Assessment of Soil Fertility Status Using Soil Nutrient Index in Three Landuse Systems in Bhutan

Suraj Chhetri[k], Tayan Raj Gurung[k], Tashi Uden[k], Madhanlal Gurung[k], Karma Lekphel Jamtsho[k]

ABSTRACT

The study was conducted to assess soil fertility status using soil nutrient index in three land use systems (dryland, wetland and orchard) in Bhutan. The total number of soil samples varied from 71 to 836 depending on soil variables. Soil samples were collected from three different land uses between July 2013 to December 2018, and analyzed, interpreted for pH, organic carbon, organic matter, primary nutrients, carbon/nitrogen ratio, total exchangeable bases, cation exchange capacity and base saturation. The data on soil variables were categorized into very low, low, medium, high and very high classes based on soil fertility ratings and nutrient index. The results revealed that soil reaction in three different land uses varied from strongly acidic to slightly alkaline with pH values varying from 4.04 to 8.20. Soil fertility with respect to organic matter was high in dryland and medium in others. In all the land uses, status of nitrogen was low, organic carbon in medium and CN ratio in good category. The level of available phosphorous and cation exchange capacity was medium in dryland and orchard but low in wetland. Available potassium and exchangeable bases were medium in dryland and low in others. Base saturation was in low category in orchard and medium in other two land uses. A positive and significant correlation of organic matter was found with nitrogen, potassium and cation exchange capacity while significant negative correlations existed between soil pH and nitrogen, organic matter and cation exchange capacity. Based on the criteria for calculating nutrient index value, besides low content of nitrogen in dryland, the soil fertility was characterized as medium in dryland, low in wetland and low - medium category in orchard.

Keywords: *Soil fertility, Soil nutrient Index, Land use*

1. Introduction

Soil is the fundamental and most important natural resource which takes long time to renew. Soil fertility is a dynamic natural property that can change through the impact of natural and anthropogenic factors (Kavitha & Sujatha, 2015). With the increase in human population, disturbance on the earth's ecosystem and soils to produce more food and fiber will place greater demand on soils to supply essential nutrients. Intensive cropping for enhanced yield removes substantial amounts of nutrients from soil. Imbalanced and inadequate use of chemical fertilizers, improper irrigation and various cultural practices also deplete the soil quality rapidly (Medhe,

Corresponding author: *surajchh@gmail.com*
[k] National Soil Serivce Centre, DoA, Semtokha

Tankankhar, & Salve, 2012). Soil fertility alters throughout the crop season each year due to change in the quantity and availability of mineral nutrients and crop uptake. Hence, evaluation of fertility status of the soils of an area or a region is an important aspect in the context of sustainable agriculture (Singh & Mishra, 2012). Soil testing assesses the current fertility status and provides information regarding nutrient availability in soils which forms the basis for sustainable soil fertilizer management for maximizing crop yields and to sustain optimum soil health. For proper soil fertility management, farmers should know what amendments are necessary to optimize the productivity of soil. Currently, information on soil fertility status of different land use in Bhutan is lacking. Hence, this study focuses on assessment of soil fertility status using nutrient index approach in three predominant land uses systems (dryland, wetland, and orchard) in Bhutan.

2. Materials and Method

The National Soil Services Centre (NSSC), Department of Agriculture, Ministry of Agriculture and Forests (MoAF), Bhutan, conducted several Farmer-Extension Use Fertilizer Trials (FEFUT) especially in rice, wheat and potato. Long term studies on potato, maize and citrus were also carried out. Several soil fertility investigations were conducted across the country. The soil samples collected during the field work from different land use were analyzed in Soil and Plant Analysis Laboratory (SPAL) of the NSSC. The soil nutrient data pertains to the field work carried out from July 2013 to December 2018.

2.1 Soil sampling

Soil samples collections from dryland, wetland and orchard are explained below:

i) The selected dryland and wetland plots were divided into 8-10 parts in random to represent the total area. Soil samples from minimum of 8-10 points were collected at a depth of 20 cm using soil augur. Soil samples were mixed together to form one composite sample of 1 kg. The soil was then sealed in plastic bag with proper level indicating name, location and plot size.

ii) Soil samples from citrus and apple orchards were taken from 8-10 randomly selected point from the orchard. The orchards were divided into at least 8-10 parts in random for an area of not more than 1 ha. Following the tree canopy, soil samples from minimum of 8-10 parts were collected at a depth 15 cm representing top soil and 40 cm representing sub-soils from the same pit using soil augur. Samples were mixed separately to form two composite samples, top and sub soil respectively. The composite sample of 1 kg was sealed in plastic bag with proper level indicating name, location and plot size.

2.2 Laboratory Analyses

The soil samples were analyzed at Soil and Plant Analytical Laboratory (SPAL) under NSSC. The plant nutrient parameters analyzed were pH, organic carbon (OM), total nitrogen (N), available phosphorous (P), available potassium (K), cation exchange capacity (CEC) and base saturation

(BS) using standard analytical method. Soil reaction (pH) was determined by using 1:2.5 (g/v) soils: water suspension with the calibrated pH meter (Black, 1965). OM was determined by oxidizing at a temperature of approximately 120° C with a mixture of potassium dichromate and concentrated sulphuric acid following wet combustion method of Walkley and Black (1934). Exchangeable cations (BS) (Viz., Ca^{2+} , Mg^{2+}, Na^{+}, and K^{+}) were determined directly in a 1.0 mole neutral ammonium acetate filtrate using flame photometer for sodium and potassium and atomic absorption spectrometer (AAS) for calcium and magnesium as described by Black (1965). Total N was determined by semi micro Kjeldahj method using segmented flow analyser as described by Black (1965), Krom (1980) and Verdouw, Van Echteld and Dekkers (1977). Available K was extracted using $CaCl_2$ solution and the extract potassium was determined using flame photometer as described by Steele, Ramsey and Kanel (1984). Available P was determined by Bray I method using segmented flow analyzer as described by Bray and Kurtz (1945). CEC was determined using ammonium acetate at pH <7.5 and analyzed through segmented flow analyzer as described by Black (1965), Krom (1980) and Verdouw et al (1977). Moisture content was determined by drying the soil sample overnight at 105° C. The moisture correction factor was calculated from moisture content.

2.3 Soil fertility rating chart

The fertility status of the soils, different soil physio-chemical properties were classified based on the soil nutrient status rating class as given in Table 1.

Table 1. The soil analysis result: very low, low, medium, high and very high

Soil variables	Very low	low	Medium	High	Very high
pH(H20)	<4.5	4.6.5.5	5.6-6.5	6.6-7.5	>7.5
N%	<0.1	0.1-0.19	0.2-0.49	0.5-0.99	>1.0
OC%	<0.6	0.6-1.1	1.2-3.0	3.1-4.9	>5.0
OM%	1.00	1.90	5.20	8.43	>8.43
C:N ratio	9.9	10-14.9	15-19.9	20-49.9	>50
Av. P (mg/kg)	<5	5-14.9	15-29.9	>30	
Av.K (mg/kg)	<40	40-99	100-199	200-299	>300
ExBases (me/100g)	<3	3.0.74	7.5-14.9	15-29.9	>30
CEC (me/100g)	<5	5-14.9	15-24.9	25-39.9	>40
BS%	<35	35-49.9	50-64.9	65-79.9	>80

Source: RGoB/DASA, 1995 as modified by BSS 2001**.**

Where, N%= Total nitrogen percent; OC% = organic carbon percent; OM%= organic matter percent; C:N= carbon: nitrogen ratio; Av. P = available phosphorous; Av. K= available potassium; ExBases = total exchangeable bases; CEC = cation exchange capacity; BS% = base saturation percent

2.4 Nutrient index value

In order to compare the levels of soil fertility of one area with those of another it is necessary to obtain a single value for each nutrient (Denis, Patel, Kamara, & Saidu, 2016). The nutrient index introduced by Parker, Nelson, winters and Miles (1951), modified by Pathak (2010) and Kumar et al. (2013) was used. The nutrient index is a three tier system used to evaluate the fertility status of soils based on the percentage of samples in each of the three classes, i.e., low, medium and high and multiplied by 1, 2 and 3 respectively. The sum of the figures thus obtained is divided by 100 to give the index or weighted average as given in the equation below:

$$Nutrient\ Index = \{(1xA) + (2xB) + (3xC)\} \div TNS$$

Where A = Number of samples in low category; B = Number of samples in medium category; C = Number of samples in high category, TNS= Total number of samples. The rating chart is given in table 3.

Table 2. Nutrient index with range and remarks

Nutrient index	Range	Remarks
I	>1.67	Low
II	1.67-2.33	Medium
III	<2.33	High

Source: Evaluation of soil fertility status in various agro ecosystems of Thrissur district, Kerala, India. International Journal of Agriculture and Crop Sciences

2.5 Statistical Analyses

Descriptive statistics in the form of mean, minimum, maximum, standard deviation, standard error were determined. Correlation was analyzed using SPSS software version 16.0.

3. Results and Discussion

The number of soil samples assessed to study the soil fertility status using soil nutrient index for different land use are presented in Table 3.

Table 3. Number of soil samples evaluated to assess the soil fertility status using SNI for different land types

Soil Variables	Dry land	Wet land	Orchard
	No of soil samples		
pH($H_2$0)	591	414	836
N%	591	212	836
C%	591	212	828
OM%	591	404	836
C:N ratio	525	404	816
Av. P (mg/kg)	591	413	836
Av.K (mg/kg)	591	414	835
ExBases (me/100g)	205	71	664
CEC (me/100g)	206	273	641
BS%	205	273	678

Where, N%= Total nitrogen percent; OC% = organic carbon percent; OM%= organic matter percent; C:N= carbon: nitrogen ratio; Av. P = available phosphorous; Av. K= available potassium; ExBases = total exchangeable bases; CEC = cation exchange capacity; BS% = base saturation percent

Table 4. Descriptive statistics of soil variables in three landuse

Land use	Soil variables	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Dryland	pH(H20)	5.87	0.59	0.024	4.49	8.01
	N%	0.25	0.10	0.004	0.06	0.90
	OC%	2.88	1.27	0.052	0.10	7.00
	OM%	4.93	2.21	0.091	0.12	12.04
	C:N ratio	12.56	5.45	0.224	0.37	44.29
	Av. P (mg/kg)	38.28	43.85	1.804	0.05	318.54
	Av.K (mg/kg)	171.29	90.85	3.737	4.30	613.80
	ExBases (me/100g)	11.85	5.258	0.357	1.86	36.39
	CEC (me/100g)	21.44	7.03	0.490	2.14	45.14
	BS%	58.87	49.28	3.442	9.31	701.65
Wetland	pH(H20)	5.77	0.74	0.036	4.49	8.16
	N%	0.13	0.07	0.005	0.01	0.35
	C%	1.59	0.787	0.054	0.06	4.50
	OM%	2.58	1.20	0.060	0.10	7.74
	C:N ratio	13.33	8.86	0.440	0.43	89.53
	Av. P (mg/kg)	22.84	35.037	1.720	0.05	216.50
	Av.K (mg/kg)	75.60	81.449	4.000	0.05	630.0
	ExBases (me/100g)	5.01	4.77	0.566	0.13	15.42
	CEC (me/100g)	10.53	4.26	0.258	2.80	32.0
	BS%	65.23	37.20	2.251	2.43	169.60
Orchard	pH(H20)	5.57	0.72	0.020	4.04	8.20
	N%	0.22	0.14	0.005	0.01	1.40
	C%	2.32	1.02	0.040	0.01	6.70
	OM%	3.95	1.77	0.060	0.02	11.52
	C:N ratio	12.87	8.55	0.300	0.13	92.00
	Av. P (mg/kg)	38.68	68.19	2.360	0.03	566.85
	Av.K (mg/kg)	93.49	71.37	2.470	0.05	462.12
	ExBases (me/100g)	7.32	4.73	0.180	0.47	27.39
	CEC (me/100g)	20.18	7.80	0.310	0.04	53.26
	BS%	39.96	29.87	1.15	1.91	318.14

3.1 Soil reaction (pH)

The pH of the soils of three land uses ranged from 4.04 to 8.20 indicating extremely acid to alkaline (Table 4). On assessing the soil acidity, it was found that 61% of samples were within medium range of soil reaction in dryland, 37.7% in wetland and 47% in orchard. Only less than 1% of the samples were within extremely acid range in dryland and wetland and 5% in orchard. Wetland had the maximum number of soil samples within alkaline range with 2.42%, 1.2% in orchard and 0.68% in dryland respectively (Figure 1). The mean value of the soil samples analyzed were in medium range (5.74), slightly acidic in nature. This could be due to prevailing geology which is dominated by granitic genesis in the north and phyllite schist in the south (Norbu & Floyd, 2001) which produce acid and acidity is aggravated due to leaching and soil erosion which washes alkaline elements (calcium, magnesium, sodium and potassium) away (Bradford, 2014).

3.2 Organic carbon (OC)

The OC percent of the three land uses varied from 0.01 to 7.0 (Table 4) with average of 2.26. Wetland had the maximum number of soil samples within low range (28.78%), orchard (9.42%) and dryland (6.6%). Medium to high level of OC was observed in orchard (88.16%), dryland (84.44%) and in wetland (71.22%) (Figure 1).

3.3 Organic matter (OM)

The OM percent of three land uses varied from 0.02 to 12.04 (Table 4) indicating very low to very high OM content in the soil. High to very high level of OM was observed in dryland (42.47%) followed by orchard (21.31%) and wetland (4.7%).Wetland had the maximum number of soil samples with low level of OC (28.78%) and OM (32.67%) (Figure 1). The low levels of OC and OM in wetland may be due to less usage of organic manure in major rice growing dzongkhags (Yeshey, Bajgai, & Ghimiray, 2014).

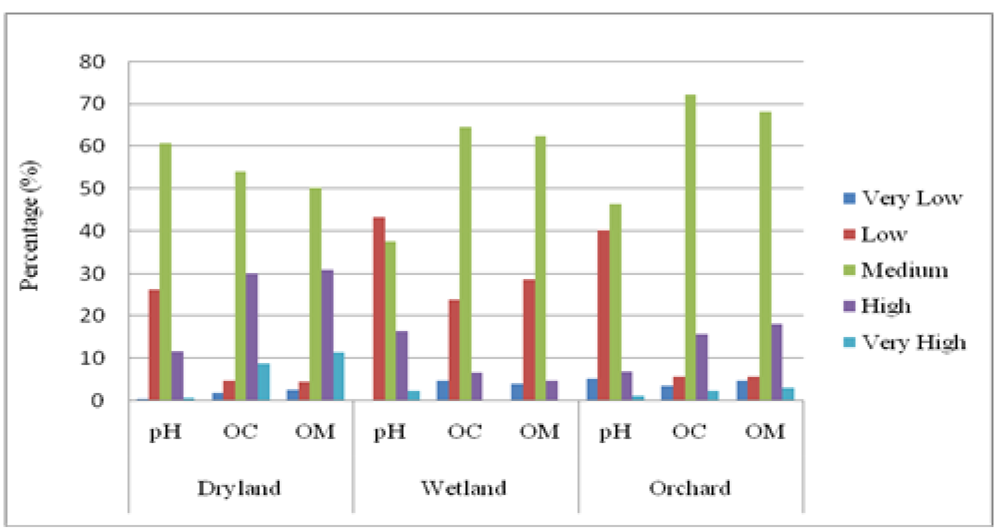

Figure 1. % pH, organic carbon and organic matter of dryland, wetland and orchard

3.4 Total Nitrogen (N)

The N percent of the soils of three land uses varied from 0.01 to 0.09 (Table 4) with a mean value of 0.2. The means of dry land and orchard was higher than the mean of wet land (0.13). The low level of N content in wetland soils could be due to low level of OM (32.67%) (Figure 2), since OM is one of the main sources of N requirement of the crops (Kavitha & Sujata, 2015). Out of cumulative total of 1639 soil samples analyzed for N, only 2.86% of the soils were observed within very high to high range, 48.63% within medium range and 48.51% within low to very low range. The low level of N content may be related to soil management and moreover N content in soils is dependent on temperature, rainfall and altitude. In addition, continuous and intensive cultivation leading to high crop removal together with insufficient replenishment could be the reason for high degree of N deficiency in these soils (Denis et al., 2016).

3.5 Phosphorous (P)

The P level of the soils of three land uses varied from 0.03 – 318.54 mg/kg (Table 4) with average P of 33.27. Wetland had the maximum number of soil samples (62.96%) within very low to low range, followed by orchard (50.24%) and dryland (40.44%) respectively. Excess level of P content in dryland (40.61%) wetland (20.58%) and in orchard (33.25%) was also observed (Figure 2). Due to acidic nature of the soils, phosphate ions react with aluminum and iron to form less soluble compounds (Jensen, 2010) and with imbalanced usage of phosphatic fertilizer over a period of time, phosphate level could have built up in the soils resulting in excess levels. Excess level of P in the soil not only impairs the availability and uptake of essential nutrients by plants but also leads to soil and water pollution (Kavitha & Sujata, 2015).

3.6 Potassium (K)

The K level of the soils of three land uses varied from 0.05 – 630 mg/kg (Table 4) indicating very low to very high K content (Table 4) with average of 113.46 mg/kg. The K deficiency level was low in dryland (21.15%), high in orchard (64.07%) and in wetland (73.91%) (Figure 2). The low content of K in orchard soils might be due to the low use of K containing fertilizers especially in citrus (NSSC 2013). The probable reason for low level of K in wetland could be due to leaching condition brought in by irrigation coupled with soil acidity which does not permit retention of potassium on the soil exchangeable complex (Kavitha & Sujata, 2015). Medium to high K content was recorded in dryland (78.85%), wetland (26.09) and in orchard (35.93%) (Figure 2). The low level of K content is not much of concern as soil parent materials are generally K rich (Norbu & Floyd 2001).

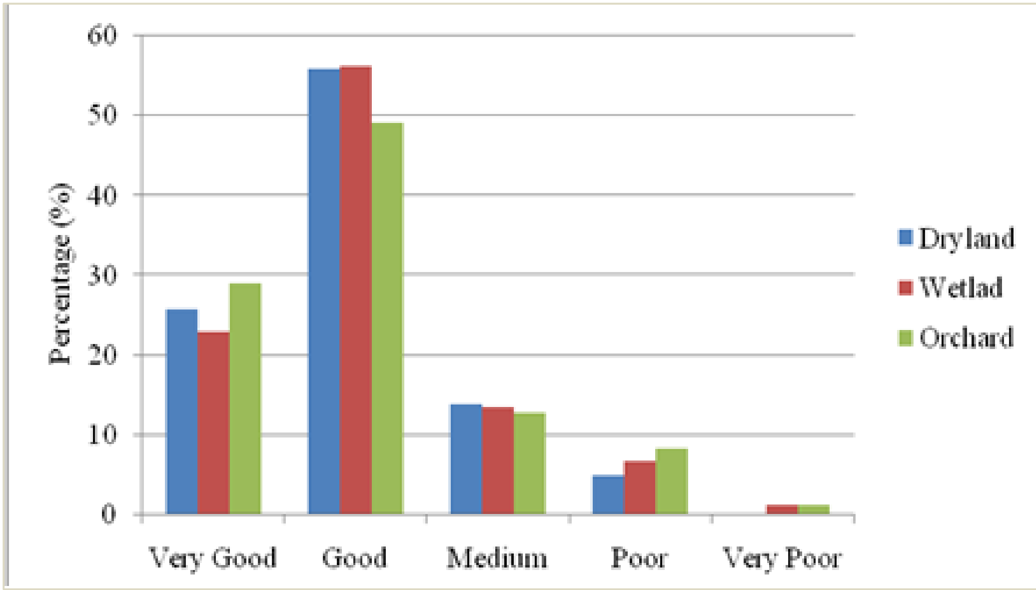

Figure 2. % N, P, K content of dryland, wetland and orchard

3.7 C/N ratio (CN)

The level of CN ratio varied from 0.13 to 92 (Table 4) with average of 12.92 in the soils of three land uses. The CN was within good to very good range in all land uses (Figure 3) probably due to good OC and low level of N content.

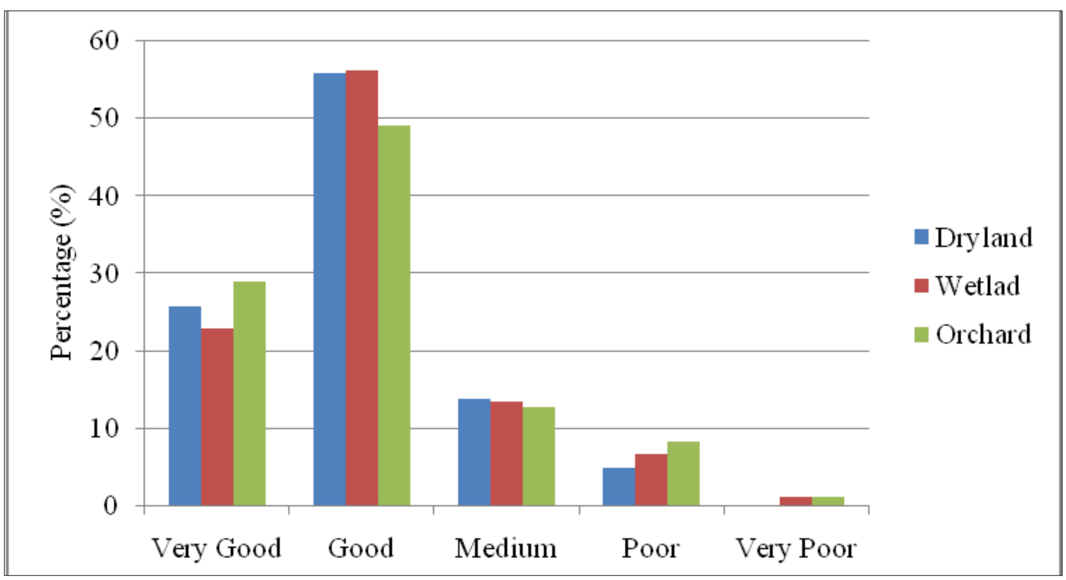

Figure 3. % CN content of soils of three landuse

3.8 Exchangeable bases (Exbases)

The Exbases (calcium, magnesium, potassium and sodium) of the soils ranged from 0.13 to 36.39 me/100g (Table 4) with average of 8.06. The levels of Exbases were within medium to high in dryland (81.47%), orchard (43.68) and in wetland (39.44%) (Figure 4).

3.9 Cation exchange capacity (CEC)

The CEC of the soils of three land uses ranged from 0.04 to 53.26 (Table 4) indicating very low to very high ability of the soil to hold or store exchangeable cations. On assessing the soil CEC, it was found that 86.06% of samples were within very low to low range in wetland, 28.7% in orchard and 20.87% in dryland. Dryland had the maximum number of soil samples within medium to high range with 81.47%, 70.36% in orchard and 13.92% in wetland respectively (Figure 4). The mean values of the soil samples analyzed were within medium range (17.38%). The probable reason for low CEC in wetland could be due to less content of OM (32.67%) and soil acidity with pH >5.5 (39%) and leaching of cations especially in rice growing area.

3.10 Base saturation (BS)

The BS percent of the soils of three land uses ranged from 1.91 to 701.65 (Table 4) with mean of 54.69. The level of BS of the soils varied from very low to medium in orchard (85.99%), dryland (68.78%) and in wetland (49.09%). Maximum number of soil samples having high BS was recorded in wetland with 50.91%, 31.22% in dryland and 14.01% in orchard (Figure 4). BS and pH are positively correlated; low pH would have low BS (Leticia 2017) that could be the reason having maximum soil samples within very low to medium range. The variations in the level of BS in wetland with 50.91% of soil samples within high range could be due to less number (n=273) of soil samples interpreted for BS as compared to pH (n=414).

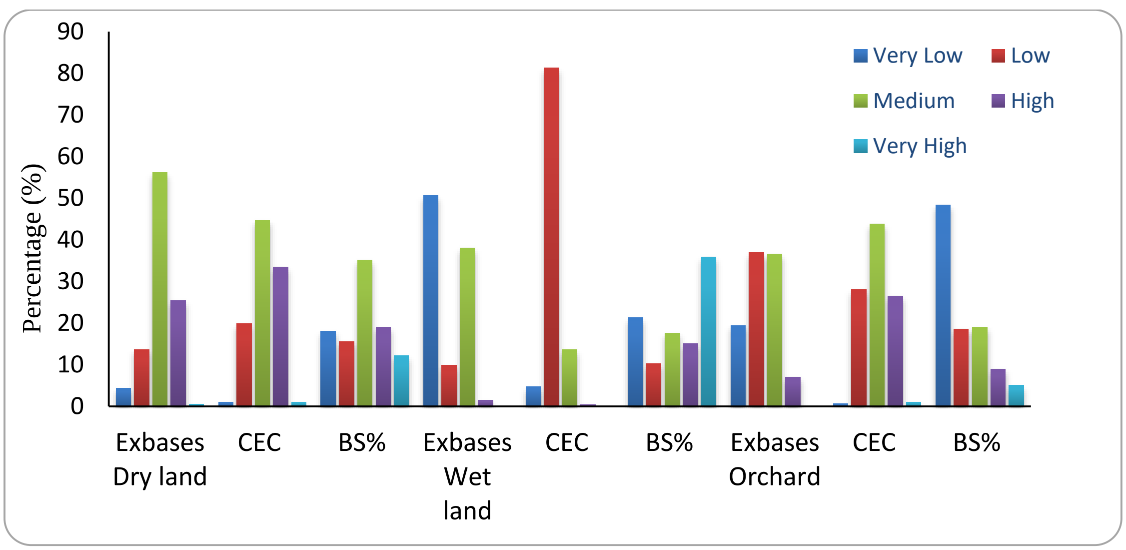

Figure 4. % Exbases, CEC, BS content of dryland, wetland and orchard

3.11 Relationship among selected soil variables

The soil pH exhibited significant but negative correlation with N and CEC, negative and non-significant correlation with OM. N was significantly correlated with OM, K, CEC, but negatively correlated with BS which was non-significant. Negative correlation was also observed between N and P at significant level. OM was significantly correlated with K and CEC but negative and significant correlation was recorded with P and BS. Available P was significantly correlated with K and BS, and negative non-significant correlation was observed with CEC but significant negative correlation was recorded with N. Available K was significantly correlated with all soil variables. CEC and BS were negatively correlated at significant level (Table 5). Negative and significant correlation between soil pH and N indicated that an increase in soil pH decreases N, which might be due to volatilization loss of N with rise of soil pH (Bhat et al., 2017). Similar results were also reported by Khokhar et al. (2012) and Patil, Saler and Gaikwad (2015) indicating significant and negative correlation between soil pH and N.

Soil Variables	pH	N	OM	P	K	CEC	BS
pH	1	-.072**	-.033	.115**	.404**	-.120**	.552**
N		1	.475**	-.071**	.170**	.382**	-.015
OM			1	-.062**	.220**	.475**	-.142**
P				1	.186**	-.013	.081**
K					1	.221**	.324**
CEC						1	-.301**
BS							1

**significant at the 0.01 level and * the 0.05 level

N%= Total nitrogen percent; OC% = organic carbon percent; OM%= organic matter percent; C:N= carbon: nitrogen ratio; Av. P = available phosphorous; Av. K= available potassium; ExBases = total exchangeable bases; CEC = cation exchange capacity; BS% = base saturation percent

4. Nutrient indices value of three land use

In order to compare the levels of soil fertility of one area with those of another it is necessary to obtain a single value for each nutrient (Denis et al., 2016). Nutrient index value is the measure of nutrient supplying capacity of soil to plants (Singh, Sharma, & Singh, 2016). The soil nutrient index of the three land use was calculated from low, medium and high ratings of soil nutrients. If the index value was less than 1.67, the fertility status was low and the value between 1.67-2.33 was medium. If the value was greater than 2.33, the fertility status was high. Among the three land uses, soil pH was low in orchard and medium in other land uses. In all land uses, a level of total N was low, OC was medium and CN was low. On the other end P fertility status was low in wetland and medium in other land use. Levels of K were medium in dryland and low in other land use.

Total Exbases was medium in dryland and low in other land use. The level of CEC was medium in dryland and orchard but low in wetland. BS (calcium, magnesium, sodium and potassium) was low in orchard and medium in other land use (Table 6).

Table 6. Soil nutrient index of three land use

Soil variables	Nutrient Index		
	Dryland	Wetland	Orchard
Nitrogen (%)	1.65	1.19	1.54
Organic carbon (%)	2.33	1.78	2.09
Organic matter (%)	2.35	1.72	2.12
Carbon:Nitrogen ratio	1.23	1.29	1.31
Available Phoshorous (mg/kg)	1.97	1.58	1.83
Available Potassium (mg/kg)	2.15	1.33	1.45
Total Exchangeable Bases (me/100g)	2.03	1.41	1.51
Cation exchange capacity (me/100g)	2.14	1.14	1.99
Base saturation (%)	1.98	2.19	1.47

Table 7. Soil fertility rating based on soil nutrient index of three land use

Land use	Soil variables								
	N (%)	OC(%)	OM%	C:N	Av. P	Av. K	Exbases	CEC	BS (%)
Dryland	L	M	H	L	M	M	M	M	M
Wetland	L	M	M	L	L	L	L	L	M
Orchard	L	M	M	L	M	L	L	M	L

L=Low, M=Medium, H=High

5. Conclusion

Based on the criteria for calculating nutrient index value, besides low content of nitrogen in dry land, the soil fertility was characterized as medium in dryland, low in wetland and low - medium category in orchard. The nutrient index value of soil pH ranged from low to medium, the mean pH value of three land use were slightly acidic (<5.6), which may not be a serious problem, since nutrients are moderately available to plants within pH level of 5.5 to 6.5 (Kavitha & Sujata, 2015). Among the different land use, status of OM was high in dryland. Deficiency of N was observed in all land uses. The level of C/N ratio was low within good range, good for crop production since low C/N ratio allows faster decomposition of OM and the release of excess available nitrogen in the soil for growing plants. Deficiency of P, K, Exbases, and CEC were observed in wetland where as the level of these soil variables were in medium category in dryland but in orchard, the level of P and CEC was medium, and K and Exbases were in low category. The level of OC was in medium category in all land uses; however, deficiency of BS was noted in orchard.

Recommendation

Although pH of the soil reaction was within medium range (<5.5) where nutrients are moderately available, improving soil quality of acid soils by liming to adjust pH could increase nutrient availability, improve soil structure, improve microbial activity and improve symbiotic nitrogen fixation by legumes.

Based on the low level of total nitrogen, it is recommended to use more organic manure to improve soil organic matter to increase N content of the soils and reduce chemical fertilizer especially urea application (N fertilizer) and also to improve CN ratio and CEC of the soils.

In all landuse systems, there is an urgent need to enhance recommended dose of nutrients to improve soil fertility. In addition, these studies also provide some soil research needs such as relationship between increasing pH and declining N and build up of OC and CN with regard to different cropping practices.

Reference

Bhat, Z. A., Padder, S. A., Ganaie, A. Q., Dar, N. A., Rehman, H. U., & Wani, M. Y. (2017). Correlation of available nutrients with physico-chemical properties and nutrient content of grape orchards of Kashmir. *Journal of Pharmacognosy and Phytochemistry*, *6*(2), 181-185.

Black, C. (1965). Particle fraction and particle size analysis In *Methods of Soil Analysis. Part II* (pp. 1372-1376). Madison, Wisconsin: American Society of Agronomy Inc.

Bradford, T. (2014) *Acid soil is made from granite and shale bedrock.* Syracuse, New York: Syracuse.com.

Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil science*, *59*(1), 39-46.

Denis, A. M. K., Patel, P. L., Kamara, A. M., & Saidu, D. H. (2016). Assessment of soil fertility status using nutrient index approach. *International Journal of Food, Agriculture and Veterinary Sciences, 6*(3), 1-15.

Jensen, T. L. (2010). International Plant Nutrition Institute (IPNI) *IPNI Plant Nutrition Today, Fall 2010*(2).

Kavitha, C., & Sujatha, M. P. (2015). Evaluation of soil fertility status in various agro ecosystems of Thrissur District, Kerala, India. *International Journal of Agriculture and Crop Sciences*, *8*(3), 328.

Khokhar, Y., Rattanpal, H. S., Dhillon, W. S., Singh, G., & Gil, P. S. (2012). Soil fertility and nutritional status of Kinnow orchards grown in aridisol of Punjab, India. *African Journal of Agricultural Research, 7*(33), 4692-4697.

Krom, M. D. (1980). Spectrophotometric determination of ammonia: a study of a modified Berthelot reaction using salicylate and dichloroisocyanurate. *Analyst, 105*(1249), 305-316.

Kumar, P., Kumar, A., Dhyani, B. P., Kumar, P., Shahi, U. P., Singh, S. P. (2013). Soil fertility status in some soils of Muzaffarnagar District of Uttar Pradesh, India, along with Ganga canal command area. *African Journal of Agricultural Research, 8*(14), 1209-1217.

Medhe, S. R., Tankankhar, V. G., & Salve, A. N. (2012). Correlation of chemical properties, secondary nutrients and micronutrient anions from the soils of Chakur Tahsil of Latur district, Maharashrta. *Journal of Trends in life sciences, 1*(2).

Norbu, C., & Floyd, C. (2001). *Changing soil fertility management in Bhutan: effect on practices, nutrient status and sustainability*. Paper presented at the Annual meetings of soil science society of America, Charlotte, NC, USA.

Parker, F. W., Nelson, W. L., Winters, E., & Miles, I. E. (1951). The broad interpretation and application of soil test information. *Agronomy Journal, 43*(3), 105-112.

Pathak, H. (2010). Trend of fertility status of Indian soils. *Current Advances in Agricultural Sciences (An International Journal), 2*(1), 10-12.

Patil, R. B., Saler, R. S., & Gaikwad, V. B. (2015). Nutritional survey of different vineyards in Nashik district. *Mahararashtra Journal of Basic Sciences, 1*, 6-12.

Singh, G., Sharma, M., Manan, J., & Singh, G. (2016). Assessment of soil fertility status under different cropping sequences in District Kapurthala. *Journal of Krishi Vigyan, 5*(1), 1-9.

Singh, R. P., & Mishra, S. K. (2012). Available macro nutrients (N, P, K and S) in the soils of Chiraigaon block of district Varanasi (UP) in relation to soil characteristics. *Indian Journal of Scientific Research, 3*(1), 97-100.

Steele, L. D., Ramsey, K. J., & Kane, P. F. (1984). Elimination of aliquoting in automated flame photometric determination of K2O in fertilizers. *Journal-Association of official analytical chemists, 67*(4), 847-849.

Verdouw, H., Van Echteld, C. J. A., & Dekkers, E. M. J. (1978). Ammonia determination based on indophenol formation with sodium salicylate. *Water Research, 12*(6), 399-402.

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science, 37*(1), 29-38.

Yeshey, Bajgai, Y., & Ghimiray, M. (2014). Soil nutrient management for rice in Bhutan: current practices and future strategies. *Journal of Renewable Natural Resources Bhutan, 10*, 184-194.