Soil microbial biomass in cropland and forest ecosystem in eastern Nepal

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Abstract

Soil microbial biomass carbon (MB-C) and nitrogen (MB-N) were estimated in some man-made cropland ecosystems and Sal forest natural ecosystem in eastern Nepal. In these cropping systems MB-C ranged between 244 µg g^{-1} and 425 µg g^{-1} soil, minimum in tea cultivation and maximum in uncultivated paddy field. MB –N ranged from 24.7 µg g^{-1} to 43.2 µg g^{-1} soil, which was minimum in paddy field at mature crop stage and maximum in uncultivated paddy field. Towards natural ecosystem five landslide damaged sites selected in Sal forest ecosystem were 1 yr., 4yr., 15yr., 40yr., and 58-year old. Under these sites MB-C was minimum (132µg g-1) in 1-yr old site and maximum (638 µg g^{-1}) in 58- yr old site. Similarly, MB-N was also minimum (14 µg g^{-1}) in 1-yr and maximum (55 µg g-1) in 58- yr old site. In comparison to undisturbed mature Sal forest 58 year old site showed 82 % recovery in soil microbial biomass which indicates the re-establishment of soil nutrients and restitution of nutrients cycling.

Key words: Cropping system, tropical moist forest, landslide, restoration.

Introduction

Soil microbial biomass is a small, active, living and labile fraction of soil organic matter. Though, it represents a small fraction of total soil organic matter, but it is an active fraction due to its rapid turnover rate and fast release of available nutrients to the plants and thus contributing to nutrient cycling process far greater than its size (Schnurer *et al.*, 1985). Century model divides the soil organic matter into three fractions with different turnover time: (a) active fraction with most rapid turnover time (0.14 yr) (b) slow fraction having an intermediate turnover time (5 yr) and (c) passive fraction with longest turnover time (150 yr) (Parton *et al.*, 1989). The active fraction represents the live soil microbial biomass.

Soil microorganisms play a key role in the decomposition of complex organic matter of plant residues and the cycling of plant nutrients by acting both as a sink (immobilization) and as a source (mineralization) of plant nutrients (Fosu *et al.*, 2007). The size of soil microbial biomass can be taken as functional index of soil fertility and indicator of soil quality. Soil microbial biomass carbon (MB-C) comprises 1-5 % of total organic carbon (Nsabimana *et al*., 2004). MB-C could respond more rapidly to changes of soil environment than soil organic matter due to its high turnover rate (Powlson *et al*., 1987). Microbial biomass serves both as the transformation agent and source-sink of nitrogen (Bonde *et al*., 1998). Thus, microbial biomass nitrogen (MB-N) may have significant impacts on nitrogen availability and overall soil nitrogen cycling.

Contribution of soil microbial biomass towards nutrients flow and organic matter turnover has led to use it as a tool for soil management and perturbation studies (Smith & Paperdick, 1993). Informations on measurement and dynamics soil microbial biomass are available from dry tropical forest soil, mine spoils, grassland soil and agricultural soil (Srivastava & Singh, 1991; Kujur & Patel, 2012). However, the information on microbial biomass in different cropping systems is lacking. In the present investigation an attempt has been made to assess the level of soil microbial biomass in cropland (artificial ecosystem) and forest (natural ecosystem). Further, recovery pattern in soil microbial biomass has also been documented within a chronosequence of 1 to 58 yr old landslide damaged sites.

Materials and Methods

Study Sites

In the cropping ecosystem, study sites were selected in different croplands as: Paddy field- at beginning of cultivation, Paddy field with mature crop stage, Paddy field- uncultivated, Banana cultivation, Sugarcane cultivation and Tea cultivation in eastern Nepal. In the forest ecosystem, landslide damaged sites of 1 yr, 4 yr, 15 yr, 40 yr and 58 yr-old were selected in the tropical moist forest region in Eastern Siwaliks of Nepal. Comparisons were made with an undisturbed mature Sal forest located in the same region.

Determination of microbial biomass C and N

Soils were collected from 3 random locations at each site. At each location, soil was collected from 3 pits, composited and pooled as one replicate. After carefully removing the organic materials and fine roots, composited field moist soil samples were sieved through a 2 mm mesh screen and were preconditioned for 7 days at room temperature. Soil microbial biomass C and N were estimated according to Brooks *et al.* (1985) and Vance *et al.* (1987).

Results

Soil microbial biomass in cropland system

Microbial biomass carbon (MB-C) ranged between 244 μg g^{-1} and 425 μg g^{-1} minimum in tea cultivation and maximum in uncultivated paddy field. Microbial biomass nitrogen (MB-N) ranged between 24.7 μg g^{-1} and 43.2 μg g^{-1}, minimum in paddy field at mature crop stage and maximum in uncultivated paddy field (Table 1).

Table 1. Soil microbial biomass (μg g^{-1}) in some cropping ecosystems in eastern Nepal.

Study Sites	MB-C	MB-N	MB-C:NMB
Paddy field-beginning cultivation	352 ±34	32.8 ± 1.2	10.7
Paddy field-mature crop stage	280± 15	24.7± 1.7	11.3
Paddy field-uncultivated	425 ±21	43.2 ± 1.7	9.8
Banana cultivation	368± 86	32.5 ±1.5	11.3
Sugarcane cultivation	297 ±50	27.0±1.5	11.0
Tea cultivation	244 ±45	26.2± 1.2	9.3

MB-C:MB-N ratio was narrow in tea cultivation and wide in banana cultivation and paddy field at mature crop stage. Soil microbial biomass carbon and nitrogen as percentage of soil organic carbon and total nitrogen in cropland ecosystem are presented in table 2. Percentage of microbial biomass carbon was higher (5.2%) in banana cultivation and minimum (2.2%) in tea cultivation. Similarly, percentage of microbial biomass nitrogen was also maximum (6.5%) in banana cultivation and minimum (2.9%) in tea and uncultivated paddy field.

Table 2. Soil microbial biomass C and N as % of soil organic C and total N in some cropping ecosystems in eastern Nepal.

Study Sites	**Microbial Biomass % of**	
	Organic C	**Total N**
Paddy field-beginning cultivation	4.3	5.5
Paddy field-mature crop stage	3.8	3.5
Paddy field- uncultivated	3.4	2.9
Banana cultivation	5.2	6.5
Sugarcane cultivation	4.4	5.4
Tea cultivation	2.2	2.9

Soil microbial biomass in Sal forest ecosystem

In the natural ecosystem the level of soil microbial biomass carbon and nitrogen were higher than cultivated ecosystem. The soil of mature Sal forest stand contained 778 µg g^{-1} MB-C and 65 µg g^{-1} MB-N (Table 3). In the Sal forest region landslide damaged site of different age showed minimum MB-C (132 µg g^{-1}) and MB-N (14 µg g^{-1}) in 1 yr- old site and maximum MB-C (638 µg g^{-1}) and MB-N(55µg g^{-1}) in 58 yr- old landslide site. MB-C: MB-N ratio was narrow (9.4) at 1 yr- old site and wide (12.0) is undisturbed mature Sal forest stand. Soil microbial biomass carbon and nitrogen as percentage of soil organic carbon and total nitrogen was lower in natural forest ecosystem than in cultivated cropland system (Table 4).

Table 3. Soil microbial biomass (µg g^{-1}) in landslide sites and mature Sal forest in eastern Nepal.

Study site	**MB-C**	**MB-N**	**MB-C:MB-N**
Landslides sites (Age-year)			
1 year	132 ± 13	14 ± 1.7	9.4
4 year	215 ±18	21 ±2.3	10.2
15 year	408 ±30	38± 3.3	10.7
40 year	568± 43	50 ±4.6	11.4
58 year	638± 43	55 ± 3.9	11.6
Mature Sal forest	778 ±51	65 ± 5.4	12.0

Table 4. Soil microbial biomass C and N as percentage of organic C and total N, respectively in landslide sites and mature Sal forest in eastern Nepal.

Landslide sites	**Microbial Biomass as % of**	
Age of sites(yr)	**Organic C**	**Total N**
1 year	1.7	1.8
4 year	2.2	2.3
15 year	2.6	2.5
40 year	2.8	2.6
58 year	2.6	2.4
Mature Sal forest	2.5	2.2

Percentage of microbial biomass carbon was minimum (1.7) in 1 yr- old site and maximum (2.8) in 40 yr- old site. Similarly, percentage of microbial biomass nitrogen was also minimum (1.8) in 1 yr- old site and maximum (2.6) in 40 yr- old site. ANOVA suggested that the variations in microbial biomass C and N were significantly different for sites ($P \leq 0.001$).

Discussion

Soil microbial biomass was lower in cropland system than the natural forest ecosystem. Soil microbial biomass is a potential source of plant nutrients, and a higher level of soil microbial biomass is an indicator of soil fertility (Garcia *et al*., 2002).In the cultivated land , the organic matter is not recycled as in the forest ecosystem. Within the cropping system, uncultivated paddy field for one year showed maximum MB-C and MB- N due to addition of organic matter in the soil as it happens in the grassland ecosystem. Soil with relatively higher organic matter input usually develops a larger microbial biomass. Soil microbial biomass is sensitive to changes through management practices, environmental fluctuation and cropping system (Shah *et al.,* 2010).

Within the forest ecosystem, due to landslide disturbance, level of soil microbial biomass was reduced by 83% in 1-yr-old site in comparison to mature Sal forest. However, as the organic matter is added in soil during succession, the level of soil microbial biomass increased with passage of time and 58-yrs-old site showed 82% recovery in soil microbial biomass in relation to mature Sal forest. Recovery pattern was faster in the beginning (up to 15 yr old) due to addition of soft and easily decomposable plant materials. Microbial biomass responds quickly to changes in soil management and is used as an indicator of soil quality (Chu & Grogan, 2010).

MB-C: MB-N ratio was narrow (9.8) in tea cultivation and wide (11.3) in banana cultivation among the cropping systems while it was narrow (9.4) in 1 yr-old site and wide (11.6) in 58 yr old site among the landslide sites. Similar range of MB-C: MB-N ratio (8.72 to 11.63) was reported by Kujur and Patel (2012) and (7.5 to 10.3) by Srivastava and Singh (1991) for certain Indian tropical soils and (8.7 to 13.2) by Dalal and Mayer (1987) for Australian arable soils. An increase in the size of microbial biomass is coupled with a widening of MB-C:MB-N ratio. Soil microflora is a composite of several group of organisms and each microbial group may have a different C:N ratio. C:N ratio of bacteria is often between 3-5, while in fungi it ranges from 7- 15 (Poul & Clark, 1996). Lower MB-C:MB-N ratio represents bacterial dominance while higher MB-C:MB-N ratio represents fungal dominance in microbial biomass. Landslide disturbance altered both the size and composition of microbial biomass.

In the cropland system MB-C and MB-N as percentage of soil organic C and total N were relatively higher than forest ecosystem. The ratio of microbial biomass nutrient to soil nutrient present the quantum of soil nutrient reflected in microbial biomass, which provides an insight into the soil fertility status. Soil microbial biomass respond more rapidly to changes of soil environment than soil organic matter (Powlson *et al.,* 1987).

Soil microbial biomass, represented a small fraction (2-3%) of soil organic C and total N, which increased during the course of recovery of landslide sites. The values obtained for microbial biomass as percent of soil organic C and total N in the present study closely approximated with the values (2.8 & 2.9%, respectively) reported by Srivastava and Singh (1991) in dry tropical forest of India. Higher accumulation of soil microbial biomass at 58-yr – old site indicates the re-establishment of soil nutrients and restitution of nutrient cycling.

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