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Research Article

Assessment of Soil Nutrient Status Under Different Rice Based Cropping Systems in Ratuwamai Municipality, Morang

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Abstract

The experiment was conducted in Ratuwamai Municipality, Morang, Nepal to assess the impact of various cropping systems on soil fertility and nutrient status. Four different cropping systems (Rice-Wheat-Rice, Rice-Mustard-Maize, Rice-Maize and Rice-Mustard-Rice) were selected as treatments and all treatments were replicated five times in Randomized Complete Block Design. Soil samples from 0-15 cm depth were collected from each site and evaluated for soil pH, Soil Organic Matter content (SOM), Total Nitrogen (N), available phosphorus (P), available potassium (K), sand silt and clay content. All the tested parameters except Soil N content, sand content and clay content were found to be significantly affected by the cropping system. The soil in all four cropping systems were found acidic in nature with pH ranging from (4.18-4.48). The Soil Organic Matter was recorded highest (1.84%) from Rice-Maize based system and lowest amount of Soil Organic Matter was observed in Rice-Mustard-Rice based system. The highest N content (0.19%) was recorded from the Rice-Mustard-Maize cropping system and the lowest N content (0.02%) was recorded from Rice-Wheat-Rice cropping system which is statistically similar to Rice-Mustard-Rice based cropping system. The highest P content (163.95kg/ha) was recorded from Rice-Mustard-Maize and the lowest (75.28kg/ha) was recorded from Rice-Mustard-Rice based cropping system. The highest K content (169.18kg/ha) was recorded from Rice-Mustard-Rice cropping system and the lowest K content (57.76kg/ha) was observed in Rice-Wheat-Rice based system. The highest silt content (48.38%) was recorded from Rice-Mustard-Maize cropping system. The result indicated that the Soil Organic Matter, Nitrogen and Potassium were found to be deficit nutrients in all the cropping system.

Keywords: Soil Fertility; Soil Nutrient Status; Cropping System; Soil pH; Organic Matter

Introduction

Rice (*Oryza sativa L.)* is the most important cereal crop of the world providing staple food for more than 50 percent of the world population and ranks first in Nepal (Gadal, 2019). As Nepal is an agricultural country, majority of people (65.6%) is directly involved in Agriculture sector (MoALD, 2075). Agriculture contributes about 31.7 % of GDP, which contributes major role in Nepalese Economy (MOF, 2074/75). In Nepal, rice is grown in three agro-ecological regions (Terai and Inner Terai- 67 to 900; Mid Hills- 1000 to 1500 masl; and High Hills- 1500 to 3050 masl) under two water regimes (Irrigated, Un-irrigated) and in two topographic conditions (lowland and upland). Rice dominates the country's crop sector accounting for over 42.5 percent (168,047 ha) of the total area under food grains and shares 51.6 percent in total food grain production (MOALD, 2017). As the most important staple food of Nepalese people, rice supplies about 40% of the food calorie intake and contributes nearly 20% to the agricultural gross domestic product (AGDP) and almost 7% to GDP (MOALD, 2017). In case of Morang, the area of rice cultivation is 118,775 hectare; total rice production is 475,036 Metric tons and total yield is 4.00 Mt/ha (MOALD, 2017).

Soil is a complex system comprised of minerals, soil organic matter (SOM), water and air (Joshi et al., 2009). Soil quality includes mutually interactive attributes of physical, chemical and biological properties, which affect many processes in the soil that make it suitable for agricultural practices and other purposes (Rakesh et al., 2012). The texture, structure colour etc. are important soil physical parameters. Similarly, soil reaction (pH), organic matter, macro and micro-nutrients etc. are also important soil chemical parameters. These properties play important role for the soil fertility and determined after soil testing (Brady & Weil, 2005). In Southern Africa, the most limiting factor to agricultural productivity is soil fertility (Ramaru et al., 2000). The evaluation of soil fertility includes the measurement of available plant essential nutrients and estimation of capacity of soil to maintain a continuous supply of plant nutrients for a crop. Soil is the greatest treasure that human have acquired free of cost and is one of the most valuable natural resources of the world (Brady & Weil, 2005). Soil properties vary spatially and temporally from a field to a larger region scale, and are influenced by both intrinsic (soil formation factors, such as soil parent materials) and extrinsic factors (soil management practices, fertilization and crop rotation) (Cambardella & Karlen, 1999).

Cropping system refers spatial and temporal aspects of crop sequence and management technique used on particular agricultural field over a period of years. Cropping systems are designed to maximize the crop production to achieve human need for food, fiber, other raw materials, wealth and satisfaction (FAO, 2016). Rice-wheat rotation is one of the largest agricultural production systems of the world, occupying 13.5 million ha of cultivated land in South Asia and several million hectares in China (Singh et al., 2013). Rice-Wheat Cropping system is rice based in Nepal with rice alone contributing 20% of GDP and 53% of total cereal production which includes one third of the total calorie intake of Nepalese (Pandey et al., 2021). The intensively cultivated Rice-Wheat system is fundamental for employment, income generation, and livelihood security for millions in South Asia (Singh et al., 2013).

Humans are dependent on plants as their food source and soil is the primary medium for plant growth. It is the source of nutrient element to the plants (Kharal, 2017). Soil, being the source of infinite life is the most crucial and precious natural resource, and not a renewable in short period. Sustainable crop production requires a good understanding of the fertility status of the soil in order to impose appropriate nutrient management strategies (Khadka et al., 2018). Before the introduction of modern high yielding cultivars, net nutrient removal by rice crop was small and even poor soil had the capacity to supply sufficient nutrients to sustainable low yield levels of traditional cultivars (Doberman et al., 1998). Fertility is one of the vital factors of soil productivity which is directly related to the loss or gain of plant nutrients (Magar, 2015). The role of plant nutrients in crop production is well established. The nutrients have to be available for the crops in quantities as required for a yield target. Any limiting or deficient nutrient will limit the crop growth. So, it will be better to understand the soil nutrient status under different cropping system to develop proper soil management strategies helping in designing the planning crop cultivation in proposed area (STSS, 2000). The main objective of this research was to investigate the impact of different cropping systems on soil nutrients dynamic in Ratuwamai, Morang.

Materials and Methods

Study Area

The study was carried out at Prime Minister Agriculture Modernization Project, Rice Zone, Morang Nepal. The study was conducted in Ratuwamai municipality with coordinates, latitude 26º29'37.8" N and longitude 87º38'38" E and elevation from 83 meter above mean sea level. Ward number 6, 7, 8 and 9 was the research site. In the study site almost all farmers have cultivated rice in different scales. They cultivate rice in two season i.e. main season rice and spring season rice.

Soil Samples Collection And Analysis

Research was conducted in Randomized Complete Block Design (RCBD) by selecting field operating on four different yearly cropping systems (Rice-Wheat-Rice, Rice-Mustard-Maize, Rice-Maize and Rice-Mustard-Rice) for 2-3 years as treatments. Major prevailing cropping system in the study site were identified by visual observation and focus group discussion with farmers. The cropping systems were replicated five times comprising a total of twenty-five soil sampling plots. The samples from each plot were collected within the same vicinity having same topography and climate in order to maintain homogeneity within the replication.

Soil samples were collected from each cropping system following the random sampling technique. Soil samples were collected from 0-15cm depth from the surface in each cropping system. Total 5 sub samples were collected from each plot within a replication. These samples were then pooled using standard procedure to get 0.5 kg of composite sample. A total of 25 composite soil samples from each cropping systems were collected, air dried in shade then chemically analyzed for various soil properties. The soil samples were analyzed in regional soil laboratory Jhumka, Sunsari using standard analytical procedure as described in Table 1.

Data Analysis Techniques

Data obtained from soil chemical analysis were subjected to ANOVA analysis appropriate to one way randomized complete block design using R studio. When significant difference existed between treatment means, comparison of the means was done using Fisher-LSD test at 5% significance level.

Results and Discussion

Soil pH Status

The pH value of Rice-Wheat-Rice, Rice-Mustard-Maize, Rice-Maize and Rice-Mustard-Rice based cropping system was in acidic range (pH<6.0). The effects of different cropping systems on soil pH were non significant (Table 3). The highest soil pH (4.48) was found in Rice-Mustard-Rice based cropping system and the lowest soil pH (4.18) was observed in Rice-Mustard-Maize based cropping system. Our results are lined with (Devkota et al., 2019). Addition of excess nitrogen based fertilizers twice in a year during rice cultivation, removal of plant and animal products might be the reason for soil acidity of command area.

Soil Organic Matter Content (%)

The soil organic matter content of Rice-Wheat-Rice, Rice-Mustard-Maize, Rice-Maize and Rice-Mustard-Rice based cropping system was highly significant (Table 3). The highest soil organic matter content (1.84%) was found in Rice-Maize based cropping system and the lowest soil organic matter content (0.54%) was observed in Rice-Mustard-Rice based cropping system with mean value 0.92%. The rating of soil organic matter content in all cropping system was low (< 2.5%). The results of present study are related to (Porpavai et al., 2011) in Rice-legume-Maize based cropping system.

Total Nitrogen (%)

The total Nitrogen content of Rice-Wheat-Rice, Rice-Mustard-Maize, Rice-Maize and Rice-Mustard-Rice based cropping system was highly significant (Table 3). The highest value of nitrogen content (0.19%) was found in both Rice-Mustard-Maize and the lowest nitrogen content (0.02%) was observed in Rice-Wheat-Rice based cropping system with mean value (0.08%). The rating of total nitrogen content in all cropping system was low (< 0.1%) except Rice-Mustard-Maize based cropping system. The present findings are in accordance with (Chaudhary et al., 2015), (Porpavai et al., 2011) and (Yadvinder-Singh & Bijay-Singh, 2001) in Rice-Wheat based cropping system.Nitrogen from rice-wheat systems can often be lost due to ammonia volatilization, denitrification and leaching.

Table 1: Laboratory analysis techniques for varoius soil chemical properties.

Parameters	Analysis method
Soil Texture	Hydrometer Method
Soil pH	Digital pH Meter
Organic Matter Content	Grahams' Calorimetric Method
Nitrogen	Kjeldahl Distillation
Phosphorus	Modified Oslen's Method
Potassium	Ammonium Acetate Extraction Method (Pratt, 1965) using Flame Photometer

Table 2: Classification of soil fertility by National Agriculture Research Council (NARC).

Soil parameters	Low	Medium	High
Soil organic matter (%)	< 2.5	2.5-5.0	> 5.0
Total N (%)	< 0.1	0.1-0.2	> 0.2
Available P (kg/ha)	< 30	30-55	> 55
Available K (kg/ha)	< 110	110-280	> 280
Soil parameter	**Acidic**	**Neutral**	**Alkaline**
Soil pH	< 5.5	5.5-6.5	>6.5

Available Phosphorus (kg/ha)

The available soil phosphorus of Rice-Wheat-Rice, Rice-Mustard-Maize, Rice-Maize and Rice-Mustard-Rice based cropping system was highly significant (Table 3). However, the highest phosphorus content (163.95 kg/ha) was found in Rice-Mustard-Maize based cropping system and the lowest phosphorus content (75.28 kg/ha) was observed in Rice-Mustard-Rice based cropping system with mean value (106.05 kg/ha). The rating of available phosphorus content in all cropping system was high (> 55 kg/ha). Similar results has been found by (Yadvinder-Singh & Bijay-Singh, 2001), (Harish, 2020) and (Gupta et al., 2007). Double application of high dose DAP in rice in summer and in Maize in spring might be the reason of high Phosphorus content in Rice-Mustard-Maize cropping pattern. It has also reported that rice-wheat based cropping system that yields 7 t/ha of rice and 4 t/ha of wheat removes more than 30 kg phosphorus from the soil (Harish M.N, 2020) and (Joshy & Deo, 1976).

Available Potassium (kg/ha)

Potassium content of Rice-Wheat-Rice, Rice-Mustard-Maize, Rice-Maize and Rice-Mustard-Rice based cropping system was statistically highly significant (Table 3). The highest potassium content (169.18kg/ha) was found in Rice-Mustard-Rice cropping system whereas the lowest potassium content (57.76kg/ha) was found in Rice-Wheat-Rice cropping system with mean value (108.44kg/ha). The rating of available potassium content in Rice-Mustard-Rice and Rice-Mustard-Maize cropping system was medium (110-280 kg/ha) and low (< 110kg/ha) in Rice-Wheat-Rice and Rice-Maize cropping system. Similar results are found in (Sumithra etal., 2013) and (Hasanuzzaman, 2018). Most of the soils in the Indo-Gangetic Plain contain illite as dominant clay mineral and are medium to high in ammonium acetate extractable K and so, the response of rice and wheat to applied K are generally small (Yadvinder-Singh & Bijay-Singh, 2001). It might be the reason having highest K content in Rice-Mustard-Rice cropping system. However, Rice-Wheat cropping system that yields 7 t/ha of rice and 4 t/ha of wheat removes 300 kg/ha of potassium from the soil (Harish, 2020).

Soil Texture

The sand and clay content were statistically non-significant for following cropping system whereas available silt content is statistically significant (Table 4).

Soil texture was relative content of particles of various sizes, such as sand, silt and clay in the soil. Water holding capacity, permeability, irrigation requirement and erodibility like factors are highly related to the soil texture of the field (Brady & Weil, 2005). Soil texture has an extremely significant influence on the physical and mechanical behaviors of the soil (Roy et al., 2006).

However, there might not be any review paper which signifies the impact of cropping system on sand, silt and clay content of soil. The above result showing significancy silt might be due to geographical variation. Cropping system might affect soil texture if crop residuals are left on the field. Maize-Barley based cropping system and various tillage system have positive impacts on soil bulk density and total soil porosity (Naeem et al., 2020).

Table 3: Effects of cropping system on soil nutrient status in Ratuwmai Municipality.

Parameters	**Soil pH**	**Soil Organic Matter content (%)**	**Total Nitrogen (%)**	**Available phosphorus (kg/ha)**	**Available potassium (kg/ha)**
Rice-Wheat-Rice	4.32^{ab}	0.63^{bc}	0.02^{c}	80.08^{c}	57.76^{C}
Rice-Mustard-Maize	4.18^{b}	0.68^{b}	0.19^{a}	163.95^{a}	124.46^{B}
Rice-Maize	4.20^{b}	1.84^{a}	0.08^{b}	104.91^{b}	82.35^{c}
Rice-Mustard-Rice	4.48^{a}	0.54^{c}	0.03^{c}	75.28^{c}	169.18^{a}
LSD(0.05)	0.262^{NS}	0.142***	0.013***	15.48***	32.06***
SEM(±)	0.036	0.0106	9.705	126.2	541.5
C.V%	4.42%	11.11%	11.28%	10.59%	21.45%
Grand Mean	4.29	0.92	0.08	106.05	108.44

Means followed by same letter in a column are not significantly different among each other based on Fisher-LSD test at 5% level of significance. *: Significant at 5% level of significance; **: highly significant at 5% level of significance; ***: highly significant at 5% level of significance; NS: Not significant.

Table 4: Effects of cropping system on soil texture status in Ratuwmai Municipality.

Parameters	Sand (%)	Silt (%)	Clay (%)
Rice-Wheat-Rice	42.18[a]	42.06[b]	15.74[a]
Rice-Mustard-Maize	37.32[a]	48.38[a]	14.30[a]
Rice-Maize	40.61[a]	42.14[b]	17.24[a]
Rice-Mustard-Rice	37.04[b]	44.80[ab]	18.16[a]
LSD (0.05)	5.75[NS]	4.68*	4.26[NS]
SEM (±)	17.43	11.57	9.59
C.V%	10.62%	7.67%	18.92%
Grand Mean	39.29	44.34	16.36

Means followed by same letter in a column are not significantly different among each other based on Fisher-LSD test at 5% level of significance. *: Significant at 5% level of significance; **: highly significant at 5% level of significance; ***: highly significant at 5% level of significance; NS: Not significant.

Conclusion

Effects of different Rice based cropping system on soil nutrient status was evaluated in Ratuwamai Municipality, Morang. Soil in all four cropping systems were found to be acidic. The soil organic matter content was recorded highest from Rice-Maize based system and lowest from Rice-Mustard-Rice based system and is statistically highly significant. The SOM content was rated very low which showed that experimental cropping system were deficit in SOM content. The Nitrogen content from all cropping system was also rated low except Rice-Mustard-Maize cropping system and statistically highly significant. The available phosphorus content from all cropping system was also highly significant and rated high which showed that experimental cropping system were excess in phosphorus content. The available potassium content was recorded highest from Rice-Mustard-Rice based system and lowest from Rice-Wheat-Rice based cropping system and is statistically highly significant.The potassium content was rated low to medium which showed that Rice-Wheat-Rice and Rice-Maize cropping system were deficit in K content. Likewise, sand and clay content was recorded statistically non-significant and silt content was recorded statistically significant. The availability of soil nutrients also depends on fertilizer and manure application trend and fertility management practices. Thus, for sustainable management of soil fertility and resources effective nutrient management technique should be coupled with appropriated cropping system. Soil Organic Matter, Nitrogen and Potassium were found to be deficit nutrients at command area of rice zone.

Authors' Contribution

Ashok Sah and Prakash Gurung designed the research plan. Ashok Sah performed experimental work and collected the required data. They analysed the data and prepared the manuscript, critical revised and finalized the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

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