ISSN 2250-3153

Effect of Traditional Fire on N-Mineralization in the Oak Forest Stand of Manipur, North East India.

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Abstract- The effect of traditional fire on available soil nitrogen and rate of N-mineralization in the oak forest soil of Lambui hill, Ukhrul district, Manipur, North East India have been studied. The rate of ammonification, nitrification and mineralization varied from 0.08 to 5.99 µg $g^{-1}month^{-1}$, 0.40 to 2.52µg $g^{-1}month^{-1}$ and 0.46 to 9.09µg $g^{-1}month^{-1}$of soil in the traditional burnt site, 0.31 to 3.93µg g^{-1} $month^{-1}$, 0.14 to 2.52µg $g^{-1}month^{-1}$ and 0.48 to 5.67µg $g^{-1}month^{-1}$ of soil in the unburnt site and 0.19 to 4.00µg $g^{-1}month^{-1}$, -0.09 to 2.17µg $g^{-1}month^{-1}$ and 0.33 to 5.61µg $g^{-1}month^{-1}$ of soil in the control site respectively for different months throughout the year. The rate of ammonification, nitrification and mineralization were found to be higher in the traditional burnt site followed by unburnt and control forest site which may be due to the increase of decomposable organic matter and increase of soil temperature during the operation of traditional fire treatment. Significant positive correlation was observed in ammonification and mineralization rate with soil moisture, soil temperature and organic carbon. The variation on the rate of N mineralization was explain R=0.98, R^2=0.96, F=96.20 ($P<0.05$) by the linear regression model of soil temperature.

Index Terms- Traditional Fire, oak forest stand, Temperature, Ammonification, N-mineralization

I. Introduction

Mineralization of organic soil N is fundamentally linked with forest productivity, and attention has shifting from static measures of N availability to dynamic measures of N release (Keeney, 1980). Rates of mineralization are influenced by various environmental factors (Morecroft et al., 1992). It often differs with forest type, elevation, and topographic position (Garten and Van Migroet, 1994; Power, 1900). Knowledge of soil N dynamics is critical to understand how forest management practice may affect long-term soil productivity substrate quality, quantity, environmental conditions and soil micro-organisms control soil dynamics (Stanford and Smith, 1972; Goncalves and Carlyle, 1994). Harvesting and site preparation activities may change soil structure, environmental conditions, substrate availability, and ultimately nitrogen dynamics in various forest ecosystems. In Manipur the subtropical and temperate oak forest stands has been fastly replaced by scrub forest due to various pressures such as felling of timber, fuel wood and slash and burning for shifting cultivation. Fire becomes a very important ecological tool why it shaping vegetation structure of these forest ecosystems. Fire can be a great value in the management of forest ecosystem and uncontrolled condition it can destroy independent of its composition, age, density and diversity (Bessie and Johnson,1995).

There is a growing need for better understanding the effect of fire on nutrient availability particularly N-biochemical processes in forest soils. The soil nutrient dynamics are highly sensitive to environment change and therefore, can provide important information about early ecosystem response to management activities (Diaz-Rovina et al., 1996; Trasar-Cepeda et al., 1998). The increase in nitrification and mineralization after fire of the various ecosystems of the world has been reported by several workers (Adams and Atwill, 1986; Singh et al., 1991 and Yadava and Devi, 2005). The objective of the present study was to analyze monthly and seasonal variation in the rate of ammonification, nitrification and mineralization and their relationship with different treatment i.e. burnt, unburnt and control sites. We also emphasized to predict the best explanatory variable among the interested covariates by using linear regression analysis in unburnt and burnt sites.

II. Materials and Methods

The Lambui hills of Ukhrul district Manipur, north east India was the study site which falls at $25^0$01' N Latitude and $94^0$02' E Longitude at the distance of 65 km from Imphal city at an altitude of 1470 m from mean sea level. It was located at the transition between sub-tropical and temperate region and were dominated by five oak tree species such as *Lithocarpus dealbata*, *Lithocarpus fenestrata*, *Quercus griffithii*, *Quercus serrata* and *Castanopsis tribuloides*. The climate of the area is monsoonic with warm moist summer and cool dry winter. The mean maximum temperature varies from 16.49^0 C (January) to 33.30^0 C (August) and mean minimum temperature from 3.52^0 C (January) to 20.16^0 C (August) with average annual rainfall of 1258.9 mm.

III. Soil analysis

The soil samples were collected at monthly intervals from the three forest sites for measurement of Inorganic-N, rate of ammonification, nitrification and N-mineralization. The soil organic carbon was also estimated by Warkly-Black Partial oxidation method. The soil temperature was measured by clinical thermometer and soil moisture by the soil moisture meter. The nitrogen mineralization *in situ* was conducted at monthly intervals by using buried bag techniques (Eno, 1960). The soil samples were collected randomly from 0-10cm in the study sites by using steel cover (6.5 cm diameter). Each soil sample was divided into two parts and the first part of the soil samples were sealed in sterilized polyethylene bags after removing coarse stones, roots and large recognizable organic debris and later on incubated at the same depth. After one month, the buried bags were retrieved and analyzed for final ammonium and nitrate concentration. The second part of the soil sample was brought to the laboratory for the measurement of initial Inorganic-N (NH_3-N and NO_3-N). Each sample was sieved (2 mm) to remove stone, coarse, roots and other recognizable plant debris. The initial ammonium and nitrate concentration was determined within 24 hours following standard procedure (Anderson and Ingram, 1993). Soil were extracted for N-analysis by shacking 10g of soil in 50ml of 2M KCl for 30 min and filtered with Whitman 42 filter paper, Buchner funnel and a vacuum manifold. The extracts were analyzed for colorimetric determination of (NH_4-N and NO_3-N) in Spectrophotometer. The changes in ammonium and nitrate concentration were obtained by subtracting the initial concentration from the corresponding final concentration and the resultant values are referred to as ammonification and nitrification rates. The net N-mineralization rate was calculated by the changes in extractable ammonium-N and nitrate-N over one month.

IV. Data Analysis

Data were analyzed using split-site experimental design with monthly representing sites. The mean values of monthly, seasonal nitrate, ammonia, Inorganic-N, ammonification, nitrification and N-mineralization in soil depth (0-10cm) were analyzed with ANOVA. The mean values for initial ammonia and nitrate of 0-10cm depth are compared with ANOVA. The correlation analysis of soil moisture, temperature and organic carbon with ammonification, nitrification and N-mineralization were studied for three sites. The complexity of N-mineralization rate in the present study is influenced by different covariates such as soil moisture, temperature, organic carbon, site quality etc. which gives the different nature and dynamics of N-mineralization. A colinearity diagnostic was develop to understand the problem of multicolinearity among the independent variable for a suitable model development. A linear regression model was developed to understand the variability of the rate of N mineralization after examining the scatter plot. The plot was appear to be suitable for regression because the rate of mineralization is increased with the increase of soil temperature. A binary dummy variable (0 and 1) is adopted to quantify the site quality. The statistical treatment of the study is performed through SPSS V.11.

V. Result and discussion

Initial NH_3-N, NO_3-N and Inorganic-N

The initial concentration of NH_3-N, NO_3-N and Inorganic-N in the unburnt, burnt and control site exhibited highest in winter months (January, February) and lowest in (July). Monthly trends was significant ($P<0.05$) except May (Fig. 1, 2 and 3). Seasonally the higher concentration was observed in winter season followed by summer and rainy season in all the three study sites (Tab.1). The annual NH_3-N, NO_3-N and Inorganic-N were higher in the burnt site than unburnt and control site. The annual NO_3-N was found higher in the control site and lowest in the unburnt site (Tab. 1).The F-Values (ANOVA) of annual initial NH_3-N, NO_3-N and Inorganic-N of three seasons showed significant $P<0.001$ (unburnt and burnt; burnt and control) and $P<0.05$ for NO_3-N, $P<0.01$ for NH_3-Nand Inorganic-N (unburnt and control) (Tab. 2).

Ammonification

The monthly variation in the rate of ammonification in the unburnt, burnt and control site were found highest in the month of (July) and lowest in winter months (December, January). The rate of ammonification was found high in the rainy season (except control site) followed by summer and winter season in all the sites. The annual rate of ammonification was higher in burnt sites followed by unburnt and control site (Tab. 3). The F-value (ANOVA) of annual ammonification rate showed significant $P<0.01$ (unburnt and burnt) and $P<0.01$(control and unburnt) (Tab. 4). Annual ammonification rate of three forest site showed signification correlation with soil moisture r=0.933 ($P<0.01$), soil temperature r=0.982 ($P<0.01$), soil organic carbon r=0.916 ($P<0.01$) (Tab. 5).

Nitrification

The rate of nitrification was found highest in rainy months (June, July) and found lowest in winter months (November, December) in all the sites. The monthly trends were found fluctuation (Fig. 5). In all the three study sites the higher rate of nitrification was observed in the rainy season followed by summer and winter season. The annual nitrification rate was higher in the burnt site followed by unburnt and control sites (Tab. 2). The F-value (ANOVA) of annual nitrification rate showed significant $P<0.01$(control and burnt) (Tab. 4).

N-Mineralization

The monthly rate of N- mineralization was found fluctuation with lower in (December, January) and higher in (June, July) of unburnt and burnt; (April and May) for control site (Fig. 6). In the unburnt and control sites the highest rate was exhibited in the summer months followed by rainy and winter months. In the burnt site the higher rate of N-mineralization was found in rainy season and lowest in the winter season. Its annual rates were also found maximum in the burnt than followed by unburnt and control sites (Tab. 2). The F-Value (ANOVA) of annual N-mineralization showed significant $P<0.01$(unburnt and burnt) and $P<0.001$ (unburnt and control) (Tab. 4). The N-mineralization rate showed significant correlation with soil moisture r=0.951 ($P<0.01$), soil temperature r=0.980 ($P<0.01$) and organic carbon r=0.951 ($P<0.01$) (Table 5).

Linear regression colinearity diagnostics in shows that second dimension i.e. soil temperature have Eigenvalue (0 >0.38) and Condition Index (3.46<15) indicates there is no problem of multicolinearity (Tab.6). The remaining three covariates viz. organic C, moisture and site quality exhibited Condition Index (>30) was excluded with large problem of multicolinearity. The linear regression analysis model explain R=98% (R^2=0.96) variation in the rate of N-mineralization with F=96.20, ($P<0.05$).

Mineralization rate = 0.38 x Temp. (^{0}C) – 4.19

It is significant at t=9.8 ($P<0.05$). If the temperature is at 22^{0}C the predicted rate of N-mineralization would be 4.19□ □ □ g g^{-1} $month^{-1}$).The P-P plotted residuals of the model follow the 45^0

line (Fig. 7). The plot indicates that the normality assumption is not violated. The linear regression model analysis for the SE shows lower error (SE = 0.16) (Tab. 7).

The concentration of initial NH_3-N, NO_3-N and Inorganic-N was found higher in the winter season followed by the summer season and lower in the rainy season in the unburnt, burnt and control sites. The wide variations in the values of Inorganic-N could be due to variation of mineralization rates, uptake by plants and microbes and losses through soil erosion, leaching, runoff and denitrification. The lower NH_3-N, NO_3-N and Inorganic-N in the rainy season may be due to greater demand for these nutrients by plants which grow vigorously during this time. The losses of Inorganic-N through leaching and denitrification during the rainy season can also be another factor. The higher value of Inorganic-N in the winter season may also be associated with the low demand by plants during the dormant period. In the tropical and subtropical forest of north east India also reported similar trend (Maithani et al., 1998; Yadava and Devi, 2005).

The annual Inorganic-N content of control, unburnt and burnt forest sites was significantly higher in burnt sites. This may be due to organic matter input by fire and the lower nitrogen uptake by plants. In all the three study sites the value of NH_3-N was found to be higher than NO_3-N, this may be due to the acidic nature of soil. In the acidic nature of soil only a few autotrophic nitrifying microorganisms can grow well in the acidic soil. The rate of nitrification in the oak forest of Missouri Ozarks is regulated indirectly by NH_3-N, availability (Donalson and Henderson, 1990).

The significant variation in the rate of ammonification, nitrification and N-mineralization were recorded in the three study site. In the three study sites the rate of ammonification, nitrification and N-mineralization were higher in the rainy season, this may be due to higher activities of the soil microorganisms. The activities of microorganisms were enhanced leading to higher decomposition of organic matters with the onset of rains. It was evident by the correlation and covariance analysis which showed significant relation with soil moisture, soil temperature and organic carbon. A similar correlation was also reported in the Western Juniper forest, Boreal Aspen forest (Subarctic Alaska Forest Bates et al., 2002, Carmosini et al., 2003 and Grunzwig et al., 2003). The higher rate of ammonification, nitrification and N-mineralization during the rainy season was reported in the mixed oak forest (Knoeep and Swank, 1998). However, the lower rate of ammonification, nitrification and N-mineralization were found during the winter season in all the three study sites which may be due to the cold and dry period as the soil moisture were very low in this season thereby harming microbial activity. Same trend have been reported by (Gonclaves and Carlyle, 1994; Leiros et al., 1999; Singh et al., 1991; Morecroft et al., 1992; Clein and Schimel, 1995; Maithani et al., 1998). A similar result has also been reported in the subtropical Dipterocarpus Forest of Manipur North East India (Yadava and Devi, 2005).

The annual N-mineralization in all the three sites was significantly higher in the burnt forest site followed by unburnt and control site. The higher rate of N- mineralization in the burnt site may be due to the larger input of decomposable substrate (Singh et al., 1991). Some workers have also reported increase of nitrification and N-mineralization after fire (Knoepp and Swank, 1995; Deluca et al., 2005).

The rate of ammonification, nitrification and N-mineralization in the present oak forest stand may have relationship with decomposition rate. As the decomposition rate can be analyzed by the substrate quality and also prevailing environmental condition like soil moisture, soil temperature, organic carbon etc. In the present study the primary information of substrate quality is not available. However there is significant correlation between ammonification, N-mineralization with soil moisture, soil temperature and organic carbon in both the study sites (Singh et al., 1991; Morecroft et al., 1992; Clein and Schimel, 1995; Maithani et al., 1998; Leiros et al., 1999).

The higher N-mineralization rates in the summer and rainy months when the moisture and temperature were highest in unburnt and burnt site. It is obvious that in the soil with greater N-mineralization potential, may detect seasonal patterns when seasonal appropriate moisture and temperature conditions are exhibited (Zhou et al., 2009). Among the four interested covariates only soil temperature explain the variation in the rate of N-mineralization R=98% (R^2=0.96) with the observed and model prediction in the present study. The interested covariates viz. soil moisture, organic carbon, site quality does not explain due to high correlation among them. Studies in the temperate regions of the world it is found that the rates are greatest when soil temperature were high, in summer (Virzo De Santo et al., 1982; Nadelhoffer et al., 1989; Son and Lee, 1997; Knoeep and Swank, 1998). The increased of microbial efficiency with the increase of soil temperature from to decompose organic matter (15^0C to 25□C) (Steinweg et al., 2008 and Karhu et al., 2010). The lower rate of N-mineralization in winter season may be due to limiting moisture and temperature in the winter. In the tropical forest soils temperature were not limiting whereas soil moisture fluctuations between wet and dry seasons largely regulate N-mineralization rates (Wong and Nortcliff, 1995). The present study site is transition between temperate and the subtropical forest ecosystem therefore, it is true that temperature is one of the best limiting factors to explain the rate of N-mineralization in study sites.

Table-1:Seasonal variation in concentration of NH_3-N, NO_3-N and Inorganic-N mean+SE (µg g^{-1}). in control, unburnt and burnt site

Season	Control site			Unburnt site			Burnt site		
	NH_3-N	NO_3-N	Inorganic N	NH_3-N	NO_3-N	Inorganic N	NH_3-N	NO_3-N	Inorganic N
Summer	5.71±0.04	3.60±0.03	9.31±0.07	4.93±0.10	2.90±0.05	7.12±0.15	6.30±0.14	3.52±0.10	9.31±0.25
Rainy	2.65±0.04	2.64±0.04	6.12±0.06	2.20±0.08	1.70±0.04	4.95±0.15	4.77±0.27	3.33±0.18	7.58±0.31
Winter	9.10±0.03	7.40±0.03	12.16±0.07	8.42±0.08	3.26±0.08	11.68±0.16	11.80±0.30	4.60±0.09	16.41±0.39
Annual	5.82±0.02	4.55±0.02	6.89±0.03	5.18±0.08	2.62±0.06	7.92±0.14	7.62±0.24	3.82±0.12	11.10±0.32

N= 3, (µg g^{-1}).

Table-2:The F- Values (ANOVA) of NH_4-N, NO_3-N and Inorganic-N of three seasons.

Compara -tive sites	NH_4-N				NO_3-N				Inorganic N			
	Summer	Rainy	Winter	Annual	Summer	Rainy	Winter	Annual	Summer	Rainy	Winter	Annual
Unburnt Burnt	183.21***	258.30***	345.73***	278.50***	101.93**	246.84***	934.84***	251.32***	166.29***	187.62***	377.06***	250.08***
Control Unburnt	85.74**	9.29*	28.52**	37.46**	14.77*	47.71**	3.56	13.33*	51.25**	19.46*	13.15*	25.97**
Control Burnt	329.73***	338.98***	146.87***	260.08***	5.10	338.98***	76.18**	142.96***	169.02***	342.95***	220.57***	65.14***

N= 3, (µg g^{-1} $month^{-1}$); '*'; '**'; '***'; F- value with it is significantly different ($P<0.05$), ($P<0.01$) and ($P<0.001$) respectively.

Table-3: Seasonal variations in concentration of ammonification, nitrification and N-mineralization mean+ SE (g g^{-1} $month^{-1}$). in control, unburnt and burnt site

Season	Control site			Unburnt site			Burnt site		
	Ammonification	Nitrification	Mineralization	Ammonification	Nitrification	Mineralization	Ammonification	Nitrification	Mineralization
Summer	3.36±0.01	1.12±0.00	4.03±0.02	2.35±0.03	1.19±0.20	4.03±0.02	3.95±0.29	1.02±0.08	4.98±0.37
Rainy	1.90±0.02	1.49±0.01	3.22±0.04	3.24±0.09	1.66±0.17	3.22±0.04	5.50±0.34	2.14±0.01	7.99±0.01
Winter	0.73±0.01	0.25±0.02	0.84±0.18	0.84±0.01	0.22±0.00	0.84±0.17	0.52±0.48	0.31±0.01	0.71±0.59
Annual	1.02±0.01	0.95±0.00	2.69±0.04	2.12±0.44	1.02±0.12	2.70±0.04	3.29±0.41	1.16±0.03	4.56±0.32

N= 3, (µg g^{-1} $month^{-1}$).

Table-4: The F-Values (ANOVA) of Ammonification, Nitrification and N-mineralization of three seasons.

Comparative sites	Ammonification				Nitrification				N-mineralization			
	Summer	Rainy	Winter	Annual	Summer	Rainy	Winter	Annual	Summer	Rainy	Winter	Annual
Unburnt Burnt	93.70**	123.92***	1.28	24.47**	1.66	23.68**	433.20***	3.60	38.47**	415.69***	0.55	36.97**
Control Unburnt	18.84*	5.34	240.10***	30.99**	0.39	3.05	10.99	1.00	24.94**	366.68***	1.66	80.07**

Control Burnt	24.66**	7.66*	0.62**	0.82	3.58	135.12***	249.64***	873.61***	0.09	1903.37***	0.40	17.01

N= 3, (µg g^{-1} $month^{-1}$); '*'; '**'; '***'; F-value with it is significantly different (P<0.005), (P<0.01) and (P<0.001) respectively.

Table 5: Pearson's correlation analysis between ammonification, nitrification, mineralization, soil moisture, soil temperature and soil organic carbon in the three study sites.

	AA	AN	AM	ASN	AST	AOC
Annual Ammonification	1					
Annual Nitrification	.673	1				
Annual Mineralization	.986**	.777	1			
Annual Soil Moisture	.933**	.671	.951**	1		
Annual Soil Temperature	.982**	.662	.980**	.980**	1	
Annual Soil Organic Carbon	.916*	.740	.951**	.989**	.965**	1

'*'; '**' Correlation is significant at the 0.05, 0.01 level (2-tailed); N= 6.

Table 6: Colinearity diagnostics for the four interested covariates in a five dimensional model study.

Model	Dimension	Eigen value	Condition Index
1	1	4.615	1.000
	2	.385	3.464
	3	2.863E-04	126.955
	4	1.087E-04	206.056
	5	2.825E-06	1278.137

a. Dependent Variable: Annual Mineralization

Table 7: A linear regression model to the prediction of rate of N mineralization by using soil temperature.

Dependent variable	**Independent variable**
Annual N mineralization	Annual mean Temperature (^{0}C)
	R=0.98 R^2=0.96 Std. Error=0.16 Regression row=Sum Sq. 2.341, df 1, Mean Sq. 2.34 Residual row= Sum Sq. 0.09, df 4, Mean Sq. 0.24 F=96.20*. Constant coefficient= - 4.19 Temperature coefficient=0.381 t=9.8*

* Significant level at P<0.05

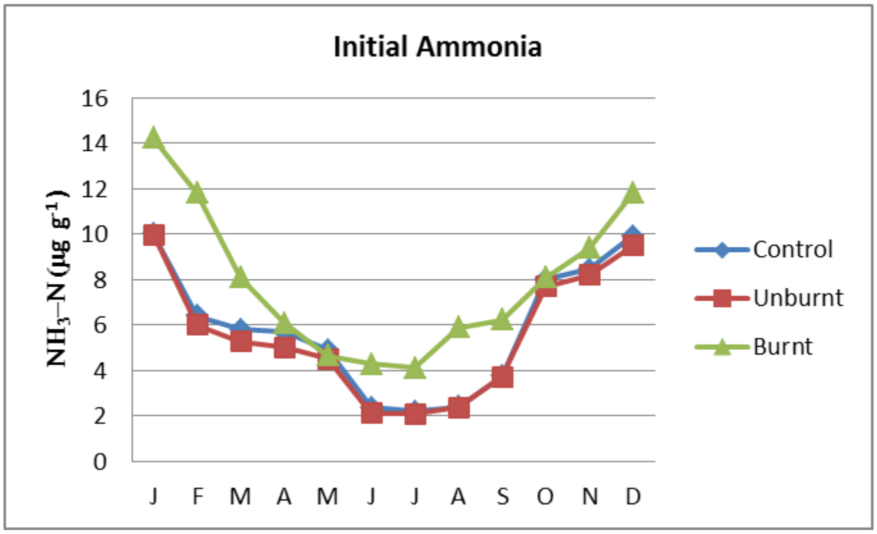

Figure 1: Monthly trends of initial concentration of NH_3-N (□ g g^{-1}) in the burnt, unburnt and control forest sites.

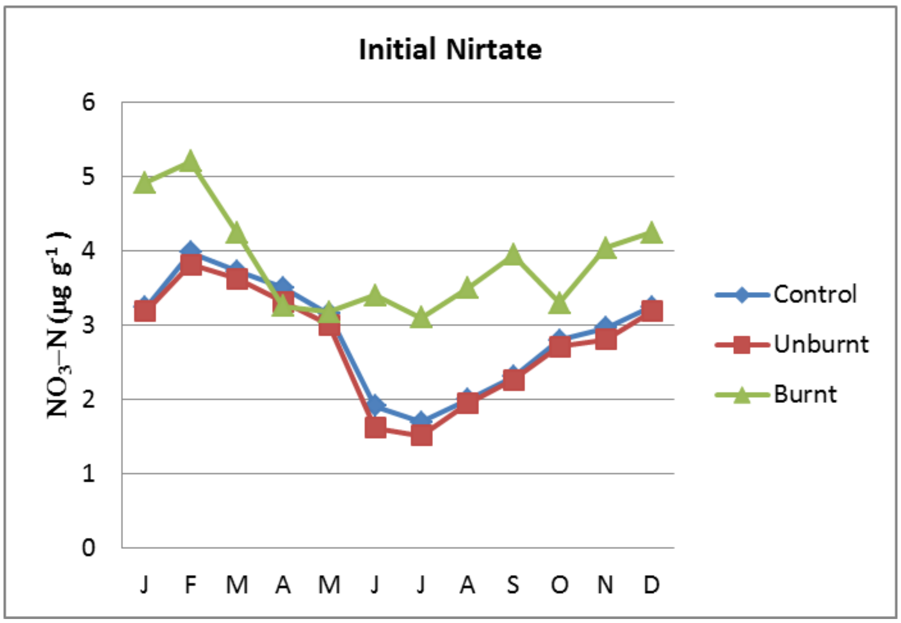

Figure 2: Monthly trends of the initial concentration of NO_3-N (µg g^{-1}) in the control, unburnt and burn forest sites.

ISSN 2250-3153

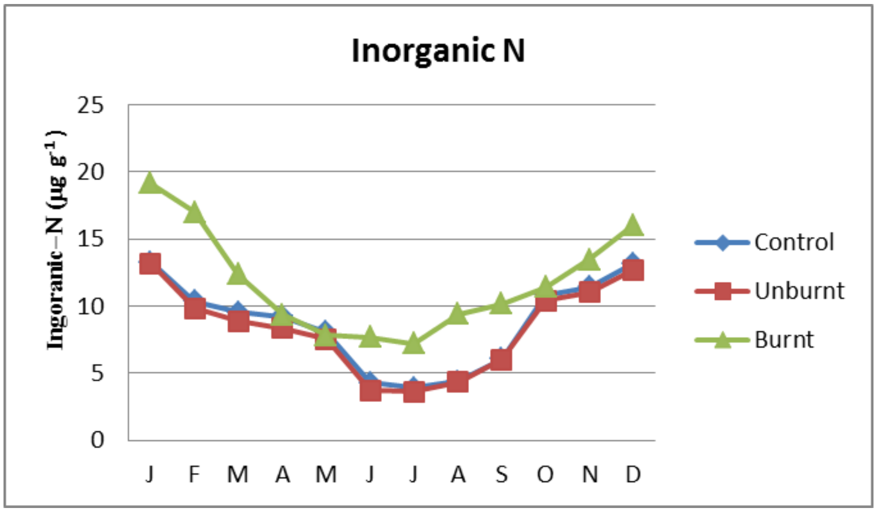

Figure 3: Monthly trends of inorganic-N concentration µg g^{-1}) in the unburnt, burnt and control forest sites throughout the year.

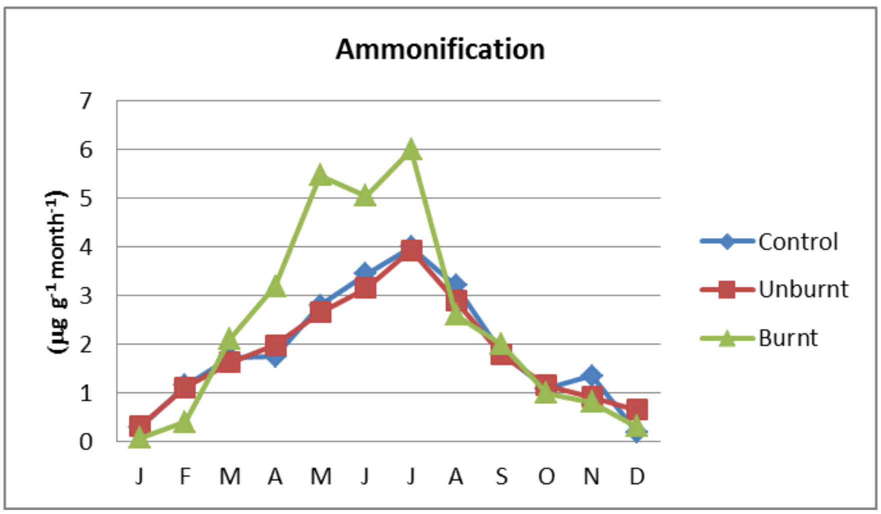

Figure 4: Monthly rate of ammonification □ □ □ g^{-1}g month^{-1}) in the unburnt, burnt and control forest sites throughout the year.

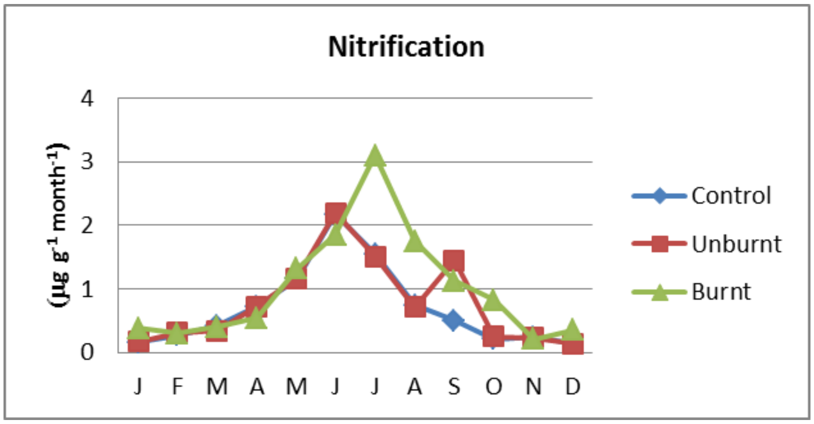

Figure 5:Monthly rate of nitrification □ □ □ g g^{-1} month^{-1}) in the three oak forests sites throughout the year.

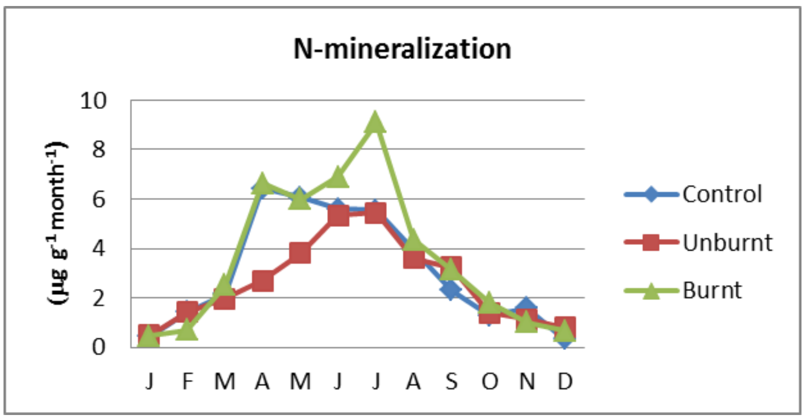

Figure 6: Monthly rate of N-mineralization μg g^{-1} month^{-1}) in the three oak forest sites throughout the year.

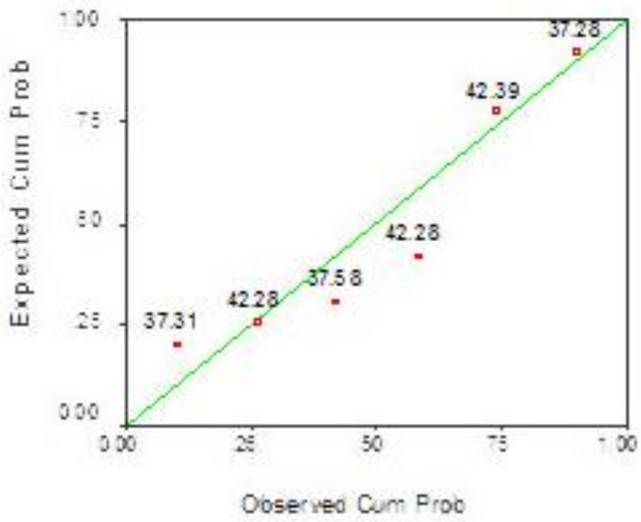

Figure 7: Relationship between N-mineralization rates predicted from field soil temperature data and in situ N-mineralization measurements (0-10 cm).

I. CONCLUSION

It is confirmed that climate changes had significant effect on the rate of N-mineralization in the subtropical temperate oak forest of Manipur. From the comparative study of the three sites, it is obvious burnt site have more N dynamics than unburnt and control site. A slit increase of soil temperature in the burnt site by the traditional fire treatment took major critical role on the rate of N-mineralization. Among the interested covariates, soil temperature of unburnt and burnt site can also predict the rate of N-mineralization. The realization of the ecological limiting factor could lead to the better management concept.

ACKNOWLEDGEMENT

We are thankful to University Grants Commission, New Delhi for financial assistance and grateful to the Head Department of Botany (P.G.) D.M. College of Science, Imphal, Manipur for providing all necessary facilities.

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