A comparative account of the microbial biomass-N and N-mineralization of soils under natural forest, grassland and crop field from dry tropical region, India

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ABSTRACT

This study investigated microbial biomass-N (MB-N) and N-mineralization in soils of four different vegetation systems including forest (sal), mixed forest, savanna and cropland ecosystems in the Vindhyan region, India. A change was noted in the above region due to physiographic differences and anthropogenic disturbances. Annually the soil moisture (SM) content across the different study sites ranged from 7.5 to 24.3% being maximum in forest sites compared to savanna and cropland sites. The NH_4^+-N, NO_3^--N and MB-N concentrations varied from 4.3 to 10.2 μg/g, 1.1 to 5.8 μg/g and 21.3 to 90.2 μg/g dry soil, respectively, with minimum values in the wet and maximum values in the dry season. The trend of seasonal variation in net N-mineralization was similar to that of moisture content but counter to the concentrations of inorganic-N and MB-N. The net N-mineralization rates at different investigated sites ranged from 4.5 to 37.6 μg/g month. Cultivation reduced the N-mineralization and MB-N by 58.5% and 63.5%, respectively. Experiments showed that the percentage contribution of MB-N to total-N was 8.01 to 19.15%. MB-N was positively correlated with the inorganic-N ($n = 180$, $r = 0.80$, $P < 0.001$) but negatively with soil moisture ($n = 180$, $r = 0.79$, $P < 0.001$) and net N-mineralization rates ($n = 180$, $r = 0.92$, $P < 0.0001$). The higher N-mineralization and MB-N in the soil of forest ecosystem was reported compared to savanna and cropland and the order of soil MB-N levels and net N-mineralization followed the sequence: forest (sal) > mixed forest > savanna > cropland.

Keywords: dry tropical forest; cropland; microbial biomass; N-mineralization; soil moisture

The seasonally dry tropical forest of Vindhyan region (India) is supported by nutrient-poor soils and a wide variation in vegetation composition occurs in the above region due to physiographic differences and anthropogenic disturbances (Singh and Kashyap 2006). Nutrient withdrawal from senescing leaves and nutrient immobilization in the microbial biomass (MB) were suggested as nutrient-conserving strategies developed in response to nutrient poverty, and thus MB constitutes the major nutrient source for plant growth in the study ecosystems (Raghubanshi et al. 1990).

Soil microbial biomass, the living part of soil organic matter, functions as a transient nutrient sink and is responsible for releasing nutrients from organic matter for use by plants (e.g. N, P and S) (Smith and Paul 1990). It was shown that microbial biomass-N (MB-N) contributes to the primary N source of potentially mineralizable N in soil (Bonde et al. 1988). N-mineralization and immobilization are soil microbial processes governed by C availability and are supposed to be linked closely to active fractions of soil organic matter (Hassink 1994). Soil microbes are typically C-limited (Smith and Paul 1990); lower microbial biomass in soils from conventional agroecosystems is often caused by reduced organic-C content in the soil (Flieβbach and Mader 2000). The soil MB was used as an index of soil fertility, which depends primarily on the rates of nutrient fluxes (Singh et al. 2007). The quantity and quality of organic inputs are the most important factors affecting MB and community structure (Peacock et al. 2001).

N-mineralization is a crucial process to supply N for plant growth and productivity in the ecosystem (Milkha and Rice 2004, Tripathi and Singh 2007). Hence, the soil N transformation in an ecosystem may serve as index of potential availability and ecosystem losses of nitrogen. In forest ecosystems environmental and biological factors (anthropogenic disturbances) affect N-mineralization (Wang et al. 2004, Singh and Kashyap 2006). MB and microbial activities are affected by different soil macroclimatic conditions in different ecosystems with soil moisture being the key factor in functioning of the ecosystem in dry tropics (Lodge et al. 1994).

MB serves as the estimate of microbial N immobilization and the soil microorganisms mediate many of the major processes during soil N cycling. Hence, in any disturbance in forest ecosystem, the MB could be one of the important factors, which may significantly affect the nutrient availability to plants. As the turnover rate of nutrients is very important for the functioning of different ecosystems, dynamics of MB and its role in plant nutrition in nutrient-poor soils of dry tropical and other similar ecosystems is of major significance (Azam et al. 2003).

Plant growth in seasonally dry tropical forest ecosystems regulates the temporal and spatial distribution of organic inputs in the form of plant roots, leaves and residues which in turn may influence the dynamics of soil MB and N-cycling (Singh et al. 1989). The effect of topography, burning and grazing, micro and macro aggregates of soil on MB and N-cycling processes in agricultural and forest ecosystems is well documented (Singh et al. 1991, Singh and Singh 1995, Singh and Kashyap 2006). Nevertheless, little is known about the variations of soil MB-N and N-mineralization along a gradient of different vegetation covers in seasonally dry tropical regions. The objectives of this study were to determine (i) the effects of vegetation type (sal-dominated dry tropical forest, mixed forest, savanna and cropland), season and soil characteristics on MB-N and N-mineralization, and (ii) relationships between MB-N and soil moisture, inorganic-N and N-mineralization rates.

MATERIALS AND METHODS

Study area and vegetation. Vindhyan Plateau is a largely erosional surface, where red-colored and fine-textured sandstone (Dhandraul orthoquartzite) is the prevailing rock. The soils are ultisols, and are within the hyperthermic formation of typical Plinthustults with Ustorthents (Raghubanshi 1991). These soils are leached, shallow and low in nutrients and organic matter and have moderate water-holding capacity (Singh and Kashyap 2006).

A typical monsoonal character dominates the seasonally dry tropical climate. There is a cold winter (November–February), a hot summer (April–June) and a warm rainy season (July–September). Warm temperatures (24–36°C) and high relative humidity (70–95%) prevail during the rainy season. During the winter, temperature ranges from 10 to 25°C and January is the coldest. Summer is dry and hot with temperatures ranging between 30 to 45°C. The annual rainfall averages 820 mm, of which 86% falls during the rainy season. The different meteorological data during the present study were obtained from office of Renukoot Forest Division, Uttar Pradesh, Government of India. There is an extended dry period of about 9 months.

Study sites were distributed on the Vindhyan plateau in two adjoining districts, Mirzapur and Sonebhadra (Uttar Pradesh, India). The major ecosystems investigated included forest, mixed forest, savanna and cropland. The major population in the above region is of tribals having very low mental status. Agricultural practices are very poorly developed and depend on natural rains. The crop yields and job opportunities are very poor. So, the forest area has a great anthropogenic pressure and it is not only need-based but also activity-, occupation- and habit-based. Consequently, most of the people earn their income from the collection of forest products, sale of firewood and timbers.

The forest site (lat. 24°17'52", long. 83°6'36" and alt. 355 m msl) was dominated by *Shorea robusta* (C.F. Gaertn.) and is considered as one of the best sal forests of India with a density of 2210 woody plants/ha with other frequently occurring tree species, such as *Acacia catechu* (L.F. Wild.), *Anogeissus latifolia* (Roxb. ex DC) Wall. ex Bedd., *Hardwickia binata* (Roxb.) etc.

The mixed forest site (lat. 25°10', long. 82°45' and alt. 355m msl) was dominated by *Boswellia serrata* (Roxb.) commonly called as Shallaki followed by the other occurring tree species namely *Lannea coromandelica* (Houtt.) Merrill, *Nyctathes arbor-tristis* L., *Holarrhena antidysenterica* (Roth.) A. DC., *Ziziphus glaberrima* (Sedgw) Santap., etc. (tree density 490 plants/ha).

The savanna site (lat. 24°26'36", long. 83°3'18" and alt. 299 m msl) was dominated by *Butea monosperma* (Lamk.) Taub., with a tree density of 330 different woody plant/ha (other frequently occurring tree species were: *Chrysopogan fulvus* (Spreng.) *Heteropogan contortus* (L.) P. Beav. ex R. & S., *Adina cordifolia* (Roxb.) Hook. F. ex Brandis. etc.).

The Barkaccha cropland site on the Vindhyan plateau (resulting from manual forest clearing for cultivation purpose during 1979 covering an area 113.3 km^2) was under *Oryza sativa* L. (rice)/*Lens culinaris* Medicus (lentil) cultivation (Singh and Singh 1995). The site has been maintained as dry land (rain fed) agro-ecosystem with minimum tillage since 1990. However, tall grasses, thorny semi-arid bushes and sparse tree previously dominated the cropland site (lat. 25^{o}10', long. 82^{o}45' and alt. 299 m msl). Singh and Kashyap (2007) have already described the potential vegetation of this religion. Rice is grown in the rainy season followed by lentil in winter. The chemical fertilizer (NPK: 80 kg N/ha, 40 kg P/ha, 30 kg K/ha; for N urea, for P single super phosphate and for K muriate of potash) were used in June 1990 and every year the inputs were applied only once a year. The cropland site, located in the Barkaccha Agriculture Farm is managed by the Banaras Hindu University.

Field work. Soil samples were collected seasonally from September 1995 to August 2000 (August for rainy season, December for winter and May for summer season) from each site in triplicate by removing soil monoliths (10 × 10 × 15 cm). In order to randomize, the distance between the soil sampling at each site were at least 50 m. It was thoroughly mixed and the large fragments of plant materials (live roots) were removed by hand-sorting to inhibit the N immobilization (Ross 1987). Each soil sample was divided into two halves. One part was used for analysis of physico-chemical properties of soil and the second part for the determination of inorganic-N, N-mineralization and MB-N. Soils were mixed thoroughly by hand, sieved through 2 mm mesh and stored at 4°C till further analysis. From this composite stock three soil sub-samples from each site were drawn for further analysis. Sampling was confined to 15 cm as the majority of roots were located in this layer.

Laboratory work. Sub-samples were dried at 105°C for 24 h to measure the gravimetric soil moisture. Field-moist samples were sieved through a 2-mm mesh screen for the analysis of extractable mineral N and P concentrations. Once during the study period 12 (1 year × 3 replicates × 4 sites), air-dried soil samples were used to determine the texture, organic C, total N and P. Particle-size distribution (texture) was analysed using sieves of different mesh size (Indian Standards 1965), and the pipette method (Piper 1944). Bulk density (BD) was determined by measuring the weight of dry soil of a unit volume to a 10-cm depth. Soil pH was measured by glass electrode (1:2, soil:water ratio). Water-holding capacity (WHC) was measured using perforated circular brass boxes as described by Piper (1944). Organic C was analyzed by dichromate oxidation and titration with ferrous ammonium sulphate (Walkley 1947). Total N was analysed by macrokjeldahl digestion (Jackson 1958) and total-P was measured colorimetrically after $HClO_4$ digestion (Jackson 1958).

Soil moisture (SM) content (% on dry soil basis) was determined according to Buresh (1991). NH_4^+-N (μg/g dry soil basis) was extracted by 2M KCI and analyzed by the phenate method (APHA 1985). NO_3^--N (μg/g dry soil basis) was determined using the phenol disulfonilic acid method, with 2M $CaSO_4$ as the extractant (Jackson 1958). Plant-available P ($NaHCO_3$-Pi, pH 8.5, μg/g dry soil basis) was determined by the ammonium-molybdate-stannous chloride method (Jackson 1958). N-mineralization rate (μg/g Mo dry soil) was determined *in situ* using buried bag techniques (Eno 1960, Roy and Singh 2003). The soil samples were air dried to bring the moisture content to about 55% of the full WHC and stored at room temperature (27 ± 2°C) for 4–6 days to settle down the respiration after sieving (Srivastava and Singh 1989). MB-N in all the conditioned soils was determined by the chloroform extraction method (Brookes et al. 1985). The flush of total-N was obtained by subtracting the K_2SO_4-extractable N in unfumigated soil from that of the fumigated soils, and divided by a fraction value (K_N) of 0.54 (Brookes et al. 1985) of biomass-N after chloroform fumigation.

Statistical analyses. All results are expressed on an oven-dried soil (105°C, 24 h) basis. Seasonal means of pooled data were analyzed through ANOVA and by correlation analysis using Statgraphics Software (Statistical Graphics Corporation 1986).

RESULTS AND DISCUSSION

The major physico-chemical properties of soils of different sites investigated are presented in Table 1. The textural class of the study sites was sandy-loam to sandy-clay-loam while BD ranged from 1.2 to 1.5 g/m^3. The WHC was greater in forest soils (41.1 to 45.3%) compared to savanna and cropland (40.3 to 39) soils. The WHC of soil increased significantly with increasing soil organic-C concentrations along a gradient of vegetation types. The bulk densities of the two forest soil systems were lower than the cropland and savanna ecosystems. Both, the increase in WHC and decrease in BD in forest soils compared to cropland and savanna soils suggest that the soil

Table 1. Physico-chemical properties of soils of study sites.

Soil properties	Sites				LSD*
	forest (sal)	mixed forest	savanna	cropland	
Soil texture					
Sand (%)	38.2 ± 0.56	39.1 ± 0.67	28.1 ± 0.43	30.0 ± 0.43	1.10
Silt (%)	20.3 ± 0.43	57.2 ± 0.65	67.8 ± 0.87	53.5 ± 0.56	0.40
Clay (%)	1.2 ± 0.11	3.7 ± 0.09	1.8 ± 0.34	16.5 ± 0.22	3.70
Gravel (%)	40.3 ± 1.23	–	2.3 ± 0.33	–	0.11
Bulk density (g/m^3)	1.20 ± 0.08	1.23 ± 0.44	1.30 ± 0.23	1.40 ± 0.04	0.01
WHC (%)	45.3 ± 1.23	41.0 ± 0.59	40.3 ± 0.98	39.1 ± 0.54	1.40
pH	6.4 ± 0.77	6.4 ± 0.76	6.9 ± 0.23	6.6 ± 0.12	0.20
Total-C (μg/g dry soil)	27024 ± 76.99	22344 ± 56.56	16356 ± 54.89	14022 ± 44.45	1392
Total-N (mg/g dry soil)	1322 ± 14.87	1342 ± 15.11	1090 ± 12.77	913 ± 9.45	143
Total-P (mg/g dry soil)	378 ± 7.98	349 ± 5.11	213 ± 8.98	109 ± 4.23	43
C/N ratio	20.4 ± 0.41	16.6 ± 0.34	15.0 ± 0.42	15.3 ± 0.42	0.29

*$P < 0.05$; values are means of three replicates ± 1 S.E.

porous structures and the hydrothermal conditions improved as vegetation cover increased. Zhang et al. (1988) and Singh et al. (1989) have also reported an increase in soil BD due to cultivation. All the sites had slightly acidic to neutral pH, except savanna being slightly alkaline, and across different experimental sites it ranged from 6.4 to 6.9. The total-C concentration in forest soils was higher (22.344 to 27.024 μg/g dry soil) than in savanna and cropland soils (16.356 to 8.822 μg/g dry soil). Total-N and total-P concentrations and C/N ratios were also higher at the two forest sites compared to savanna and cropland. Across the different study sites total-N and total-P ranged from 143 to 1342 μg/g dry soil and 43 to 378 μg/g dry soil, respectively. The C/N ratio of the forest ecosystems ranged from 16.6 to 20.4, while that of cropland and savanna ranged from 15.0 to 15.3. The soil physico-chemical properties were different for different vegetation covers. Soil physical and chemical properties can be significantly improved for the vegetation systems having higher organic matter content such as forest (sal), mixed forest ecosystems compared to savanna and cropland ecosystems. The cultivation caused a decrease in total-C and total-N by 48.1% and 31%, respectively. The soil N and C losses from an agro-ecosystem can be due to its removal of crops (Tripathi and Singh 2007). In natural ecosystems, most of the organic matter produced by vegetation is returned to the soil, but after cultivation much of it is removed for human and animal consumption and relatively marginal amount is returned back to the soil (Srivatava and Singh 1991).

During the year across the different study sites SM contents and N-mineralization rates ranged from 6.3 to 24.3% and 4.5 to 37.6 μg/g month respectively, being maximum in rainy and minimum in summer season (Table 2). Differences in SM contents and N-mineralization rates due to sites, seasons and site × season interaction were significant ($P < 0.001$). At different sites, the seasonal pattern of inorganic-N (NH_4^+-N and NO_3^--N) and MB-N exhibited reverse trend being low in wet while high in dry period and varied from 1.1 to 7.9 μg/g dry soil and 21.3 to 90.2 μg/g dry soil respectively (Table 2). Inorganic-N and MB-N values showed a significant difference depending on the site, season and site × season interaction ($P < 0.001$). The values of soil MB-N were significantly related to SM, inorganic-N and N-mineralization (Table 3).

The reason for decreased SM level in the cropland compared to forest ecosystem in present investigation may be due to the decrease in organic matter and aeration following cultivation, which may promote drying (Table 2). In cultivated soils, evaporation is a moisture-loss mechanism in the 0–10 cm soil layer and there was about 17% decline in the soil moisture following cultivation. The seasonal pattern for NH_4^+-N and NO_3^--N values in the present study indicates that they declined in forest soils compared to cropland soils. The increase in NH_4^+-N in cropland soils may be due to higher percentage of net am-

Table 2. Seasonal variations of soil moisture (%), inorganic-N (μg/g dry soil), N-mineralization rate (μg/g Mo dry soil) and microbial biomass-N (MB-N) (μg/g dry soil)

Parameters	Seasons	Sites				LSD*
		forest (sal)	mixed forest	savanna	cropland	
Soil moisture	rainy	24.3 ± 0.44	22.5 ± 0.65	17.6 ± 0.57	18.4 ± 0.23	6.3
	winter	18.2 ± 0.84	13.5 ± 0.43	11.7 ± 0.68	12.4 ± 0.48	3.5
	summer	11.2 ± 0.62	10.0 ± 0.80	6.3 ± 0.32	7.5 ± 0.18	1.8
NH_4^+-N	rainy	5.0 ± 0.14	4.3 ± 0.09	4.6 ± 0.09	5.2 ± 0.17	0.3
	winter	6.1 ± 0.18	5.1 ± 0.14	6.3 ± 0.21	6.8 ± 0.15	0.5
	summer	7.9 ± 0.21	6.2 ± 0.39	8.1 ± 0.88	10.2 ± 0.26	1.8
NO_3^--N	rainy	2.7 ± 0.06	2.7 ± 0.13	1.8 ± 0.08	1.1 ± 0.06	0.2
	winter	4.7 ± 0.12	3.4 ± 0.35	1.9 ± 0.08	1.7 ± 0.06	0.6
	summer	5.8 ± 0.08	4.1 ± 0.08	2.6 ± 0.15	2.4 ± 0.10	0.5
N-mineralization	rainy	37.6 ± 0.54	25.9 ± 0.63	20.7 ± 3.79	17.3 ± 0.84	12.1
	winter	25.5 ± 2.15	9.3 ± 1.64	9.2 ± 0.35	9.3 ± 1.73	7.7
	summer	11.7 ± 2.09	4.8 ± 0.10	4.7 ± 0.09	4.5 ± 0.14	6.2
MB-N	rainy	62.5 ± 3.47	45.1 ± 0.95	25.1 ± 2.30	21.3 ± 1.26	12.3
	winter	79.6 ± 1.07	70.1 ± 0.71	30.6 ± 2.83	25.1 ± 1.14	10.4
	summer	90.2 ± 0.95	85.6 ± 0.30	40.1 ± 1.10	38.4 ± 1.16	7.5

*$P < 0.05$; values are means pooled data ± 1 S.E. Total 45 soil samples (3 seasons × 3 replicates × 5 years) were analysed per site

monification rates and its accumulation on the top horizon of the soil, and the least loss of NH_4^+-N in run off. This may be one of the conserving strategies of N in the nutrient-poor soils in dry tropical regions to check N loss from the altered ecosystems. Further, immobilization of the inorganic nutrients in soil MB and uptake by plants is comparatively lower, and consequently, there is accumulation of inorganic-N (NH_4^+-N and NO_3^--N) in the cropland ecosystem. Nevertheless, tillage also causes an increase in inorganic-N. Reduced plant cover also means reduced nutrient uptake, hence inorganic-N in the cropland soils. The seasonal pattern of N-mineralization was similar, being the highest in wet season and lowest in dry season (Table 3). It is evident that the N-mineralization is moisture-controlled in dry tropical regions. Consequently, the N-mineralization was enhanced significantly in all the sites of dry tropical soils during rainy season due to high soil moisture, which is limiting in the tropical deciduous forest (Singh and Kashyap 2006). The reason for higher N-mineralization rates

Table 3. Correlation analysis and significance level for the relationship of MB-N (Y, μg/g dry soil) with soil moisture (X, %), inorganic-N (X, μg/g dry soil) and N-mineralization rate (X, μg/g month). Correlation analyses were performed on pooled data across different study sites and seasons

Y-variable	*X-variable*	*a*	*b*	*n*	*r*	*P*
MB-N	soil moisture[a]	27.12	–0.44	180	0.79	< 0.01
	inorganic-N[a]	–1.46	0.22	180	0.80	< 0.01
	N-mineralization[a]	8.52	–1.84	180	0.90	< 0.001
	N-mineralization[b]	10.88	–2.64	180	0.92	< 0.001

[a] $Y = ax$ (a is in log); [b] $Y = \exp(a + bx)$

in forest ecosystems, as compared to cropland may be due to the higher organic-C and total-N content in the soil. Further, higher soil MB also contributes to the enhancement of N-mineralization rates after wetting of the soil. Perakis and Hedin (2002) reported that the N losses from undisturbed cool temperate rain forest in the southern hemisphere are much lower. Consequently, the pool of inorganic-N is lower, but the potential of net N-mineralization higher in the forest ecosystem.

The N-mineralization was positively correlated with SM (n = 180, r = 0.98, P < 0.001) and negatively with NH_4^+-N (n = 180, r = 0.92, P < 0.001), NO_3^--N (n = 180, r = 0.90, P < 0.001) contents of soil. The variability in N-mineralization rate was 59.2% due to variability in SM content. A positive relation of N-mineralization rate to SM indicated that the process was water-limited.

Seasonal variation in MB-N (Table 2) was similar to that of inorganic-N being the highest in summer and lowest in rainy season. Ross (1987) and Srivastava and Singh (1989) also reported seasonal fluctuations in soil microbial biomass. The microbial communities of droughty soils are pre-adapted to moisture stress and accumulate intracellular solutes under conditions of low water potential (Sparling et al. 1987). According to Sanchez (1976) and Raghubanshi (1991), the microbial activity continues during the summer season, because the microbial activity is sensitive to water potential and the increase in soil water potential in the rainy season may induce plasmoptysis (when a cell bursts because it has taken in too much water as a result of being placed in a hypotonic environment). Reduced MB and increased microbial turnover in the wet period may result from feeding by expanded microbivore (invertebrates feeding on microbes) population (Raghubanshi et al. 1990). The dynamics of soil MB-N are associated with environmental (such as soil moisture and temperature) and biological events (such as activities of microbial-feeding fauna, litter inputs etc.), which affect microbial growth (Chen et al. 2003). The low levels of MB-N in our study in the wet season could also be due to a greater demand of nutrients by plants during rainy season (active plant growth period) that may limit the nutrient availability to soil microbes and therefore lower MB-N. This situation is reflected in the reciprocal relationships between the magnitude of MB-N and SM and N-mineralization rate (Table 3).

The present investigation also indicates that the conversion of forest into savanna and cropland resulted in a decrease in MB-N (Table 2). This situation could arise because of the conversion of forest into cropland with the resultant decrease in the quantity of plant biomass and reduction in organic-C and N including reduced microbial N-immobilization, thus a decrease in the amount of MB-N in soil might be expected. The decline in SOM and microbial biomass may result from lower inputs of organic matter into soil. Consequently, the MB decreases along the organic matter gradient. A positive effect of organic fertilizers on the microbial biomass C and N content in soil was observed in long-term field experiments with continuous cultivation of silage maize and with crop rotation (Cerny 2008). The loss due to savannization (conversion of forest into savanna due to deforestation) in MB-C, N and P were 34.8, 41.5 and 30.8%, respectively, in dry tropical soils (Srivastava and Singh 1991). The contribution of MB-N to total-N from forest to cropland ecosystem ranged from 2.88 to 3.53%, which is in close agreement with the values reported from undisturbed ecosystems and agro-ecosystems soils in India (Srivastava and Singh 1989, Singh et al. 2007). The MB-N was negatively correlated with SM (n = 180, r = 0.79, P < 0.001) and N-mineralization (n = 180, r = 0.92, P < 0.0001) but it was positively correlated with inorganic-N (n = 180, r = 0.80, P < 0.001) (Table 3). This situation may arise because of the enhanced SM conditions in rainy season and mineralization of MB to furnish available-N demands for vigorously growing plants during active growth conditions (wet period).

It may be concluded that the anthropogenic pressure on forest ecosystem in the Vindhyan region is one of the major cause for conversion of forest into savanna and cropland for agricultural purpose. The conversion of forest into cropland has resulted in decrease of N-mineralization potential and the MB-N content. It indicates that the N-mineralization potential declined substantially over a period of 28 years in the cropland. Therefore, there is a need for a nutrient management plan for efficient use of nutrient from the soil pool and to check the soil N loss after conversion of forest into cropland. Incorporation of green manure, Farm Yard Manure or crop residues increases nutrient availability, MB and N-mineralization of cropland ecosystems resulting in the high crop yield as well as in the increase in nutrient status of nutrient poor soils in dry tropical regions.

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REFERENCES

APHA (1985): Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington D.C.

Azam F.A., Farooq S., Lodhi A. (2003): Microbial biomass in agricultural soils-determination, synthesis dynamics and role in plant nutrition. Pakistan Journal of Soil Science, *6*: 629–639.

Blumfield T.J., Xu Z.H., Chen C. (2005): Mineral nitrogen dynamics following soil compaction and cultivation during hoop pine plantation establishment. Forest Ecology and Management, *204*: 131–137.

Bonde T.A., Schnurer J., Rosswall T. (1988): Microbial biomass as a fraction of potentially mineralizable nitrogen in soils from long-term field experiments. Soil Biology and Biochemistry, *20*: 447–452.

Brookes P.C., Landman A., Pruden G., Jenkinson D.S. (1985): Chloroform fumigation and the release of soil nitrogen: a rapid direct extraction method to measure microbial biomass nitrogen in soil. Soil Biology and Biochemistry, *17*: 837–842.

Buresh R.J. (1991): Extraction of ammonium, nitrate and nitrite from soil. IFDC/IRRI Collaborative Project.

Chen C.R., Xu Z.H., Blumfield T.J., Hughes J.M. (2003): Soil microbial biomass during the early establishment of hoop pine plantation: seasonal variation and impacts of site preparation. Forest Ecology and Management, *186*: 213–225.

Černý J., Balík J., Kulhánek M., Nedvěd V. (2008): The changes in microbial biomass C and N in long-term field experiments. Plant, Soil and Environment, *54*: 212–218.

Eno C.F. (1960): Nitrate production in the field by incubating the soil in polyethylene bags. Soil Science Society of America Proceedings, *24*: 277–279.

Flieβbach A., Mader P. (2000): Microbial biomass and size-density fractions differ between soils of organic and conventional agricultural systems. Soil Biology and Biochemistry, *32*: 757–768.

Hassink J. (1994): Active organic matter fractions and microbial biomass as predictors of N-mineralization. European Journal of Agronomy, *3*: 257–265.

Indian Standards (1965): Indian Standards: 2720, Part IV: Grain size Analysis. Indian Standards Institute, New Delhi.

Jackson M.L. (1958): Soil Chemical Analysis. Prentice Hall, New Jersey.

Jaramillo V.J., Sanford J.R.R.L. (1985): Nutrient cycling in tropical deciduous forests. In: Bullock S.H., Mooney H.A., Medina E.O. (eds.): Seasonally Dry Tropical Forests. Academic Press, New York: 347–362.

Lodge D.J., McDowell W.H., McSwiney C.P. (1994): The importance of nutrient pulses in tropical forest. Trends in Ecology, *9*: 384–387.

Milkha M.M., Rice C.W. (2004): Nitrogen mineralization from a soil with differing N supply capacities. Agronomy abstracts. ASA-CSSA-SSSA International Annual Meeting, 4, Seattle.

Murphy P.G., Lugo A.E. (1986): Ecology of tropical dry forest. Annual Review of Ecology, Evolution and Systematics, *17*: 67–88.

Peacock A.D., Mullen M.D., Ringelberg D.B., Tyler D.D., Hedrick D.B., Gale P.M., White D.C. (2001): Soil microbial community responses to dairy manure or ammonium nitrate applications. Soil Biology and Biochemistry, *33*: 1011–1019.

Perakis S.S., Hedin L.O. (2002): Nitrogen loss from unpolluted South American forest mainly via dissolved organic compounds. Nature, *415*: 416–419.

Piper C.S. (1944): Soil and Plant Analysis. Inter Science Publication, Adelaide.

Raghubanshi A.S., Srivastava S.C., Singh R.S., Singh J.S. (1990): Nutrient release in leaf litter. Nature, *346*: 227.

Raghubanshi A.S. (1991): Dynamics of soil biomass C, N and P in a dry tropical forest in India. Biology and Fertility of Soils, *12*: 55–59.

Ross D.J. (1987): Microbial biomass estimated by the fumigation-incubation procedure, seasonal fluctuations and influence of soil moisture content. Soil Biology and Biochemistry, *19*: 397–404.

Roy A., Singh K.P. (2003): Dynamics of microbial biomass and nitrogen supply during primary succession on blast furnace slag dumps in dry tropics. Soil Biology and Biochemistry, *35*: 365–372.

Sanchez P.A. (1976): Properties and Management of Soils in the Tropics. John Wiley, New York.

Singh J.S., Raghubanshi A.S., Singh R.S., Srivastava S.C. (1989): Microbial biomass acts as a source of plant nutrients in dry tropical forest and savanna. Nature, *338*: 499–500.

Singh J.S., Kashyap A.K. (2006): Dynamics of viable nitrifier community, N-mineralization and nitrification in seasonally dry tropical forest and savanna. Microbiological Research, *161*: 169–179.

Singh J.S., Kashyap A.K. (2007): Contrasting pattern of methanotrophs in dry tropical forest soils: effect of soil nitrogen, carbon and moisture. Microbiological Research, *162*: 276–283.

Singh R.S., Raghubanshi A.S., Singh J.S. (1991): Nitrogen mineralization in dry tropical savanna: effects of burning and grazing. Soil Biology and Biochemistry, *23*: 269–273.

Singh S., Ghosal N., Singh K.P. (2007): Variations in soil microbial biomass and crop roots due to differing resource quality inputs in a tropical dry land agro ecosystem. Soil Biology and Biochemistry, *39*: 76–86.

Singh S., Singh J.S. (1995): Microbial biomass associated with water stable aggregates in forest, savanna and cropland soils of a seasonally dry tropical region, India. Soil Biology and Biochemistry, *27*: 1027–1033.

Smith J.L., Paul E.A. (1990): The significance of soil microbial biomass estimations. In: Bollag J.M., Stotzky G. (eds.): Soil Biochemistry. Vol. 6. Marcel Dekker, Inc., New York, 357–396.

Sparling G.P., Milne J.G., Vincent K.W. (1987): Effect of moisture regime on the microbial contribution to Olsen P values. Journal of Agricultural Research, *30*: 79–84.

Srivastava S.C., Singh J.S. (1989): Effect of cultivation on microbial biomass C and N of dry tropical forest soil. Biology and Fertility of Soils, *8*: 343–348.

Srivastava S.C., Singh J.S. (1991): Microbial C, N and P in dry tropical forest soils: effects of alternate land uses and nutrient flux. Soil Biology and Biochemistry, *23*: 117–124.

Statistical Graphics Corporation. (1986): Statgraphics Statistical Graphics System. USA.

Tripathi N., Singh R.S. (2007): Cultivation impacts nitrogen transformation in Indian forest ecosystems. Nutrient Cycling in Agroecosystems, *77*: 233–243.

Voroney R.P., Van Veen J.A., Paul E.A. (1981): Organic C dynamics in grassland soils. II. Model validation and simulation of long-term effects of cultivation and rainfall erosion. Canadian Journal of Soil Science, *61*: 211–224.

Walkley A. (1947): A critical examination of a rapid method for determining organic carbon in soils. Effects of variations in digestion conditions and of inorganic soil constituents. Soil Science, *63*: 251–264.

Wang C., Xing X., Han X. (2004): Advances in study of factors affecting soil N mineralization in grassland ecosystems. Soil Biology and Biochemistry, *15*: 2184–2188.

Zhang H., Thompson M.L., Sandor J.A. (1988): Compositional differences in organic matter among cultivated and uncultivated Argiudolls and Hapludalfs derived from loess. Soil Science Society of America Journal, *52*: 216–222.

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