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Tree diversity and carbon fraction variation in urban forests of central India with reference to Gwalior division, India

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Abstract

Importance of conservation due to declining nature of biodiversity in urban forestry has gained lot of attention. Biodiversity plays a prominent role in mitigation of atmospheric carbon dioxide in addition to fertility of soil. Permanent quadrats (20 x 20 m) were established for estimation of phytosociological parameters and carbon stock at two different sites. Results of qualitative parameters revealed highest density as well as relative density for Pongamia pinnata at site I while for Prosopis juliflora at site II. Azadirachta indica dominated both the site I and site II with 100% and 75% frequency followed by IVI (55.56) and (42.66), basal area (3115.28) and (4567.06) at respective sites. Simpson's Diversity Index was recorded highest at site I and lowest at site II while Shannon Wiever index and Menhinick's Richness was observed highest at site II as compared to site I. Both the sites were found with diversity of species as per Sorensen coefficient. Carbon stock was calculated highest at site II with AGC 72.56 ton/ha, BGC 10.88 ton/ha and TC 83.44 ton/ha respectively. Winter season showed maximum attributes of soil carbon with highest at surface layer of soil. Soil organic carbon, soil organic matter along with fractions I and fraction III was found maximum at site II as compared to Site I. The study concluded that diversity has main role in sustaining the environment through number of processes. Management practices can prove effective to enhance the plantation which would be helpful in mitigation of climate change.

Keywords: Urban forestry, phytosociological characters, carbon sequestration, carbon fractions, seasonal variation.

Introduction

Biodiversity enhance ecosystem productivity and nutrient retention[1] with great potential in carbon capture hence, plays main role in supporting the ecosystem. Linkage of biomass and diversity is strongly influenced by anthropogenic activities in urban managed forests. Interacting between vegetation and environment is provided by qualitative description[2] and quantitative analysis act as tool to assess conservative nature[3] by providing good evidence for status of biodiversity and distribution pattern[2]. Plants act as an absorber of CO_2 by utilizing the carbon with the help of photosynthesis, converts into biomass, ultimately cause reduction in atmospheric carbon[4,5]. Estimation of tree carbon stocks gained importance[6] and plays important role in the sustainable management of CO_2 with long term benefits[7]. Rate of carbon sequestration is changing with growth, death and decomposition of vegetation in soil[4] which acts sink as well as source for atmospheric carbon depending upon the type of land use and management[8,9]. Soil organic carbon as a part of the natural carbon cycle had 3 times more carbon than atmosphere and 3.8 times than biotic pool[10]. Removal of CO_2 from the atmosphere and storing it in soil enhance the quality and biodiversity[10-12]. Soil organic carbon storage provide stability and improve the water holding capacity of soil[12] and depends on the quantity and quality of organic matter returned to the soil. The land use as well as land cover has been considered as indicator for particular ecosystem in understanding the variation of urban ecosystem by applying managed practices and connecting people with nature for sustainable growth[13]. The role of urban forestry in carbon sequestration has gained importance and current assessment is going on in this perspective. Gwalior division is considered to be species rich with good diversity[14], thus present investigation has been conducted to evaluate the qualitative and quantitative parameters of diversity in addition to carbon fixing potential for which two sites were selected possessing planted as well as natural vegetation with proper management by respective heads. The storage of soil carbon has been studied extensively in different fractions during different seasons and relation between diversity and carbon stock was assessed during the current study.

Materials and methods

Study area: The study was conducted during the year 2016-17 at two different sites Sun temple (N $26^0$14'10.72'' and E $078^0$13'07.49'') designated as site I and Jiwaji University campus (N $26^0$12'11.10'' and E $078^0$11'44.88'') as site II at Gwalior district of Madhya Pradesh located in central India. The climate variation is high with hot and dry weather ranging temperature up to 48^0C during summer and chill winter decreasing temperature up to 1^0-5^0C. The region have elevation of an average 197 meters above msl with three distinct seasons' viz. summer, monsoon and winter.

Sampling technique: Permanent quadrats of (20 m x 20 m) were established at each site by simple random sampling method for estimation of various phytosociological parameters i.e., qualitative like Density, Relative Density, Frequency, Relative Frequency, Abundance, Relative Dominance, Basal Area, IVI (Importance Value Index) and quantitative like Simpson's Diversity Index, Shannon Wiever index, Menhinick's Richness and Sorensen coefficient.

Simpson's Diversity Index[15]: D=Σni (ni-1)/N (N-1)

Where: ni = total number of each individual species, N = Total number of all the species.

Shannon Wiever index[16]: H = Σ (pi) (ln pi)

Where: Pi = proportion of total sample belonging to i species.

Menhinick's Richness[17]: D = S/√N

Where: S = number of different species presented in sample, N = Total number of individuals in the sample.

Sorensen coefficient[18] : S_S = 2a/ (2a + b + c)

Where: Ss=Sorensen similarity coefficient, a = number of species common to both quadrats, b = number of species unique to the first quadrat and c = number of species unique to the second quadrat.

Ss may be represented in terms of dissimilarity (D_S = 1.0 - S_S) which provide the difference of species between two sites. Carbon stock of tree species was determined by non-destructive methods with field survey and allometric equations. Above ground biomass (AGB) was calculated[19]. All live trees with diameter ≥ 10 cm was recorded by measuring girth at breast height (GBH) with simple measuring tape and later convert into diameter.

Carbon was considered as 50% of biomass[20] and 15% of above ground carbon (AGC) as below ground carbon (BGC)[21]. Soil sampling was done at two different soil depth i.e. 0-10cm and 10-20cm with the help of soil corer during different seasons. Soil organic carbon was assessed by using Walkley and Black method[22] and fractions of carbon were assessed with the help of modified Walkley and Black method[23] and further differentiated into three different fractions very labile pool (fraction I), labile pool (fraction II) and less labile pool (fraction III).SOM was determined by conventional factor of 1.724 by Waxman and Stevens[24].

Statistical analysis: The sigma stat 3.5 software was used for statistical analysis in order to find out significant difference in result by subjecting to ANOVA for SNK test at significant level of P<0.05. Prism pad 5 was used for graphical representation along with excel.

Results and discussion

Estimation of phytosociological parameters: The estimation of all the phytosociological parameters was done and results revealed that *Pongamia pinnata* showed highest density as well as relative density with (5.75) and (25.56) respectively at site I (Table-1) and *Prosopis juliflora* (5.5) and (21.78) at site II (Table-2). *Azadirachta indica* showed maximum frequency 100% and 75% with Relative Frequency 13.33 and 8.57 at site I and site II respectively. Abundance was found highest for *Pongamia pinnata* (11.5) at site I and *Prosopis juliflora (22)* at site II. The Relative Dominance was found highest for *Azadirachta indica* at both the sites with 22.23 at site I and 28.15 at site II.IVI (Importance Value Index) was also recorded maximum for *Azadirachta indica* at both the sites with value 55.56 and 42.66 at site I and site II respectively. Some other species also showed good IVI value which include *Pongamia pinnata* (37.90), *Delonix regia* (28.35) and *Cassia siamea* (22.12) at site I and *Prosopis juliflora* (24.80), *Ziziphus species* (19.08) and *Annona squamosa* (19.05) at site II. *Azadirachta indica* was dominant and frequently occurring species and showed maximum basal area 3115.28 at site I and 4567.06 at site II respectively. Basal area was also recorded good for *Delonix regia* (1792.4), *Bombax ceiba* (1516.24) and *Callistemon lanceolatus* (1204.54) at site I and *Mangifera indica* (2466.24), *Albizia lebbeck* (1366.32) and *Phyllanthus emblica* (1173.01) at site II (Table-1, Table-2).

Status of biodiversity was assessed with different diversity indices in which Simpson diversity index recorded 0.13 and 0.08 for site I and site II with Shannon Weiner index 2.35 and 2.82 at site I and site II respectively. Menhinick's richness index had values of 1.79 and 2.79 at site I and site II respectively (Table-3). Sørensen coefficient (Ss) was recorded 0.39 (39%) between the two sites and the Dissimilarity coefficient (D_S) 0.61.

Carbon stock estimation and variation: The carbon stock estimation was observed at both the sites and results revealed that highest AGC (72.56 ton/ha), BGC (10.88 ton/ha) and TC (83.44 ton/ha) was found highest at site II as compared to site I with AGC (64.02 ton/ha), BGC (9.6 ton/ha) and TC (73.62 ton/ha) (Figure-1).

The SOC estimation revealed that for 10 cm of soil depth highest SOC was recorded at site II (1.19%) in winter season and lowest at site II (0.71%) in summer season. While at 20 cm of depth site I (0.91 %) had highest in monsoon and lowest (0.51%) in summer season. SOC showed decreasing trend with increasing soil depth at both the sites (Figure-2). Similarly soil organic matter (SOM) had highest (2.05%) for 10 cm in winter and lowest (1.22%) in summer for same depth at site II. At 20 cm highest SOM was recorded (1.56%) in monsoon and lowest (0.87%) in summer at site I (Figure-3). Fraction I of carbon was observed highest at site II (0.65%) during winter and (0.36%) during monsoon at 10 cm and 20 cm respectively. Similarly lowest value was recorded during summer season at site II for both the depth with 0.30% for 10 cm and 0.21% for 20 cm respectively (Figure-4). Fraction II of carbon was recorded highest (0.59%) in monsoon and lowest (0.08%) in winter at 10 cm of soil depth for site I. Similar observation for 20 cm depth with highest at site I (0.45%) in monsoon and lowest at site II (0.02%) in winter season (Figure-5). Fraction III for 10 cm depth revealed highest 0.44% in winter and lowest 0.13% in summer at site II, while for 20 cm of soil depth highest was recorded at site II (0.37%) in winter and lowest at site II (0.08%) in monsoon (Figure-6). All the results were subjected to software sigma stat 3.5 for statistical analysis (ANOVA) following SNK method and found no significant variation at $p<0.05$ level of significance between the sites.

Table-1: Phytosociological parameter of tree vegetation at site I.

Species Name	Family	D	F	A	BA	RD	RF	RDo	IVI
Delonix regia	Caesalpiniaceae	1.25	75	1.67	1792.4	5.56	10.00	12.79	28.35
Holoptelea integrifolia	Ulmaceae	0.25	25	1	58.04	1.11	3.33	0.41	4.86
Pongamia pinnata	Fabaceae	5.75	50	11.5	796.02	25.56	6.67	5.68	37.90
Dalbergia latifolia	Fabaceae	0.75	75	1	1077.95	3.33	10.00	7.69	21.03
Azadirachta indica	Meliaceae	4.5	100	4.5	3115.28	20.00	13.33	22.23	55.56
Callistemon lanceolatus	Myrtaceae	0.25	25	1.0	1204.54	1.11	3.33	8.60	13.04
Nerium indicum	Apocynaceae	1	50	2	428.11	4.44	6.67	3.06	14.17
Cassia fistula	Caesalpiniaceae	1	75	1.3	433.4	4.44	10.00	3.09	17.54
Syzygium cumini	Myrtaceae	0.25	25	1	998.73	1.11	3.33	7.13	11.57
Phoenixsylvestris	Arecaceae	0.5	25	2	692.52	2.22	3.33	4.94	10.50
Albizia lebbeck	Fabaceae	0.5	25	2	774.88	2.22	3.33	5.53	11.09
Dalbergia sissoo	Fabaceae	1.5	50	3	330.99	6.67	6.67	2.36	15.70
Plumeria rubra	Apocynaceae	0.75	25	3	114.49	3.33	3.33	0.82	7.48
Polyanthia longifolia	Annonaceae	1	25	4	29.26	4.44	3.33	0.21	7.99
Tabernaemontana divaricata	Apocynaceae	0.5	25	2	42.2	2.22	3.33	0.30	5.86
Cassia siamea	Caesalpiniaceae	2.5	50	5	607.88	11.11	6.67	4.34	22.12
Bombax ceiba	Malvaceae	0.25	25	1.11	1516.24		3.33	10.82	15.26

D= Density, F= Frequency, A= Abundance, BA = Basal Area, RD= Relative Density, RF= Relative Frequency, RDo= Relative Dominance, IVI= Important Value Index.

Table-2: Phytosociological parameter of tree vegetation at site II.

Species Name	Family	D	F	A	BA	RD	RF	RDo	IVI
Pongamia pinnata	Fabaceae	1.75	50	3.5	37.4	6.93	5.71	0.23	12.87
Tectona grandis	Lamiaceae	3.75	25	15	180.82	14.85	2.86	1.11	18.82
Terminalia arjuna	Combretaceae	0.5	25	2	315.3	1.98	2.86	1.94	6.78
Nerium indicum	Apocynaceae	0.25	25	1	20.38	0.99	2.86	0.13	3.98
Delonix regia	Caesalpiniaceae	1.25	25	5	627.82	4.95	2.86	3.87	11.68
Mimusops elengi	Sapotaceae	0.75	25	3	39.99	2.97	2.86	0.25	6.08
Dolichandrone spathacea	Bignoniaceae	1	25	4	491.2	3.96	2.86	3.03	9.85
Azadirachta indica	Meliaceae	1.5	75	2	4567.06	5.94	8.57	28.15	42.66
Phyllanthus emblica	Phyllanthaceae	0.5	50	1	1073.01	1.98	5.71	0.53	8.22
Albizia lebbeck	Fabaceae	0.25	25	1	1366.32	0.99	2.86	6.61	10.46
Ziziphus species	Rhamnaceae	1.25	50	2.5	957.07	4.95	5.71	8.42	19.08
Dalbergia sissoo	Fabaceae	0.5	50	1	1023.09	1.98	5.71	5.90	13.59
Leucaena leucocephala	Mimosaceae	0.25	25	1	58.04	0.99	2.86	6.31	10.16
Atrocarpus heterophyllum	Moraceae	0.25	25	1	25.8	0.99	2.86	0.36	4.21
Prosopisjuliflora	Mimosaceae	5.5	25	22	485.34	21.78	2.86	0.16	24.80
Acacia leucophloea	Fabaceae	0.75	25	3	193.55	2.97	2.86	2.99	8.82
Callistemon lanceolatus	Myrtaceae	0.25	25	1	561.78	0.99	2.86	1.19	5.04
Ficus racemosa	Moraceae	0.5	25	2	839.85	1.98	2.86	3.46	8.30
Murraya Koenigii	Rutaceae	0.25	25	1	23.01	0.99	2.86	5.18	9.03
Syzygium cumini	Myrtaceae	0.25	25	1	25.8	0.99	2.86	0.14	3.99
Psidium guajava	Myrtaceae	1.25	25	5	37.12	4.95	2.86	0.16	7.97
Polyalthia longifolia	Annonaceae	0.5	25	2	370.42	1.98	2.86	0.23	5.07
Aegle marmelos	Rutaceae	0.25	25	1	215.29	0.99	2.86	2.28	6.13
Mangifera indica	Anacardiaceae	0.25	25	1	2466.24	0.99	2.86	1.33	5.18
Annona squamosa	Annonaceae	0.25	25	1	42.12	0.99	2.86	15.20	19.05
Citrus aurantifolia	Rutaceae	0.75	50	1.5	86.5	2.97	5.71	0.26	8.94
Terminalia catappa	Combretaceae	0.25	25	1	38.54	0.99	2.86	0.24	4.09
Cinnamomum camphora	Lauraceae	0.5	25	2	54.14	1.98	2.86	0.33	5.17

D= Density, F= Frequency, A= Abundance, BA = Basal Area, RD= Relative Density, RF= Relative Frequency, RDo= Relative Dominance, IVI= Important Value Index.

Table-3: Quantitative evaluation of study sites**.**

Diversity Indecies	SITE I	SITE II
Simpson Index of Diversity	0.13	0.08
Shannon Weiner Index	2.35	2.82
Menhinick's Richness	1.79	2.79

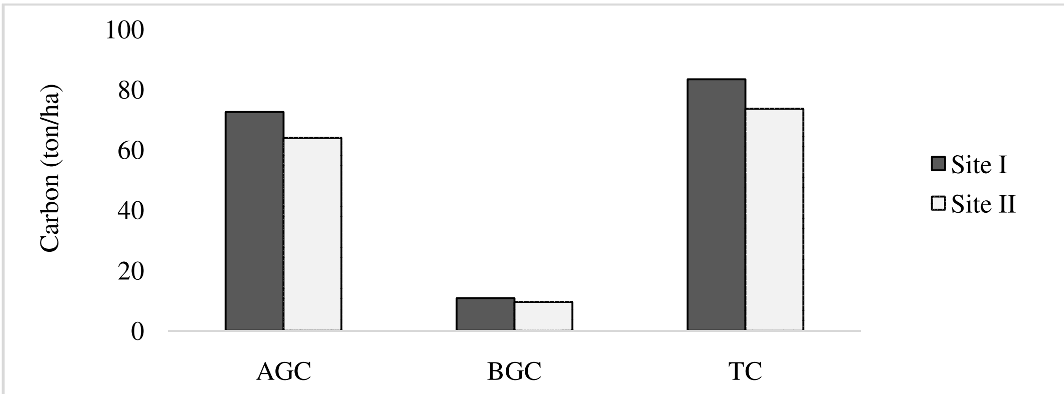

Figure-1: Carbon stock of standing vegetation at two sites.

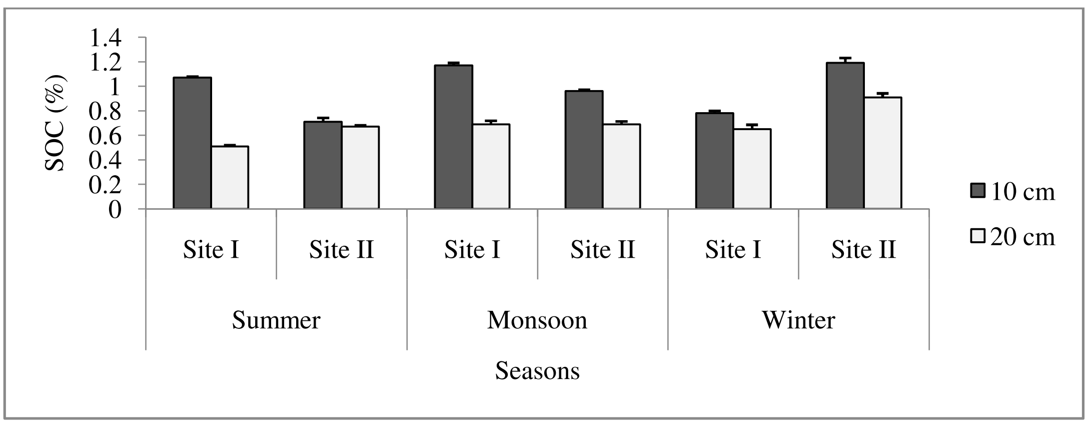

Figure-2: SOC variation during different seasons.

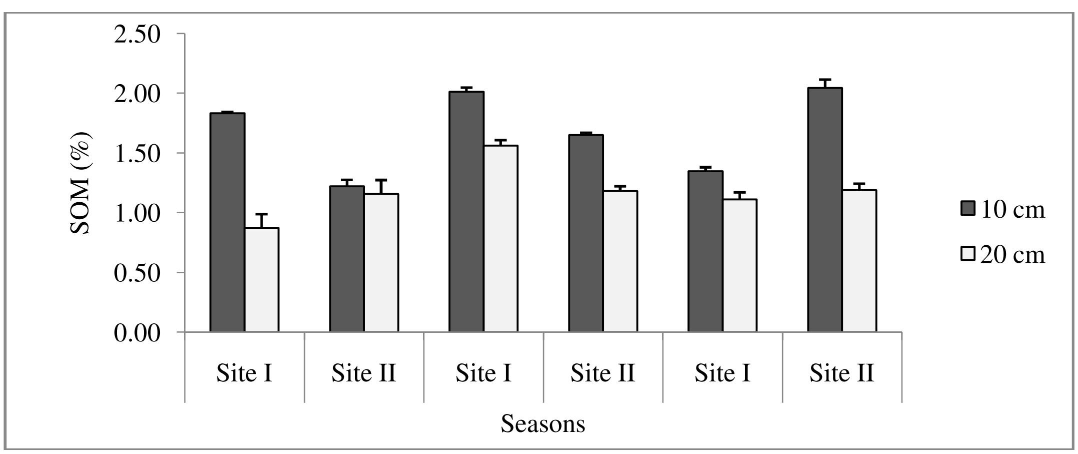

Figure-3: SOM variation during different seasons.

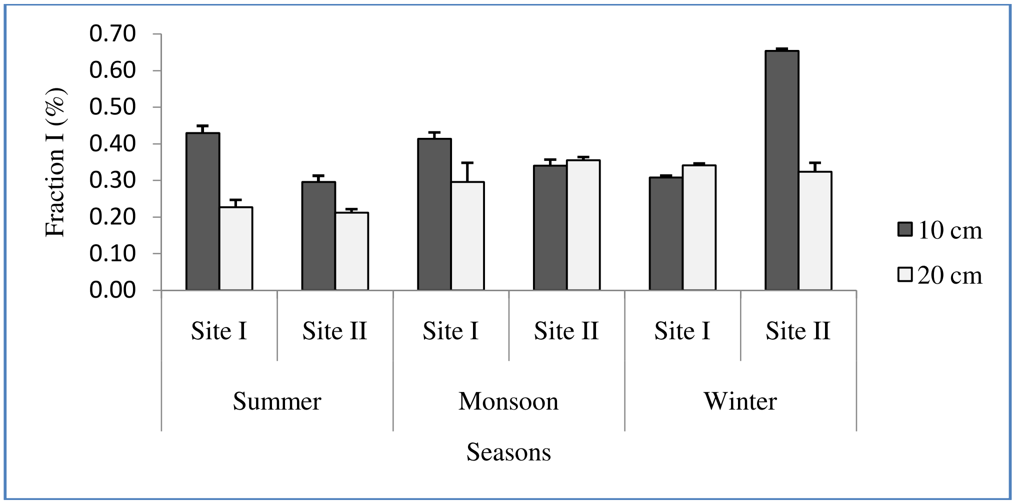

Figure-4: Fraction I variation during different seasons.

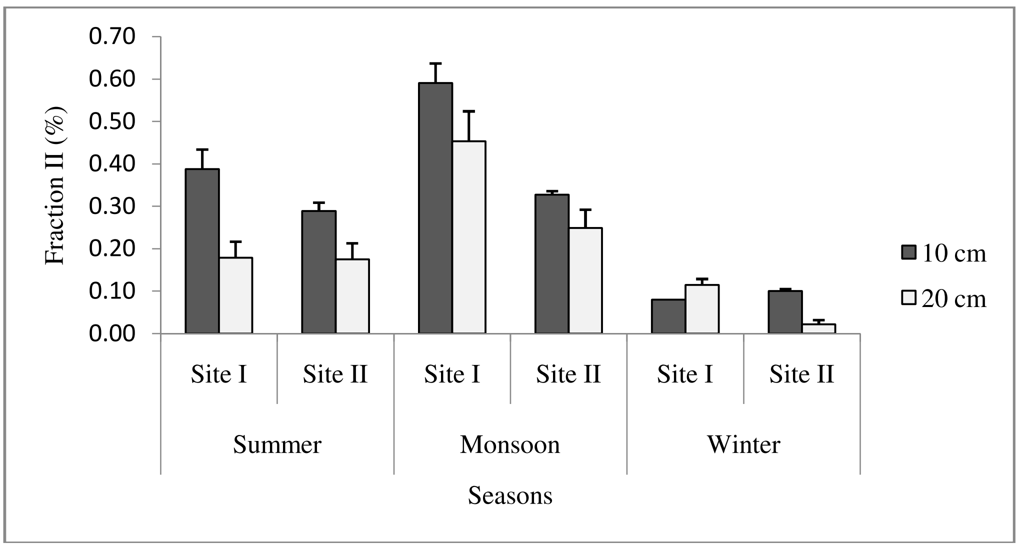

Figure-5: Fraction II variation during different seasons.

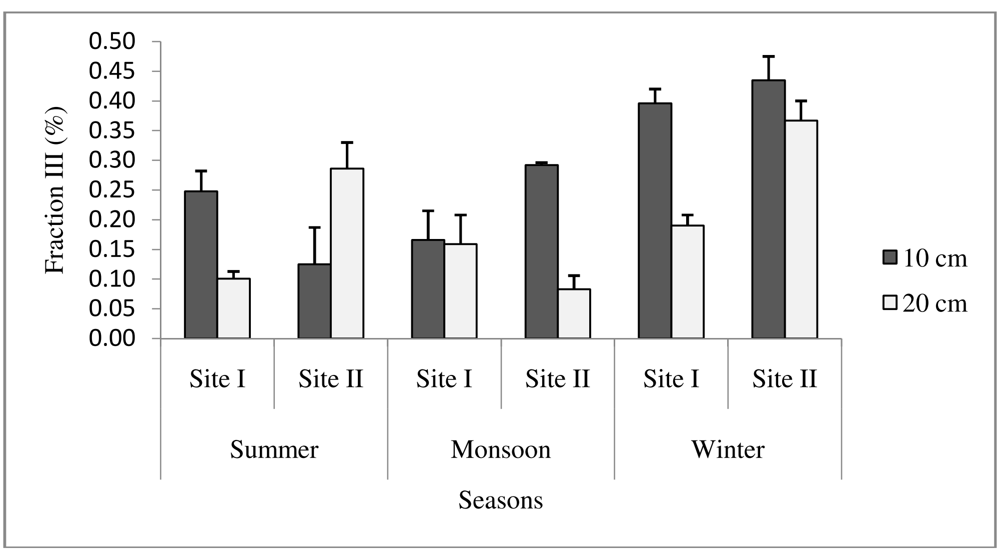

Figure-6: Fraction III variation during different seasons.

Discussion: Simpson diversity index indicates higher diversity of species at site II than site I depicting variety of species at former than later. Simpson index was found highest than[14] while working in the same region. Shannon Weiner index is commonly used for species diversity characterization and current study was found of having good diversity with higher value at site II than site I. Shannon Weiner index also indicates the abundance and evenness of species[14]indicating highest abundance at site II than site I reason for the same may be maximum number of species present. Rich diversity of species was observed at both the sites which was proved by applying Menhinick's Richness index indicating highest at site II as compared to site I. The seasonal variation of SOC was observed during current study[25,26] with maximum value of SOC in winter[26,27] and lowest in summer[28] may be due to high temperature[29].

Similarly soil organic matter observed highest in winter[30] and lowest in summer because of dynamics in nature due to various climatic factors as revealed[28]. Carbon fraction variation in different seasons was observed with higher value at surface layer of soil than sub surface layer similar to SOC[31] and soil organic matter which may be due to decomposition of varies component of litter along with microbial degradation[32]. Among different fractions of soil, fraction I was found highest than fraction II and fraction III similar results were observed[33] which are in harmony with current results. Soil carbon fractions are sensitive to the environmental condition and modify the soil structure[34] which may justify the variation of soil carbon fractions during current study. Different soil characteristics are affected by deforestation and removal of litter which modify the soil quality[13] and same may happen if proper management for sustainable growth of vegetation would not be taken into account at the selected sites.

Conclusion

Plantation plays an important role in reducing atmospheric CO_2 thus directly helps in mitigation of greenhouse gases. Good diversity provides litter inputs to the soil which after decomposition improve the fertility of the soil thereby helps in sustaining the environment. SOC was maximum at surface layer with highest during winter along with all the fractions. Seasons had great role in variation of SOC and other fractions. Management can play prominent role by planting more and more plants which not only improve soil quality but sustains the environment.

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