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# Effect of Disturbance on the Status of Soil Microbial Biomass in Tropical Sal Forest in Eastern Nepal

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**Abstract:** *The present study was conducted to investigate the effect of disturbance on the status of soil microbial biomass and physico-chemical characteristics of soil in disturbed and undisturbed stand of tropical sal (**Shorea robusta**) forest during summer. The forest soil was sandy loam. The percentage of sand and silt increased as increases depth but clay decreased with increase in depth of soil in both forests. The pH value of both forests was (disturbed 5.41 and undisturbed 5.29) slightly acidic. Maximum Water holding capacity (WHC) was higher in undisturbed forest (60.14%) than disturbed forest (55.04). Undisturbed forest showed greater organic carbon (1.71%) and total nitrogen (0.138%) than disturbed forest (OC -1.44% and TN - 0.118%). The microbial biomass carbon and microbial biomass nitrogen of undisturbed forest (MB-C - 324.29 μg $g^{-1}$and MB-N - 43.49 μg $g^{-1}$) was higher than disturbed forest (MB-C - 207.74 μg $g^{-1}$ and MB-N - 35.84 μg $g^{-1}$). Organic carbon, total nitrogen, microbial biomass carbon and microbial biomass nitrogen decreased with increasing soil depth in both forests. The MB-C: MB-N ratio indicate the bacterial dominance in disturbed stand (5.56) and fungal dominance in undisturbed stand (7.63). In the present work soil organic carbon and total nitrogen were reduced by 18% and 12%, respectively in the disturbed stand while soil microbial biomass carbon was reduced by 43% and microbial nitrogen by 18% for the same disturbed forest stand. It reflects a quick response of disturbance on soil microbial biomass.*

**Key words**: *Jalthal, tropical Sal forest, physico-chemical properties, disturbed, undisturbed forest.*

## Introduction

Sal forest is distributed in Tarai, Bhabar, Siwalik, Dun, foot hills of Nepal Himalaya. Sal (*Shorea robusta* Gaertn. f.) is the dominant species in Tarai and is the main source of timber and also used as fuel wood (Jackson, 1994). Growth of *Shorea robusta* and other tree species such as *Terminalia alata* and *Syzygium cumini* in tropical forest is highly influenced by nitrogen, phosphorus, potassium and soil PH (Bhatnagar, 1965). Tropical and subtropical forests are disturbed by variety of causes, mainly due to anthropogenic activities such as human settlement in forest area, clearance of forests and its conversion into agricultural land, grazing, firewood collection and forest fire are important causes of destruction, etc. Disturbances cause long term soil degradation and nutrients loss, consequently physical, chemical, mineralogical and biological properties of soil becomes changed (Certini, 2005).

Physico-chemical properties of forest soil vary in space and time because of variation in topography, climate, weathering processes, vegetation cover and microbial activities (Paudel and Shah, 2003). Fine roots and litter are main sources of soil organic matter which influences the physico-chemical characteristics of soil such

as texture, water holding capacity, pH and nutrients availability. Soil microbial biomass is an active fraction of soil organic matter. Though, it represents a small fraction of soil organic matter but is an active fraction due to its rapid turn over rate and fast release of available nutrients to the plants and thus contributing to nutrient cycle process for greater than this size. Thus microbial biomass acts as an important ecological indicator and is responsible for decomposition and mineralization of plant and animal residues in soil and nutrient cycling and maintenance of soil structure (Duffkova and Murova, 2011).

Soil microbial biomass shows quick response to any change in the ecosystem. In Nepal work on soil microbial biomass is limited. Mandal (1999) has reported the recovery in soil microbial biomass in landslide damaged tropical moist sal forest ecosystem in Nepal Himalaya. In the present work an attempt has been made to assess the effect of human disturbance on the status of soil microbial biomass in tropical sal forest at Jalthal located in Jhapa district, eastern Nepal.

**Materials and methods**

Tropical sal forests at Jalthal is located at an altitude of 62 msl near Kechana (lowland of Nepal) of Jhapa district in Nepal. It occupies an area of 6300 ha and lies in between 26°28′20.7″ and 26°30′56.4″ N and 87°56′33.6″ and 88°2′42.8″ E. The climate is tropical monsoon type and there are three seasons summer, rainy and winter. Based on data for 2011 mean monthly minimum temperature was 18.54°C and mean monthly maximum temperature was 32.12°C. Average annual rainfall was 1498.4 mm. The texture of soil in forest area is sandy loam. Sal forest at Jalthal is a dense deciduous vegetation and one of the most fragile and complex ecosystems of eastern part of Nepal. The forest floor altitudinal variation ranges from 62 msl to 129 msl. It is a Sal *(Shorea robusta* Gaertn.) dominated mixed tropical forest, and other associate species are *Lagerstroemia parviflora, Dillenia pentagyna, Terminalia bellerica*, *T. chebula, Sizygium cuminii*, etc. The forest is peculiar as it has some hill plant species *viz*. *Castanopsis indica*, *Schima wallichii*, *Michelia champaca* and *Madhuca longifolia*. It is also habitat for rare and endangered species like *Cycas pectinata, Dalbergia latifolia* and *Rauwolfia serpentina*. Jalthal Sal forest is highly disturbed by human settlement near the vicinity of forest area. Causes of disturbance of this forest are grazing, firewood collection, litter collection, timber cutting and forest fire which highly effect the physico-chemical properties of soil. The main objective of this study was to assess the effect of disturbance on the physico-chemical properties and status of soil microbial biomass in the sal forest of Jalthal.

The study was carried out in tropical sal forest of Jalthal during summer season (May 2012) where disturbed and undisturbed stands were selected for detail study. Soil samples were collected from fifteen random locations on disturbed and undisturbed sites from different depths 0-15 cm and 15- 30 cm. At each location soil was collected from three pits, composited and pulled as one replicate. After carefully removing fine roots and organic materials the air dried samples were sieved through a

2 mm mesh screen from both types of forest stand and used for chemical analysis. Water holding capacity (WHC) and texture of soil was determined as the methods described by (Piper, 1966). Soil pH (1:2.5 ratio of soil: water) was measured with digital pH meter. Soil organic carbon (SOC) was determined by partial oxidation method (Walkley and Black, 1934). Total nitrogen (TN) content of soil was determined using the micro- Kjeldal methods (Jackson, 1958). Soil microbial biomass carbon (MB-C) and soil microbial nitrogen (MB-N) were determined by chloroform- fumigation method following Vance *et al*. (1987 a) and Brookes *et al*. (1984).

**Results**

Soil physico-chemical properties of disturbed and undisturbed sal forest of Jalthal such as pH, soil texture, water holding capacity, organic carbon, total nitrogen, biomass of microbial carbon and nitrogen has been studied and results is presented in Tables 1 and 2. Both undisturbed and disturbed forests had sandy loam type of soil texture. The disturbed forest was composed of 50% sand, 34.26% silt and 15.73% clay whereas in undisturbed forest had 54% sand, 28.53% silt and 17.46% clay. While percentage of sand and silt increased with increase in depth of soil but percentage of clay decreased with increase in depth in both disturbed and undisturbed forests stand (Table 1). The pH value was 5.29 in undisturbed forest and 5.41 in disturbed forest stand. The pH value increased with increase in depth of soil in both forest stands. The WHC was a little higher in undisturbed forest (60.16%) than disturbed forest stands (59.04%), and decreased with increase in depth of the soil. Organic carbon was also higher in undisturbed forest (1.71%) than disturbed forest (1.44%), and decreased with increases in soil depth. Total nitrogen of undisturbed forest was 0.138% and in disturbed forest 0.118%, and also decreased with increase in depth of soil. The C: N ratio of undisturbed forest (12.39) was a little higher than disturbed forest stands (12.2).

Table 1. Physiochemical properties of soil in disturbed and undisturbed stands in tropical sal forest in eastern Nepal (values are ±1 SE)

| **Parameters** | **0–15 cm** | | **15–30 cm** | |
|---|---|---|---|---|
| | **Distrubed** | **Undistrubed** | **Distrubed** | **Undistrubed** |
| Soil texture | | | | |
| Sand% | 50.0±2.74 | 54±2.14 | 53.86±3.18 | 61.46±1.35 |
| Silt% | 34.26±2.68 | 28.53±1.84 | 36.53±2.76 | 31.33±0.88 |
| Clay% | 15.73±1.54 | 17.46±1.16 | 9.73±0.95 | 7.2±0.80 |
| Textural class | Sandy loam | Sandy loam | Sandy loam | Sandy loam |
| PH | 5.41±0.04 | 5.29±0.04 | 5.65±0.29 | 5.53±0.03 |
| WHC (%) | 59.04±1.69 | 60.16±1.90 | 54.63±1.56 | 54.54±1.98 |
| Organic C (%) | 1.44±0.14 | 1.71±0.1 | 0.89±0.07 | 0.91±0.06 |
| Total nitrogen (%) | 0.118±0.004 | 0.138±0.004 | 0.10±0.003 | 0.112±0.003 |
| C:N ratio | 12.2 | 12.39 | 8.9 | 8.12 |

Soil microbial biomass carbon of undisturbed forest (324.29 µg $g^{-1}$) was higher than disturbed forest (207.74 µg $g^{-1}$) (Table 2). Microbial biomass nitrogen was also higher in undisturbed forest (43.39 µg $g^{-1}$) than disturbed forest (35.84 µg $g^{-1}$). MB-C: MB-N ratio was 5.66 (lower) in disturbed forest while this ratio was 7.63 (high) in undisturbed forest stand.

Table 2. Soil microbial biomass in disturbed and undisturbed forest stands (0-15 cm depth) in tropical sal forest in Eastern Nepal (values are ±1 SE)

| **Parameters** | **0-15 cm** | |
|---|---|---|
| | **Disturbed** | **Undisturbed** |
| Microbial biomass C (µg $g^{-1}$) | 207.74± 19.13 | 324.29±17.51 |
| Microbial biomass N (µg $g^{-1}$) | 35.84±2.42 | 43.49±3.47 |
| MB-C:MB-N | 5.66 | 7.63 |
| MB-C as% of organic C | 1.44 | 1.89 |
| MB-N as% of total N | 3.07 | 3.08 |

The present value of MB-C in soil organic carbon was 1.44 in disturbed forest site and it was 1.89 in undisturbed forest site. Similarly, MB-N in total soil N was 3.07% in disturbed forest and 3.08% in undisturbed forest stands. In the upper layer (0-15 cm depth) of both forest stands soil organic carbon was significantly correlated with total soil nitrogen (Figs. 1 and 5). Soil organic carbon and nitrogen showed correlation with soil microbial biomass C and microbial N in the disturbed (Figs. 2, 3) and undisturbed (Figs. 6, 7) sites. Soil microbial carbon and microbial nitrogen was also significantly correlated in disturbed (Fig. 4) and undisturbed (Fig. 8) stands.

Fig. 1. Soil organic carbon (%) and total nitrogen (%) in 0-15 cm soil depth of disturbed stand

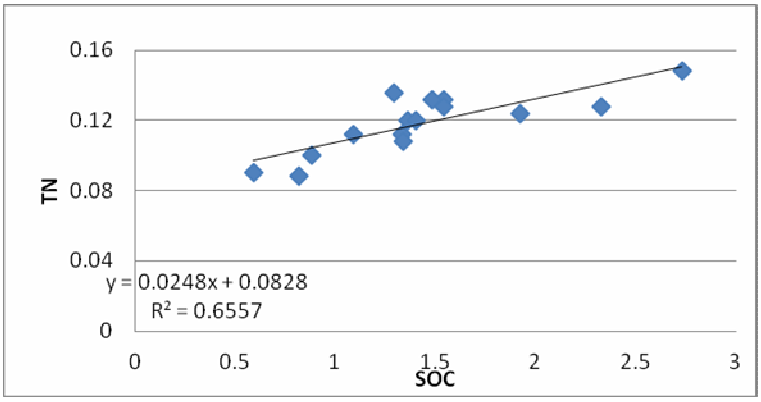


Fig. 2. Soil organic carbon (%) and microbial biomass carbon (µg $g^{-1}$) in 0-15 cm soil depth of disturbed stand

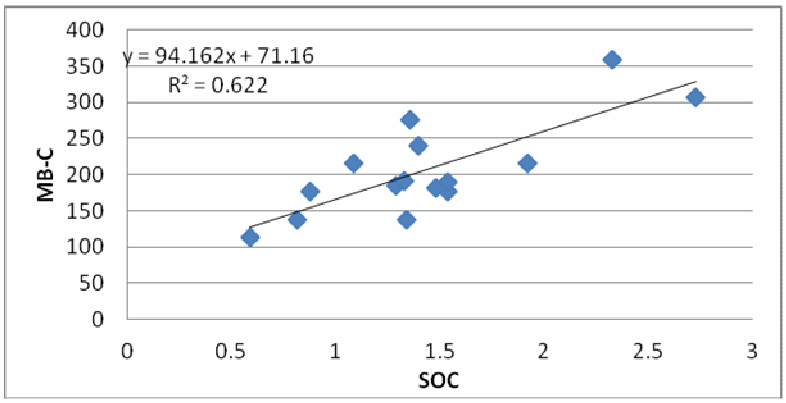



Fig. 3. Total nitrogen (%) and microbial biomass nitrogen (µg $g^{-1}$) in 0-15 cm soil depth of disturbed stand

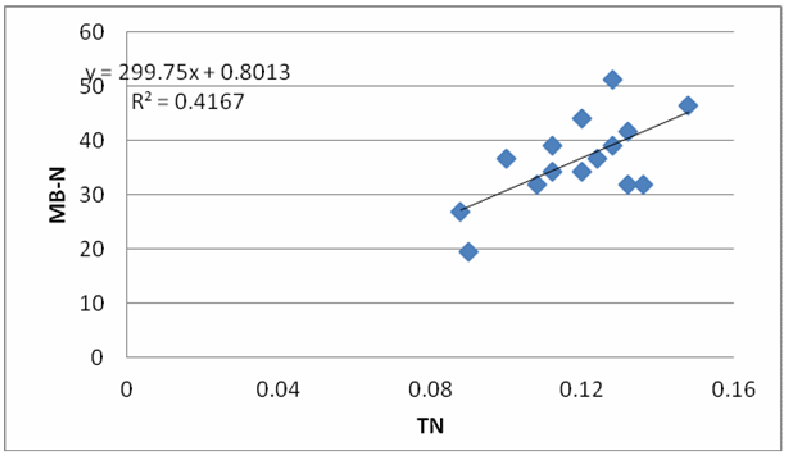



Fig. 4. Microbial biomass carbon (µg $g^{-1}$) and microbial biomass nitrogen (µg $g^{-1}$) in 0-15 cm soil depth of disturbed stand

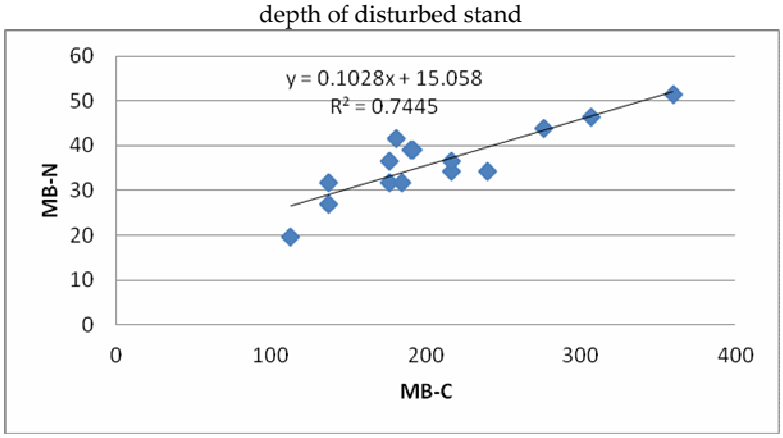


Fig. 5. Soil organic carbon (%) and total nitrogen (%) in 0-15 cm soil depth of undisturbed stand

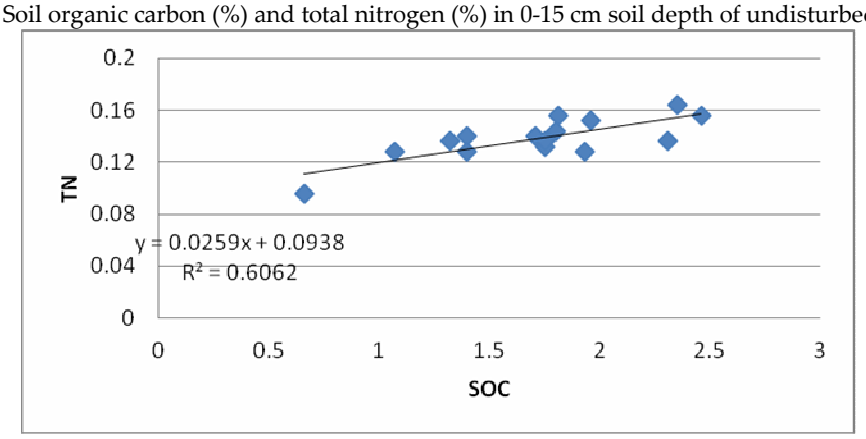



Fig. 6. Soil organic carbon (%) and microbial biomass carbon (µg $g^{-1}$) in 0-15 cm soil depth of undisturbed stand

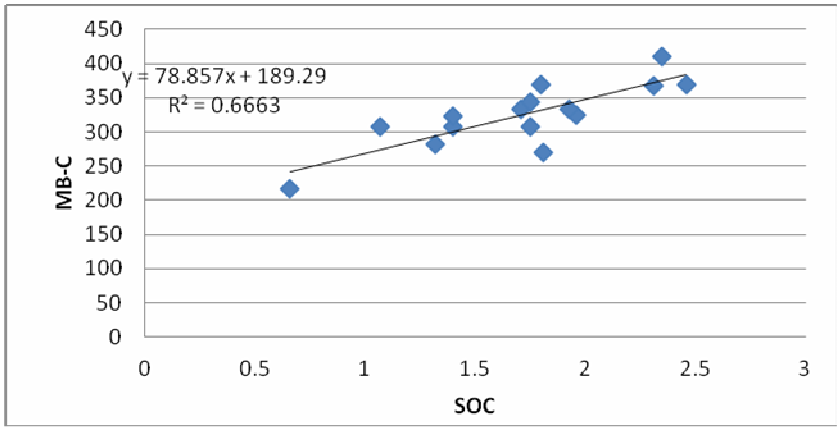



Fig. 7. Total nitrogen (%) and microbial biomass nitrogen (µg $g^{-1}$) in 0-15 cm soil depth of undisturbed stand

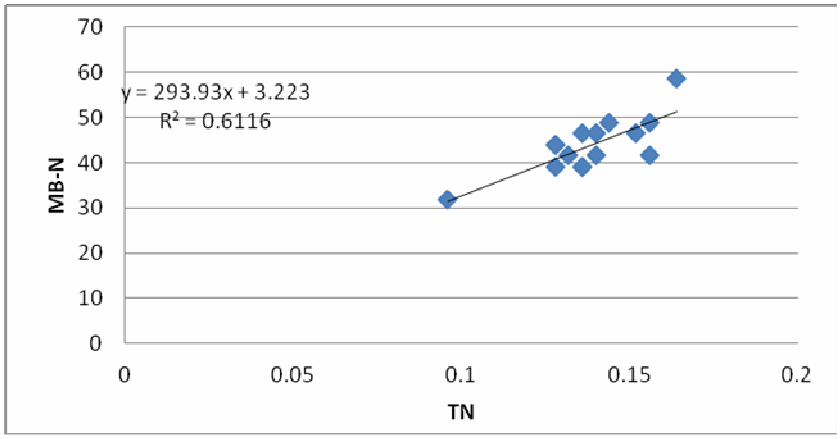
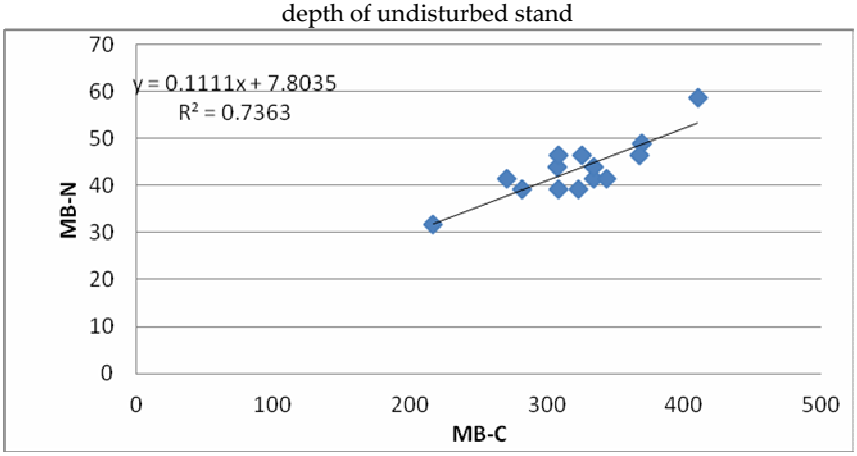


Fig. 8. Microbial biomass carbon (μg $g^{-1}$) and microbial biomass nitrogen (μg $g^{-1}$) in 0-15 cm soil depth of undisturbed stand




## Discussion

*Physico-chemical characteristics of soil:* Tropical forests are exposed to a variety of disturbances worldwide ranging from frequent localized events to less frequent, landscape level or multiple disturbance events (Barbuiya, 2006). Disturbances which compact the soil and remove the litter layer from top soil have significant effect on nutrient cycling processes and forest re growth.

Soil texture in both disturbed and undisturbed forests were sandy loam type. This result was similar to the result of Paudel and Shah (2003) reported for mixed sal forest of Udayapur and with the report for Shrestha (1997) in Chitrapani and Sigdel (1994) in Royal Chitwan National Park. Sandy loam texture is common in Tarai which support dense sal forest and other timber plants (Shah, 1997).

In present study the soil pH in undisturbed forest was 5.29 in 0- 15 cm depth, which was slightly lower than disturbed forest. Semwal *et al*. (2009) found that pH value in undisturbed oak forest (4.4-5.5) was more acidic than disturbed oak forest (5.6-5.9) of Rudraprayag and Pauri in the Garwal Himalaya, India. Shrestha (1992) reported that in the Tarai most of the soils are acidic. In the present study the soil pH was less acidic then reported by Paudel and Shah (2003) in pure Sal forest but result was more or less similar of mixed Sal forest. The pH value of soin recorded in the present study was lower than the values reported by Sigdel (1994) in Royal Chitwan National Park (5.90-6.42) and by Varghese *et al*. (2012) in Eravikulam National Park (6.1-6.8). The pH of undisturbed forest soil was slightly lower than disturbed forest which may be due to high amount of plant debris on the surface, decomposition of which leads to the accommodation of organic acid resulting in acidity of soil (Chen and Yan, 2000). Soil pH also influences the availability of plant nutrient and it is a good indicator of forest fertility (Black, 1968). Healthy Sal regenerating area has low pH in soils (Bhatnagar, 1965).

Water holding capacity was almost same in undisturbed and disturbed forest. Semwal *et al*. (2009) reported lower WHC in disturbed than undisturbed forest. Paudel and Shah (2003) found that WHC of mixed Sal forest was 49.80%. This was lower in comparison to WHC of disturbed and undisturbed Jalthal Sal forest. Water holding capacity of soil of undisturbed forest is higher because of finer texture and higher organic Carbon of the soil.

Soil organic matter increases the ion exchange capacity (Johnston, 1986), WHC (Salter and Williams, 1969) and availability of nutrients (Schnitzer and Khan, 1978). Soil organic carbon is the main terrestrial carbon pool (Bats, 1996). Soil organic carbon showed minimum variation in between disturbed and undisturbed forest at Jalthal (Table 1). Semwal *et al*. (2009) also found same trend of organic carbon in disturbed and undisturbed forests of Rudraprayag and Pauri, Uttarakhnd. Soil organic carbon was higher in undisturbed forest due to high litter decomposition and compact vegetation. Changes in soil micro environment due to deforestation leads to disruption of decomposition process which ultimately results into poor carbon and nutrient balance in the soil (Baubhuiya, 2006). Intensive grazing reduces soil organic matter, compact the soil surface layer and ultimately increases the surface run of (Faizul *et al.,* 1995).

Total nitrogen of undisturbed forest was higher than disturbed forest at Jalthal, and the same trend was found at lower depth. Semwal *et al*. (2009) also reported that total nitrogen was higher in undisturbed (0.230%) than disturbed (0.199%) pine forest of Uttarakhand. Paudel and Shah (2003) reported 0.11% total nitrogen from mixed Sal forest in Udaypur. Shrestha (1997) reported similar value of total nitrogen in Chitrepani forest (0.04%-0.09%). The data reported by Juwa (1987) in Nagarkot (0.18%-0.28%) and Sigdel (1994) in Royal Chitwan National Park (0.13%) are also comparable with the present work. The low nitrogen in Sal forest has been due to continuous loss through leach and run off (Allen, 1964) and it is good for Sal dominant and regeneration area (Bhatnagar, 1965).

*Soil microbial biomass in response of disturbance:* Soil microbial biomass may be the main source of nutrients for the plant and may help in nutrient conservation (Singh *et al.,* 1989). Microbial biomass carbon and nitrogen decreased in disturbed forest stand which were higher in undisturbed forest stand in the present study. Bharbuiya (2006) reported microbial biomass C in disturbed (246-361 $\mu g\ g^{-1}$) and undisturbed (548-1146 $\mu g\ g^{-1}$) forest which had same trend as in the present study. Similarly the microbial N values were (27.05-48.16 $\mu g\ g^{-1}$) in disturbed forest and (45.29-92.72 $\mu g\ g^{-1}$) in undisturbed forest in Meghalaya. The microbial biomass C and microbial N were lower in the undisturbed site than value (MB-C-778 $\mu g\ g^{-1}$ and MB-N-65 $\mu g\ g^{-1}$) reported by Mandal (1999) in undisturbed Panchakanya sal forest on plateau of Sunsari district, Nepal. Arunachalan and Arunachalan (2000) reported microbial Carbon (1522 $\mu g\ g^{-1}$) and Nitrogen (285 $\mu g\ g^{-1}$) of subtropical hill forest at Mawphlang Meghalaya India. Relatively dense growth of plants, greater accumulation of litter and

fine root on undisturbed area favors the growth of microbial population and accumulation of Carbon and Nitrogen in the microbial biomass.

Due to effect of disturbance, the level of microbial biomass carbon (MB-C) is reduced by 43% in disturbed site. Microbial biomass N (MB-N) is also reduced in disturbed site but by 17.6% only. It shows that the rate of reduction is more in MB-C than MB-N. On the other hand, MB-C in soil organic carbon was 1.41 while MB-N in total soil N was 2.98 in disturbed site. This also reflects that reduction in MB-C was more than MB-N.

MB-C : MB-N ratio was lower in disturbed site and higher (8.20) in undisturbed site. Soil microflora is a composite of several group of organism 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 and Clark, 1989). Low MB-C: MB-N ratio in disturbed site may reflect the bacterial dominance in the soil microbial biomass as bacterial tissue is richer in protein than fungi. Visser *et al*. (1983) reported that bacteria increased significantly than fungi and actinomycetes in the disturbed soils in Alberta, Canada. On the other hand high MB-C: MB-N ratio in the undisturbed forest stand may reflect the dominance of fungi in soil microbial biomass.

Disturbance alters the composition of soil microbial biomass which shows quicker response than the soil organic matter to any change in the ecosystem (Powlson and Jenkinson, 1981). In the present work soil organic carbon and total nitrogen were reduced by 18% and 12%, respectively in the disturbed stand while soil microbial biomass C was reduced by 43 and microbial N is reduced by 18% for the same disturbed forest stand. It reflects a quick response of disturbance on soil microbial biomass.

A comparative account of soil physico-chemical properties in disturbed and undisturbed forest indicated that the optimum values were found under undisturbed forest. The nutrient level in the soil are controlled by atmospheric variables on one hand through the growth of plant shoots and on the other by the mineralization of litter and dead roots by microbial activity. The decomposed humus content is added more to the soil to maintain mineral richness and fertility of soil as compared to disturbed forest (Semwal *et al*., 2009). Anthropogenic disturbance in disturbed forest causes the degradation of physical and chemical properties of soil and status of soil microbial biomass. Analysis of physico-chemical properties of soil including microbial biomass following disturbed forest ecosystem are important for evolving appropriate strategies for the reclamation of degraded ecosystem.

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