Indian Journal of Ecology (2022) 49(5): 1654-1660
DOI: https://doi.org/10.55362/IJE/2022/3711

Manuscript Number: 3711
NAAS Rating: 5.79

Digital Mapping of Soil Physicochemical Properties of Ramban District of Jammu and Kashmir using Geographic Information System

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Abstract: A study was carried out to assess and generate the prediction maps of the physicochemical properties of the soils in the Ramban district. The Ramban district of Jammu and Kashmir covers an area of 113787 ha and falls in the temperate zone of the state. It is an upland valley in the north-east corner of Jammu region. Soil samples were collected from the entire Ramban district in a stratified random manner. The digitization process and generation of maps was carried out with ArcGIS 10.0. Sandy loam was the dominant textural class in the district. Soil pH varied widely across the Ramban district ranging from as low as 5.70 to as high as 7.90. The electrical conductivity (EC) ranged from 0.16 to 6.90 dS m^{-1}.Organic carbon (OC) was found to be in a range from 0.11 to 1.95%.The calcium carbonate content ranged from traces to 2.20%. Cation exchange capacity (CEC) had values ranging from 4.34 to 42.04 cmol p^+/kg. Almost all recorded physicochemical properties of Ramban district soils were conducive for crop growth, although the major area of the district was either devoid of cultivation or difficult to cultivate because the region is having undulating topography.

Keywords: Mapping, Soil, Physicochemical properties, Geographic information system

Soil is a dynamic natural body which develops as a result of pedogenic natural processes during and after weathering of rocks(Wagh 2014). It consists of mineral and organic constituents, processing definite chemical, physical, mineralogical and biological properties having a variable depth over the surface of the earth and providing a medium for plant growth (Osman 2012). Soil is a heterogeneous, diverse and dynamic system and its properties change in time and space continuously. Heterogeneity may occur at a large scale (region) or at small scale (community), even in the same type of soil or in the same community (Hussain et al 2021). Soil which is a natural resource has variability inherent to how the soil formation factors interact within the landscape. However, variability can occur also as a result of cultivation, land use and erosion (Wani 2016, Singh et al 2021).Soil properties vary spatially from a field to a larger regional scale and it is affected by soil forming factors which can be termed as intensive factors and extrinsic factors such as soil management practices, fertility status and crop rotation (Gull et al 2020). Variability is an inherent soil condition, and its origin is influenced by both natural conditions (Various factors and pedogenic processes) and induced conditions through the use and management of them (Gull et al 2020, Sun et al 2003). Those soil properties that are most altered by soil management will be those with the greatest variability (Chhagan et al 2019, Jan et al 2020, Ovalles 1992). Sustainable crop production requires a good understanding of the fertility status of the soil in order to impose appropriate nutrient management strategies (Khadka et al 2018, Singh et al 2021). Fertility management based on soil tests is an effective strategy for enhancing productivity in agricultural soils with considerable geographical variability due to the combined effects of physical, chemical, and biological processes .The key markers of soil fertility include soil physical properties (Texture, structure), pH, organic matter, macro- and micronutrients, among many others (Brady et al 2008). These parameters can correctly determine plant growth and development. Understanding the current state of soil fertility is critical for developing effective soil management techniques and devising crop cultivation plans in the proposed area. Global Positioning Systems (GPS) and Geographic Information Systems (GIS) are also excellent tools for assessing soil spatial variability. The current study aims to improve soil resource management, agricultural production, and serve as a guideline for future research in the field. The main objective of this research was to determine various soil physico-chemical properties of district Ramban, to develop their maps and to delineate problem soil of district Ramban for future planning and management.

MATERIAL AND METHODS

Study area: Ramban district is in Jammu Division of Jammu and Kashmir UT of India (Fig. 1) and is located in the lap of Pir Panjal Range of the mighty Himalayas between at 33° 14' N and 75° 17'E longitudes with an average elevation of 1,156 metres from sea level. The temperature in case of District Ramban rises as high as 42°C in the low-lying areas, located in between steep mountains on the banks of river Chenab and drops to sub-zero in the high altitude areas. However, the average annual temperature is 21.1 °C. The climate of Ramban varies momentously due to its uneven topography. Ramban experiences a subtropical climate. Ramban district come under the climate type- Interior Mediterranean, mild winter, dry and hot summer. The average annual rainfall in the district is 1209 mm. The rainfall varies from place to place in the district due to topographic variation. The major crops grown in the district are maize and paddy, whereas the majority of the area is rainfed (90%) which is under cultivation.

Collection and analysis of soil samples: A total of 114 surface soil samples were taken randomly across whole district. Soil samples were taken on basis of stratified random sampling. Location coordinates of sampling sites The collected soil samples were air- dried, ground with wooden pestle and mortar and sieved through 2-mm sieve, labelled, stored and analysed for pH (1:2.5 soil: water suspension), EC (1:2 soil: water supernatant), organic carbon (OC) (Walkley & Black, 1934), $CaCO_3$ and Cation exchange capacity (CEC) by (Piper 1966). Soil texture was determined by the International pipette method. The USDA textural triangle was used for determining textural classes (Parkin 1993).

Mapping and interpolation: Mapping of spatial distribution of soil properties require spatial interpolation methods. In the present study, interpolation technique inverse distance weighting (IDW) was employed and soil maps of each property were generated using ArcMap 10.0. These interpolation techniques have been commonly used in mapping of soil properties (Caridad Cancela, 2002; Nayak et al 2006; Schloeder et al 2001).

RESULTS AND DISCUSSION

Soil texture: Ramban soils were classified into ten different categories depending upon the varying content of sand, silt, and clay. Clay loam texture was dominant (25.44%) in the district followed by clay, silty clay, silt loam, and silt clay loam soils represented sufficient samples (21.05, 17.54, 11.40 and 7.02%), respectively in the district (Fig. 2). Sand percentage in soil varied widely across district from as low as2.96% to as high as 86.96% (Table 1). The coefficient of variation (CV)

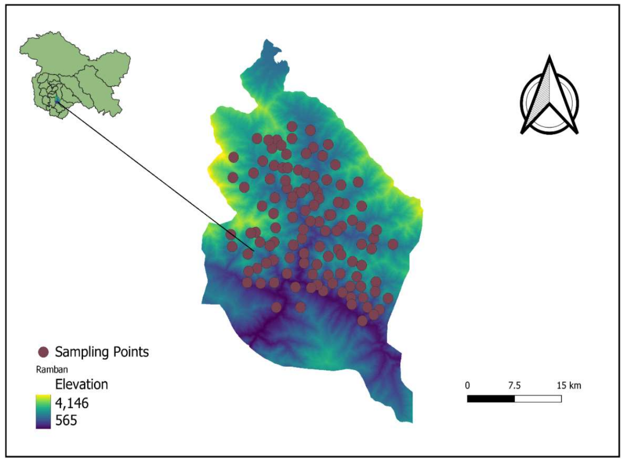

Fig. 1. Study area map and sampling points

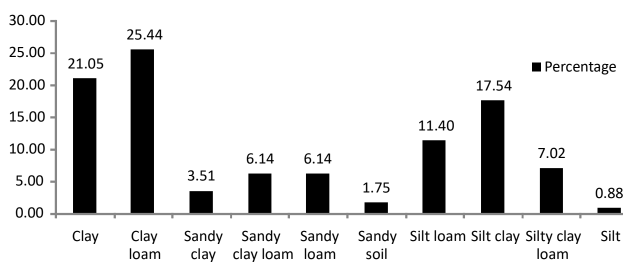

Fig. 2. Percentage distribution of different textural groups

Table 1. Descriptive statistics of sand, silt, clay, pH (1:2.5), electrical conductivity, calcium carbonate, organic carbon and cation exchange capacity of soils of Ramban District

Name of parameter	Minimum	Maximum	Range	Mean	Coefficient of variation (%)	Standard Error	Skewness	Kurtosis
Sand (%)	2.96	86.96	2.9-86.96	31.10	58.78	1.71	0.55	-0.08
Silt (%)	4.00	90.00	4.00-90.00	33.59	47.69	1.50	0.67	0.29
Clay (%)	7.04	67.04	7.04-67.04	35.30	36.47	1.20	-0.27	-0.21
pH	5.70	7.90	5.70-7.90	6.98	6.10	0.03	-0.67	0.42
EC (dS m^{-1})	0.16	6.90	0.16-6.90	1.01	113.71	0.10	3.20	11.71
OC (%)	0.11	1.95	0.11-1.95	0.86	49.24	0.04	0.33	-0.61
$CaCO_3$ (%)	----	2.20	0 -2.20	0.29	146.73	0.04	1.91	4.12
CEC (Cmol p+/kg)	4.34	42.04	4.34-42.04	19.73	40.66	0.75	0.33	-0.19

was 58.78%, skewness and kurtosis was 0.55and -0.08respectively. Based on skewness distribution was approximately asymmetric (>0.5) and negative kurtosis indicates that the distribution has lighter tail and flatter peak than normal distribution (Fig. 3a). Silt and clay also varied widely across district from as low as 4.00 and 7.04% to as high as 90.00 and 67.04% with CV of 47.69 and 36.47% (Table 1), respectively. Skewness and kurtosis were 0.67, -0.27 and 0.29, -0.21, respectively (Fig. 3b,c).Sand content insoils of Ramban district mainly varied between 20 to 40%. However, on south-western side sand content was between 40 to 60% (Fig. 2a). In case of silt majority area of district Ramban had silt content between 30 to 40%followed by area containing 20 to 30% (Fig. 2b).In clay majority of area in Ramban district had 20 to 30% clay followed by the area on eastern side having 40 to 50% clay content in soils, although scattered patches of less than 20 % clay were also noticed (Fig. 2c).Differentiation in the textural composition of soils is caused by pedogenic and geological processes (Schoonover & Crim, 2015). Soil organic matter and nutrient contents, pore size, water availability, and leaching losses of nutrients are controlled by the soil texture (Plante et al 2006; Scott et al 1996).

Soil pH: Soil pH is the key factor influencing soil organic matter, nutrient availability and their dynamics (Rasmussen et al 2018). The10.52% of the samples were in acidic range having pH less than 6.5, soil pH ranging from 6.5-7.5 constitute 85.08% and basic soils having greater than 7.5 constitute only 5.26% of the total soil samples (Table 2). Acidic soils can be attributed to hilly terrain, which leads to leaching of salts and making soils acidic. Soil pH in theRamban district varied across district from 5.70 to 7.90 with mean of 6.98 (Table 1). Frequency distribution curve of data was negatively skewed (-0.67) and kurtosis (0.42) (Fig. 3d). Suitable soils for most of the crops are in pH range of 6.5-8.7 (Havlin et al 2004). Coefficient of variation of data was recorded 6.10%. CV of pH is in consonance with the findings of Aishah et al (2010). Soils present in majority area of district Ramban was neutral to basic. Very small patches of the district on south-western side were acidic in reaction (Fig. 2d). The wide variation in soil pH was mainly observed due to variation in topography, slope and use of amendments at varying rates (Jiao et al 2016, Jatav et al 2007, Seibert et al 2007).

Electrical conductivity: EC of the soils ofRamban varied widely as low as 0.16to as high as 6.90 dS m^{-1} (Table 1). Frequency distribution curve of EC was positively skewed (3.20) (Fig. 5a). Soils with an EC<0.8 with mean value in that group 0.45 dS m^{-1} represented 62.28% of the total samples, other category where EC>0.8 with mean of 1.93 dS m^{-1}represented 37.71% of the total samples, respectively (Table 2). EC was mostly under safe limits except some patches where EC was more than critical value (Fig. 4a). Dissolved salts cause an ionic imbalance, which prevents nutrients from being absorbed. The fundamental effect of

Table 2. Critical ranges and distribution of pH (1:2.5), electrical conductivity, calcium carbonate organic carbon and cation exchange capacity of soils of Ramban district

Categories range	Mean	Percentage out of total Samples
pH		
Normal (6.5-7.5)	7.08	85.08
Acidic (< 6.5)	6.16	10.52
Basic (> 7.5)	7.63	5.26
EC		
Normal (< 0.8)	0.45	62.28
Saline (> 0.8)	1.93	37.71
$CaCO_3$		
0.0–1.00	0.22	93.85
1.01–5.00	1.54	6.14
Organic carbon		
Low < 0.40	0.22	11.40
Medium 0.40–0.75	0.55	30.70
High > 0.75	1.16	57.89
CEC		
Low < 20	13.82	55.26
High > 40	40.32	0.87

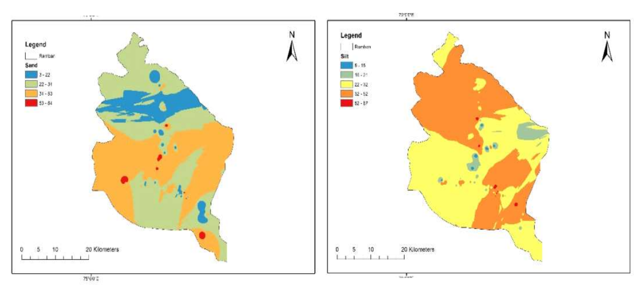

Fig. 3. Thematic maps of sand (a) silt (b), clay (c) and pH (d) of Ramban soils

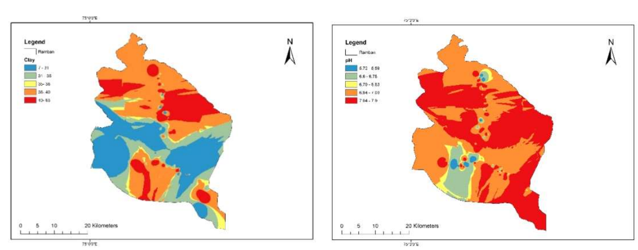

Fig. 4. Thematic maps of sand (a) silt (b), clay (c) and pH (d) of Ramban soils

high EC is the plant's inability to compete with ions in soil solution (Bajwa and Choudhary 2014). The high percentage of land in low EC could be attributable to salt leaching from intensive irrigated agriculture and the expansion of submerged paddy cultivation.

Calcium carbonate: Calcium carbonate is mainly derived from rock minerals. However, certain environmental conditions like more evaporation and less rainfall leads to its accumulation in soils. $CaCO_3$ content of soils ranged from traces to 2.20% (Table 1). Frequency distribution curve of $CaCO_3$ was positively skewed (1.91) (Fig. 5b). The first category (0.0-1.00% $CaCO_3$) had an average of 0.22% and the second category (1.01-5.0% $CaCO_3$) with 1.54% constituting 93.85 and 6.14% of the total samples taken, respectively (Table 2). The study area was non-saline, with lowest mean value observed in forests and highest in wastelands, which could be owing to $CaCO_3$ and salt accumulation in wastelands and a higher amount of decaying litter in the forest (Kiflu & Beyene, 2013). Shamsi et al (2010) revealed that high $CaCO_3$ is mainly in agricultural lands than in natural systems. Tillage action removes surface horizons with less calcium carbonate due to erosion, causing outcropping of the bottom horizons with more calcium carbonate, resulting in high $CaCO_3$ in agricultural land use. Vafaeizadeh et al (2016) observed that agricultural soils have more $CaCO_3$ than pasture and forest lands, which is compatible with the findings of our study. The Ramban Plateau lies in higher Himalayas which is coupled with an assemblage of silty material at the top (10-12m. thick) underlain by silt and angular fragments of mainly quartzites and schists (80m thick) mixed in varied proportions (Sharma et al 2012).

Organic carbon: Soil organic carbon is considered as vital and essential for maintaining soil productivity and health and also helps in the improvement of soil quality parameters (Funderburg, 2020).Organic carbon in soil varied from as low as 0.11% to high as 1.95% (Table 1). Frequency distribution curve of OC was slightly skewed (0.33) (Fig. 5c). In Ramban district southern side of district has more OC than northern side. OC content was higher mostly in forest areas (Fig. 4c). Many factors such as topography, land-use, field management and vegetation may influence the spatial variability of OC (Francaviglia et al 2017, Parras-Alcántara et al 2015, Sahoo et al 2019). Nine textural classes were reported in district (Fig. 1) with varying topography as Ramban District consists of hills and valleys. Out of total samples taken 11.40% were low, 30.70% were medium, and 57.89% were in high range (Table 1). The 57.89% of total samples were high in range comprising mainly of forest area. A likely explanation was that in the forest soils, lower temperatures at higher altitudes limited carbon decomposition, which resulted in increased carbon accumulation (Nath et al 2018). The higher SOC may be

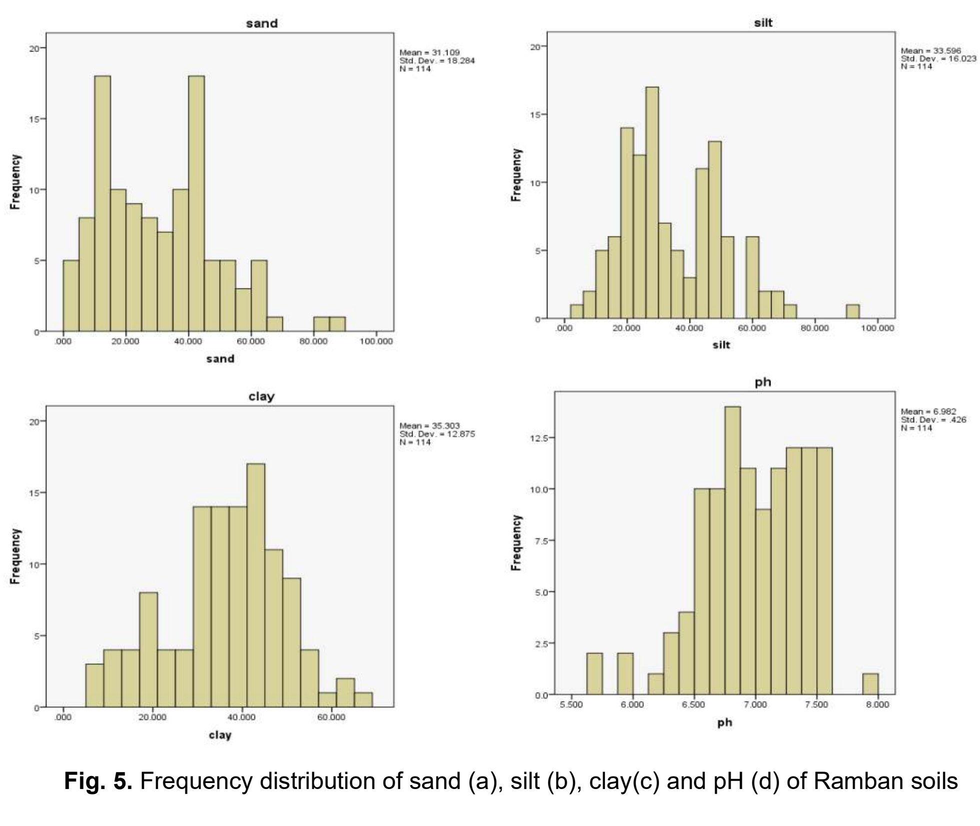

Fig. 5. Frequency distribution of sand (a), silt (b), clay(c) and pH (d) of Ramban soils

attributed due to high above and below ground biomass which increases soil OC by organic tissues, litter and secreting root exudates rich in binding agents increasing physical stability and microbial activity (Kukal et al 2008, Smith 2008, Wang et al 2014). Land use is a major factor influencing SOC storage because it affects the amount and quality of litter added, decomposition rate and processes of organic matter stabilization in soils.

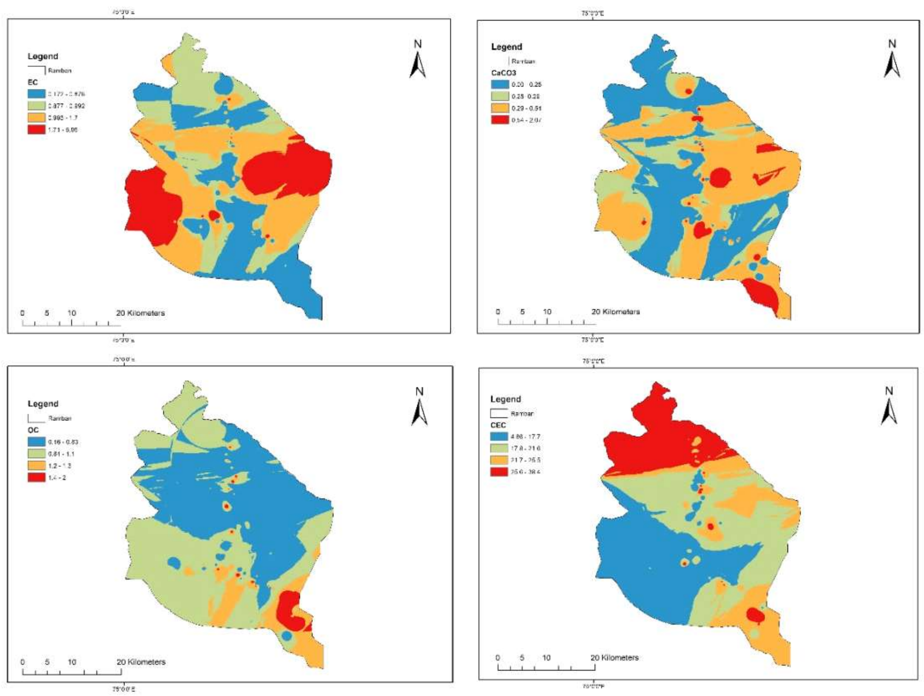

Fig. 6. Thematic maps of EC (a), $CaCO_3$ (b), OC (c) and CEC (d) of Ramban soils

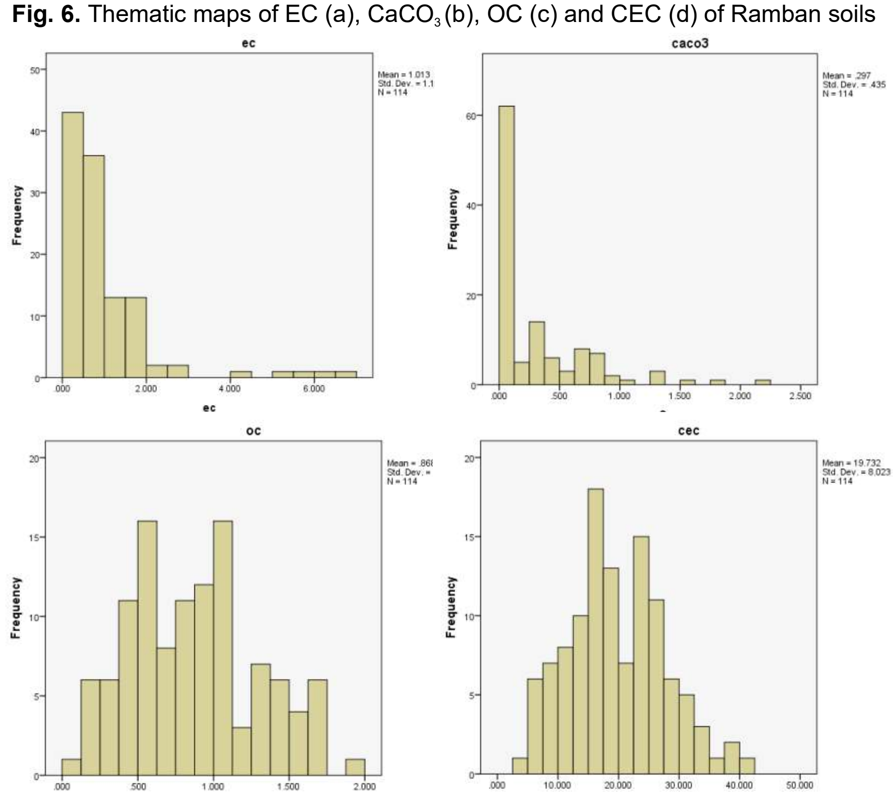

Fig. 7. Frequency distribution of EC (a), $CaCO_3$ (b), OC (c) and CEC (d) of Ramban soils

Cation exchange capacity: The CEC values ranged from 4.34 to 42.04 cmol p^+/kg. Different soil types, texture, land-use types, humus, clay and soil fertility management all contribute to this wide range of results (Selassie et al 2015, Huang et al 2016, Lazaratou et al 2020) (Table 2). Frequency distribution curve of CEC was slightly skewed (0.33) (Fig. 5d). The CEC was less than 20 cmol p^+/kg with mean value of 13.82 and in the other category >40 cmol p^+/kg with mean value of 40.32 cmol p^+/kg (Table 2) (Fig. 4c). CEC is an important indexing parameter for evaluating soil fertility and buffering capacity since it shows soil nutrient conservation and buffering capability (Bagherzadeh and Gholizadeh 2018, Muntiani 2021). Panagopoulos et al (2006) found that the kriging method performed better than IDW, while others showed that kriging was no better than alternative methods (Sekulic et al 2020, Fuhg et al 2021).

CONCLUSION

Majority of the soils in district were neutral in reaction, followed by acidic and alkaline soils. Due to lower temperatures at higher altitudes, it reduced carbon loss, where majority of the samples had a high OC concentration, resulting in increased carbon storage. The study area had mainly moderate CEC as recorded in majority of samples, followed by high CEC. Almost all of the physicochemical properties of Ramban district soils were favourable for crop cultivation, despite the fact that a large portion of the district was either barren or difficult to cultivate due to the study area's sloppy topography, which made cultivation difficult. We can plan resource allocation and distribution in the region with the help of the maps generated, where policymakers and state agencies will be able to draft appropriate development plans with the use of these maps.

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Received 12 May, 2022; Accepted 09 September, 2022

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