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Soil Fertility Assessment and Mapping of Regional Agricultural Research Station, Parwanipur, Bara, Nepal

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ABSTRACT

Soil fertility assessment is a key for sustainable planning of a particular area. Thus, the present study was conducted to assess the soil fertility status of the Regional Agricultural Research Station, Parwanipur, Bara, Nepal. The study area is situated at the latitude $27^0$4'40.9''N and longitude $84^0$56'9.85"E at 75masl altitude. Altogether 76 soil samples were collected based on the variability of land at 0-20 cm depth. The texture, pH, OM, total N, available P_2O_5, K_2O, Ca, Mg, S, B, Fe, Zn, Cu and Mn content in the samples were determined following standard analytical methods. Arc-GIS 10.1 was used for soil fertility mapping. The soil structure was angular blocky, and varied between grayish brown (10YR 5/2) and dark grayish brown (10YR 4/2) in color. The sand, silt and clay content were 24.41±0.59%, 54.57±0.44% and 21.03±0.32%, respectively and categorized as silt loam and loam in texture. The soil was moderately acidic in pH (5.67±0.09), low in organic matter (0.74±0.04%) and available Sulphur (0.8± 0.1 ppm). The total nitrogen (0.06±0.001%), available boron (0.59±0.08ppm) and available zinc (0.51±0.05ppm) were low. Furthermore, available potassium (50.26±2.95ppm), available calcium (1674.6±46.3ppm) and available magnesium (175.43± 8.93ppm) were medium. Moreover, available copper (1.36±0.06 ppm) and available manganese (16.52±1.12 ppm) were high, while, available phosphorus (77.55±6.65 ppm) and available iron (85.88±7.05 ppm) were found high. It is expected that the present study would help to guide practices required for sustainable soil fertility management and developing future agricultural research strategy in the farm.

Keywords: Nutrient index, Research strategy, Soil fertility mapping, Soil properties, Soil testing

सारांश

खेतीको मुख्य आधार नै माटो हो । माटोलाई जिबित राख्नको लागि त्यसमा उपलब्ध उर्बरा शक्तिले ज्यादै महत्वपूर्ण भूमिका खेल्दछ । कुनै पनि क्षेत्रको माटोलाई दिगो तरिकाले व्यबस्थित गर्नको निम्ति उर्बराशक्तिको बारेमा जानकारी राख्नु अति नै आबश्यक रहन्छ । तसर्थ २७°४'४०.९"अक्षांस र ८४°५६'९.८५" देशान्तर तथा समुद्र सतहबाट ७५ मिटर उचाईमा अबस्थित क्षेत्रिय कृषि अनुसन्धान केन्द्र, परवानीपुर, बारा स्थित अनुसन्धान फार्मको माटोको उर्बराशक्तिको अवस्था पहिचान गर्ने उद्देश्यले सन् २०१५ मा एउटा अध्ययन गरियो । जस अनुरुप जमिनको विविधतालाई मध्यनजर गरेर जमिनको सतहबाट २० से.मी. गहिराईको ७६ वटा नमुना संकलन गरियो । साथै, नमूना संकलन गरिएको ठाउँको अवस्थिति पहिचान गर्न जी. पी. एस्. उपकरण प्रयोग गरिएको थियो । यसरी संकलन गरिएको माटो नमूनालाई माटो बिज्ञान महाशाखा, खुमलटारको प्रयोगशालामा परिक्षण गरिएको थियो । यसरी गरिएको सम्पूर्ण अध्ययनलाई आर्क जी. आइ. एस्. १०.१ सफ्टवेयरद्धारा नक्सांकन गरियो । अध्ययनको रिपोर्टलाई हेर्दा, माटोको भौतिक गुणमा संरचना कोणात्मक ब्लक, दुई प्रकारको रङ - फुस्रो खैरो र कालो फुस्रो खैरो साथै बुनौटपाँगो दोमट समुहमा बढी पाइएको थियो । यसैगरी रसायनिक गुणमा पी. एच्.को स्तर अम्लिय (५.६७+०.०९) तथा प्रांगारिक पदार्थ (०.७४+०.०४५५) र सल्फर (०.८+०.१ पि.पि.एम.) अति कम मात्रामा पाइएको थियो । साथै, कम मात्रामा नाईट्रोजन (०.००६+०.००१५५), बोरन (०.५९+०.०८ पि.पि.एम.) र जस्ताको मात्रा (०.५१+०.०५ पि.पि.एम.) पाइएको थियो । यसैगरी, पोटासियम (५०.२६+२.९५पि.पि.एम.), क्याल्सियम (१६७४+४६.३पि.पि.एम.) र म्याग्नेसियम (१७५४३+८.९३ पि.पि.एम.) को अवस्था मध्यम पाइएको थियो । अन्य तत्वहरु, तामा (१.३६+०.०६ पि.पि.एम.) र म्याग्निज (१६.२५+१.१२ पि.पि.एम.) धेरै,तथा फस्फोरस (७७.५५+६.६५पि.पि.एम.) र फलाम (८५.८८+७.०५पि.पि.एम.) अति धेरै मात्रामा पाइएको थियो । बिरुवालाई आवश्यक पर्ने तत्वहरु कमी तथा अति बढि हुँदा उसको वृद्धि विकासमा असर गर्ने भएकोले विशेष गरि त्यस्ता तत्वहरुको उचित व्यवस्थापनमा ध्यान दिनु आवश्यक देखिन्छ । अन्तमा, यस अध्ययनबाट प्राप्त माटो अनुसन्धान रिपोर्टको आधारमा अनुसन्धान केन्द्रले भविष्यमा कृषि अनुसन्धान योजना तर्जुमा गर्दा महत्वर्पुण हुने देखिन्छ ।

INTRODUCTION

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. Soil fertility is commonly defined as the inherent capacity of a soil to supply plant nutrients inadequate amounts, forms, and suitable proportions required for maximum plant growth (Von Uexkuell 1988). Soil fertility varies spatially from field to larger region scale, and is influenced by both land use and soil management practices (Sun et al 2003). The soil fertility evaluation is the measurement of available plant nutrients and estimation of capacity of soil to maintain continue supply of plant nutrients for agricultural practices.

Soil test-based fertility management has been proven to be an effective tool for increasing productivity of agricultural soils having high spatial variability resulting from the combined effects of physical, chemical or biological processes (Goovaerts 1998). The soil physical properties (texture, structure and color), pH, organic matter, primary nutrients, secondary nutrients and micronutrients (B, Fe, Zn, Cu and Mn) etc are the key indicators of soil fertility (Brady and Weil 2002). These parameters indeed can predict the plant growth and development. Understanding of the soil fertility status is vital to develop proper soil management strategies helping in designing the planning crop cultivation in proposed area. In evaluating the soil spatial variability, Global Positioning Systems (GPS) and Geographic Information Systems (GIS) are also important tools. GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data (Burrough and McDonnell 1998).

Regional Agricultural Research Program (RARS), Parwanipur, Bara is an important multidisciplinary research station under the Nepal Agricultural Research Council to generate appropriate agriculture production technologies for addressing the problems of the central terai regions of Nepal. Poor soil fertility is a major constraint in the different research domains of NARC (Khadka et al 2016a, Khadka et al 2016b, Khadka et al 2016c, Khadka et al 2016d, Khadka et al 2017). To date, studies on soil fertility status in Regional Agricultural Research Station, Parwanipur, Bara was rarely evaluated and documented. Due to this, there is lacking for sustainable practices for soil management as well as developing research strategy relating farm condition. Therefore, the present study aims to evaluate the soil fertility status of the Regional Agricultural Research Station, Parwanipur, Bara, Nepal.

MATERIALS AND METHODS

Study Area

The study was carried out at Regional Agricultural Research Station, Parwanipur, Bara, Nepal (**Figure** 1). The research farm is situated at the latitude $27^0$4'40.9''N and longitude $84^0$56'9.85"E as well altitude 75m above sea level. This area is located in central terai region of Nepal and near to the Birgunj city. The climate is hot in the summer, while cold in the winter. The different crops (rice, wheat, maize, lentil, mustard etc), vegetables (cauliflower, cabbage, brinjal, radish etc) and fruits (mango, litchi, sapota etc) grown in the different blocks of the farm.

Soil Sampling

Surface soil samples (0-20 cm depth) were collected from Regional Agricultural Research Station, Parwanipur, Bara, Nepal during 2015. The total 76 soil samples were collected from the research farm by soil sampling auger (**Figure** 2). The exact locations of the samples were recorded using a handheld GPS receiver. The random method based on the variability of the land was used to collect soil samples.

Laboratory Analysis

The collected soil samples were analyzed at laboratory of Soil Science Division, Khumaltar. The different soil parameters tested as well as methods adopted to analyze have been shown in the **Table** 1.

Statistical Analysis

Descriptive statistics (mean, range, standard deviation, standard error, coefficient of variation) of soil parameters were computed using the Minitab 17 package. Rating (very low, low, medium, high and very high) of determined values were based on Soil Science Division, Khumaltar, Lalitpur, Nepal. The coefficient of variation was ranked according to the procedure of (Aweto 1982) where, CV $\leq$ 25% = low variation, CV $\geq$25 $\leq$ 50% = moderate variation, CV >50% = high variation. Arc Map 10.1 with spatial analyst function of Arc GIS software was used to prepare soil fertility maps, while interpolation method employed was ordinary kriging. Similarly, the nutrient index was also determined by the formula given by Ramamoorthy and Bajaj (1969).

$$\text{Nutrient index (NI)} = (N_L \times 1 + N_M \times 2 + N_H \times 3) / N_T$$

Where, N_L, N_M and N_H are number of samples belonging to low, medium and high classes of nutrient status, respectively and N_T is total number of samples analyzed for a given area. Similarly, interpretation was done as value given by Ramamoorthy and Bajaj (1969) shown on the **Table** 2.

Table 1. Parameters and methods adopted for the laboratory analysis at Soil Science Division, Khumaltar

SN	Parameter	Unit	Methods
1	Texture	-	Hydrometer (Bouyoucos 1962)
2	Colour	-	Munshell-colour chart
3	Structure	-	Field-feel
4	pH	-	Potentiometric 1:2 (Jackson 1973)
5	Organic matter	%	Walkely and Black (Walkely and Black 1934)
6	Total N	%	Kjeldahl (Bremner and Mulvaney 1982)
7	Available P_2O_5	ppm	Olsen (Olsen et al 1954)
8	Available K_2O	ppm	Ammonium acetate (Jackson 1973)
9	Available Ca	ppm	EDTA Titration (El Mahi et.al 1987)
10	Available Mg	ppm	EDTA Titration (El Mahi et.al 1987)
11	Available S	ppm	Turbidimetric (Verma1977)
12	Available B	ppm	Hot water (Berger and Truog 1939)
13	Available Fe	ppm	DTPA (Lindsay and Norvell 1978)
14	Available Zn	ppm	DTPA (Lindsay and Norvell 1978)
15	Available Mn	ppm	DTPA (Lindsay and Norvell 1978)
16	Available Cu	ppm	DTPA (Lindsay and Norvell 1978)

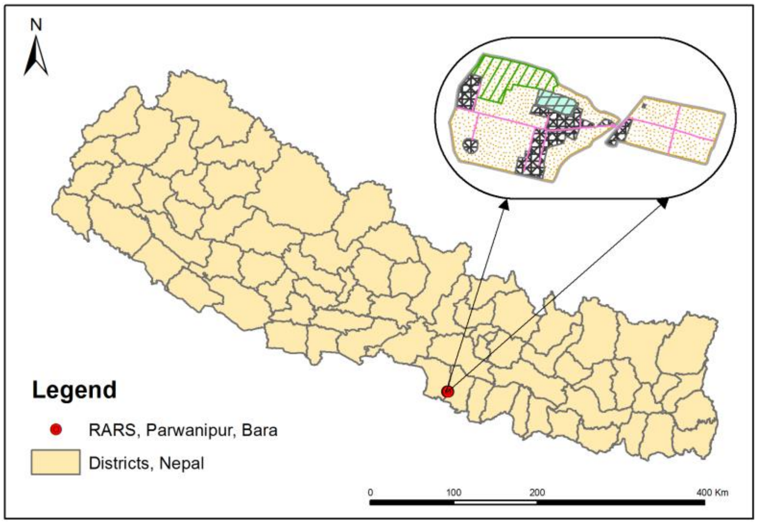

Figure 1. Location map of Regional Agricultural Research Station, Parwanipur, Bara, Nepal

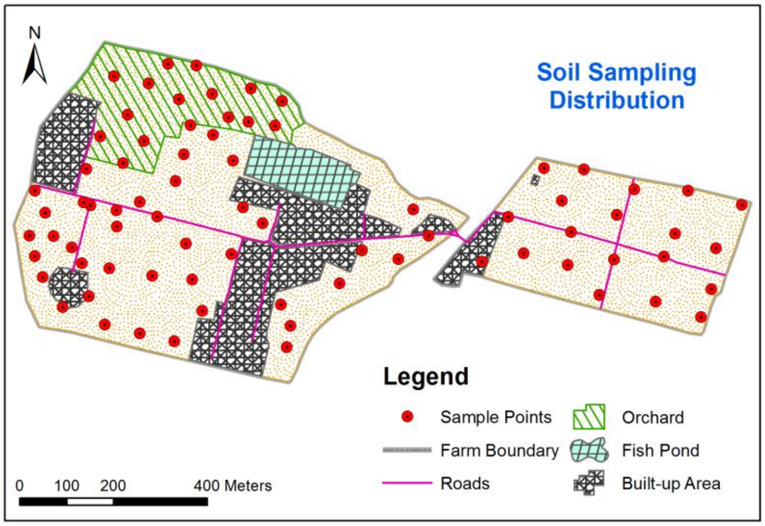

Figure 2. Distribution of soil sample points during soil sampling

Table 2. Rating chart of nutrient index

SN	Nutrient index	Remark
1	<1.67	Low
2	1.67-2.33	Medium
3	>2.33	High

RESULTS

For evaluation of soil fertility status of the study area texture, color, structure, pH, OM, Primary nutrients, secondary nutrients and micronutrients (B, Fe, Zn, Cu and Mn) were determined and presented under the following headings.

Soil Texture

The particle size distribution of the soils showed that sand content ranged from 15.6 to 41.1% with a mean of 24.41%. Clay content ranged from 14.8 to 26.2% with a mean of 21.03%, while silt content ranged from 40.8 to 63.2% with a mean of 54.57%. The two textural class; silt loam and loam were determined, but majority of the area contains silt loam (**Figure** 3). The variability of sand, silt and clay were 1.22%, 7.04% and 13.46%, respectively. This showed low variability among the studies samples.

Table 3. Soil texture status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Descriptive statistics	Soil texture		
	Sand	Silt	Clay
		%	
Mean	24.41	54.57	21.03
Standard Deviation	5.18	3.84	2.83
Standard Error	0.59	0.44	0.32
Min.	15.6	40.8	14.8
Max.	41.4	63.2	26.2
CV%	21.22	7.04	13.46
Class		**Silt Loam; Loam**	

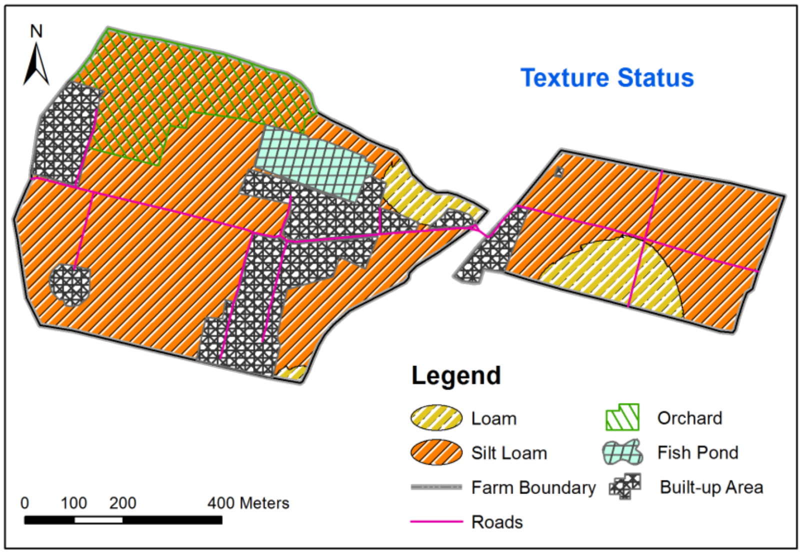

Figure 3. Soil texture status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Soil Color

It is an easily observable characteristic and is an important criterion in description and classification of soils. In general, it was varied between grayish brown (10YR 5/2) and dark grayish brown (10YR 4/2) in color.

Soil Structure

Soil structure influences amounts and nature of porosity in soils. In overall, angular blocky soil structure was observed on the study area.

Table 4. Soil fertility status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

	Soil fertility parameters				
Descriptive statistics	pH	OM %	N	P_2O_5 ppm	K_2O
Mean	5.67	0.74	0.06	77.55	50.26
Standard Deviation	0.76	0.37	0.01	57.95	25.69
Standard Error	0.09	0.04	0.001	6.65	2.95
Min.	4.45	0.05	0.04	1.10	9.60
Max.	7.76	1.68	0.09	337.88	159.60
CV%	13.43	49.88	18.24	74.73	51.12

Soil Reaction (pH)

The soil pH content varied from 4.45 to 7.76 with a mean of 5.67 (**Table** 4). This shows that soil pH of the study area were moderately acidic in nature (Figure 4).The soil reaction showed low variability (13.43%) among the soil samples.

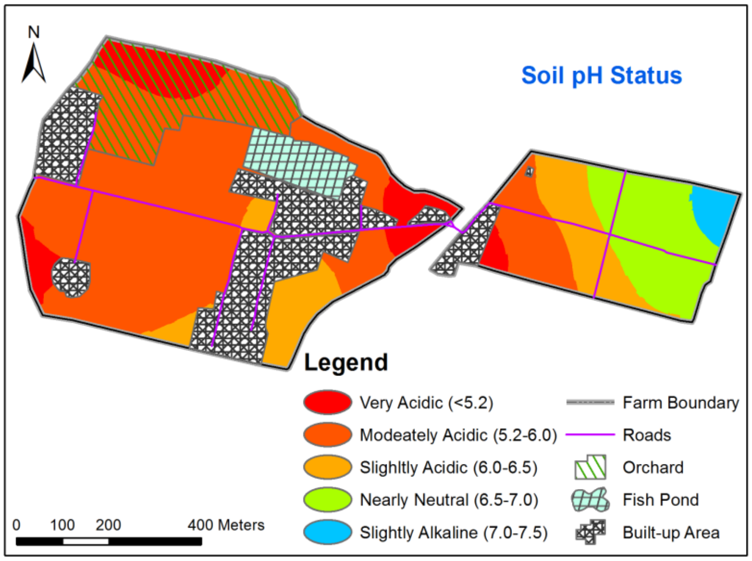

Figure 4. Soil pH status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Organic Matter

The organic matter analyzed in all sampled exhibited in the range of 0.05 to 1.68% with a mean of 0.74% (**Table** 4).This indicates very low status organic matter (**Figure** 5, **Table** 7). Organic matter showed moderate variability (49.88%) in the investigated soil samples.

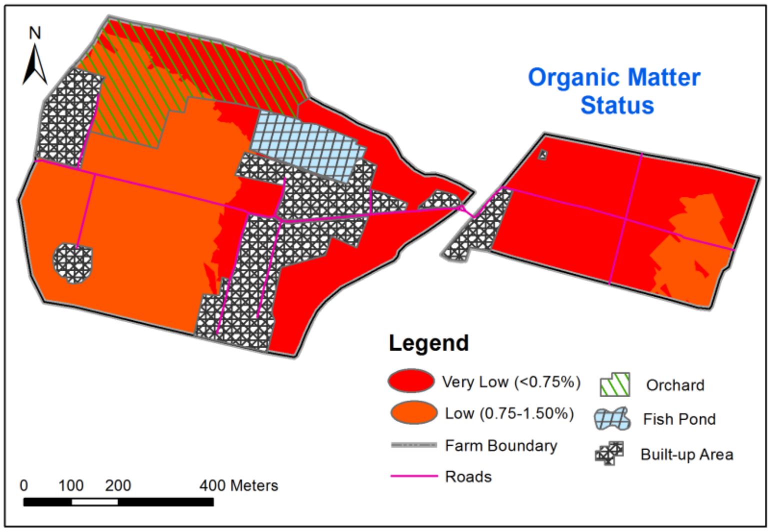

Figure 5. Organic matter status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Total Nitrogen

The total nitrogen content ranged from 0.04 to 0.09% with the mean of 0.06% (**Table** 4). This shows low status of total nitrogen (**Figure** 6, **Table 7**). Low variability (18. 24%) in total nitrogen was observed among the sampled soils.

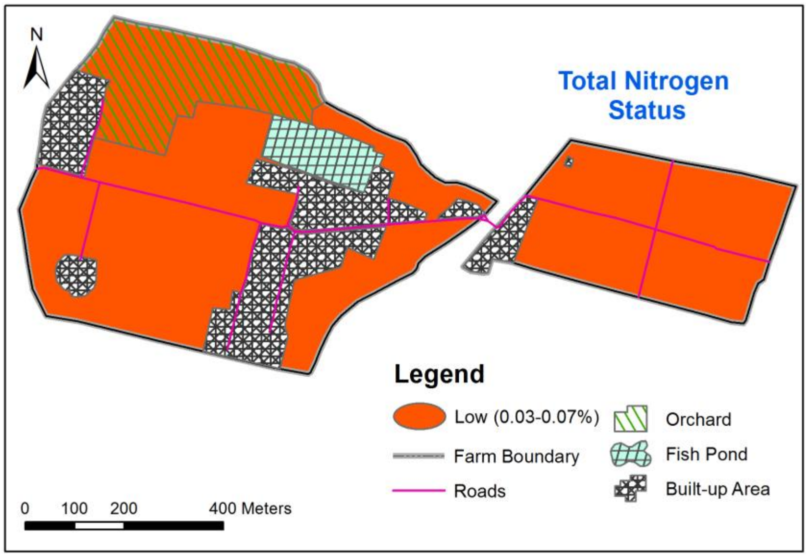

Figure 6. Total nitrogen status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Available Phosphorus

The available phosphorus varied from 1.10 to 337.88 ppm with a mean of 77.55 ppm (**Table** 4). This shows very high status of available phosphorus (**Figure** 7, **Table** 7).Available phosphorus showed high variability (74.73%) among the studied soil samples.

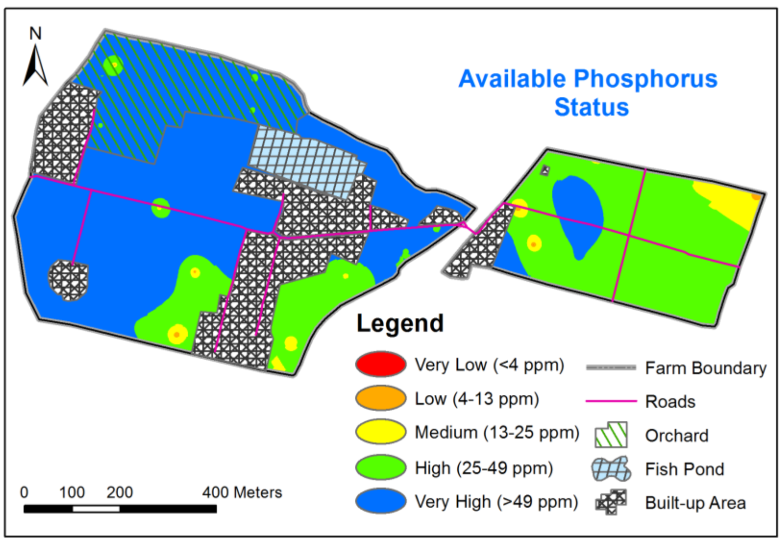

Figure 7. Available phosphorus status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Available Potassium

Available potassium content ranged from 9.60 to 159.60 ppm with a mean of 50.26 ppm (**Table** 4). This indicates medium status of available potassium (**Figure** 8, **Table** 7). High variability (51.12%) in available potassium was observed among the soil samples.

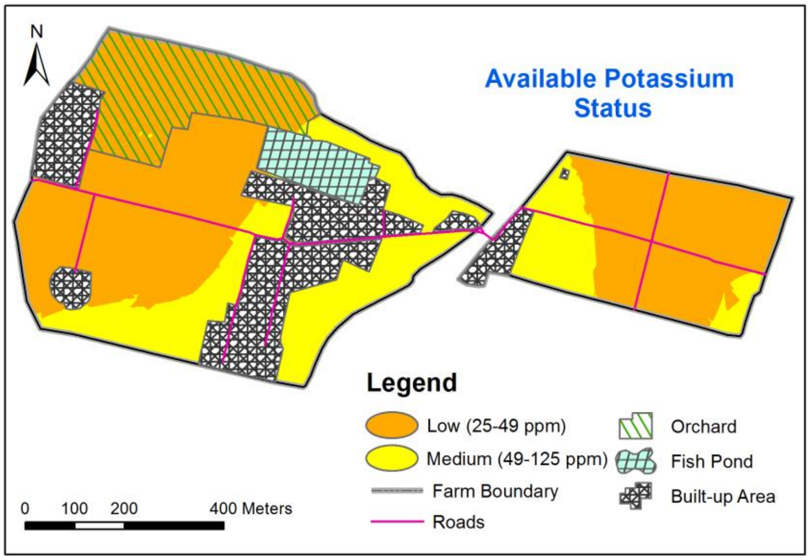

Figure 8. Available potassium status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Table 5. Soil fertility status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

	Soil fertility parameters (ppm)			
Descriptive statistics	**Ca**	**Mg**	**S**	**B**
Mean	1674.6	175.43	0.8	0.59
Standard Deviation	404.01	77.87	0.94	0.73
Standard Error	46.3	8.93	0.1	0.08
Min.	816	57.60	0.05	0.02
Max.	3144	489.60	5.36	4.04
CV%	24.13	44.39	122.48	123.27

Available Calcium

The available calcium content exhibited from 816 to 3144 ppm with a mean of 1674.6 ppm (**Table** 5).This indicates medium status of available calcium (**Figure** 9, **Table** 7). Low variability (24.13%) in available calcium was observed between the soil samples.

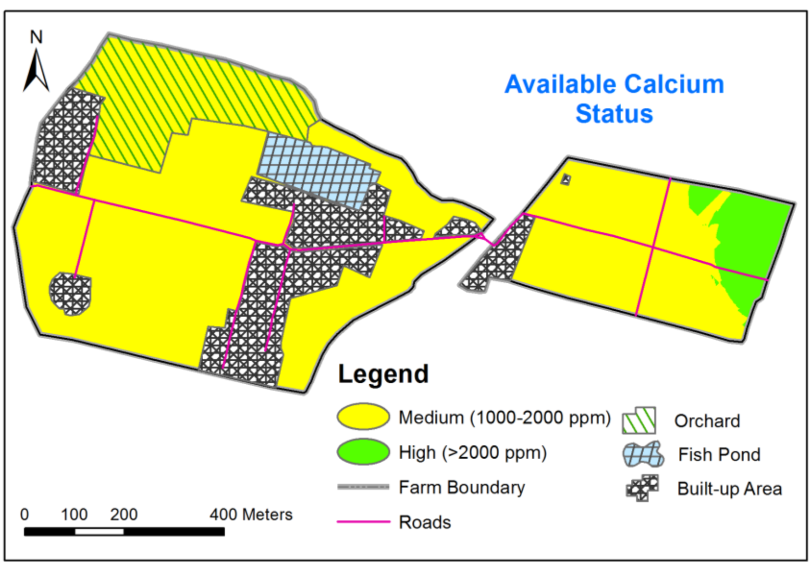

Figure 9. Available calcium status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Available Magnesium

The available magnesium content varied from 57.6 to 489.6 ppm with a mean value of 175.43 ppm (**Table** 5). This shows medium status of available manganese (**Figure** 10 **Table 7**). The variation in the available magnesium of the soil was moderate, with coefficients of variation of 44.39%.

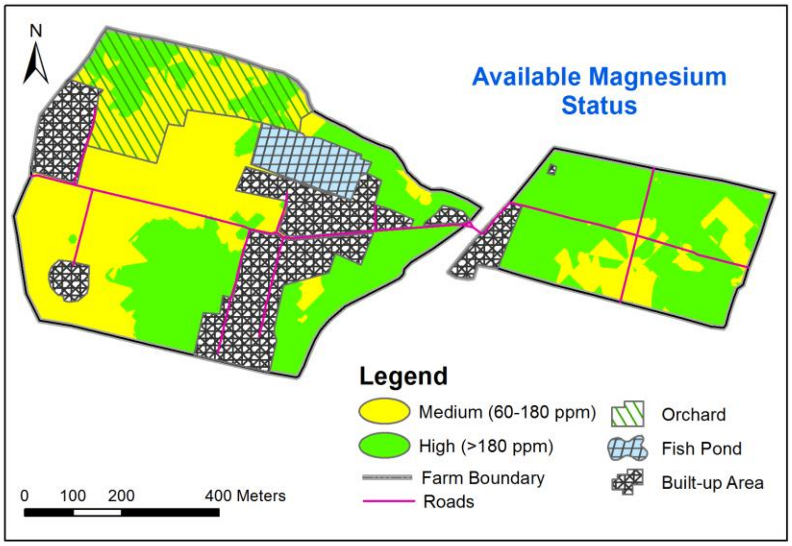

Figure 10. Available magnesium status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Available Sulphur

Available sulphur varied from 0.05 to 5.36 ppm with a mean of 0.80 ppm (**Table** 5). This shows very low status of available sulphur (**Figure** 11, **Table** 7). Available sulphur showed high variability (122.48%) in the soil samples.

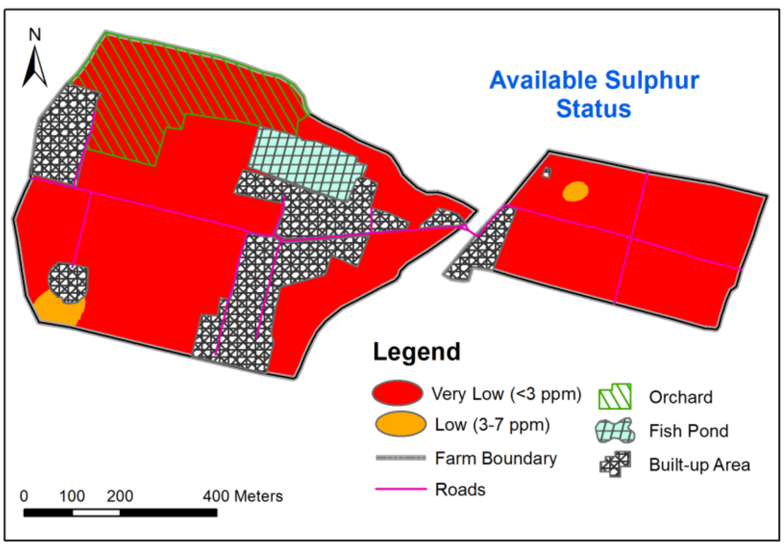

Figure 11. Available sulphur status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Available Boron

The available boron content ranged from 0.02 to 4.04 ppm with a mean of 0.59 ppm (**Table** 5). This exhibits low content of available boron (**Figure** 12, **Table** 7). The variation in the available boron of the soil was high, with coefficients of variation of 123.27%.

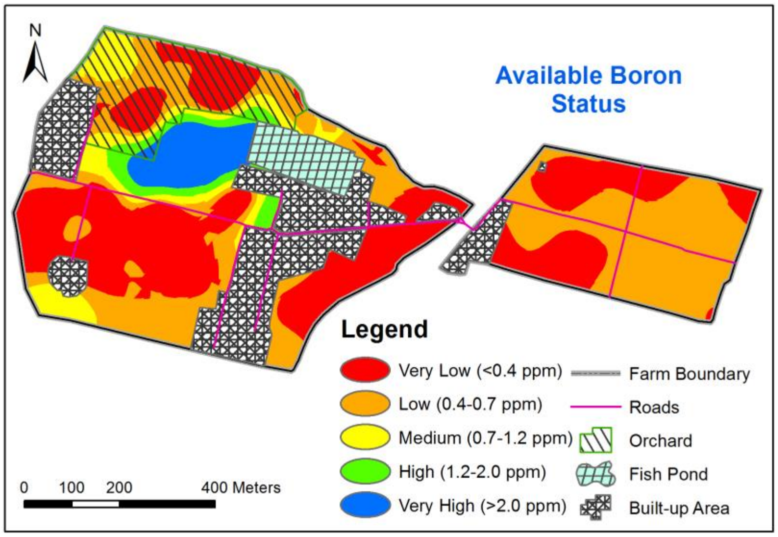

Figure 12. Available boron status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Table 6. Soil fertility status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

	Soil fertility parameters (ppm)			
Descriptive statistics	**Fe**	**Zn**	**Cu**	**Mn**
Mean	85.88	0.51	1.36	16.52
Standard Deviation	61.42	0.44	0.49	9.73
Standard Error	7.05	0.05	0.06	1.12
Min.	0.04	0.01	0.22	0.38
Max.	281.66	1.72	2.94	47.16
CV, %	71.52	86.17	36.24	58.90

Available Iron

The available iron content ranged from 0.04 to 281.66 ppm with a mean of 85.88 ppm. This indicates very high status of available iron (**Figure** 13, **Table** 7). Available iron showed high variability (71.52%) among the soil samples.

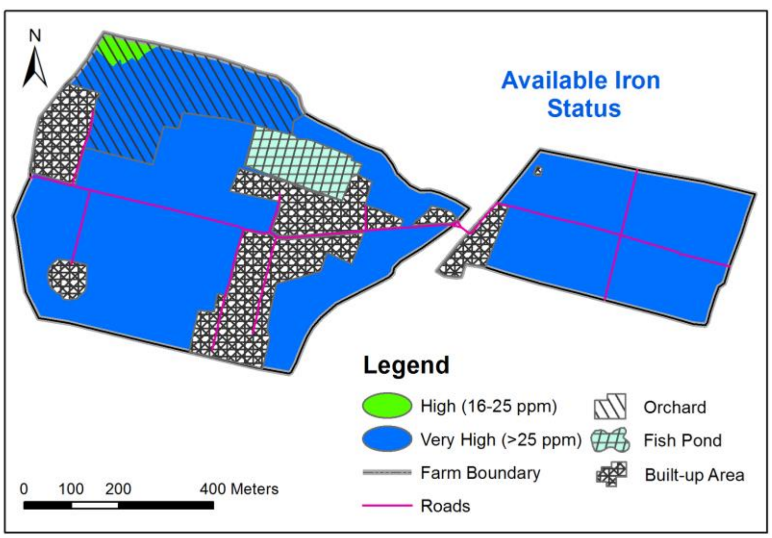

Figure 13. Available iron status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Available Zinc

The available zinc content varied from 0.01 to 1.72 ppm with a mean of 0.51 ppm (**Table** 6). This reveals low status of available zinc (**Figure** 14, **Table** 7).The available zinc showed high variability (86.17%) among the soil samples.

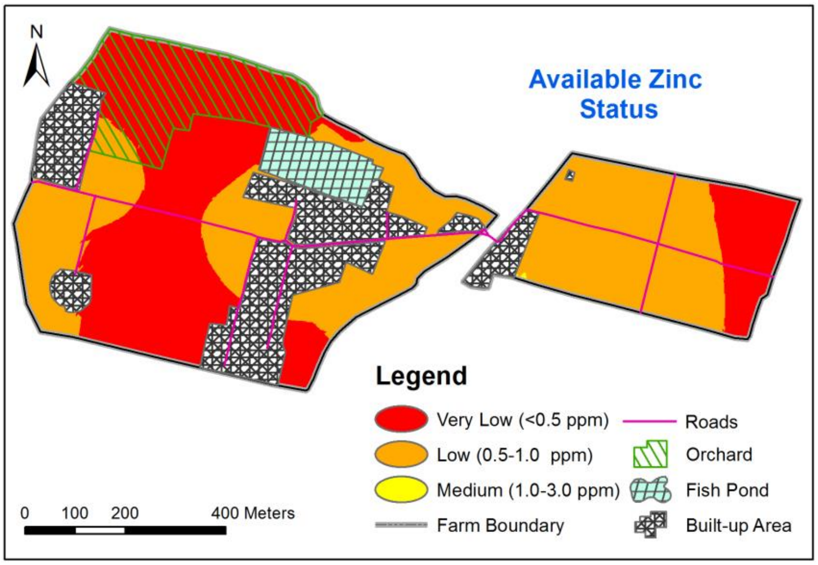

Figure 14. Available zinc status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Available Copper

The available copper of the soil ranged from 0.22 to 2.94 ppm with a mean of 1.36 ppm (**Table** 6). This reveals high status of available copper (**Figure** 15, **Table** 7).Moderate variability (36.24%) in available copper was recorded among the soil samples.

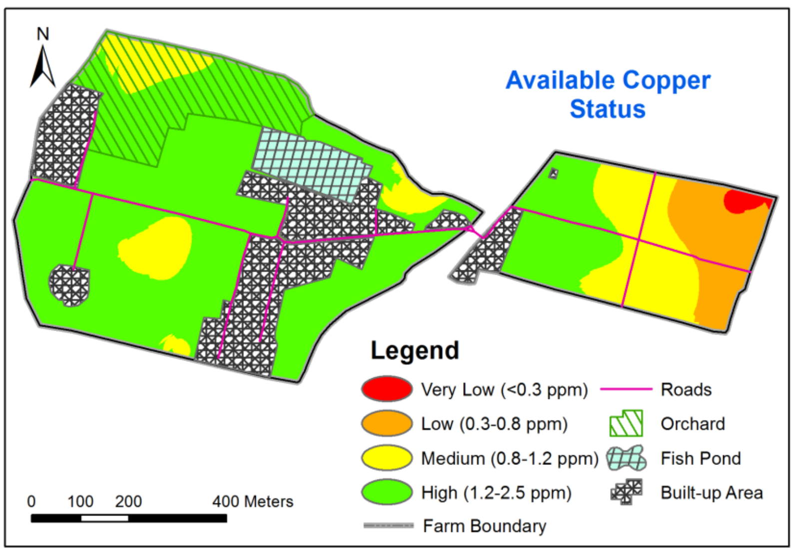

Figure 15. Available copper status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Available Manganese

The available manganese of the soils ranged from 0.38-47.16 ppm with a mean of 16.52 ppm (**Table** 6). This exhibits high status of available manganese (**Figure** 16, **Table** 7).The available manganese showed high variability (58. 09%) among the studied soil samples.

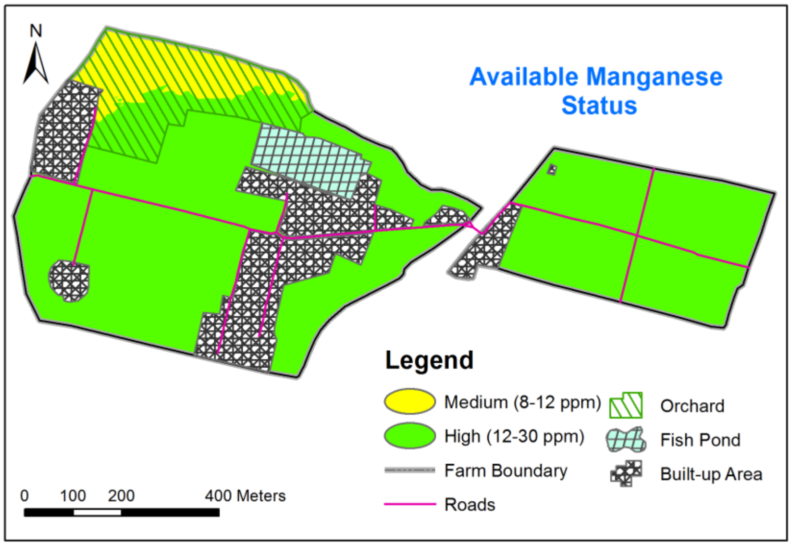

Figure 16. Available manganese status of Regional Agricultural Research Station, Parawnipur, Bara, Nepal

Table 7. Nutrient indices of studied parameters of Regional Agricultural Research Station, Parwanipur, Bara, Nepal

SN	Parameters	Low	Medium	High	Nutrient index	Remarks
			%			
1	OM	96.68	1.32	-	1.01	Low
2	N	87	13	-	1.13	Low
3	P_2O_5	9.21	11.84	78.95	2.70	High
4	K_2O	59.21	38.16	2.63	1.43	Low
5	Ca	1.32	82.89	15.79	2.14	Medium
6	Mg	9.21	46.05	44.74	2.36	Medium
7	S	100	-	-	1.0	Low
8	B	84.21	6.58	9.21	1.25	Low
9	Fe	3.95	1.32	94.74	2.91	High
10	Zn	89.47	10.53	-	1.11	Low
11	Cu	9.2	25.0	65.8	2.57	High
12	Mn	21.1	18.4	60.5	2.39	High

DISCUSSION

Soil texture has an extremely significant influence on the physical and mechanical behaviors of the soil (Rai et al 2011). The proportion of silt and clay content was high in the farm (Table 3), because of such characteristics there might be problems of soil compaction, hence directly affecting for tillage operation and water drainage. Therefore, tillage operation should have to do in the appropriate moisture conditions. Similarly, over flooding during irrigation may causes water stagnation stress for plants. In overall, the observed soil texture (silt loam and loam) had proper water and nutrient holding capacity; hence suitable for most of the crops. Panda (2010) reported medium textured soils like loam and silt loam are considered suitable among all the soil texture for most of the crops. Furthermore, the observed structure (angular blocky) also indicates medium permeability of the water in the farm.

The measure of soil pH is an important parameter which helps in identification of chemical nature of the soil (Shalini et al 2003), as it affects availability of essential plants nutrients. Soil pH was moderately acidic in the majority of area, but possesses different classes from very acidic to slightly alkaline (Table 4, Figure 4). The adoption of heterogeneous management practice during experimentation from longer period might be reason for this. The acidity causing practice like unbalanced long term use of urea might also be the cause of high acidity (Bolan and Hedley 2003).The normal pH range for optimal mineral elements availability for most crops is 6.0 to 7.5 (Sanchez et al 2003). Therefore, in the sites where moderately and very acidic pH agricultural lime should be applied at the rate of 3.96 t/ha and 5.64 t/ha, respectively.

Organic matter plays a major role in soil physical, chemical and biological properties and acts as a source of nutrients, while increase nutrients exchange sites and affect the fate of applied pesticides (Alabandan et al 2009).

The low status of organic matter in the farm might be due to low incorporation of organic matter such as organic manure, green manure etc. This may also be due to negligence to perform resource conservation technologies such as crop residue burning in the field and conventional tillage by which soil is agitated by digging, stirring, and overturning using mechanical or human-powered tilling methods such as shoveling, picking, mattock work, hoeing, and raking etc. Furthermore, that might also result of high mineralization of organic matter stock due to high temperature in the soil might be another cause of low status of organic matter. The adequate incorporation of organic manure, vermin-compost, green manure etc. and adoption of resource conservation technology during cultivation is important for organic matter improvement in the field.

Nitrogen is one of the most important plant nutrients and the most frequently deficient of all nutrients (Havlin et al 2010). The inadequate supply of respective inorganic as well organic fertilizer might be the cause for those nutrients which are low in status. Moreover, the low organic matter status in the farm might also be the cause of low total nitrogen. Being low content of total nitrogen, 100% of the recommended nitrogen dose is requires for adequate supply of nitrogen for crops in the farm (Joshi and Deo 1975).

Phosphorus is known as the master key nutrients to agriculture because lack of available Phosphorus in the soils limits the growth of both cultivated and uncultivated plants (Foth and Ellis 1997). Phosphorus is in agriculture field are added second to nitrogen in frequency of use as fertilizer nutrient (Trohel and Thompson 1993).The residual accumulation of phosphate ion due to long-term use of inorganic phosphate fertilizer and its high fixation affinity might be the cause of high amounts of available phosphorus in the majority sites. In the farm, the phosphorus application may be frequent in the form of chemical fertilizers like DAP; SSP before starting every new crops. The area having low, medium and high status of available phosphorus application of 100%, 60% and 40%, respectively of the recommended phosphorus dose is adequate for crops (Joshi and Deo 1975).

Potassium is the third most required element by the plants, which plays an important role for the biochemical and physiological processes that influence plant growth and development (Wang 2013). The nutrient mining due to inadequate supply of their source for the crops might be the cause of low potassium in the majority sites of the farm. The area having low and medium status of available potassium application of 100% and 60%, respectively of the recommended potassium dose is adequate for adequate supply of potassium (Joshi and Deo 1975). Moreover, the available calcium and magnesium content was satisfactory, but soil acidity management is crucial for its maintenance. The high acidity reduces the availability of cation like calcium and magnesium (Goswami et al 2012).

Sulphur is an essential nutrient for plant growth due to its presence in proteins, glutathione, phytochelatins, thioredoxins, chloroplast membrane, lipids, and certain coenzymes and vitamins (Takahashi et al 2011). Similar to total nitrogen, low status of organic matter might be the cause of low available sulphur content. Various factors conducive for sulphur deficiency low content of organic matter is considered major one (Havlin et al 2010). Moreover, negligence for the need of sulphur nutrient for the crop causes sulphur mining because crop regularly uptake sulphur nutrient from the soils. Being low content of sulphur, application of S @ 15-20 kg/ha in the 2 years interval is important for reducing sulphur deficiency stress for crops (Khatri-Chettri 1991).

The available boron and available zinc content is inadequate in the farm (Figure 12; Figure 14). Similar to sulphur, low organic matter status as well as negligence about the need of boron and zinc for crops in the farm might be the cause of low boron and zinc status. Application of B @ 2-3 kg/ha/year can recover the boron deficiency stress for crops in the farm (Khatri-Chettri 1991). Similarly, application of Zn @ 4-8 kg/ha can improve the zinc deficiency stress for crops (Khatri-Chettri 1991). On the other hand, available copper and manganese content was adequate in the farm.

The available iron content was very high in the farm (Figure 13).The occurrence of high amount of primary and secondary iron minerals like olivine, siderite, goethite, magnetite etc. might be the cause of high content available iron (Havlin et al 2010). High iron availability may show iron toxicity symptoms in crops (Das 2000). Therefore, proper care should to take for antagonistic elements of the iron like K, Zn etc.

The determined nutrient index data also supported soil fertility status of the research farm (Table 7). The high variation on the particular nutrients might be due to adoption of heterogeneous management practice in the farm. Therefore, before starting any experiment keeping fallow the land for one season can be a suitable option for reduction of error due to soil fertility heterogeneity.

The soil acidity amelioration and organic matter improvement is prerequisite for sustainable soil fertility management in the farm. The fertilizer for each crop should be applied based on the determined status in the farm. The proper nutrient management practice should be adopted especially for those nutrients having very low and very high in status, because crop may suffer from their stress. The research farm can be used for various research works like organic carbon improvement, available sulphur, boron and zinc improvement, selection of iron toxicity tolerant crops genotypes, evaluation of disease, insect and pest interaction with soil fertility parameters, selection of low sulphur, boron and zinc stress tolerant crop genotypes etc. Therefore, it is anticipated that the findings of the present study would help to guide required practices for sustainable soil fertility management as well as developing future research strategy in the farm.

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REFERENCES

Alabadan BA, PA Adeoyo and EA Folorunso. 2009. Effect of different poultry wastes on physical, chemical and biological properties of soil. Caspian J. Environ. Sci. **7**(1):31 – 35.

Aweto AO. 1982. Variability of upper slope soils developed under sandstones in South-western Nigeria. Georg. J. **25**:27-37.

Berger KC and E Truog. 1939. Boron determination in soils and plants. Ind. Eng. Anal. Ed. **11**:540 – 545.

Bolan NS and MJ Hedley. 2003. Role of carbon, nitrogen and sulfur cycles in soil acidification **In**: Handbook of soil acidity (Z Rengel, ed). Marcel Dekker, New York.

Bouyoucos GJ. 1962. Hydrometer method improved for making particle-size analysis of soils. Agron. J. **53**:464 – 465.

Brady NC and RR Weil. 2002. The nature and properties of soils. 13th ed. Pearson Prentice Hall. New Jersey.

Bremner JM and CS Mulvaney. 1982. Nitrogen total. **In**: Methods of soil analysis. Agron. No. 9, Part 2: Chemical and microbiological properties, 2nd ed. (AL Page, ed). American Society of Agronomy, Madison, WI, USA; **pp**. 595 – 624.

Burrough PA and RA McDonnell. 1998. Principle of geographic information systems. Oxford: Oxford University Press.

Das DK. 2000. Micronutrients: their behavior in soils and plants. Kalyani Publishers, New Delhi; **pp**.113–121.

El MahiY, IS Ibrahim, HM AbdelMajid and AM Eltilib. 1987. A simple method for determination of calcium and magnesium carbonate in soils. Soil Sci. Soc. Am. J. **51**:1152-1155.

Foth HD and BG Ellis. 1997. Soil fertility, 2nd ed. Lewis CRC Press LLC., USA.

Goovaerts P. 1998. Geo-statistical tools for characterizing the spatial variability of microbiological and physic-chemical soil properties. Biol. Fertil. Soil. **27**: 315-334.

Goswami NN, RK Rattan, G Dev, G Narayanasamy, DK Das, SK Sanyal, DK Pal and DLN Rao. 2012. Fundamental of Soil Science. Indian Society of Soil Science, New Delhi, India.

Havlin HL, JD Beaton, SL Tisdale and WL Nelson. 2010. Soil Fertility and Fertilizers- an introduction to nutrient management. 7thed. PHI Learning Private Limited, New Delhi.

Jackson ML. 1973. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Joshy D and GP Deo. 1975. Fertilizers Recommendations for Major crops of Nepal. Division of Soil Science and Agricultural Chemistry, Department of Agriculture, HMG/Nepal.

Khadka D, S Lamichhane, S Khan, S Joshi and B. Pant. 2016d. Assessment of soil fertility status of Agriculture Research Station, Belachapi, Dhanusha, Nepal. J. Maize Res. Dev. **2**(1):43-57.

Khadka D, S Lamichhane, B Thapa, BR Baral and P Adhikari. 2016a. An assessment of soil fertility status of national maize research program, Rampur, Chitwan, Nepal. Imp. J. Interdiscip. Res. **2**(5):1798-1807.

Khadka D, S Lamichhane, DN Tiwari and K Mishra. 2017. Assessment of soil fertility status of National Rice Research Program, Hardinath, Dhanusha, Nepal. Int. J. Agric. Environ. Res. **3**(1):86-105.

Khadka D, S Lamichhane, R Malla and S Joshi. 2016c. Assessment of soil fertility status of Oilseed Research Program, Nawalpur, Sarlahi, Nepal.Int .J. Adv. Res. **4**(6):1472-1483.

Khadka D, S Lamichhane, S Shrestha and BB Pant. 2016b. Assessment of soil physico-chemical properties of Sugarcane Research Program, Jitpur, Bara, Nepal. Int .J. Adv. Res. **4**(5):56-66.

Khatri-Chhetri TB. 1991. Introduction to Soils and Soil fertility. Tribhuvan University Institute of Agricultural and Animal Science, Rampur, Chitwan, Nepal.

Lindsay WL and WA Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. **42**: 421 – 428.

Olsen SR, CV Cole, FS Watanabe and LA Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Dep. Agric. Circ. 9, USA.

Panda SC. 2010. Soil management and organic farming.Agrobios, Jodhpur, India.

Rai S, AK Chopra, P Chakresh, K Dinesh, S Renu and PM Gupta. 2011. Comparative study of some physicochemical parameters of soil irrigated with sewage water and canal water of Dehradun city. Ind. Int. J. Environ. Sci. **3**(3):318 – 325.

Ramamurthy B and JC Bajaj. 1969. Available nitrogen, phosphorus and potassium status of Indian soils. Fert. News. **14**:25-36.

Sanchez PA, CA Palm and SW Boul. 2003. Fertility capability classification: A tool to help assess soil quality in the tropics. Geoderma. **114**:157-185.

Shalini K, HS Devenda and SS Dhindsa. 2003. Studies on causes and possible remedies of water and soil pollution in Sanganer town of Pink City. Ind. Int. J. Environ. Sci. **7**(1):47-52.

Sun B, SL Zhou and QG Zhao. 2003. Evaluation of spatial and temporal changes of soil quality based on geostatistical analysis in the hill region of subtropical China. Geoderma **115**:85-99.

Takahashi H, S Kopriva, M Giordano, K Saito and R Hell. 2011. Sulfur assimilation in photosynthetic organisms: molecular functions and regulations of transporters and assimilatory enzymes. Ann. Rev. Plant Biol. **62**:157–184.

Trohel FR and LM Thompson. 1993. Soils and soil fertility. 5^{th} ed. Oxford University Press., New York.

Verma BC. 1977. An improved turbidimetric procedure for the determination of sulphate in plants and soils. Talanta **24**:49 – 50.

Von Uexkuell HR. 1988. Nutrient cycling in soil management and smallholder development in the Pacific Islands. **In**: IBSRAM (International Board for Soil Research and Management) Proceedings, Bangkok.

Walkley AJ and IA Black. 1934. Estimation of soil organic carbon by the chromic acid titration method. Soil Sci. **37**:29-38.

Wang M, Q Zheng, Q Shen and S Guo. 2013. The Critical Role of Potassium in Plant Stress Response. Int. J. Mol. Sci. **14**(4):7370–7390.