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SPATIAL ANALYSIS OF SELCETED SOIL PARAMETERS IN POTATO GROWING AREAS OF MOUNTAINOUS REGION OF GILGIT-BALTISTAN, PAKISTAN

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Abstract

The study explores the spatial variability of soil parameters in potato growing valleys of CKNP region, Gilgit-Baltistan, Pakistan. Soil sample's location was documented through handheld GPS. Investigation reveals that soil of study area varies from loam to silty loam having pH values from 7.23 to 8.30 along with 0.45-1.39 electrical conductivity. Soil organic matter was found adequte in 1.04% tested samples. None of the samples had adequate level of NO_3-N. However, adequate PO_4-P and K was detected in above 90% tested samples. GIS maps indicates that soil parameters were spatially distributed amongst the valleys or even within the same valley. Digital mapping is an important action that provides vital information about soil nutrients, leading to a sustainable agriculture operation. GIS maps will help potato growers in crop management decisions like efficient utilization of fertilizer, reducing cost of production which will be resulted in increase productivity. Study will improve farmer's livelihood and play a vital role in reducing environmental pollution.

Key words: Soil parameters, Spatial variability mapping, GIS, GPS, Potato, CKNP (Central Karakoram National Park), Mountanious region and Gilgit-BaltistanPakistan.

Introduction

Solanum tuberosum L. (potato) is an economic and 4th widely grown food crop following rice, wheat and corn (Moeinil *et al*., 2011). Its high energy contents expanding its consumption in developing countries, which made it a valuable cash crop for millions of farmers Ahmed *et al*., (2012) considered it to be a major crop to achieve nutritional security of the nation; while Khan & Khan (2010) said that any investment in potato crop would enhance farm earnings and foreign exchange and Memon (2016) concluded that development of this crop would help in resolving the issue of unemployment.

In Pakistan its cultivation on over 174,400 acres in 2014-15; with total production of 38 million tones (Memon, 2016). In Gilgit-Baltistan region, potato is grown on 8526 ha with average production of 15.72 t/ha (Anon., 2009a). However, Anon., (2010) reported average yield of 46.27 t/ha in Netherland and US, while in UK average figure is around 41.43 t/ha.

Continuous decline in productivity of potato crop in Pakistan caused by non-availability of vigorous and certified seed, absence of better returns cultivars, poor management, ineffective agronomic practices and inefficient utilization of land (Anon., 2009b; Qasim *et al*., 2013). Naqvi *et al*., (2019) reported that healthy and certified potato seeds would enable farmers to achieve higher and sustainable yield; however, they concluded that it could not be achieved under inadequate and untimely mineral nutrition availability. Assessment of soil fertility status of an area is a significant feature in perspective of sustainable agriculture. In an era of sustainable agriculture, soil management is important because irrigation, tillage and fertilizer application scientifically affect soil properties and availability of nutrients for the crop (Paz-Gonzalez *et al*., 2000). Furthermore soil properties are severely affected by soil intrinsic and extrinsic factors (Cambardella & Karlen, 1999). Traditionally management of soil fertility has been treated as homogenous and allowing to estimate fertilizer requirements on field basis as whole. Later on this approach has been rejected (Flower *et al*., 2005; Santra *et al*., 2008). Availability of soil nutrients either in deficient or excess would affects crops growth performance. So the knowledge of spatial variability and soil nutrient distribution patterns is crucial for maintenance of soil fertility and judicious fertilizer application. Information about elemental status of nutrients in the soil is vital for setting up a balanced fertilizer application to attained higher crop production (Malakouti *et al*., 2009). The estimation of spatial variability with in soil is now possible by adopting modern technologies like remote sensing; GIS and GPS. During the last few years, GIS and geo-statistical techniques are widely used to study mapping and spatial variability patterns of soil characteristics (Lark, 2002). These technologies helped in making field locations for accurate mapping by computing complex spatial relationship of factors responsible for soil fertility. This resulted in creating interest in the utilization of soil sampling techniques that trying to describe the variability in soil fertility factors within a field. Besides soil; GIS-based models are also used in hydrology, environmental studies, disease distribution mapping and degradation of land (Wang &

Qin, 2006). GIS and GPS are important to generate spatial maps of nutrients status, which help in good agricultural management systems and formulating plans for sustainable agricultural development (Sood *et al.*, 2009). Farmers all over the world and especially in mountainous region of Gilgit-Baltistan, Pakistan continuously struggling with the availability of information about the soil. Without these information and guidelines, the agricultural sectors faces a lot of problems in term of decline in crop yield and leads to low profitability and food insecurity. The GIS maps are important for appropriate fertilizer recommendations and monitoring of soil nutrients and also to calculate toxicity or deficiency of particular plant nutrient elements in soil. The soil nutrient maps are helpful tools to quantifying land resources. So for no scientific report has been available on the spatial variability of soil properties of the study area. Present investigations suggest that that an applicable competency is essential in order to collect intelligence of the spatial variability in soil properties of the investigation area for the preparation of soil maps engaging GIS techniques, especially Interpolation.

The interpolation approach often exploit in agriculture include inverse distance weighting (IDW) and kriging (Franzen & Peck, 1995; Weisz *et al*., 1995). Both methods estimate values at unsampled locations based on the measurements from the surrounding locations with certain weights assigned to each of the measurements Inverse distance weighting is easier to implement, while kriging is more time-consuming and cumbersome. Several other studies, however, found inverse distance weighting to be more accurate than kriging (Weber & Englund, 1994).

Keeping this in view, the current investigation was conducted to characterize spatial variability of selected soil properties in the study area that could help on site specific fertilizer recommendation and helps to increase potato production.

Materials and Methods

Description of the study area: Gilgit-Baltistan encompassing 72,496 square kilometers and provide home to about two million people. The area is one of the most mountainous landscape of the world and situated almost above 3000m sea level, surrounded by great mountain ranges of Himalayas, Karakorum and Hindukush. Climate of the area varies widely ranging from monsoon influenced moist temperate zone in western Himalayas to arid and semi-arid cold desert in the northern Karakoram and Hindukush. Below 3000m annual precipitation is less than 200mm but there is a strong gradient with the altitude and over 2000mm snowfall annually above 6000m. Temperature in the valley bottoms varies from extreme 40°C in summer to less than -10°C in winter (Akbar *et al.*, 2011; Kazim *et al.*, 2015; Ismail *et al*., 2018). The current study was carried in the four potato growing valleys of CKNP which encircle 3 main administrative districts; Gilgit, Skardu and Ghanche. With an approximate area of ten thousand km² whereas the buffer zone (7400 km²) of Central Karakoram National Park (97,608 people residing in 230 village settlements). Wheat and corn are main crops while potato is widely grown as cash crop (Fig. 1).

Collection of soil sample: Ninety six soil samples in potato field from four valleys of Central Karakoram National Park were collected at depth of 0-20cm. Latitude and longitude were recorded for each sample point using global positioning system (GPS). After air drying soil samples were screened through 2mm sieve. Different parameters such as pH and electric conductivity (1:1 ratio). Organic matter (Nelson & Sommers, 1982), soil saturation % (Malik *et al*., 1984), AB-DTPA extractable NO_3-N, PO_4-P and K as described in ICARDA manual by Ryan *et al*., (2001) were analyzed. The criteria used to categorize the soil parameters (Malik *et al*., 1984) are given in Table 1.

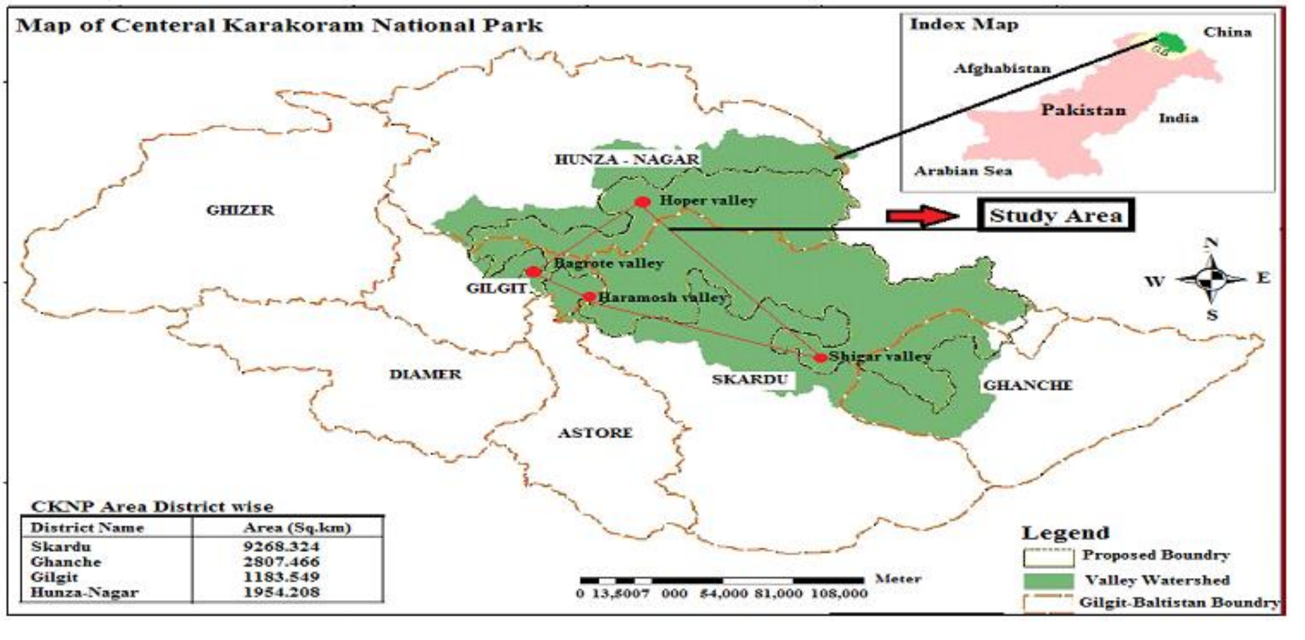

Fig. 1. Location map of study area.

Table 1. The criteria used to categorize the soil samples.

Measurement	Low	Medium	Adequate
Nitrate (NO3-N)	<11	11-20	>20
Phosphate (PO4-P)	<4	4-7	>7
Potassium (K)	<60	60-120	>120
O.M	<0.86	0.86-1.29	>1.29
	20-30 %	Sandy loam	
Saturation %	31-45 %	Silty loam or Loamy	
	46-65 %	Clay loam	

Soil Nutrient mapping: A database file (dbf) file consisting of data for X and Y coordinate in respect of sampling site location was created. A shape file of study was created in Arc Map 10.1. The dbf file was opened in the project window and in X-field, X-coordinate was selected and in Y-field, Y-coordinate was selected. The Z field was used for different nutrients. Interpolation method employed was IDW as described previously (Binita *et al*., 2009; Singh *et al*., 2010; Patil *et al*., 2011). The IDW is one of the mostly practical and deterministic intertpolation techniques for mapping of soil parameters in the field of soil science. IDW appraisals were made based on adjacent known sites. The weights allocated to the interpolating points are the inverse of its disatance from the interpolation point. Therefore, the close points are made-up to have more weights than distant points. The known sample points are implicit to be self-governing from each other (Robinson & Metternicht, 2006).

$$Z(x_0) = \frac{\sum_{i=1}^{n} \frac{x_i}{h_{ij}^{\beta}}}{\sum_{i=1}^{n} \frac{1}{h_{ij}^{\beta}}}$$

where z(x0) is the interpolated value, n representing the total number of sample data values, xi is the ith data value, hij is the separation distance between interpolated value and the sample data value, and ß denotes the weighting power.

Results

Descriptive statistics of selected soil parameters of potato field of study area is presented in Table 2. In Bagrote valley, the mean values recorded for pH, electric conductivity, organic matter and saturation percentage were 7.99, 1.01dSm^{-1}, 1.03% 41.37% respectively, while, mean values of soil NO_3-N, PO_4-P and K were 8.38, 7.91 and 259.04 mg kg^{-1}. The mean data for soil parameters i.e. pH (7.62), electric conductivity (1.05dSm^{-1}), organic matter (1.01%), saturation percentage (39.10), NO_3-N (8.14 mg kg^{-1}), PO_4-P (10.34mg kg^{-1}) and K (239.32 mg kg^{-1}) was recorded in Haramosh valley. In Hoper valley, the mean values of soil pH, electric conductivity, organic matter and saturation percentage were recorded as 7.84, 1.18, 1.03%, 43.35%, while, NO_3-N, PO_4-P and K were found as 8.43, 8.91 and 309.85mg kg^{-1}. Results pertaining to soil parameters in Shigar valley have been recorded as the mean values for pH (7.77), electric conductivity (0.87 dSm^{-1}), organic matter (1.03%) and saturation percentage (40.12) while macronutrient NO_3-N (6.20mg kg^{-1}), PO_4-P (7.54mg kg^{-1}) and K (162.17mg kg^{-1}). Spatial distribution map of soil parameters of Bagrote valley showed that soil pH of majority of the area fell in the range of 7.98-8.04; eclectic conductivity 0.09-1.00dSm^{-1}, organic matter 0.96-1.06%, and saturation percentage 39-43%. The spatial distribution map of soil macronutrients indicates NO_3-N in low to medium range, while, PO_4-P and K were adequate when compared to standard rating (Fig. 2). In Haramosh valley spatial distribution map showed that the pH of valley was slightly alkaline (>7) with normal electric conductivity (<4 dSm^{-1}) and loam or silty loam soil. Majority of the area falls in medium organic matter contents (0.86-1.29%), low to medium NO_3-N (<11, 11-20mg kg^{-1}), with adequate PO_4-P (>7mg kg-^{1}) and K (>120mg kg-^{1}) in the tested samples (Fig. 3). In Hoper valley soil pH, electric conductivity, organic matter and saturation percentage results pertaining more or less similar while micronutrient showed that NO_3-N was low (<11mg kg^{-1}) in 90% tested samples, while PO_4-P (>7mg kg^{-1}) and K (>120mg kg^{-1}) were in adequate range (Fig. 4). Spatial distribution map showed that the most of the area appears slightly alkaline with normal electric conductivity and medium organic matter. Whereas, with saturation percentage in the range of 39-44, NO_3-N 4.14-7.45, PO_4-P 7.26-7.85 and K 139-187mg kg^{-1}in Shigar valley (Fig. 5). The overall study showed that the soil of area was loamy or silty loam with 7.23-8.30pH range and normal electric conductivity. Organic matter content of the study area was low (15.62%), medium (83.33%) and adequate (1.04%). Similarly, NO_3-N low (85.42%) and medium (14.58%), while, PO_4-P and K was adequate in 95% tested samples (Table 3).

Table 2. Descriptive statistics of soil parameters of valleys of study area.

Valleys	pH		OM%		EC(dSm^{-1})		Sat.%	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Bagrote	7.80-8.10	7.99 ± 0.06	0.80-1.22	0.99 ± 0.12	0.80-1.30	1.0 ± 0.12	37.0-48.0	41.37 ± 2.96
Haramosh	7.23-7.98	7.61 ± 0.20	0.75-1.26	1.02 ± 0.13	0.67-1.51	1.05 ± 0.22	35.0-45.0	39.10 ± 2.22
Hoper	7.38-8.30	7.84 ± 0.27	0.84-1.30	1.02 ± 0.11	0.80-1.98	1.18 ± 0.26	39.0-48.0	43.35 ± 2.99
Shigar	7.35-8.13	7.77 ± 0.25	0.78-1.21	1.00 ± 0.12	0.45-1.39	0.87 ± 0.22	36.0- 44.0	40.12 ± 2.193
Valleys	Micronutrient AB-DTPA (mg kg^{-1})							
	NO_3-N		PO_4-P		K			
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD		
Bagrote		8.83 ± 2.04	8.06-21.70	7.91 ± 0.17	190-3642	59.04 ± 59.46		
Haramosh	4.71-11.60	8.14 ± 1.82	7.44-8.15	10.34 ± 3.25	178-3002	39.32 ± 39.20		
Hoper	5.18-11.36	8.43 ± 1.64	7.85-10.42	8.91 ± 1.02	222-3703	09.85 ± 34.67		
Shigar	3.03 -8.56	6.2 ± 1.29	6.68 -8.14	7.54 ± 0.49	115-2361	62.17 ± 33.29		

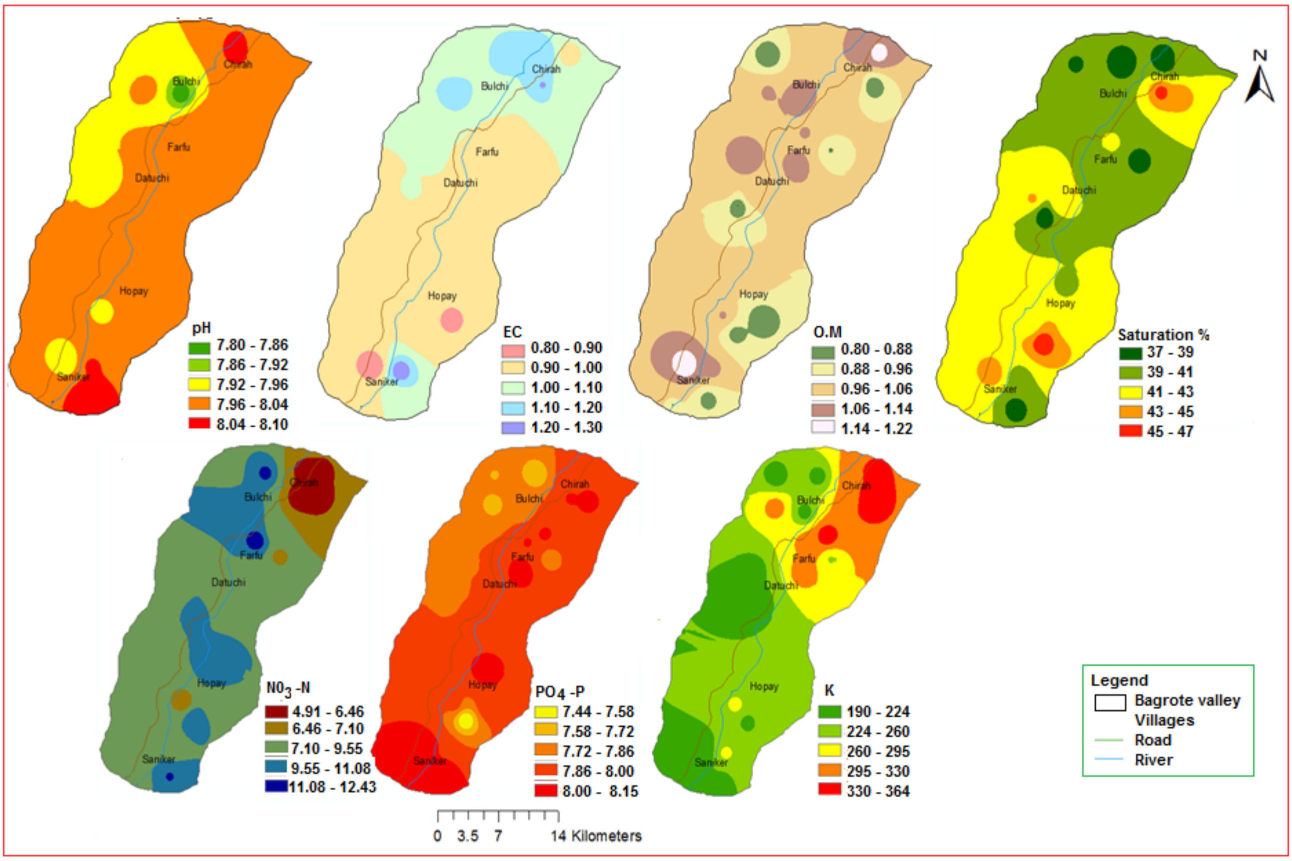

Fig. 2. Spatial variability mapping of soil parameters of Bagrote valley.

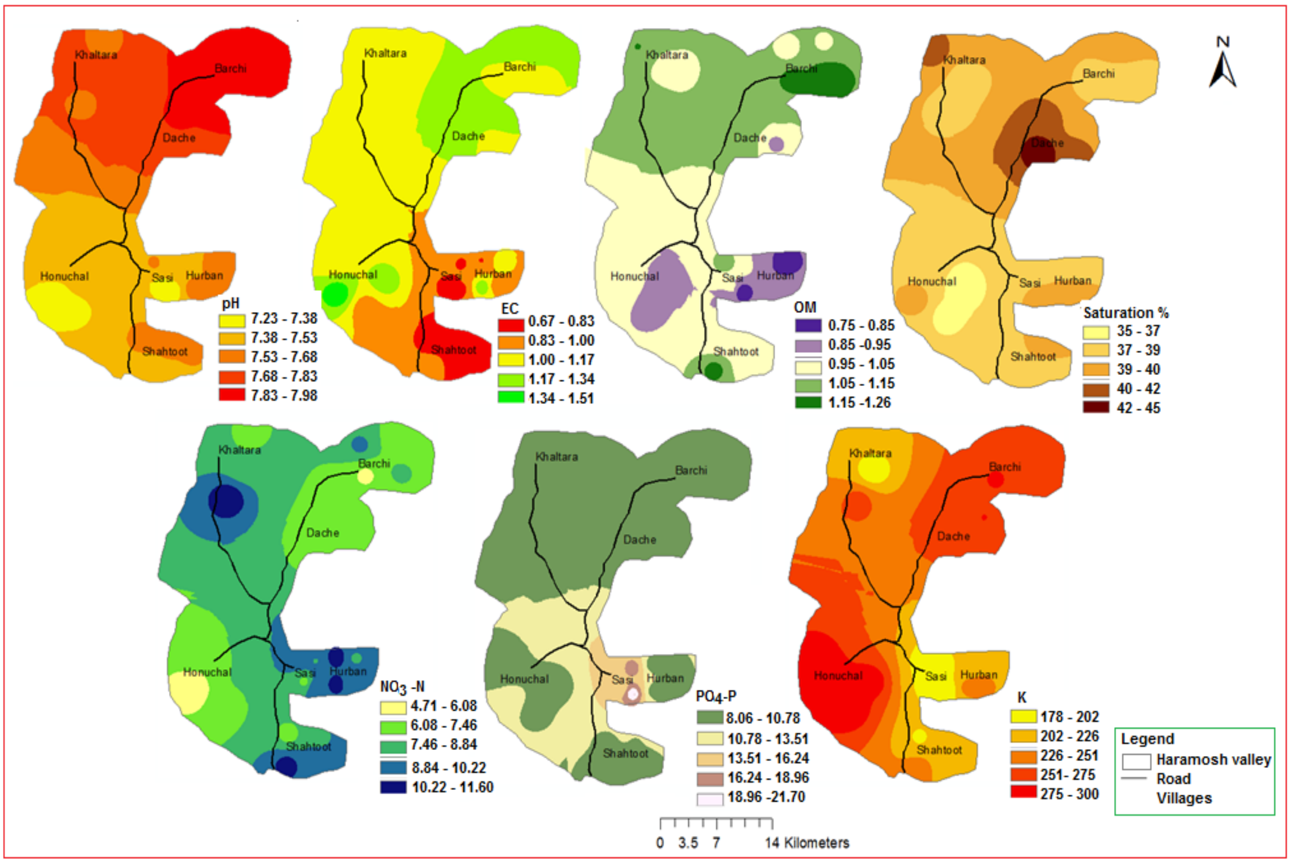

Fig. 3. Spatial variability mapping soil parameters of Haramosh valley.

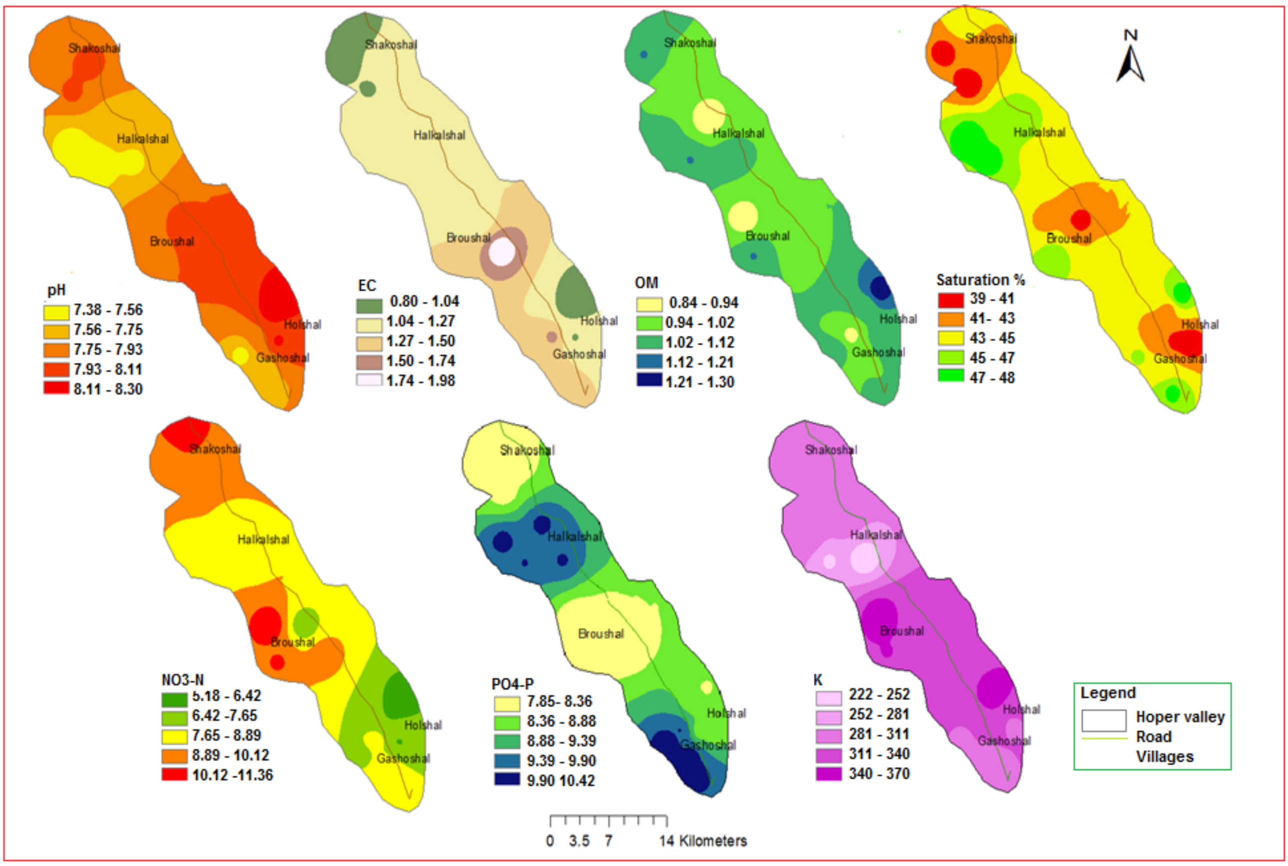

Fig. 4. Spatial variability mapping of soil parameters of Hoper valley.

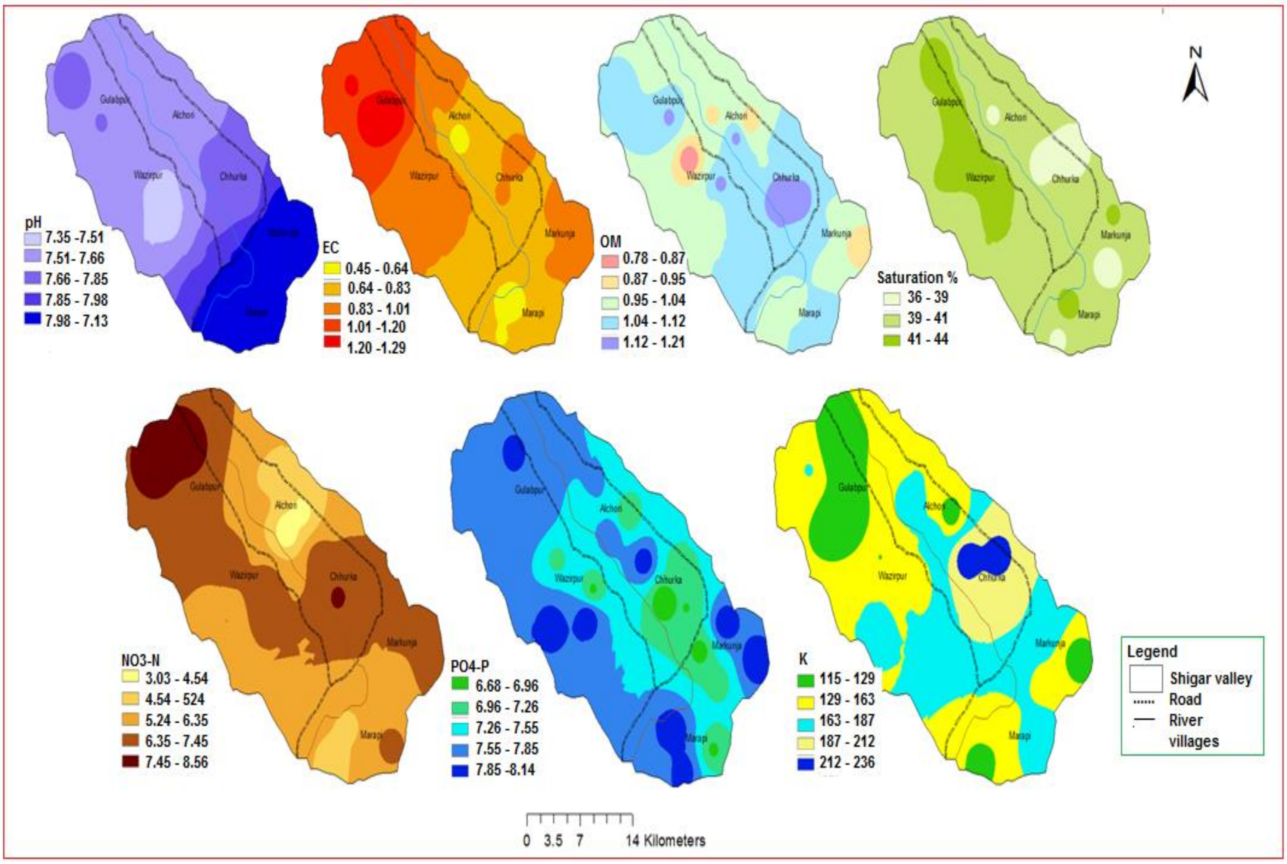

Fig. 5. Spatial variability mapping of soil parameters of Shigar valley.

Table 3. Soil physical and macronutrients categorized in different ranges of study area.

Valley	N.S	OM			NO_3-N			PO_4-P			K		
Soil status		L	M	A	L	M	A	L	M	A	L	M	A
Bagrote	N= 24	25.0	75.0	0.0	66.67	33.33	0.0	0.0	0.0	100	0.0	0.0	100
Haramosh	N = 28	7.14	92.86	0.0	85.71	14.29	0.0	0.0	0.0	100	0.0	0.0	100
Hoper	N = 20	15.0	85.0	5.0	90.0	10.0	0.0	0.0	0.0	100	0.0	0.0	100
Shigar	N= 24	16.67	83.33	0.0	100	0.0	0.0	0.0	20.83	79.17	0.0	16.67	83.33
	N = 96	15.62	83.33	1.04	85.42	14.58	0.0	0.0	5.21	94.79	0.0	4.17	95.83
Soil pH		7.23-8.30											
EC		Normal											
Saturation %		Loamy or silty loam											

N.S = No of soil sample; L = Low, M = Medium; A = Adequate

Discussion

In the current study spatial variability of soil parameter were assessed and soil nutrients maps were prepared by using interpolation spatial analysis function by IDW. The soil nutrients were classified into different categories which clearly showed variability within the valleys even within the same village. The overall results showed that the soil of study area is loamy or silty loam with pH range of 7.23 to 8.30 and normal electric conductivity. Soil organic matter status was low to medium and macronutriens NO_3-N low, PO_4-P and K were found adequate in the tested soil samples. Cambardella *et al*., (1994) stated that spatial dependency of soil properties were due to intrinsic factors (soil formation factors, such as parent materials); while weak spatial dependency can be attributed to extrinsic factors (soil management practices, such as fertilization).

Wei *et al*., (2008) reported that the mapping of the variability of soil chemical characteristics with an appropriate sampling approach could be used to improve productivity of fertilizer based on site-specific nutrient management concept. Majority of soil samples were medium organic matter, which might be due to low incorporation of farm yard manure which leads to low availability of NO_3-N. The results were in agreement with Ashok (2000) who presented same views. The main source of organic matter is crop residues but unfortunately in the study region as well as most of the developing countries, crop residues are used to feed animal, fuel purposes and negligible amount is left in the field, while, in developed countries, crop residues are burned in the fields to facilitate straw disposal, seed bed preparation and weed control (Biederbeck *et al*., 1980; Kauser, 1996). The potassium concentration of study area was adequate which might be due to high application of potassium fertilizer or soil having K rich micaceous and feldspars minerals in parent material (Ravikumar *et al*., 2007). The PO_4-P distribution map shows adequate amounts in the most soil samples except few. This was most likely due to high PO_4-P input in potato crops in the region, mostly through diammonium phosphate (DAP) application. This statement was agreed by the local farmers during personal communication. Whiteman (1985) reported that soil of Northern areas (Gilgit-Baltistan) was silt to sandy loam, with alkaline pH, low organic matter and total nitrogen. However, organic matter and total nitrogen were slightly high at higher altitude. He also reported no prevalent symptom of nutrient deficiency in Gilgit-Baltistan soils. Difference of soil properties like pH, O.M, E.C and saturation % of study area might be due to drainage pattern, cropping sequence, use of fertilizer and parent material. Similar findings were also reported by Rehman (2001). Baber *et al*., (2004) categorized Gilgit's soils as silt loam to silt clay with pH range from 7.34 to 8.03, EC from 0.06-0.5dSm^{-1}, low to medium organic matter; nitrogen was recorded deficient, while P ranged from 2.0-28.30 and K between 27.1-129.48mg kg^{-1}. The findings were more or less similar to the current study. Jatav *et al*., (2013) investigated spatial analysis of macronutrient and physical properties of potato growing areas of District Punjab, India and found pH ranging from 5.0 to 8.2, organic carbon 0.2-0.7%, nitrogen 186.3-355.6kg ha^{-1}, potassium 67.5-189.0ppm and phosphorus 10.1-53.9ppm. In general, soils of the study area were slightly acidic to alkaline and majority of them were low in soil organic carbon, nitrogen and potassium except phosphorus. Our findings in the current research slightly deviates from the above statement, however, in general soil macronutrients are same. This is the first ever study to determine soil nutrient status of potato producing areas of CKNP region, Gilgit-Baltistan. It helps in improving fertilizer application for achieving higher yields as well as the farmers of this remote region of Pakistan are going to get benefit. Spatial variability of soil parameters were found within the villages of study area. In general soil of study area was loamy or silty loam with 7.23-8.30 range of pH and EC from 0.45 to 1.39 along with soil organic matter status low to medium, macronutriens; NO_3-N low, PO_4-P and K was found adequate in tested soil samples.

Conclusions

GIS application for the assessment of soils was instrumental in establishing relationship between available nutrients in soil and its concentration in potato. With rapid advancement have been made in precision agriculture, GIS is applied for diverse exploration of agriculture activities. This study has explored soil nutrient status of potato growing valleys of CKNP region Gilgit-Baltistan through GIS Interpolation. Results reveal that there was considerable spatial variability in the soil parameters of the study area. Spatial variability of soil parameters were found varies within the valley of study area. These maps will help potato growers and department agriculture for spotoneous decision-making in crop management decisions like fertilizer use effeciency, reducing cost of production and resulted in increase productivity. Study will improve farmer's livelihood and reduce environmental pollution.

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