

Evaluation of soil fertility status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

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Abstract

Soil fertility evaluation of an area or region is most basic decision making tool for the sustainable soil nutrient management. In order to evaluate the soil fertility status of the Regional Agricultural Research Station (RARS), Tarahara, Susari, Nepal. Using soil sampling auger 81 soil samples (0-20 cm) were collected based on the variability of land. The collected samples were analyzed for their texture, structure, colour, pH, OM, N, P₂O₅, K₂O, Ca, Mg, S, B, Fe, Zn, Cu and Mn status. The Arc-GIS 10.1 software was used for the preparation of soil fertility maps. The soil structure was granular to sub-angular blocky and varied between brown- dark grayish brown and dark gray in colour. The sand, silt and clay content were 30.32±1.4%, 48.92±0.89% and 20.76±0.92%, respectively and categorized as loam, clay loam, sandy loam, silt loam and silty clay loam in texture. The soil was moderately acidic in pH (5.98±0.08). The available sulphur (2.15±0.21 ppm), available boron (0.08±0.01 ppm) and available zinc (0.35±0.03 ppm) status were very low, whereas extractable magnesium (44.33±6.03 ppm) showed low status. Similarly, organic matter (2.80±0.07%), total nitrogen (0.09±0.004 %), extractable calcium (1827.90±45.80 ppm) and available copper (1.15±0.04 ppm) were medium in content. The available phosphorus (39.77±5.27 ppm), extractable potassium (134.12±4.91 ppm), and available manganese (18.15±1.15 ppm) exhibits high status, while available iron (244.7±19.70 ppm) was very high. The fertilizer recommendation can be done based on determined soil fertility status to economize crop production. Furthermore, research farm should develop future research strategy accordance with the prepared soil data base.

Keywords: Macronutrients, micronutrients, research strategy, soil fertility maps, soil variation.

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Introduction

Soil is a complex system comprised of minerals, soil organic matter (SOM), water, and air (Vishal et al., 2009; Flores-Magdaleno et al., 2011). 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 purpose (Rakesh et al., 2012). The texture, structure, colour etc. are important soil physical parameters. Similarly, soil reaction (pH), organic matter, macro and micronutrients etc. are also important soil chemical parameters. These properties play important role for the soil fertility and determined after soil testing (Brady and Weil, 2004). 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 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

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practices, fertilization and crop rotation) (Cambardella and Karlen, 1999). Describing the spatial variability of soil fertility across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data (Burrough and McDonnell, 1998).

Nepal Agricultural Research Council (NARC) was established to strengthen agriculture sector in the country through agriculture research. Regional Agricultural Research Station (RARS), Tarahara, Sunsari, Nepal is an important wing among the research stations of NARC, in order to generate appropriate crop production technologies for the eastern Nepal. Studies related to the soil fertility status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal are scarce. Therefore, it is important to investigate the soil fertility status and may provide valuable information relating to crop research. Keeping these facts, the present study was conducted with the objective to estimate the soil fertility status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal.

Material and Methods

Study area

The study was carried out at Regional Agricultural Research Station, Tarahara, Sunsari, Nepal (Figure 1). The research farm is situated at a latitude 26°42'17.4''N and longitude 87°16'43.9''E as well altitude 125 m above sea level.



Figure 1. Location map of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Soil sample collection

Surface soil samples (0-20 cm depth) were collected from Regional Agricultural Research Station, Tarahara, Sunsari, Nepal during 2016. A total of 81 soil samples were collected from the research farm (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 for the collection of 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 is shown on the Table 1.

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

S.N.	Parameters	Units	Methods
1	Soil texture		Hydrometer (Bouyoucos, 1962)
2.	Soil colour		Munsell-colour chart
3.	Soil structure		Field-feel
4.	Soil pH		Potentiometric 1:2 (Jackson, 1973)
5.	Soil organic matter	%	Walkely and Black (Walkley and Black, 1934)
6.	Total N	%	Kjeldahl (Bremner and Mulvaney, 1982)
7.	Available P ₂ O ₅	ppm	Olsen (Olsen et al., 1954)
8.	Extractable K ₂ O	ppm	Ammonium acetate (Jackson, 1973)
9.	Extractable Ca	ppm	EDTA Titration (El Mahi et al.,1987)
10.	Extractable Mg	ppm	EDTA Titration (El Mahi et al.,1987)
11.	Available S	ppm	Turbidimetric (Verma, 1977)
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)

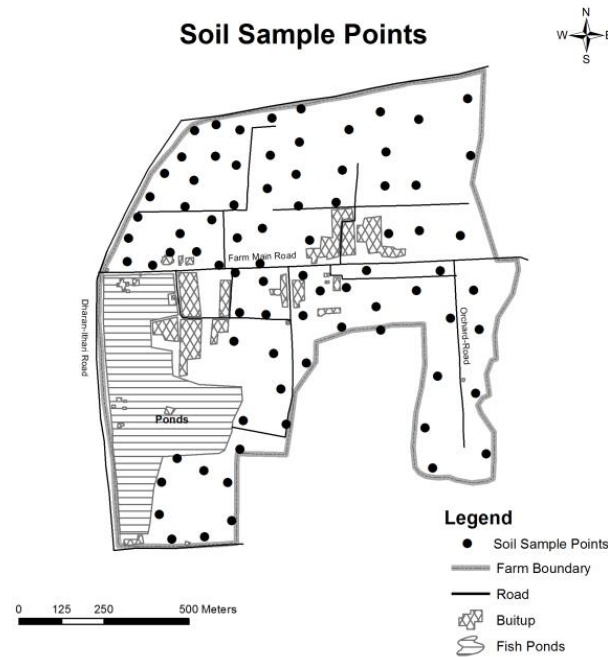


Figure 2. Distribution of soil sample points during soil sampling

Statistical analysis

Descriptive statistics (mean, median, range, standard deviation, standard error, coefficient of variation) of soil parameters were computed using the Minitab 15 package. Rating (very low, low, medium, high and very high) of determined values were based on Soil Science Division, Khumaltar. The coefficient of variation was ranked according to the guidelines of (Aweto, 1982) where, $CV < 25\%$ = low variation, $CV > 25 \leq 50\%$ = 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).

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

Where, N_L , N_M and N_H are number of samples falling in 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 shown on the Table 2.

Table 2. Rating Chart of Nutrient index

S.N.	Nutrient Index	Value
1.	Low	<1.67
2.	Medium	1.67-2.33
3.	High	>2.33

Results and Discussion

The soil fertility status of the study area was assessed with respect to texture, colour, structure, pH, organic matter, primary nutrients, secondary nutrients and micronutrients such as B, Fe, Zn, Cu, and Mn and the results obtained are presented and discussed in the following headings.

Soil texture

Texture is one of the most important physical property of soils as it affects water retention, nutrient availability, pore space, slope stability aeration and erosion susceptibility (Brady and Weil, 2004). The % of sand were ranged from 6.6 to 67.0 % with a mean of 40.32 % and that of % silt were 24.8 to 62.2 % with a mean of 48.92%, while the range of % clay were 6.2 to 36.2 % with a mean of 20.76% (Table 3). Five textural classes such as loam, clay loam, sandy loam, silt loam and silty clay loam were observed in the 34%, 10%, 4%, 32% and 20%, respectively of the studied samples (Table 3, Figure 3 and 4). The coefficients of variation between the soil samples were 41.58%, 16.32% and 39.82% for sand, silt and clay contents, respectively. The occurrence of different types of land (low land, medium low land, upland etc.) might be the cause of different types of texture in the farm. Khadka et al. (2017) also found different classes of texture

within the single research farm of similar size at National Rice Research Program, Hardinath, Dhanusha, Nepal.

Table 3. Particle size distribution of soils of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Descriptive Statistics	Particle size distribution		
	Sand, %	Silt, %	Clay, %
Mean	30.32	48.92	20.76
Standard Error	1.40	0.89	0.92
Standard Deviation	12.61	7.99	8.27
Min.	6.60	24.80	6.20
Max.	67.00	62.20	36.20
CV%	41.58	16.32	39.82

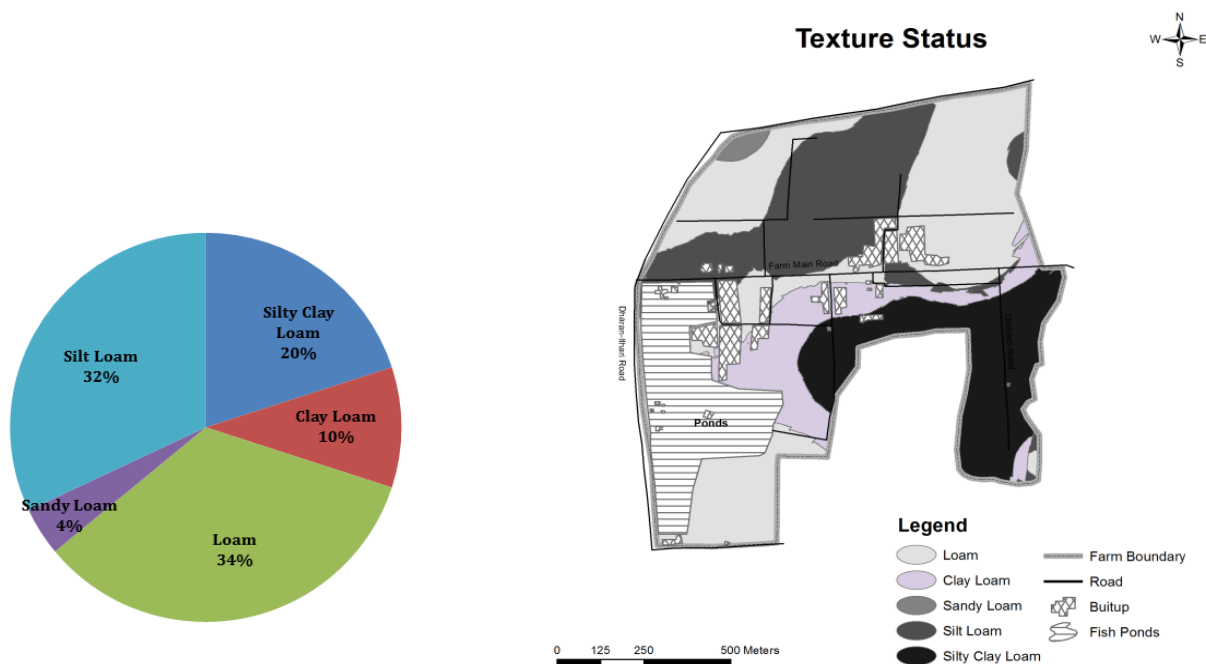


Figure 3. Distribution of Soil texture in the studied Samples

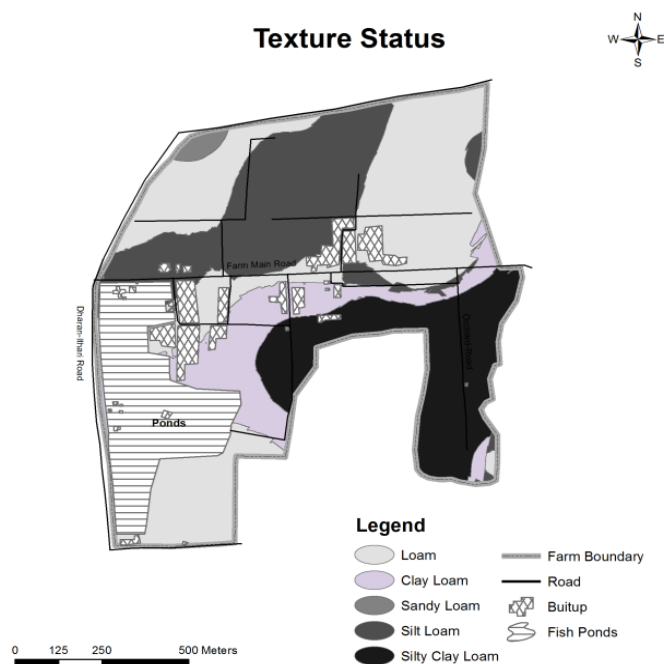


Figure 4. Soil texture status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Soil colour

Soil colour is an indirect measure of other important characteristics such as water drainage, aeration, and organic matter content of soils (Foth, 1990). Three kinds of colour namely; 10YR 4/2 (dark grayish brown), 10YR 4/1 (dark gray) and 10YR 5/3 (brown) were observed but 10YR 4/2 (dark grayish brown) was dominant.

Soil structure

The arrangement and organization of primary and secondary particles in a soil mass is known as soil structure. It controls the amount of water and air present in soil (Brady and Weil, 2004). Majority of the area contains sub-angular blocky structure, except granular at orchard site. The granular structure in orchard site might be due to less disturbance of soil.

Soil reaction (pH)

Soil pH is an important chemical parameter as it helps in ensuring availability of plant essential nutrients (Deshmukh, 2012). The pH of soil was varied from 4.49 to 7.58 with a mean value of 5.98 (Table 4). This indicates moderately acidic soil reaction (pH). The pH of soil samples was found to be 41.98% of sample showed moderately acidic, 20.99% samples were slightly acidic, 11.11% samples were very acidic, while 16.05% samples were nearly neutral and only 9.88% samples were slightly alkaline in nature. The soils are acidic might be as a result of the leaching of basic Cation or due to incessant uptake by crops grown on the field (Brady and Weil, 2004). The soil acidity implied that nutrients are likely to be available or unavailable

for crop uptake. Therefore, agriculture lime should be incorporate to increase soil pH of the very acidic and moderately acidic sites as shown on the Figure 5 and 6. The soil pH showed low variability (12%) in the studied soil samples. The adoption of heterogeneous management practice and occurrence of different types of land in the farm might be the reason for different classes of soil reaction (pH). Khadka et al. (2017) also found different classes of pH within the single research farm of comparable size of National Rice Research Program, Hardinath, Dhanusha, Nepal.

Table 4. Soil fertility status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Descriptive Statistics	Soil Fertility Parameters				
	pH	OM, %	N, %	P ₂ O ₅ , ppm	K ₂ O, ppm
Mean	5.98	2.80	0.09	39.77	134.12
Standard Error	0.08	0.07	0.004	5.27	4.91
Standard Deviation	0.69	0.66	0.04	47.41	44.19
Min.	4.49	0.78	0.01	1.16	58.2
Max.	7.58	4.42	0.22	229.58	344.4
CV%	12	24	42	119	33

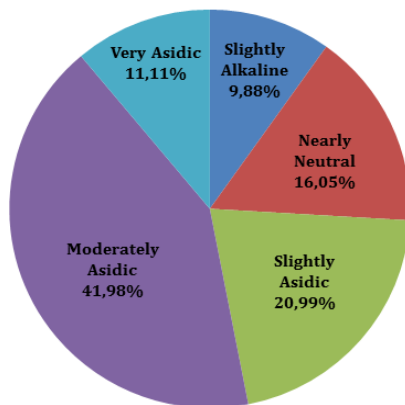


Figure 5. Distribution of soil reaction (pH) of the studies samples

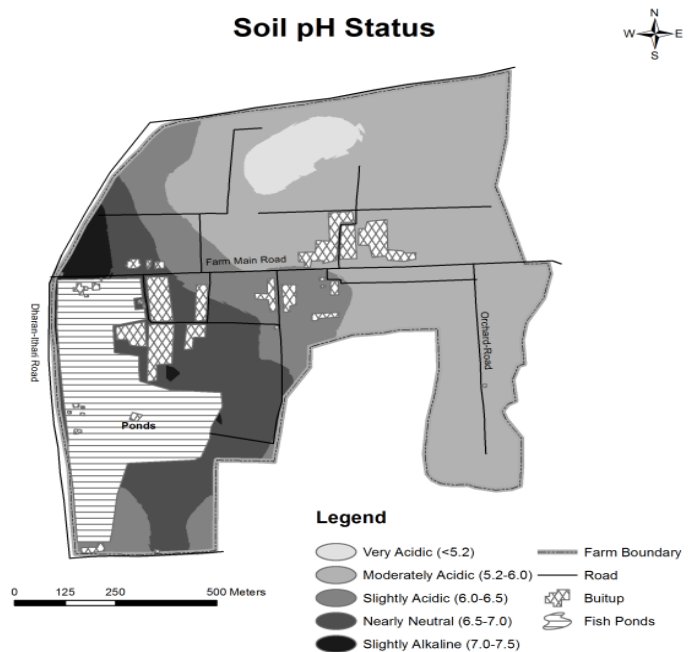


Figure 6. Soil pH status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Soil organic matter

Organic matter has a vital role in agricultural soil. It supplies plant nutrient, improve the soil structure, water infiltration and retention, feeds soil micro-flora and fauna, and the retention and cycling of applied fertilizer (Johnston, 1986). The organic matter content was ranged from 0.78 to 4.42% with a mean value of 2.80% (Table 4). This indicates medium status of the organic matter. Distribution of soil samples with respect to organic matter content indicates that about 6 % samples had low organic matter, while 49 % were medium and other 44 % samples had higher organic matter (Figure 7, Table 5). Organic matter showed low variability (24%) among the soil samples. This farm is more sustainably running than the majority of the terai regions farms of NARC. Because the organic matter content is satisfactory than most of the others (Khadka et al., 2016b; Khadka et al., 2016d; Khadka et al., 2017). The farm should run more consistently as adopted present practice for organic matter improvement in the future.

Total nitrogen

Nitrogen is one of the most important plant nutrients and the most frequently deficient of all nutrients (Havlin et al., 2010). The total nitrogen content was ranged from 0.01 to 0.22% with a mean value of 0.09%

(Table 4). This showed medium status of total nitrogen. The study indicates that about 38% of the sample exhibited low and 58 % under medium and other 4 % in high range of nitrogen content (Figure 8, Table 5). Moderate variability (42%) in total nitrogen was observed among the sampled soils. The satisfactory conditions in the organic matter might be the reason for medium status in total nitrogen. Those areas which have low status should be applied with full dose (100%) of the recommended nitrogen dose, whereas 75% of the recommended dose in medium status area might be sufficient (Joshy and Deo, 1976).

Table 5. Nutrient indices and percentage distribution of studied soil parameters of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

S.N.	Parameters	% distribution of samples					NI	Remarks
		VL	L	M	H	VH		
1.	OM		6	49	44		2.38	H
2.	N		38	58	4		1.65	L
3.	P ₂ O ₅	4.94	20.99	29.63	24.69	19.75	2.22	M
4.	K ₂ O	-	-	46.91	51.85	1.23	2.53	H
5.	Ca	-	-	67	33	-	2.33	M
6.	Mg	-	69	28	2	-	1.33	L
7.	S	75.3	23.5	1.2	-	-	1.01	L
8.	B	100	-	-	-	-	1.00	L
9.	Fe	-	-	-	-	100	3.00	H
10.	Zn	74.07	23.46	2.47	-	-	1.01	L
11.	Cu	-	22.22	38.27	39.51	-	2.21	M
12.	Mn	2.47	11.11	17.28	60.49	8.24	2.59	H

*VL=Very Low; L= Low; M= Medium; H= High; VH= Very High; NI= Nutrient Index

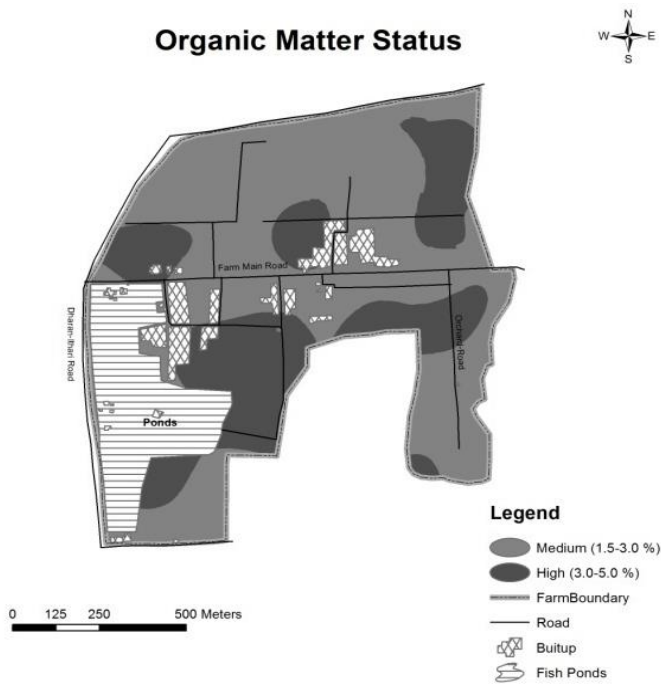


Figure 7. Organic matter status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

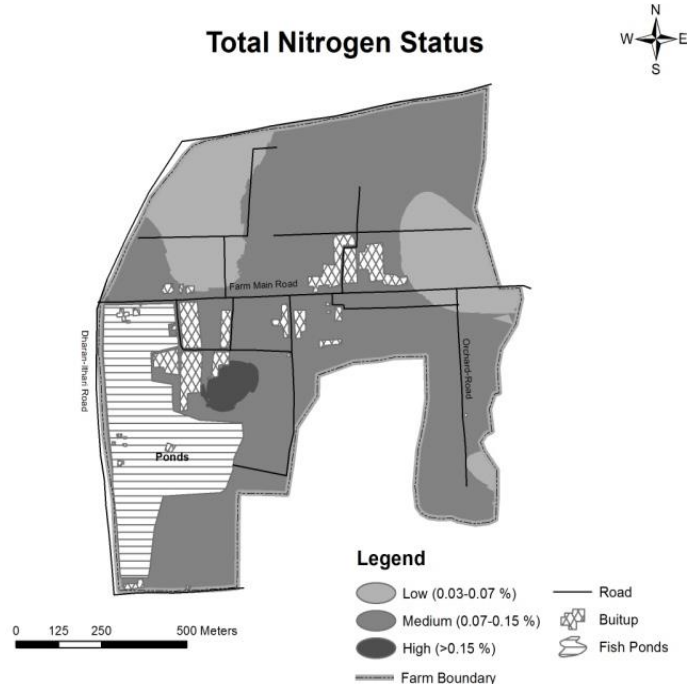


Figure 8. Total nitrogen status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Available phosphorus

Phosphorus plays an important role in energy transformations and metabolic processes in plants (Rai et al., 2012). The available phosphorus was ranged from 1.16 to 229.58 ppm with the mean value of 39.77 ppm (Table 4). This revealed high status of available phosphorus. The study indicates that about 4.94 % of the samples exhibited very low and 20.99% were low, while 29.63% samples were medium and 24.69 % under high and 19.75 % in very high range of Phosphorus content (Figure 9, Table 5). Available phosphorus showed high variability (119%) among the tested soil samples. The different classes of available phosphorus that the farm possesses might be due to adoption of heterogeneous management practices as well as occurrence of different classes of pH. The area having low, medium and high status, 100%, 60%

and 40%, respectively of recommended phosphorus dose should be applied in the farm (Joshy and Deo, 1976).

Extractable potassium

Potassium is not an integral part of any major plant component but it plays a key role in a vast array of physiological process vital to plant growth from protein synthesis to maintenance of plant water balance (Sumithra et al., 2013). The extractable potassium content was varied from 58.2 to 344.4 ppm with a mean value of 134.12 ppm (Table 4). This suggests high status of extractable potassium. The data reveals that 51.85 % soil samples tested were in high level of extractable potassium, while 46.91% samples were medium and other 1.23 % samples were very high in status (Figure 10, Table 5). Moderate variability (33%) in extractable potassium was determined among the soil samples. The satisfactory conditions of extractable potassium in the farm might be due to the optimum application of potash as well as less loss of potassium ion from the soil. Because majority of the study area soil texture of the study area was fine.. The fertilizer recommended practice is similar with phosphorus already mentioned in the phosphorus section for medium and high status.

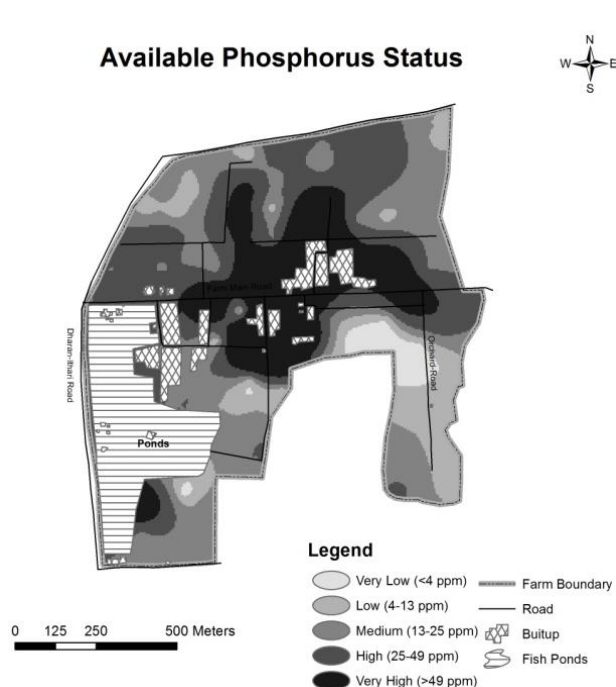


Figure 9. Available phosphorus status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

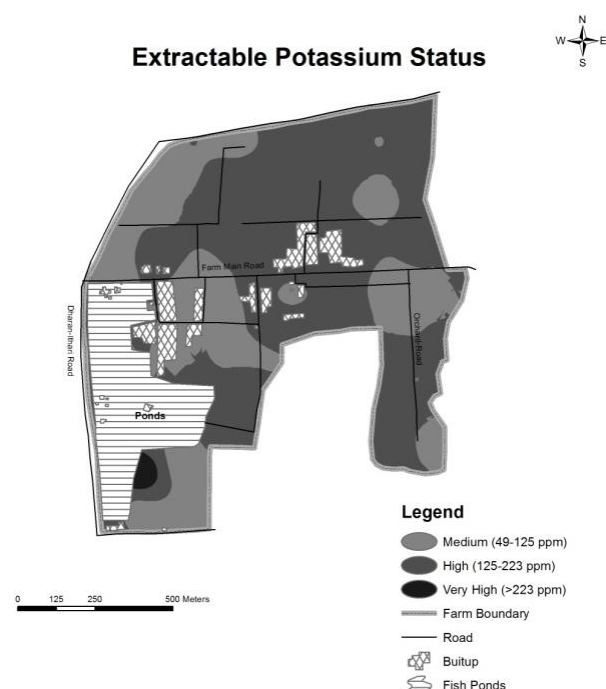


Figure 10. Extractable potassium status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Extractable calcium

Calcium is a key regulator of plant responses to endogenous stimuli and stress signals of both biotic and abiotic nature (Lecourieux, 2006). The extractable calcium content was ranged from 1034 to 2728 ppm with a mean value of 1827.9 ppm (Table 6). This showed medium status of extractable calcium. As per the percentage category, majority samples (67%) were medium and only 33% samples were high in status (Figure 11, Table 5). Low variability (23%) in extractable calcium was observed among the soil samples.

Table 6. Soil fertility status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Descriptive Statistics	Soil Fertility Parameters			
	Ca, ppm	Mg, ppm	S, ppm	B, ppm
Mean	1827.90	44.33	2.17	0.08
Standard Error	45.80	6.03	0.21	0.01
Standard Deviation	411.80	54.27	1.93	0.07
Min.	1034	1.5	0.09	0.01
Max.	2728	330.0	8.70	0.35
CV%	23	122	89	87

Extractable magnesium

Magnesium ions (Mg^{2+}) are the second most abundant Cation in living plant cells, and they are involved in various functions, including photosynthesis, enzyme catalysis, and nucleic acid synthesis (Tanoi and Kobayashi, 2015). The extractable magnesium content was varied from 1.5 to 330.0 ppm with a mean value of 44.33 ppm (Table 6). This indicates low status of extractable magnesium. As per the percentage category; majority samples (69%) were low, while 28% samples were medium and only 2% samples were high in status (Figure 12, Table 5). The variation (122%) in the extractable magnesium of the observed samples is high. The maintenance of slightly acidic to slightly alkaline soil pH is suitable option for increasing availability of magnesium in the soil (Havlin et al., 2010).

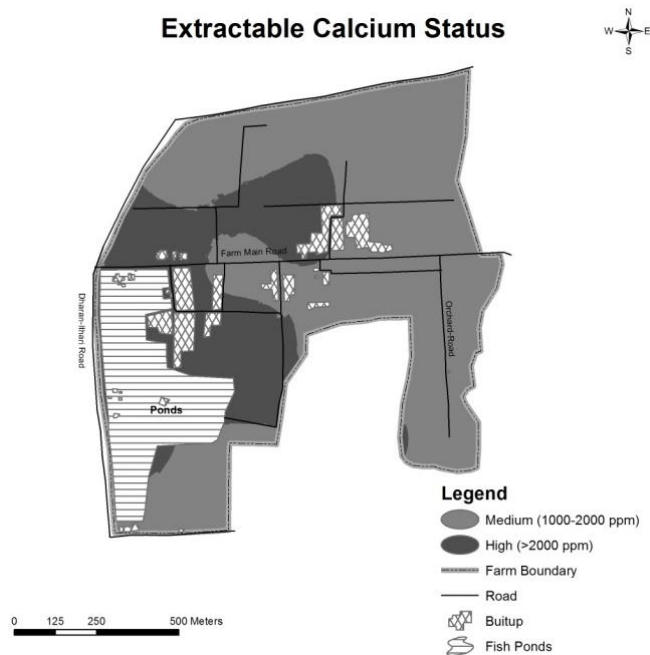


Figure 11. Extractable calcium status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

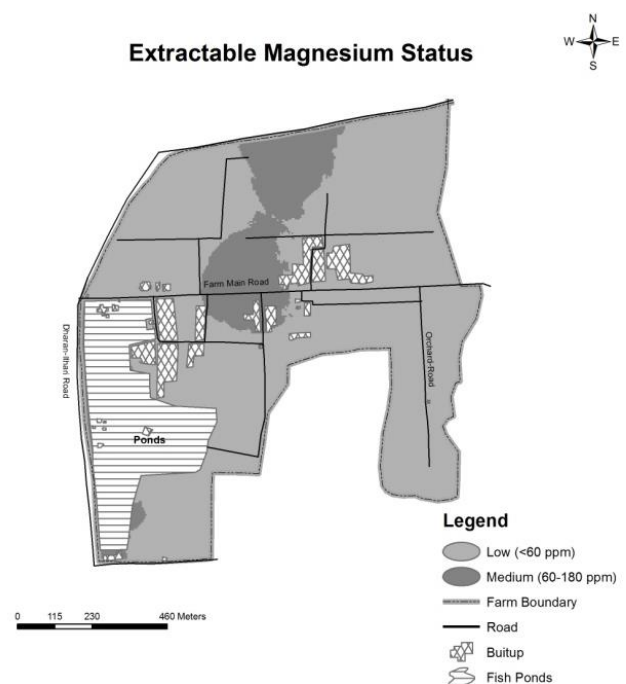


Figure 12. Extractable magnesium status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Available sulphur

Sulphur is an essential nutrient for plant growth due to its presence in proteins, glutathione, phytochelatin, thioredoxins, chloroplast membrane lipids, and certain coenzymes and vitamins (Takahashi et al., 2011). The available sulphur was ranged from 0.05 to 8.70 ppm with a mean value of 2.17 ppm (Table 6). This showed very low status of available sulphur. With regard of percent category, majority samples (75.3%) were very low, while 23.5% samples were low and 1.2% samples were medium in status (Figure 13, Table 5). Available sulphur showed high variability (89%) in the soil samples. Low sulphur is a major limiting factor for crop production in the terai region of Nepal (Khadka et al., 2016a, Khadka et al., 2016c, Khadka et al., 2016d; Khadka et al., 2017). The sulphur is a component of organic matter released after their mineralization (Havlin et al., 2010). The organic matter is satisfactory but available sulphur is low, which might be due to the occurrence of high nitrogen among all in the organic matter. Application of sulphur containing fertilizer regularly is sustainable option for reducing deficiency stress for plants.

Available boron

Boron is one of two nonmetal micronutrients required by plants for their cell wall structural integrity (Havlin et al., 2010). The available boron content was ranged from 0.01 to 0.35 ppm with a mean value of 0.08 ppm (Table 6). This indicates very low status of available boron. As per the percentage category, all the samples (100%) were very low in available boron (Figure 14, Table 5). High variability (87%) in available boron was observed among the soil samples. Boron content is also inadequate in the nearby sites of the study area (Khadka et al., 2016d; Khadka et al., 2017). Regular soil application of 2-3 kg/ha Boron is suitable option for reducing boron deficiency stress for the plants.

Available iron

Iron is an essential nutrient for plants. It accepts and donates electrons, and it plays important roles in the electron transport chains associated with photosynthesis and respiration (Das, 2000). The available iron content was varied from 38.4 to 793.0 ppm with a mean value of 244.7 ppm (Table 7). This indicates very high status of available iron. As per the percentage category, all the samples (100%) possessed very high content of available iron (Figure 15, Table 5). Available iron showed high variability (72%) among the soil samples. The iron content is high in the most of the terai region of Nepal (Khadka et al., 2015; Khadka et al., 2016a; Khadka et al., 2016b; Khadka et al., 2017). The very high availability of iron might be due to high possibility of primary and secondary iron minerals like hematite, olivine, siderite, goethite, magnetite etc (Das, 2000). High iron availability reduces the uptake of elements K, P, Mn and Zn, thereby increasing the deficiency symptoms of these nutrients (Fageria et al., 2008). Therefore, proper management of these nutrients is one option for reducing deficiency stress of these nutrients due to iron toxicity. Similarly, selection and cultivation of iron toxicity tolerant genotype is another suitable option for its toxicity management.

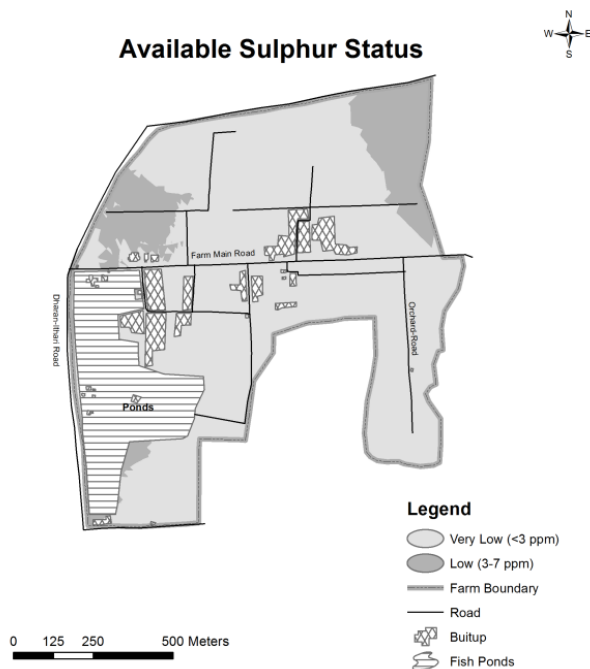


Figure 13. Available sulphur status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

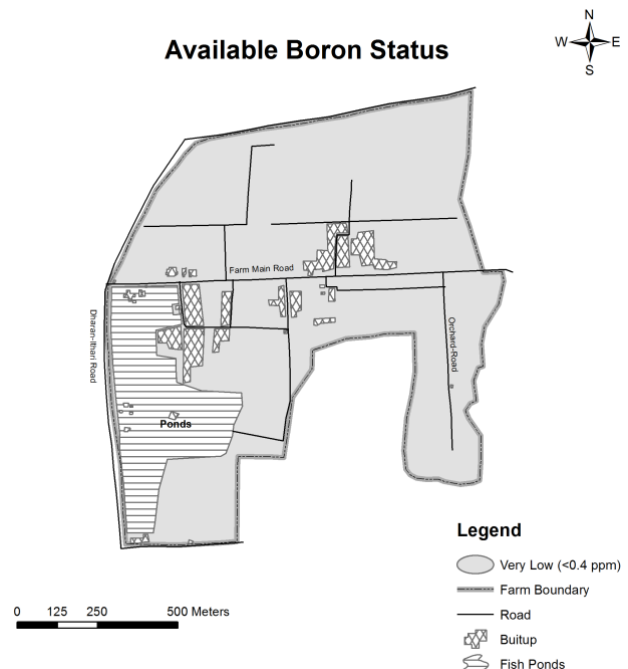


Figure 14. Available boron status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Table 7. Soil fertility status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Descriptive Statistics	Soil Fertility Parameters			
	Fe, ppm	Zn, ppm	Cu, ppm	Mn, ppm
Mean	244.70	0.35	1.15	18.15
Standard Error	19.70	0.03	0.04	1.15
Standard Deviation	177.40	0.30	0.37	10.35
Min.	38.40	0.004	0.30	0.20
Max.	793.0	1.52	1.94	51.28
CV%	72	86	32	57

Available zinc

Zinc plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome (Havlin et al., 2010). The available zinc content was ranged from 0.004 to 1.52 ppm with a mean value of 0.35 ppm (Table 7). This showed very low status of available zinc. As per the percentage category; majority of samples (74.07%) were

very low, while 23.46% samples were low and only 2.47% samples showed medium in status (Figure 16; Table 5). The available zinc showed high variability (86%) among the soil samples. Zinc content is inadequate in the nearby sites of the study area (Khadka et al., 2016d; Khadka et al., 2017). Regular soil application of 6-8 kg/ha Zinc is suitable option for reducing zinc deficiency stress for the plants.

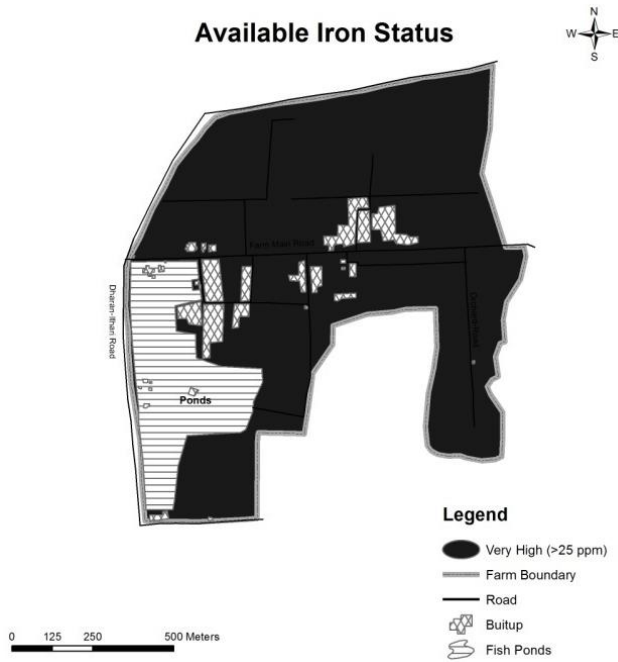


Figure 15. Available iron status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

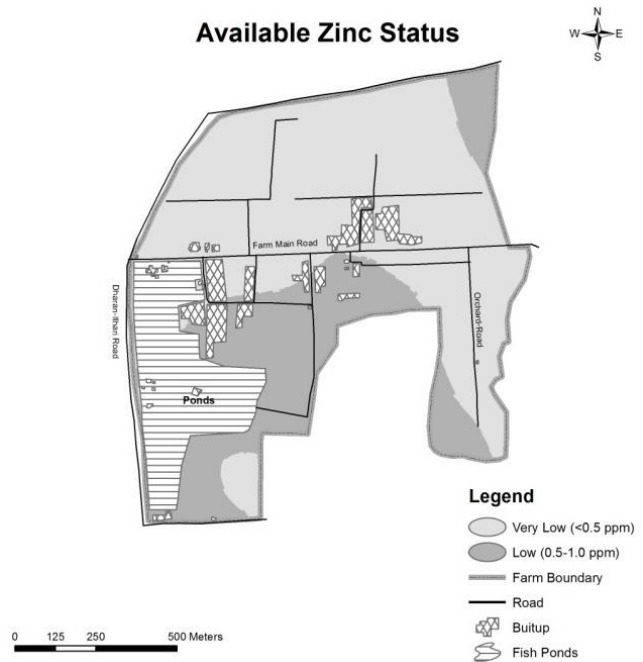


Figure 16. Available zinc status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Available copper

Copper is one of the oldest known metals and is the 25th most abundant element in the Earth's crust. The available copper of the soil depicted from 0.30 to 1.94 ppm with a mean of 1.15 ppm (Table 7). This showed medium status of available copper. As per the percent category, 22.22%, 38.27% and 39.51% samples were low, medium and high in status, respectively (Figure 17, Table 5). Moderate variability (32%) in available copper was recorded among the soil samples.

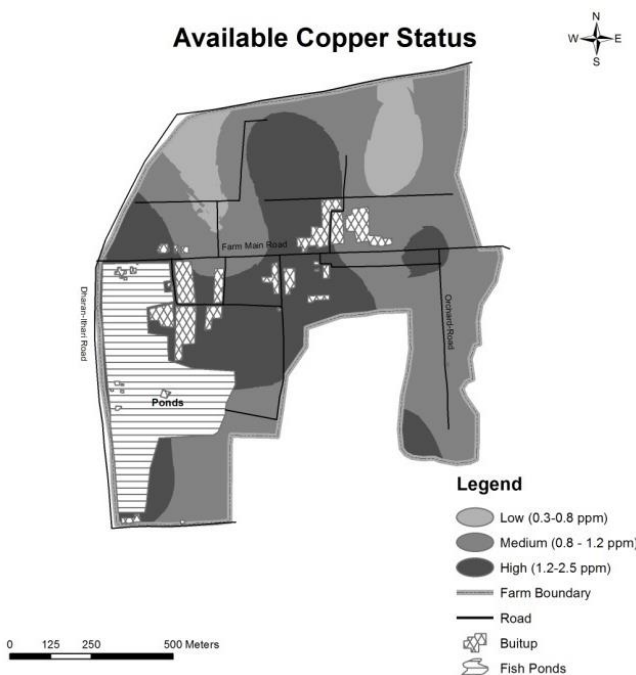


Figure 17. Available copper status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

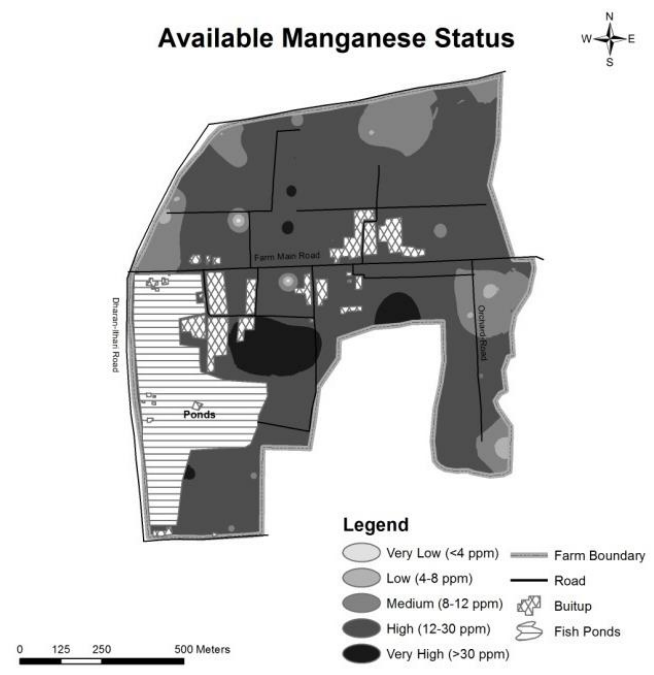


Figure 18. Available manganese status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal

Available manganese

Manganese is the tenth-most abundant element on the surface of the earth. It is involved in many biochemical functions, primarily acting as an activator of enzymes such as dehydrogenases, transferases, hydroxylases, and decarboxylases involved in respiration, amino acid and lignin synthesis, and hormone concentrations (Burnell, 1988). The available manganese of the soils ranged from 0.20-51.28 ppm with a mean of 18.15 ppm (Table 7). This exhibits high status of available manganese. As per the percentage category, majority of samples (60.49%) were high, while other 17.28%, 11.11% , 8.24% and 2.47% samples exhibited medium, low, very high and very low in status, respectively (Figure 18, Table 5). The available manganese showed moderate variability (52%) among the studied soil samples.

Conclusion

The prepared soil data base is very useful for fertilizer recommendations for different crops to economize their production. The crops may suffer from the deficiency and toxicity stress of the particular determined such nutrients. The proper nutrient management should be adopted especially for these nutrients during cultivation. Similarly, soil fertility variation is very high in the majority of nutrients due to various intrinsic and extrinsic factors. Keeping one season fallow before starting any experiment is advisable for reducing error in the experimentation due to soil fertility variation. Furthermore, the research farm should develop future research strategy like identification of iron toxicity, boron and zinc deficiency stress tolerant genotypes, soil acidity amelioration mechanism etc. based on the prepared soil data base.

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