ASSESSMENT OF THE SPATIAL DISTRIBUTION AND MAPPING SOIL PHYSICO-CHEMICAL PROPERTIES OF NALGAD MUNICIPALITY, JAJARKOT, NEPAL

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ABSTRACT

A detailed soil inventory study using Global Positioning System (GPS) and Geographical Information System (GIS) was conducted in Nalgad Municipality of Jajarkot, Nepal in 2019. A preliminary reconnaissance survey during pre–field activities and detail field work was carried out to study the soil type and physico-chemical properties based on the soil pit. A total of 51 soil pits were taken in the field representing varied micro topography. Soil Sample pits covering all the units were dug based on the interpreted soil map, topographical map, ZY-3 Satellite imagery for determination of soil profile. Soil classification of the area was done based on the USDA soil taxonomy and the dominant soil orders found in the region were Entisols (15.13 %) and Inceptisols (83.60%). A total of 51 geo-referenced composite soil samples from a depth of 0-20 cm was collected from each pit and analyzed in laboratory for texture, soil pH, soil organic matter, total nitrogen, available phosphorus and exchangeable potassium. Majority of the soil are loam and loamy sand type. There is very low to high level of organic matter present in the study area with more proportion of land under high range of organic matter (64.98%). Total Nitrogen content in soil of the study area ranges from very low to very high level with high level of Nitrogen (65.51%) in major proportion. Low to very high level of available phosphorous content was found in the study area with the dominance of very high level of phosphorous (71.40%). Exchangeable Potassium level in the study area is very high to low. Around 42% land have very high level of potassium. From the soil test result, major nutrients status in soil were found to be good but integrated land management practices should be encouraged for improving land productivity. The generated soil maps may be helpful to stakeholders for planning, monitoring and evaluating the soil status for effective agricultural production.

Keywords: GIS, Nalgad municipality, soil, soil map

INTRODUCTION

Soil is everything more than life for us, as we are totally dependent on agriculture for our livelihood from time immemorial (Adhikari and Hartemink, 2016). Whatever the technological advances achieved, soil will always be necessary for humans to grow most of the food, fodder and fiber they need (Chen *et al.*, 2022). The growing population and decreasing soil productivity is a problem that has long gone unsolved. In order to make optimum use of our limited soil resources, we need detailed

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information about their characteristics, types, and distribution on landscape. The use of high spatial resolution maps and digital techniques to map soil properties is of particular importance. Describing the spatial variability of soil across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced (Reddy *et al.*, 2018). The use of GIS and GPS for land use planning and soil mapping is popular and gaining acceptance worldwide which are adopted for better management of land and other resources for sustainable crop production (Palaniswami *et al.*, 2011). In agriculture, GPS and GIS technologies have been based on the geo-statistical analysis and several studies have been conducted to characterize the spatial variability of different soil properties (Hwang *et al.*, 2007; Weindorf and Zhu 2010; Liu *et al.*, 2013).

Systematic land use planning is an effective tool to formulize national level land use policy for utilization of land according to its productive capacity and usefulness (GIZ, 2011). GIS-based soil maps are useful for developing solutions to resource management issues such as land management, soil erosion, soil degradation, fertility evaluation and urban planning (Tomlinson *et al.*, 1987). GIS generated soil maps may serve as a decision support tool for nutrient management (Iftikar *et al.*, 2010) and it also helps to determine plant nutrient availability and distribution and the pattern of nutrient depletion in the project area. Among the different geo-statistical methods, ordinary kriging is widely used to map the spatial variation of soil fertility because it provides a higher level of prediction accuracy (Song *et al.*, 2013). The main objective of the study was to prepare a scientific and comprehensive soil map of Nalgad Municipality of Jajarkot District, a part of Karnali Province of federal Nepal and characterize the spatial distribution of soil physico-chemical properties such as soil type, texture, pH, organic matter and major nutrients.

MATERIALS AND METHODS

STUDY AREA

Nalgad Municipality of Jajarkot District, a part of Karnali Province of federal Nepal and geographically lies in high hill and Mahabharata range. The spatial area of the Municipality comprised by covering the watershed areas of Nalgad River and Bheri River as the confluence area of the Nalgad into Bheri River and named as Nalgad municipality.

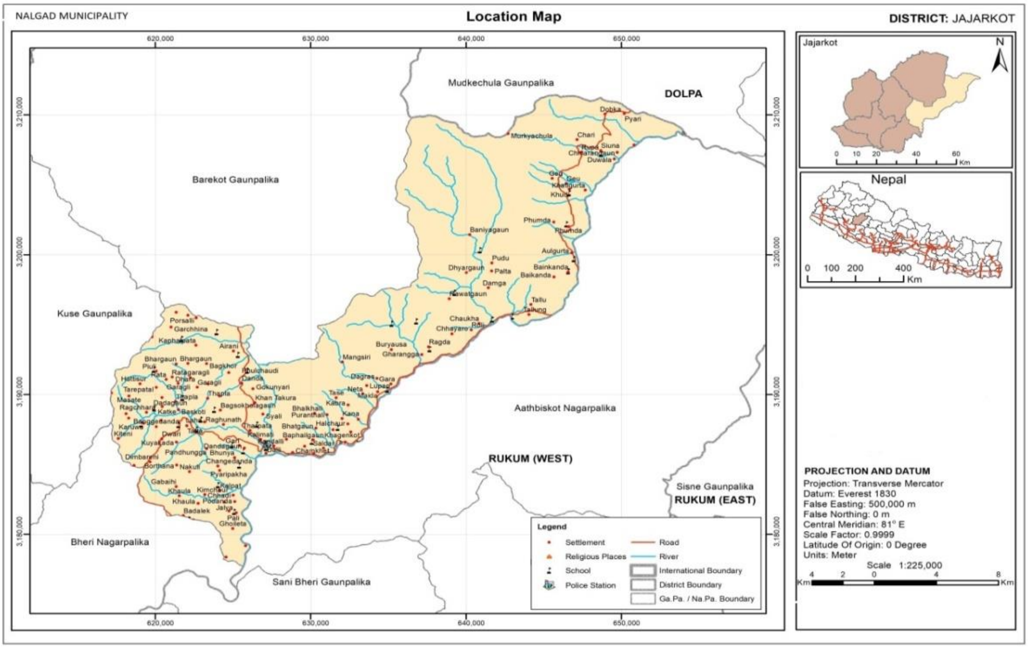

Figure 1: Location Map of Nalgad Municipality, Jajarkot

The municipality extends from 82˚12'4.941" east to 82˚34'54210" eastern longitudes and 28˚ 42'47.759" north to 29˚01'2.792" northern having an area of 387.44 square km with 43.56 km north-south length and 17.15 km east-west width (Figure 1). Its elevation ranges from 760 to 5212 meter above sea level.

DETERMINATION OF SAMPLING POINTS

The digital LRMP maps, land system, land capability and land use at the scale of 1:50,000 and geological Map scale at 1:125000 together with Municipality map and Topographic - thematic layers at 1: 25,000 and ZY-3 Satellite imagery provided by National Land Use Project/ Survey Department and available reports were reviewed in connection with preparation of soil map prior to the field survey. The soil mapping units were demarcated based on the land units that also identified capturing the local topography variation. The description of soil mapping unit and the symbol was formed with the integration of land system, landform, land type and geological map and land use/land cover. Soil mapping units derived from Land units were formed and overlaid on Standard False Color Composite (RGB: 432) of the project area at the scale of 1:10000. Altogether 51 soil pits and their location were obtained for the soil pits collection where detailed soil profile was studied. The spatial distribution of those soil pits are shown in Figure 2.

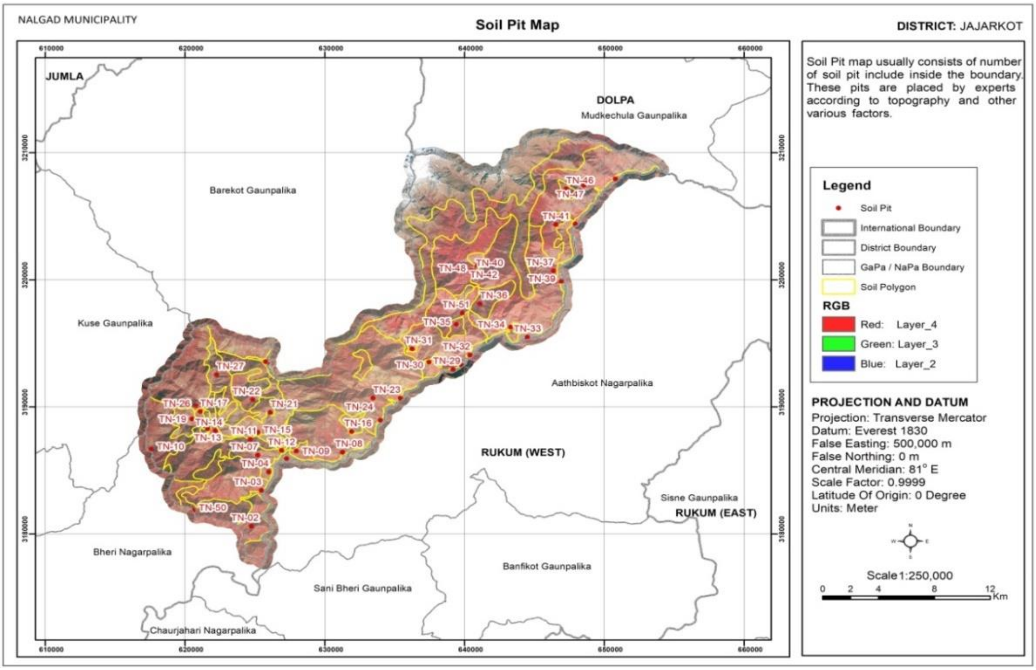

Figure 2. Sample soil pit location map of Nalgad Municipality

A preliminary reconnaissance survey was carried out during the pre –field activities to get the insight of ground situation of project area regarding the association of landform and soil. Soil Sample pits covering all the units were dug based on the interpreted soil map, topographical map, and ZY-3 satellite imagery for determination of soil profile. The digging of soil pits was carried out from 5th September 2019 to 20th September 2019 at the concerned Municipality. These sample pits were studied in the field for soil mapping and soil profile observation. Each soil profile (pedon) description is carried out as per the Standard Soil Profile Description Form provided from Survey Department, Ministry of Land Management, Co-operatives and Poverty Alleviation, Nepal. Soil of each horizon was described following USDA guidelines.

SOIL SAMPLING AND ANALYSIS

Composite soil samples from 20 cm depth of top layer were collected from area around each pit and the samples were analyzed at Soil and Fertilizer Testing Laboratory, Hetauda to examine the chemical properties (N, P, K, OM, pH) of soil including soil texture. Top layer or epi-pedon particularly first horizon was examined in the laboratory for the purpose of soil fertility assessment whereas sub-surface or endopedon was assessed for the soil classification purpose. The soil samples collected were preserved in airtight plastic bags, dried in shade and powdered to pass through

2 mm size sieve that were used for examination of physical and chemical analysis in the laboratory using the specific methods

Table1. Methods adopted for soil analysis in laboratory

Soil Sample Tests	Analysis Method
Texture	Hydrometer method (Gee and Bauder, 1986)
pH	Beckman electrode pH meter (Cottenie *et. al.*, 1982)
Organic Matter content	Walkley and Black Method (Walkley and Black, 1934)
Available Phosphorous(P_2O_5)	Modified Olsen sodium bicarbonate method (Olsen et. al.,1954) extraction and detected in spectrophotometer in 560 nm
Available Potassium(K_2O)	1 N neutral ammonium acetate 5 min shaking and filtered through Whatman No 42 filter paper and detected through flame ignition (Pratt, 1965)
Total Nitrogen(N)	Kjeldahl method (Bremner and Mulvany, 1982)

SOIL MAPPING

Soil association as the universally accepted for soil mapping was adopted in order to correlate the soil pit and soil mapping units. The rating (very low, low, medium, high and very high) of determined values were based on National Soil Science Research Centre, Khumaltar, Nepal (table 2). Based on morphological and chemical analysis data soils are classified according to Soil Taxonomy (USDA, 2010). After completing the field study, the soil pits location was transferred into base map and image through GIS data analysis. Arc Map 10.1 with geo-statistical analyst extension of Arc GIS software was used to prepare spatial distribution map of soil parameters at 1:25000 scale, while interpolation method employed was ordinary kriging with stable semi-variogram. Descriptive statistics of soil properties, including mean, standard deviation, coefficient of variation, minimum and maximum were calculated using STAR software.

Table 2. Rating for different soil chemical parameters given by NSSRC for hill region of Nepal

Rating	Organic Matter (%)	Total Nitrogen (%)	Available P_2O_5 (Kg/ha)	Available K_2O (Kg/ha)
Very Low	<1.0	<0.05	<10	<55
Low	1-2.5	0.05-0.1	10-30	55-110
Medium	2.5-5.0	0.1-0.2	30-55	110-280
High	5-10	0.2-0.4	55-110	280-500
Very High	>10	>0.4	>110	>500

Range for pH: Very strongly acidic= >5.0; strongly acidic= 5.0-5.5; moderately acidic= 5.5-6.0; slightly acidic= 6.0-6.5; Neutral= 6.5-7.5; slightly alkaline= 7.5-8.5; moderately alkaline= 8.5-9.0; strongly alkaline=>9.0

RESULTS AND DISCUSSIONS

SOIL TYPES

Soils of Nalgad Municipality of Jajarkot district are classified based on the information of soil derived from soil pits and soil mapping unit level according to the USDA Soil Taxonomy. The soils are grouped according to Soil Orders, Sub-Orders, Great Groups, and Sub-Groups. Table 3 and Figure 3 present Soil Taxonomy classification for the soils of Nalgad Municipality.

Table 3. Soil Taxonomy Classification of Nalgad Municipality

SN	Soil Order	Sub order	Great Group	Sub Great Group	Area Ha	Percent (%)
1	Entisols	Orthents	Cryorthents	Lithic Cryorthents	3637.43	9.40
			Ustorthents	Lithic Ustorthents	2217.52	5.73
2	Inceptisols	Ustepts	Dystrustepts	Lithic Dystrustepts	14829.14	38.32
				Typic Dystrustepts	1019.80	2.64
			Haplustepts	Lithic Haplustepts	5277.39	13.64
			Humustepts	Lithic Humustepts	10466.31	27.05
				Typic Humustepts	759.63	1.96
3	Waterbody				489.75	1.27
Total					38696.96	100.00

In Nalgad Municipality, two major orders of soil were found viz. Entisols and Inceptisols. The majority of the soil is occupied by Inceptisols followed by Entisols. Lithic Dystrustepts occupied the largest area (38.32%) followed by Lithic Humustepts, Lithic Haplustepts, Lithic cryoorthents, Lithic Ustorthents, typic Dystrustepts and typic Humulstepts. In total Inceptisols occupied 83.60% area and Entisols occupied 15.13% area. The details of the area coverage by individual soil group was presented in table 3. The distribution of different soil types is well depicted in figure 3.

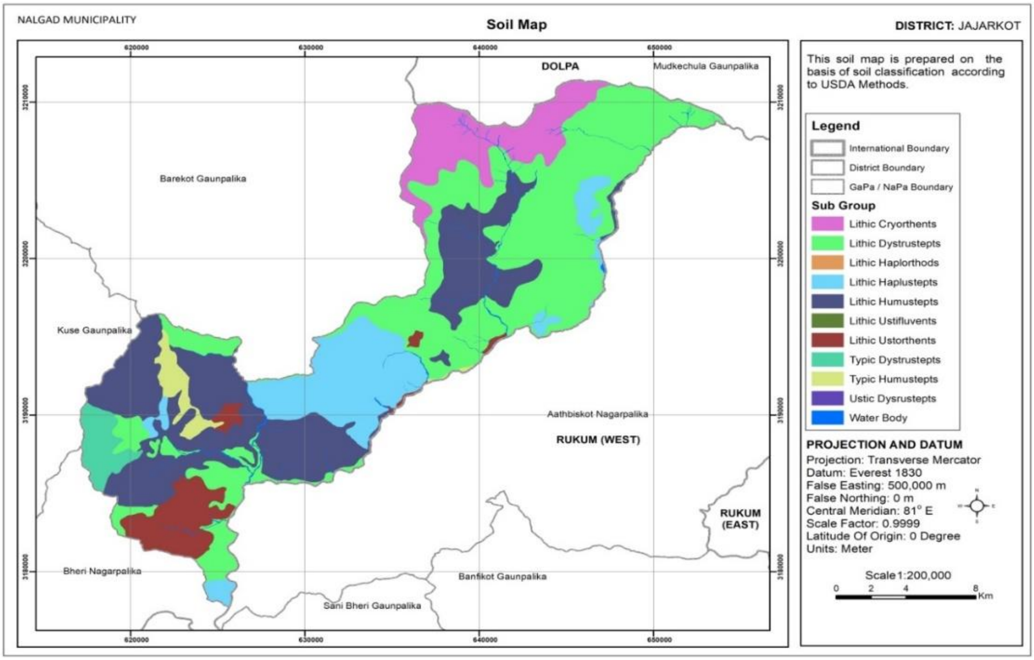

Figure 3. Soil map of Nalgad Municipality, Jajarkot, Nepal

Soil Order Inceptisols are extensively found in the Nalgad municipality having deep with well-developed properties of A and B horizons. In this order Haplustepts, Dystrustepts and Humustepts Great Groups are found in our study area of Nalgad Municipality.

Soil order Entisols found in the study area typically have little or no development of soil horizons and these soils are characterized not by the kinds of horizons that have formed but rather by their minimal degree of soil development. In particular areas, Entisols occurring more stable landscape positions. In these areas, the soils consist mostly of quartz or other minerals that are resistant to the weathering needed to form soil horizons or the soil-forming processes are hindered by extreme environmental conditions.

PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL

The results of soil analysis were presented in the table 3 and figure 4 to 9 for better understanding of the soil parameters that were investigated in the laboratory. The coefficient of variation (CV) ranged from 10.05 % (in pH) to 84.14 % (in K2O). The range of CV for the soil sampling locations suggested different degrees of heterogeneity among the properties studied. Majority of the soil are loam (51.71 %) and loamy sand type (17.44%). The site inhabiting loam texture is good for cultivation various kinds of crops and fruits, while in silty loam, clay and clay loam site care should be taken for tillage and water management.

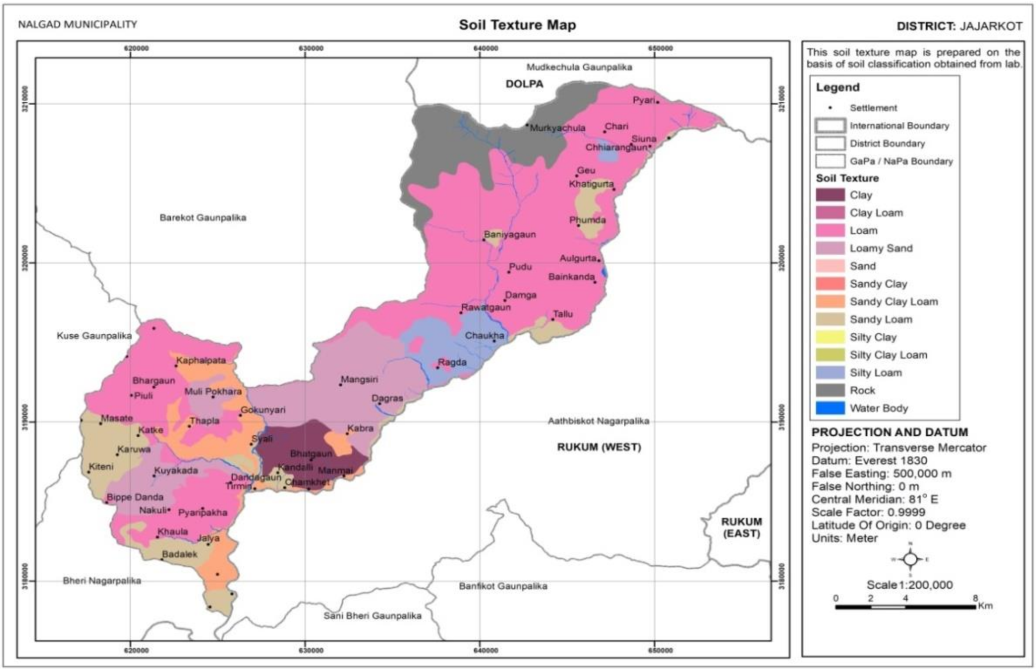

Figure 4. Soil texture map of Nalgad Municipality

The distribution of soil pH varied from highly acidic to moderately alkaline but most of the soils are neutral (45.01 %).The pH is an excellent indicator for determining chemical nature of the soil (Shalini *et al.*, 2003). The determined pH is suitable for most of the crops and fruits while special care should be taken in the acidic pH inhabiting sites.

Table3. Summary statistical overview for soil chemical properties of Nalgad Municipality (N = 51)

Soil Parameter	Mean	Standard deviation (SD)	coefficient of variation (CV)	Minimum	Maximum
pH	7.1	0.72	10.05	4.45	8.4
Organic matter (%)	4.45	1.88	42.19	0.33	6.45
Total Nitrogen (N %)	0.25	0.12	49.62	0.03	0.47
Available P_2O_5 (Kg/ha)	229.74	181.18	78.86	18.91	680.10
Available K_2O (Kg/ha)	375.92	316.46	84.14	87.60	1503.6

There is very low to high level of organic matter present in the study area with mean value of 4.45 % and more proportion of land (64.98 %) under high range of organic matter. Organic matter plays important role for improving various physical, chemical and biological properties (Hoyle *et al.*, 2011). Therefore, different organic matter improving program (adding compost, crop residue retention etc.) is suggested regularly for maintaining organic matter in long-term. Total Nitrogen content in the study area ranges from very low to very high level with high level of Nitrogen (65.51%) in major proportion followed by medium level of nitrogen (13.01%) of the area. Very low to very high level of available phosphorous content was found in the study area with the dominance of very high level of phosphorous (71.40%) followed by high (13.16 %) and low (1.56%) level of phosphorus. Available potassium level in the study area is very high to low. Around 41.71% land have very high level of potassium, 16.28% land have high level, 27.62% have medium level of potassium and 3.72% have low level of potassium in Nalgad municipality.

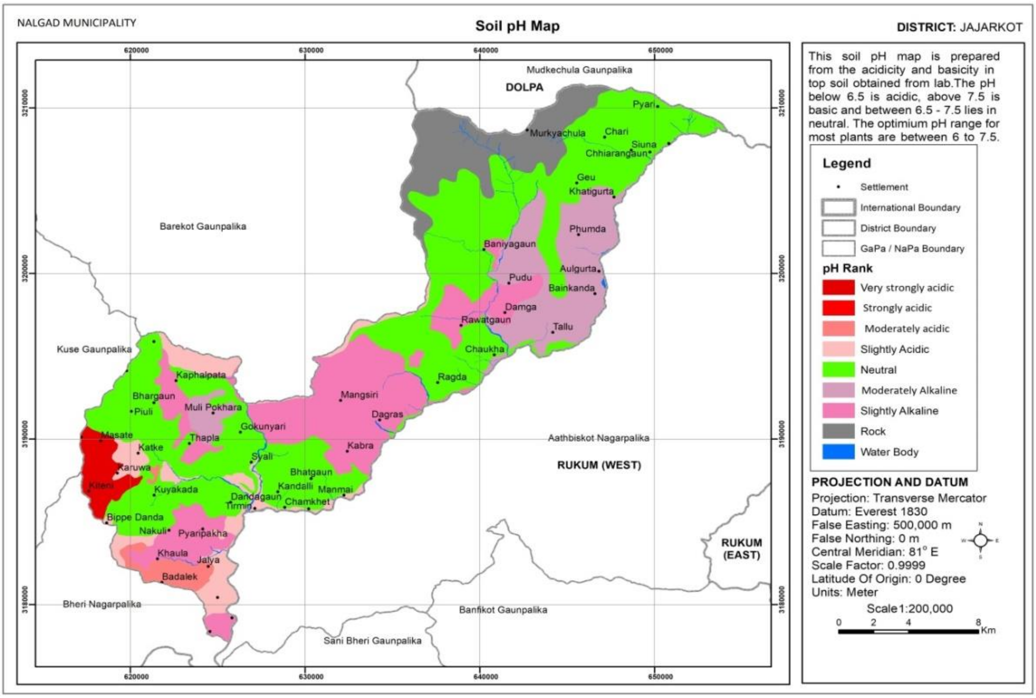

Figure 5. Soil pH map of Nalgad Municipality

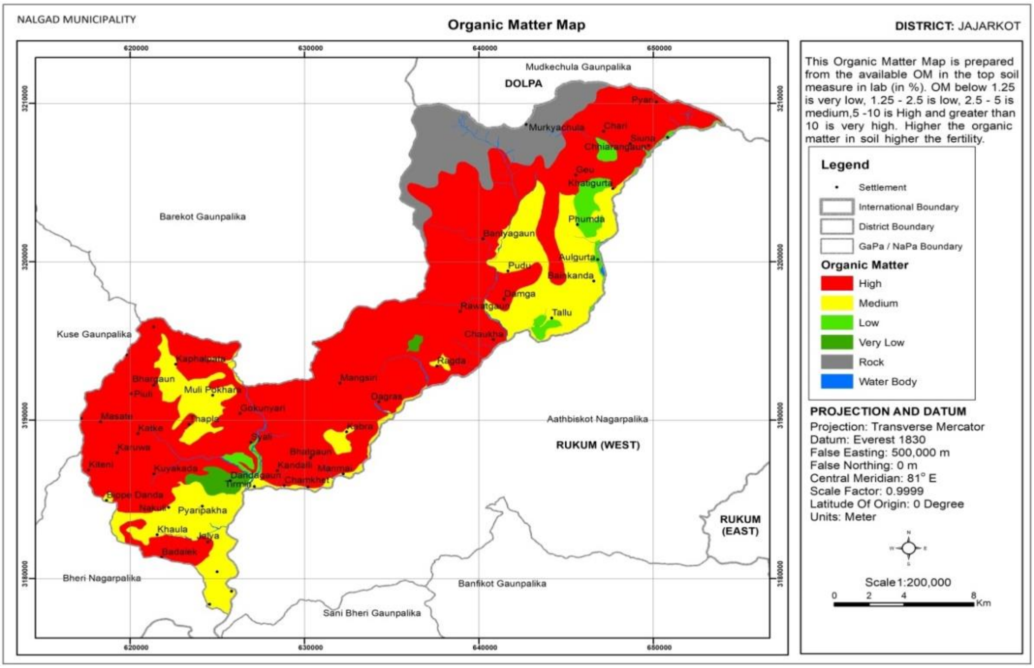

Figure 6. Soil organic matter map of Nalgad Municipality

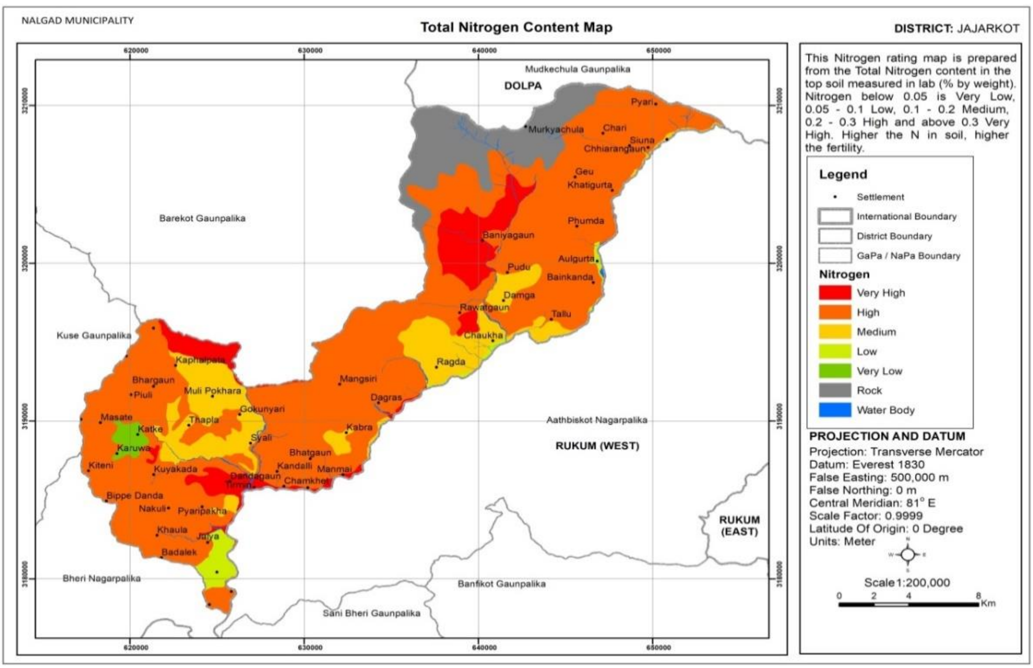

Figure 7. Nitrogen Map of Nalgad Municipality

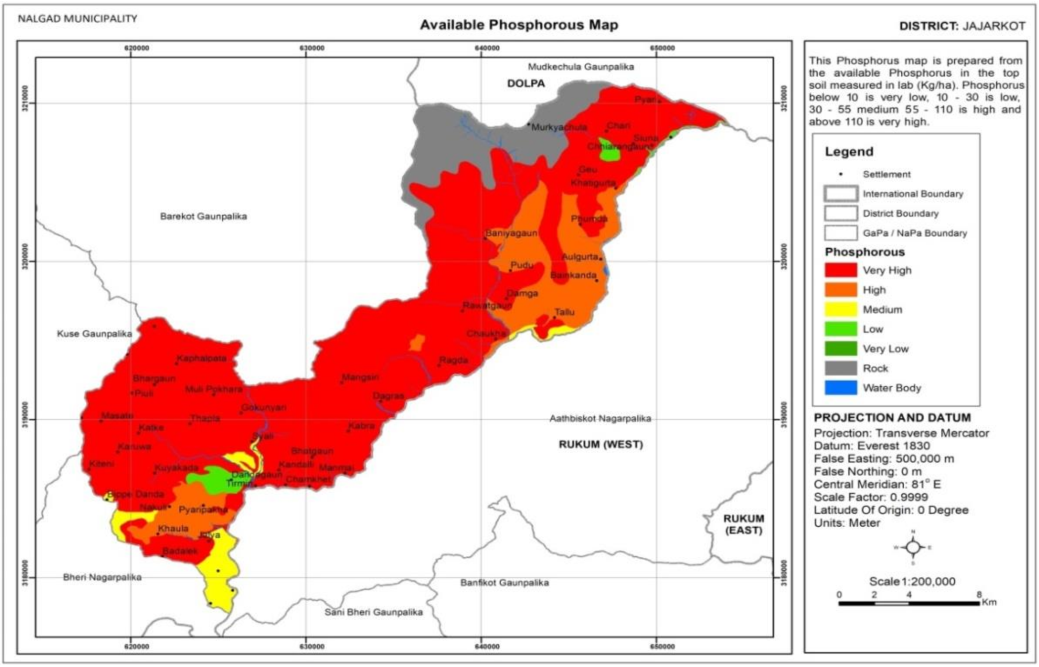

Figure 8. Phosphorous Map of Nalgad Municipality

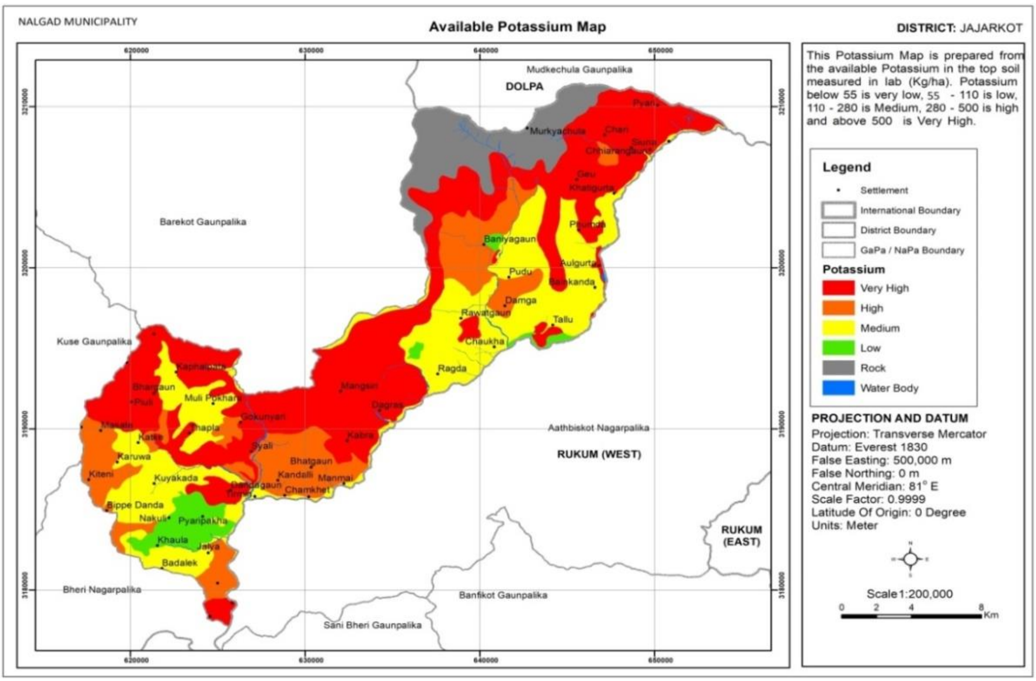

Figure 9. Potassium Map of Nalgad Municipality

Looking towards the spatial distribution of different soil nutrients, nitrogen content in soil is not sufficient which further triggered by the prevalence of nitrogen leaching, soil erosion and poor mineralization of organic matters. Phosphorus and potassium content in soil are in medium to high level. Organic matter in the soil ranges from low to high and majority of soil pH varies from medium acidic to neutral. The area having very low, low, medium and high status of major nutrients, 120 %, 100 %, 75% and 50% respectively of recommended dose of fertilizers should be recommended for adequate supply of nutrients for crops and no need of any fertilizers to those area having very high status of major nutrients (Joshi and Deo, 1975; Vista *et al.*, 2021).Farmers' must emphasize on site specific nutrient management having balance application of chemical fertilizers along with making best use of organic resources. Majority of the soil have loam to sandy loam texture which are consider as good soil and suitable for crop production. Therefore, an integrated nutrient management practices where all sources of plant nutrients (mineral fertilizers, compost, bacterial fertilizers) can be scientifically used for sustainable agriculture growth. Sustainable plant nutrients management leads to improve productivity thereby improve the livelihood of the people and better environment since it takes into consideration of the factors that may have negative effect on soil and environment (Carson, 1992; Serchan and Gurung, 1995).

CONCLUSIONS

The major soil orders found in Nalgad municipality on the basis of USDA soil taxonomy were Entisols (15.13 %) and Inceptisols (83.60%). In the context of soil available nutrients, organic matter content in the soil ranges from very low to high, total nitrogen ranges from very low to very high with high level in major proportions, available phosphorus with low to very high range and available potassium content ranges from low to very high. Soils of Nalgad municipality are dominated by Inceptisols characterized by moderate fertility status from agriculture perspective. Soil analysis of study area showed that the soil of Nalgad is suitable for most of sub-tropical crops in lower parts and warm temperate and temperate crops in upper part of municipality but care should be given in organic matter management by reducing their loss through erosion, improving the availability of nitrogen, phosphorous and to some extent potassium and pH management. Organic matter should be enriched in low level region and reclamation of moderately to very high acidic soil is recommended. The area having very low, low, medium and high status of major nutrients, 120 %, 100 %, 75% and 50% respectively of recommended dose of fertilizers should be recommended for adequate supply of nutrients for crops and no need of any fertilizers to those area having very high status of nutrients. Major nutrients status in soil were found to be good but integrated land management practices should be encouraged that include agroforestry, animal husbandry, sloping agricultural land technology and other sustainable soil management technology for improving land productivity. This study is not sufficient for proper crop zoning but should be used for further crop zoning initiative and policy intervention in agricultural commercialization of the Municipality.

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