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Soil fertility mapping of Karchhana block Prayagraj

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Abstract
The study was conducted to determine the soil fertility status of Karchhana Block in Prayagraj District (U.P.). The current study, "Soil fertility mapping of Karchhana block, Prayagraj," was conducted in 2022-2023 and involved the collection of twenty-seven soil samples from the nine designated locations from various places covering the whole block and sample points were tagged through Map-INR software. The laboratory tests for analysis of soil properties were carried out at the CSSRI, Karnal and at the department of soil science at the Naini Agricultural Institute. The results of primary and secondary nutrients in the soil samples were then mapped using Arc-GIS software (10.4.1) by assigning three fertility classes, low, medium, and high combined with GPS co-ordinates and the rest area was interpolated by Arc-GIS. The soil fertility maps clearly revealed that the study area is moderate in fertility status with medium ranges of macronutrients in the sample. The observed area was sufficient in N, P, OC, Mn, and Mg but low in S. Through maps, the farmer and agriculture professionals can take advantage of the technology for the betterment of the sector and the nutrient status of a broad area can be known digitally. This idea was undertaken from the recent projects of NBSSLUP.

Keywords: Spatial variation, fertility mapping, GIS, Arc-GIS, *etc.*

Introduction
Soil fertility is a crucial factor influencing crop yield and plays a significant role in promoting sustainable agricultural practices. Assessing soil fertility and its variations across different regions is essential for precision agriculture and effective decision-making Gajbhiye (2018) [8]. Technological advancements such as the Global Positioning System (GPS) and Geographic Information System (GIS) have enhanced soil fertility mapping, offering valuable data to support policy-making and agricultural strategies for balanced nutrient management. The use of GPS and GIS enables the systematic collection of georeferenced soil samples, facilitating the generation of spatial data related to nutrient distribution. GIS, in particular, serves as a powerful tool for integrating various spatial data types, including agro-climatic zones, land use patterns, and soil management practices. It provides an extensive set of functions for data collection, storage, retrieval, transformation, and visualization of real-world spatial information (Sharma 2004) [9]. Moreover, GIS aids in managing and analyzing large datasets containing statistical, spatial, and temporal information, which can be used to create maps, reports, and textual analyses for informed land use planning. In recent years, the Food and Agriculture Organization (FAO) has worked on developing GIS applications in conjunction with agro-ecological zoning. This system enables researchers, planners, and policymakers to efficiently integrate and analyze georeferenced data from multiple sources, such as soil composition, vegetation, geology, and land cover, to enhance the understanding and management of natural resources (Fernandez *et al*. 1993) [7].

Materials and Methods
Site description
The study to be undertaken in Karchhana block (25.2758° N, 81.9494° E) is situated in the south-eastern part of the Prayagraj district of Uttar Pradesh state. The karchhana block consists of 303 villages *viz*., Basadila, Basahi, Bastar, Beerpur. Bhunda etc. The mean minimum and maximum relative humidity varied between 10 to 56 percent and 41 to 87%. Karchhana district receives the advantage of the Ganga River as groundwater is available.

The majority of the people are dependent on agriculture. Its texture and depth vary from place to place. The block is a part of the basin of the Ganga River. The total irrigated area in the district is 3, 92,132 hectares out of 5,57,012 hectares of the total area.

Table 1: Farmers detail of Karchhana block Prayagraj

Village name of Karchhana block	Farmer's name	Land type	Latitude	Longitude
V1-Dharawara	Shri Ganesh	Cultivated land (crop rotation)	25.20972	81.78583
V2-Jamoli	Shiva Ram	Cultivated land (crop rotation)	25.243492	81.84972
V3-Karchana	Ramkishor	Cultivated land (crop rotation)	25.18222	81.88278
V4-Mirakhpur	Prabhat	Cultivated land (crop rotation)	25.18778	81.96861
V5-Panwar	Omprakash	Cultivated Paddy	25.23639	81.74278
V6-Ramgadva	Ramdev	Cultivated land (crop rotation)	25.26083	81.56167
V7-Thari	Jagan	Cultivated land (crop rotation)	25.095	81.63028
V8-Pawar	Asharam	Cultivated Paddy	25.21389	81.63778
V9-Mandawa	Nathuram	Cultivated land (crop rotation)	25.32444	81.5891

Collection of soil samples and laboratory analysis

Nine soil samples, representing distinct physiographic units, were chosen based on field observations and variations in morphological features and soil site characteristics.

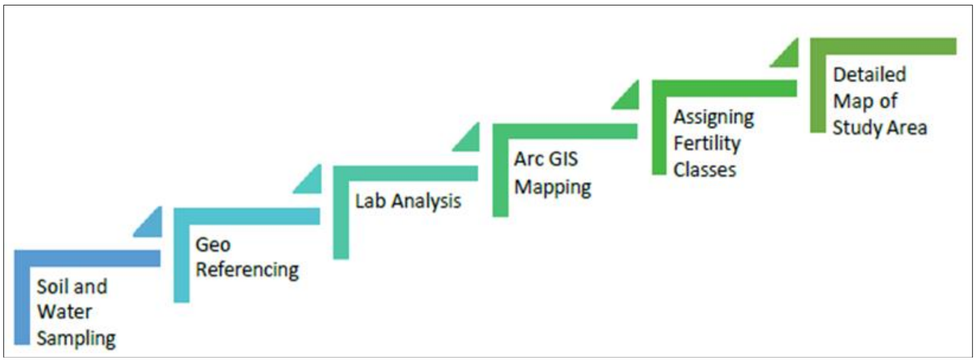
Table 2: The methods of analysis for different soil parameters

S. No.	Particulars	Scientist Name	Methods	Unit
		Physical Properties		
1.	Bulk Density	Black (1965)	Pycnometer	Mg m^{-3}
2.	Particle Density	Black (1965)	Pycnometer	Mg m^{-3}
3.	Soil Colour	Albert Henry Munsell (1971)	Munsell Colour Charts	—
4.	Textural Class (Sand, Silt, Clay)	Bouyoucos (1927)	Bouyoucos Hydrometer	Percentage (%)
5.	Pore Space	Black (1965)	—	Percentage (%)
6.	Water Holding Capacity	Muthuval *et al.* (1992)	Graduated Measuring Cylinder	Percentage (%)
		Chemical Properties		
7.	Soil pH (1:2.5)	Jackson (1958)	Digital pH Meter	—
8.	Electrical Conductivity (1:2.5)	Wilcox (1950)	Digital Conductivity Meter	dS m^{-1}
9.	Organic Carbon	Walkley and Black (1947)	Wet Oxidation Method	Percentage (%)
10.	Available Nitrogen	Subbiah and Asija (1956)	Soil Alkaline Permanganate Method	kg ha^{-1}
11.	Available Phosphorus	Olsen *et al.* (1954)	Photometric Colorimeter Method	kg ha^{-1}
12.	Available Potassium	Schollenberger and Simon	Flame Photometric Method	kg ha^{-1}
13.	Exchangeable Ca^{2+} and Mg^{2+}	Jackson (1973)	Neutral Normal NH_4OAc	Meq/100 g
14.	Available Sulfur	Chesnin and Yien (1951)	Turbidimetric Method	mg kg^{-1}

Soil fertility mapping

The spatial variability of each attribute was analyzed using spatial descriptive statistics, and the data was subsequently integrated into an ArcGIS platform. ArcGIS for Desktop software facilitates the identification of patterns, relationships, and trends that may not be immediately evident in traditional databases, spreadsheets, or statistical tools. Beyond simply mapping data points, ArcGIS Desktop provides capabilities for data management, integration, advanced analysis, process modeling, and automation, with results presented in professional-quality maps (Awasthi *et al.*, 2005) [2].

To estimate soil properties at unsampled locations within the study area, an interpolation technique such as inverse distance weighting (IDW) or kriging was applied, generating continuous surface maps for each parameter.



Flow chart of soil fertility mapping GIS and GPS software used

GIS and GPS software used

Software	Description
Google Earth Pro 7.1.1	Facilitates the import of GPS coordinates and generates ".kml" files for seamless integration with GIS platforms.
ArcGIS	A comprehensive and flexible GIS application designed for spatial data analysis and mapping.
ArcInfo	A robust GIS tool that encompasses the features of ArcView and ArcEditor while offering advanced geoprocessing and data conversion capabilities. Widely used by professionals for data modeling, analysis, and map visualization.
ArcView	A full-featured GIS software designed for visualizing, analyzing, and managing spatial data.
Other Windows-based Software	Includes applications like DIVA GIS and MS Office, utilized for database development and analysis.

Results and Discussion

Physical Properties

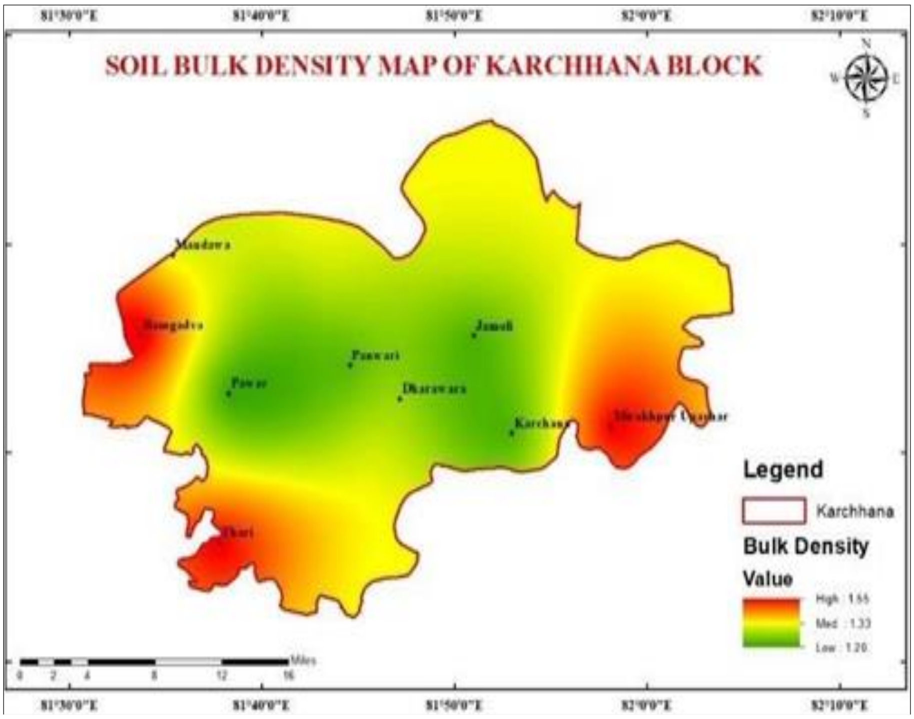
The textural classification of soil in different villages in Ganga riverbank of Karchhana block. The texture classification of soil samples showed sandy loam in all villages.

Table 3: Soil Physical Properties of Soil in Karchhana Block Prayagraj

Village of Karchhana Block	Bulk density (Mgm-3)	Particle density (Mg m-3)	Porosity (%)	Water Holding Capacity (%)
V1-Dharawara	1.30	2.56	45	42.34
V2-Jamoli	1.23	2.19	48	47.00
V3-Karchhana	1.23	2.45	43	42.00
V4-Mirakhpur	1.54	2.86	39	36.00
V5-Panwari	1.24	2.50	44	42.00
V6-Ramgadva	1.56	2.98	42	41.00
V7-Thari	1.53	2.79	43	40.00
V8-Pawar	1.21	2.17	47	44.00
V9-Mandawa	1.36	2.87	41	39.00
CD	0.018	0.412	2.414	2.054
S. Em. (±)	0.538	0.122	0.814	0.691
Result	S	S	S	S

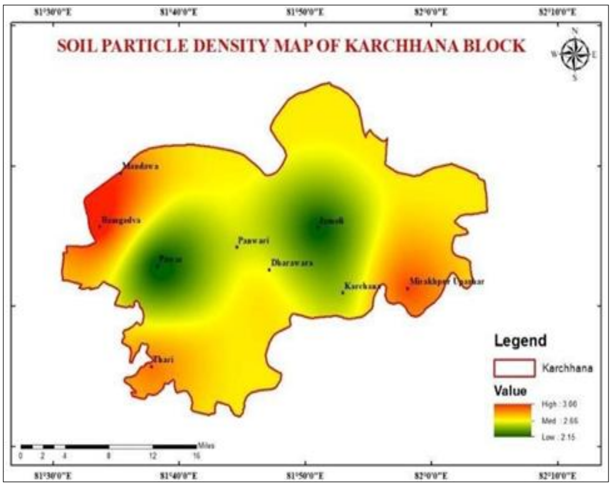
Soil Bulk Density (Mg m-3)

The bulk density of the soil varied between 1.2 and 1.54 Mg m^{-3}. Among the sampled locations, V4-Mirakhpur exhibited the highest bulk density at 1.54 Mg m^{-3}, followed closely by V7-Thari at 1.53 Mg m^{-3}. In contrast, V8-Pawar recorded the lowest bulk density at 1.21 Mg m^{-3}. These findings align with the significant results reported by Ahad *et al*. (2015) [1].



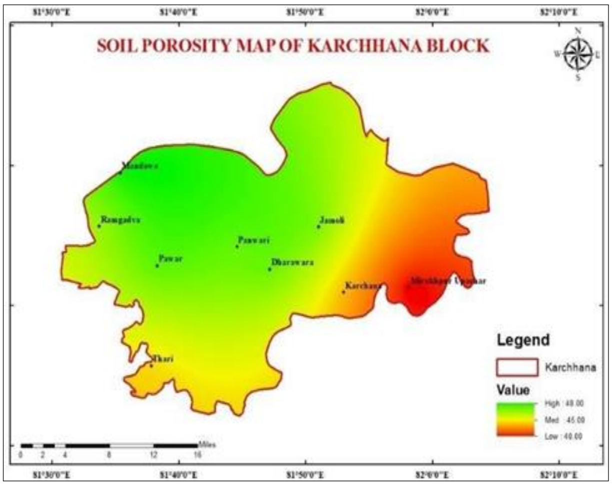
Soil Particle Density (Mg m-3)

The soil particle density at a depth of 0-15 cm ranged from 2.17 to 2.98 Mg m^{-3}. The highest particle density was recorded at V6-Ramgadva (2.98 Mg m^{-3}), followed by V4-Mirakhpur (2.86 Mg m^{-3}), while the lowest was observed at V8-Pawar (2.17 Mg m^{-3}). These findings are consistent with the results reported by Chaudhari *et al*. (2013) [4].



Soil Porosity (%)

Soil porosity in a soil samples ranges from 39.0-48%. V2-Jamoli reported as highest porosity of 48% followed by V8-Pawar of 47%, while V4-Mirakhpur reported as lowest porosity i.e. 39%. Significant results were observed by (Ahad *et al*., 2015) [1].



Water Holding Capacity (%)

The soil's water holding capacity ranged from 36% to 47%. The highest water holding capacity was recorded at V2-Jamoli (47%), followed by V8-Pawar (44%), attributed to the high organic carbon content. In contrast, the lowest water holding capacity was observed at V4-Mirakhpur (36%), likely due to its lower organic carbon content. These findings align with the results reported by Das *et al*. (2018) [5].

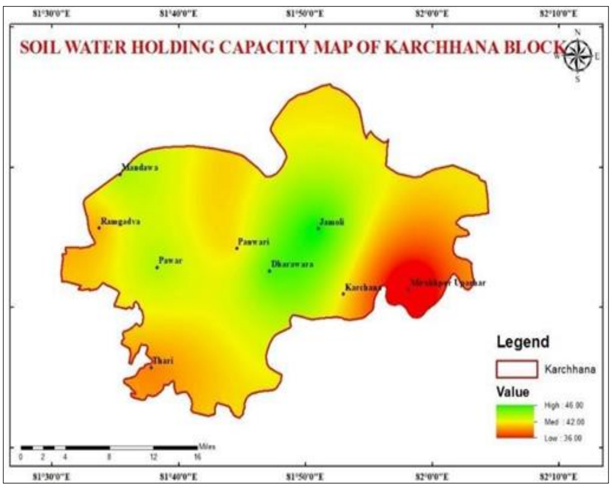
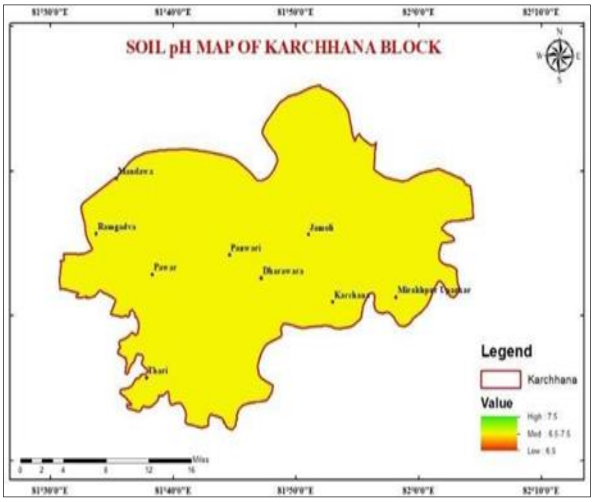


Table 4: Chemical properties data of soil in karchhana block

Village No	pH	EC (dSm^{-1})	OC (%)
V1-Dharawara	7.4 8	0.1 3	0.4 1
V2-Jamoli	7.6 2	0.3 2	0.4 1
V3-Karchana	7.1 3	0.5 1	0.3 2
V4-Mirakhpur	7.4 2	0.8	0. 45
V5-Panwari	7.9 8	0.9	0.3 5
V6-Ramgadva	7.8 8	1.3	0.2 5
V7-Thari	7.9 5	0.5	0.2 2
V8-Pawar	7.8 1	0.7	0.4 9
V9-Mandawa	7.5 7	0.9 9	0.5 9
S. Em. (±)	0.1 0 0	0.1 1 6	0.0 1 1
CD	0.2 9 7	0.0 3 4	0.0 3 3
Result	S	S	S

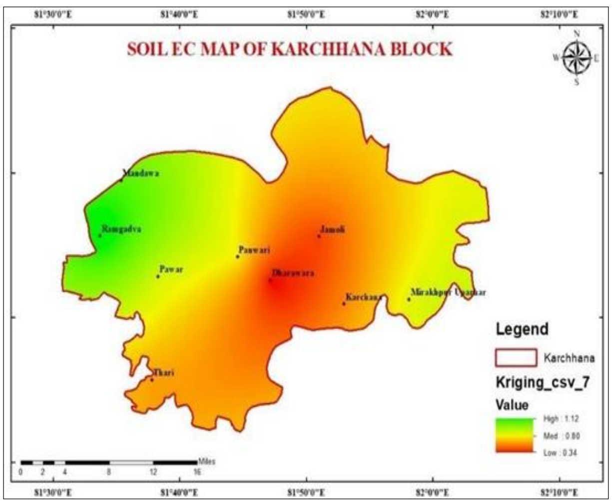
Soil pH

The pH of the soil samples ranged from 7.13 to 7.98. The highest pH was recorded at V5-Panwar (7.98), followed by V7-Thari (7.95), while the lowest was observed at V3-Karchhana (7.13). These results indicate that the soil pH falls within the neutral range, which is significant for nutrient availability. Similar findings were reported by Basavaraja *et al*. (2017) [3].



Soil EC (dS m^{-1})

The electrical conductivity (EC) of the soil samples ranged from 0.13 to 0.99 dS m^{-1}, with significant variations. The highest EC was recorded at V9-Mandwa (0.99 dS m^{-1}), followed by V5-Panwari (0.90 dS m^{-1}), while the lowest was observed at V1-Dharawara (0.13 dS m^{-1}). These findings are consistent with the results reported by Basavaraja *et al*. (2017) [3].



Soil Organic Carbon (%)

The organic carbon content in soil samples ranged from 0.25% to 0.49%, with significant variations. The highest organic carbon was recorded at V8-Mandawa (0.49%), followed by V4-Mirakhpur (0.45%), while the lowest was observed at V6-Thari (0.25%). The lower organic carbon levels can be attributed to minimal vegetation being used as residue and the rapid degradation caused by the tropical climate across the block. These findings align with the results reported by Deshmukh *et al*. (2012) [6].

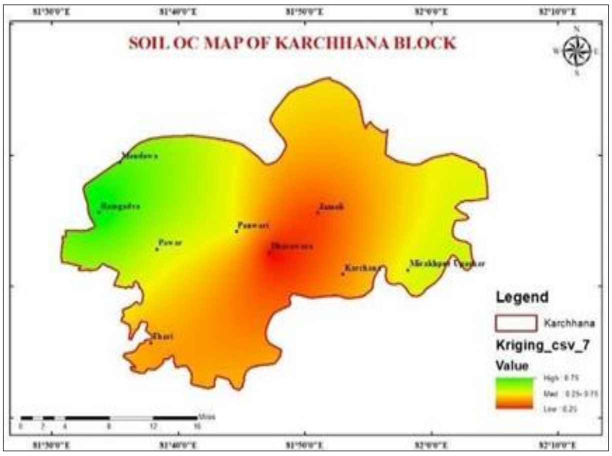
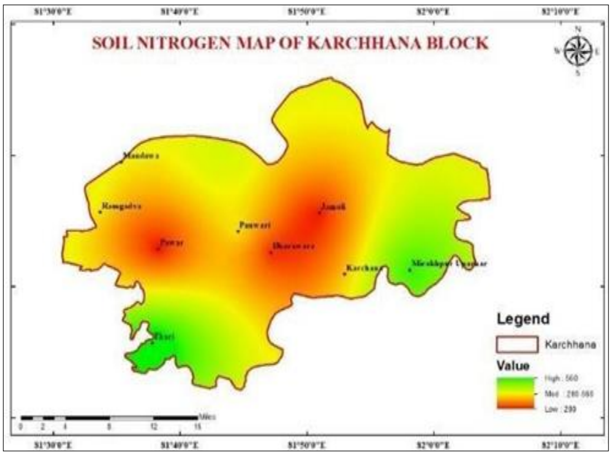


Table 5: Macro nutrients data of soil in karchhana block

Sample No	N (Kg ha^{-1})	P (Kg ha^{-1})	K (Kg ha^{-1})
V1 Dharawara	123	8	110
V2 Jamoli	110	12	145
V3 Karchana	287	9	134
V4 Mirakhpur	567	15	167
V5 Panwari	323	9	210
V6 Ramgadva	323	18	123
V7 Thari	670	34	212
V8 Pawar	102	28	94
V9 Mandawa	345	13	74
S. Em. (±)	6.35	0.20	2.26
CD	18.8	0.60	6.74
Result	S	S	S

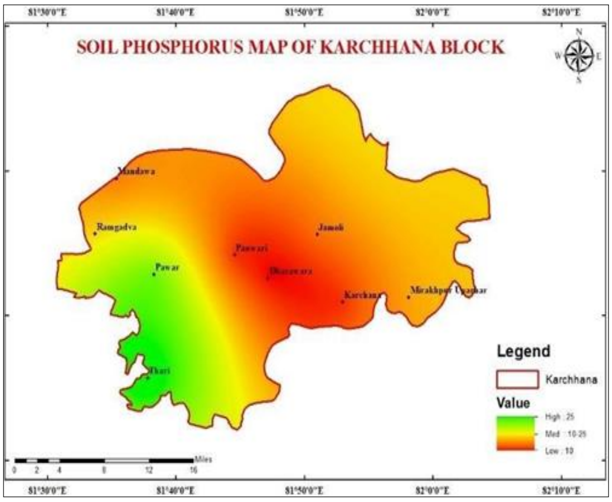
Soil Nitrogen (kg ha^{-1})

The nitrogen content in soil samples ranged from 110 to 670 kg ha^{-1}, showing significant variation. The highest nitrogen content was recorded at V7-Thari (670 kg ha^{-1}), followed by V4-Mirakhpur (570 kg ha^{-1}), while the lowest was observed at V2-Jamoli (110 kg ha^{-1}). These findings are consistent with the results reported by Sheeba *et al*. (2019) [11].



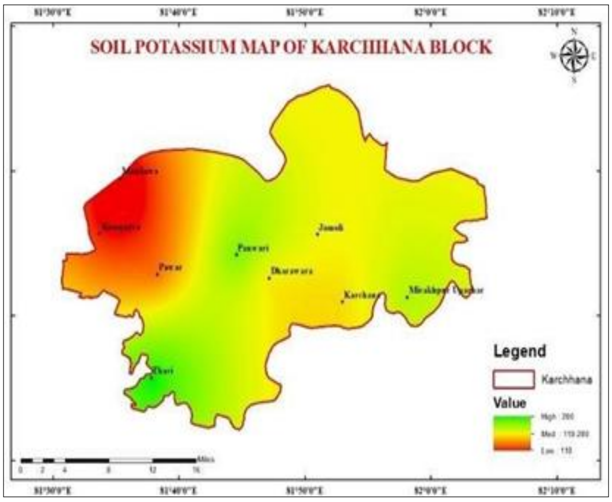
Soil Phosphorus (kg ha^{-1})

The phosphorus content in soil samples varied between 8 and 34 kg ha^{-1}, with significant differences. The highest phosphorus level was recorded at V7-Thari (34 kg ha^{-1}), followed by V8-Panwar (28 kg ha^{-1}), while the lowest was observed at V1-Dharwara (8 kg ha^{-1}). These findings align with the significant results reported by Das *et al*. (2018) [5].



Soil Potassium (kg ha^{-1})

The potassium content in soil samples ranged from 74 to 212 kg ha^{-1}, showing significant variation. The highest potassium level was recorded at V7-Thari (212 kg ha^{-1}), followed by V5-Panwari (210 kg ha^{-1}), while the lowest was observed at V9-Mandawa (74 kg ha^{-1}). The overall potassium status in the region was found to be moderate, likely due to the presence of alluvial soil, which typically contains moderate to high levels of available potassium. These findings are consistent with the results reported by Sharma *et al*. (2014) [10].



Conclusion

The soil test results for the Karchhana block indicate that the soil condition ranges from neutral to alkaline. All soil samples fall within the permissible limits of electrical conductivity (EC), making them suitable for most crops. Around 58.3% of the samples exhibited a medium level of organic carbon, likely due to high temperatures that accelerate decomposition in the sub-humid tropical climate. More than half of the samples showed a medium status for nitrogen and potassium, while potassium and sulfur levels were generally low.

The moderate fertility status of the block can be attributed to excessive use of fertilizers and pesticides, along with improper land management practices. The soil pH was found to be slightly acidic to neutral, and the water samples displayed minimal sodium hazard. However, 70.83% of the water samples were unsuitable for irrigation due to high alkalinity. While total water hardness was low, the moderate presence of soluble salts suggested a poor to moderate irrigation water quality index, with all samples falling into the poor category for irrigation use.

The integration of GPS and GIS technology provides an efficient method for analyzing large-scale, multi-disciplinary data in the Karchhana block. These tools aid in decision-making for soil health assessments and the development of nutrient fertility maps, which can guide farmers in understanding soil-crop interactions. This approach will also help in applying appropriate fertilizer recommendations, ultimately improving soil productivity and sustainable agricultural practices.

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