Effect of season, soil and land use pattern on soil N-mineralization, Ammonification and Nitrification: A study in Arunachal Pradesh, Eastern Himalaya

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doi: 10.6088/ijes.2014050100008

ABSTRACT

Net N-mineralization, ammonification and nitrification as influenced by climatic factors, soil characteristics and land use patterns were studied soils of two different land use patterns prevalent in East Siang district, Arunachal Pradesh. Ammonification and nitrification rate varies significantly (p<0.001) between the land use pattern and seasons. The greater amount of N-mineralization was recorded during the rainy season in both the land use patterns while during the spring season (Paddy AES) and rainy season (Homegarden). Ammonification rate is positively correlated with soil pH, SOC, NH4-N and NO3-N. Conversely, nitrification rate is negatively correlated to ammonium and nitrate concentration which suggests that available nitrogen concentration was not saturated in these agricultural systems. Lesser nitrification rate compared to the ammonification rate would be helpful in conserving the soil nitrogen.

Key words: Gentrification, immobilization, microbial activities, nutrient management, tropical ecosystems.

1. Introduction

N transformation in agro-ecosystems is very indispensable to sustain the future crop production (Tiessan et al. 1982, 1994). Numerous researches on nutrients cycling have concluded that nitrogen (N) is crucial to terrestrial production, predominantly in tropical ecosystems either in agro-ecosystems or natural forest (Chao et al. 1993; Firestone 1982; Vogt et al. 1986). However, N mineralization fluctuate its net rate significantly in different areas and seasons (Gelfand and Yakir 2008; Tripathi and Singh 2009; Yan et al. 2009).

N-mineralization process is influenced by biomass inputs, microbial activities, and different abiotic factors such as microclimatic variations and land use patterns. Agricultural practices may modify the plant composition and soil characteristics which regulate the water content, nutrient availability and energy in the soil (Sumi 1997; Rhoades and Coleman 1999). Recycling of organic matter from the plants residues is an important source of nitrogen and it is maintained through mineralization-immobilization processes in agro-ecosystems. Tillage can accelerate the release of nutrients from soil organic matter to the soil, where they can either be taken up by plants or enhance the leaching which may leads to loss of soil carbon and nitrogen in the agricultural lands (Fox and Bandel 1986).

Potential mineralization rate ensures the amount of soil organic matter which is mineralized and subsequently considered as the indicator of soil fertility status. Therefore, measurement
of net N-mineralization in soil is very important for the management of nutrients and sustainable agricultural productivity. Keeping the importance of it in account, present study had been undertaken to understand the effect of various agro-management, climatic conditions and soil depths on dynamics of N-mineralization (in situ).

2. Materials and method

2.1 Study site

The East Siang District where the present study was carried out is often referred to as the gateway of Arunachal Pradesh. It is located between 27°30’ to 29°20’ North latitude and 94°42’ to 95°35’ East longitude and forms a part of Eastern Himalaya. The climatic conditions in the district vary from place to place due to mountainous nature of the terrain. The topography of the district is variable and the elevation ranges from 130 to 752 m asl. Average monthly rainfall of the district is 470 mm. Two land use systems prevalent in the district i.e., Homegarden and Paddy AES were selected for the detail study.

2.2 Methods

The study was conducted for a period one annual cycle (June, 2011 to May, 2012). Soil samples were collected monthly basis from the five places of the respective study sites from two depths (0-15cm and 15-30cm) in replicates. Field moist soil was used for the determination of mineralization. A sub sample of each soil was air dried, grinded and sieved (<150mm) prior to the samples used for further physico-chemical analysis. Soil texture was determined by Boyocous hydrometric method, water holding capacity, porosity, total nitrogen, available phosphorus, available potassium were determined following the method outlined by Allen et al. (1974). Bulk density, soil moisture content, soil pH, ammonium-N and nitrate-N were determined by method as outlined by Anderson and Ingram (1993). SOC was determined by rapid titration method (Walkley and Black 1934).

2.3 N-mineralization

In-situ N-mineralization was determined using buried-bag technique (Eno 1960). Five paired soil cores were collected in each site. One of the cores from each pair was sealed in sterile polyethylene bag after removing coarse roots and larger organic debris, and reinserted to its respective depth. The other soil cores were brought to the laboratory and ammonium and nitrate concentrations were determined. After one month, the buried bags were retrieved and the soil samples were pooled according to depth and analyzed for final ammonium and nitrate concentrations. Changes in ammonium and nitrate concentrations were obtained by subtracting initial concentration from corresponding final concentration, and the resultant values were referred to as ammonification and nitrification rates, respectively. Net N-mineralization was calculated as the sum of changes in extractable ammonium-N and nitrate-N over one month.

All the data collected were statistically analyzed to compare seasonal and annual mean and related characters. The data on soil were analyzed using ANOVA to study the various agro-ecosystems, sampling period and soil depth on different properties of soils and their changes. Correlation analysis was completed following Zar (1974).
3. Results and discussion

3.1 Soil characteristics

The soil textures were sandy loam and sandy clay loam in nature among the sites (Table 1). Silt content is very low in all the sites and ranges between 1.8% and 2.8%. Soil texture governs the other soil properties including biological characteristics. Clay is considered as the most reactive part of soils in terms of actual seat of reactions due to its small size and high surface area. More clay content in soil could result in increased porosity, drainage and decreased water retention (Tessier et al. 1992). However, agricultural practices have not much effect on silt content, since a very less content was found in present study (0.82-3.1%). WHC of the soil ranges from 65.12% to 66.22% in different sites and showed significant variation among the sites (P<0.05). WHC of surface soil layer was found to be greater than the subsurface layer. As found in porosity, water holding capacity also decreases with soil depth which might be due to high amount of organic carbon and clay in the surface than subsurface soils, which promote formation of aggregates and retention of water (Gupta et al. 2010). Bulk density varies significantly between the sites (P<0.05). Negative correlation was observed between SOC and BD in the present study, which was in support of result of Sharma and Qahar (1989) who also reported a negative correlation between BD and SOC from outer Himalayas. Porosity decreases with increase in soil depth except the Homegarden. Soil porosity and pore size distribution were negatively affected by the intensity of land use. Higher values of porosity could be due to more organic matter content and high amount of fine fractions which has a higher surface area (Gupta et al. 2010). Decline in porosity leads to reduce pore size distribution which has an impact on productive capacity of the agricultural soil.

Table 1: Soil physical properties under selected land use pattern (values are the means of four seasons across 1 year).

<table>
<thead>
<tr>
<th>Land use pattern</th>
<th>Depth (cm)</th>
<th>Physical property</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sand (%)</td>
</tr>
<tr>
<td>Homegarden</td>
<td>0-15</td>
<td>73.80 ±0.80</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>74.20 ±0.32</td>
</tr>
<tr>
<td>Paddy AES</td>
<td>0-15</td>
<td>73.80 ±0.3</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>72.60 ±0.38</td>
</tr>
</tbody>
</table>

±SE (n=3)

Concentration of SOC was found to be greater in surface soil layer than the subsurface soil layer in Homegarden (Table 2). Variation in SOC under different agro-ecosystems may be due to the crop plant composition and the soil fertility management. Ploughing causes the breakdown of aggregates, may further increase the degradation processes by exposing organic material to biodegradation and oxidative agents (Six et al. 2000). Accumulation of human and other wastes also enhances the SOM. TKN ranges between 0.42% and 0.49%
among the land use patterns. Significant variations were found between the soil depths and among the sites (P<0.01). Available phosphorus varies between 13.64 and 41.98 µg g⁻¹ in the study site and significant variations was found between depths and sites (P<0.01). Sources of P are pedogenic and anthropogenic sources, but the majority of P being introduced as mineral fertilizers and different organic sources such as manure, crop residues in the agricultural fields. Variations in available P concentration among the agro-ecosystems could be primarily due to application of phosphorus rich fertilizers as it has been observed from a few agro-ecosystems in Ruksin where conventional farming is in common practice. However, higher concentration of available potassium was found in the agro-ecosystems where crop plant parts are left after the harvesting. Hence, a good proportion of potassium is conserved in the soil through the crop residues in the agricultural fields. Uses of farm yard manure (FYM) also improve the nutrients availability in the soil.

**Table 2:** Chemical characteristics of soil under different land use pattern (values are the means of four seasons across 1 year).

<table>
<thead>
<tr>
<th>Land use pattern</th>
<th>Dept h (cm)</th>
<th>Chemical property</th>
<th>SOM (%)</th>
<th>SOC (%)</th>
<th>CO₂</th>
<th>Ava. P</th>
<th>Ava. K</th>
<th>TKN (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homegarden</td>
<td>0-15</td>
<td>2.41±0.0</td>
<td>1.4±0.03</td>
<td>34.24±2.9</td>
<td>41.98±1.1</td>
<td>145.15±13.2</td>
<td>0.49±0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>2.26±0.0</td>
<td>1.31±0.0</td>
<td>40.32±4.3</td>
<td>38.61±0.5</td>
<td>180.99±38.3</td>
<td>0.49±0.0</td>
<td></td>
</tr>
<tr>
<td>Paddy AES</td>
<td>0-15</td>
<td>1.29±0.0</td>
<td>0.75±0.0</td>
<td>30.24±6.2</td>
<td>16.85±0.1</td>
<td>426.05±38.2</td>
<td>0.42±0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>1.38±0.0</td>
<td>0.8±0.1</td>
<td>31.36±3.7</td>
<td>13.64±0.2</td>
<td>373.63±61.2</td>
<td>0.42±0.0</td>
<td></td>
</tr>
</tbody>
</table>

±SE (n=5)

**4. Ammonification and Nitrification (µg g⁻¹ month⁻¹)**

Ammonification rate varies significantly (p<0.001) between the land use pattern and seasons while depth-wise variation was not found significant. In the Homegarden maximum ammonification rate was recorded during the month of August. Higher rate of nitrification was found during the monsoon months. Paddy AES showed the higher nitrification rate during the month of July and Homegarden in December. Minimum nitrification rates were recorded during the month of September (Paddy AES) and June (Homegarden). However, significant variation was recorded between months and agro-ecosystems (p<0.001). Rate of ammonification was greater than the nitrification in all sites. Similar results were also reported by Tangjang (2005) and Das et al. (1997) from the agro-forestry and subtropical humid forest of north east India. Denitrification in anaerobic conditions might have negative effect on the nitrification which is based on nitrate-N determination. It also might be due to heavy rainfall and increased soil moisture content which leads to development of anaerobic life forms and decrease the rate of oxygen diffusion inside the soil pores.
**Table 3:** Monthly variations in the concentrations of ammonium and nitrate (µg g⁻¹) under selected land use pattern

<table>
<thead>
<tr>
<th>Month</th>
<th>Depth (cm)</th>
<th>Agro-forestry</th>
<th>Paddy AES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NH₄-N</td>
<td>NO₃-N</td>
</tr>
<tr>
<td>Jun.'10</td>
<td>0-15</td>
<td>8.99±1.41</td>
<td>2.80±0.00</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>11.34±1.56</td>
<td>1.75±0.04</td>
</tr>
<tr>
<td>July'10</td>
<td>0-15</td>
<td>9.23±0.47</td>
<td>2.31±0.98</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>9.65±0.26</td>
<td>2.65±0.00</td>
</tr>
<tr>
<td>Aug.'10</td>
<td>0-15</td>
<td>11.34±0.49</td>
<td>7.81±0.12</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>8.77±0.78</td>
<td>4.42±0.31</td>
</tr>
<tr>
<td>Sep.'10</td>
<td>0-15</td>
<td>10.43±1.93</td>
<td>7.65±0.06</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>8.77±2.10</td>
<td>2.83±0.32</td>
</tr>
<tr>
<td>Oct.'10</td>
<td>0-15</td>
<td>11.28±1.00</td>
<td>2.16±0.09</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>12.23±1.16</td>
<td>2.40±0.03</td>
</tr>
<tr>
<td>Nov.'10</td>
<td>0-15</td>
<td>6.57±0.59</td>
<td>2.10±0.15</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>6.46±2.16</td>
<td>2.07±0.01</td>
</tr>
<tr>
<td>Dec.'10</td>
<td>0-15</td>
<td>5.91±0.10</td>
<td>2.31±0.22</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>5.80±3.98</td>
<td>2.31±0.04</td>
</tr>
<tr>
<td>Jan.'11</td>
<td>0-15</td>
<td>11.28±1.27</td>
<td>4.26±0.07</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>11.17±2.36</td>
<td>4.02±0.03</td>
</tr>
<tr>
<td>Feb.'11</td>
<td>0-15</td>
<td>9.30±0.22</td>
<td>1.98±0.26</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>9.19±0.69</td>
<td>2.43±0.38</td>
</tr>
<tr>
<td>Mar.'11</td>
<td>0-15</td>
<td>6.33±0.98</td>
<td>1.86±0.16</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>6.22±0.84</td>
<td>2.16±0.10</td>
</tr>
<tr>
<td>Apr.'11</td>
<td>0-15</td>
<td>5.49±0.99</td>
<td>2.19±0.04</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>5.38±0.90</td>
<td>2.10±0.08</td>
</tr>
<tr>
<td>May'11</td>
<td>0-15</td>
<td>5.94±0.53</td>
<td>2.34±0.07</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>5.83±0.67</td>
<td>2.16±0.14</td>
</tr>
</tbody>
</table>

Variation in inorganic-N pools might be due to three factors, namely variation in mineralization rates, uptake by plants and microbes and losses through soil erosion, leaching, run-off and denitrification (Maithani et al. 1998). During the winter season, inorganic N pool was found to be higher which might be due to lower uptakes of nutrients by the crop plants. Uses of different organic residues to improve the soil fertility and proper decomposition increases the available N pool in the agricultural systems. A huge amount of nitrate concentration may be lost due to plant uptake during the maturation of the crops. Consideration of the mineralization processes will permit reduction or illumination of application during the mature phases of development. Much excess inorganic N is also generated between the harvests and subsequent plantings. Most of the manure N is applied in the organic form and organic N remains in the soil until it is being mineralized. An understanding of temperature effects on mineralization can help to predict the mineralization during the year. Cool weather would be responsible for slow mineralization during the winter period which helps a significant inorganic nitrogen sources during this period of the year. Management practices may consider this by increasing application rates of organic manures during the winter and then reducing them during the summer to meet overall farm nutrient...
management goals. On the annual basis, warmer climates will converge to steady state condition more quickly than cooler climates because organic N half-lives are considerably shorter under warmer conditions.

Leaching and percolation due to heavy rain and soil erosion are also responsible for low concentration of the NO$_3^-$ during rainy season. However, the significance of denitrification which is paramount factors responsible for nitrogen loss during the rainy season cannot be ruled out. Variation in soil types and soil texture led to differences in soil moisture, inorganic N concentrations and net N-mineralization rates. In the present study, mineralization rate is positive correlated with the ammonium, nitrate concentration and soil moisture in the surface soil depth. Climates interact with the soil properties, including soils microflora and affect the size as well as chemical nature of soils organic N pool.

4.1 N-mineralization (µg g$^{-1}$ month$^{-1}$)

N-mineralization showed significant variations between the seasons (p<0.001) in the present study (Table 5). The greater amount of N-mineralization was recorded during the rainy season in both the land use patterns. On the other hand, minimum mineralization rates were found during the spring season (Paddy AES) and rainy season (Homegarden). Mean N-mineralization rates were greater in the Homegarden (5.65 µg g$^{-1}$ month$^{-1}$) followed by Paddy AES (5.02 µg g$^{-1}$ month$^{-1}$) and (Table 4). Ammonification rate is positively correlated with soil pH, SOC, NH$_4$-N and NO$_3$-N. This indicates the overall importance of detrital decomposition and nutrient release on the ground surface that facilitates a greater nutrient flux in the soil. On the other hand, nitrification rate is negatively correlated to ammonium and nitrate concentration which suggests that available nitrogen concentration was not saturated in these agricultural systems.

Higher mineralization might be due to elevated soil temperature and moisture content during this period in the agricultural systems (Cassman and Munns 1980; Eghball 2000). Minimum mineralization rates during the winter period which could be associated with the low decomposition rates because of low microbial activities and greater immobilization of inorganic N resulting in reduced N-mineralization. Mineralization rate may increases during the spring season due to increase in temperature (Katterer et al. 1998; Numan et al. 2000). Based on the literature available and findings of present study it can be concluded that soil temperature and moisture content could have a strong effect on N mineralization reactions. Microbial activities are limited at soil temperature near freezing and increase with rise in soil temperature and maximum N-mineralization occurs when the soil temperature reaches 30-35°C. In dry soils, N-mineralization is low because soil microbial activities are limited due to low water availability. In saturated soils, lack of oxygen limits the N mineralization because only soil microorganisms that can survive under anaerobic conditions are active.

Table 4: Monthly variations in soil N-mineralization (µg g$^{-1}$ month$^{-1}$) under selected land use type

<table>
<thead>
<tr>
<th>Month</th>
<th>Depth (cm)</th>
<th>Homegarden</th>
<th>Paddy AES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Jun.'10</td>
<td>0-15</td>
<td>6.35±3.09</td>
<td>1.42±0.51</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>7.05±3.07</td>
<td>1.61±0.07</td>
</tr>
<tr>
<td>July'10</td>
<td>0-15</td>
<td>6.38±3.19</td>
<td>1.45±0.32</td>
</tr>
</tbody>
</table>
Mineralization tends to be greater in course textured soil, low in clay and lower as the clay content increases in the soil. Fine textured soils with high in clay content are abundant in microspores in which organic matter can find physical protection from microbial decomposition. Soils rich in organic matter tend to have high N-mineralization rates. The interaction of the N-mineralization and immobilization processes is closely connected to the carbon cycle, because decomposing microorganisms derive their energy from carbon compounds they find in soil organic matter carbon and nitrogen compounds in soil organic matter can be placed in two pools: a labile active and stabilized (passive) pool. The labile pool is composed of microbial biomass, particulate organic matter (fine plant residues) and compounds that are readily decomposed by soil microorganisms. The stabilized pool of organic matter is composed primarily of complex stable organic compounds that are resistant to microbial decomposition.

Table 5: Three way ANOVA showing the effects of depth, agro-ecosystem and month on Ammonification, Nitrification and N-mineralization

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ammonification</th>
<th>Nitrification</th>
<th>N-mineralization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>Depth</td>
<td>1</td>
<td>0.041</td>
<td>NS</td>
</tr>
<tr>
<td>Month</td>
<td>11</td>
<td>25.18</td>
<td>0.000</td>
</tr>
<tr>
<td>LUP</td>
<td>7</td>
<td>77.52</td>
<td>0.000</td>
</tr>
<tr>
<td>Depth X Month</td>
<td>11</td>
<td>2.571</td>
<td>0.005</td>
</tr>
</tbody>
</table>
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International Journal of Environmental Sciences Volume5 No.1, 2014

| Depth X LUP | 7 | 5.514 | 0.001 | 7 | 4.411 | 0.001 | 1 | 0.660
---|---|---|---|---|---|---|---|---
| Month X LUP | 77 | 8.197 | 0.001 | 7 | 10.10 | 0.000 | 7 | 2.775
| Depth X Month X LUP | 77 | 2.597 | 0.001 | 7 | 4.250 | 0.001 | 7 | 0.646

df- degree of freedom, P- significant level, LUP-land use pattern, SOC-Soil organic carbon, TKN-total kjedhal nitrogen, NS-not significant.

5. References


