Summer			Monsoon			Winter		
	Avg.±SD		SE	Avg.±SD		SE	Avg.±SD		SE
				OF					
0-5 cm	0.13	±0.003	0.002	0.11	±0.002	0.001	0.12	±0.005	0.003
5-10 cm	0.12	±0.003	0.002	0.10	±0.003	0.002	0.09	±0.009	0.005
10-15 cm	0.09	±0.004	0.002	0.10	±0.001	0.000	0.10	±0.007	0.004
15-20 cm	0.09	±0.002	0.001	0.12	±0.006	0.004	0.12	±0.000	0.000
20-30 cm	0.09	±0.003	0.001	0.09	±0.003	0.002	0.10	±0.003	0.002
Avg.(0-30cm)	0.10	±0.003	0.002	0.103	±0.003	0.002	0.11	±0.005	0.003
				CF					
0-5 cm	0.10	±0.004	0.002	0.09	±0.001	0.001	0.11	±0.005	0.003
5-10 cm	0.12	±0.002	0.001	0.10	±0.003	0.002	0.09	±0.004	0.002
10-15 cm	0.09	±0.001	0.001	0.08	±0.006	0.003	0.10	±0.002	0.001
15-20 cm	0.09	±0.001	0.001	0.11	±0.002	0.001	0.09	±0.003	0.002
20-30 cm	0.08	±0.002	0.001	0.09	±0.001	0.001	0.11	±0.004	0.002
Avg.(0-30cm)	0.10	±0.002	0.001	0.10	±0.003	0.002	0.10	±0.004	0.002
				PF					
0-5 cm	0.201	±0.04	0.02	0.20	±0.03	0.02	0.22	±0.02	0.01
5-10 cm	0.219	±0.05	0.03	0.21	±0.047	0.03	0.22	±0.0363	0.02
10-15 cm	0.221	±0.03	0.02	0.22	±0.02	0.01	0.22	±0.0234	0.01
15-20 cm	0.227	±0.04	0.02	0.23	±0.04	0.02	0.23	±0.0234	0.01
20-30 cm	0.229	±0.02	0.01	0.24	±0.03	0.02	0.23	±0.0432	0.02
Avg.(0-30cm)	0.22	±0.03	0.02	0.22	±0.03	0.02	0.22	±0.03	0.02
				UPF					
0-5 cm	0.14	±0.02	0.01	0.14	±0.043	0.02	0.14	±0.023	0.01
5-10 cm	0.13	±0.01	0.01	0.13	±0.032	0.02	0.15	±0.032	0.02
10-15 cm	0.13	±0.03	0.02	0.15	±0.021	0.01	0.14	±0.012	0.01
15-20 cm	0.16	±0.01	0.01	0.14	±0.015	0.01	0.16	±0.0324	0.02
20-30 cm	0.17	±0.03	0.02	0.17	±0.02	0.01	0.14	±0.041	0.02
Avg.(0-30cm)	0.15	±0.02	0.01	0.15	±0.03	0.02	0.15	±0.03	0.02

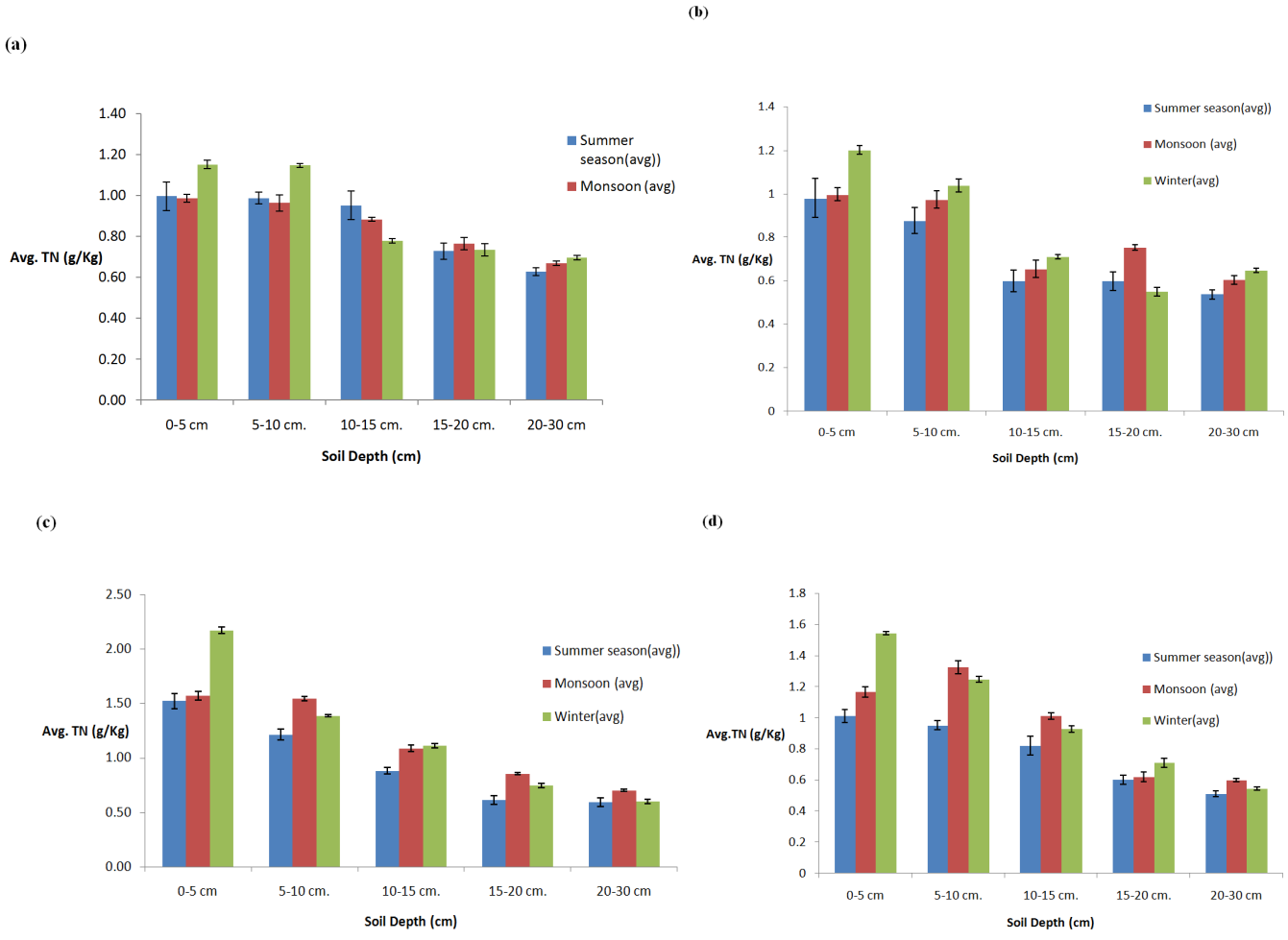


Fig.5. Seasonal variation in soil TN in the different landuses in different soil depth. (a) Organic Farming (OF) (b) Chemical Farming (CF) (c) Protected Forest (PF) (d) Unprotected Forest (UPF). Error bars represent standard deviation. Each value refers to mean +/- SD(n=3)

Table 5. Seasonal variation total Nitrogen (g/kg) in different land use

Depth	Summer			Monsoon			Winter		
	Avg.±SD		SE	Avg.±SD		SE	Avg.±SD		SE
				OF					
0-5 cm	1.00	±0.07	0.05	0.99	±0.02	0.01	1.15	±0.02	0.01
5-10 cm	0.99	±0.03	0.02	0.96	±0.04	0.03	1.15	±0.01	0.01
10-15 cm	0.95	±0.07	0.05	0.88	±0.01	0.01	0.78	±0.01	0.01
15-20 cm	0.73	±0.04	0.03	0.76	±0.03	0.02	0.73	±0.03	0.02
20-30 cm	0.63	±0.02	0.01	0.67	±0.01	0.01	0.70	±0.01	0.01
Avg.(0-30cm)	0.86	±0.05	0.03	0.85	±0.02	0.02	0.90	±0.02	0.01
				CF					
0-5 cm	0.98	±0.09	0.06	1.00	±0.03	0.02	1.20	±0.02	0.01
5-10 cm	0.88	±0.06	0.04	0.98	±0.04	0.03	1.04	±0.03	0.02
10-15 cm	0.60	±0.05	0.04	0.65	±0.04	0.03	0.71	±0.01	0.01
15-20 cm	0.60	±0.043	0.03	0.75	±0.012	0.01	0.55	±0.02	0.01
20-30 cm	0.54	±0.021	0.01	0.60	±0.02	0.01	0.65	±0.01	0.01
Avg.(0-30cm)	0.72	±0.05	0.04	0.80	±0.03	0.02	0.83	±0.02	0.01
				PF					
0-5 cm	1.52	±0.07	0.05	1.57	±0.04	0.03	2.17	±0.03	0.02
5-10 cm	1.21	±0.05	0.04	1.54	±0.02	0.01	1.38	±0.01	0.01
10-15 cm	0.88	±0.03	0.02	1.09	±0.03	0.02	1.11	±0.02	0.01
15-20 cm	0.61	±0.04	0.03	0.85	±0.01	0.01	0.74	±0.02	0.01
20-30 cm	0.59	±0.04	0.03	0.70	±0.01	0.01	0.60	±0.02	0.01
Avg.(0-30cm)	0.96	±0.05	0.03	1.15	±0.02	0.02	1.20	±0.02	0.01
				UPF					
0-5 cm	1.01	±0.04	0.03	1.17	±0.034	0.02	1.55	±0.01	0.01
5-10 cm	0.95	±0.03	0.02	1.33	±0.041	0.03	1.25	±0.02	0.01
10-15 cm	0.82	±0.06	0.04	1.01	±0.02	0.01	0.93	±0.02	0.01
15-20 cm	0.60	±0.03	0.02	0.62	±0.03	0.02	0.71	±0.03	0.02
20-30 cm	0.51	±0.02	0.01	0.60	±0.01	0.01	0.55	±0.01	0.01
Avg.(0-30cm)	0.78	±0.04	0.03	0.95	±0.02	0.02	1.00	±0.02	0.01

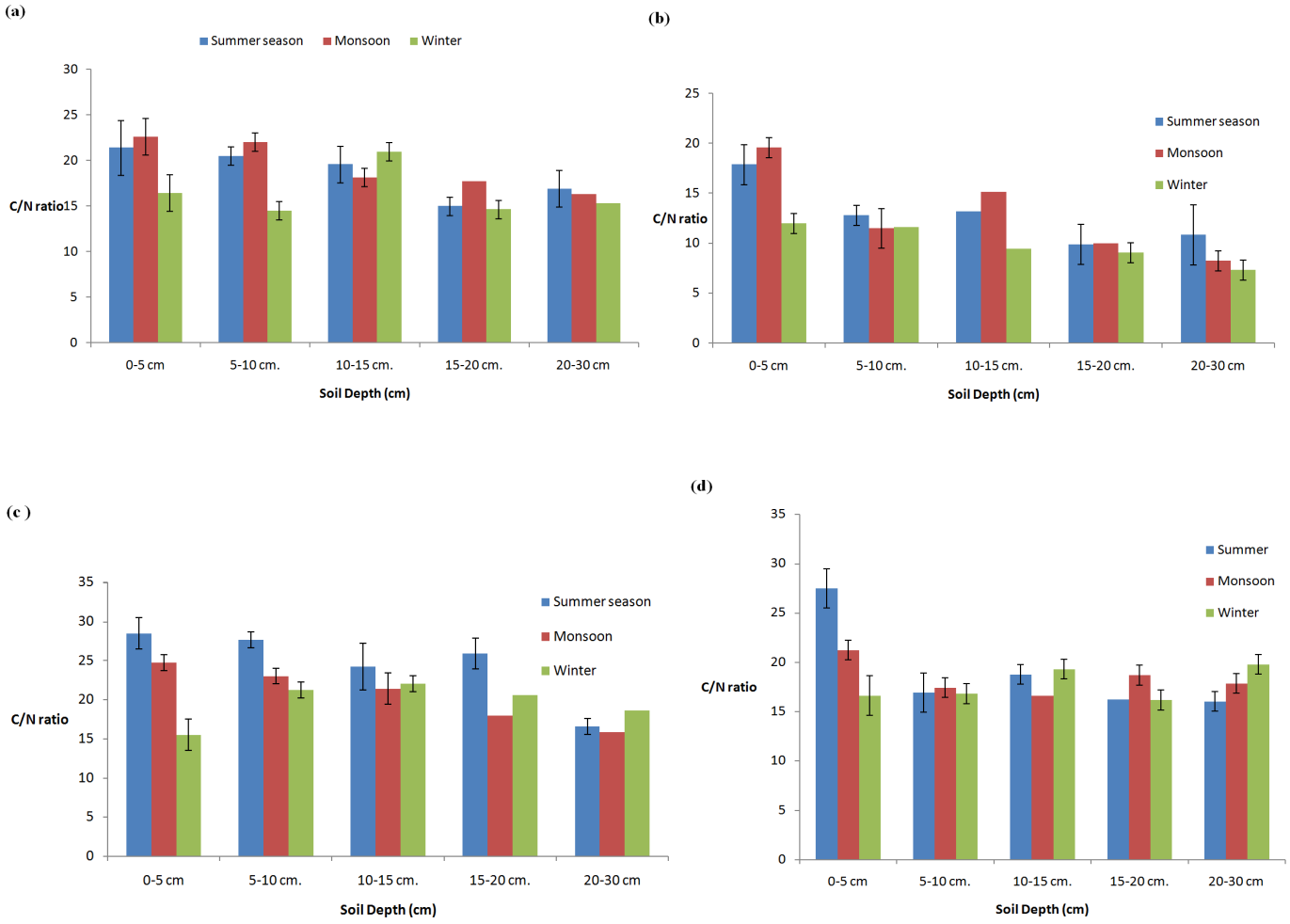


Fig. 6. Seasonal variation in C/N ratio in differentLand use in different soil depth. (a) Organic Farming (OF) (b) Chemical Farming (CF) (c) Protected Forest (PF) (d) Unprotected Forest (UPF). Error bars represent standard deviation. Each value refers to mean +/- SD(n=3)

Effect of Seasons on TN Stock in different land use

Significant differences (P<0.05) in soil total nitrogen (TN) were observed among the sampling depth in all three seasons (summer, monsoon, and winter) in all the studied (OF, CF, PF, UPF) Land use (Fig-5). TN decreased down the profile of all the studied land use in all three seasons (Table-5). The decreasing relationship SOC and TN, across the depth has been acknowledgedin previous studies (Wells *et al*., 2012; Li *et al*., 2013; Sinoga *et al*., 2012; Lawrence etal., 2015).No significant differences (p<0.05) were recorded on soil TN across the seasons in all the land use. The average value of TN (0-30cm depth) in summer, monsoon and winter, in OF were found as 0.86±0.05, 0.85±0.02, 0.90±0.02 respectively in CF were found as 0.72±0.05, 0.80±0.03, 0.83±0.02 respectively, in PF 0.96±0.05, 1.15±0.02, 1.20±0.02 respectively in UPF it were found as 0.78±0.04, 0.95±0.02, 1.00±0.02 respectively. Other studies have reported variable results in relation to the seasonal effects on the nitrogen content of the soil. Such as Olojugba (2015) reported Significant differences in soil TN across the seasons.

Effect of Seasons on soil pH in different land use

A significant difference (p<0.05) was observedin soil pH both across the depth and across the seasons. Soil pH increased down the profile of all the studied land use in all three seasons (Fig-7).The average value of soil pH across the depth (0-30cm) in Summer, Monsoon, and Winter in OF was found at 6.84±0.03, 7.17±0.02, 7.06±0.01 respectively in CF was 6.99±0.01, 7.30±0.01 and 7.28±0.02 respectively, in PF were 6.73±0.02, 7.15±0.02 and7.01±0.02 respectively and in UPF were observed as 6.80±0.02, 7.17±0.02 and 7.03±0.02 respectively (Table-7). In all the land use pH was observed highest in monsoon while lowest in summer seasons. It may be due to vertical movement of dissolved cations, water down the depth leads to increase in soil pH. The negative correlation between soil pH and SOC in the sampling depth implied that H^+ released from soil organic matter could decrease pH since organic matter is one of the chief sources of H^+ in soil (Satrio *et al*., 2009).

Table 6. Seasonal variation in C/N ratio in different Land Use

Depth	Summer			Monsoon			Winter		
	Avg.±SD		SE	Avg.±SD		SE	Avg.±SD		SE
OF									
0-5 cm	21.39	±3	2.12	22.61	±2	1.41	16.42	±2	1.41
5-10 cm	20.47	±1	0.71	22.02	±1	0.71	14.48	±1	0.71
10-15 cm	19.56	±2	1.41	18.12	±1	0.71	20.96	±1	0.71
15-20 cm	14.97	±1	0.71	17.69	±0	0.00	14.63	±1	0.71
20-30 cm	16.90	±2	1.41	16.31	±0	0.00	15.29	±0	0.00
Avg.(0-30cm)	18.66	±2	1	19.35	±1	1	16.36	±1	1
CF									
0-5 cm	17.9	±2	1.41	19.6	±1	1	11.98	±1	0.71
5-10 cm	12.8	±1	0.71	11.5	±2	1	11.62	±0	0.00
10-15 cm	13.2	±0	0.00	15.1	±0	0	9.45	±0	0.00
15-20 cm	9.9	±2	1.41	10.0	±0	0	9.07	±1	0.71
20-30 cm	10.8	±3	2.12	8.3	±1	1	7.33	±1	0.71
Avg.(0-30cm)	12.91	±1.6	1.13	12.89	±0.8	0.57	9.89	±0.6	0.42
PF									
0-5 cm	28.49	±2	1.41	24.74	±1	0.71	15.52	±2	1.41
5-10 cm	27.67	±1	0.71	23.01	±1	0.71	21.26	±1	0.71
10-15 cm	24.22	±3	2.12	21.43	±2	1.41	22.04	±1	0.71
15-20 cm	25.91	±2	1.41	17.94	±0	0.00	20.59	±0	0.00
20-30 cm	16.57	±1	0.71	15.83	±0	0.00	18.66	±0	0.00
Avg.(0-30cm)	24.57	±1.8	1.27	20.59	±0.8	0.57	19.61	±0.8	0.57
UPF									
0-5 cm	27.47	±2	1.41	21.23	±1	0.71	16.62	±2	1.41
5-10 cm	16.91	±2	1.41	17.43	±1	0.71	16.82	±1	0.71
10-15 cm	18.76	±1	0.71	16.60	±0	0.00	19.28	±1	0.71
15-20 cm	16.25	±0	0.00	18.68	±1	0.71	16.17	±1	0.71
20-30 cm	16.05	±1	0.71	17.86	±1	0.71	19.78	±1	0.71
Avg.(0-30cm)	19.09	±1	0.85	18.36	±0.8	0.57	17.73	±1.2	0.85

Effect of Seasons on C/N ratio in different land use

No significant differenceacross the depth was observed in C/N ratio in the OF, PF, and UPF except in CF. Whereas C/N ratio decreases down the profile in CF in summer, winter and monsoon seasons (Fig.-6). Similar to SOC and soil TN no significant differences (p>0.05) were recorded in soil C/N ratio across the seasons in the all four studied land use. The average value ofthe C/N ratio in (0-30cm depth) in summer, monsoon, and winter, in OF were found at 18.66±2, 19.35±1 and 16.36±1 respectively, in CF were found as 12.91±1.6, 12.89±0.8 and 9.89±0.6 respectively, in PF were 24.57±1.8, 20.59±0.8 and 19.61±0.8 respectively while in UPF it was founded 19.09±1, 18.36±0.8 and 17.73±1.2 (Table-6).

Effect of Seasons on soil EC in different land use

A significant difference (p<0.05) were observed in soil EC both across the depth and across the seasons. Soil ECdecreased down the profile of all the studied land use in all three seasons (Fig-8). The average value of soil EC across the depth (0-30cm) in Summer, Monsoon, and Winter OF was found as 0.70±0.01, 0.47±0.01 and 0.47±0.01 respectively in CF were found as 0.61±0.01, 0.43±0.02 and 0.43±0.01 respectively, in PF were found as 0.94±0.02, 0.51±0.01 and 0.52±0.01 respectively in UPF were found as 0.94±0.01, 0.51±0.01 and 0.51±0.02 respectively (Table-8). In the four land use, soil EC was observed highest in summer season while almost same in monsoon and winter seasons.

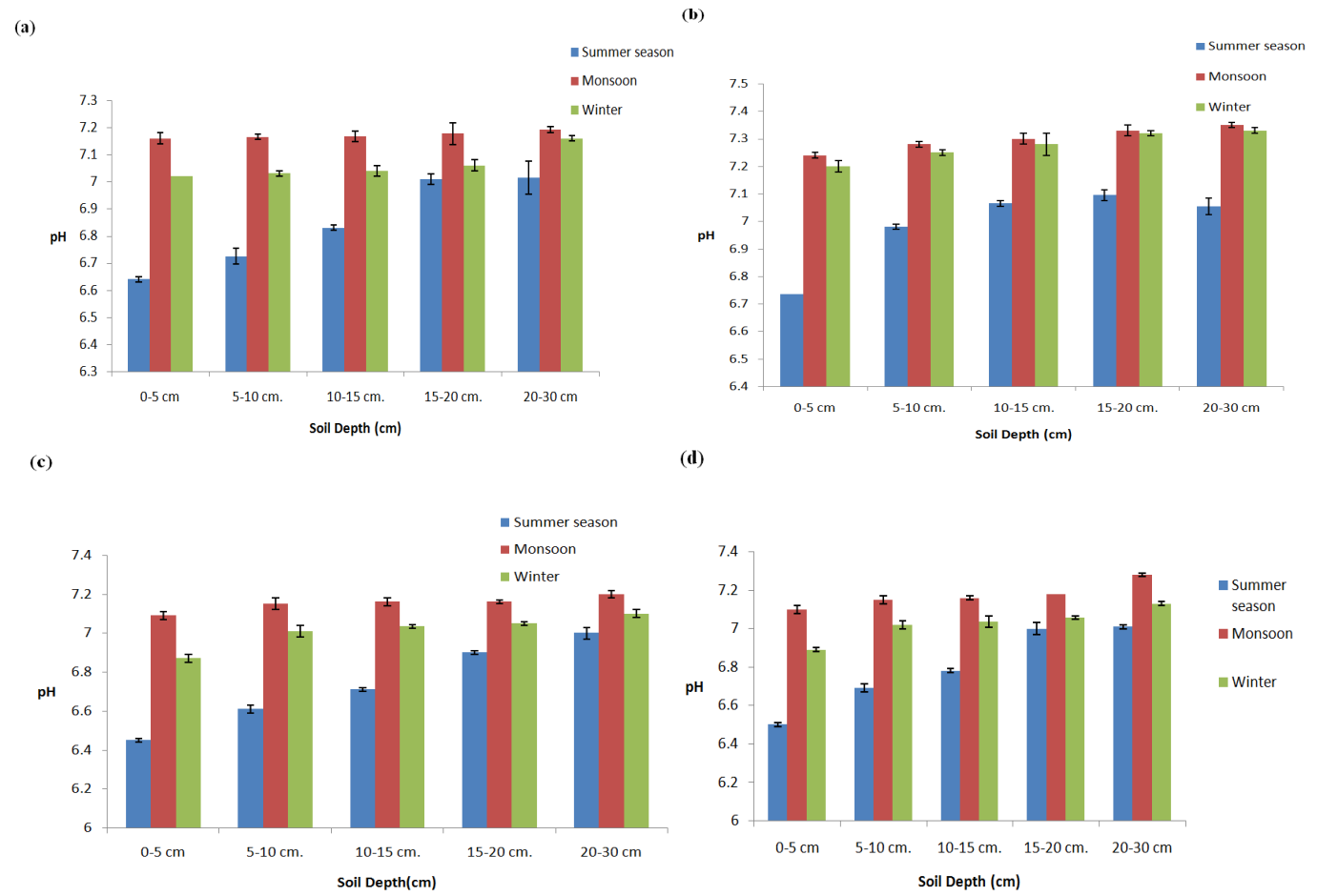


Fig. 7. Seasonal variation in Soil pH in differentLand use in different soil depth. (a) Organic Farming (OF) (b) Chemical Farming (CF) (c) Protected Forest (PF) (d) Unprotected Forest (UPF). Error bars represent standard deviation. Each value refers to mean +/- SD(n=3)

Table 7. Seasonal variation in soil pHin different Land Use

Depth	Summer			Monsoon			Winter		
	Avg.±SD		SE	Avg.±SD		SE	Avg.±SD		SE
OF									
0-5 cm	6.64	±0.01	0.01	7.16	±0.02	0.01	7.02	±0.01	0.00
5-10 cm	6.73	±0.03	0.02	7.17	±0.01	0.01	7.03	±0.01	0.01
10-15 cm	6.83	±0.01	0.01	7.17	±0.02	0.01	7.04	±0.02	0.01
15-20 cm	7.01	±0.02	0.01	7.18	±0.04	0.03	7.06	±0.02	0.01
20-30 cm	7.02	±0.06	0.04	7.19	±0.01	0.01	7.16	±0.01	0.01
Avg.(0-30cm)	6.84	±0.03	0.02	7.17	±0.02	0.01	7.06	±0.01	0.01
CF									
0-5 cm	6.74	±0	0.00	7.24	±0.01	0.01	7.20	±0.02	0.01
5-10 cm	6.98	±0.01	0.01	7.28	±0.01	0.01	7.25	±0.01	0.01
10-15 cm	7.07	±0.01	0.01	7.30	±0.02	0.01	7.28	±0.04	0.03
15-20 cm	7.10	±0.02	0.01	7.33	±0.02	0.01	7.32	±0.01	0.01
20-30 cm	7.06	±0.03	0.02	7.35	±0.01	0.01	7.33	±0.01	0.01
Avg.(0-30cm)	6.99	±0.01	0.01	7.30	±0.01	0.01	7.28	±0.02	0.01
PF									
0-5 cm	6.45	±0.01	0.01	7.09	±0.02	0.01	6.87	±0.02	0.01
5-10 cm	6.61	±0.02	0.01	7.15	±0.03	0.02	7.01	±0.03	0.02
10-15 cm	6.71	±0.01	0.01	7.16	±0.02	0.01	7.03	±0.01	0.01
15-20 cm	6.90	±0.01	0.01	7.16	±0.01	0.01	7.05	±0.01	0.01
20-30 cm	7.00	±0.03	0.02	7.20	±0.02	0.01	7.10	±0.02	0.01
Avg.(0-30cm)	6.73	±0.02	0.01	7.15	±0.02	0.01	7.01	±0.02	0.01
UPF									
0-5 cm	6.50	±0.01	0.01	7.10	±0.02	0.01	6.89	±0.01	0.01
5-10 cm	6.69	±0.02	0.01	7.15	±0.02	0.01	7.02	±0.02	0.01
10-15 cm	6.78	±0.01	0.01	7.16	±0.01	0.01	7.04	±0.03	0.02
15-20 cm	7.00	±0.03	0.02	7.18	±0	0.00	7.06	±0.01	0.01
20-30 cm	7.01	±0.01	0.01	7.28	±0.01	0.01	7.13	±0.01	0.01
Avg.(0-30cm)	6.80	±0.02	0.01	7.17	±0.02	0.01	7.03	±0.02	0.01

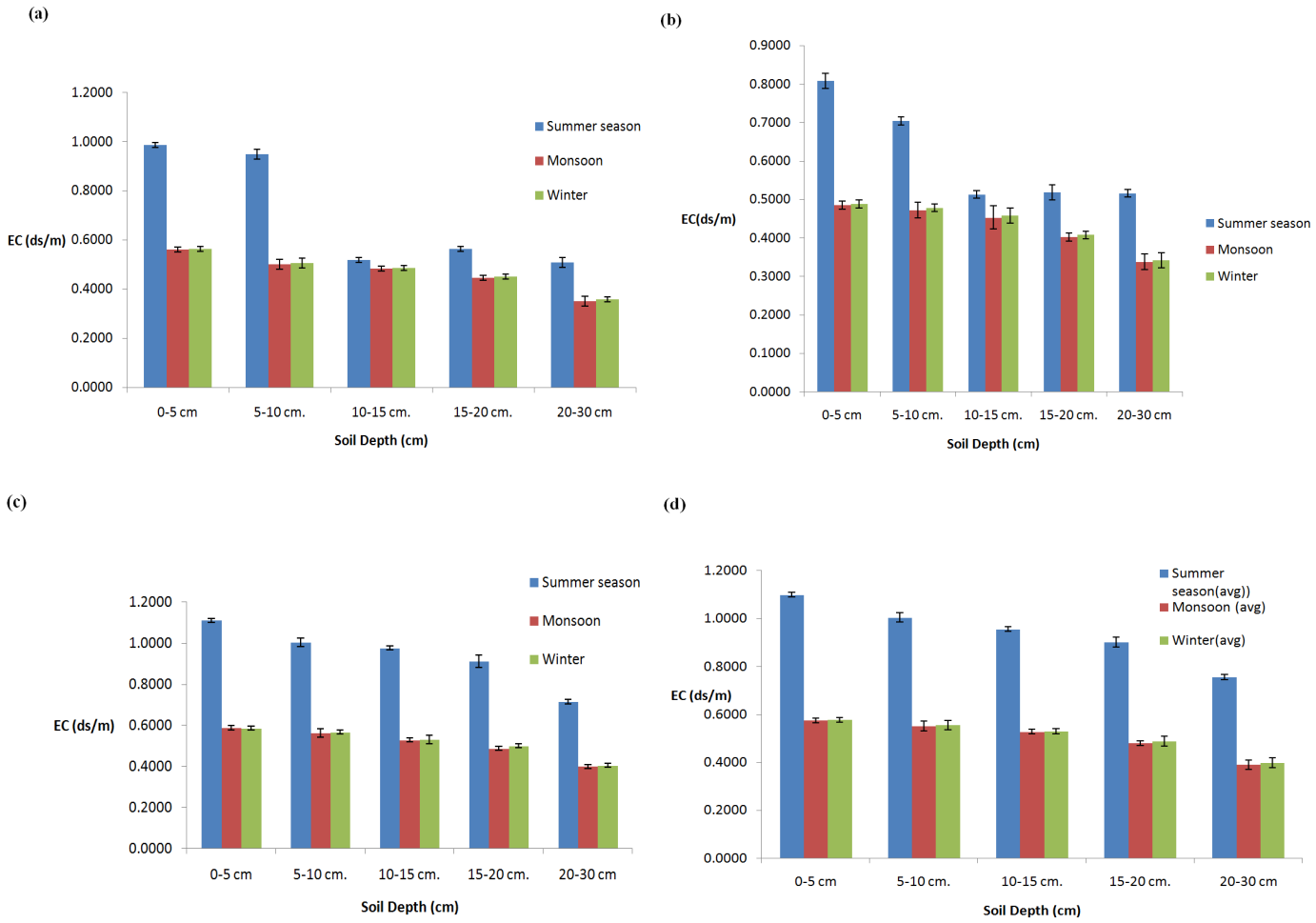


Fig.8. Seasonal variation in soil EC in differentLand use in different soil depth. (a) Organic Farming (OF) (b) Chemical Farming (CF) (c) Protected Forest (PF) (d) Unprotected Forest (UPF). Error bars represent standard deviation. Each value refers to mean +/- SD(n=3)

Table 8. Seasonal variation in soil EC in different Land Use

Depth	Summer			Monsoon			Winter		
	Avg.±SD		SE	Avg.±SD		SE	Avg.±SD		SE
OF									
0-5 cm	0.99	±0.01	0.01	0.56	±0.01	0.01	0.56	±0.01	0.01
5-10 cm	0.95	±0.02	0.01	0.50	±0.02	0.01	0.51	±0.02	0.01
10-15 cm	0.52	±0.01	0.01	0.48	±0.01	0.01	0.49	±0.01	0.01
15-20 cm	0.56	±0.01	0.01	0.45	±0.01	0.01	0.45	±0.01	0.01
20-30 cm	0.51	±0.02	0.01	0.35	±0.02	0.01	0.36	±0.01	0.01
Avg.(0-30cm)	0.70	±0.01	0.01	0.47	±0.01	0.01	0.47	±0.01	0.01
CF									
0-5 cm	0.81	±0.02	0.01	0.485	±0.01	0.01	0.49	±0.01	0.01
5-10 cm	0.70	±0.01	0.01	0.472	±0.02	0.01	0.48	±0.01	0.01
10-15 cm	0.51	±0.01	0.01	0.453	±0.03	0.01	0.46	±0.02	0.01
15-20 cm	0.52	±0.02	0.01	0.402	±0.01	0.01	0.41	±0.01	0.01
20-30 cm	0.52	±0.01	0.01	0.338	±0.02	0.01	0.34	±0.02	0.01
Avg.(0-30cm)	0.61	±0.01	0.01	0.43	±0.02	0.01	0.43	±0.01	0.01
PF									
0-5 cm	1.11	±0.01	0.01	0.59	±0.01	0.01	0.59	±0.01	0.01
5-10 cm	1.01	±0.02	0.01	0.56	±0.02	0.02	0.57	±0.01	0.01
10-15 cm	0.98	±0.01	0.01	0.53	±0.01	0.01	0.53	±0.02	0.01
15-20 cm	0.91	±0.03	0.02	0.49	±0.01	0.01	0.50	±0.01	0.01
20-30 cm	0.72	±0.01	0.01	0.40	±0.01	0.01	0.41	±0.01	0.01
Avg.(0-30cm)	0.94	±0.02	0.01	0.51	±0.01	0.01	0.52	±0.01	0.01
UPF									
0-5 cm	1.10	±0.01	0.01	0.58	±0.01	0.01	0.58	±0.01	0.01
5-10 cm	1.01	±0.02	0.01	0.55	±0.02	0.01	0.56	±0.02	0.01
10-15 cm	0.96	±0.01	0.01	0.53	±0.01	0.01	0.53	±0.01	0.01
15-20 cm	0.90	±0.02	0.01	0.48	±0.01	0.01	0.49	±0.02	0.01
20-30 cm	0.76	±0.01	0.01	0.39	±0.02	0.01	0.40	±0.02	0.01
Avg.(0-30cm)	0.94	±0.01	0.01	0.51	±0.01	0.01	0.51	±0.02	0.01

The positive correlation between EC and SOC across the soil depth and the negative correlation between EC and soil pH across the soil depth werefound in all land-use types which were in agreement with the results of Martel *et al*. (1978) and Bahrami *et al*. (2010). The SOC content had a stronger effect on the EC than on soil pH in this study.

Conclusion

In this paper, seasonal and depth wise variation in SOC, TN soil pH and soil EC in Four land use of Delhi NCR region were investigated. As per the investigation, significant seasonal and depth wise variations were observed in soil pH and soil EC in all the four land use of Delhi NCR but the only variation across the depth was observed in SOC and TN. No significant differences were observed across the three seasons (summer, monsoon, and winter) in the SOC, TN and C/N ratio in all the four selected land use.Soil pH increased down the profile, whereas SOC, TN and soil EC decreases down the profile of all studied land use three seasons. Among the four selected land use Only PF has shown the significant difference in SIC across the depth and in OF, CF, and UPF no significant difference in SIC were observed across the depth of soil.SIC increases down the profile in PF in summer and winter seasons only, but remains almost same in across the depth in winter seasons.No significant differenceacross the depth was observed in C/N ratio in the OF, PF, and UPF except in CF. Whereas C/N ratio decreases down the profile in CF in summer, winter and monsoon seasons. Thus, the present study was an attempt to examine and document the seasonal variations of the chemical properties under different land use. It is hoped that the study will provide useful information in the future.

Acknowledgments: The authors would like to acknowledge Indian Institute of Technology Delhi for giving the platform for this work. The work is a part of Ph.D. research work.

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