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Assessment of Soil Variation in Kaithal District using GIS and GPS

Mohit Sharma, R.S. Garhwal, K.K. Bhardwaj, Anil Kumar*, Charan Singh, Sunil Kumar, Amit Kumar and Saloni Yadav

Department of Soil Science, CCS HAU, Hisar-125 004, India
**E-mail: anilchauhan999111@gmail.com*

***Abstract*:** The current investigation was conducted in Kaithal district, focusing on Kalayat, Rajound, Pundri and Dhand block. The samples were collected from 106 villages across different blocks using GPS and maps were prepared subsequently using GIS. Soils in all four blocks was non saline, low to medium in organic carbon content and texture ranging from sandy loam to clay loam, loam and sandy clay loam. Bulk density varied between 1.32-1.59 Mg m^{-3}. Soils of all four blocks were low in available nitrogen (N) content, intermediate too high in phosphorus (P) and potassium (K) content and high in sulfur (S) content. All four blocks possess medium nutrient index in terms of phosphorus and potassium, whereas, these blocks have high values for sulphur nutrient index.The positive correlation was observed between the soil organic carbon and available N, P, K and S of soil. Inappropriate agricultural practices, intensive farming, monoculture cropping patterns and excessive irrigation contribute to soil fertility degradation. To mitigate these adverse effects, toned to employ a combination of biofertilizers, organic manures and appropriate use of chemical fertilizers.

***Keywords*:** Fertility, GIS, GPS, Nutrient index

Soil is a crucial natural resource that supports the production of food, fodder, and fuel essential for the sustainability of humans and animals. As populations grow, the demand for food increases, placing greater pressure on soil resources. Throughout history, the success and survival of civilizations have been closely tied to the ability of their soils to provide necessary resources. This presents a significant challenge for scientists, planners, administrators, and farmers who must work to ensure food security for both current and future generations by managing soil resources efficiently. Evaluating the fertility status of the soil is essential for making well-informed decisions in agriculture. It enables farmers to grasp the nutrient composition of their soil, guiding choices on fertilization, crop selection and planting methods to optimize both crop yields and quality. Soil testing facilitates precise fertilizer application by analysing essential nutrients like nitrogen, phosphorus and potassium, as well as secondary and micronutrients to reducing costs and mitigating environmental impact. At global scale, about one-third of arable soils are deficient in micronutrients, particularly in zinc (Zn) (Cakmak et al 2017).

Haryana soils are among the most arable soil in northern India but still lack adequate nutrients for plant growth. Despite increased fertilizer use to cultivate high-yielding crop varieties, crops continue to extract more macro and micronutrients from the soil and ultimately leading to soil nutrient deficiency. In Haryana, the current status of Zn, Fe, Mn, Cu and B varied from 1.11 to 36.50, 0.0-55.00, 0.00-48.60, 0.00-13.00 and 0.00-13.70%, respectively with an average deficiency of 15.3, 21.6, 6.1 5.2 and 3.3 % (Shukla et al 2015). Kaithal is the northeastern district of Haryana, encompasses an area of 2317 square kilometres and is situated between 28° 31' and 30 ° 11' N latitudes and 76 ° 10' and 76 ° 41' E longitudes. The region is drained by the Yamuna, Ghaggar, Markanda and other seasonal streams that originate from the Siwalik range. It is predominantly covered by old and recent alluvial deposits of the Indo-Gangetic plain. The main crops grown in the region include wheat, rice, sugarcane, cotton and sorghum. Soil samples from Guhla block of Kaithal district indicate low levels of OC, N and P in 96, 16 and 16% of total samples, respectively (Sharma et al 2024).

Consequently, it is imperative to conduct regular evaluations of soil fertility to monitor alterations in both macro and micronutrient levels within the soil and to identify the specific nature and extent of any multi-nutrient deficiencies present. The present study has been designed with the following primary objectives to evaluate the soil fertility status of various blocks of Kaithal district and classify the soil according to its fertility characteristics.

MATERIAL AND METHODS

Study area: The Kalayat, Rajound, Pundri and Dhand blocks were selected for the study. The district lies between latitudes 29°31' and 30°12'N, and longitudes 76°10' and 76°42'E. There are 31 villages in Kalayat block, 24 villages in Rajound block, 25 villages in Pundri block and 26 villages in Dhand block. The district experiences a tropical steppe climate,

which is semiarid and humid. Annual rainfall averages 511 mm, evenly spread across the area. The southwest monsoon usually arrives in late June. There are two main soil types: sierozem and desert soils. According to the soil testing and research laboratory in Kaithal, the soils in this district range from sandy to sandy loam in texture.

Soil sampling and analysis: For the current investigation, a total of 212 soil samples were collected at depth of 0-15 cm from 106 villages spanning various blocks. The number of soil samples across the various blocks, namely Kalayat, Rajound, Pundri and Dhand were 62, 48, 50 and 52, respectively. The soil samples were randomly collected from farmer's fields using a post hole auger and the longitude and latitude coordinates of each sampling site were recorded with a handheld GPS device. The collected samples were brought to the laboratory dried in the air, then crushed and sieved through a two mm sieve. Then soil samples underwent analysis for nutrient availability using standard analytical techniques mentioned below in Table 1.

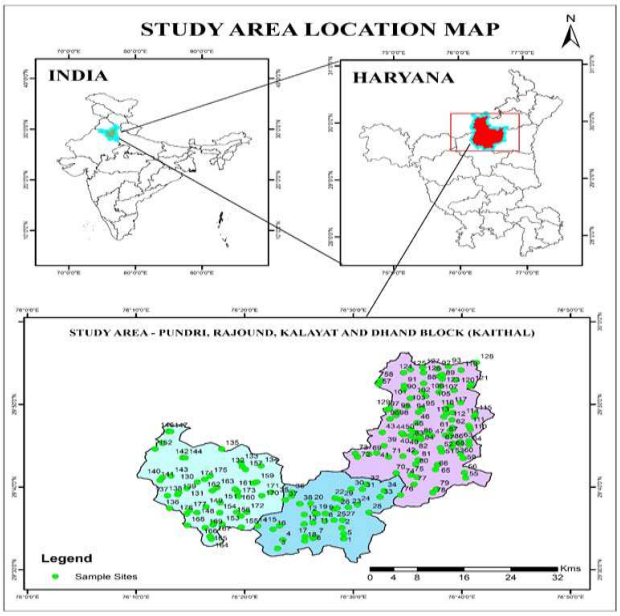
Statistical analysis: Correlation between soil properties and nutrients was worked out using the corplot package of R Software and graphs were prepared using R statistical program. Distribution maps for soil macronutrient status were created using ArcGIS 10.3 software.

RESULTS AND DISCUSSION

Soil pH: The mean value of pH of the soils was 8.09, 8.13, 8.22 and 8.04, in Kalayat, Rajound, Pundri and Dhand block, respectively (Table 3). Out of 212 soil samples, all the samples were alkaline in nature and none of the samples were acidic in these blocks. The main reason for the alkaline nature of these soils could be due to the presence of basic parent material and reaction between the soil colloids and applied fertilizers, this led to the creation of basic cations on the exchangeable sites of the soils (Sharma et al 2024). The alkaline nature might be high base saturation with uneven rainfall distribution, which resulted in accumulation of ions. Gyawali et al (2016) reported similar observations in the Kaithal district of Haryana.

Electrical Conductivity (EC): The mean EC of the soils was 0.45, 0.39, 0.38 and 0.45 dS m^{-1}, in Kalayat, Rajound, Pundri and Dhand block, respectively (Table 3). Out of total 212 soil samples, none of the samples were saline in these blocks. It indicated that soils in all four blocks were non-saline. Dabi (2011) mentioned that well-drained soil conditions resulting from intensive land use facilitate the removal of excess salts through percolating and drainage water. Sharma et al (2024) reported similar observations of leaching of base in Guhla block of Kaithal district.

Soil Organic Matter (OC): The mean OC of the soils was 0.46, 0.47, 0.44 and 0.49%, in Kalayat, Rajound, Pundri and Dhand block, respectively (Table 2). In general out of 212 soil samples, 42 % samples fell under low status, 53 % samples



Map 1. Location map of various blocks of Kaithal district

Table 1. Field parameters with their corresponding methods

Parameter	Methods/Instrument	Reference
pH	Potentiometric method	Jackson (1973)
Texture	International Pipette Method	Piper (1966)
EC(dS m^{-1})	Conductivity Meter	Jackson (1973)
Bulk density (Mg m^{-3})	Core Sampler	Bodman (1942)
Organic carbon (%)	Wet digestion method	Walkley and Black (1934)
Available N (kg ha^{-1})	Kjeldahl distillation	Subbiah and Asija (1956)
Available P (kg ha^{-1})	$NaHCO_3$ extraction and colorimetry	Olsen et al (1954)
Available K (kg ha^{-1})	NH_4OAc and Flame photometry	Jackson (1973)
Available S (kg ha^{-1})	-	Chensin and Yien (1950)
Nutrient Index	-	Parker et al (1951)

were medium and 5 % of the soil samples were high in OC category in these blocks. Majority of the samples in these blocks were with medium SOC and this could be due to the continuous rice-wheat system, which might have contributed more residues in soil (Sharma et al 2024). However, low SOC might be ascribed due to high rate of organic matter decomposition under hyperthermic temperature regime which results to extremely high oxidizing conditions reported by (Singh et al 2014).

Soil texture: The soil texture in the Kalayat block ranged from sandy loam to loam, in Rajound block from sandy loam to loam, in Dhand block from sandy clay loam to clay loam, in Pundri block from sandy clay loam to clay loam, and in Guhla block from sandy loam to loam (Table 3). These findings align with those of Gora (2013) and Gyawali et al (2016) in the Kaithal district of Haryana.

Bulk Density (BD): The average bulk density content of soils of Kalayat, Rajound, Dhand and Pundri block 1.50, 1.51, 1.37 and 1. (Table 3). Similar results were found by Singh et al (2014) and Gyawali et al (2016) in Kaithal district of Haryana.

Table 2. Block wise soil fertility status of Kaithal District

Parameters	Range	Mean	Number of samples in the fertility category			NI	Remarks
			Low	Medium	High		
Kalayat (62)							
Organic (g kg^{-1})	0.27-0.92	0.46	24	37	1	1.62	Low
Available N (kg ha^{-1})	90-263	157	61	1	0	1.01	Low
Available P (kg ha^{-1})	6-32	14.7	14	36	12	1.96	Medium
Available K (kg ha^{-1})	58-540	287	6	29	27	2.32	Medium
Available S (mg kg^{-1})	19-430	116	1	1	60	2.95	High
Rajound (48)							
Organic (g kg^{-1})	0.25-0.92	0.47	23	21	4	1.60	Low
Available N (kg ha^{-1})	117-248	164	48	0	0	1.00	Low
Available P (kg ha^{-1})	6-29	13.5	11	32	5	1.87	Medium
Available K (kg ha^{-1})	106-720	270	5	30	13	2.16	Medium
Available S (mg kg^{-1})	48-282	124	0	0	48	3.00	High
Dhand(50)							
Organic (g kg^{-1})	0.24-0.91	0.44	26	23	1	1.46	Low
Available N (kg ha^{-1})	118-249	170	50	0	0	1.00	Low
Available P (kg ha^{-1})	5-30	12.6	15	29	6	1.82	Medium
Available K (kg ha^{-1})	80-454	248	4	33	13	2.18	Medium
Available S (mg kg^{-1})	39-355	121	0	1	49	2.98	High
Pundri (52)							
Organic (g kg^{-1})	0.17-0.95	0.49	16	32	4	1.76	Medium
Available N (kg ha^{-1})	90-268	164	50	2	0	1.03	Low
Available P (kg ha^{-1})	6-32	14.5	10	34	8	1.96	Medium
Available K (kg ha^{-1})	105-606	288	7	36	9	2.03	Medium
Available S (mg kg^{-1})	39-235	113	0	1	51	2.98	High

Table 3. Block wise physico-chemical properties of Kaithal District

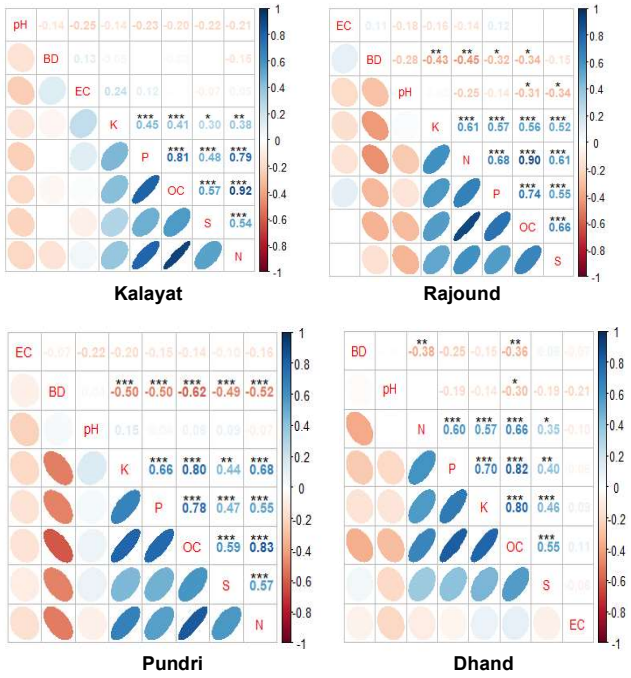
Block	pH		EC (dS m^{-1})		Bulk density (Mg m^{-3})		Texture
	Range	Mean	Range	Mean	Range	Mean	
Kalayat	6.9-9.1	8.09	0.12-1.82	0.45	1.46-1.59	1.50	SL to L
Rajound	6.9-9.0	8.13	0.11-1.39	0.39	1.46-1.59	1.51	SL to L
Dhand	7.1-9.1	8.04	0.13-1.69	0.45	1.32-1.43	1.37	SCL to CL
Pundri	7.4-9.1	8.22	0.11-0.77	0.38	1.35-1.45	1.39	SCL to CL

Available Nitrogen (N): The mean f N of the soils was 157, 164, 170 and 164 kg ha^{-1}, in Kalayat, Rajound, Pundri and Dhand block, respectively (Table 2). In general out of 212 soil samples, 98 % samples fell under low status, 2 % samples were medium and 0 % of the soil samples were high in N category in these blocks. Majority of the samples in Kalayat, Rajound, Pundri and Dhand block was with low N fertility with nutrient index 1.01, 1.00, NI 1.03 and 1.00, respectively (Table 2). The N deficiency in the study could be due to losses of nitrogen by volatilization, runoff, microbial fixation and denitrification. Higher decomposition rate of organic materials due to harsher temperature in the region may also contribute to the less N in the soil (Kumar 2019). Similar result was observed by in the Kaithal district of Haryana, where all the soil samples were deficient in N (Gyawali et al 2016).

Available Phosphorus (P): The mean P of the soils was 14.7, 13.5, 12.6 and 14.5 kg ha^{-1}, in Kalayat, Rajound, Pundri and Dhand block, respectively (Table 2). In general out of 212 soil samples, 23 % samples fell under low status, 61 % samples were medium and 16 % of the soil samples were high in P category in these blocks. Majority of the samples in Kalayat, Rajound, Pundri and Dhand block were found with medium P fertility (NI 1.96, 1.87, 1.96 and 1.82, respectively level) (Table 2). This could be due to the external application of phosphatic fertilizers in the field (Habtamu et al 2014 and Kumar et al. 2012). The findings are consistent with studies carried out in the Kaithal district of Haryana by Singh et al (2011) and Sharma et al (2024).

Available Potassium (K): The value of K of the soils was 287, 270, 248 and 228 kg ha^{-1}, in Kalayat, Rajound, Pundri and Dhand block, respectively (Table 2). In general out of 212 soil samples, 23 % samples fell under low status, 61 % samples were medium and 16 % of the soil samples were high in K category in these blocks. Most of the samples in Kalayat, Rajound, Pundri and Dhand block were with medium K fertility level (NI 2.32, 2.16, 2.03 and 2.18, respectively) (Table 2). It could be probably due to potassium-rich parent material like feldspar and illite may be present in the soil (Sharma et al 2024).

Available Sulphur (S): The mean S of the soils was 116, 124, 121 and 113 kg ha^{-1}, in Kalayat, Rajound, Pundri and Dhand block, respectively (Table 2). In general out of 212 soil samples, 0 % samples fell under low status, 2 % samples were medium and 98% of the soil samples were high in S category in these blocks. Majority of the samples in Kalayat, Rajound, Pundri and Dhand block were with high S fertility level (NI 2.95, 3.00, 2.98 and 2.98, respectively) l (Table 2).The high S status of soil may be due to the continuous application of sulphur containing fertilizer (zinc sulphate) in the cropping system of rice and wheat.

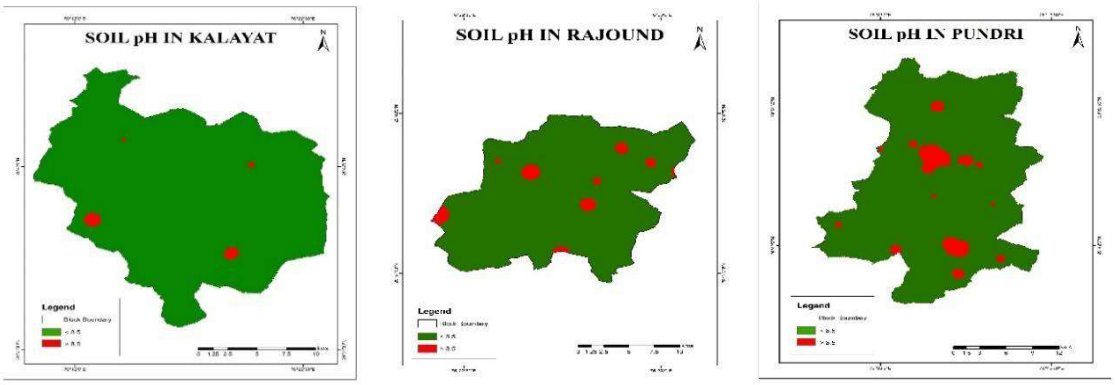


*Significant at the 0.05 level, ** Significant at the 0.01 level and *** Significant at the 0.001 level, NS = Non-Significant

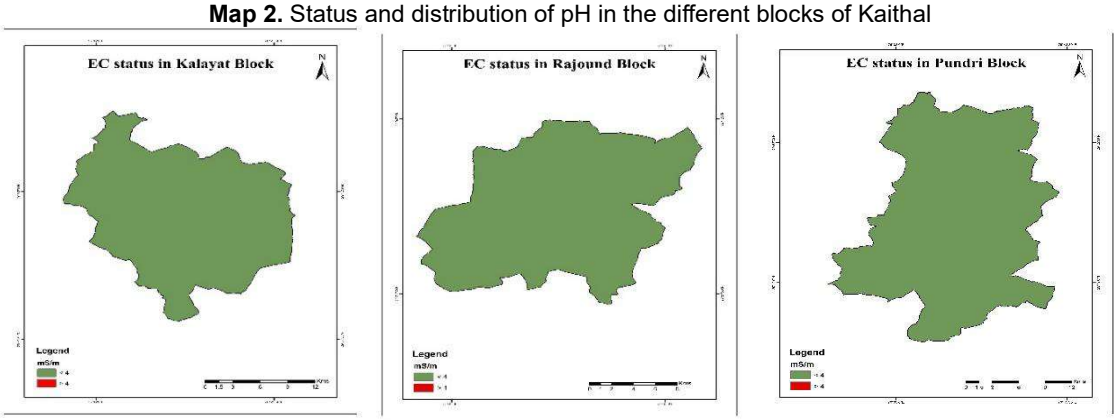
Fig. 1. Correlation of soil properties and nutrients of different blocks of Kaithal

Correlation between Soil Properties and Nutrients

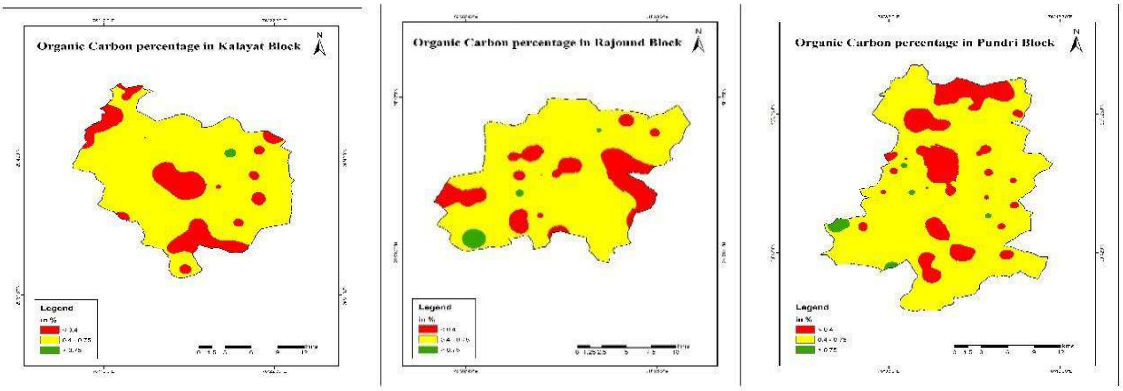
In the correlation matrix of the Kalayat, Dhand, Pundri and Kalayat block, OC exhibited a strong and statistically significant positive correlation with N P K and S content. The distinct correlation exists between OC and N content, as organic matter releases mineralizable N in accordance with its soil concentration. Therefore, the OC status of the soil can predict the availability of N, indicating a positive correlation. Meysner et al (2006) found that about 93 to 97% of the total nitrogen in soil is closely linked to organic matter (OM). Hailu et al (2015) confirmed that the trends observed in total nitrogen closely paralleled those of soil organic matter, underscoring a significant relationship between organic matter and total nitrogen. This was demonstrated by the strong and statistically significant positive correlation with organic matter. It has been reported that S in soils is mostly associated with organic matter (Nor 1981). Elevated levels of available phosphorus are linked to higher organic matter content. Organic matter enhances phosphorus levels by replacing the H_2PO^{4-} ions on adsorption sites through anion replacement, consequently increasing the amount of organic phosphorus that is mineralized into inorganic phosphorus (Havlin et al 2005; Bhat et al 2017). The correlation analysis indicates positive relationship between OC and K (Kumar et al 2023). This association might be explained through the presence of minerals bearing potassium in the silt and clay



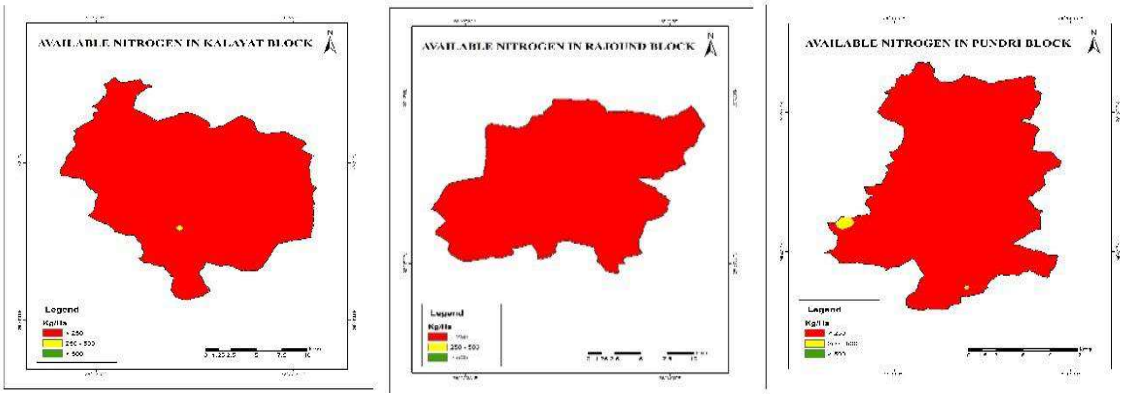
Map 2. Status and distribution of pH in the different blocks of Kaithal



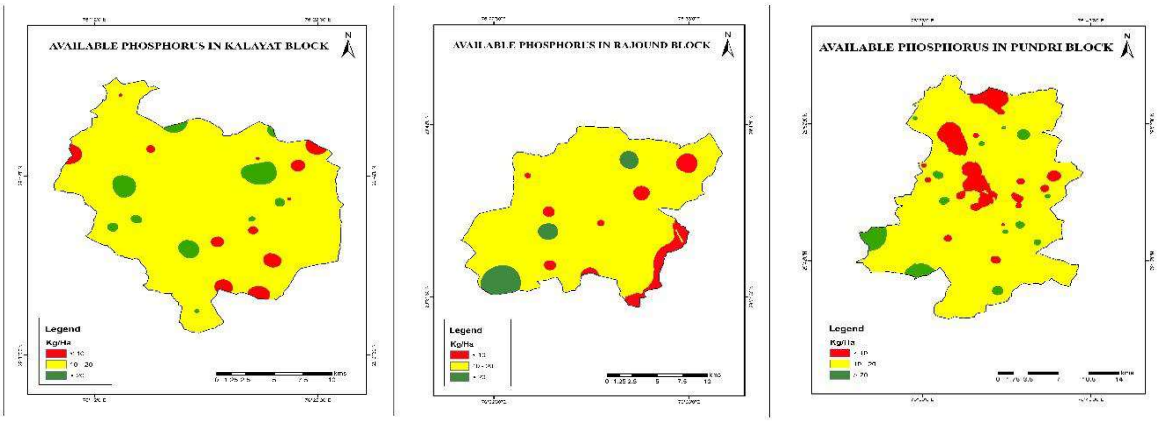
Map 3. Status and distribution of EC in the different blocks of Kaithal



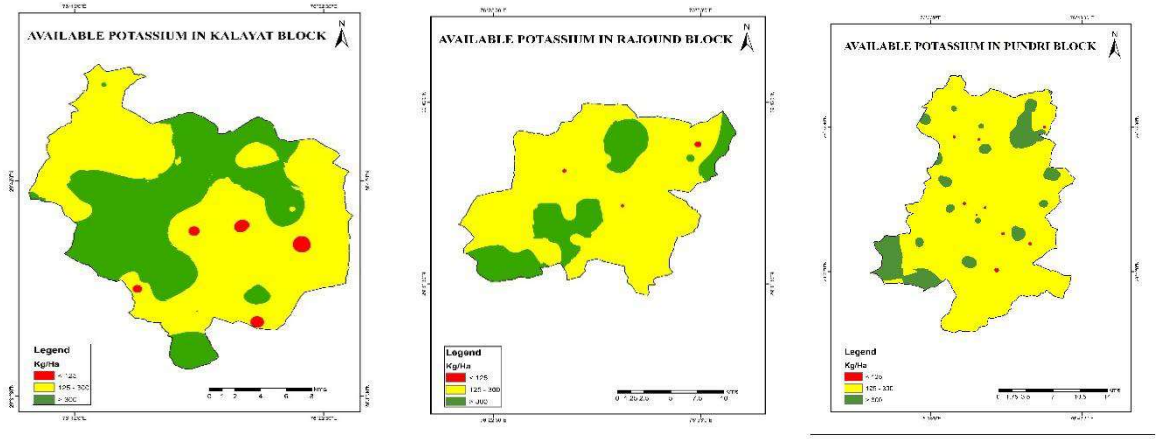
Map 4. Status and distribution of OC in the different blocks of Kaithal



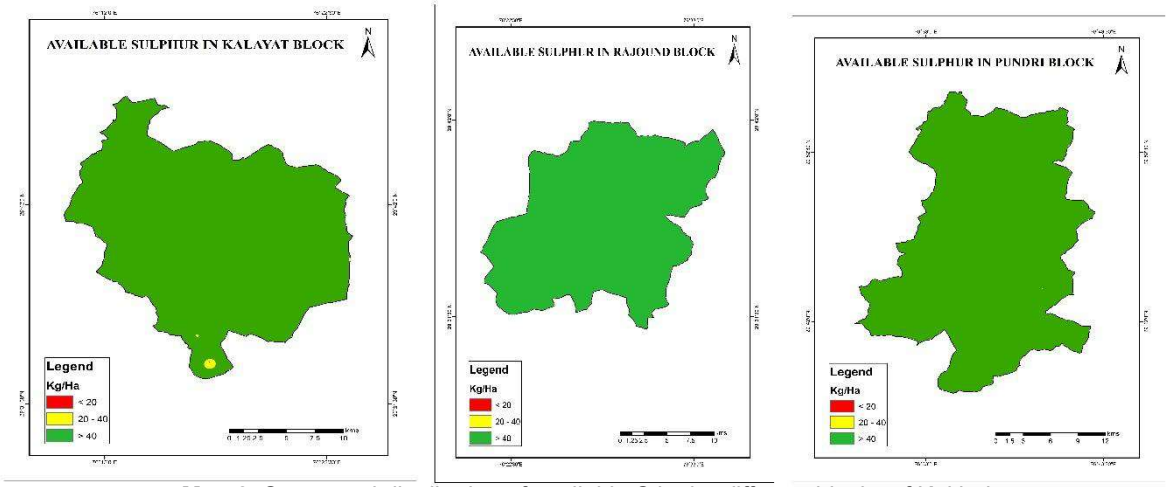
Map 5. Status and distribution of available N in the different blocks of Kaithal



Map 6. Status and distribution of available P in the different blocks of Kaithal



Map 7. Status and distribution of available K in the different blocks of Kaithal



Map 8. Status and distribution of available S in the different blocks of Kaithal

fractions, which include feldspars, illite and mica (Deka et al 1995, Reza et al 2014). Sharma et al (2024) witnessed equivalent findings within the Kaithal region of Haryana.

CONCLUSION

The physical and chemical characteristics of soil were assessed in the Kalayat, Rajound, Pundri and Dhand blocks. Parameters including pH, EC, organic carbon (OC), available nitrogen, available phosphorus, available potassium and available sulphur were examined for the study. In general, the soils in all four blocks exhibited non saline nature with neutral to alkaline pH and low to medium organic carbon content.

They were also non-calcareous. The soil texture varied across the blocks: Kalayat block ranged from sandy loam to loam, Rajound block from sandy loam to loam, Dhand block from sandy clay loam to clay loam and Pundri block from sandy clay loam to clay loam. Soils of all blocks were categorized as low in available N content, medium to high in P and K content and high in S content.

AUTHOR'S CONTRIBUTION

Mohit Sharma: Data curation, Formal analysis, Investigation, Methodology, Software, original draft, Review and editing, R S Garhwal: Investigation, Methodology, original draft, Review and editing, K.K. Bhardwaj: Conceptualization, Review and editing, Anil Kumar: Conceptualization, original draft, Software, Review and editing, Charan Singh: Software, Review and editing, Sunil Kumar: Review and editing, Amit Kumar: Review and editing and Saloni Yadav: Review and editing

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