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Geo-spatial characterization of soil chemical properties of some potato growing pockets in dry temperate region of North-West Himalayas

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Abstract

The present study seeks to understand the spatial variability in soil fertility status through mapping in Lahaul valley of Himachal Pradesh for which triplicate soil samples were collected from nine sampling sites from different farmers' fields ranging between 2550-3146 m above mean sea level and were analyzed for soil pH, organic carbon, electrical conductivity, calcium carbonate, available nitrogen, phosphorus, potassium and sulphur and exchangeable Ca and Mg. The geo-spatial maps were prepared for each variable. The results revealed that soils in different sampling sites were near neutral in reaction, contained higher OC content, moderate EC and $CaCO_3$, low to medium in available nitrogen, medium in available phosphorus and sulphur, and high in available potassium along with optimum exchangeable Ca and Mg. This analytic work would help to devise accurate soil management practices and an absolute soil sampling system for effective sustainable agricultural production in Lahaul valley of Himachal Pradesh.

Keywords: Geo-spatial characterization, north-western Himalayas, soil chemical properties, temperate region

India is the second-largest producer of potatoes in the world, behind China. In India, potato is grown in an area of 2.203 million hectares with production of 56.173 million tonnes in 2020-2021(Anonymous 2022c). In Himachal Pradesh, potato is grown in 15.06 thousand hectares land with a production of 196.30 thousand metric tonnes and productivity of 13.0 metric tha^{-1} in 2020-2021 (Anonymous 2022 a). Lahaul Valley of the Lahaul & Spiti district, plays a significant role in meeting the national demand for high-quality potato seed, facilitated by its favourable climate. In 2020-21, the valley produced 3 thousand metric tonnes of potatoes across 501 hectares (Anonymous 2022b).

The Trans-Himalayan zone, encompassing India's cold desert region, remains untouched by the Indian monsoon, as they lie in the rain shadow of the Himalayan Mountain systems. This unique region is characterized by a combination of challenging environmental factors like sparse rainfall coupled with heavy snowfall, extreme temperature fluctuations, limited vegetation, high UV and intense solar radiation, and extremely xeric conditions (Devi and Thakur 2011).Himachal Pradesh comprises four agro-ecological zones: low hills, mid-hill sub-humid, high-hill temperate, and high-hill dry temperate. The latter includes Lahaul & Spiti, Kinnaur and parts of Chamba district (Pangi and Bharmour). Within the Lahaul & Spiti district, which spans 911,198 hectares, Lahaul covers 201,087 hectares area, of which 2,156 hectares are cultivated.

The Lahaul Valley is predominantly characterized by barren, uncultivated land (77%) and pastures (22%). Cultivation, only limited to the summer months (April-September), relies mostly on glacial meltwater for irrigation. Vast area lying waste can be put under cultivation if river water be used for irrigation. The valley's main crops include pea, potato, rajmash, exotic vegetables and apple. Potato, a nutrient-demanding crop, requires optimal fertilization for high yields. However, current imbalanced fertilizer practices risk soil degradation and reduced productivity. Therefore, a comprehensive understanding of the soil environment is crucial for developing appropriate fertilizer recommendations for potato cultivation in this high-hill temperate region.

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Previous soil studies in the valley have primarily focused on the chemical properties related to pea, potato (Parmar *et al*. 1999), rajmash (Datt *et al*. 2009) and seabuckthorn (Sharma and Singh 2017), with limited experimental work on pea, tomato, carrot, Brussels sprout and rajmash (Sharma *et al*. 2003; Sharma and Sharma 2004; Sharma *et al*. 2005; Datt *et al*. 2006; Kumar *et al*. 2017). This current investigation aims to address this gap by assessing key soil chemical properties in various potato-growing locations within the Lahaul Valley.

Materials and Methods

Description of study areas

The present study was undertaken in nine sampling locations of Lahaul valley in Himachal Pradesh. Lahaul and Spiti is an integral part of Indian cold desert area of Northern- western Himalayan region, located in the alpine arid zone of Himachal Pradesh, which comprise of two subdivisions – Lahaul and Spiti. The area is characterized by dry temperate zone, which remain covered with snow generally from November to March and in some areas even up to mid of May. The annual rainfall and temperature in this zone is very low throughout the year even falling to sub-zero during night. This zone lies between 31°44’55" North and 32°59’57" East latitude and 76°46’29" North and 78°41’34" East longitude.

Collection of soil samples

Random soil sampling was carried out during *kharif* 2022 from the areas under potato cultivation. Triplicate soil samples at 0–15 cm depth were collected from nine sites using steel auger.A total of 27 soil samples were drawn. The details of geographical location, altitude and coordinates of the study area are as follows Rangbay ($32^0$35'38"N and $76^0$56'36"E; altitude:3038m), Yangthang ($32^0$37'55"N and $76^0$51'53.6"E; altitude:2864m), Kwang ($32^0$38'53"N and $76^0$49'14"E; altitude:2905m), Rapring ($32^0$38'12.5"N and $76^0$52'18"E; altitude:3026m), Phura ($32^0$37'44.6"N and $76^0$52'11.6"E; altitude:2888m), Tozing ($32^0$35'23"N and $76^0$57'22.6"E; altitude:2998m), Malang ($32^0$35'33"N and $76^0$56'43.6"E; altitude:3129m), Chokhang ($32^0$35'24"N and $76^0$56'35"E; altitude:3131m) and Kain ($32^0$45'26"N and $76^0$56'41"E; altitude: 2610m) and depicted in Figure 1.

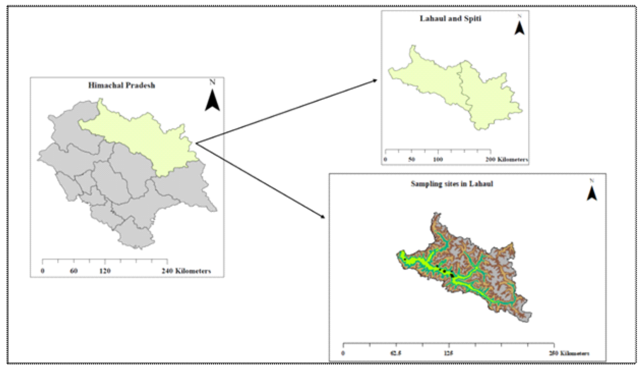

Fig. 1 Study area map

Sample processing and analysis

The collected samples were stored in polythene bags, labeled, and transported to the laboratory for analysis. In laboratory, the raw samples were air-dried and ground in a mortar pestle, sieved through a 2-mm sieve, and stored in plastic bags for further analysis. The samples were analyzed for different soil chemical properties (pH, EC, OC, $CaCO_3$, available major nutrients (N, P and K) and secondary nutrients (Ca, Mg and S) as per standard procedures.

Statistical Analysis

The data was analyzed in MS Excel Stat for descriptive statistics to determine range, mean and standard deviation. The thematic maps of different soil properties were prepared using IWD (Inverse Weighted Distance) in Q GIS software.

Results and Discussion

Soil pH

The mean value of soil pH varied from 6.7-6.9 in Rangbay, 6.9-7.0 in Yangthang, 6.8-7.0 in Kwang, 6.7-6.8 in Rapring, 6.9-7.0 in Phura, 6.7-6.8 in Tozing, 6.6-6.7 in Malang, 6.6-6.7 in Chokhang and 7.1-7.2 in Kain. The corresponding mean values of pH for above sites were 6.8, 6.9, 6.9, 6.8, 6.9, 6.7, 6.6, 6.6 and 7.1, respectively (Table 1). The results revealed that wide variation was observed among different sampling sites and the mean pH values depicted that most of the sampling sites were near neutral except for that in Kain where soils were found to be slightly alkaline in nature (Table 1). Further, three sites namely Chokhang, Malang and Tozing observed slightly low pH value as compared to rest of the sampling site. However, the difference in pH value was only 0.2 to 0.3 units and such variation in soil pH might be due to crop management practices e.g. use of fertilizer and organic

Table 1. Descriptive statistics for soil pH, OC, EC and $CaCO_3$

Location	pH	OC	EC	$CaCO_3$	N	P	K	Ca	Mg	S
Rangbay	6.8± 0.05	12.7±1.0	0.25± 0.029	6.73± 0.32	281.0± 2.86	20.1± 1.30	472.1 ±5.62	9.5 ±0.85	5.1 ±0.98	14.2± 1.75
Yangthang	6.9± 0.07	12.9± 0.476	0.24± 0.03	6.36± 0.73	274.5± 5.36	20.3 ±1.91	481 ±6.14	10.9 ±1.57	5.1 ±0.97	16.1 ±1.31
Kwang	6.9± 0.07	12.9 ± 1.23	0.24± 0.05	6.26± 0.47	279.9± 3.13	19.9± 1.17	469.7 ±2.12	9.0 ±0.57	6.7 ±0.55	15.6 ±2.36
Rapring	6.8± 0.07	13.2± 0.40	0.23± 0.05	6.40± 0.60	273.7 ±6.65	20.1± 1.95	469.7 ±2.90	9.1 ±1.78	6.4 ±0.72	16.2 ±1.75
Phura	6.9± 0.07	13.7± 0.40	0.24± 0.05	6.42± 0.62	274.4± 3.80	20.4 ±2.32	481 ±7.19	9.6 ±0.71	7.3 ±1.85	15.3 ±1.60
Tozing	6.7± 0.05	13.0± 1.25	0.25± 0.03	6.70± 0.55	277.1± 2.86	18.1 ±1.30	480± 5.62	8.7± 1.25	5.7 ±0.55	17.7± 1.65
Malang	6.6 ±0.02	12.7 ±1.05	0.25 ±0.04	6.43 ±0.45	278.2 ±5.36	17.2± 1.91	476.8± 6.14	8.7± 0.35	4.9 ±0.36	17.8 ±1.41
Chokhang	6.6 ±0.03	13.6 ±0.55	0.25 ±0.02	6.63 ±0.65	268.1± 3.13	18.3± 1.17	477.3± 2.12	8.4 ±1.03	5.5± 0.57	17.0± 2.55
Kain	7.1 ±0.06	13.6 ±1.06	0.33 ±0.03	8.73 ±0.61	264.9± 6.65	20.4± 1.95	487.8± 2.90	12.8 ±1.40	6.7 ± 0.50	16.4 ±1.55

manures followed by the farmers. The near neutral soil pH at these sites might be attributed to parent material dominated by calcite and dolomite accompanied by low precipitation which retains the basic cations like Ca^{2+}, Mg^{2+} in the soil solution thereby rendering it to near neutral.

Soil EC

The soil electric conductivity showed variation of 0.21-0.28 (mean 0.25), 0.21-0.27 (mean 0.24), 0.20 - 0.30 (mean 0.24), 0.19-0.29 (mean 0.23), 0.21-0.29 (mean 0.23), 0.22-0.29 (mean 0.25), 0.21-0.30 (mean 0.25), 0.24-0.28 (mean 0.26) and 0.32-0.37 (mean 0.33) in soil of Rangbay, Yangthang, Kwang Rapring, Phura, Tozing, Malang, Chokhang and Kain, respectively (Table 1, depicted in Figure 2A). In general, the EC values showed little variation among different sampling sites.However, soils in Kain had slightly higher valuesbut majority of the study soils fall in optimum range which is considered best for crop production. However, the EC of these soils does not have any significant variation proving that there is equal cumulative accumulation of salts along the altitude (Charan *et al*. 2013).

Soil OC

The observed variation in soil organic carbon content of Rangbay, Yangthang, Kwang, Rapring, Phura, Tozing, Malang, Chokhang and Kain was from 11.7-14.2 , 12.6-13.5, 11.9-14.3, 12.9-13.7, 12.9-14.5, 11.7-14.2, 11.7-13.8, 13.1-14.2 and 12.7-114.8 with corresponding mean value of 12.7, 12.9, 12.9, 13.2, 13.7, 13.0, 12.7, 13.6 and 13.6, respectively (Table 1, depicted in Figure 2B). The cold arid bio-climate of Himachal Pradesh contains more soil organic carbon and soil organic matter due to decrease in temperature at high altitude. The low temperature prevailing in study area might have decreases the microbial and enzymatic activity; rendering the soil high in organic matter thereby unaffected by microbial decomposition. Therefore, low temperature with increase in altitude is the major factor determining the high soil organic matter with increase in altitude (Kumar *et al*. 2019). Cold desert crops have higher root: shoot ratios, shallower root distributions and above ground litter fall and root mortality are the two primary processes that contribute to soil carbon inputs in high altitude soils (Charan *et al*. 2013).

Soil $CaCO_3$

The range and mean values recorded for CaCO3 carbonate were 6.3-7.1 and 6.73, 5.8-7.2 and 6.36, 5.9-6.8 and 6.26, 5.8-7.0 and 6.40, 5.9-7.1 and 6.42, 6.2-7.3 and 6.60, 5.8-7.2 and 6.43, 5.8-7.7 and 6.63 and 8.2-9.4 and 8.73, respectively in Rangbay, Yangthang, Kwang, Rapring, Phura, Tozing, Malang, Chokhang and Kain (Table 1, depicted in Figure 2C). The data suggested that study soils showed wide variation in $CaCO_3$ content in soil but contained sufficient amount of $CaCO_3$ for successful crop production. The wide variations and $CaCO_3$ sufficiency might be due to the sedentary parent material and feldspars (potassium and plagioclase feldspar) and quartzite, as the dominant mineral. Another reason might be due to low temperature and respiration rate and high snow precipitation. Since, temperature affects $CaCO_5$ equilibrium directly through its influence on the solubility constant and indirectly through its effect on the partition of precipitation inputs between evapo-transpiration and leaching (Feng *et al*. 2002), resulting high calcium carbonate.

Available nitrogen

A variation ranging from 278.7-284.2 in Rangbay (mean 281.0), 269.3-280.0 (mean 274.5) in Yangthang, 277.3-283.4 in Kwang (mean 279.9), 268.7-281.3 in Rapring (mean 271.3), 270.6-278.2 in Phura (mean 274.4), 269.6-284.1 in Tozing (mean 277.1), 272.8-283.6 in Malang (mean 278.2), 264.7-271.4 in Chokhang (mean 268.1) and 260.1-270.3 in Kain (mean 264.9) was recorded in relation to available nitrogen in potato fields (Table 1, Figure 2D).Inspite of high soil organic carbon content of the potato fields, the available nitrogen was medium which might be because of low rate of decomposition of organic carbon. Andreeva *et al*. (2022) found that soil available nitrogen transformation decreases at high altitude resulting medium availability of nitrogen.

Available P

The range and mean values recorded for available phosphorus were 18.8-21.4 and 20.1,18.6-22.4 and 20.3, 18.7-21.0 and 19.9, 18.8-22.4 and 20.1, 18.9-23.1 and 20.4, 16.7-19.2and 18.1, 15.8-18.3 and 17.2, 17.5-19.2 and 18.3 and 19.5-21.7 and 20.4, respectively in Rangbay, Yangthang, Kwang, Rapring, Phura, Tozing, Malang, Chokhang and Kain (Table 1,

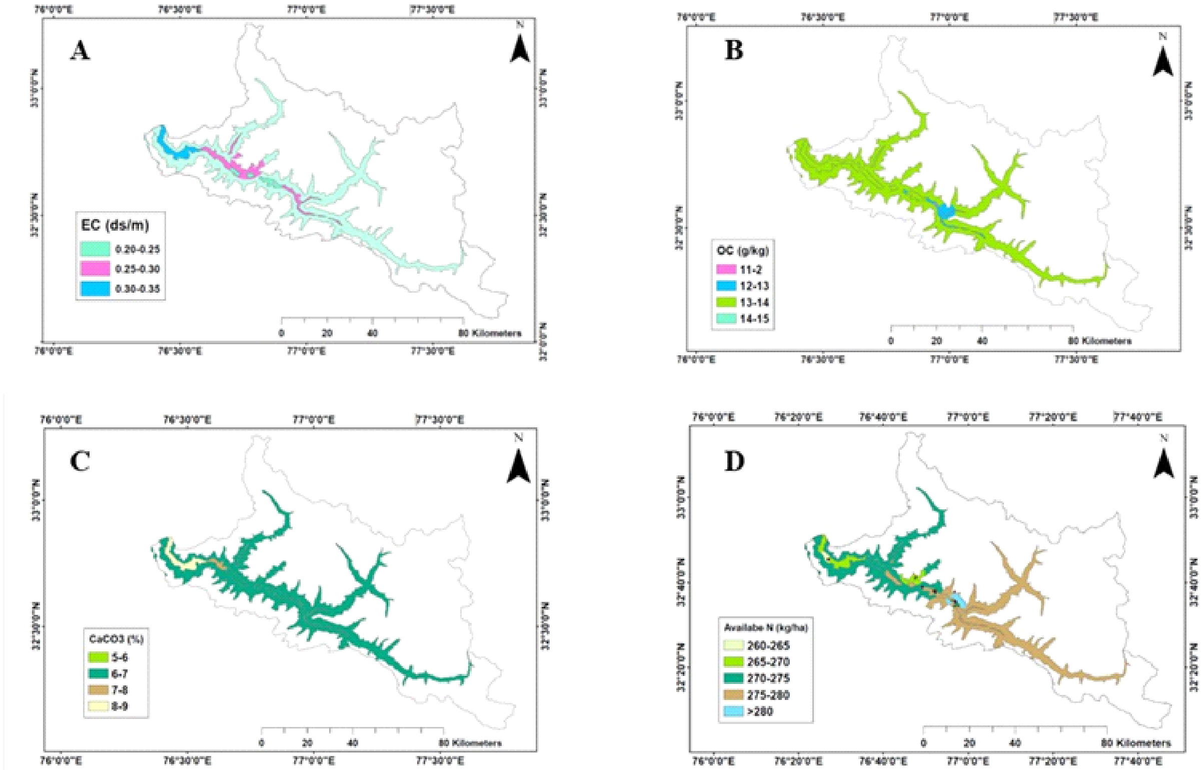

Fig.2 Spatial variability of A: EC (ds m^{-1}), B: OC (g kg^{-1}), C: $CaCO_3$ (%) and D: available N (kg ha^{-1}) in different sites

depicted in Figure 3A). The results demonstrated that all sampling sites in Lahaul had medium status of available phosphorus. The availability of phosphorus in soil is highly pH dependent with maximum

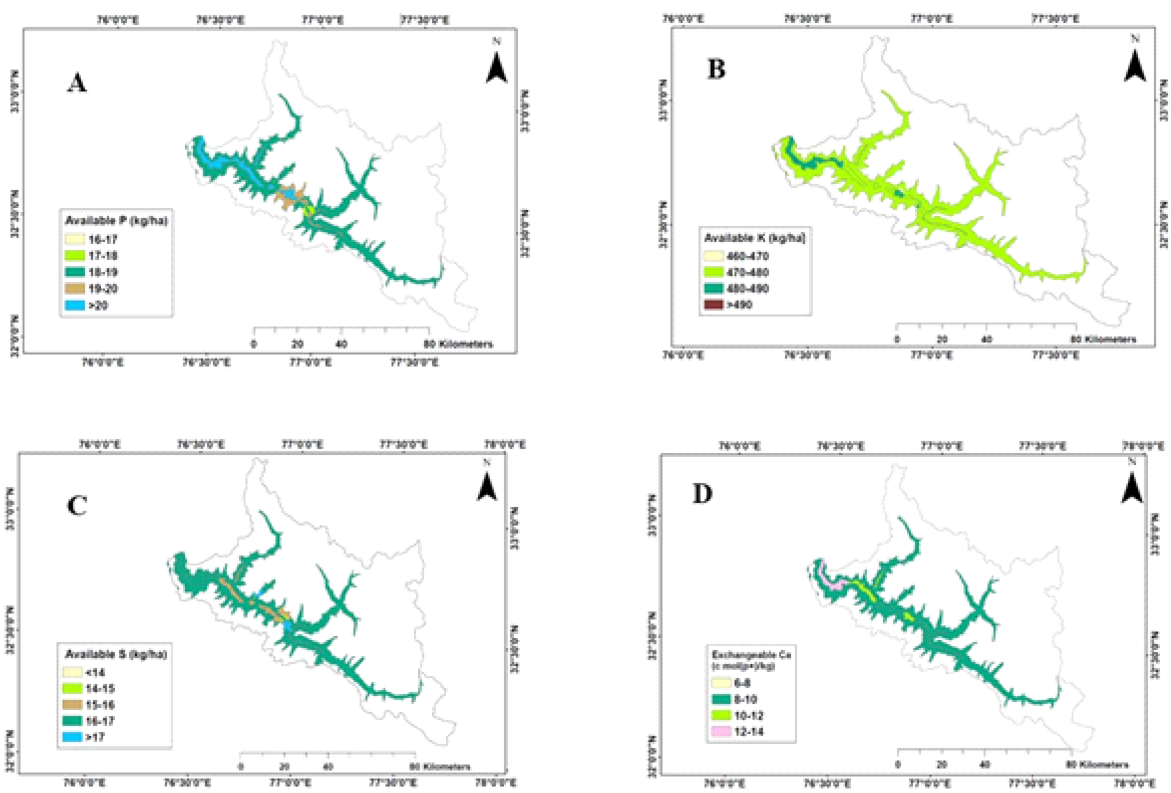

Fig.3 Spatial variability of A: available P (kg ha^{-1}), B: available K (kg ha^{-1}), C: available S (kg ha^{-1}) and D: exchangeable Ca (c mol p (+) kg^{-1}) in different sites

availability near neutral soil pH. The study soils had favorable soil pH (medium P status) hence resulted in to higher build-up.The high organic matter content present in study area led to the formation of organo phosphate complexes and coating of iron and aluminum particles by humus which helped prevention of P fixation resulting better P availability (Dar *et al*. 2017). These results are confirmed from of Malik and Haq (2022), who also reported medium P status at high altitude.

Available K

Rangbay, Yangthang, Kwang, Rapring, Phura, Tozing, Malang, Chokhang and Kain samplinglocation observed range and mean values of available potassium in potato field from 467.6-478.4 and 472.1, 475.3-487.5 481.1, 467.3-471.3 and 469.7, 466.8-472.6 and 469.7, 474.3-488.6 481.0, 476.8-483.2 and 480.0, 472.6-483.2 and 476.8, 472.4-481.4 and 477.3 and 481.6-494.6 and 487.8, respectively (Table 1, depicted in Figure 3B). The data showed that these soils had extensively high potassium present in them. The higher status of K in these soils might be due to the sedentary parent material and feldspars (potassium and plagioclase feldspar) as the dominant mineral (Parmar *et al*. 2008)along with intense weathering and subsequent release of labile K from organic residues. Huynh *et al*. (2022) have also observed greater amount of K at high altitude. These results are also in agreement with the findings of Wani *et al*. (2017), who observed similar results for apple orchard at high altitude of Kashmir valley.

Available S

The mean value of available sulphur in soil varied from 12.5-16.0 in Rangbay, 14.7-17..3 in Yangthang, 13.9-18.3 in Kwang, 14.5-18.0 in Rapring, 6.88-7.13.8-17.0 in Phura, 16.8-19.2 in Tozing, 16.3-19.1 in Malang, 14.5-19.6 in Chokhang and 14.9-18.0 in Kain. The corresponding mean values of pH for above sites were 14.2, 16.1, 15.6, 16.2, 15.3, 17.7, 17.8, 17.0 and 16.4, respectively (Table 1, depicted in Figure 3C). The data demonstrated that study sites in Lahaul valley contained medium to high sulphur content whichmay be attributed to the more organic matter content present in soils at high altitude. The organic matter has significant positive relationship with available S in soils through its effect on sulphate adsorption, organic S formation and mobilization of S through microbial activity (Watwood *et al*. 1988). Therefore, it is evident that the factors prevailing in study sites have positive effect on the status and availability of secondary nutrients in soils.

Exchangeable Ca and Mg

The measured range and mean values for calcium in study sites were 8.7-10.4 and 9.5, 9.7-12.7 and 10.9, 8.4-9.5 and 9.0, 7.9-11.2 and 9.1, 8.9-10.3 and 9.6, 7.5-10.0 and 8.7, 8.4-9.1, and 8.7, 7.6 to 9.6 and 8.4 and 11.4-14.2 and 12.8, respectively for Rangbay, Yangthang, Kwang, Rapring, Phura, Tozing, Malang, Chokhang and Kain sampling location. Likewise, range and mean values with respect to magnesium in above sites were 4.3-6.2 and 4.8, 4.1-6.0 and 5.1, 6.2-7.3 and 6.7, 5.8-7.2 and 6.4, 5.9-9.4 and 7.3, 5.2-6.3 and 5.7, 4.6-5.3 and 4.9, 4.9-6.0 and 5.5 and 6.2-7.2 and 6.7, respectively (Table 1, depicted in Figure 3D and Figure 4, respectively). The data revealed that calcium and magnesium in study sites existed inoptimum range which may be attributed tothe parent material containing limestone with substantial quantity of dolomite and shale along with illite and chlorite minerals which strongly influenced calcium and magnesium concentration through mineral weathering and soil formation processes. Such parent materials subsequently affect the cation exchange capacity and base saturation of exchangeable sites might have resulted in optimum values of exchangeable Ca and Mg (Bailey *et al*. 2004).

Conclusion

For improving the soil sampling strategies and site-specific management practices across area of study in

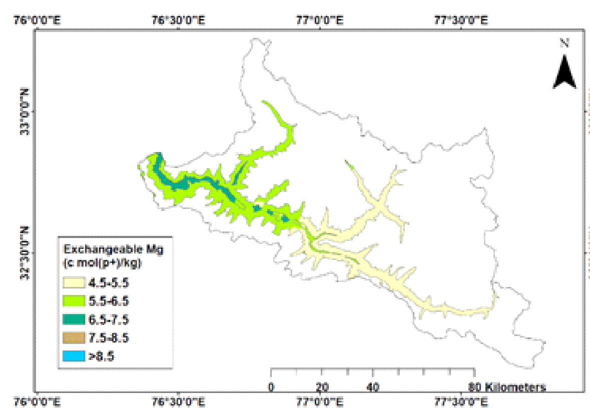

Fig.4 Spatial variability of exchangeable Mg (c mol p (+) kg^{-1}) in different sites

accordance with their management and reclamation requirements, spatial distribution of soil properties can be used positively. The variability of the measured soil chemical parameters will help to explain eventual anomalies of the results of future planned experiments. Based on the soil variability maps generated for the valley, it is also recommended that adequate fertilization and good crop and/or soil management need to be practiced in order to progress the productivity and fertility of the soils for sustainable production of potato.

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