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Short Communication

Effect of Forest Conversion into Tea Plantation on the Available Nitrogen in the Soils at Andro, Northeast India

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ABSTRACT

We studied the changes in NH_4^+-N and NO_{3-}N in the soil after conversion of a sub-tropical forest into tea plantation in Northeast India. The forest is dominated by *Lithocarpus fennestrata* and *Passania pachyphlla* and part of the forest was felled for tea (*Camellia sinensis*) plantation intercepted by *Emblica officinalis* and *Cymbopogon cladestinus*. The NH_4^+-N ranged from 2.19 (December) to 4.84 µg g^{-1} soil (June) in forest and 2.53(January) to 4.91 µg g^{-1} soil (June) in tea plantation during the year. NO_3-N ranged from 0.66 (April) to 3.88 µg g^{-1} soil (March) in forest and 0.72 (April) -2.98 µg g^{-1} soil (March) in tea plantation. NH_4^+-N was recorded to be highest in rainy followed by summer and winter in both the sites. Seasonal changes in NH_4^+-N and NO_3-N values may be due to the variation in the mineralization rates, uptake by plants and microbes through soil erosion, leaching and denitrification. Significant positive relationship between NH_4^+-N and soil temperature, soil organic carbon and total soil nitrogen in both the sites indicates that these are the controlling factors in the NH_4^+-N concentration. NH_4^+-N and NO_3-N concentrations were relatively higher under tea plantation than the forest.

Key Words: Denitrification; Nitrogen; Mineralization; Soil Temperature; Subtropical Forest

INTRODUCTION

Forested soils are being increasingly transformed to agricultural fields in response to growing demands of food crop. Land use changes affect soil properties and thus nutrient cycling dynamics. Nitrogen is a limited nutrient for plant growth in forest ecosystems (Aber *et al.* 1989). In forest ecosystems, a lot of organic nitrogen is transformed into inorganic N after disturbance such as clearing and harvesting. There is a large annual flux of N through the ammonium and nitrate pools in terrestrial ecosystems (Schlesinger 1997).

NH_4^+-N and NO_3-N represents the available inorganic forms of nitrogen in the soil. Plants take up mainly inorganic form as ammonia and nitrate and produce inorganic N compounds which return to the soil through litter. NH_4^+-N is present in higher concentration than NO_3-N as it is vulnerable to leaching and denitrification. The availability of N limits biomass production in many ecosystems (Chapin 1996). Nitrogen can easily be lost from the soil through leaching and volatilization. Leaching occurs when the NO_3^- is moved downward through soil profile by water, rainfall, floods etc. Soil N availability depends on transformation processes, such as mineralization, immobilization, volatilization, nitrification and denitrification. Nitrate losses have been associated with forest site disturbances in which plant removal reduces biological demand for N, while the onset of new site conditions generally increases ammonification rates (Likens *et al.* 1969). Increasing NH_4^+ fixation can be a way in building up an available N pool in soils to optimize crop recovery and minimize N losses into the environment (Liu *et al*. 2008) as the NH_4^+ ions after penetration into the clay mineral interlayer are excluded from nitrification (Guo *et al.* 1983) and are thus protected against leaching. The NH_4^+ pool can thus function as a kind of buffer that could influence N losses from soils and mineral N availability to crops.

The available N pools (NH_4^+ and NO_3) accounts for less than 2% of the total N content of soils in deciduous forests (Melillo, 1981). The N availability is influenced by many factors such as soil temperature, humidity, vegetation type, litter quality, and disturbance regimes (Sulkava et al. 1996). Work on the fixation and availability of fixed NH_4^+ in different crops during growing season has been reviewed by Nieder (2011) and Batlle-Aguilar (2011) Typical assessments of N availability include "snapshot" tests of soil NH_4^+ or NO_3^- pools at one or more times in the growing season, or measures of net mineralization and nitrification (i.e., increase or decrease in NH_4^+ or NO_3^- over a given period of time). A number of studies have been done on the forest ecosystem by several workers in India under different land use types in the humid tropics of Arunachal Pradesh (Arunachalam and Arunachalam 2006); Dipterocarpus forest of Manipur, Northeast India (Devi and Yadava 2005); natural forest, grassland and crop field from dry tropical region (Singh *et al*. 2009) and Indian dry tropical forest (Tripathi and Singh 2009). However, information on available N in the soils on transformation of forests is lacking. We tested the hypothesis whether forest conversion into tea plantation led to increase or decrease in the available nitrogen in the soils of tea plantation at Andro, Northeast India.

STUDY SITE

The study site is located at $24^0$76 N Latitude and $94^0$05 E Longitude and 808-815 m asl in the Imphal East District of Manipur at Andro, Northeast India. The forest site is dominated by *Lithocarpus fennestrata* and *Passania pachyphylla* . A part of the forest has been cleared and converted into the tea plantation in last seven years. Tea (*Camellia sinensis*) plantation is intercepted by *Emblica officinalis* and *Cymbopogon cladestinus* for providing shade to the tea plantation. Experimental sites were earmarked in the forest and another in tea plantation for detailed investigation.

The climate of the area is monsoonic with three distinct seasons viz. rainy (June-October), winter (November-February) and summer (March-May). The mean maximum temperature varied from 23.84^0C (December) to 31.22^0C (September) and the mean minimum temperature ranged from 5.29^0C (January) to 23.49^0C (September).

The mean annual rainfall ranged from 3.95 mm (December) to 226.45 mm (July). Annual mean rainfall is 1193.2 mm. The average relative humidity of air varied from 68.63% (May) to 82.63% (August). March constitutes the transitional month between winter and summer while October is the transitional month between rainy and winter.

EXPERIMENTAL SET UP AND SOIL ANALYSIS

Two experimental study sites have been earmarked in forest and tea plantation site. Each site has been divided into five plots randomly and soil samples were collected at random from each plot. Soil samples were composited to represent five soil samples for each study site. The samples were collected from soil depth 0-10cm soil layer every month from 2008-09 and on seasonal basis during 2009-2010. The soil texture was analyzed by International Pipette method (Gee and Bauder 1986). Soil temperature was determined using a soil thermometer, soil moisture by gravimetric method and soil pH is determined by pH meter (1:5 soil water suspension). Soil organic carbon and total nitrogen were estimated by the methods given by Anderson and Ingram (1993) and Bremner and Mulvaney (1982).

Plant materials and other unwanted debris were removed and the soil samples were divided into two parts for each soil depth. The first part was sealed in sterilized polyethylene bag after removing coarse fine roots, stones and large recognizable debris and incubated in the soil at 0-10cm soil depth. Buried bag technique (Eno, 1960) was used for estimating the concentration of NH_4-N and NO_3-N. The second part of the soil was brought to the laboratory, air dried and were sieved in a 2mm mesh to remove the unwanted materials for estimating Inorganic-N. The concentration of NH_4-N and NO_3-N were extracted from the soil by 2M KCL and the initial concentration was determined within 24 hours by FIAStar 5000 (Flow Injection Analyser) FOSS Tecator AB, Sweden. All the analysis was done in five replicates and data are the mean value of five different plots of each study site. Statistical analysis of the data was done by using SPSS version 6.1.

RESULTS

The soils of both the study sites was sandy loam and acidic in nature. Soil moisture and temperature was more or less similar in both the sites. However, soil organic carbon and total soil nitrogen was higher in forest than tea plantation sites (Table 1).

NH_4-N concentration ranged from 2.19 (December) to 4.84 µg g^{-1} soil (June) in forest and 2.53 (January) to

Table1. Physico-chemical characteristics of soil in forest and tea plantation at Andro, NE India. All values are Mean±SE, with the range given in parentheses.

Parameters	Forest	Tea plantation
Soil moisture (%)	12.85 ± 1.78 (4.01- 25.84)	12.85 ± 1.78 (5.04- 22.04)
Soil Temperature (°C)	24.08 ± 0.39 (22.60 – 26.80C)	24.08 ± 0.39 (24.40 – 29.20)
Soil organic C (%)	3.51 ± 0.03 (2.78 – 4.20)	2.86 ± 0.02 (2.16 – 3.51)
Total soil N (%)	0.47 ± 0.06 (0.33 – 0.57)	0.41 ± 0.06 (0.33 – 0.49)

Values cited in the table are the annual mean and ranges of the value are given in the parenthesis

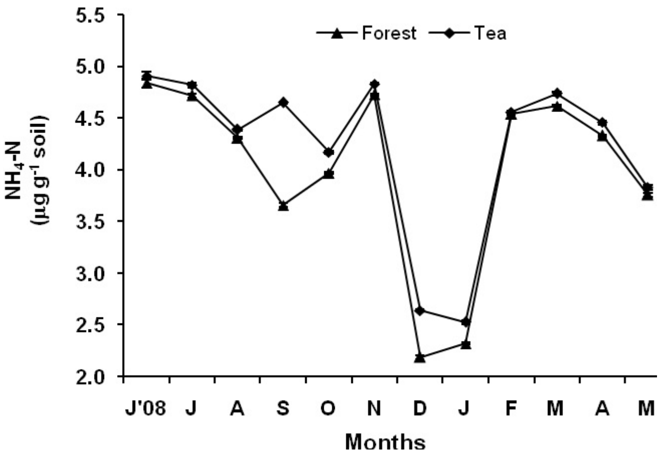

Figure 1. Monthly changes in NH_4-N concentration in forest and tea plantation in the different months throughout the year

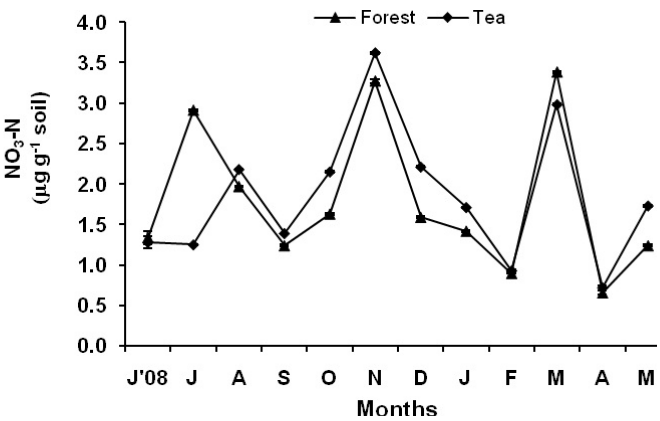

Figure 2. Monthly changes in NO_3-N concentration in forest and tea plantation in the different months throughout the year

4.91 µg g^{-1} soil (June) in tea plantation (Figure 1). NO_3-N concentration ranged from 0.66 (April) to 3.38 µg g^{-1} soil (March) in forest and 0.72 (April) to 2.98 µg g^{-1} soil (March) in tea plantation (Figure 2). NH_4-N was recorded to be highest in rainy followed by summer and winter in forest site. Similar trend was recorded in tea plantation. NO_3-N was recorded highest in rainy season followed by winter and summer in forest whereas it was highest in winter followed by summer and rainy seasons in tea plantation (Table 2). NH_4-N and NO_3-N exhibited significant positive correlation with soil temperature, soil organic carbon and total soil N in both the study sites (Table 3).

Table 2. Seasonal variation in the concentration of NH_4-N and NO_3-N in forest and tea plantation site (µg g^{-1} soil)

Seasons	Forest site		Tea plantation site	
	NH_4-N	NO_3-N	NH_4-N	NO_3-N
Rainy	4.30	1.82	4.59	1.65
Winter	3.45	1.79	3.64	2.12
Summer	4.24	1.76	4.24	1.76
Annual	4.00± 0.26	1.79± 0.26	4.21± 0.24	1.84± 0.24

Table 3. Correlation coefficients (r) between NH_4-N and NO_3-N with soil temperature, soil organic carbon and total soil N.

Parameters	Forest site		Tea plantation site	
	NH_4-N	NO_3-N	NH_4-N	NO_3-N
Soil temperature	0.59*	-0.58	0.59*	-0.48
Soil organic C	0.63*	0.12^{NS}	0.64*	-0.25
Total soil N	0.61*	0.18^{NS}	0.61*	-0.47

*Significant at P>0.01, NS – not significant

DISCUSSION

In our study, NH_4-N was comparatively higher than that of NO_3-N in both the sites may be due to greater rate of ammonification in the present study sites and potential loss of NO_3-N to leaching during rainy season. The acidic nature of the soil may have inhibited the growth and activity of autotrophic nitrifiers in the soil to some extent resulting in lower nitrification rates (Chao *et al.* 1993). Nadelhoffer (1984) suggested that the variation in NH_4-N concentrations in soil during different seasons depend on net ammonification rate. The concentration of NH_4-N and NO_3-N were found to be maximum in rainy season followed by summer and winter season in forest site**.** Similar observations were reported by Ghoshal (2002) in a dryland agro-ecosystem of the Banaras Hindu University. Ghosh and Dhyani (2012) studied N transformation rates in traditional and agroecosystem of central Himalaya and found decreased mineral N concentration during cropping season. The comparatively higher concentration of NH_4-N in the rainy season may be associated with the fast luxuriant growth of microbes and the increased anaerobic conditions. Minimum value of NH_4-N in winter may be due to low soil moisture and temperature which hampers the microbial activities. Seasonal changes in NH_4-N and NO_3-N values may be due to the variation in the mineralization rates, uptake by plants and microbes through soil erosion, leaching and denitrification. The available nitrogen (NH_4-N and NO_3-N) is comparatively more in the rainy season than in other seasons in both the forest and the tea plantation.

Positive significant relationship between soil temperature, soil organic carbon and total soil N in both the sites indicates that soil temperature, soil organic carbon and total soil N have strong influence inNH_4^+-N concentration in both the study sites. Similar findings were also reported by Powers (1990) in the southern Appalachian mountains of western North Carolina. Tea plantation was very sensitive to the fluctuations of temperature and moisture due to its lower vegetation coverage.

CONCLUSION

Land use changes affected soil properties and nutrient cycling dynamics. We found that on conversion of forest into tea plantation there is a slight increase in available nitrogen in the soils of Manipur, Northeast India. The present study also shows the strong seasonality in NH_4^+-N, NO_3-N and available N in the two study sites. Soil temperature and organic carbon are the controlling factors on the available nitrogen in the forest and tea plantation. Forest conversion into tea plantation led to 2.56% and 1.30 % increase in NH_4-N and NO_3-N respectively. However, further detail investigation on long term basis is required to assess changes in available N on conversion of forest to tea plantation for sustainable development in the region.

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