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Physicochemical Properties of Long-term Rice-fallow Cultivation and Uncultivated Soils of Nalbari, Assam, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

We aimed to assess the changes in physical and chemical properties of soils due to long-term continuous cultivation of rice under a rice –fallow system and that was compared with adjacent uncultivated soils. Soil samples were collected from respective sites and some soil physical (bulk density; BD, water holding capacity; WHC, and moisture content; MC) and chemical properties (pH, electrical conductivity; EC, organic carbon; OC, available N, available P, available K, exchangeable Ca, exchangeable Mg, available S, available Zn and available B) analyzed were evaluated using descriptive statistics. The results indicated that the soils under cultivation with rice- fallow were significantly ($P<0.05$) higher in BD (1.40 Mg m^{-3}) and lower in WHC (41.34%) than the adjacent uncultivated soils (BD=1.34 Mg m^{-3} & WHC=42.26%). Soil's chemical properties were significantly

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($P<0.05$) lower in cultivated rice-fallow soils than the uncultivated soils (pH=5.51 and 5.93, OC=0.63 and 0.89%, available N=245.56 and 418.37 kg ha^{-1}, available P= 31.27 and 42.62 kg ha^{-1}, available K=120.98 and 145.90 kg ha^{-1}, exchangeable Ca=5.35 and 5.93 C mol (p+) kg^{-1}, available S=53.42 and 61.14 kg ha^{-1}, available Zn=0.31 and 0.39 mg kg^{-1} and available B=0.41 and 0.48 mg kg^{-1}) respectively. Continuous cultivation of crops without adopting proper management practices leads to decline in soil physical and chemical properties and proper management practices have to be adopted to sustain the properties of soil and crop productivity.

Keywords: Chemical properties; physical properties; productivity; rice –fallow; uncultivated.

1. INTRODUCTION

Soil physical and chemical properties play a vital role in maintaining soil fertility that has been threatened by various improper agricultural practices resulting deterioration of soil health and productivity. Continuous cultivation of crops with improper management practices in the long-term deteriorates soil's physical and chemical properties and declines crop yield [1]. A better understanding of the impact of continuous cultivation on soil properties is, therefore, essential for the improvement of soil quality and sustaining soil health and productivity. A comparison of soil under natural vegetation and adjoining cultivated soils has revealed that prolonged agricultural land use alters some soil properties, mostly those related to fertility [2]. Continuous cultivation with frequent tillage results in a rapid loss of organic matter through increased microbial activity [3]. Changes in soil properties due to continuous cultivation and management practices and their consequences on crop productivity is an important area of research for soils of Nalbari district, Assam.

Nalbari district is located in the central Western part of Assam and is one of the agriculturally important districts in the Lower Brahmaputra Valley Zone of Assam lies between 26^0 N Latitude and 91^0 E Longitude with mean elevation 89 m above msl and comes under AESR 15.2 Q8B8 and 16.1C10A9. Though the district comprises 2.6% of the state's geographical area, it has 5.46% and 4.96% of the state's net and gross cropped area, respectively. The district of Nalbari is primarily agrarian, with about 80% of the population directly or indirectly dependent on agriculture and allied activities. Rice is the major crop and rice-based cropping systems are predominantly practiced by the farmers in the district and the majority of the area comes under the rice-fallow system. Farmers cultivate rice crop with improper management practices that involves imbalance and injudicious use of nutrients, low farm input, and removal of residues from the field may lead to a decline soil organic carbon resulting decline in the productivity and sustainability of intensive rice-based cropping system.

We carried out the current study to assess the impact of long-term continuous cultivation of rice crops under the rice–fallow system on the physical and chemical properties of soils compared with adjacent uncultivated soils.

2. MATERIALS AND METHODS

Geo-referenced (N: $26^0$31.882 ' to $26^0$18.224' and E: $091^0$30.536' to $091^0$15.750') soil samples (0-15 cm) from rice -fallow cultivated soils were collected after the harvest of rice crops during the year 2014-16 as well as the soil samples from adjacent uncultivated sites were also collected. The representativeness and uniformity of the fields were taken into consideration while collecting the soil samples. The sampling is focused on the plough layer because; this is where most soil quality changes are expected to occur due to long-term land use and soil management practices. A total of 120 soil samples, 60 from cultivated rice-fallow and 60 from uncultivated soils, were collected covering 23 villages. At the time of the collection of soil samples, the crop history including management practices was recorded by the respective farmer. The soil samples were mixed uniformly, air dried in the shade and sieved with a 2 mm sieve and kept in zipped poly pouches with proper labelling inside and outside the packet for analysis of physicochemical properties.

The physical properties like bulk density (BD), soil moisture content, soil texture, and water-holding capacity of soils were determined for soil samples collected from cultivated rice-fallow as well as adjacent uncultivated soils. For the determination of BD, undisturbed soil samples were collected from the field in natural conditions using a tube core sampler (5.2 cm diameter and 9 cm length) following the standard method [4].

The MC was determined using the gravimetric method for field moist soils by drying at 105^{0}C for 24 hours [4]. The texture of the soil samples was determined by the International Pipette Method [4]. Maximum WHC in percentage was determined by using Keen Rackzowski Box [4]. The chemical properties such as soil pH, electrical conductivity, organic carbon (OC), Cation Exchange Capacity (CEC), available N, P, K, exchangeable Ca & Mg, available S, and micronutrients such as available Zinc and boron were estimated following standard procedure [5].

Descriptive statistics was used for calculating the characteristics like mean, standard deviation (SD), minimum & maximum of analyzed soil physical and chemical properties. To compare the means of each soil parameter between cultivated rice-fallow and uncultivated soils, the paired t-test was carried out. SPSS software (version 16.0) was used for analysis of the entire dataset.

3. RESULTS AND DISCUSSION

3.1 Crop History and Soil Management Practices under Rice-Fallow System

High-yielding rice variety Ranjit has been grown for the past 10 years along with a few other varieties like *Bahadur* and *Mahsuri* and other traditional varieties of *Joha* and glutinous rice - *Bora*, *Baismuthi* under rain-fed conditions as mono-crop. The average yield of rice is recorded as (4.3 t ha^{-1}) for HYV and 2.5 to 3.0 t ha^{-1} for traditional varieties. The use of organic manure was low and very irregular. Nutrient management conjoint with unscientific use of urea and SSP and very little use of MOP leading to imbalanced nutrition. Tillage operation was carried out by power tiller and /or tractor. Farmers noticed the yield decline over the years. After the harvest of the rice, the field remains fallow.

3.2 Soil Physical Properties

3.2.1 Soil texture

The soil textures of the selected sites of the rice-fallow system were recorded as sandy, loamy sand, sandy loam, loam, silt loam and clay (Table 1). The textural distribution of soils varied widely depending upon the parent materials. This conformed with the findings of extensive research works carried out on 107 soil series of Assam by Vadivelu *et al*. [6] including the soil series of Maroa, Tihu, and Nalbari of Nalbari district.

3.2.2 Bulk Density (BD)

The mean value of bulk density (BD) of the soils under the rice-fallow system differed significantly ($P<0.05$; Table 1). In the cultivated rice-fallow soils, 91.67% of soils showed a higher BD values and in the case of uncultivated soils, 36.67% were found to have higher BD. The higher BD in rice growing sites might be due to soil compaction arising from puddling operations during rice cultivation. Singh *et al*. [7] reported that excessive tillage and wet tillage (puddling) under the rice-wheat cropping system, resulted in gradual compaction of soils thus increasing the BD. Both wetting-drying and freezing-thawing cycles after tillage may also cause the bulk density to increase because of natural soil reconsolidation as reported by Assouline, [8] and Hu *et al*. [9]. The farm mechanization in tillage operation with continuous use of power tiller/tractor and less incorporation of organic inputs in soils also contributed towards a higher value of BD.

3.2.3 Moisture Content (MC)

The mean soil moisture content (MC) of the cultivated rice-fallow soils was non-significant with uncultivated soils (Table 1). Both cultivated and uncultivated soils showed a higher soil MC in 98.33 and 100% of the selected sites, respectively. The higher soil moisture content might be due to the collection of soil samples immediately after the harvest of rice and characterized by the poorly drained characteristics of rice soils. Janssen *et al*. [10] reported that puddling over many years has the potential to increase the plant’s available water capacity in the puddled layer, but reduces the small coarse and meso-porous (50 to 0.2 µm) in the plow pan. In the case of uncultivated soil, it was attributed to the higher organic matter which helps in the retention of water.

3.2.4 Water Holding Capacity (WHC)

The mean value of maximum WHC of cultivated rice-fallow and uncultivated soils varied significantly ($P<0.05$; Table1) in which >80% of sites showed high WHC. The soil texture in the study sites varies from sandy loam, loam, silt loam and clay and WHC is invariably controlled by soil texture.

3.3 Soil Chemical Properties

3.3.1 Soil organic carbon (OC)

The mean value of OC of cultivated rice-fallow and uncultivated soils varied significantly ($P<0.05$; Table 2 and Fig. 1). Of the total cultivated rice-fallow soils only 15% soils were in the high range of OC compared to 76.67% in uncultivated soils. In the present investigation, inappropriate soil management with low inputs, excessive tillage, and continuous mono-cropping primarily with rice for longer periods might have declined OC in cultivated rice soils compared to uncultivated soils (where no-tillage operations were done). Cooper *et al.* [11] reported that conventional tillage caused a huge soil C loss by soil erosion and increasing soil OC decomposition rate while no-tillage increased soil OC pool in the soil by improving soil structure, reducing erosion, enhancing aggregate stability, and providing physical protection.

3.3.2 Soil pH

The mean value of soil pH of cultivated rice-fallow and uncultivated soils remained non-significant (Table 2 and Fig. 1), in which 60 and 83.33% of sites showed moderately acidic in cultivated and uncultivated soils respectively. Earlier Reza *et al*. [12] reported that the cultivated soils were moderately acidic in Assam which conforms with the present findings.

3.3.3 Cation Exchange Capacity (CEC)

The low status of CEC in the cultivated rice-fallow and uncultivated soils as recorded (Table 2). Moral and Borah [13] also reported a lower value of CEC in the soils of LBVZ of Assam. Moreover, the results conformed with the findings of extensive research works carried out on the Nalbari soil series of Assam by Vadivelu *et al*. [6].

3.3.4 Electrical Conductivity (EC)

The electrical conductivity (EC) of the soils under rice cultivation and uncultivated soils exhibited no significant difference (Table 2). Karmakar [14] reported that the EC of Assam soil is low (<1 dSm^{-1}) indicating no salinity problem in Assam soils and has no adverse effect on crop growth.

3.3.5 Soil available Nitrogen (N)

Conventional rice agro ecosystems, especially in Assam, have been characterized by low input of chemical fertilizers and organic amendments, leading to a decline in the available nutrient status. The mean value of available N content of soils under rice cultivation and uncultivated soils varied significantly ($P<0.05$; Table 2 and Fig. 1). In the cultivated rice soils 66.67% of the samples were low in available N content compared to 3.33% in uncultivated soils. N is highly mobile in the soil and has the highest probability, among the major nutrients, to be lost from the rice eco-system through volatilization and leaching especially in high- rain-fall areas like Assam. Higher organic matter content in uncultivated soils is attributed to a higher level of available N in soils as compared to cultivated rice-fallow soils. Moreover, the use of low input of chemical fertilizers and organic amendments is characteristic of the crop growing system of Assam, leading to a decline in available nutrients status. The cultivated soils in the subtropical region coupled with a preponderance of tillage practices and low external inputs are rarely sufficient in N as reported by Sanyal, *et al.* [15] which conforms with the present study.

3.3.6 Soil available Phosphorus (P)

The mean value of available P content of the soils under rice cultivation was higher than uncultivated soils and varied significantly ($P<0.05$; Table 2 and Fig. 1). The soil under rice cultivation showed 1.67% of soils as low, and 98.33% in medium range and 3.33% were high in available P content. Since the soils of Nalbari district of Assam are acidic with low CEC, the low to medium range of available P in the soils under cultivated soils might be primarily due to the soil acidity that fixes the P into unavailable form as Al and/or Fe phosphate as well as low rate of application of phosphatic fertilizers as evidenced during soil samples collection. This was also reported that the average P fertility index is low to medium in Al and Fe-rich alluvial soils of Assam by Vadivelu *et al*. [6].

3.3.7 Soil available potassium (K)

The estimation of available K significantly ($P<0.05$) differed across the location of the surveyed sites (Table 2 and Fig. 1). In the cultivated rice soils 70.00% of the total samples were low in available K content, whereas 46.67% of the soils were found to be low in the case of uncultivated soils. Das *et al.* [16] reported that most of the soils are low in available K content under different land use systems in Assam, and needs K fertilization to sustain crop yield.

Table 1. Descriptive statistics of soil physical properties

Parameters	Cultivated			Uncultivated			Paired t-test value
	Minimum	Maximum	Mean (±SD)	Minimum	Maximum	Mean (±SD)	
BD (Mg m^{-3})	1.25	1.6	1.40 (±0.06)	1.2	1.50	1.34(±0.07)	8.07*
MC (%)	13.60	34.80	26.58(±6.03)	15.40	35.30	27.01(±5.09)	1.86 *ns*
WHC (%)	19.80	63.10	41.34(±11.17)	21.20	63.70	42.26(±11.13)	6.80*

*ns- non significant; * Significant at < 0.05 probability level.*

Table 2. Descriptive statistics of soil chemical properties

Soil chemical Parameters	Cultivated			Uncultivated			Paired t-test value
	Minimum	Maximum	Mean (±SD)	Minimum	Maximum	Mean (±SD)	
pH	4.6	7.0	5.51(±0.51)	5.0	7.4	5.93 (±0.67)	4.3*
EC (dSm^{-1})	0.01	0.08	0.03 (±0.01)	0.01	0.06	0.03 (±0.01)	0.38*ns*
CEC [C mol. kg^{-1}]	4.42	12.31	6.72 (±1.79)	4.51	12.41	6.88 (±1.83)	0.62*ns*
OC (%)	0.45	1.03	0.63 (±0.12)	0.54	1.70	0.89 (±0.22)	12.86*
N (kg ha^{-1})	110.50	510.4	245.56 (±86.07)	255.4	545.0	418.37(±85.45)	13.71*
P (kg ha^{-1})	20.57	47.57	31.27(±5.87)	30.5	57.2	42.62 (±6.82)	13.64*
K (kg ha^{-1})	64.8	240.33	120.98 (±37.62)	10.0	300.10	145.90 (±54.32)	4.28*
Ca [C mol. kg^{-1}]	1.40	13.20	5.35 (±2.97)	1.7	13.2	5.93 (±2.66)	3.05*
Mg [C mol. kg^{-1}]	0.4	4.6	2.13 (±1.02)	0.80	5.0	2.38 (±0.93)	1.53*ns*
S (kg ha^{-1})	3.67	112.9	53.42 (±23.22)	28.8	121.2	61.14 (±20.52)	6.49*
Zn (mg kg^{-1})	0.13	0.86	0.31 (±0.12)	0.25	0.66	0.39 (±0.09)	7.63*
B (mg kg^{-1})	0.11	0.89	0.41 (±0.15)	0.30	0.78	0.48 (±0.11)	4.68*

*ns- non significant; * Significant at < 0.05 probability level.*

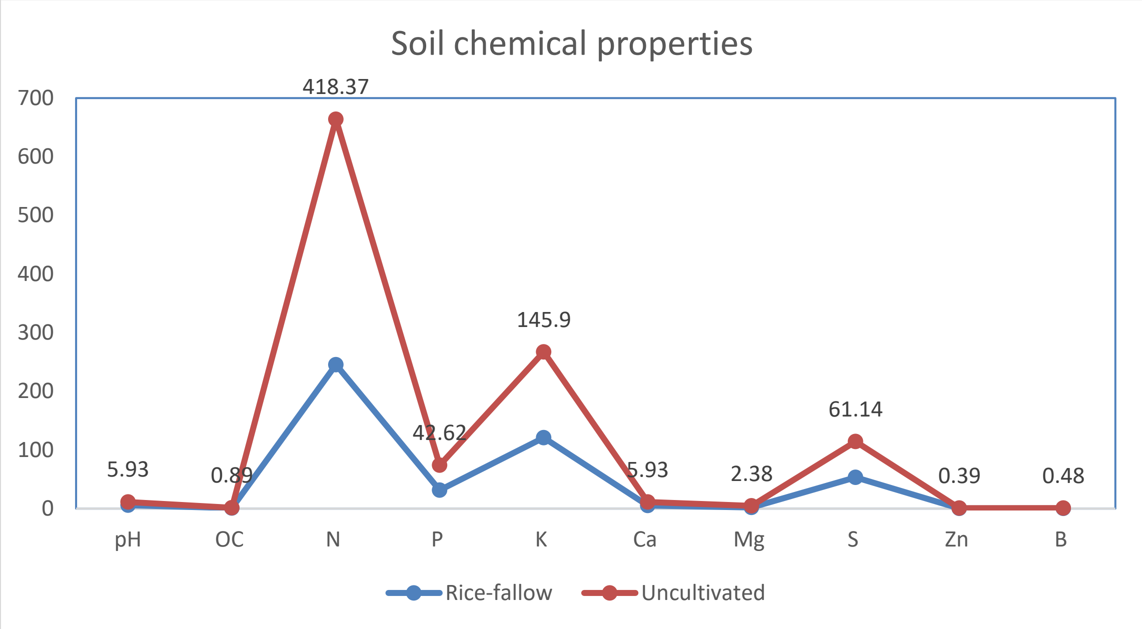

Fig. 1. Soil chemical properties under rice-fallow and uncultivated soils

3.3.8 Exchangeable Calcium (Ca)

Nutritional responses to Ca can occur with sensitive crops in acid soils with low CEC in high rain fall zones. The estimation of exchangeable Ca widely differed across the locations (Table 2 and Fig. 1). The results illustrated that more than 50% of soils belonged to low to medium exchangeable Ca content. A similar status of exchangeable Ca was also observed in a pedological study carried out in Assam soils by Dey and Sehgal, [17].

3.3.9 Exchangeable Magnesium (Mg)

The mean exchangeable Mg content in cultivated sites of rice-fallow was lower than the uncultivated sites (Table 2 and Fig. 1). The results illustrated that more than 50% of soils under the rice-fallow system belonged to the low to medium category in exchangeable Mg content. Extensive research works carried out by Vadivelu *et al*. [6] in the Nalbari soil series of Assam reported 3.81 C mol (p+) kg^{-1} Ca+Mg which conformed with the present investigation.

3.3.10 Soil available Sulphur (S)

The mean available S content in cultivated sites of rice-fallow was lower than uncultivated sites (Table 2 and Fig. 1). The results illustrated that more than 60% of soils under the rice-fallow system belonged to the high category in available S content. In the present study, a high level of S is due to the continuous indiscriminate use of S-containing fertilizers. Moreover, the higher content of S in uncultivated soils might be attributed to the high level of organic matter as compared to cultivated rice-fallow soils.

3.3.11 Soil available Zinc (Zn)

The mean DTPA-Zn content in cultivated sites of the rice-fallow, was lower than uncultivated sites (Table 2 and Fig. 1) and differed significantly ($P<0.05$). The results illustrated that more than 90% of soils under the rice-fallow system were deficient in DTPA-Zn content. Similar findings of Zn deficiencies in the soils of Assam were also observed by Reza, *et al.* [18].

3.3.12 Soil available Boron (B)

The estimated mean available B content in cultivated sites of rice-fallow was lower than uncultivated sites (Table 2 and Fig. 1). The results illustrated that more than 70% of soils under the rice-fallow system belonged to the deficient category in available B content. B deficiencies in Assam soils were reported by Choudhari *et al.* [19] which were attributed to the leaching of B during monsoon rain and less use of B in soil.

4. CONCLUSION

The present investigation indicated that due to the continuous cultivation of rice crops, there was an increase in BD value of soils as compared to the adjacent uncultivated soils. Similarly, the nutrient status of soil also showed a declining trend. Continuous cultivation of rice crops in the long term declines the soil's physical and chemical properties. Therefore, the cultivation of crops with proper soil management practices like balanced use of chemical fertilizers based on soil test values, use of organic manures, and inclusion of legume crops in crop sequence etc. has to be adopted for sustaining soil health and crop productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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