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Organic carbon, nitrogen pool and microbial abundance indifferent rice soils of Manipur valley, India

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A study was undertaken in three blocks of Manipur viz. Haorang, Wangoi and Sawombung after rice harvest covering upland, midland and lowland areas. The oxidizable organic carbon (OC) of these soils was found to be fairly good and ranged from 5.0 to 18.1 g/kg. The average pH values of 5.72, 5.45 and 5.33 were noticed in the soils of Haorang, Wangoi and Sawombung blocks respectively. Significant relationships were observed between the organic carbon and mineralized nitrogen pools. The NO_3-N content was found to be positively correlated with oxidizable OC (r = 0.335*), total N (r = 0.480**) and NH_4-N (r = 0.818**) of these soils. The colony forming unit (CFU) of total viable bacteria (TVB), aerobic Non-Symbiotic nitrogen fixing bacteria (ANFB), phosphate solubilizing bacteria(PSB), actinomycetes and fungi varied widely. There was fair increase of microbial populations at pH=5.7 and effect of pH was more for PSB and ANFB.The abundance of microbes in the three land types was as follows: upland– ANFB>TVB>PSB >actinomycetes> fungi; Midland- TVB> ANFB>PSB>actinomycetes> fungi; and lowland –PSB>TVB>ANFB>actinomycetes> fungi.

Key words: Organic carbon (OC), nitrogen pool, microbial abundance, rice soil.

INTRODUCTION

Organic matter (OM) acts as the storehouse of essential nutrients and source or sink to atmospheric CO_2 (Lal, 2002). An increase in soil organic carbon (OC) levels is directly linked to the amount and quantity of organic residues return to the soils (Mandal et al., 2007). indicated by higher microbial biomass and elevated soil respiration (Sparling et al., 2003). The soil solution concentration of N, P, S and several micronutrients are intimately related to organic fraction in soil (Havlin et al., 2005). Soil OC is the second largest carbon pool on the surface of the earth after the oceans (Batjes, 1996; Swift, 2001) and the possibility of increasing the OC content of the soil through changing agronomic management

practices may play a role in combating climate change (Lal, 2002). It plays a key role in soil function, determining soil quality, water holding capacity and susceptibility of soil to degradation (Giller and Cadisch, 1997; Feller et al., 2001). The continuous transformations (mineralization) under the action of biological, chemical and physical factors make them to degrade. Decomposition of OM is important, as rapid decomposition of OM may lead to release of N as NH_3. Prolonged submergence of soils for double or triple rice crops, on the one hand, may retard oxidation and also confer character of recalcitrance to soil organic carbon (Olk et al., 2002). In these soils, the relation between OC

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with different forms of soil nitrogen that is, NH_4-N and NO_3-N the N transformation system also gets deviated. These include crop N uptake dynamics, N fertilizer management, rainfall, irrigation, soil texture, and N transformations in the soil (Wang et al., 2010). However, the effect of this change in the soil microbial community on soil N transformation, especially the interactions of the soil fungal community with plant growth are not known (Li et al., 2010). Nitrogen fractionation during mineralisation is controlled by carbon (C) and the N availability to the soil by microbial community (Dijkstra et al., 2006, 2008).They are also important for understanding the processes of soil C sequestration (Bronson et al., 2004). We attempted to assess the underlying relations of OC with different pools of N and to understand better how topographic change, variation in soil water submergence, and low soil acidity affect the diversity of microbial communities in rice soils.

MATERIALS AND METHODS

Sampling site

Manipur is wedged between hills from all sides and it is one among seven sister states of North-Eastern India. The state lies 790 m above MSL, at 23°83′ N to 25°68′ N latitudes and 93°03′ E to 94°78′ E longitudes with total area of 22,327 km² and net cultivated area of 1,99,623 ha. This hilly state receives heavy rains during May till the middle of October with an average annual rainfall of about 1468 mm favouring rain fed farming. All the soils under the study belong to Typic Haplaquent. Since decades, single rainfed rice crop predominate the study area. Normal transplanting was done after puddling where water is not limiting or by broadcasting where water scarcity existed. During late October to early November 2008, after rice harvest, we collected soil samples (0 to 15 cm depth) from dry fields by using core sampler. At each sampling site, 10 replica soil cores (10 m apart) were collected and combined to make composite. It covered three selected blocks viz., Haorang, Wangoiand Sawombung making 15 composite samples. These soils were categorized based on the topography and duration of water stagnation during cropping season, that is, 3 upland soils included Maklang, Lairenkabi and Phayeng (foothill soils with gentle slope and submergence only during some crop stages of season); 7 midland soils included Lamsang, Awang Khunou, Lairenjam, Malom Tulihal, Thongdabi, Leimarok, Sakok, Waiton (water stagnation during rainy season to mid cropping season); 4 lowland soils included Hiyangthang, Langthabal, Khundrakpam, Takhel (where water stagnates in most of the cropping season). The samples varied from clay to loam with CEC ranging from 13.40 to 32.80 cmol/kg soil.

Soil analysis

Samples were measured for pH with the help of glass electrode (Jackson, 1973) after calibrating with standard buffer solution at room temperature. The oxidizable OC content of the soil samples was determined by rapid titration/wet oxidation method (Walkeley and Black, 1934). Total nitrogen contents of the soil samples were determined by the modified Kjeldahl method whereas NH_4-N and NO_3-N were estimated by distillation of extracts (Jackson, 1973). Nitrate nitrogen is determined in soil extract (dried at 55°C for 12 to16 h) by Kjeldahl distillation in presence of Devarda alloy. In both

the process the ammonium borate is formed which is indicated by change in colour from pink to green and it is titrated against standard 0.02 N HCl turning to distinct pink as end point. Available phosphorus content of the soils was determined after extracting the samples with 0.03 N NH4F in 0.025 N HCl (Bray and Kurtz, 1945).

Microbial population analysis

The colony forming unit of TVB, ANFB, PSB, actinomycetes and fungi, present in the soils were enumerated following serial dilutions at ($\times 10^5$), ($\times 10^4$), ($\times 10^4$), ($\times 10^4$) and ($\times 10^3$), respectively and by pour plate method in their respective suitable media. The counting of the colonies of TVB, ANFB, PSB, actinomycetes and fungi as apparent on the respective plate was made after the lapse of requisite incubation period in the incubator at 30±1°C. The TVB count was made on Thornton's agar medium (1922), (pH adjusted to 7.4, after sterilization). Count of aerobic non-symbiotic nitrogen fixing bacteria (ANFB) was made in Jensen's (1930) nitrogen free agar medium (pH adjusted to 7.0). The count of PSB was done by inoculating them in solidified Pikovskaya's medium, pH adjusted to 7.4 (Pikovskaya, 1948). Jensen's agar medium (Jensen's, 1930) was used for the enumeration of actinomycetes (pH adjusted to 6.5-6.6 after sterilization). Martin's rose Bengal streptomycin agar medium (Martin, 1950) was used for counting fungi. For this, a stock solution of streptomycin was prepared by dissolving 10.0 mg of streptomycin in 2.0 ml of distilled water of sterilized distilled water and was added to the medium at the time of plating.

Statistical analysis

The statistical analysis for various soil analytical data like mean, standard deviation, standard error mean, critical difference, correlation co-efficient, regression etc. were determined by SPSS (16.0). Correlation coefficient among OC, total-N, NH_4-N and NO_3-N were calculated at 1 and 5% levels of probability.

RESULTS AND DISCUSSION

Soil organic carbon

The oxidizable OC of these soils ranged from 5.00 g/kg to as high as 18.10 g/kg with an average of 7.54, 9.24 and 10.8 g/kg in the soils of Haorang, Wangoi and Sawombung blocks, respectively (Table 1). Among them, the soil of Phayeng, Hiyangthang, Leimarok, Waiton and Khundrakpam showed high OC (>10 g/kg). Highest OC was obtained in Hiyangthang (18.1 g/kg) followed by Leimarok (16.3 g/kg).

The average pH value 5.72, 5.45 and 5.33 were noticed in the soils of Haorang, Wangoi and Sawombung blocks, respectively. Due to the release of weak organic acids during decomposition of organic matter might lower the pH of soil.

This drives soil into lower redox potentials by virtue of electron donation by organic substrates through enzymatic reactions. Highest accumulation of OC was found in lowland followed by midland and upland. With increase in oxidizable OC there was an increase in N pool in the soil (Figure 1). The increase in their contents was more for NH_4-N as compared to NO_3-N.

Table 1. Bock wise soil pH, organic carbon, total OC, nitrogen pool (ammonical, nitrate and total N) and available phosphorus.

Block	Location	pH	Oxid. OC (g kg^{-1})	Total OC (g kg^{-1})	NH$_4$-N (mg kg^{-1})	NO$_3$-N (mg kg^{-1})	Total N (g kg^{-1})	Avl. P (mg kg^{-1})
Haorang	Maklang	5.82±0.02	7.83±0.06	10.4±0.05	24.27±0.08	18.44±0.08	2.0±0.15	11.34±0.01
	Lamsang	5.70±0.01	7.40±0.30	9.90±0.40	22.57±0.14	13.92±0.20	1.7±0.05	8.84±0.07
	AwangKhunou	5.59±0.01	6.00±0.00	8.00±0.00	18.19±0.22	11.38±0.06	1.8±0.15	19.51±0.09
	Lairenkabi	6.37±0.02	6.13±0.15	8.10±0.21	28.90±0.15	18.19±0.08	2.2±0.10	22.71±0.18
	Phayeng	5.10±0.03	10.4±0.06	13.9±0.06	28.40±0.02	12.79±0.16	2.7±0.20	12.51±0.08
Mean		5.72	7.54	10.06	24.47	14.94	2.08	14.98
Wangoi	Hiyangthang	4.96±0.01	18.1±0.25	24.2±0.35	31.42±0.32	18.12±0.23	2.7±0.06	16.37±0.12
	Langthabal	5.87±0.04	5.00±0.20	6.70±0.25	15.24±0.05	9.38±0.04	1.3±0.20	20.49±0.11
	Lairenjam	5.57±0.01	6.73±0.06	8.90±0.11	18.24±0.28	9.54±0.02	1.4±0.15	13.62±0.11
	Malom	5.63±0.02	6.90±0.00	9.20±0.00	21.36±0.01	13.22±0.16	1.7±0.06	25.17±0.15
	Thongdabi	5.21±0.01	9.50±0.20	12.7±0.25	27.27±0.23	15.67±0.02	2.6±0.15	11.16±0.13
Mean		5.45	9.24	12.34	22.71	13.19	1.94	17.36
Sawom-bung	Leimarok	5.22±0.02	16.3±0.10	21.8±0.10	21.54±0.22	13.49±0.21	2.3±0.20	18.03±0.14
	Sakok	5.58±0.07	6.80±0.20	9.10±0.25	22.61±0.22	13.62±0.01	1.7±0.15	20.88±0.09
	Waiton	5.74±0.06	11.3±0.20	15.1±0.30	18.99±0.26	11.71±0.26	2.7±0.20	17.18±0.01
	Khundrakpam	5.02±0.04	10.3±0.65	13.8±0.90	25.41±0.30	14.15±0.02	2.3±0.20	12.72±0.13
	Takhel	5.11±0.03	9.33±0.06	12.4±0.06	23.48±0.19	13.34±0.08	1.9±0.15	25.17±0.01
Mean		5.33	10.8	14.44	22.41	13.26	2.18	18.80
SEm (±)		0.017	0.132	0.180	0.120	0.080	0.089	0.060
CD (P = 0.05)		0.049	0.381	0.520	0.347	0.231	0.257	0.173
(P = 0.01)		0.066	0.513	0.700	0.467	0.311	0.346	0.233

Oxid. - Oxidizable, Avl. - Available, Yakovchenko VP, Sikora LJ, Milner PD (1998). Carbon and Nitrogen mineralization of added particulate and macro-organic matter. Soil Biol. Biochem. 30:2139-2146.
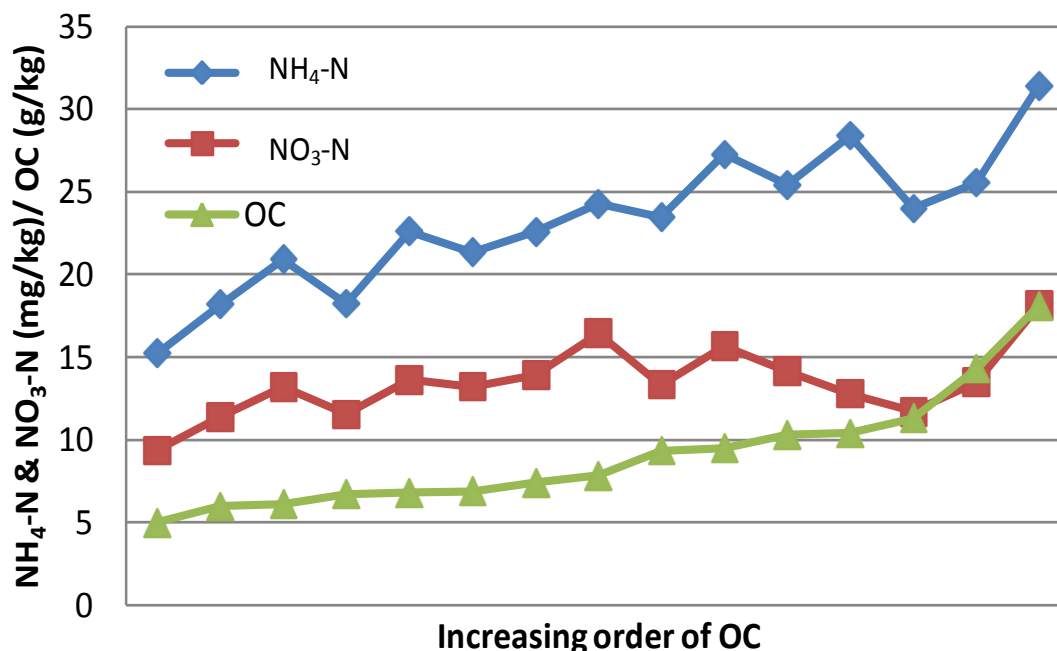
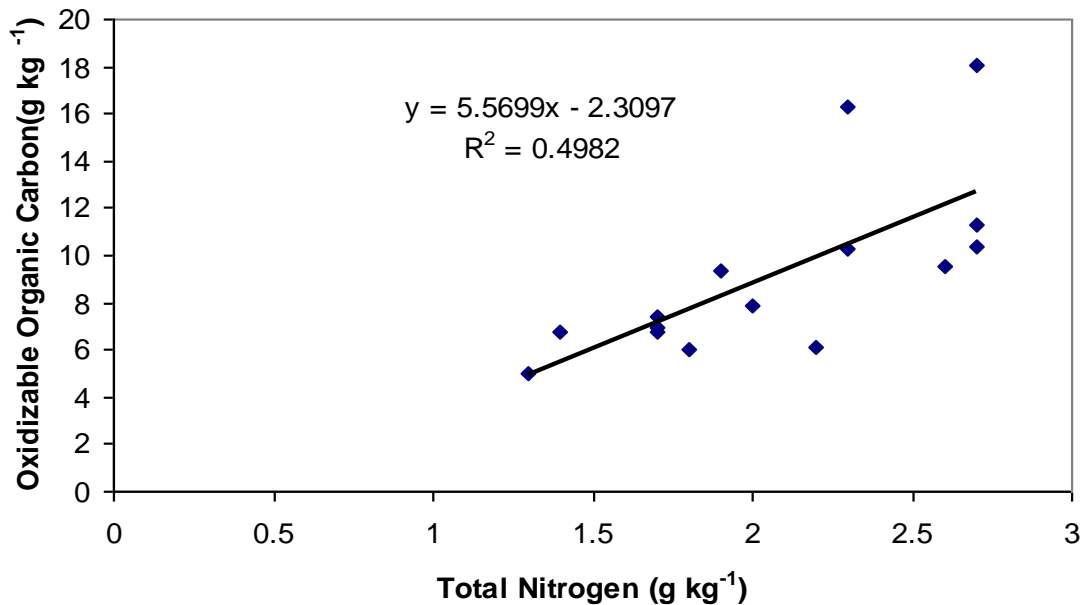**Figure 1.** Increasing inorganic nitrogen pool with increasing organic carbon content.

Figure 2. Linear regression line and corresponding regression of total-N and oxidizable OC.

Nitrogen pools in soil

The analytical results of total-N, NH_4-N and NO_3-N are presented in Table 1. The total-N contents in the soils of Haorang, Wangoi and Sawombung blocks were 2.08, 1.94 and 2.18, respectively. Out of fifteen locations, three locations of Haorang block viz. Phayeng, Lairenkabi and Maklang, two soils of Wangoi block viz. Hiyangthang and Thongdabi, and three soils of Sawombung block viz. Waiton, Leimarok and Khundrakpam have shown comparatively high in total-N content. The oxidizable OC of these soils were also found to be fairly high, which might be the reason for higher nitrogen. The OC is the principal reserve of N in the soil and some tropical soil may contain large quantities of mineral N in the top 2 m depth (Havlin et al., 2005). The macro organic matter additions to soil can result in N immobilization (Whalen et al., 2000) or increase in mineralization (Yakovchenko et al., 1998).

Ammonical nitrogen content in five soils of each block viz. Haorang, Wangoi and Sawombung were 24.47, 22.71 and 22.41 mg/kg, respectively. Highest NH_4-N (31.42 mg/kg) was obtained in the soil of Hiyangthang of Wangoi block followed by soils of Lairenkabi and Phayeng of Haorang block, Thongdabi of Wangoi block and Khundrakpam of Sawombung block. This indicated that the NH_4-N contents in soils these three blocks were more or less accompanied with their total-N content. The NO_3-N content in all the soils was found to be always lower than that of NH_4-N content. This may be due to higher rate of ammonification than nitrification which is controlled by soil microorganisms. Nitrate nitrogen content of the five soils of each block viz.

Haorang, Wangoi and Sawombung varied from 11.38 to 18.44, 9.38 to 18.12 and 11.71 to 14.15 mg/kg with mean values of 14.94, 13.19 and 13.26 mg/kg, respectively. Highest content of NO_3-N (18.44 mg/kg) was obtained in the soil of Maklang of Haorang. In other soils, the amount of NO_3-N was also good. This indicated that NO_3-N content of soils of the three blocks were not much varied and more or less accompanied with the total-N and NH_4-N content of those soils.

The large gap between total-N and mineralized nitrogen (NO_3+ NH_4-N) an indication that there is large N reserve in these soils.

Relationship among organic carbon, total- N, NH_4-N and NO_3-N

The regression equation of oxidizable OC and total-Nindicated that, the minimum oxidizable OC value observed was 2.3097 and increase with the value of 5.5699 g/kg total-N for every unit increase in oxidizable OC (Figure 2). Similarly, the regression between oxidizable OC and NH_4-N showed that, the minimum oxidizable OC value predicted was 0.1652 and increase with the value of 0.3896 mg/kg for every unit increase in oxidizable OC (Figure 3). And for OC and NO_3-N indicated that, the minimum oxidizable OC value observed were 3.0706 g/kg and increase with 0.4443 mg/kg for every unit increase in oxidizable OC (Figure 4).

This showed the existence of positive correlation among them. The total-N content of the soils established highly significant correlation (r = 0.682**) with that of oxidizable OC content of the soils (Table 2). The content

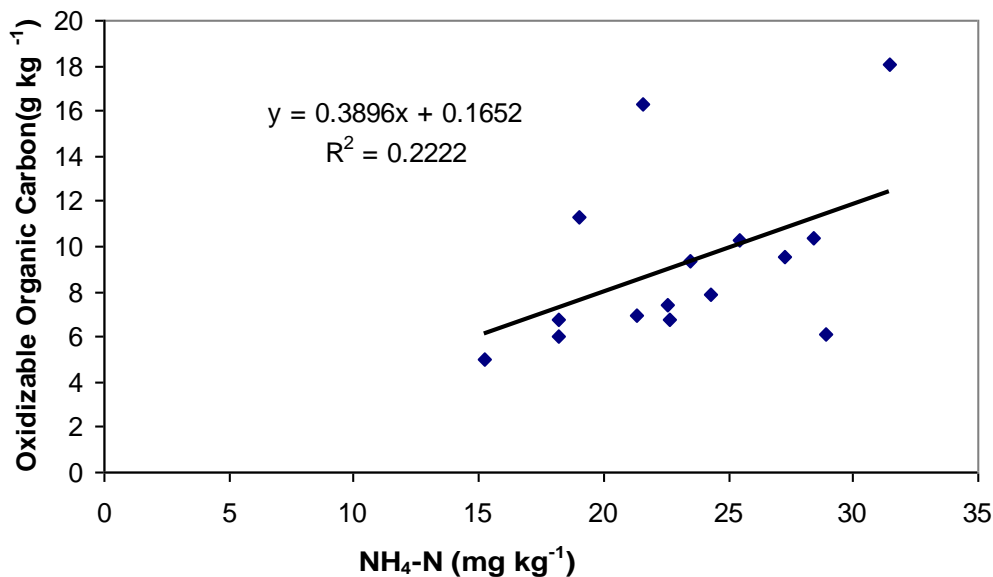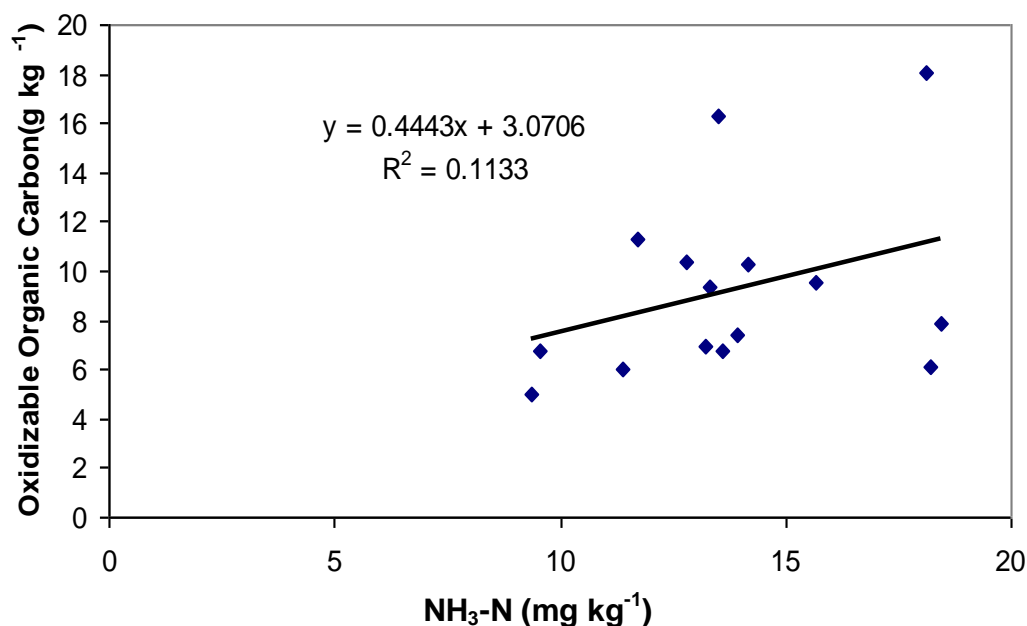**Figure 3.** Linear regression line and corresponding regression of NH_4-N and oxidizable OC.

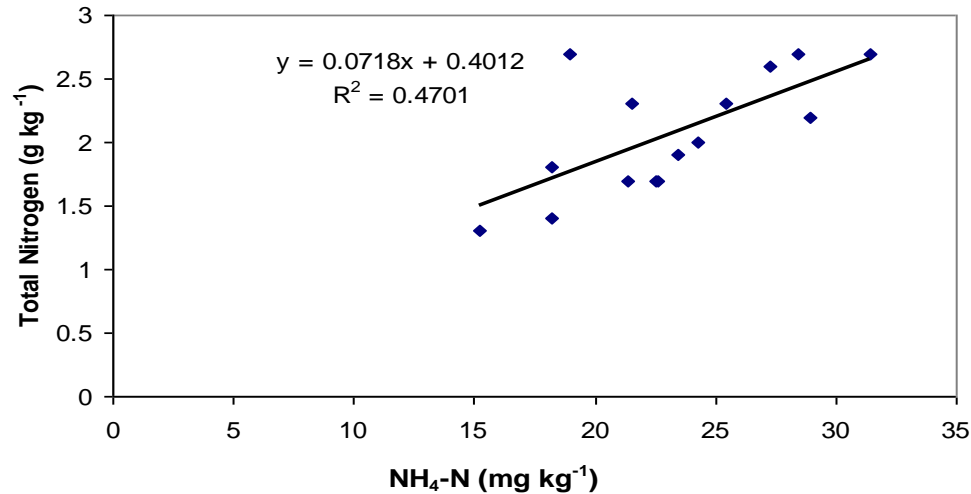**Figure 4.** Linear regression line and corresponding regression of NO_3-N and oxidizable OC.

of the NH_4-N was also found to be significantly correlated with total-N (r = 0.667**) and oxidizable OC (r = 0.471**) of the soils. The regression equation between NH_4-N and oxidizable OC (Figure 4) showed that, the minimum observed value of oxidizable OC was 0.1652 g/kg and increase with 0.3896 mg/kg for every unit increase in NH_4-N. The NO_3-N content was found to be positively correlated with oxidizable OC (r = 0.335*), total-N (r = 0.480**) and NH_4-N (r = 0.818**) content of the soils.

Bronson et al. (2004) registered that, the potentially mineralizable N concentration was correlated with total soil N concentration (*r* = 0.73) to a similar degree as potentially mineralizable C was correlated with total soil C concentration (*r* = 0.70). And potentially mineralizable N concentration was moderately correlated with potentially mineralizable C (*r* = 0.56). From the regression equation, between total-N and NH_4-N (Figure 4) and NO_3-N (Figure 6) showed to be all positively correlated and indicate that
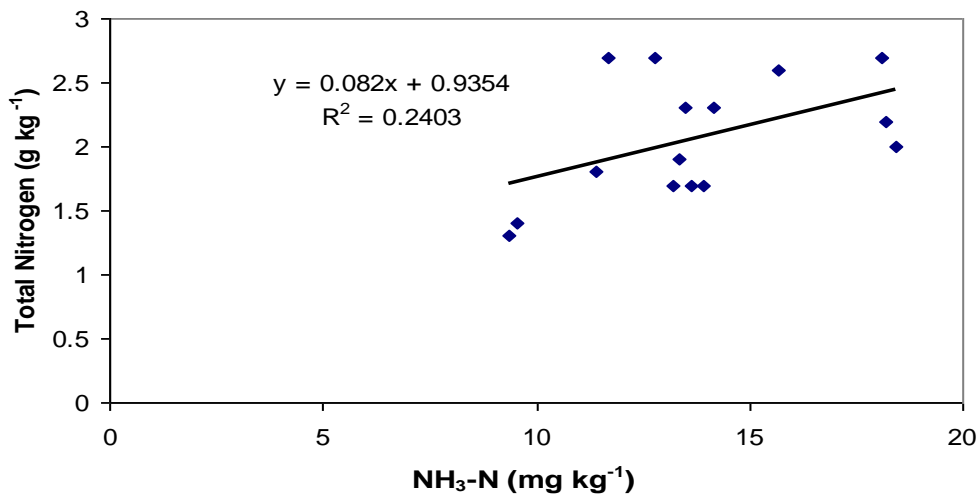
Table 2. Correlation coefficient (r) between oxidizable organic carbon and N pools in soil.

Oxidizable OC		Total OC	Total – N	NH_4-N
Total OC	0.999**			
Total – N	0.682**	0.681**		
NH_4-N	0.471**	0.469**	0.667**	
NO_3-N	0.335*	0.334*	0.480**	0.818**

** Significant at P = 0.01 * Significant at P = 0.05.

Figure 5. Linear regression line and corresponding regression of NH_4-N and total- N.

Figure 6. Linear regression line and corresponding regression of NO_3-N and total-N.

the minimum values of total nitrogen are 0.4012 and 0.9354 (g/kg) which increase with 0.0718 NH_4-N (mg/kg) and 0.082 NO_3-N (mg/kg) for every corresponding unit increase in total nitrogen respectively. The regression between NH_4-N and NO_3-N (Figure 7) also showed positive correlation with minimum value of NH_4-N obtained was 5.15 (mg/kg) and rise of 1.3074 NO_3-N

(mg/kg) for every corresponding unit increase in of ammonical nitrogen.

Microbial populations

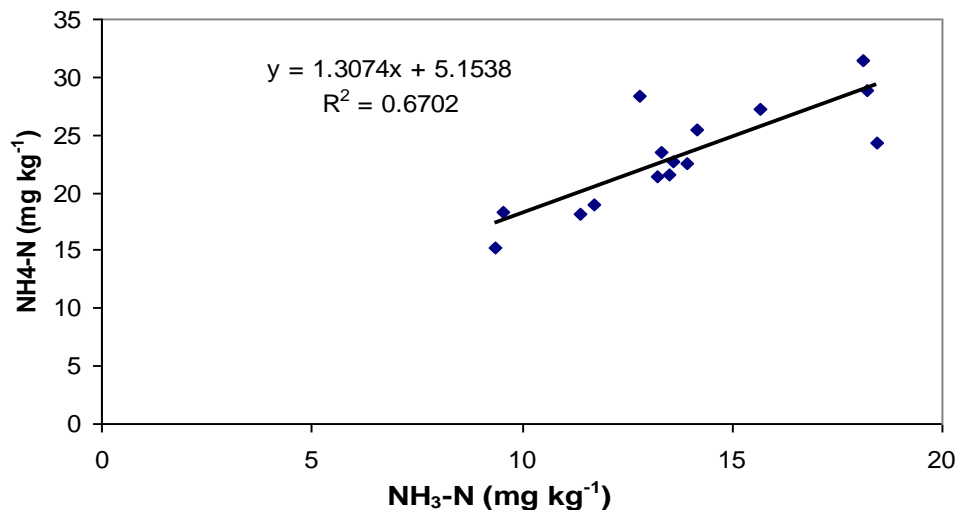The CFU of TVB, ANFB, PSB, actinomycetes and fungi

Figure 7. Linear regression line and corresponding regression of NO_3-N and NH_4-N.

Table 3. Microbial CFU of three different rice soil groups.

| Spot name	Land type	TVB	PSB	Actino-mycetes	Fungi	ANFB
Lairenkabi	Upland	192	83	84	54	143
Maklang	Upland	143	167	117	79	182
Phayeng	Upland	129	66	54	86	162
Mean		154.67	105.33	85	73	162.33
Hiyangthang	Lowland	182	113	86	85	89
Khundrakpam	Lowland	98	175	77	68	191
Langthabal	Lowland	173	190	161	68	182
Takhel	Lowland	104	101	83	93	90
Mean		139.25	144.75	101.75	78.5	138
AwangKhunou	Midland	101	97	75	99	125
Lairenjam	Midland	141	121	146	76	134
Lamsang	Midland	110	74	82	66	119
Leimarok	Midland	121	179	53	70	150
Malom	Midland	118	125	128	78	131
Sakok	Midland	136	131	122	66	167
Thongdabi	Midland	171	67	70	90	74
Waiton	Midland	181	111	98	93	96
Mean		134.88	113.13	96.75	79.75	124.50

varied widely, 98-192, 74-191, 66-190, 70-161 and 54-99 colonies, respectively (Table 3). Most of microorganisms increased their populations with increasing soil pH. With increasing populations of PSB and ANFB did not have visible influence on available of P and N-pools. Bacteria and ANFB was more abundant in upland followed by lowland and midland. In case of PSB and actinomycetes their abundance was in the order, lowland> midland> upland. For fungal population, lowland and midland has equal contributions and least for upland. But the three land types did not vary significantly in this regard. The abundance of microbial populations that is, CFU, in the three land types followed; upland – ANFB> TVB > PSB >actinomycetes> fungi; midland - TVB >ANFB> PSB >actinomycetes> fungi; and lowland – PSB >TVB>ANFB>actinomycetes> fungi (Figure 8).

Conclusions

Dynamics of C, N and microbial abundance, especially in
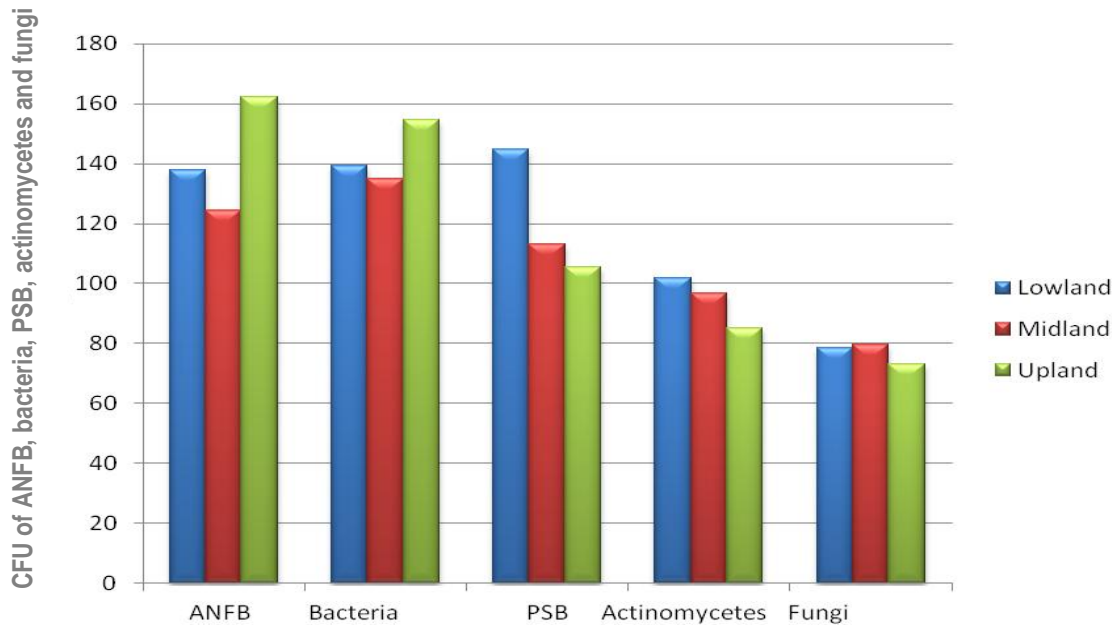
Figure 8. Dominance of microbial populations in lowland, midland and upland rice soils.

rice soils of Asia are important to study C sequestration for increasing soil health and mitigating greenhouse gas emissions as the processes are mediated by microbes. From the above study, it may be concluded that, irrespective of land types, the oxidizable OC, total- N, NH_4-N and NO_3-N in rice soils are positively correlated. The soils under the study has moderately high organic carbon content which constantly affects the growth of microbial population and their abundances influencing the equilibrium of nitrogen form in soil. Efficient management and utilization of organic matter in the rice and other arable soils may be the promise to increase soil resistance and resilience facilitating increase attributes of soil health or quality ultimately affecting carbon sequestration.

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