Research Article

Geostatistical based soil fertility mapping of Horticultural Research Station, Rajikot, Jumla, Nepal

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ABSTRACT

Geostatistical soil mapping is important for determining spatial distribution of soil parameters. This study was conducted to assess soil spatial distribution of the Horticultural Research Station, Rajikot, Jumla, Nepal. The total 27 samples were collected randomly at a depth of 0-20 cm by using soil sampling auger. A GPS device was used for determination of geographical position of soil sampling points. The collected samples were analyzed following standard analytical methods in the laboratory of National Soil Science Research Centre, Khumaltar. The Arc-GIS 10.1 software was used for the mapping spatial distribution of various soil parameters. The observed data revealed the structure was sub-angular blocky and granular, whereas colour were dark brown to dark grayish brown and dark yellowish brown. The sand, silt and clay content were ranged 24.40-72.10%, 19.40-63.10% and 6.20-14.50%, respectively and categorized loam, sandy loam and silt loam in texture. The soil pH was slightly acidic to moderately alkaline (5.01-8.06), and very low available sulphur (0.59-2.41 mg/kg) and very low to low available boron (0.04-0.87 mg/kg). Moreover, very low to medium available manganese (2.18-13.46 mg/kg), very low to very high available iron (4.50-138.58 mg/kg), and low to medium available magnesium (7.20-177.60.53 mg/kg) and zinc (0.26-1.66 mg/kg). Similarly, medium total nitrogen (0.09-0.22%), medium to high organic matter (1.71-6.26%) and available calcium (1200-3144 mg/kg), medium to very high available phosphorus (3.71-82.4 mg/kg) and potassium (59.37-173.05 mg/kg). Correspondingly, high to very high available copper (0.78-4.20 mg/kg). The determined soil test data can be used for sustainable soil management as well as developing future research strategy in the farm.

Keywords: Arc-GIS, Jumla, Ordinary kriging, Soil fertility mapping, Soil analysis

INTRODUCTION

Soil is a natural dynamic body, and plays important role for agriculture production (Jones, 2011). Soil can play their role accurately, when it is fertile and productive. In Nepal, Keeping fertile- productive soil has great challenges because of various intrinsic and extrinsic factors continuing in the soil system. The soil erosion, reduced organic matter, nutrients mining and imbalance use of various agro-chemical

are the major cause of reducing productivity of soils in Nepal (Tripathi, 2019). Moreover, most of the sites of Nepal soil organic matter, boron and sulphur are extremely critical in status due to natural and human- induced factor (Khadka *et al.*, 2016; Khadka *et al*., 2017; Khadka *et al*., 2018). In addition, increasing soil acidity is also greater challenge for increasing crops production in Nepal (Tripathi, 2019).

The soil fertility evaluation is the most basic decision making tool in order to efficient plan for sustainable soil management (Havlin *et al*., 2010). Soil testing, Plant analysis, Biological tests and Visual deficiency symptoms are the commonly used methods for soil fertility evaluation (Panda, 2010). Among them soil testing is most popular as well as more scientific then other methods. Soil testing provides information regarding soil physico-chemical characteristics, which is useful for recommending amounts and types of fertilizer and other amendments for increased and profitable crop production (Biswas and Mukherjee, 2015). The bulk density, 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 (Panda, 2010). Among them, some physical parameters can be determined in the field, while most of the chemical parameters in the laboratory.

Soil properties vary spatially in an area might be due to the effect of various factors such as soil management practices, indigenous fertility status, crop rotation, nature of standing crop etc. (Cambardella and Karlen, 1999). The Global Positioning Systems (GPS) and Geographic Information Systems (GIS) are important tools, which makes easier for describing spatial variability of soil fertility in a different area. For preparing thematic soil fertility maps collecting soil samples by using GPS has greater role (Mishra *et al.*, 2013). Similarly, Geographical Information System (GIS) is a potential tool used for easy access, retrieval and manipulation of larger natural resources data often difficult to handle manually. It facilitates manipulation of spatial and attributes data of diverse origin (Mandal and Sharma, 2010). Based on the geo-statistical analysis, several studies have been conducted to characterize the spatial variability of different soil properties for digital soil mapping (Weindorf and Zhu, 2010; Liu *et al*., 2013). Among the different geo-statistical methods for interpolation, ordinary kriging is widely used to map spatial soil variation because of its higher prediction accuracy (Song *et al*., 2013).

Nepal Agricultural Research Council (NARC) was established to strengthen agriculture sector in the country through agriculture research. Horticultural Research Station, Rajikot, Jumla is an important wing among the research farms of NARC, in order to generate appropriate horticultural crop production technologies for western high hills of Nepal. This site is most food insecure place of Nepal (Acharya *et al.*, 2018). Moreover, Information on digital soil mapping of Horticultural Research Station, Rajikot, Jumla are not done yet. Therefore, it is important to investigate the soil fertility status and mapping for digital soil mapping, thus may provide valuable information relating research strategy development. Considering this, the present study was initiated with the objective to assess the soil fertility status as well as mapping their spatial distribution of Horticultural Research Station, Rajikot, Jumla, Nepal.

## MATERIALS AND METHODS

Study Area
The study was carried out at Horticultural Research Station, Rajikot, Jumla, Nepal (Figure 1). Moreover, in that site two blocks are separated namely B and C. The research station is located within the latitude 29°16'50"N to 29°12'20"N and longitude 82°12'20"E to 82°12'40"E E as well altitude 2376masl to 2398masl. The average temperature varies from 18°c to 30°c in summer and -14 °c to 8°c in winter and the annual average rainfall is 1343 mm. Apple, Walnut, Apricot, Peach, Plum, Sweet cherry, Kiwi, Potato, Pea, Bean, Cauliflower, Cabbage, Radish, Carrot and Garlic are the major horticultural crops grown in the farm.
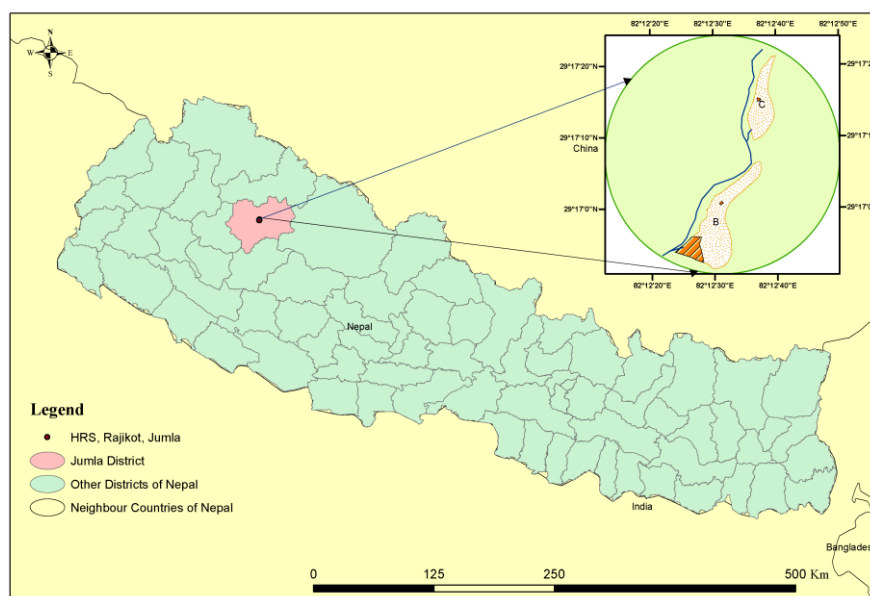
Figure 1. Location Map of Horticultural Research Station, Rajikot, Jumla, Nepal

Soil Sampling

Surface soil samples (0-20 cm depth) were collected from different sites of Horticultural Research Station, Rajikot, Jumla, Nepal during April 2017. The total 27 soil samples were collected from the two blocks (B; 15 Samples and C;12 Samples) by using 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.
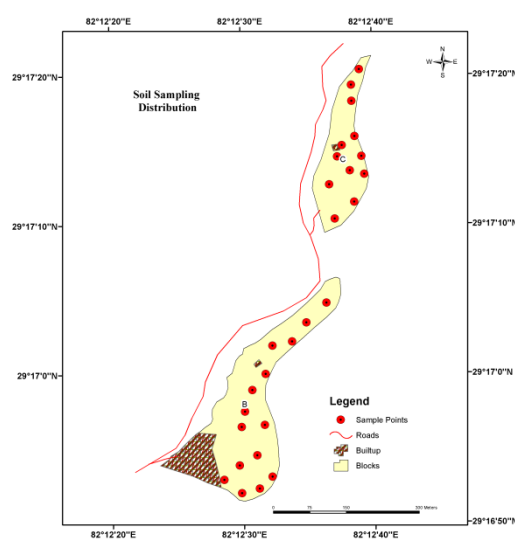
Figure 2. Soil Sample Distribution during Soil Sampling in the Study Area

Laboratory Analysis

The collected soil samples were analyzed at laboratory of National Soil Science Research Centre, 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	Unit	Methods
1.	Physical		
	Soil texture		Hydrometer (Bouyoucos, 1927)
	Soil colour		Munshell-colour chart (Munsell, 2009)
	Soil structure		Field-feel
	Bulk Density		Core (Keen and Raczkowaski, 1921)
2.	Chemical		
	Soil pH		Potentiometric 1:2 (Jackson, 1973)
	Organic matter	%	Walkely and Black (Walkley and Black, 1934)
	Total N	%	Kjeldahl (Bremner and Mulvaney, 1982)
	Available P_2O_5	mg/kg	Olsen's (Olsen $et\ al.$, 1954)
	Available K_2O	mg/kg	Ammonium acetate (Jackson, 1967)
	Available Ca	mg/kg	EDTA Titration (El Mahi $et\ al.$,1987)
	Available Mg	mg/kg	EDTA Titration (El Mahi $et.al.$,1987)
	Available S	mg/kg	Turbidimetric (Verma, 1977)
	Available B	mg/kg	Hot water (Berger and Truog, 1939)
	Available Fe	mg/kg	DTPA (Lindsay and Norvell, 1978)
	Available Zn	mg/kg	DTPA (Lindsay and Norvell, 1978)
	Available Cu	mg/kg	DTPA (Lindsay and Norvell, 1978)
	Available Mn	mg/kg	DTPA (Lindsay and Norvell, 1978)

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. The coefficient of variation was also ranked for determination of nutrient variability according to the procedure of (Aweto, 1982) where, CV ≤ 25% = low variation, CV >25 ≤ 50% = moderate variation, CV >50% = high variation.

Arc Map 10.1 with geostatistical analyst extension of Arc GIS software was used to prepare spatial distribution map of soil parameters, while interpolation method employed was ordinary kriging with stable semi-variogram. Moreover, area of rating also calculated from the raster calculator tool. Correspondingly, spatial dependency was calculated to determine strength of spatial correlation from the various parameters of semi-variogram (nugget, partial sill, sill etc.). For calculation of spatial dependency we used following formulae, and interpreted in three category namely; strong (SD=<25%), moderate (SD=25-75%) and weak (SD=>75%) (Cambardella $et\ al.$, 1994).

$$\text{Spatial Dependency (SD\%)} = \frac{Nugget}{Sill} \times 100$$

RESULTS AND DISCUSSION

The soil fertility distribution of the studied site was assessed with respect to texture, colour, structure, bulk density, 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.
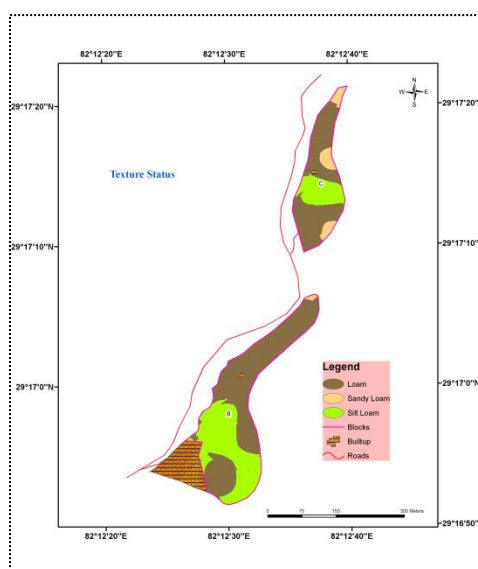
Soil Texture

Soil texture is an important physical parameter showing drainage, water holding capacity, aeration, susceptibility to erosion, organic matter content, cation exchange capacity, pH buffering capacity and soil tilth (Berry $et\ al.$, 2007).The sand content of samples ranged from 24.4 to 72.10% with a mean of 43.87% and that of silt content were 19.40 to 63.10% with a mean of 46.35%, while the range of clay content was 6.2 to 45.5% with a mean of 9.79% (Table 3). This shows loam, sandy loam and silt loam

texture, where among them distribution of loam (area: 63.38%) was dominant (Figure 3). The site inhabiting loam texture is good for cultivation various kinds of horticultural crops and fruits, while in silt loam site care should be taken for tillage and water management. The coefficients of variation between the soil samples were moderate for sand (29.85%), and silt (25.01%), whereas low for clay (20.03%).

Table 3. Soil Texture Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Descriptive Statistics	Soil separates		
	Sand	Silt	Clay
	%		
Mean	43.87	46.35	9.79
SEM	2.57	2.27	0.38
SD	13.09	11.59	1.96
Minimum	24.40	19.40	6.20
Maximum	72.10	63.10	14.50
CV%	29.85	25.01	20.03
Class (Area)	Loam (63.38%); Sandy Loam (4.36%); Silt Loam (32.26%)		

SEM=Standard error of the mean; SD=Standard deviation

Figure 3. Soil Texture Status of Horticultural Research Station, Rajikot, Jumla, 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 soil colour namely; dark brown (10YR 3/3), dark yellowish brown (10YR 4/3) and dark grayish brown (10YR 4/2) were observed in the studied sites. The observed colour denotes satisfactory amount of humus in the soil.

Soil Structure

Soil structure refers to the pattern of spatial arrangement of soil particles in a soil mass (Brady and Weil, 2004). The sub-angular blocky (block B) and granular (Block C) kind of structure was observed in all the sites. The granular structure is good for agricultural point of view because in such structure soil aggregates are separated by elongated continuous pores, which allows good water and nutrient movement, and facilitates root growth (Pagliai and Vignozzi, 2002). The sub-angular blocky structure was also satisfactory for various agricultural practices.

Bulk Density

Soil bulk density is a basic dynamic soil property that influenced by various physical and chemical properties (Chaudhari *et al*., 2013). The bulk density ranged from 1.05-1.29 g/cm^3 with a mean of 1.19 g/cm^3. This shows the bulk density is ideal for the plants growth. The satisfactory conditions of organic matter (Figure 5) as well as fine texture (Figure 3) might be the cause of relatively ideal bulk density in the farm. The optimum condition of bulk density indicates less compaction inside the soil system, which helps to make water and nutrient movement easier; hence root growth also becomes easier. This causes suitable environment for root growth of deep rooted fruits like apple, walnut etc.
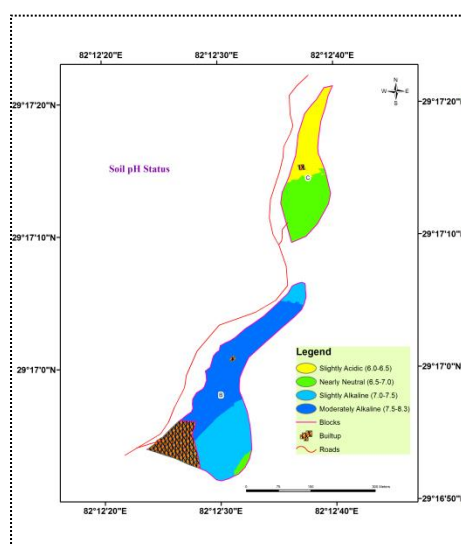
Soil pH

The pH is an excellent indicator for determining chemical nature of the soil (Shalini *et al*., 2003). The soil pH varied from 5.01 to 8.06 with a mean of 7.02 (Table 4). The distribution soil pH varied from slightly acidic to moderately alkaline, but majority area (45.08%) contained moderately alkaline range (Figure 4; Figure 17). The variation on soil management practice in the different sites of the farm from the longer period might be the cause of high variation of soil pH (moderately acidic to moderately alkaline). The determined pH is suitable for most of the vegetable crops and fruits. But special care should be taken in the slightly acidic pH inhabiting sites; because day to day nutrient management practice may decrease pH in long-term. Soil pH showed low variability (11.49%) among the soil samples.

Table 4. Soil Fertility Status of Horticultural Research Station, Rajikot, Jumla, Nepal

| Descriptive Statistics	Soil Fertility Parameters				
	pH	OM	N	P_2O_5	K_2O
		%		mg/kg	
Mean	7.02	3.80	0.15	30.18	117.38
SEM	0.16	0.21	0.01	4.46	6.59
SD	0.81	1.10	0.03	22.29	34.24
Minimum	5.01	1.71	0.09	3.71	59.37
Maximum	8.06	6.26	0.22	82.4	173.05
CV%	11.49	29.05	21.45	73.85	29.17

SEM=Standard error of the mean; SD=Standard deviation

Figure 4. Soil pH Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Organic Matter

Organic matter plays important role for improving various physical, chemical and biological properties (Hoyle *et al*., 2011). The organic matter varied from 1.71 to 6.26% with a mean of 3.80% (Table 4).The distribution of organic matter ranged from medium to high, meanwhile medium status (97.74%) was prevalent (Figure 5; Figure 17). For long-term cultivation, there may be more chance of organic matter deterioration due to various cultivation practice adopted for fruit and vegetable cultivation. Therefore, different organic matter improving program (adding compost, crop residue retention etc.) is suggested regularly for maintaining organic matter in long-term. Organic matter showed moderate variability (29.05%) among the soil samples.
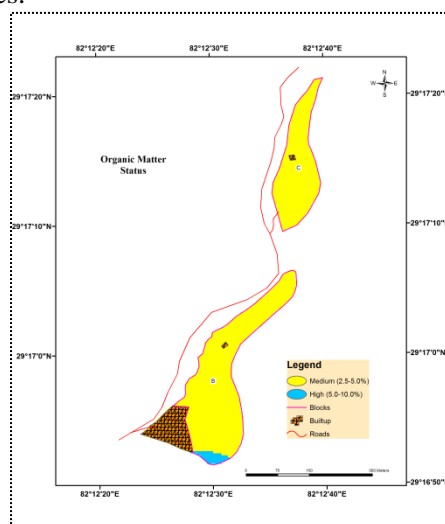
Figure 5. Organic Matter Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Total Nitrogen

Nitrogen is the most important nutrient, and required by the plant in largest proportion (Havlin *et al*., 2010). The total nitrogen ranged from 0.09 to 0.22% with a mean of 0.15% (Table 4).The data revealed all area was medium in distribution (Figure 6; Figure 17). Being medium status in all the area; 75% of the total recommended nitrogen dose is requires for adequate supply of nitrogen for crops in the farm (Joshi and Deo, 1975). Total nitrogen showed low variability (21.45%) among the soil samples.
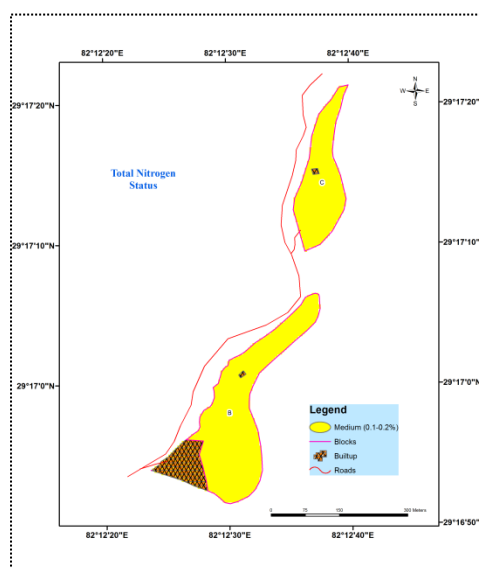
Figure 6. Total Nitrogen Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Available Phosphorus

Phosphorus is the second most limiting nutrient after nitrogen and less available to crop because of its complex chemistry in soil (Rashmi *et al*., 2014). The available phosphorus varied from 3.71 to 84.40 mg/kg with a mean of 30.18 mg/kg (Table 4).The distribution of available phosphorus was medium to very high; while high status (72.27%) was prevalent (Figure 7; Figure 17). The higher content of available phosphorus in the farm might be due to the continuous application of phosphatic fertilizers for every crop without knowing phosphorus availability in soil. The area having medium and high status, 60% and 40%, respectively of recommended phosphorus dose should be sufficient for the crops in the farm (Joshi and Deo, 1975). Available phosphorus showed moderate variability (73.85%) among the soil samples.
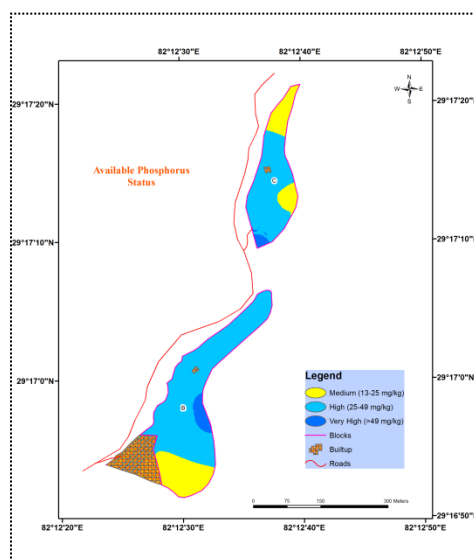

Figure 7. Available Phosphorus of Horticultural Research Station, Rajikot, Jumla, Nepal

Available Potassium

Potassium is essential for growth of all the plants, but unique on horticultural crop because of playing role for improving their quality (Mikkelsen, 2018). The available potassium varied from 59.37 to 173.05 mg/kg with a mean of 117.38 mg/kg (Table 4).The distribution of available potassium ranged from medium to high, but medium (65.66%) status was dominant (Figure 8; Figure 17). The minerals such as muscovite, biotite, feldspars, orthoclase, microcline, mica etc. are major K-bearing minerals found in the earth (Sparks, 1987).The occurrence of their different minerals; optimum organic matter status might be the cause of satisfactory conditions of available potassium in the farm. The area having medium and high status, 60% and 40%, respectively of recommended potassium dose should be sufficient for the crops in the farm (Joshi and Deo, 1975). Available potassium showed moderate variability (29.17%) among the soil samples.
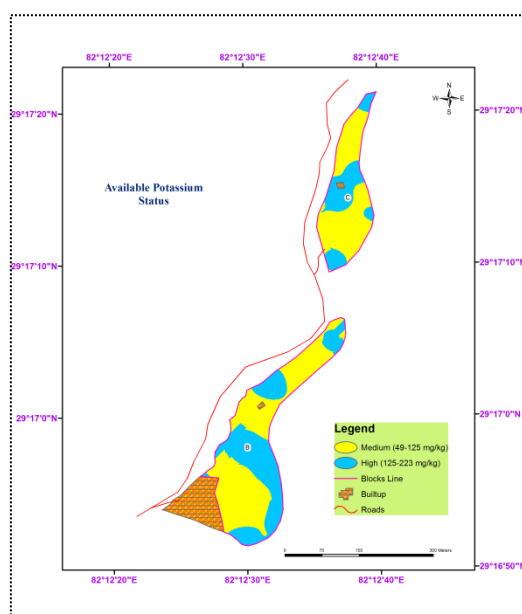
Figure 8 Available Potassium in the Agricultural Research Station, Rajikot, Jumla, Nepal
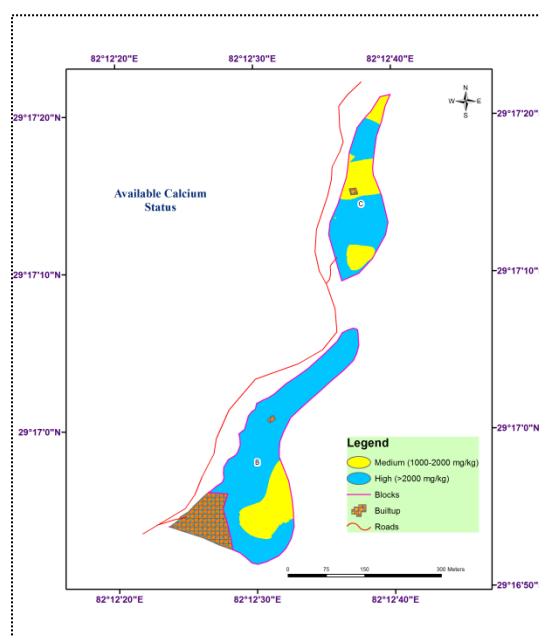
Available Calcium

Calcium is a secondary macronutrient, and is vital to run various living process in plants (Medvedev, 2005).The available calcium ranged from 1200 to 3144 mg/kg with a mean of 2264 mg/kg (Table 5).The distribution of available calcium was medium to high; whereas high status (77.60%) was dominant (Figure 9; Figure 17). The occurrence of nearly neutral to alkaline soil pH in the majority sites might be the cause of satisfactory status of available calcium. Available calcium showed low variability (24.88%) among the soil samples.

Table 5. Soil Fertility Status of Horticultural Research Station, Rajikot, Jumla, Nepal

| Descriptive Statistics	Soil Fertility Parameters			
	Ca	Mg	S	B
	mg/kg			
Mean	2264.00	50.04	0.99	0.40
SEM	108.00	7.82	0.09	0.04
SD	563.00	40.62	0.44	0.22
Minimum	1200.00	7.20	0.59	0.04
Maximum	3144.00	177.60	2.41	0.87
CV%	24.88	81.17	44.42	55.38

SEM=Standard error of the mean; SD=Standard deviation

Figure 9. Available Calcium Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Available Magnesium

Magnesium is the second most abundant cation in living plant cells, and involved in many metabolic processes namely photosynthesis, enzyme catalysis, and nucleic acid synthesis (Tanol and Kobayashi, 2015). The available magnesium varied from 7.2 to 177.6 mg/kg with a mean of 50.04 mg/kg (Table 5; Figure 17).The distribution of available magnesium was low to medium; but low status (78.50%) was prevalent (Figure 10; Table 7). Being low status, application of Mg@50-100 kg/ha (broadcast) or 10-20 kg/ha (row application) is suggested for reducing magnesium deficiency stress for horticultural crops (Khatri-Chettri, 1991). Available magnesium showed high variability (81.17%) among the soil samples.
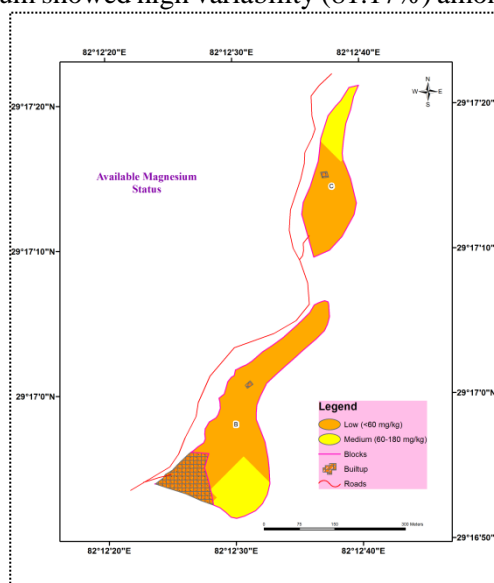
Figure 10. Available Magnesium Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Available Sulphur

Sulphur is an important element for running life of plant, but at most critical status in various sites of Nepal (Khadka *et al.*, 2016; Khadka *et al.*, 2017; Khadka *et al.*, 2018). The available sulphur ranged from 0.59 to 2.41 mg/kg with a mean of 0.99 mg/kg (Table 5).The distribution of available sulphur was very low in all the site (Figure 11; Figure 17).
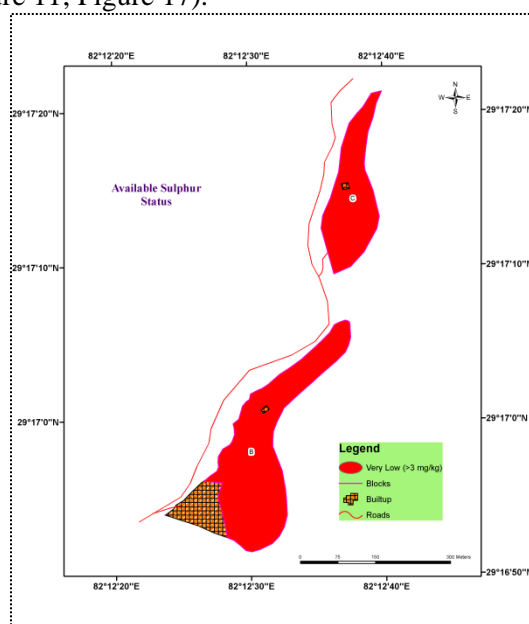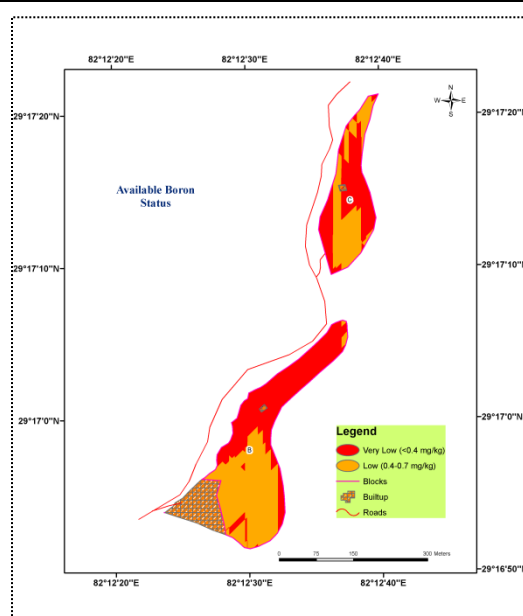

Figure 11. Available Sulphur Status of Horticultural Research Station, Rajikot, Jumla, Nepal

The intense cultivation of crops without application of sulphur containing fertilizer might be the cause of deficient status of available sulphur in the field. Being critical sulphur status, application at the rate of 15-30 kg S/ha is mandatory for reducing sulphur deficiency stress for crops (Khatri-Chettri, 1991). During sulphur fertilizer application care should have to take in slightly acidic inhibiting site, as they have acidity causing behavior. Available sulphur showed moderate variability (44.42%) among the soil samples.

Available Boron

Among the micronutrients, Boron is documented as second most deficit element after zinc in all over the world (Ahmad *et al.*, 2012). The available boron ranged from 0.04 to 0.87 mg/kg with a mean of 0.40 mg/kg (Table 5).The distribution of available boron was very low to low, but very low (51.10%) status was prevalent (Figure 11; Figure 17). The very deficient status of available boron was also reported by Khadka *et al.*, 2016; Khadka *et al.*, 2017; Khadka *et al.*, 2018; Khadka *et al.*, 2019 during their study in the various sites of Nepal. The intense cultivation of crops without addition of boron containing fertilizer might be the cause of deficient status of available boron in the field. Being inadequate boron, application of 2-3 kg B/ha is advisable for reducing boron deficiency stress for crops (Khatri-Chettri, 1991). Available boron showed high variability (53.38%) among the soil samples.

Figure 12. Available Boron Status of Horticultural Research Station, Rajikot, Jumla, Nepal
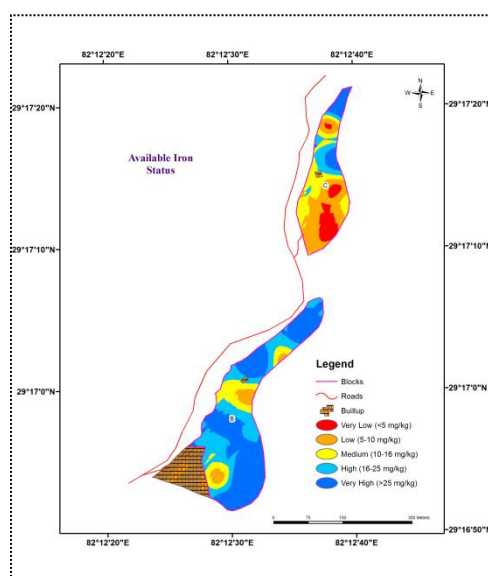
Available Iron

Iron is an important micronutrient in the life cycle of plant (Rout and Sahoo, 2015), and possesses adequate to toxic status in various sites of Nepal (Khadka *et al.*, 2016; Khadka *et al.*, 2017; Khadka *et al*., 2018). The available iron varied from 4.50 to 138.58 mg/kg with a mean of 28.24 mg/kg (Table 6).The diverse distribution ranged from very low to very high was determined, although very high status (35.40%) was prevalent (Figure 13; Figure 17). The occurrence of primary and secondary iron minerals such as hematite, olivine, siderite, goethite, magnetite etc. might be the cause of high content of available iron, because these are the major mineral containing iron element (Havlin *et al*., 2010). The high iron availability reduces the uptake of different nutrients such as P, K, Mn and Zn; thus shows deficiency stress of these elements in the plants (Fageria *et al*., 2008). Therefore, proper care should be taken for reducing deficiency stress of these antagonistic elements in very high status inhabiting sites shown in the map. Available iron showed high variability (104.37%) among the soil samples.

Table 6. Soil Fertility Status of Horticultural Research Station, Rajikot, Jumla, Nepal

| Descriptive Statistics	Soil Fertility Parameters			
	Fe	Zn	Cu	Mn
	mg/kg			
Mean	28.24	0.92	2.10	5.50
SEM	5.67	0.07	0.16	0.52
SD	29.47	0.36	0.85	2.68
Minimum	4.50	0.26	0.78	2.18
Maximum	138.58	1.66	4.20	13.46
CV%	104.37	39.24	40.46	48.68

SEM=Standard error of the mean; SD=Standard deviation

Figure 13. Available Iron Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Available Zinc

Zinc deficiency is a major micronutrient constraint for food production in every parts of the world (Welch, 2002) and considered second most deficit micronutrient after boron in Nepal (Anderson, 2007). The available zinc varied from 0.26 to 1.66 mg/kg with a mean of 0.92 mg/kg (Table 6).The distribution of available zinc ranged from low to medium, however low status (70.28%) was dominant (Figure 14; Figure 17). The inadequate zinc, means there may have more chance being zinc mining problem. Therefore, application of Zn@4-8 kg/ha (broadcast) or 2-4 kg/ha (band placement) is suggested for reducing this problem (Khatri-Chettri, 1991). Available zinc showed moderate variability (39.24%) among the soil samples.
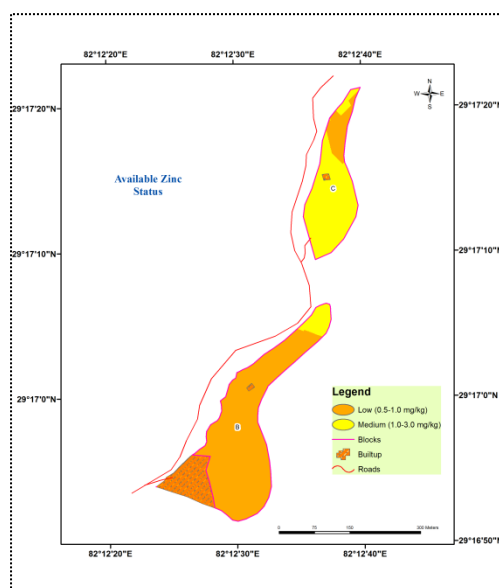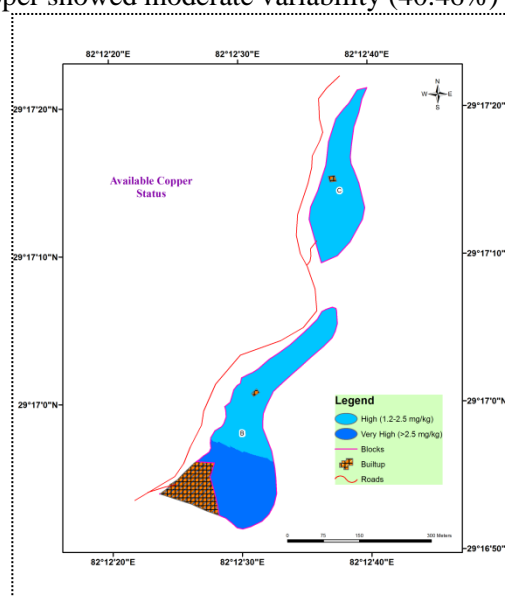

Figure 14. Available Zinc Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Available Copper

Copper is an important micronutrient for plant growth and development, although it is also potentially toxic (Yruela, 2005). The available copper ranged from 0.78 to 4.20 mg/kg with a mean of 2.10 mg/kg (Table 6).The distribution of available copper was high to very high, even though high (area: 63.98%) status was dominant (Figure 15; Figure 17). The high level of available copper may showed different

kinds of toxic effects in the plants. Low seed germination, inhibition of root and shoot growth, disturbance on photosynthetic apparatus and pigments etc. may be the toxic effects of copper (Adrees *et al.*, 2015). Being high status of available copper in the soil, care should be taken during fungicide, pesticides, herbicides application in the field because these chemical already contains copper element (Husak, 2015). Available copper showed moderate variability (40.46%) among the soil samples.

Figure 15. Available Copper Status of Horticultural Research Station, Rajikot, Jumla, Nepal

Available Manganese
Manganese is an important micronutrient, acts as a cofactor, activates various enzymes involved in the oxidation–reduction, decarboxylation and hydrolytic reactions in plants (Mousavi *et al*., 2011). The available manganese varied 2.18 to 13.46 mg/kg with a mean of 5.50 mg/kg (Table 6).
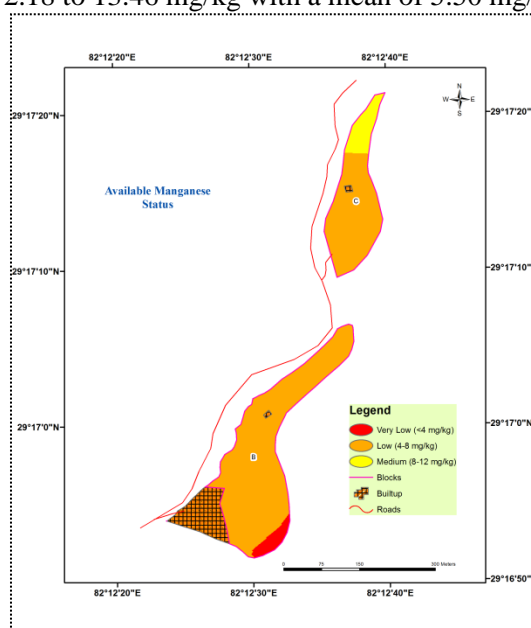
Figure 16. Available Manganese Status of Horticultural Research Station, Rajikot, Jumla, Nepal
The distribution of available manganese ranged from very low to medium, while low status (91.13%) was widespread (Figure 16; Figure 17). The intense cultivation of crops without application of

manganese containing fertilizer might be the cause of deficient status of available manganese in the field. Being inadequate available manganese, application of 8-16 kg Mn/ha is advisable for reducing manganese deficiency stress in plants (Khatri-Chettri, 1991). Available manganese showed moderate variability (48.68%) among the soil samples.
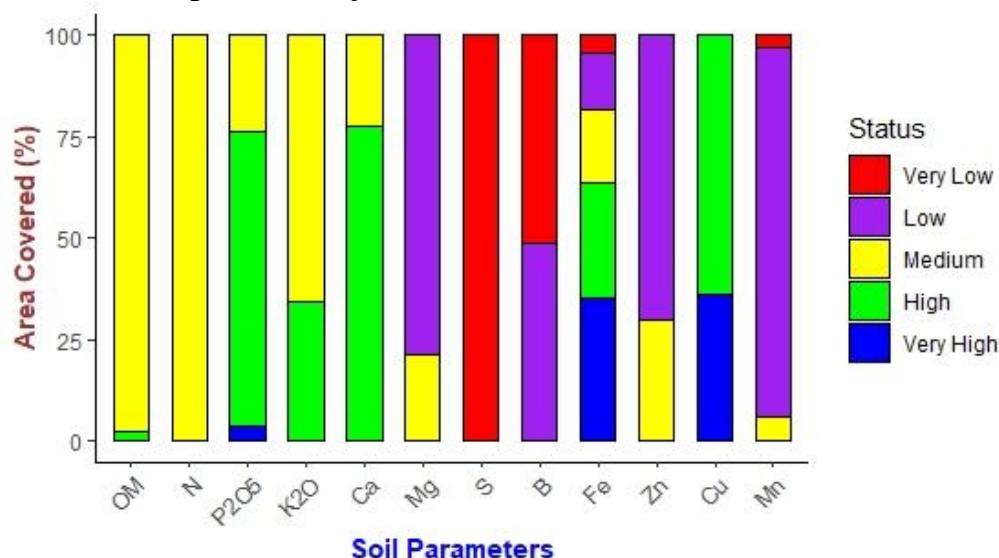
Figure 17. Coverage Area of Fertility Parameters in Horticultural Research Station, Rajikot, Jumla, Nepal

Spatial structure of studied parameters
The data regarding various parameters of stable semi-variogram ordinary kriging interpolation method for different soil properties showed weak to strong spatial dependency (Table 7). The strong spatial dependency (SDI=<25%) was determined on potassium, calcium and iron; means these parameters have less or do not influence of artificial factor like tillage, fertilization and other management practice. But they are mainly affected by natural factor like climate, parent materials, topography, soil type etc.

Table 7. Summary of semi-variogram parameters for studied soil parameters

SN	Parameters	Range (m)	Nugget (C_0)	Sill (C_0+C_1)	SDI%	Interpretation
1.	Sand	86.3	112.61	236.87	45.54	moderate
2.	Silt	90.52	72.83	139.02	38.53	moderate
3.	Clay	911.52	3.69	4.11	89.78	moderate
4.	pH	542	0.3	0.89	33.71	moderate
5.	OM	283.61	0.71	1.66	42.77	moderate
6.	N	283.61	0.00059	0.0014	42.45	moderate
7.	P_2O_5	184.36	323.35	738.35	43.87	moderate
8.	K_2O	90.52	0	1690.33	0	strong
9.	Ca	86.31	0	418488.4	0	strong
10.	Mg	920.9	1515.25	1854.84	81.69	weak
11.	S	920.9	0.19	0.19	100	weak
12.	B	920.9	0.049	0	100	weak
13.	Fe	90.52	0	844.8	0	strong
14.	Zn	509.05	0.079	0.18	44.21	moderate
15.	Cu	237.58	0.46	0.64	71.88	moderate
16.	Mn	233.63	3.73	6.73	55.42	moderate

Most of the parameters possessed moderate spatial dependency (SDI=25-75%) means have both artificial and natural influence for the spatial structure. On the other hand, magnesium, sulphur and

boron determined weak spatial dependency (SDI=>75%) indicates more influence of artificial factor than the natural factors (Chien et al., 1997).

CONCLUSIONS

The determined soil test data can be used mainly in two purposes. First one is for sustainable soil management, while another for developing research strategy as being a farm of research station. The studied physical properties symbolize the current status is satisfactory for agricultural purpose. Soil pH is suitable for growing horticultural crops, but care should taken at slightly acidic sites as there may chance of reducing pH due to various nutrient management practice. The organic matter is optimal in the farm. For maintaining present status, existing organic matter management practice should be continued. The fertilizer should be applied for each crops based on the determined nutrient distribution status shown in the prepared digital maps. The plants may suffer from deficiency stress of low, and toxicity stress of very high status of nutrients. The proper care should be taken for such types of nutrients and sites shown in the maps. For enhancing research efficacy of the horticultural crops in the farm, future research strategy should be built based on the prepared digital distribution map.

Authors' Contributions
D. Khadka planned, designed and conducted this experiment. S. Lamichhane, R. K. Giri, B. Chalise, R. Amgain and S. Joshi helped during this experiment. All authors approved the final version of this manuscript.

Conflict of interest
The author declares no conflicts of interest regarding publication of this manuscript.

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