SEASONAL CHANGES IN SOIL MICROBIAL BIOMASS UNDER DIFFERENT AGRO-ECOSYSTEMS OF ARUNACHAL PRADESH, NORTH EAST INDIA

S. I. Bhuyan[1], O. P. Tripathi[2] and M. L. Khan[2]

ABSTRACT

The study was carried out to investigate the soil microbial biomass C, N and P of major agro-ecosystems prevalent in East Siang district, Arunachal Pradesh viz., Soybean, Millet, Maize and Vegetable agro-ecosystem. The study was conducted for a period of an annual cycle during the year 2010-11. Microbial biomass C and N ranged between 199.61 and 238.35 µg g^{-1} and 15.46 and 26.55 µg g^{-1} respectively. It was found to be higher in the surface soil layer than the subsurface layer in all the agro-ecosystems. Microbial biomass P significantly varied among the seasons and sites ($P<0.05$). Microbial C/N ratio was found to be higher in subsurface soil layer than the surface soil layer and the ratio varied between 8.83 and 13.94 in all the sites. Microbial biomass C contribution to total soil organic carbon was 1.13%-3.37%. Microclimatic variations and different agricultural practices were found to affect the changes in microbial biomass.

Key words: *Immobilization, Microbial population, Plant residues.*

INTRODUCTION

Microbial biomass is the active fraction of soil organic matter, which include bacteria, actinomycetes, fungi, algae, protozoa and other micro fauna and represents an important labile pool of nutrients in the soil (Henrot and Robertson, 1994). Microbial activities associated with the mineralization of important nutrients play crucial roles in the biogeochemical cycling of carbon (C), nitrogen (N), and phosphorus (P) (Schoenholtz *et al.,* 2000). Soil nutrients status and its transformation are greatly interrelated to the amount of microbial biomass present in the soil. Hence, it could be employed as a sensitive indicator of soil quality in agricultural lands (Rice *et al.,* 1986). However, microbial activities are very sensitive to anthropogenic influences such as conventional tillage, irrigation, fertilizer application etc. (Arunachalam, 2003; Liebig *et al.,* 2004).

Different types of agricultural practices are prevalent in north eastern India and the soils of these fields are managed in different ways since it is not only related to economic condition but also to the social and cultural faith of indigenous people (Bhuyan, 2012). Different land use patterns and continuous cultivation are responsible for the variation in the level of organic matter input and subsequent loss of soil organic carbon (SOC) from the agricultural lands leading to alteration of microbial biomass (Srivastava and Singh, 1989).

Present study was conducted to investigate the temporal and spatial dynamics of soil microbial biomass C, N and P and its role in soil nutrients conservation under different agro-ecosystems (AES) prevalent in the East Siang district of Arunachal Pradesh.

[1] *Department of Botany, University of Science & Technology, Meghalaya, 9th Mile, Ri-Bhoi, Meghalaya-793101, India.*

[2] *Department of Forestry, North Eastern Regional Institute of Science and Technology, Nirjuli-791109, Arunachal Pradesh, India.*

MATERIALS AND METHODS

Study site

East Siang district, Arunachal Pradesh where the present study was conducted is located between $27^0 30'$ to $29^0 20'$ North latitude and $94^0 42'$ to $95^0 35'$ East longitude and forms a part of the Eastern Himalaya. The topography of the district is variable and the elevation ranges from 130 to 752 m asl. The climatic conditions in the district vary from place to place due to mountainous nature of the terrain. It is hot and humid at the lower altitudes and in the valleys wrapped by marshy thick frost, while it becomes colder in the higher altitudes. Average monthly rainfall of the district is 470mm. The mean minimum and maximum temperature ranges between 12.2 ^{0}C and 32.4 ^{0}C, the maximum temperature observed during the month of June and minimum in January. The study was conducted during the year 2010-2011 in four major sole cultivation types widespread in the district viz., Soybean, Millet, Maize and Vegetable agro-ecosystem. All the systems except, Vegetable AES are being traditionally managed by the indigenous people which is beneficial for both on- and off-farm environments. To maintain soil fertility local farmers do not depend on purchased inputs but on locally available and renewable resources. They use different organic manures, household wastes etc. in the agricultural fields. However, Vegetable AES is a conventional type of system, where chemical plant protectants, chemical fertilizers and intensive irrigation are common.

Soil sampling and Analysis for characterization

The study was conducted for a period of an annual cycle. Soil samples were collected from each stands during July, October (2010), January and April (2011), representing, rainy, autumn, spring, and winter, respectively. From ten locations of the relevant study sites and from two depths namely 0-15 cm and 15-30 cm in three replicates samples were collected sing a steel corer, 5 cm inner diameter. Samples were brought to the laboratory to analyze their physico-chemical and microbiological characteristics. Field moist soil was sieved trough <2mm and stored at 4^{0}C until the measurement of microbial biomass C, N and P, respiration. A subsample of each soil was air dried, ground and sieved through <150mm prior to the use of samples for physico-chemical analysis.

Soil texture was determined by Boyoucous hydrometric method given by Allen *et al.,* (1974). Water holding capacity, porosity, total N, available P, extractable K, Ca and Mg were determined following the method outlined by Allen *et al.,* (1974). Soil bulk density, moisture content, pH, ammonium-N and nitrate-N were determined by method as outlined by Anderson and Ingram (1993). SOC was determined by rapid titration method (Walkley and Black, 1934).

Microbial biomass C, N and P

Chloroform fumigation-extraction method was used to estimate microbial C (MBC), N (MBN) and P (MBP). MBC and MBN were determined using 15 g fresh soil by chloroform fumigation extraction method given by Brookes *et al.,* (1985) and Vance *et al*., (1987). MBP was determined following the method outlined by Brookes *et al*., (1982) using 0.5M $NaHCO_3$ as extracting solution. The MBC, MBN and MBP were calculated as follows:

Microbial C = (EC of fumigated soil – EC of unfumigated soil) × 2.64

Where, EC is extractable C and 2.64is the correction factor

Microbial N = (EN in fumigated soil – EN in unfumigated soil)/0.54

Where, EN is extractable N and 0.54 is the correction factor

Microbial P = (EP of fumigated soil – EP of unfumigated soil)/0.40

Where, EP is extractable P and 0.40 is the correction factor

The data collected from each of the selected stands were analyzed using three-way ANOVA to test the effect of soil depth, season and AES on microbial biomass C, N and P and it was detected whether they were statistically significant or not. Correlation analysis was completed following Zar (1974) to study the relationship between soil characteristics and microbial biomass.

RESULTS AND DISCUSSION

Soil characteristics of the study sites

The soil textures were sandy loam and sandy clay loam in nature among the agro-ecosystems (Table 01). Clay content in Vegetable agro-ecosystem was higher in subsurface layer while the other systems reveal a reverse trend.

Table 01: Variations in soil physical properties in different agro-ecosystems

Agro-ecosystem	Depth (cm)	Physical properties						
		Sand (%)	Clay (%)	Silt (%)	Textural Class	WHC (%)	BD g cm^{-3}	Porosity
Soybean AES	0-15	73.80 ±0.80	24.10 ±0.27	2.10 ±0.11	Sandy clay loam	66.06 ±0.73	1.04 ±0.03	60.23 ±0.44
	15-30	74.20 ±0.32	23.40 ±0.13	2.40 ±0.12		65.12 ±0.91	0.96 ±0.02	63.54 ±0.36
Millet AES	0-15	71.10 ±0.47	26.00 ±0.18	2.90 ±0.06	Sandy clay loam	82.97 ±0.69	0.84 ±0.10	67.70 ±0.23
	15-30	72.00 ±0.42	24.90 ±0.21	3.10 ±0.01		81.94 ±1.25	1.00 ±0.06	61.54 ±0.26
Maize AES	0-15	74.60 ±0.87	24.20 ±0.13	1.20 ±0.1	Sandy clay loam	74.44 ±0.93	0.96 ±0.10	63.00 ±0.85
	15-30	75.20 ±0.19	23.98 ±0.07	0.82 ±0.03		73.25 ±1.19	0.88 ±0.11	66.16 ±0.78
Vegetable AES	0-15	74.6 ±0.10	24 ±0.03	1.4 ±0.05	Sandy loam	64.44 ±7.69	0.94 ±0.07	61 ±1.53
	15-30	74 ±0.5	24.2 ±0.04	1.8 ±0.06		58.66 ±5.91	0.87 ±0.16	63.5 ±1.49

±SE (n=8)

Water Holding Capacity (WHC) of the soil varied from 58.66% to 82.97% in different sites. It decreased with soil depth which might be due to the comparatively higher presence of organic carbon and clay in the surface soils than in the sub-surface soils. These may have also promoted the formation of aggregates retaining more water (Gupta *et al*., 2010). Bulk density was recorded between 0.84 and 1.04 g cm^{-3} (Table 01). Bulk density increased with increasing soil depth due to possible greater compaction. Porosity decreased with increasing soil depth except for the Soybean AES which might be due to minimum tillage. Higher values of porosity in upper layer also could be due to more organic matter content and high amount of fine fractions which has a higher surface area (Gupta *et al*., 2010).

The soil was acidic in nature and pH ranged between 4.75 and 6.06 in the sites (Table 02). Use of different chemical fertilizers such as urea, DAP etc. minimize the soil pH. Low soil pH during the monsoon season in most of the systems might be also due to the penetration and percolation of surface material to the subsurface soil depths due to heavy rain during this season. The range of calcium was between 1.17 and 2.33 Cmol/kg among the

Table 02: Variations in soil chemical properties in selected agro-ecosystems

Properties	Depth (cm)	Agro-ecosystem			
		Soybean AES	Millet AES	Maize AES	Vegetable AES
SOM (%)	0-15	2.41±0.05	3.10±0.04	4.31±0.03	1.47±0.05
	15-30	2.26±0.01	2.97±0.01	2.41±0.07	0.86±0.05
SOC (%)	0-15	1.40±0.03	1.80±0.02	2.50±0.02	0.85±0.03
	15-30	1.31±0.01	1.72±0.01	1.40±0.04	0.50±0.03
CO_2 (mgCO_2 hr^{-1})	0-15	34.24±2.95	51.36±3.92	29.92±3.97	40.32±8.71
	15-30	40.32±4.36	28.80±5.92	23.04±2.79	32.32±3.84
Ava. P (µg g^{-1})	0-15	41.98±1.11	7.97±0.28	8.58±0.67	43.51±0.28
	15-30	38.61±0.56	10.42±0.45	7.97±0.53	36.16±0.16
Ava. K (µg g^{-1})	0-15	64.80±5.93	96.20±21.57	457.00±63.94	441.57±67.50
	15-30	80.80±17.13	127.40±18.85	190.20±30.46	389.90±39.21
Total N (%)	0-15	0.49±0.03	0.46±0.03	0.55±0.12	0.42±0.03
	15-30	0.49±0.06	0.44±0.06	0.54±0.03	0.43±0.06
NH_4-N (µg g^{-1})	0-15	11.28±0.48	9.21±0.16	6.00±0.30	7.2±0.15
	15-30	10.38±0.54	8.39±0.25	5.80±0.05	6.92±0.45
NO_3-N (µg g^{-1})	0-15	2.16±0.10	1.98±0.01	2.79±0.08	2.87±0.12
	15-30	2.77±0.01	2.11±0.02	2.90±0.05	2.34±0.01
pH	0-15	5.75±0.36	6.05±0.07	5.35±0.23	4.80±0.17
	15-30	5.65±0.16	6.06±0.02	5.35±0.12	4.75±0.20
Ca (C mol kg^{-1})	0-15	1.98±0.26	2.11±0.14	2.33±0.39	1.17±0.06
	15-30	1.88±0.22	2.25±0.19	2.21±0.33	1.19±0.03
Mg (C mol kg^{-1})	0-15	1.03±0.02	0.98±0.03	1.12±0.03	1.12±0.02
	15-30	1.01±0.02	0.99±0.02	1.15±0.02	1.07±0.03

±SE (n=8)

agro-ecosystems.

Higher Ca may be due to acidic soil and higher percentage of sandy soil in the present study. Continuous cultivation processes may leads to more loss of Mg as compared to Ca, as a result Ca is found higher in the agricultural fields. SOC varied significantly from 0.50% to 2.50%. Minimum SOC was found in the Vegetable AES which was conventionally managed system. Continuous cultivation processes and tillage could be other responsible factor for low SOC. On the other hand, maximum value of SOC was recorded in the Maize AES which is due to the uses of different manures, compost by the local '*Adi*' tribe.

Among the land use patterns total N ranged between 0.42% and 0.55%. Extractable NH_4^+-N was higher than the extractable NO_3^-N in the entire stands (Table 02). Greater concentration of ammonium compared to nitrate indicates the higher rate of ammonification in these sites and as result the chances of loss of nitrate-N to leaching is more especially in the sloping agricultural fields (Bhuyan, 2012). Maximum available P concentration in Vegetable AES could be primarily due to the application of phosphorus rich inorganic fertilizers as it is the only conventional farming among the agro-ecosystems.

Temporal and spatial variation in microbial biomass C, N and P

MBC ranged between 199.61 and 238.35 µg g^{-1} (Table 03). Present result is within the finding (102-2073 µg g^{-1}) of Hernot and Robertson (1994) for humid tropical soils. However, it was lower than the results of Maithani *et al.,* (1996) for north east India (203-1087 µg g^{-1}); Bauhus *et al*., (1998) for northern Quebec, Canada (279 to 910 µg g^{-1}); Sharma *et al.,* (2004) from Sikkim (219 to 864 µg g^{-1}); and Gosai *et al.,* (2010) for a rainfed agricultural field in north east India (275.70–498.17 µg g^{-1}). However, present finding is higher than the results of Arunachalam and Pandey (2003) from cultivation systems in north eastern India (175.21–200.04 µg g^{-1}) and Mahmood *et al.,* (2005) for Faisalabad, Pakistan (11-169 µg g^{-1}). It was found to be higher in the surface soil layer (0-15cm) than the subsurface (15-30cm). Maximum MBC was recorded during the winter season in Soybean, Vegetable and Millet AES while in Maize agro-ecosystem, it was found during the autumn season (Figure. 01). On the other hand, minimum values were recorded during the rainy season in all the sites. MBN ranged between 15.46 and 26.55 µg g^{-1} (Table 03). It was found to be higher in the surface soil layer than the subsurface layer in all the agro-ecosystems. Microbial biomass P significantly varied among the season and sites (P<0.05) (Table 04). Microbial biomass dynamics are may be due to differences in quantity and quality of organic carbon and nitrogen and labile soil organic matter (Smolander and Kituen, 2002; Steenwerth *et al.,* 2002).

Higher microbial biomass could be due to the higher nutrient contents present in these agricultural fields. Higher amount of soil SOC enhances the growth of microbes and causes accumulation of microbial biomass in soil. Positive significant correlation has been found between MBC and SOC in the present study (Table 05).

Higher microbial biomass C in the winter season may be due to low temperature, low microbial activities and greater nutrients retention in the soil as it was also reported by Arunachalam and Arunachalam (2000). Generally, parts of crop plants are left after harvesting in these areas which increases the amount of soil organic matter. Hence, higher nutrients contents could be associated with more accumulation of microbial biomass in the soil (Barbhuiya *et al.,* 2004). Due to the suitability of the soil moisture level for the soil biological processes and more nutrient immobilization rates during this autumn season microbial biomass also high in Maize AES (Ralte *et al.,* 2005). Minimum MB was found during the rainy season due to the favorable condition for the microbial population growth and rapid mineralization rate (Maithani *et al.,* 1998). High vegetative growth of plants during this period enhances more uptake of nutrients by the crop plant. As a result, decline the availability of nutrients to soil microbes and decreases immobilization in microbial biomass (Singh *et al.,* 1991). However, comparatively lower values were found particularly in vegetable AES. It is a conventional type of farming where tillage and repeated cultivation was observed which may leads to high mineralization rate and low microbial biomass.

In all the sites microbial C/N was found to be higher in subsurface soil layer than the surface soil layer and the ratio varied between 8.83 and 13.94 in all the sites. The mean value of microbial biomass C/N in different agro-ecosystems found to be higher in Maize AES than the other agro-ecosystems. This could be associated with the low nitrogen and relatively higher organic matter availability to soil microbes in these systems as also reported by Barbhuiya *et al.,* (2004). Similar results have been reported in incubation experiments with complex soil microbial populations (Chander and Joergensen, 2002; Joergensen and Raubuch, 2002).

Table 03: Mean one annual microbial biomass C, N and P (μg g^{-1}) and percentage contribution of microbial biomass to total soil nutrient pool

Parameter	Agro-ecosystem/soil depth(cm)							
	Soybean AES		Millet AES		Maize AES		Vegetable AES	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
MBC	228.21	207.16	213.54	199.61	234.48	221.38	238.35	215.46
	±18.43	±15.95	±2.26	±2.02	±1.93	±3.02	±21.67	±24.27
MBN	21.54	16.31	23.58	19.22	26.55	19.22	19.93	15.46
	±2.16	±1.43	±2.31	±1.15	±0.62	±0.61	±1.35	±0.65
MBP	9.74	7.26	12.24	9.48	13.55	9.68	9.28	7.28
	±1.53	±0.96	±1.65	±1.24	±1.77	±1.67	±1.26	±0.77
MBC/MBN	10.60	12.70	9.06	10.38	8.83	11.52	11.96	13.94
	±8.53	±11.12	±0.98	±1.77	±3.12	±4.92	±16.07	±37.17
MBC/MBP	23.44	28.54	17.45	21.05	17.30	22.87	25.69	29.59
	±12.02	±16.64	±1.37	±1.64	±1.09	±1.81	±17.26	±31.32
MBN/MBP	2.21	2.25	1.93	2.03	1.96	1.99	2.15	2.12
	±1.41	±1.50	±1.40	±0.93	±0.35	±0.37	±1.07	±0.84
Percentage contribution of								
MBC to SOC	1.46	1.40	1.32	1.26	1.13	1.14	3.37	3.37
	±0.03	±0.44	±0.02	±0.24	±0.07	±0.03	±0.01	±0.01
MBN to total N	0.68	0.59	0.85	0.54	0.46	0.35	1.23	0.90
	±0.14	±0.14	±0.14	±0.18	±0.03	±0.02	±0.01	±0.02
MBP to total P	2.71	1.62	4.83	5.32	4.00	3.32	2.64	2.38
	±0.10	±0.08	±0.14	±0.12	±0.02	±0.03	±0.03	±0.06

±SE (n=8)

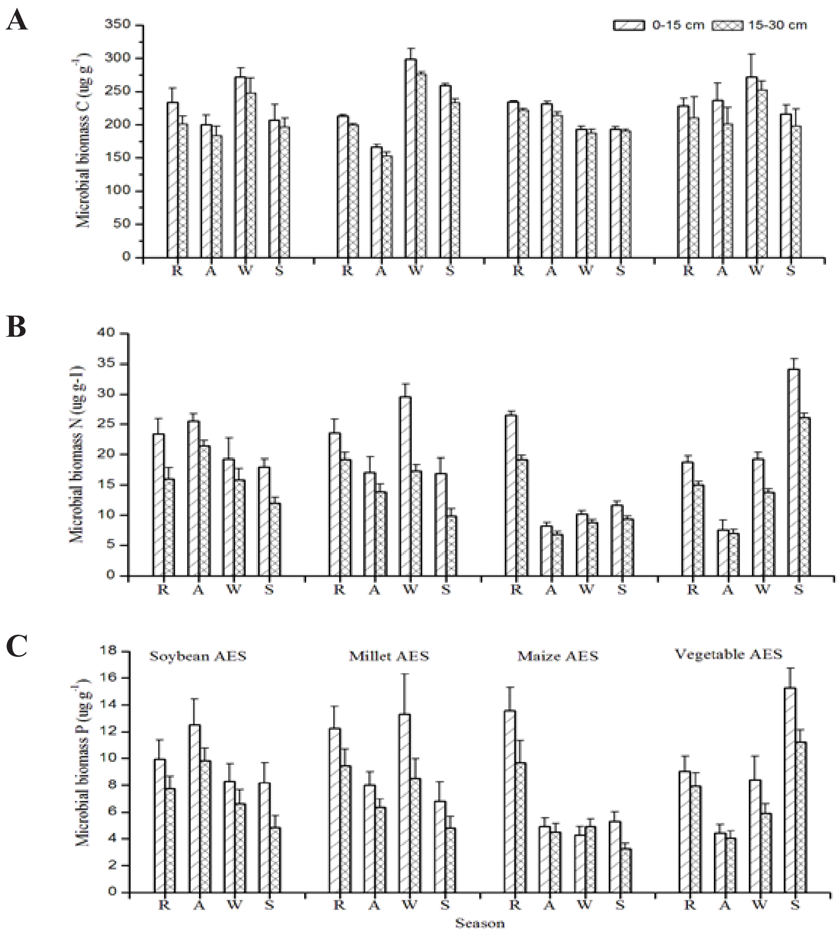

Figure 01: Seasonal variations in microbial biomass carbon (A), nitrogen (B) and phosphorus (C) in different land use pattern. Vertical bars symbolize standard error (n=5). R=rainy, A=autumn, W=winter, S=spring.

Table 04: Three way ANOVA showing the effect of AES (agro-ecosystem) season and soil depth on microbial biomass C, N and P ($\mu g\ g^{-1}$)

Variable	MBC			MBN			MBP		
	df	F-ratio	P	df	F-ratio	P	df	F-ratio	P
AES	3	0.315	0.814	3	0.777	0.515	3	1.535	0.224
Depth	1	1.790	0.190	1	2.589	0.117	1	2.777	0.105
Season	3	0.395	0.757	3	1.634	0.200	3	4.257	0.012
AES x Depth	3	0.036	0.99	3	0.280	0.838	3	0.204	0.892
AES x Season	9	0.847	0.579	9	1.848	0.097	9	2.206	0.048
Depth x season	3	0.026	0.994	3	0.155	0.925	3	0.142	0.933
AES x depth x season	9	0.086	0.999	9	0.079	0.999	9	0.190	0.993

df- degree of freedom, P-significant level.

MBC- microbial biomass carbon, MBN- microbial biomass nitrogen MBP-microbial biomass phosphorus

Table 05: Correlation coefficient ('r') of microbial biomass with soil physical and chemical Properties

	Depth (cm)	Sand (%)	Clay (%)	Porosity	SMC (%)	pH	SOC (%)	Total N (%)	Available P (µg g^{-1})
MBC (µg g^{-1})	0-15	0.006	-0.136	0.029	0.314	0.094	0.165*	0.246	-0.415
	15-30	0.014	0.174	-0.577	-0.066	0.321	0.227	0.180*	0.371
MBN (µg g^{-1})	0-15	-0.416	0.339	-0.011	0.575**	0.510	0.139	-0.076	-0.248
	15-30	0.064	0.207	-0.226	-0.340	-0.357	-0.122	-0.269	-0.330
MBP (µg g^{-1})	0-15	0.038	-0.025	-0.278	0.259	0.019	-0.069	-0.263	0.094
	15-30	-0.002	-0.106	0.006	-0.338	-0.297	-0.045	-0.542	0.139*

n=8, p<*0.05; **0.01

SMC-soil moisture content, SOC- soil organic carbon

Decomposition rates of plant residues may change the microbial population and also affect the nutrients ratio (Tate *et al.,* 1997). However, Singh and Singh, (1993) reported each microbial group may have different C/N or C/P ratio and the predominance of one group may result in the prevalence of a ratio.

Contribution of microbial C, N and P to soil nutrients pool

Percentage contribution of MBC to total soil organic carbon ranged between 1.13% (Maize AES) and 3.37% (Vegetable AES) (Table 03). Microbial biomass N and P contributed 0.35-1.23% and 1.62-5.32% to TKN and total P respectively. In the present study, contribution of microbial biomass C to SOC found comparatively higher than the range reported by Vance *et al*., (1987) for a strongly acidic soil (1.8–2.9%); Maithani *et al.,* (1996) for north eastern India (0.7-1.7%); Moore *et al*., (2000) for different land use systems (1.0%); and Mahmood *et al.,* (2005) for wheat-maize cropping systems in Pakistan (0.91% and 1.11%). Higher contribution indicates microbial biomass has potentially a greater role in soil C turnover than the plant detritus matter in agricultural systems. Soil microbial biomass could be a better indicator of ecosystems recovery than the other ecological processes such as litter or root dynamics (Arunachalam and Pandey, 2003). However, the percentage contribution of microbial N to total soil N was much lower ranging from 0.35-1.23%. It indicates low immobilization and high mineralization in microbial biomass, which leads to loss of N from the ecosystems (Maithani *et al.,* 1998).

However, significant positive correlations between microbial biomass C, N and P indicate that the dynamics of these three elements are closely interlinked in the nutrients poor tropical soils (Arunachalam, 2003).

CONCLUSION

Microbial biomass is affected by management practices, soil characteristics and environmental factors which vary during seasons. Seasonal variations had a greater impact on soil microbial biomass and labile C concentrations than management techniques. However, most of the fields except Vegetable AES are being traditionally managed and to maintain the soil fertility different organic manures, household wastes etc. are used in the agricultural fields by the indigenous people. It has a great role in the concentration of microbial biomass, which contributes a major portion to soil nutrient pool.

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