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Dynamics of carbon, nitrogen and phosphorus concentration in soil microbial biomass under different land uses in Loess soil region of Pakistan

Sidra Munawar[1], Syed Moazzam Nizami*[2], Tariq Mahmood[3], Muhammad Nawaz Chaudhary[1]

[1]*College of Earth and Environmental Sciences, Punjab University, Lahore, Pakistan*

[2]*College of Forestry, Fujian Agriculture & Forestry University, Fuzhou, China*

[3]*University College of Agriculture, Sargodha University, Sargodha, Pakistan*

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Abstract

Soil microbial biomass (SMB) assumed as gauge of biological quality as well as fertility. The quality and quantity of SMB is affected by different land uses. Therefore, the spatial variability of soil microbial biomass under three prominent land uses (agricultural land, grazing land and natural scrub forest) in the loess soil region of Pakistan was investigated. Overall, three hundred soil monoliths (100 from each land use) collected during 2014-15 from the loess soil region of Pakistan. Laboratory investigations were carried out for microbial biomass carbon, nitrogen and phosphorus (MBC, MBN & MBP) following standard protocols. The relationships were developed among land use pattern, soil microbial biomass and soil nutrients availability. The study revealed that the average value of MBC was 419 mg kg^{-1}, 644 mg kg^{-1}, and 749 mg kg^{-1} in agricultural land, grazing land and natural forests respectively. The mean value of MBN was 14.49, 11.99 and 109 mg kg^{-1}, while MBP value was 5.49, 7.89 and 24.49 mg kg^{-1} in crop land, grass land and forest land respectively. A negative correlation was found between SMB (MBC, MBN and MBP) and pH and EC, while positive relationships was seen with TOC, NO_3-N and available P. In the forest land sue the SMB and nutrients availability were maximum followed by grazing land and minimum in agricultural land use of the loess soil region. The study highlights the variation of concentration of microbial biomass C, N and P and is thought provoking for management of different land uses in this region.

* **Corresponding Author:** Syed M. Nizami ✉ nizami@fafu.edu.cn

Introduction

Soil microbial biomass (SMB) is of utmost importance gearing to soil biological quality and fertility. SMB not only controls the nutrients liberation and immobilization but also play an important role in nutrient cycling and acts as labile nutrients pool (Jenkinson and Ladd 1981; Wu *et al.*, 1993; Baudoin *et al.,* 2003). The changes in soil organic carbon and nitrogen can readily be detected by measuring changes in SMB (Wang *et al.,* 2016). The concentration of SMB can be affected by soil physiochemical properties, microclimate, agricultural practices and different land uses factors which lead to significant variation with respect to both time and locality (Powlson *et al.*, 1987; Insam, 2001; Pietri and Brookes, 2008; Yang *et al.,* 2008). However, due to short term and long term influence of these factors it is difficult to investigate their combined effect on SMB, but studies with limited field data on their distribution on both spatial and temporal scales can be carried out in different land uses.

In comparison to components of organic matter soil microbial biomass has fast turnover rate (Sparling *et al.* 1998). It controls biological actions and give support in maintaining soil fertility (Frazao *et al.,* 2010). A long term investigations on soil microbial biomass in different land uses can be useful in predicting respective soil conditions (Sharma *et al.,* 2004). In the natural ecosystems after the death of the microorganism different kinds of nutrients are liberated in to the soil (Wardle, 1992). High spatial heterogeneity within the soil profile, for soil carbon(C) and SMB has been reported in grazing land in comparison to agricultural lands (Caldero´n *et al.,* 2000). Soil microbial biomass in the agricultural lands may be altered by different agricultural practices (Liu *et al.,* 2008). The soil microbial properties have a great relationship with soil physical condition (Zhou and Ding, 2007). Land use patterns can transform soil C contents because of the reaction mediated by soil microorganisms (Dube *et al.,* 2009). Different land use patterns not only affect the quality and content of soil nutrients but also influence SMB (Yang *et al.* 2008).

The forestland conversion into cropland by deforestation may results in significant alterations in the size of SMB (Singh *et al.* 2009). Deforestation is one of the most important factors that change the amount of C, N and P in SMB. There is great impact of tree species on microbial community structure and soil fertility. Deforestation and land-use changes may have important consequence not only for availability of inorganic nutrients but also for SMB stability. Thus, any modification in forest ecosystem due to deforestation may cause significant reduction in nutrient availability to plants. SMB is very important in the functioning of forest ecosystems, dynamics of SMB play a significant role in nutrient availability to forest trees. The SMB in dry tropical forest soils also effect on the nutrient availability, climatic factors, soil pH, temperature etc. (Singh and Kashyap, 2006).

This study was designed to investigate the effect of different land uses (Agricultural, grazing lands and natural forests) on the concentration of C, N and P in SMB of the loess soil region of Pakistan. Most of the loess soil deposits are in Pothwar Plateau of Pakistan. However at few other places loess deposits also occur in Peshawar Plain (Peshawar Basin) and parts of Hazara. In the past, loess were developed over very large area of the Himalayas but were eroded. Now one can see only small surviving patches. So we may say that Loess deposits are fairly widespread in Pothwar, occur at places in Peshawar Plain and Lower Hazara and as small patches elsewhere. There is information gap regarding soil microbial biomass in the soil data sets of this region. Such information would be useful to maintain the physical and chemical properties of soil for sustainability of different land uses in the region. So, the main goals of this research is oriented towards investigating the effect of different land uses on concentration of C, N and P in SMB, and to develop relationship among SMB and physio-chemical properties under different land uses in the loess soil region.

Material and methods

Study area

Geographically, the loess soil region in Pakistan lies at 32° 32' and 34° 0' north latitude and 70° 17' and 73° 5' east longitude with an average rainfall of 250-750 mm per year. It is distributed over more than one million hectares area. The region is locally known as Pothwar plateau, consisting of both flat and undulated land surface which appears in the form of either low hills or broken gullies. Loess Soils are widespread in the Pothwar region. These soils have developed over what we call the Pothwar Silts which were deposited between 20000 to 70000 years ago. These "Pothwar Silts" commonly known as "Pothwar Loess" was formed by glacial or pluvial episodes (De Terra, 1939). According to (Rendell, 1992) Thermoluminisence dating of these deposits from Pothwar Loess yielded the following chronology (i) 18,000 yrs. BP -End of loess deposition in Pakistan. It coincides with last glacial maximum in NW Europe (ii) 75,000-18,000 yrs. BP-Main phase of loess deposition (unweathered loess) (iii) 170,000 yrs. BP -Early phase of loess deposition. These loess deposits and associated soils have also been discussed by (Bender and Raza, 1995; Kazmi and Jan, 1997). These are silts and clayey silts. Other soils developed in Pothwar Region are as follows: (i) Soils developed over mudstones of Siwalick Group. These soils are rich in clay i.e. silty clays and clays. The clay is dominantly illite, however, there are rare intervals of smectite. (ii) Fluvials soils developed over fluvial deposits in the flood plains and terraces of streams. These soils range from silty clays to clayey silts (The clay is dominantly illite). Some soils also have fine sands in them. The plateau receives more than 70% of rainfall during July and August (monsoon season) each year. Water erosion is the major problem of the region mainly caused by high intensity of monsoon rainfall. Being a rainfed area, it significantly contributes to GDP of the country through agriculture (Nizami, 2004). The cash crops in the region includes*:* *Triticum aestivum* (Wheat), *Lens culinaris* (lentil), *Vigna radiate* (Mungbean), *Brassica napus* (Oilseed rape); *Zea mays* (Maize), *Cicer arientum* (Gram) and *Arachis hypogaea* (Groundnut).

The main grass species of Pothwar are *Cynodon dactylon, Cenchrus cilliarus, Elucine indica and Hetropogon contortus* while dominant tree species in forest land are Phulai (*Acacia modesta),* Kahu (*Olea ferrogenia)* and Sanatha *(Dodonaea viscosa).*

Study design

A complete randomized research design was adopted in this study. Three prominent land uses in the regions were identified *viz a viz* agricultural land, grazing land and natural scrub forest. Overall, three hundreds undisturbed soil monoliths (100 from each land use at depth of 0-20cm) collected from the loess soil region of Pakistan. The samples were collected with the help of soil core made up of stainless steel having 6cm diameter and 20cm height. In crop land areas soil samples were taken from *Triticum aestivum, Zea mays, Arachis hypogaea and Vigna radiata* fields. In grass land soil sampling sites dominant grasses were *Cynadon dactylon, Cenchrus cilliarus, Elucina indica and Hetropogon contartos* while dominant tree species in forest land sampling were *Acacia modesta, Olea ferruginea and Dodonea viscosa*. After bringing the samples to the laboratory, all the debris in the form of stones, branch litter and root litter were removed. Later, all the soil samples were passed through 2 mm mech. After removing the sub samples for chemical analysis, rest of the soil samples were kept at 4°C for microbial analysis.

Soil physio –chemical analysis

The standard protocols for determining soil physical and chemical properties were adopted. Boyoucos Hydrometer method was used to determine the soil texture and different textural class were assigned vide International Soil Science Society guidelines ISSS triangle; (Gee and Bauder, 1986). Available phosphorus (P) and Nitrate-Nitrogen (NO_3-N) were determined by Olsen`s method and colorimetric method respectively (Horta and Torrent 2007). Spectrophotometer was used to record the transmittance (Olsen and Sommers 1982). The extraction and titrations were carried out to investigate the Total organic carbon (TOC) (Nelson and Sommer, 1982). Soil pH was determined with the help of soil pH meter following 1:1 (soil: water) suspension procedure (McLean, 1982).

Moreover, soil samples were extracted in saturated paste to investigate the electrical conductivity (EC_e) with the help of conductivity meter (Rhoades, 1996).

Laboratory works for soil microbial biomass

Soil samples from each land use were investigated for C, N and P concentrations in the SMB using standard protocols in the laboratory.

Soil microbial biomass carbon (MBC)

In order to investigate the soil microbial biomass carbon protocol of fumigation extraction were followed. Two 50ml glass container were washed and dried. A 10gm soil sample was placed in one container beaker and 30 ml alcohol free chloroform in other container. Both the containers were kept inside the desiccator for fumigation at 25 °C for 24 h. Later on, samples were filtered individually after mixing with 0.5 M K_2SO_4 (50ml). Additionally, one more 10g soil sample was fumigated and extracted in the same way. Then a digested tube was filled with 1 ml of potassium dichromate (0.0667 M) and 4ml of extracted samples was poured into it. Later the solution was heated at 150 °C for 30 minutes and 5 ml conc. H_2SO_4 was slowly added. Then the contents were shifted to another glass container (100ml) and indicator solution at a rate of 3-4 drops was poured in to it. Finally the solution was titrated against ferrous ammonium sulphate solution till the change in content coloration.

Soil microbial biomass nitrogen (MBN)

Same fumigation method was also adopted to investigate the soil microbial biomass N using sample of 10 g fresh soil. Kjeldahl digestion was used to extract the total N. A 0.2 g soil with mixed with 4.4 ml digestion mixture [350 ml hydrogen peroxide (30%); selenium powder 0.42gm and lithium Sulphate 14gm]. A 420ml sulphuric acid was added to this mixture and then digested at 360°C for 2 hours. We also adjusted the steam distillation apparatus and mixed the alkali mixture (Sodium hydroxide 500gm and sodium thiosulphate 25gm in 1000 ml water) at rate of 25ml with aliquot (sample) and placed in the reaction chamber. Then we took 25 ml distillate in a flask already having 5 ml of boric acid solution (indicator). We titrated it with hydrochloric acid to get the grey end point. The titration point was recorded in the titration funnel and subtracted the blank value to have corrected titre.

Soil microbial biomass phosphorus (MBP)

To investigate the soil microbial biomass nitrogen again standard fumigation extraction method followed. Two sub samples of 2.5g each of oven dried soil were prepared. One sub sample was fumigated for 24 hours at 25 °C with alcoholic free atmospheric chloroform ($CHCl_3$). The other sub sample was kept in open air at 25 °C for one day. Later both the samples extracted with sodium bicarbonate ($NaHCO_3$ 0.5M; pH 8.5 adjusted) shaking for 30 minutes. Later, ascorbic acid (4.0 ml) and molybdate reagent (3.0 ml) were mixed in the glass tube and aliquot (1ml) was added in it. After development of color which took one hour, spectrophotometer (Agilent 8453 UV-Visible Spectrophotometer) was used to record the reading at wave length of 880nm. Finally using Potassium dihydrogen phosphate (KH_2PO_4), the standards (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 ppm) of Phosphorus were organized to get graphic presentation.

Statistical analysis

Data on the soil microbial biomass C, N & P and other soil physical and chemical properties including pH, electrical conductivity (EC), percentage of sand silt and clay, total organic carbon, available phosphorous and No_3-N were subjected to ANOVA for testing the differences due to site. All the statistical analyses were made using SPSS software (ver.16) package. The correlation between MBC, MBN, MBP, MBC: MBN, MBC: MBP, NO3-N, Available phosphorus, Total Organic Carbon, pH, EC and Clay percentage of each land use was also determined. The statistical software Sigma plot ver12.5 was used for graphical presentation.

Results and Discussion

Soil physio-chemical properties

The analysis of the soil physio-chemical properties of agriculture, grazing lands and natural forest revealed that the forest land use in this loess soil region are slightly alkaline in nature as compare to the soil in other two different land use. The percentage of sand is maximum in the soil under agricultural land use, while clay and silt percentage is maximum in the soil of grazing land.

Moreover, the total organic carbon (TOC) and available phosphorus is also maximum under forest land use. The one way ANOVA pointed out significant difference in the pH, electrical conductivity (EC), percentage of sand silt and clay, total organic carbon, available phosphorous and No_3-N of the soils of all the and uses in this region (Table 1).

Table 1. Soil Physio-Chemical Properties among land uses in Loess Soil region.

Properties	Units	Agricultural Land	Grazing lands	Forestland	P Value
pH (1:2)		7.9	7.9	8.0	<0.001
EC (1:2)	ds m^{-1}	0.157	0.136	0.106	<0.001
Sand	%	35.9	28.8	34.1	<0.001
Silt	%	38.9	44.2	42.7	<0.001
Clay	%	25.1	26.8	23.1	<0.001
TOC	%	0.118	0.158	0.161	<0.005
Available Phosphorous	mg kg^{-1}	11.7	15.3	43.7	<0.005
No_3N	mg kg^{-1}	25.5	20	143.9	<0.005

Soil microbial biomass carbon (MBC)

The investigation on the soil microbial biomass carbon in the three different land uses of the region revealed that maximum amount of MBC is in the forest land use followed by grazing lands and lowest in the agricultural lands in the region.

The average values of MBC in all the land uses were 749, 649, 419 mg kg^{-1} respectively in forest, grazing lands and agricultural lands (Fig 1). Moreover, the one way ANOVA indicated significant ($P<0.001$) different in MBC of all the land uses (Table 2).

Table 2. ANOVA in the concentration of the MBC, MBN & MBP in all land uses in the region.

Landuse	df	MBC	MBN	MBP
Forest land	99	749.00***	106.01***	44.00***
Grazing Land	99	649.00***	13.09***	12.20***
Agric. Land	99	419.21***	14.01***	9.0***

Df = degree of freedom; *** = ($p<0.001$); MBC = Microbial biomass carbon; MBN = Microbial biomass nitrogen; MBP = Microbial biomass phosphorus.

The higher MBC in forest land areas followed by grazing lands is consistent with the studies carried out in savanna and shrub land ecosystems throughout the globe (Reyes-Reyes *et al.*, 2002). Microbial biomass carbon values of the current study are in line with the results of the conducted by (Vance *et al.*, 1987) and (Hernot and Robertson, 1996) who reported a range of (102-2073 mg kg^{-1}) for soils of different forest ecosystem in the sub-tropical regions. The MBC values also reported by different scientists are in range from 279-910 mg kg^{-1} in different soil classification, soil texture and plant community (Bauhus *et al.*, 1998; Sharma *et al.*, 2004). Among different sites in pure forest ecosystem; mixed deciduous forest ecosystem and grassland system, the value of microbial biomass C, N and P was revealed as 312-653; 32-75 and 19-31mg kg^{-1} respectively (Singh *et al.*, 2010). (Arunachalam and Pandey, 2003) revealed the MBC value for forest soils as 1684 mg $kg^{-1}$and for pasture land 806.1 mg kg^{-1} , while for cultivated soil (Hu *et al.*, 1997) reported 248 mg kg^{-1}.

Soil microbial biomass nitrogen (MBN)

The analysis of the soil microbial biomass nitrogen showed an average value of 106, 13.01, 14.09 mg kg^{-1} MBN respectively in forest, grazing land and agricultural land (Fig. 1). The soils of the forest land use in this region exhibits maximum amount of MBN in comparison to other land uses. A significant difference ($P<0.001$) the concentration of MBN was indicated by one way ANOVA in all the land uses (Table 2).

Looking into the concentration of MBN, differences may be because of the variation in environmental conditions, foliage cover, soil physical properties, vegetation root depths and management of different land uses (Vasquez-Murrieta *et al.,* 2007).

The study revealed that higher value of microbial biomass nitrogen was depicted by forest land use, because climatic condition of forest are suitable for more growth of vegetation which results in high residual accumulation and as a feedback the microbial activity is enhanced and microbes release nitrogen in soil. So ultimately concentration of nitrogen in forest land is higher than grazing land.

On the other hand comparing the grazing land with agricultural land use the MBN concentration is comparatively more in grazing land because as in the later agricultural crops are grown for short rotations each year (may be biannual) which lead to depletion of MBN and other nutrient concentrations in the soil with the passage of time.

Table 3. Collinearity test among all the parameters.

	NO_3-N	Available phosphorus	Total Organic Carbon	pH	EC	Clay
MBC	0.39	0.59	0.79	0.11	-0.19	-0.01
MBN	0.84	0.99	0.34	0.39	-0.34	-0.34
MBP	0.79	0.99	0.32	0.35	-0.31	-0.29
MBC:MBN	-0.57	-0.57	0.29	-0.26	0.29	0.39
MBC:MBP	-0.51	-0.56	0.49	-.0.30	0.35	0.24

The values of microbial biomass nitrogen revealed by this study are consistent with that of (Sharma *et al.*, 2004) who determined a value ranged from 30-142 mg kg^{-1} for different land use types including agriculture, wasteland and agro forestry. According to (Diaz-Ravina *et al.,* 1988) large leaved deciduous forests soils have (132-240 mg kg^{-1}) and evergreen forest (42-242 mg kg^{-1}) MBN concentrations in the soils. A microbial biomass nitrogen concentration ranged from 16-257 mg kg^{-1} was also reported by (Chen *et al.*, 2003) in soils of coniferous forest. In the grassland study, a soil MBN concentration range of 50-463 mg kg^{-1} has been declared by (Garcia and Rice, 1994). Microbial biomass nitrogen also determined by (Cleveland *et al.*, 2003) in the forest soil which have value (mean 251.3 mg kg^{-1}) are closely related to present study and pasture soils (153.9 mg kg^{-1}).

Soil microbial biomass phosphorus (MBP)

An average value of MBP was determined from the soil samples of each land use. The forest soil was having 44 mg kg^{-1} MBN concentration while the agricultural and grazing lands were having 12.20 and 9.40 mg kg^{-1} respectively (Fig.1). The one way ANOVA also revealed significant difference ($P<0.001$) in concentration of MBP in soil of all the land uses in the region (Table 2).

Moreover , the statistical analysis to determine the correlation coefficients between MBC, MBN, MBP, MBC: MBN, MBC: MBP, NO3-N, Available phosphorus, Total Organic Carbon, pH, EC and Clay percentage was also carried out and the results have been presented in (Table 2). It was revealed that the concentration of soil microbial biomass (MBC, MBN and MBP) have negative correlations with EC and clay % while positive relationships with pH, TOC,

NO_3-N and available P. Moreover, on the other hand MBC: MBN and MBC: MBP also showed negative relationship (Table 3). Soil microbial biomass and nutrients availability were maximum in forest land followed by grazing lands and minimum in agricultural land use in the loess soil region of Pakistan.

Another reason that contented significant differences in SMB (C, N and P) concentrations is increasing the level of disturbance, destabilizes SMB (Wardle, 1998).

Results of present study highly promising with the results of the several studies which reported the increased SMB value in upper soil layer (Salinas-Garcia *et al.*, 2002). Moreover, the carbon, nitrogen and phosphorous concentration in microbial biomass is consistence with the values reported in the earlier studies (Kaur *et al.*, 1998). Generally, agricultural crop cultivation results in high decline within soil microbial carbon and phosphorous than other in other land uses (Gunapala and Scow, 1998) due to increase in erosion losses of soil.

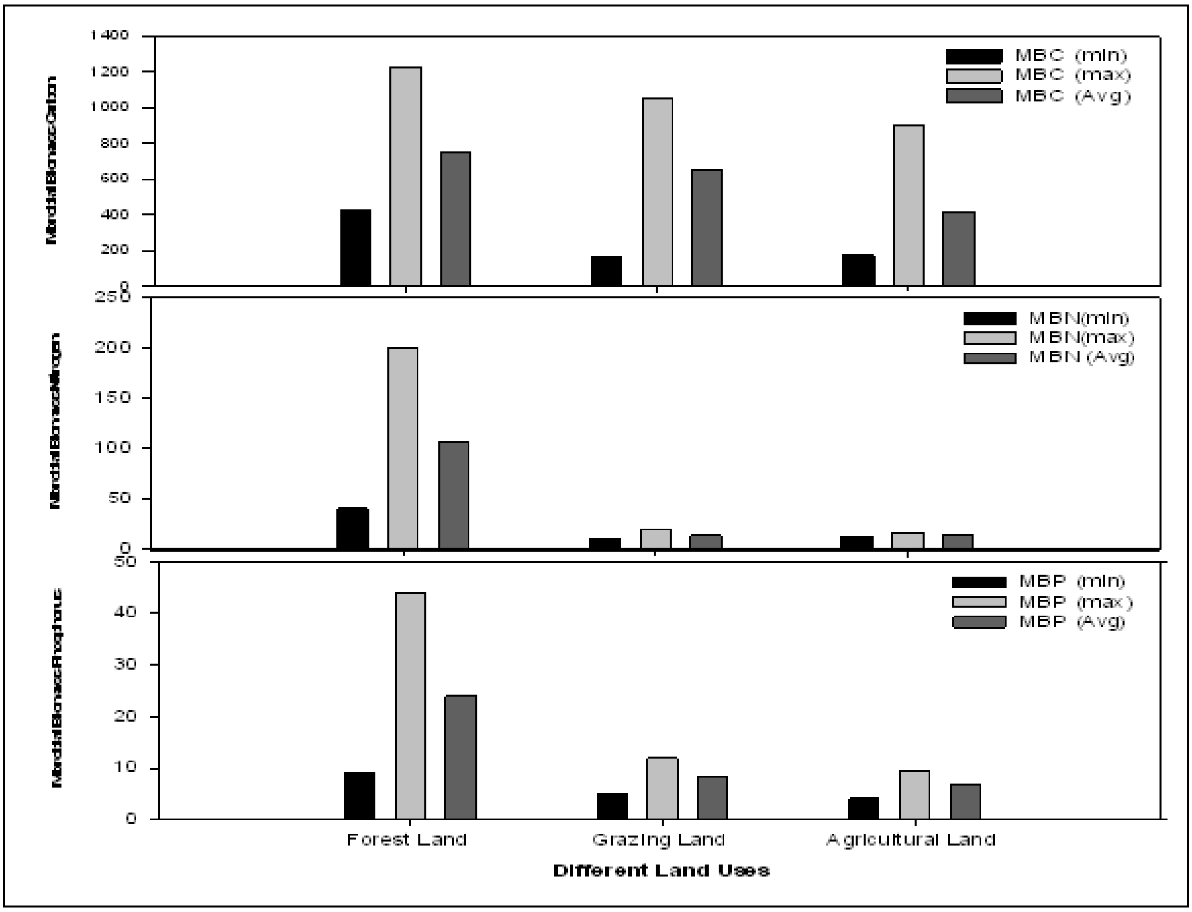

Fig. 1. Minimum, Maximum and Average Concentration (mg kg-1) of MBC, MBN and MBP in soils of different land uses.

A high rhizo deposition was reported in grazing land than forest land because the ratio of fungi and bacteria act as indicator of MBC: MBN (Mazzoncini *et al.,* 2010). (Balota *et al.,* 2003) recommended that larger MBC to MBN ratio will show larger fungal fraction in comparison with bacterial biomass in different land uses.

Therefore, it was articulated that the MBC to MBN ratio shows spatial variation beside the change in location and climate. It may designate that the fungal proportion to bacterial biomass was elevated in grass land and crop land then the forest land.

Earlier studies revealed that MBC to MBN ratio for temperate soils lies in the range of 6 and 8 (Lovell *et al.*, 1995; Aponte *et al.*, 2014).

The range of the ratio between MBC: MBN for humid agro ecosystems have been reported 7 and 13 (Mazzarino *et al.*, 1993). In tropical region, forest conversion to agriculture resulted in the decreasing soil carbon concentration by 20–50% (Eswaran *et al.*, 1993). (Singh *et al.,* 2014) investigated the MBC: MBN in different arable soils and reported a range of 8.7 to13.2. Almost similar ratio viz a viz 10.5-13.8 was reported in forest soils of tropical areas (Srivastava and Singh, 1989). The low microbial biomass carbon to microbial biomass nitrogen ratio was mentioned for utisol soil due to different soil reactions, farming system and macroclimate (Wang *et al.,* 2004; Alvear *et al.,* 2005). The MBC: MBN is more than the normal values reported (Jenkinson, 1988). In another study the normal value of MBC:MBP ranged from 15-63; microbial MBC: MBN ratio ranges from between 3.1-8.4 (Sarathchandra *et al.*, 1984). The ranges of MBC: MBN in soils of china was recorded as 5.05-9.6 (Xing *et al.,* 2010).

The nutrient SMB ratio determined in the current study in quite promising with values highlighted for grasslands in earlier studies. Microbial carbon to nitrogen ratio is supplementary normally reported to be 6.7 (Jenkinson, 1988) and (Sarathchandra *et al.*, 1984) noticed a range of 15-63 for MBC: MBP. Moreover, the microbial carbon to phosphorus ratio vary significantly from 15 to 63 in pasture lands while in the tropical soils a range from 9 to 23 has been reported (Sarathchandra *et al.,* 1984; Singh *et al.,* 1989). Therefore, the values revealed in our study are consistent with the proposed range for this type of climatic region. The C: N of the microbial biomass are generally accounted to be about 6.7 (Jenkinson, 1988) and the range of microbial carbon and phosphorous are more likely to be 15 to 63 (Sarathchandra *et al.*, 1984).

The land uses differences resulted in variations of soil physio-chemical properties (Zhang *et al.,* 2008). The significant difference for soil organic matter between wooded areas, pastures and agricultural lands are associated to plant coverage, SOC content and root systems, due to wide discharge of organic acids from roots and CO_2 concentrations free from roots and microorganisms.

High density of roots in the surface soil, high productivity, and complete removal of a vegetation cover every year lead to extended soil organic matter pools (Syers, 1997).

Elevated input of organic matter and easily availability of compounds of organic matter lead to greater contents of microbial biomass and microbes actions. This help to release the nutrient like phosphorus in the soil and nitrate nitrogen which are more due to microbial activities in the forest land compare to the cultivated and grassland (Singh *et al.*, 2010). As in present study results showed that microbial carbon and total organic carbon have positive co-relation because increase microbial biomass increases soil TOC. So when microbial biomass increased; activity of microbes also increased in favorable macro and micro climatic conditions thus, act as the source of available nutrients like N.

Microbial biomass carbon acts as labile fraction of soil total organic carbon. With increase of total carbon microbial carbon also increased. The total organic carbon distribution of microorganisms and their activity in soils may be a general indicator of potential microbial activity also has strong relation with electrical conductivity and clay because clay acts as active soil particle in chemical reactions. It has more adsorptive forces that bind the secretion of plant around clay particle and enhances the release of microbial carbon.

The electrical conductivity also increases due to total organic carbon which provide caution exchange site for different cations. As we noticed that MBC, phosphorous, and nitrogen are absolutely correlated (P < 0.05), because it act as substrate and faster turnover rate which act as catalyst for availability of different nutrients. Having close affiliation by total carbon and soil MBC: MBN ratios the answer could be justified because the (Kandeler *et al.*, 1999) justified well the slam associations between microbial biomass and soil organic matter (Alvear *et al.,* 2005). A positive relation between MBC and MBN (P < 0.01) shows a close association between changes of nitrogen in soil.

Soil organic carbon and concentration of available phosphorous are correlated with the increasing and decreasing order of the latitude (Gao *et al.*, 2004, Yu *et al.*, 2005). Main reasons behind this are the change in concentration of both the parameters in different agro ecological condition (Piao *et al.,* 2001; Yu *et al.,* 2005).

With increase in temperature reclamation time also increase due to high accumulation of organic matter in north than south. The increase in temperature also increases disintegration rate of soil organic matter (Piao *et al.,* 2001).

Conclusion

The study highlights that forest land use system in the loess soil region of Pakistan is most productive in terms of soil microbial biomass C, N and P concentration. Among the agriculture and grazing land uses grazing land exhibits more SMB concentration.

Moreover, the soil microbial biomass C, N and P concentrations have positive correlation with total organic carbon, NO_3-N and available P in all land uses of the region. The results of the study are beneficial for future management of all these land uses in this region of Pakistan.

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