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Measurement of N-mineralization, Nitrification and Ammonification Rates in Agricultural Soils of Arunachal Pradesh, North East India

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Abstract: *This study was conducted with an aim to analyze the N-mineralization, nitrification and ammonification rates under three prominent agro-ecosystems viz., Maize, Forest garden and Soybean agro-ecosystem of East Siang district, Arunachal Pradesh. Study was conducted during the year 2011-12 following standard methodology. Soil samples were collected on monthly basis from 8-10 places of every selected system from two depths (0-15 cm and 15-30 cm) in replicates. NH_4-N showed its maximum values during the autumn and winter period and minimum values during the spring season (Soybean AES) and spring season (Forest garden and Maize AES). Soybean AES recorded the higher nitrate-N whether minimum in Forest garden. Extractable NH_4^+-N was higher than the extractable NO_3^-N in all the agro-ecosystems. Significant variations in ammonification and nitrification were found in different agro-ecosystems and seasons as well. Ammonification was found to be higher than the nitrification rate in all the agro-ecosystems. In most of the agro-ecosystem, higher mineralization was recorded during the rainy season and minimum during the winter period. The rate of mineralization largely depends on nitrogen and other nutrients content of residues which comes through the decomposition processes of organic materials with the help of soil microbes, and regulates the nutrient budget in soil.*

Keywords: *Immobilization, Inorganic nitrogen, Microbial activities, Plant uptake.*

1. Introduction

A very small part of nitrogen present in the environment is readily available for plant uptake; however, through the activities of soil microorganism the organic nitrogen present in soil organic matter is converted into plant useable form (inorganic form of nitrogen) [1]. Ammonium (NH_4^+), produced through heterotrophic mineralization may either consumed by the plants through several bio-chemical processes such as plant uptake, nitrification, immobilization and volatilization or further oxidized to form nitrate (NO_3^-). Therefore, nitrogen mineralization has a crucial importance in ecosystems where nitrogen (N) has been reported to be a limiting nutrient for plant growth. Soil mineralization is influenced by biomass inputs, microbial activities, and different abiotic factors such as microclimatic variations and agricultural practices. 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 [2]. However, mineralization rate ensures the soil organic matter concentration 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. The primary objective of this study was to determine the N-mineralization (in situ) dynamics, nitrification and ammonification rates under different agro-ecosystems in Arunachal Pradesh.

2. Materials and Methods

2.1. Study Site

East Siang district, Arunachal Pradesh is between $27^{0}30'$ to $29^{0}20'$ North latitude and $94^{0}42'$ to $95^{0}35'$ East longitude and forms a part of Eastern Himalaya where the present study was conducted. The topography of the district is variable and the elevation ranges from 130 to 752 m asl. The climatic conditions in the district vary from place to place due to mountainous nature of the terrain. It is hot and humid at the lower altitudes and in the valleys wrapped by marshy thick frost, while it becomes colder in the higher altitudes. The rainfall of the district is 618.7 mm in Jan-May and 2334 mm in June-July [3]. The study was conducted for an annual cycle (June, 2011 to May, 2012) in four major agro-ecosystems widespread in the district viz., Maize AES, Forest garden and Soybean AES.

2.2. Soil Sampling

The study was conducted for an annual cycle during the June 2010 to May 2011. Soil samples were collected (using a steel corer, 5 cm inner diameter) monthly basis from the five places of the respective study sites at approximately 100 m intervals at each site from two depths (0-15cm and 15-30cm). The soil samples were stored in air-tight metal container and transported to laboratory within 24 hours of collection. Field moist soil was sieved (<2mm) and used for analysis of mineral-N ($NH4^+$ -N and NO_3^--N and N-mineralization and nitrification. A subsample of each soil was air dried, grinded and sieved (<150mm) prior to the samples used for further physico-chemical analysis.

2.3. Laboratory Analysis

Soil texture was determined by Boyoucous hydrometric method given by Allen et al. (1974) [4]. Water holding capacity, porosity, total nitrogen, available phosphorus, available potassium, Ca and Mg were determined following the method outlined by Allen et al. (1974) [4]. Bulk density, soil moisture content, soil pH, correlation with clay (r=-0.80) was observed in the present study, which indicates that higher BD may be due to low clay and high sand content. Different levels of erosion of soil depending upon the slope and management practices also responsible for higher bulk density [12]. Bulk density increases with increase in soil depth in Forest garden, which might be due to greater

ammonium-N and nitrate-N were determined by method as outlined by Anderson and Ingram (1993) [5]. SOC was determined by rapid titration method [6]. In-situ N-mineralization was determined using buried-bag technique [7]. 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.

2.4. Statistical Analysis

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) [8] to study the relationship between soil characteristics and microbial biomass.

3. Results and Discussion

3.1. Soil Characteristics of the Study Sites

The soil textures were sandy loam and sandy clay loam in nature among the sites (Table 1). Variation in soil physico-chemical properties in different fields might be due to dynamic interactions among environmental factors such as climate, parent material, topography and land cover/land use [9].

Land use patterns as well as agricultural management have a significant impact on soil characteristics such as SMC, BD and texture which consecutively reflect the soil fertility status of a given area [10, 11].

Higher concentration of sand might be due to the effect of a nearby stream and land filling by the relatively coarser materials. A positive correlation between clay content and porosity has been found in the present study ($P<0.05$). Positive correlation with sand (r=0.66) and significant negative

compaction that might have occurred in the lower horizons of the soil profiles with time. Soil porosity and pore size distribution were negatively affected by the intensity of land use. Maximum soil porosity might be due to minimum tillage or other cultivation practices in that soil. However, decline in porosity leads to reduce pore size distribution which has an impact on productive capacity of the agricultural soil. WHC decreases with soil depth which might be due to high amount of organic carbon and clay in the surface than sub-surface soils, which promote formation of aggregates and retention of water [13]. Different compositions of organic manures were used to maintain the soil fertility and these compositions may have influence on increase in soil pH. Uses of different chemical fertilizers such as urea minimize the soil pH. Low soil pH might be also due to the penetration and percolation of surface material to the subsurface soil depths due to heavy rain during the monsoon season. Variation in SOC under different agro-ecosystems may be due to the differences in plant species composition and the soil fertility management [14]. Continuous cultivation processes and tillage could be other responsible factor for low SOC. Maximum value of SOC was recorded in the Maize AES which is due to the uses of different manures, compost by the local 'Adi' tribe. Accumulation of human and other wastes also enhances the

Table 1. *Soil Characteristics of Different Agro-ecosystems (values are the mean of 1 year)*

Properties	Depth (cm)	Agro-ecosystem		
		Maize AES	**Forest garden**	**Soybean AES**
Soil moisture (%)	0-15	23.48±0.08	24.7±1.02	26.4±1.12
	15-30	22.08±1.83	25.15±0.82	25.34±1.08
Sand (%)	0-15	74.60±0.87	71.8±0.43	73.8±0.80
	15-30	75.20±0.19	72.2±0.55	74.2±0.32
Clay (%)	0-15	24.20±0.13	25.7±0.22	24.1±0.27
	15-30	23.98±0.07	25.3±0.2	23.4±0.13
Silt (%)	0-15	1.20±0.1	2.5±0.03	2.1±0.11
	15-30	0.82±0.03	2.3±0.3	2.4±0.12
Textural Class		Sandy loam	Sandy clay loam	Sandy loam
Water holding capacity (%)	0-15	74.44±3.93	77.26±6.86	66.06±2.73
	15-30	73.25±7.19	72.5±1.19	65.12±9.91
Bulk density (g cm^3)	0-15	0.96±0.10	0.72±0.09	1.05±0.03
	15-30	0.88±0.11	0.8±0.04	0.96±0.02
Porosity (%)	0-15	63.00±0.85	72.3±1.10	60.23±0.44
	15-30	66.16±0.78	69.23±1.26	63.54±0.36
Soil Organic Carbon (%)	0-15	2.50±0.02	2.10±0.03	1.40±0.03
	15-30	1.40±0.04	1.78±0.02	1.31±0.01
Available P (µg g^{-1})	0-15	8.58±0.67	4.86±0.20	41.98±1.11
	15-30	7.98±0.53	4.21±0.16	38.61±0.56
Available K (kg ha^{-1})	0-15	1023.68±143.2	268.35±29.18	145.15±13.29
	15-30	426.05±68.23	267.9±49.29	180.99±38.37
Total nitrogen (%)	0-15	0.55±0.12	0.70±0.02	0.49±0.03
	15-30	0.54±0.03	0.71±0.01	0.49±0.06
pH	0-15	4.90±0.03	5.24±0.07	6.1±0.7
	15-30	5.10±0.06	5.30±0.05	6.18±0.6
Ca (C mol kg^{-1})	0-15	2.33±0.39	2.32±0.35	2.32±0.35
	15-30	2.21±0.33	2.11±0.31	2.11±0.31
Mg (C mol kg^{-1})	0-15	1.12±0.03	0.93±0.02	0.93±0.02
	15-30	1.15±0.02	0.9±0.01	0.90±0.01

± SE (n=5), AES-Agro-ecosystem

SOM. 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.

3.2. Ammonium-N (NH4) and Nitrate-N (NO3)

NH_4-N showed its maximum values during the autumn and winter period and minimum values during the spring season (Soybean AES) and spring season (Forest garden and Maize AES). However, depth wise variation in its concentration was not recorded across the agro-ecosystems. The maximum nitrate-N was found in the Agro Soybean AES and minimum in Forest garden. Extractable NH_4^+-N was higher than the extractable NO_3^-N in all the agro-ecosystems. Inorganic-N pools varies widely in different agro-ecosystems and seasons, which might be due

Table2. *Monthly Variations in the Concentrations of Ammonium and Nitrate (µg g^{-1}) Under Selected Land Use Pattern*

Month	Depth (cm)	Maize AES		Soybean AES		Forest garden	
		NH_4–N	NO_3–N	NH_4–N	NO_3–N	NH_4–N	NO_3–N
Jun	0-15	6.22±1.20	2.88±0.03	8.99±1.41	2.80±0.00	7.74±1.07	2.90±0.04
	15-30	9.52±1.61	2.80±0.35	11.34±1.56	1.75±0.04	5.88±2.70	2.67±0.17
July	0-15	5.65±1.18	2.34±0.01	9.23±0.47	2.31±0.98	11.74±3.19	2.34±0.01
	15-30	9.30±0.96	2.40±0.15	9.65±0.26	2.65±0.00	6.92±1.51	4.15±0.08
Aug	0-15	7.45±1.24	2.11±0.01	11.34±0.49	7.84±0.12	14.77±5.50	2.4±0.05
	15-30	10.72±0.90	4.10±0.05	8.77±0.78	4.42±0.31	4.21±4.65	3.85±1.22
Sep	0-15	6.74±1.03	2.88±0.11	10.43±1.93	7.65±0.06	13.11±3.75	2.81±0.02
	15-30	10.02±2.27	3.90±0.35	8.77±2.10	2.83±0.32	5.39±2.26	4.21±0.33
Oct	0-15	6.33±0.61	2.79±0.05	11.28±1.00	2.16±0.09	12.66±0.73	3.06±0.09
	15-30	5.40±1.76	2.94±0.06	12.23±1.16	2.40±0.03	12.24±3.30	3.12±0.23
Nov	0-15	6.33±2.14	2.49±0.13	6.57±0.59	2.10±0.15	14.88±5.08	3.69±0.10
	15-30	6.21±2.80	2.73±0.30	6.46±2.16	2.07±0.01	14.88±5.50	3.63±0.21
Dec	0-15	6.36±4.00	2.49±0.69	5.91±0.10	2.31±0.22	19.50±6.96	7.65±0.54
	15-30	5.79±3.58	2.43±0.12	5.80±3.98	2.31±0.04	19.05±7.34	7.77±1.03
Jan	0-15	7.26±3.89	2.91±0.28	11.28±1.27	4.26±0.07	18.33±2.97	6.54±0.10
	15-30	6.99±4.38	2.79±0.23	11.17±2.36	4.02±0.03	18.93±5.22	6.57±0.09
Feb	0-15	14.82±2.19	2.22±1.58	9.30±0.22	1.98±0.26	10.02±0.76	2.61±0.04
	15-30	15.54±1.75	2.58±0.87	9.19±0.69	2.43±0.38	9.72±1.31	2.19±0.63
Mar	0-15	11.04±0.99	2.07±0.13	6.33±0.98	1.86±0.16	7.05±1.16	2.55±0.34
	15-30	10.44±1.13	2.10±0.01	6.22±0.84	2.16±0.10	6.54±1.86	2.43±0.00
Apr	0-15	11.70±2.12	2.10±2.62	5.49±0.99	2.19±0.04	5.40±1.08	1.89±0.22
	15-30	8.34±0.73	2.13±1.55	5.38±0.90	2.10±0.08	5.822.13	1.74±0.10
May	0-15	5.70±0.80	2.13±0.37	5.94±0.53	2.34±0.07	4.98±3.62	1.92±0.29
	15-30	5.91±1.23	2.28±2.62	5.83±0.67	2.16±0.14	4.89±2.18	1.89±0.23

± SE (n=5)

To three factors, namely variation in mineralization rates, uptake by plants and microbes and losses through soil erosion, leaching, run-off and denitrification [15, 16]. Higher value of inorganic N pool during the winter season might be due to lower uptakes of nutrients by the crop plants. Lower concentration of the NO_3^- during rainy season may be attributed to the leaching and percolation due to heavy rain and soil erosion. Besides leaching, nitrification also greatly responsible for the decrease of NH_4^+ within the 0-20 cm soil layer [17]. 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.

Ammonium concentration compared to nitrate was always greater in the present study, which might be associated with acidic nature of the soils which might have favored the growth and activities of autotrophic nitrifiers in the soils [18]. Higher concentration of ammonium-N indicates greater rate of ammonification in these agro-ecosystems and potential higher loss of nitrate-N through leaching and runoff, which are generally observed in the hilly agricultural fields. Lower concentration of NO_3 -N than the NH_4-N might be also due to more efficient uptake of NO_3^- than NH_4^+ by the crop plants [19] or more consumption by the heterotrophic bacteria and denitrification due to high soil moisture percentage [20].

mineralization was recorded during the rainy season, which might be due to elevated soil temperature and moisture content during this period in the agricultural systems [23, 24, 25]. Ammonification rate was positively correlated with different soil properties such as soil pH, SOC, NH_4-N, NO_3-N etc. which is a sign of 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.

The rate of mineralization largely depends on nitrogen and other nutrients content of residues which comes through the decomposition processes of organic materials with the help of soil microbes, and regulates the nutrient budget in soil [26, 15]. Moreover, the greater carbon availability in the soil supports more active microbial biomass with greater nitrogen demand, thus promoting immobilization and recycling of nitrate.

Minimum mineralization rates during the winter period might be due to low decomposition rates because of low microbial activities and greater immobilization of inorganic N resulting in reduced N-mineralization. Mineralization rate

3.3. Ammonification and Nitrification (µg g-1 month-1)

Significant variations in ammonification and nitrification were found in different agro-ecosystems and seasons as well. Maximum ammonification in the Soybean agro-ecosystem was recorded during the month of August (Table 3). Different agro-ecosystems had showed higher rate of nitrification in different months while majority of the systems showed higher rate during the monsoon months.

Ammonification was found to be higher than the nitrification rate in all the agro-ecosystems. Similar results were also reported by Das et al. (1997) [21] and Tangjang (2005) [22] 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.

3.4. N-mineralization (µg g-1 month-1)

In most of the agro-ecosystem, higher

may increases during the spring season due to increase in temperature [27, 28]. Cassman and Munns (1980) [29] and Eghball (2000) [30] also reported higher mineralization during summer season which might be due to elevated soil temperature and moisture content in the agricultural systems. Microbial activities are limited in dry soils, which may also 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 remaining active. Mineralization rate may be influenced to some extent by soil texture as well. Fine textured soils with high in clay content are abundant in microspores in which organic matter can find physical protection from microbial decomposition. However, N-mineralization and immobilization processes have a close relationship to the carbon cycle, because decomposing microorganisms derive their energy from carbon compounds. BD- Bulk density, SMC-soil moisture content, WHC- water holding capacity, SOC-soil organic carbon, TKN-total kjeldahl nitrogen, NH_4-N-ammonium nitrogen, NO_3-N-nitrate nitrogen df- degree of freedom, P-significant level, SOC-Soil organic carbon, TKN-total kjedhal nitrogen, NS-not significant.

Table3. *Monthly Variations in soil N-mineralization (µg g^{-1} month^{-1}) Under Selected Land Use Type*

Month	Depth (cm)	Maize AES			Soybean AES			Forest garden		
		1	2	3	1	2	3	1	2	3
Jun	0-15	3.98 ±0.69	1.68 ±0.46	5.66 ±0.95	6.35 ±3.09	1.42 ±0.51	7.76 ±2.58	-2.67 ±0.66	1.20 ±0.24	1.47 ±0.90
	15-30	7.56 ±1.15	1.19 ±0.30	8.75 ±1.11	7.05 ±3.07	1.61 ±0.07	8.66 ±3.14	-2.20 ±2.69	2.82 ±0.82	-0.62 ±1.87
July	0-15	4.46 ±1.72	1.16 ±0.77	5.61 ±0.45	6.38 ±3.19	1.45 ±0.32	7.83 ±2.87	5.02 ±0.28	1.13 ±0.02	6.14 ±0.27
	15-30	-8.20 ±3.00	1.44 ±0.46	-6.75 ±2.58	7.18 ±3.39	0.26 ±0.69	7.44 ±2.69	1.67 ±3.27	2.53 ±0.54	4.19 ±2.73
Aug	0-15	-6.20 ±1.59	0.87 ±0.34	-5.33 ±0.79	18.77 ±7.59	0.60 ±0.19	19.37 ±7.78	6.08 ±0.06	10.86 ±5.01	16.94 ±4.95
	15-30	-9.78 ±4.85	3.20 ±1.83	-6.57 ±5.27	8.10 ±3.45	1.08 ±0.00	9.18 ±3.45	1.09 ±4.35	3.54 ±0.17	4.63 ±4.19
Sep	0-15	5.60 ±0.66	1.85 ±0.91	7.45 ±0.44	5.24 ±1.46	1.99 ±0.31	7.23 ±1.78	4.67 ±0.47	2.06 ±0.10	6.73 ±0.36
	15-30	7.41 ±3.56	1.63 ±0.33	9.04 ±2.85	3.62 ±1.14	2.42 ±2.15	6.04 ±1.01	1.28 ±3.07	-2.25 ±1.95	-0.97 ±5.02
Oct	0-15	5.67 ±0.92	2.18 ±0.75	7.85 ±1.40	10.33 ±4.81	1.09 ±0.07	11.42 ±4.73	4.14 ±0.77	2.47 ±0.14	6.61 ±0.62
	15-30	3.57 ±0.47	1.18 ±0.16	4.75 ±0.49	10.33 ±4.60	1.18 ±0.19	11.52 ±4.79	3.92 ±0.18	3.87 ±1.35	7.79 ±1.53
Nov	0-15	4.05 ±1.34	0.35 ±1.67	4.40 ±0.72	8.89 ±4.21	0.74 ±1.31	9.62 ±2.90	4.03 ±0.01	1.10 ±0.38	5.13 ±0.37
	15-30	3.11 ±1.10	-0.07 ±2.16	3.03 ±1.37	2.97 ±0.89	2.17 ±0.12	5.15 ±0.77	4.10 ±0.50	1.50 ±0.79	5.60 ±1.29
Dec	0-15	1.67 ±0.08	-1.51 ±3.38	0.16 ±3.44	3.12 ±1.44	0.32 ±3.63	3.44 ±2.19	2.55 ±0.44	1.01 ±1.26	3.56 ±1.70
	15-30	2.09 ±0.27	-1.15 ±3.08	0.94 ±2.89	1.44 ±0.13	4.02 ±1.18	5.46 ±1.06	2.45 ±0.18	1.22 ±1.19	3.67 ±1.37
Jan	0-15	3.09 ±2.62	-0.98 ±3.03	2.11 ±4.89	8.43 ±4.02	1.34 ±2.48	9.77 ±1.54	2.80 ±0.14	3.04 ±2.02	5.84 ±1.87
	15-30	2.39 ±3.48	-1.59 ±3.70	0.80 ±6.17	4.67 ±1.23	2.39 ±0.93	7.06 ±0.30	2.88 ±0.25	1.55 ±1.57	4.43 ±1.82
Feb	0-15	11.04 ±4.25	0.03 ±1.92	11.07 ±1.10	4.18 ±1.74	0.48 ±0.79	4.66 ±0.95	3.84 ±3.61	1.26 ±0.62	5.10 ±2.99
	15-30	12.92 ±6.11	0.83 ±1.18	13.74 ±3.15	8.53 ±4.19	1.08 ±0.65	9.61 ±3.55	4.44 ±4.25	-0.93 ±0.05	3.51 ±4.20
Mar	0-15	-9.92 ±5.22	1.08 ±0.62	-8.84 ±3.08	5.58 ±2.24	1.13 ±0.24	6.71 ±2.01	2.76 ±3.59	2.59 ±0.75	0.18 ±2.84
	15-30	-9.31 ±4.59	0.97 ±0.79	-8.34 ±2.47	6.58 ±3.07	0.95 ±0.53	7.52 ±2.53	-2.69 ±3.32	-1.21 ±0.12	-3.89 ±3.20
Apr	0-15	9.58 ±5.59	-0.02 ±1.74	9.56 ±2.23	5.35 ±1.34	1.03 ±0.83	6.37 ±2.17	-2.86 ±3.37	-2.99 ±1.49	-0.13 ±4.86
	15-30	7.07 ±3.88	1.40 ±0.37	8.47 ±2.38	3.12 ±0.68	0.98 ±0.47	4.10 ±1.15	-3.34 ±1.87	4.49 ±1.55	1.15 ±0.32
May	0-15	4.69 ±1.92	1.33 ±0.46	6.02 ±0.91	9.82 ±3.58	0.60 ±0.60	10.43 ±4.19	2.59 ±1.05	-3.21 ±2.28	-0.61 ±3.33
	15-30	-4.67 ±1.72	1.05 ±0.80	-3.62 ±0.41	7.21 ±3.31	0.81 ±0.21	8.02 ±3.10	2.59 ±1.04	1.54 ±0.25	4.13 ±0.80

± SE (n=3), 1-Ammonification, 2-Nitrification, 3- N-mineralization

Table4. *Correlation Coefficients (r) for the Relationships Between Soil Properties and N-mineralization Rates (µg g^{-1} month-1)*

Process	Depth (cm)	SMC (%)	BD	Sand (%)	MBC	TKN (%)	SOC (%)	Ava. P (µg g^{-1})	NH_4-N	NO_3-N	pH
Ammonification	0-15	-0.50	0.36	0.45	-0.26	0.01	0.19	-0.09	0.04	0.26	0.26
	15-30	0.48	-0.19	0.53	-0.37	0.14	-0.05	-0.10	0.06	-0.17	-0.38
Nitrification	0-15	0.39	-0.39	-0.31	0.50	0.14	0.38	-0.26	-0.15	-0.10	-0.07
	15-30	-0.17	-0.17	-0.48	0.43	0.18	-0.42	0.15	0.20	0.00	0.09
N-mineralization	0-15	0.39	-0.39	-0.31	0.50	0.14	0.38	-0.26	0.15	0.10	-0.07
	15-30	-0.17	-0.17	-0.48	0.43	0.18	-0.42	0.15	0.20	0.00	0.09

Table5. *Three Way ANOVA Showing the Effects of Depth, Agro-ecosystem and Month on Ammonification, Nitrification and N-mineralization*

Variable	Ammonification			Nitrification			N-mineralization		
	df	F	P	df	F	P	df	F	P
Depth	1	0.041	NS	1	2.439	NS	1	0.7340	NS
Month	11	25.185	0.0001	11	18.288	0.0001	11	6.4087	0.0001
Agroecosystem	7	77.521	0.0001	7	18.695	0.0001	7	1.1490	NS
Depth X Month	11	2.571	0.005	11	1.770	NS	11	0.4634	NS
Depth X Agroecosystem	7	5.514	0.001	7	4.411	0.001	7	0.6604	NS
Month X Agroecosystem	77	8.197	0.0001	77	10.107	0.0001	77	2.7756	0.0001
Depth X Month X Agroecosystem	77	2.597	0.0001	77	4.250	0.0001	77	0.6464	NS

n=15; *P<0.05

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