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Research Article

Study the Nutrient Management Practices and Soil Organic Carbon in Rice Fields, Radhi, Trashigang Bhutan

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Abstract

Soil orgnic carbon (SOC) one of the main components of soil organic matter (SOM), acts as a sink for carbon sequestration. It has been well documented that the rice cropping system and organic amendments could enhance SOC stocks. However, the capacity of rice fields to enhance SOC in Bhutan has not been well explored yet. The objective of this study was to understand the nutrient management practices in rice fields and analyse relationship between rice yield, SOC and nutrients (NPK). Soil samples from 23 households were collected and land owners were interviewed mainly focusing on rice yield and nutrient management practices. The mean rice yield in the year 2019 was 7.86 MT. The SOC ranged from 0.3% to 2.9%. The nutrients (NPK) in the soil ranged from very low (vL) to medium (M). The results showed no significant correlation between SOC and rice yield but a multiple regression equation between SOC showed a significant relationship between soil bulk density (*r*=0.46, with *p*-value=0.02679) and pH of the soil (*r*=0.53 with a *p*-value=0.009492).

Keywords: Carbon sequestration, Soil organic carbon, Rice fields, Land management practices.

INTRODUCTION

Soil organic carbon (SOC) is the main component of soil organic matter (SOM). SOC plays an important role in improving soil physical (texture, structure, bulk density, and water-holding capacity), chemical (nutrient availability, cation exchange capacity, reduced aluminum toxicity, and allelopathy), and biological (nitrogen mineralization bacteria, dinitrogen fixation, mycorrhizae fungi, and microbial biomass) properties (Fageria, 2012). In addition, SOC acts as a sink for carbon sequestration. For this, it has been increasingly given importance for the benefits of long term C sequestration and mitigate greenhouse gases (GHGs) that contribute to global warming and climate change (West & Post 2002).

In particular, studies have shown that the rice fields are the potential sources of Soil Conservation Service (Pan et al., 2004; Lu et al., 2009) and contain high SOC stocks, and have greater capacity for C sequestration (Sun Y, Huang S, Yu. X, Zhang W, 2015). In Bhutan, the SOC for paddy land for the 0-100 cm depth was found to be 120.1 Mg/ha (Dorji et al., 2014). The study also reported that the SOC varied among different LULC types and decreased with soil depth indicating that the SOC are maximum on the top parts of the soil profile.

Many studies suggested that the increase in the SOC and crop yields is linked to certain land management practices such as the use of organic manures (Zhang et al., 2010) and chemical fertilizer application (Srinivasarao et al., 2012). along with other practices such as tillage, irrigation, and crop rotation (Arunrat et al., 2016). Studies recommended combining manure and chemical fertilizers to improve the nutrient content in the soil for plant uptake (Zhang et al., 2009) and to increase crop yield (Surekha et al., 2003). For instance, the combination of manure, fertilizer, and increased irrigation facilities maintained the SOC levels and substantially increased the rice yields (Arunrat et al., 2017). In another study, the rice yield increased by 18% with the application of manure to the soil compared to that of chemical fertilizer alone in subtropical China (Bi et al., 2009). In India, the rice yield was increased when farmyard manure was applied with NPK in sandy loam soil (Satyanaraya et al., 2002).

AIMS AND OBJECTIVES

Rice is one of the widely consumed cereal in Bhutan. It is grown in about 53,055 acres with a total production of about 85,090 MT (DoA, 2016). The national average rice yield stands at 1,604 kg/acre (DoA, 2016). In order to further improve rice production in the country and to determine the long term sustainability of SOC, a detail study is necessary to quantify C inputs to the soil from the paddy field. The SOC constrain in the long run could cause stunted growth, and reduced rice yield (Arunrat et al., 2017). Therefore the objectives of this study were to:

Study the nutrient management practices such as the use of organic manures (cow dung) and synthetic chemical fertilizers (NPK) in rice cultivation,

Analyse the relationship between rice yield, SOC and nutrients (NPK)

RESEARCH METHODOLOGY

Study area

Radhi gewog is 30 km east of Trashigang Dzongkhag. Radhi gewog has 21 villages with 758 households and a total population of 5,437. The elevation ranges from 1,080 masl to 3,220 masl. The monthly average temperature varies between 120C to 220C and the average annual rainfall is1,353 mm (Tashigang Dzongkhag, 2020). For the study, a total of 23 households were selected from Dekiling, Tshangkhar, Kadamwog, Radhi under Radhi gewog (Figure 1).

Radhi is one of the major rice producer in the country and is known as the 'Rice Bowl of the East'. A total area of 1,238.16 acres land is under rice cultivation. There has been an increase in rice production from a total of 2,383.33MT in 2015 to 2,409.68 MT in 2016 (DoA, 2016). And subsequently increased to 2,533.63MT in 2017. The increase in yield is attributed to timely rainfall, improved local rice varieties, the use of power-tillers and organic manure (cow dung). 11 different varieties of rice is cultivated. Rice cultivation is done in May/June and is harvested in September-October.

Survey questionnaires

Soil samples were collected as well as the farmers were interviewed during the month of December, 2019 (post-harvest). A total of 23 households were randomly selected. Semi-structured questionnaires were used to get the required information on different management practices.

Soil sampling

Soil samples were collected randomly from 23 different sites using soil auger. At each site, 6-7 sub-samples were collected from a depth of 0-11 cm. A total of 92 samples were collected, 46 for bulk density using core cutter method

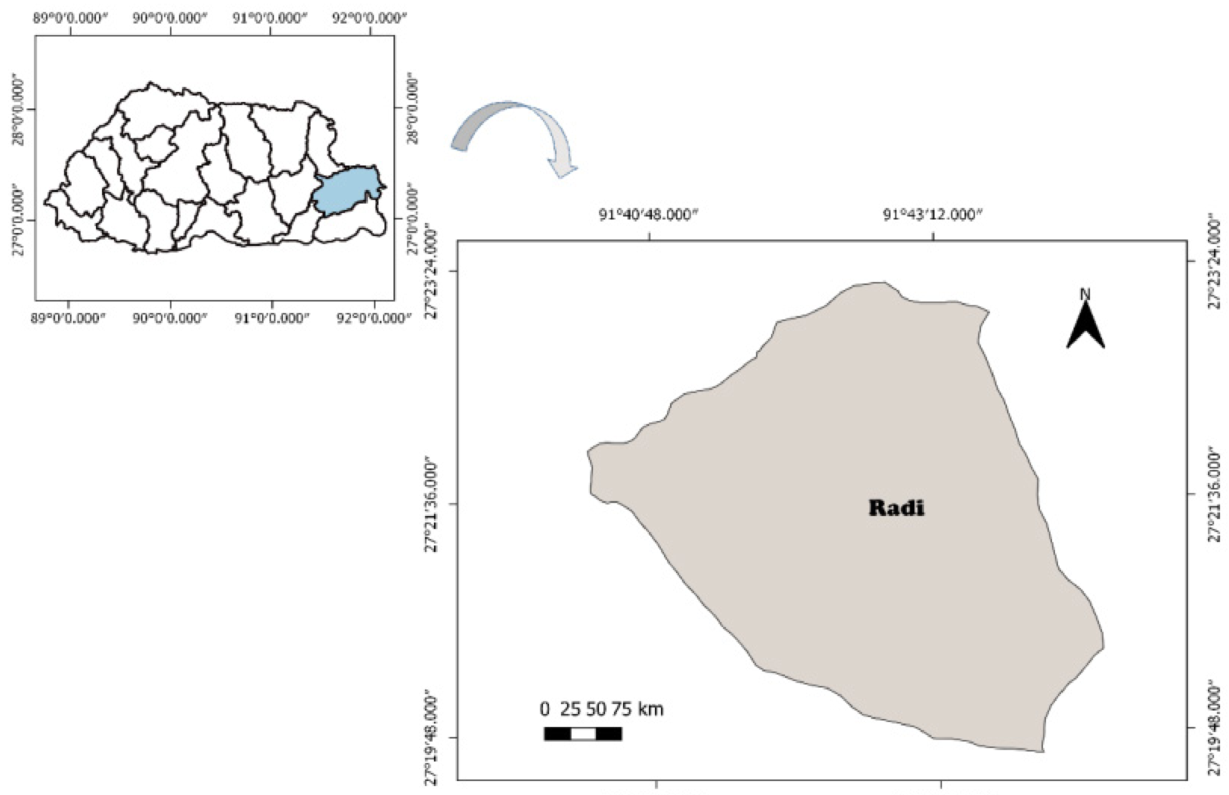

Figure 1. Study area.

and 46 for the nutrients analysis (NPK) and to measure other soil parameters (pH, soil moisture content, soil texture).

Soil analysis

Bulk density and soil moisture content were determined in the Environmental Science Laboratory, Sherubtse College. Soil samples for bulk density were oven-dried for 24 hours at 105°C and their dry weight per unit volume of the soil core were determined. Soil moisture content was calculated using gravimetric method. Nutrients (NPK, C%, N% and C: N ratio) and other parameters such as pH and soil texture were analyzed by the Soil and Plant Analytical Laboratory, National Soil Service Center (NSSC) in Thimphu. pH of the soil was potentiometric ally measured in a soil-water suspension (ratio 1 : 2.5) using pH meter. Organic Carbon was determined by the method of Walkley and Black (1934).

SOC stock was calculated using the following formula:

SOC= (BD × OC x D) × 10,000

where SOC is soil organic carbon stock (Mg C/ha),

BD is soil bulk density (g/cm^3),

OC is organic carbon content (%), and

D is soil sampling depth (cm).

Determination of phosphorous in the laboratory: Phosphorus (P) was extracted using Bray and Kurtz method (1945). The easy acid-soluble forms of phosphorus were extracted by 0.025 M HCl and 0.03 M NH_4F. In the coloration process the phosphate in the extract forms a blue coloured complex with reduced molybdenum salts. This phosphorous-molybdenum blue was measured automatically on a Segmented Flow Analyser at 882 nm.

Determination of exchangeable potassium: 2.94g of soil sample was shaken with 0.01 M calcium chloride solution in a ratio of 1:10 for one hour. The extract obtained after filtration was determined, using a Segmented Flow Analyser with a Flame photometer.

Nitrogen (N) determination in the laboratory according to John Kjeldahl (1883) method: The soil was digested with concentrated sulphuric acid in the presence of a selenium catalyst whereby the organic nitrogen is converted into ammonium sulphate. The ammonium in this digest was determined colourimetrically on a Segmented Flow Analyser. In the colouring process, salicylate, nitroprusside (catalyst) and active chlorine were added, to form a green coloured complex with the ammonium-ion. The absorption was measured at 660 nm.

STATISTICAL ANALYSIS

Statistical analyses of the data were done in R Studio (Version 1.2.5042). Pearson's Correlation coefficient was used to find the relationship between SOC and rice yield with nutrient management practices and soil parameters. All the correlations are presented in a correlation matrix (Table 2). Linear regression model was fitted between SOC and rice yield, SOC and the physical and chemical parameters and also between SOC and nutrient management practices (quality and quantity of synthetic chemical fertilizers and organic manure used). A multiple regression model between SOC and nutrient management practices, soil parameters and rice yield was also fitted.

RESULTS AND DISCUSSION

Background Information of the survey

The respondents were in 22-76 age group. The female to male ratio was 60:40. Majority of the respondents did not attend a formal education except for a few who had attended primary and secondary and non-formal education. Their main source of income is rice and textiles (raw silk/bura) during off agricultural season. Vegetables such as potatoes, garlic, and cabbage are grown for self-consumption. On an average, each household owns approximately 1.08 ha dryland and 1.46 ha wetland from which around 0.56 ha is used for rice cultivation. Three common rice varieties cultivated are Sorbang, Phobara and Sung Sung (local names). But mainly only Sorbang is sold in the market. Urea is the most commonly used synthetic chemical fertilizer. Suphala and weedicide are also used but not so extensively. Farmers invest around Nu.1320 in a year to purchase the synthetic chemical fertlizers from the local dealers. These fertilizers are applied in the field after 1-2 months of rice plantation, every once in a year. Many households have cattle for organic manure (cow dung) which is applied in the field before the rice plantation. Local people have been growing rice for more than 20 years by mainly depending on rain. According to respondents, there has been an increase in the rice production as well as in the use of chemical fertilizers over the years.

Use of synthetic chemical (NPK) and organic manure (cow dung) fertilizers

Nutrient management practices for rice cultivation at all the sites is shown in Table 1. The average rice yield is 7.86 MT/ha. SOC values ranged from 2.29 Mg C/ha to 41.47 Mg C/ha. On an average, organic manure and synthetic chemical fertilizer is applied 3.58 Mg/ha and 201.4 kg/ha respectively, synthetic chemical fertilizer application is significantly higher compared to the manure. Use of synthetic chemical fertilizers in combination with organic manure resulted in maximum yield. The use of synthetic fertilizer alone also obtained a good yield compared to application of organic manure alone. The Nitrogen (N) content in the soil ranged from 600-1400 mg/kg. Phosphorous (P) and Potassium (K) content ranged from 0.05 to 31.94 mg/kg and 26.8 to 91.84 mg/kg, respectively. The high N content in some soil samples compared to the other two nutrients (P and K) could be a result of application of Urea. Overall, N and K content in the soil is found to be very low (vL) to low (L). And the P content ranged from very low (L) to medium (M). One site showed high (H) P content which could be result of excessive use of organic manure.

Relationship between SOC, rice yield and the physical and chemical parameters

Correlations among SOC, rice yield, all the physical (bulk density (BD), soil moisture content) and chemical (Total Nitrogen, K Avail., P Avail., OC, pH) parameters and nutrient managements practices (synthetic chemical fertilizers and organic manure used) were evaluated (Table 2). There exists a weak negative correlation between SOC and amount of synthetic chemical fertilizers used and a weak positive correlation between SOC and amount of organic manure used. A multiple regression equation between SOC and rice yield, nutrient management practices (amount manure and chemical fertilizers used) and chemical and physical properties of soil showed a significant relationship between the variables (R^2=0.5702, p-value=0.02011).

Table 1. Nutrient management practices, yield and SOC.

Site No	Yield(Mg/ha/yr)	SOC (Mg C/ha)	Organic (Mg/ ha/yr)	Synthetic (kg/ha/yr)	N (mg/kg)	P Avail (mg/kg)	K Avail (mg/ kg)
s2	8.11	20.06	0.13	0	0.08*	6.37**	79.52**
s3	6.85	17.3	0	527.16	0.05*	6.43**	90.16**
s4	4.74	18.63	1.5	31.77	0.06*	6.04**	51.36**
s6	6.96	28.38	2.94	207.57	0.07*	2.57*	63.71**
s7	6.78	14.04	1.5	141.2	0.07*	17.3***	58.3**
s8	3.95	17.59	1.5	148.26	0.08*	2.33*	88.69**
s9	4.94	17.73	5	197.68	0.08*	16.87***	88.75**
s10	9.58	16.63	0.92	74.88	0.06*	4.86*	71.41**
s11	21.9	25.71	16.5	32.12	0.07*	2.05*	71.33**
s12	8.3	41.47	1.5	49.42	0.08*	0.05*	55.04**
s13	1.81	27.03	1.5	204.04	0.06*	24.28***	91.84**
s14	15.81	15.87	30	49.42	0.06*	5.13**	90.63**
s15	5.38	18.48	2	217.45	0.1**	3.66*	53.28**
s16	6.88	18.48	1.06	138.38	0.14**	1.87*	26.8*
s17	1.75	4.29	0	3.53	0.08*	0.05*	38.66*
s18	6.13	19.8	0.89	299.62	0.1*	0.05*	68.95**
s19	11.07	12.28	3	197.68	0.12**	0.79*	59.41**
s20	8.63	9.35	0.81	161.74	0.1**	0.05*	31.54*
s21	8.7	12.87	0	1087.26	0.1*	2.33*	37.24*
s22	9.49	9.79	4.5	247.11	0.12**	18.88***	71.94**
s23	9.49	12.65	1.2	197.68	0.08*	31.94****	77.99**
s24	9.64	18.73	0	72.32	0.06*	23.87***	72.1**
s25	3.95	16.59	6	345.95	0.1	17.12***	87.01**

****High, ** Medium, **Low, *Very Low

Table 2. Correlation matrix of soil parameters and nutrient management with SOC and rice yield.

Variables	BD	pH	TN	OC	P Avail.	K Avail.	sSSOC	Synthetic Fertilizer	Organic Manure	Rice Yield
BD	1									
pH	-0.1	1								
TN	-0.6	0.05	1							
OC	0.24	0.55	-0.2	1						
P Avail.	0.09	-0.09	-0.2	-0.1	1					
K Avail.	0.23	-0.08	-0.5	0.2	0.48	1				
SOC	0.46*	0.53*	-0.3	1	-0.1	0.2	1			
Chemical Fertilizer	-0.5	0.04	0.21	-0.1	-0.02	-0.1	-0.18	1		
Manure	-0	-0.17	-0.2	0.1	-0.07	0.34	0.06	-0.2	1	
Rice Yield	-0.2	0.2	-0.1	0.1	-0.13	0.06	0.1	-0.1	0.65*	1

BD: Bulk Density (g/cm^{-3}), TN: Total Nitrogen (%), OC: Organic Carbon (%), P Avail.: Available Phosphorus (mg/kg), K Avail.: Available Potassium (mg/kg), SOC: Soil Organic Carbon (Mg C /ha), Synthetic Chemical Fertilizer: NPK (Mg/ha/yr), Organic Manure: Cow Dung (Mg/ha), Rice Yield (Mg/ha). *Correlation is significant at 0.05 probability level.

Table 3. Summary of physical and chemical parameters of the soil.

Physical Parameters	Min	Max	Mean	SD
pH	5.22	6.07	5.56	0.16
OC	0.3	2.9	1.4	0.49
TN	0.05	0.14	0.08	
Avail. P	0.05	31.94	8.47	9.46
Avail. K	26.8	91.84	66.3	
		Chemical Parameters		
BD	0.85	1.31	1.15	0.13
Moisture Content	18.55	74.75	32.77	11.38
SOC	4.29	41.47	17.99	7.54

Few significant correlations are the correlation between SOC and BD (r=0.46, with p-value=0.02679) and SOC and pH of the soil (r=0.53, p-value=0.009492). The bulk density ranged from 0.85 to 1.31 g/cm^3 (Table 2). A moderate positive correlation between soil bulk density and SOC was not as expected, but the inverse correlation between SOC and BD is also indicated as normal (Sakin, 2012).

pH values ranged from 5.22 to 6.07 (Table 3) which indicated a slightly acidic soil type. It's positive correlation with SOC is mostly because of the rice straw that were left in the field even after the harvest. The rice straw may have increased the amount of organic materials that not only stabilizes the soil, but it can also increase SOC in an acidic soil (McCauley et al., 2017).

The soil texture were identified by hand and categorized as Loam (L), Silty clay loam (ZCL), Silt loam (SL). A total of 23 samples collected had clay and silt content which shows a potential relationship between SOC with clay/silt content. However, the particle sizes could not be measured, thereby, limiting the study from finding a relationship between SOC and clay/silt content.

The average soil moisture content was 32.77% (Table 2). A positive correlation was found between SOC and soil moisture content (Table 3). But a study by Minasny & McBratney (2017), showed that the increase in organic carbon in soil has a small effect on soil water content therefore the positive correlation couldn't be explained well.

CONCLUSION AND RECOMMENDATIONS

A weak positive correlation was found between SOC and rice yield, a weak negative correlation was found between SOC and amount of synthetic chemical fertilizers and a weak positive correlation was found between SOC and organic manure. However, a moderate positive correlation was observed between the SOC with bulk density and pH. These correlations didn't help in drawing a concrete conclusion because all the households in the sample group (n=23) were using both manure and chemical fertilisers. Only four households were using chemical fertilizers without any organic manure. So the SOC found in the sample soil were depending on both chemical fertilizers and manure including many other independent factors. Therefore, a combination of both organic and inorganic fertilizers is recommended, but if one is made to choose then because of a positive correlation of SOC with manure, use of manure is recommenced over chemical fertilizers. It also maintains the soil bulk density. The negative correlation that was found between SOC and synthetic chemical fertilizers was probably because all the sites were rain –fed areas. Thus, for an irrigated land a combination of manure and fertilizer should be applied.

We also recommend refraining from uprooting the rice straw till the next cultivation and leaving it in the paddy field even after the harvest of the paddy, as it maintains the soil pH.

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