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Research Article

Assessment of Soil Nutrient Status under Different Cropping Systems in Khotang, Nepal

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Abstract
Availability of plant nutrients in rhizosphere is directly influenced by types of crop grown and land use pattern. The experiment was conducted in Diktel Rupakot Majhuwagadhi Municipality, Khotang, Nepal to assess the soil nutrients dynamics as influenced by different cropping system. Five different cropping systems (Rice – Wheat, Maize – Millet, Maize – Vegetables, Ginger and Cardamom) were selected as treatments and all treatments were replicated for five times for blocking in Randomized Complete Block Design. Soil samples from 0-15 cm depth were collected from each site and evaluated for soil pH, soil organic carbon (SOC), total nitrogen (N), available phosphorus (P), and available potassium (K). All the tested parameters except N were found to be significantly affected by cropping system. Soil in all five cropping systems were found acidic (pH<6.5) in nature with pH ranging from 5.180-6.640. The SOC was recorded highest (3.102%) from Cardamom based system and lowest amount of SOC was observed in Ginger based system. The highest amount of P (32.14 mg/kg) was reported in Maize – Vegetables cropping system and lowest P content (5.72 mg/kg) was recorded from Cardamom based system. P content in Ginger based system (31.51 mg/kg) was statistically at par with that of Rice – Wheat system. The highest K content (306.50 mg/kg) was recorded from Maize – Vegetable cropping system and lowest K content (34.80 mg/kg) was observed in Cardamom based system which is statistically similar to Rice –Wheat (35.70 mg/kg) and Maize –Millet systems (77.20 mg/kg). The result indicated that cropping systems have huge impact on plant nutrient dynamics in soil.

Keywords: Soil fertility; soil nutrients dynamics; cropping system; soil organic matter

Introduction
Soil is a most valuable natural resource which is vital to life of all living and non-living things on the planet. Directly or indirectly, all living beings use soil for their shelter, food and other requirements. Soil is the primary medium for plant growth as it provides physical supports by anchorage and supply necessary plant nutrients (Pande, 2008). So, soil health is an important parameter to promote the healthy and vigorous growth of the plants. The physical, chemical and biological properties of soil determine status of soil health. Any modification in soil properties within agricultural zone limits the healthy growth of plants and crops as a whole suffer (Dutta & Dutta, 1995). Because agriculture is a soil-based industry that extracts nutrients from the soil, effective and efficient approaches to slowing that removal and returning nutrients to the soil will be required in order to maintain and increase crop productivity and sustain agriculture for the long term (Gruhn *et al*., 2000). Farming practices mines the soil nutrients from root zone thereby

decreasing their availability in soil. Intensification of farming including multispecies cropping without effective soil management thus depletes plant available soil nutrients from soil. Conservation of soils quality is necessary to intensify the food production which is essential to fulfil the growing demand of food with the increment of world population.

Soil fertility is the sum of physical, chemical, and biological factors that affect soil structure and porosity, availability of macro and micro nutrients, and the activity of biological organisms. Together, these factors influence crop growth and impose limitations on crop yield (Rowell, 1996). Soil texture, soil pH, soil nutrients, organic matter and microbial activities are important soil properties influencing soil fertility. The knowledge of soil texture is necessary to understand soil behavior and their management (Brady & Weil, 1999) as various soil properties including porosity, water and nutrient retention, rate of organic matter decomposition, infiltration, CEC etc. are dependent on soil texture. Similarly, soil pH influences several soil reactions (Bohn *et al*., 2001) and soil processes including ion exchange and plant nutrient availability (Rowell, 1996). Soil organic matter is composed of a wide range of organic substances including living organisms, carbonaceous remains of organisms inhabiting soil, and products of metabolic activities in the soil. Soil organic matter is considered as a most important element of integrated soil fertility management as it plays key role in various soil processes (Brady & Weil, 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). In order to optimize the soil health conditions ensuring agroecosystem sustainability, detail understanding of the impact of continuous cropping on soil physical, chemical, and biological properties is needed (Aparicio & Costa, 2007). The amount of organic matter in soil rhizosphere, which can be affected by the quantity and type of carbon inputs from crop biomass, FYM and compost and by management practices affecting the decomposition rate and stratification of soil organic matter, determines the effects of various cropping system on soil quality (Magdoff & Weil, 2004). According to (Wang *et al*., 2014) climate and geology are the important factors affecting soil properties on regional and continental scale, however land use may be the dominant factor of soil properties under small catchment scale. Cropping system treatments have considerable impact on all soil characteristics measured especially in the surface soil layer (Jokela *et al*., 2011). Farming in soil mines the plant nutrients from the rhizosphere and reduces soil organic matter content through repetitive harvesting of crops. This decline continues until adequate amount of organic amendments are replenished through appropriate management practice or until a fallow period allows a gradual recovery through natural ecological processes (FAO Bulletin). Yield of rice-wheat cropping system in South Asia is declining due to soil degradation, nutrient level depletion, and water pollution resulted from intensive farming, imbalance use of fertilizers and faulty irrigation practices (Ladha *et al*., 2003. Improved management practices such as no tillage, crop residue addition, cover cropping, crop rotation, and balanced fertilizers and manure application build up organic carbon content in soil (Wilhelm *et al*., 2007). Improved soil carbon accumulation facilitates microbial activity, root growth, improve buffering capacity, nutrient and water supply and soil aggregation formation (Lal *et al*., 2007). Using continuous no-till cropping systems, using cover crops, applying solid manure, and using diverse rotations that include high residue crops, which increase organic matter content and improve soil buffering capacity, minimizing changes in pH level (USDA, 1994). Similarly, integrating legumes in cropping system is often associated nitrogen recycling and increases availability of nitrogen in soil.

In past years, cropping systems in mid hill of Nepal were coupled with livestock production and forestry, with trees and crops providing fodder and bedding materials for livestock, which in turn provide draft power and manure (Brian, 1992). In this system soil fertility was largely maintained by the application of compost and manure, but in recent years a decline in soil fertility has been reported (Shrestha & Shrestha, 2000). Intensification of crop production, perhaps two to three crops per year, without addition of substantial amount of soil amendments has contributed to a decline in soil fertility (Turton *et al*., 1995). More profit-oriented production, with limiting resources, diverted the farming practice toward mono-cropping resulting into detrimental effects on soil fertility (Shrestha & Shrestha, 2000). Individual farmers within the Nepalese hill communities recognize the importance of soil fertility to productivity and to their livelihoods. Consequently, they adopt a variety of practices to manage soil fertility depending upon whether it is rain-fed terrace (*bari or tar* land) or irrigated land (*khet*) (Kiff *et al*., 1995). However, these efforts doesn’t seems promising to sort out all the problems associated with soil quality and fertility management. Therefore, further research and nutrients analysis is necessary to estimate nutrients storage in cultivated farmland so that appropriate land use plan which ensures sustainable soil management could be suggested. The main objective of this research was to investigate the impact of different cropping systems on soil nutrients dynamics in Khotang.

Materials and Methods

Study Site

Khotang is hilly district of Eastern Nepal which is occupied with sloppy terrain and undulating topography. Khotang district spreads from 26º50' N to 27°28' N latitude and 86º26' E to 86º59' E longitude. The district has total land area of 1,591 sq.km. The altitude ranges from 142 meter above sea level to 3620 meter above sea level. Similarly, climate in Khotang ranges from sub-tropical in lowland to temperate in high hills with min. temperature 5ºC to max. 30ºC. The average annual rainfall is recorded upto 168.9cm from Diktel. Soil is characterized by slightly acidic soil with clayey loam, loamy, and sandy loam texture.

Soil samples collection and analysis

Research was conducted in Randomized Complete Block Design (RCBD) by selecting field operating on five different cropping systems (Rice-Wheat, Maize-Millet, Maize-Vegetable, Ginger, Cardamom) since 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 block were collected within the same vicinity having same topography and climate in order 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 6-8 subsamples were collected randomly from each plot within a replication. These subsamples were then pooled using standard procedure to get 0.5 kg of composite sample. A total of 25 composite soil samples were collected, air dried in shade then chemically analyzed for various soil properties. The soil samples were analyzed in laboratory using standard analytical procedure as described in Table 1.

Data obtained from soil chemical analysis were subjected to ANOVA analysis appropriate to one way randomized complete block design using R. When significant difference existed between treatment means, comparison of the means was done using Duncan's Multiple Range Test (DMRT) at 5% significance level.

Results and Discussion

The output of statistical analyses was interpreted in terms of NPK level, soil pH and organic carbon content as well as DMRT test at 5% level of significance. The soil chemical properties influencing fertility and organic matter content varied between different cropping systems.

The pH value of Rice – Wheat, Maize – Millet and Cardamom based cropping system was in acidic range ($pH<6.0$) while pH in Maize – Millet and Ginger based cropping system was in neutral range ($6.0<pH>7.0$). The effects of different cropping systems on soil pH was highly significant ($P<0.001$) (Table 2). The highest soil pH (6.64) was found in Maize – Vegetable cropping system and lowest soil pH (5.18) was observed in cardamom based system. Soil pH in Rice – Wheat system (5.62) was statistically similar to that of cardamom based cropping system. According to Sevostianova *et al*. (2011) irrigation type and amount of water applied significantly affected soil pH; sprinkler and drip irrigation technique often increases soil pH in vegetable garden as leaching of basic cation is limited due to restricted percolation. Similarly, acidity in cardamom orchard might be due to lower base saturation resulted from production of H^+ ion during nitrification by alder tree, with H^+ ion displacing basic cation from soil micelle as reported by (Van Cleve & Viereck, 1972). Sharma *et al*. (2009) also reported that increased water percolation due to high rainfall leads to accelerated leaching of basic cations and nitrates from the soil profile which resulted acidity in Alder-Cardamom agroforestry system.

Table 1: Laboratory analysis techniques for various soil chemical properties

Parameters	Study method
Soil pH	Glass-calomel electrode pH meter using 1:1 soil water ratio (Cottenie *et al*., 1982)
Organic matter	Degtjareff or chromic acid titration method (Wakly & Black, 1934)
Total nitrogen	Kjeldhal distillation unit (Bremner and Mulvaney, 1982)
Available phosphorus	Modified Olsen bicarbonate method (Watanabe and Olsen,1965)
Available potassium	Ammonium acetate extraction method (Simard, 1993)

Table 2: Effects of cropping system on soil nutrients dynamics at Diktel, Khotang, Nepal (2018)

Treatments	**Soil pH**	**Soil Organic Carbon (%)**	**Total Nitrogen (%)**	**Available Phosphorus (mg/kg)**	**Available Potassium (mg/kg)**
Rice – Wheat	5.62^{c}	2.59^{bc}	0.23	8.13^{b}	35.69^{d}
Maize –	5.68^{bc}	2.97^{ab}	0.25	8.90^{b}	77.21^{c}
Millet	6.64^{a}	2.93^{ab}	0.26	32.14^{a}	166.47^{a}
Maize –	6.18^{ab}	2.43^{c}	0.21	31.51^{a}	131.41^{b}
Vegetables	5.18^{c}	3.10^{a}	0.25	5.72^{b}	60.39^{cd}
Ginger					
Cardamom					
LSD (0.05)	0.52**	0.45*	0.058^{ns}	7.96**	27.34**
SEM (±)	0.17	0.15	0.019	2.65	9.12
C.V %	6.70%	12.10%	17.60%	34.40%	21.6%
Grand Mean	5.86	2.81	0.25	17.28	94.2

Means followed by same letter in a column are not significantly different among each other based on DMRT at 5% level of significance.

The soil organic carbon (SOC) content was significant (P<0.05) among different cropping systems (Table 2). The highest SOC content (3.10%) was obtained from cardamom based system and lowest SOC content (2.43%) was recorded from field operating on ginger based system. Though, there was no trend of applying any organic amendments in cardamom, amount of soil organic carbon in cardamom field still observed highest among all. (Innangi *et al*., 2017) reported that addition of leaf litter from Alder tree was the main source of soil organic matter in Alder-Cardamom agroforestry system; accelerated decomposition of nitrogen rich leaf litter built up organic carbon content in the topsoil of cardamom orchard. The effects of cropping system on total nitrogen was statistically non-significant (P<0.05) (Table 2). However, nitrogen content in Maize-Vegetable system (0.26%) was comparatively higher than other cropping systems and ginger based system (0.21%) contained lowest nitrogen level among all. The effects of cropping system on available soil phosphorus was highly significant (P<0.001). The highest available phosphorus (32.14 mg/kg) was found in Maize – Vegetables cropping system and it was at par with and Ginger based system (31.51 mg/kg). Availability of soil Phosphorus was recorded lowest (5.72 mg/kg) from cardamom based system. Similarly, Phosphorus content in Rice – Wheat (8.13 mg/kg) and Maize – Millet (8.90 mg/kg) systems were statistically similar to Cardamom based system. The available potassium content in soil was highly significant (P<0.001) among different cropping systems (Table 2). The highest potassium (166.47 mg/kg) was obtained from Maize – Vegetable system and lowest amount of soil potassium (35.69 mg/kg) was recorded from Rice – Wheat system. The potassium availability in Ginger based system (131.41 mg/kg) was significantly higher (P<0.001) than Maize – Millet (77.21 mg/kg) and Cardamom (60.39 mg/kg) based cropping system. Highest amount of available Potassium in Maize – Vegetable system might have resulted from accumulation of K^+ ion on soil surface due to use of water saving irrigation technique that limits the leaching of K^+ ion. Rice –Wheat system, on the other hand, considered as an intensive cropping system: both Rice and Wheat are exhaustive feeder and heavily mines nutrients from the soil. It was reported that Rice – Wheat system yielding 7 t/ha rice and 4 t/ha wheat removes more than 300 kg nitrogen, 30 kg phosphorus and 300 kg per ha potassium from the soil (Singh *et al*., 2003). Therefore, lowest amount of available Potassium in Rice – Wheat system might be due to removed amount of Potassium by plant stand and losses through leeching exceeding addition via fertilizers and manure.

Conclusion

Effects of cropping system on soil nutrients dynamics was evaluated at Khotang, Nepal. Soil in all five cropping systems were found to be acidic. The soil organic carbon was recorded highest from Cardamom based system and lowest from Ginger based system. The SOC content was rated medium to high which showed that neither of the experimented cropping systems were deficit in SOC. The nitrogen content form all cropping systems were recorded high and statistically non-significant. The highest available phosphorus was obtained from Maize – Vegetables cropping system and lowest amount of phosphorus was recorded from Cardamom based system. The available potassium was also varied with cropping systems. The highest potassium content was recorded from Maize – Vegetable cropping system and lowest potassium content was observed in Rice – Wheat system. The availability of soil nutrients also depends on fertilizer and manure application trend and fertility management practices. Thus, for sustainable management of soil resources effective nutrient management technique should be coupled with appropriated cropping sequence.

Author's Contribution

Pawan Devkota & Baburam Khanal designed the research plan; Pawan Devkota & Dipendra Aryal performed experimental works & collected the required data. Pawan Devkota, Dipendra Aryal & Baburam Khanal analysed the data; Pawan Devkota & Dipendra Aryal prepared the manuscript, critical revised and all authors finalized the manuscript.

Conflict of Interest

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

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