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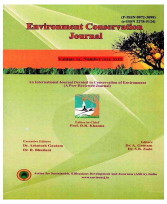

Spatial variability analysis of soil properties of Gwalior District, Madhya Pradesh

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ABSTRACT

The application of fertilizers can be optimized to maintain crop yield while reducing the amount of fertilizer input. One way to achieve this is by using soil fertility maps and fertilizer recommendations to regulate fertilizer application. In this study, statistical techniques were employed to analyze the physical-chemical quality of soils in the Gwalior region of Madhya Pradesh. The study involved collecting 95 soil samples (0-15 cm) from four blocks in the Gwalior area using GPS (Bhitarwar, Morar, Ghatigao, and Dabra), and conducting laboratory analyses. The results of the analysis showed that the pH, EC, and OC of the soil samples ranged from 7.10 to 8.90, 0.21 to 0.83 dS/m, and 0.23 to 0.98%, respectively. The soil samples also had varying levels of N, P, and K, with values ranging from 194 to 336, 6.10 to 45.00, and 69.89 to 751.30 kg/ha, respectively. The study revealed significant differences in the physicochemical properties of soil in the study area

Introduction

If farmers wish to increase crop yield and nutrient efficiency, they must first understand the regional diversity and distribution of soil features. Fertilizer guidelines suggest applying fertilizers based on the characteristics of the soil to sustain productivity while using less fertiliser. Geo statistics is a popular tool for analysing geographical variability, interpolating between point data, and calculating interpolated values with a given error from a limited number of observations (Long *et al.,* 2014; Cambule *et al.,* 2014). For crop selection , designing a cropping system and adoption of crop management practices, knowledge of geographic diversity in soil's physical, chemical, and biological properties, was essential (Liu *et al.,* 2013. Researchers looked at spatial variation in pH, organic matter, total and available NPK, and micronutrients under various soil and management strategies to improve and implement site-specific nutrient Managemnet (Franzen *et al.,* 2002; Li *et al.,* 2011). One of the most crucial elements of a system for producing food sustainably is the soil. Crop production ultimately reflects the quality of the soil, which is determined by its physicochemical characteristics and capacity to supply nutrients. Because of the different elements that go into their production and the complex interactions between these elements, soils are naturally heterogeneous (Maniyunda *et al.,* 2013). It is important to characterise the spatial variability of soil nutrients in relation to site characteristics such as climate, land use, landscape position, and other factors in order to comprehend how ecosystems function and predict how future land use change will affect soil nutrients (Wang *et al.,* 2001; Bhardwaj *et al.,* 2020; Ruhela *et al.,* 2022).

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Material and Methods

Located at latitudes 26.0283 and 78.2020 the Gwalior district of Madhya Pradesh covers a total area of 4560 km^2 and is divided into four blocks: Bhitarwar, Ghatigao, Morar, and Dabra. The district is situated at an elevation of 211.5 m above mean sea level, with the region's elevation ranging from 200 to 211.5 metres. To better understand the physical-chemical properties of the soil in the Gwalior region, a study was conducted using GPS to collect 95 soil samples (0-15 cm) from various locations across the four blocks. Figure 1 and table 1 depict the location of the study area and the sampling sites.

Description of Experimental Site:

Laboratory analysis was done at School of Agriculture, ITM, University, Gwalior (M.P.)

Soil sample collection and preparation:

GPS based Ninety-five random surface soil samples were collected at depths ranging from 0 to 15 cm from various blocks in the Gwalior district, Madhya Pradesh. The samples were then combined to form a composite sample weighing approximately 1 kg. Following air drying, the larger aggregates were

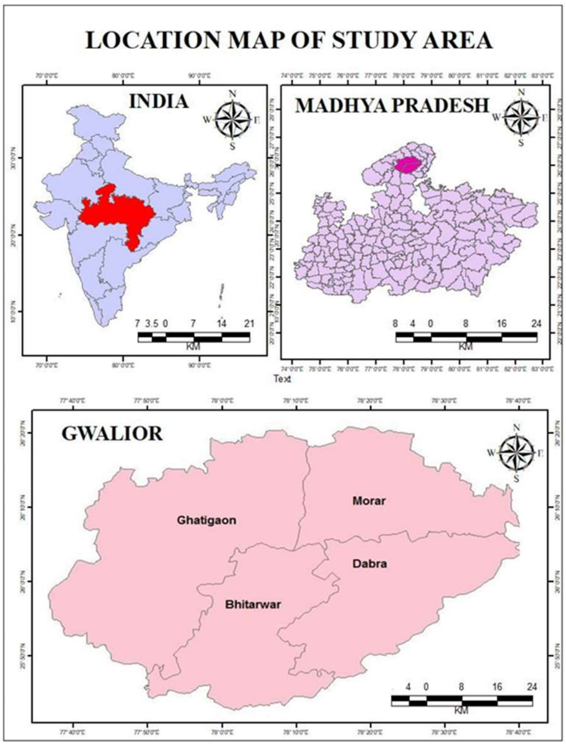


Figure :1 Location map of collecting soil samples

Table 1: Location of soil sample collection site

Block	Latitude	Longitude	Block	Latitude	Longitude	Block	Latitude	Longitude	Block	Latitude	Longitude
M1	26^{0}15’20.63’’	78^{0}15’50.97’’	D1	25^{0}57’11.58’’	78^{0}18’58.72’’	B1	26^{0}00’28.03’’	78^{0}10’25.44’’	G1	26^{0}04’50.25’’	78^{0}08’51.99’’
M2	26^{0}15’18.36’’	78^{0}1545.34’’	D2	25^{0}57’07.17’’	78^{0}19’14.88’’	B2	26^{0}00’31.38’’	78^{0}10’21.96’’	G2	26^{0}06’03.7’’	78^{0}09’07.7’’
M3	26^{0}15’20.91’’	78^{0}15’45.23’’	D3	25^{0}57’09.76’’	78^{0}19’12.26’’	B3	26^{0}00’36.02’’	78^{0}10’29.95’’	G3	26^{0}06’02.5’’	78^{0}09’04.4’’
M4	26^{0}17’24.7’’	78^{0}11’26.2’’	00444	25^{0}57’10.62’’	78^{0}19’02.46’’	B4	26^{0}00’31.91’’	78^{0}10’34.00’’	G4	26^{0}06’02.2’’	78^{0}09’15.8’’
M5	26^{0}17’20.5’’	78^{0}11’19.0’’	D5	25^{0}57’12.83’’	78^{0}19’18.50’’	B5	26^{0}00’38.02’’	78^{0}10’56.28’’	G5	26^{0}06’27.6’’	78^{0}09’04.9’’
M6	26^{0}14’01.6’’	78^{0}23’24.6’’	D6	25^{0}58’28.68’’	78^{0}20’02.26’’	B6	26^{0}03’35.80’’	78^{0}12’37.55’’	G6	26^{0}07’11.0’’	78^{0}08’39.9’’
M7	26^{0}14’03.2’’	78^{0}23’13.5’’	D7	25^{0}58’25.71’’	78^{0}20’01.44’’	B7	26^{0}03’32.99’’	78^{0}12’39.92’’	G7	26^{0}07’14.9’’	78^{0}08’45.3’’
M8	26^{0}14’00.6’’	78^{0}23’31.3’’	D8	25^{0}58’23.00’’	78^{0}19’57.40’’	B8	26^{0}03’36.74’’	78^{0}12’38.54’’	G8	26^{0}07’22.7’’	78^{0}08’47.8’’
M9	26^{0}14’00.6’’	78^{0}23’31.3’’	D9	25^{0}58’31.84’’	78^{0}20’00.93’’	B9	26^{0}03’31.40’’	78^{0}12’41.56’’	G9	26^{0}07’19.4’’	78^{0}08’50.0’’
M10	26^{0}14’04.9’’	78^{0}23’17.7’’	D10	25^{0}58’27.59’’	78^{0}20’10.05’’	B10	26^{0}03’31.44’’	78^{0}12’34.14’’	G10	26^{0}07’58.5’’	78^{0}08’36.7’’
M11	26^{0}13’58.0’’	78^{0}23’18.9’’	D11	25^{0}54’55.07’’	78^{0}18’38.40	B11	26^{0}00’12.99’’	78^{0}08’28.90’’	G11	26^{0}07’39.5’’	78^{0}01’55.5’’
M12	26^{0}13’57.8’’	78^{0}23’09.7’’	D12	25^{0}54’55.77’’	78^{0}18’36.94’’	B12	26^{0}00’02.19’’	78^{0}08’09.92’’	G12	26^{0}07’38.8’’	78^{0}01’17.2’’
M13	26^{0}13’54.0’’	78^{0}23’12.6’’	D13	25^{0}54’57.70’’	78^{0}18’40.82’’	B13	26^{0}00’02.79’’	78^{0}08’45.82’’	G13	26^{0}07’39.5’’	78^{0}01’49.3’’
M14	26^{0}13’31.4’’	78^{0}23’40.3’’	D14	25^{0}54’59.29’’	78^{0}18’39.85’’	B14	26^{0}00’04.00’’	78^{0}08’32.94’’	G14	26^{0}07’42.9’’	78^{0}01’11.4’’
M15	26^{0}13’20.4’’	78^{0}23’40.3’’	D15	25^{0}54’57.84’’	78^{0}18’37.21’’	B15	26^{0}00’15.08’’	78^{0}08’04.63’’	G15	26^{0}07’37.4’’	78^{0}01’49.8’’

gently crushed with a wooden hammer and passed through a 2 mm sieve. The sieved soils samples were in appropriately labelled sample bags and taken to laboratory for further soil analysis.

Analytical procedure:

The following procedures were used to analyze various physical and chemical parameters of soil. The electrical conductivity (EC) of soil was measured using an EC metre at a soil-to-water ratio of 1:5, and the result was converted to a soil-to-water ratio of 1:1 as recommended by USDA, Jackson 1967. The pH of soil samples was measured using a pH meter while keeping the soil-to-water ratio of 1:2.5 as suggested by Jackson 1962. The organic carbon content of soil samples was determined using Wet Digestion method Walkley and Black,1934. The amount of available nitrogen (N) was calculated using Alkaline potassium permanganate method Subbiah and Asija, 1956 , while the amount of available phosphorus (P) was determined using Sodium bicarbonate as an extractant given by Olsen,1954 and available potassium was determined using Neutral ammonium acetate extractant method by Jackson (1973).

Results and Discussion

A study was conducted to examine the physicochemical properties and nutrient content of soils in the Gwalior district. The results showed that the bulk density of the soils in Gwalior ranged from 1.26 to 1.64 Mg/m^3, with of 1.42 Mg/m^3 as the mean and a 5.74 percent variability (Fig. 2). It is well-established that the increase in bulk density is caused due to conversion of forest land into arable land and it is a reliable indicator of soil degradation severity. Higher bulk density may have resulted from increased compaction in the lower horizons of the soil profiles over time, which may have occurred as a result of varying levels of soil erosion, depending on slope and management techniques. The results showed the less porous nature of soils in the region, which ranged from 1.29 to 1.49, 38.11 to 52.45, 40.38 to 51.70, and 40.38 to 51.70 % in different (Bhitarwar, Ghatigao, Morar, and Dabra), had mean values ranging from 46.89 to 46.11, 46.11 to 46.49% (Fig. 3). Low soil porosity and compaction are indicators of high bulk density, it might hinder root development and impede the flow of air and water through the soil, These results are in line with the findings of Jain and Sigh (2013). According to statistics presented in table 2, the average percentages of sand, silt, and clay in the Gwalior district are 52.4%, 23.6%, and 24%, respectively. These values indicate that the textural class of soil in the Gwalior district is sandy loam. Typically, finer soil fractions (silt and clay) increase with depth, while sand percentages decrease. However, Boke (2004) suggested that farming activities may have led to changes in soil texture, despite being an inherent quality. Chima (2007) suggested that plant modification could also have played a role in altering particle size distribution over time, despite the natural texture of soil. Analysis the data showed that the soils in several blocks of the Gwalior district were alkaline in nature (Fig. 4). The mean soil pH in the Gwalior district varied 7.10 to 8.90, with a range of 7.20 to 8.90 across the different blocks (Bhitarwar, Ghatigao, Morar, and Dabra). The mean values for the blocks were 8.26, 8.15, 8.35, and 7.72, respectively. Variation in soil pH under different blocks of district, as whole might be due to variations in the parent material of soil, management practices & land uses. Similar variations in soil pH in different regions were reported by Yadav *et al.* (2018). Figure 5 shows electrical conductivity of soils across different blocks of the Gwalior district ranged from 0.21 to 0.83 dS/m at 25°C, with an average of 0.54 dS/m, which is within the normal range (<1 dSm^{-1} at 25°C). The low electrical conductivity in soil under study area might be due to deep water table which is certainly possible by commencement of sufficient rainfall, Similar results for different soils were also reported by Dilliwar *et al.* (2014) and Singh *et al.* (2017).

Furthermore, the organic carbon (OC%) content of soils in the Gwalior district's different blocks (Bhitarwar, Ghatigao, Morar, and Dabra) varied from 0.23 to 0.98%, with an average value ranging from 0.27 to 0.65% (Fig. 6). Variation in organic carbon content in soil samples was may be due to addition of organic matter in the soil, variability in use pattern of land, cropping sequence and crop species. Findings of that Mandal *et al.*, (2011) also revealed that, crop species and cropping systems

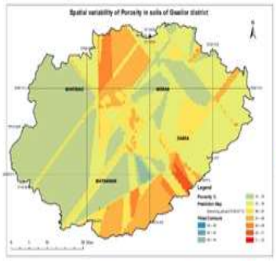


Fig:2

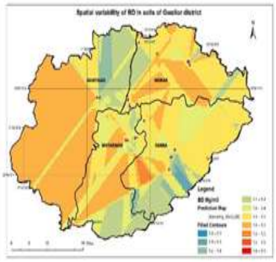


Fig:3

Figure 2-3: Spatial variability maps of physical properties of Gwalior district

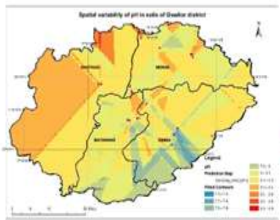
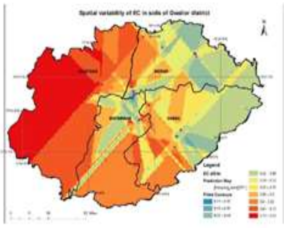


Fig:4



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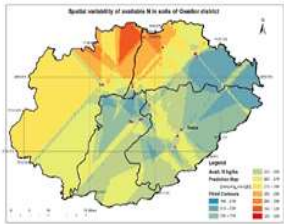

Fig:6

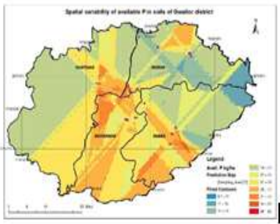

Fig:7

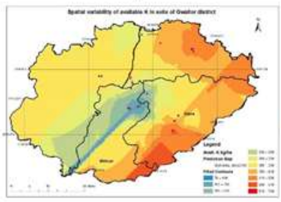

Fig:8

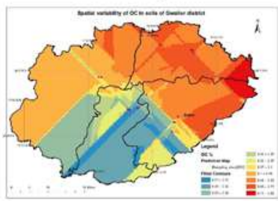

Fig:9

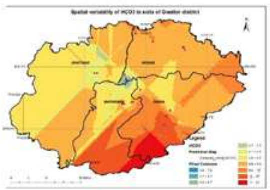

Fig:10

Fig:11

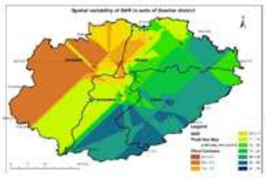

Fig:12

Fig:13

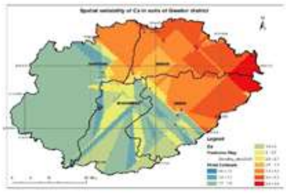

Fig:14

Figure 4-14: Spatial variability maps of Chemical properties of Gwalior district.

may play an important role for variations in soil organic carbon. Findings of Singh *et al.* (2014) and Yadav *et al.*, (2018) also support the findings of present studyWhereas, the bicarbonate content of soils in the Gwalior district ranged from 1.40 to 27.40 Cmol(P^+)/kg (Fig. 7), with an average value of 7.60 Cmol (P^+)/kg. The high coefficient of variance indicated the significant variation in bicarbonate content among the soil samples this might be due to calcareous parent materials, poor drainage and improper leaching process, similar results were reported by Dilliwar *et al.* (2014) Singh *et al.* (2014) and Yadav *et al.*, (2018) .The carbonate content of the soils varied between Gwalior, Bhitarwar, Ghatigao, Morar, and Dabra, with the highest value reported in the Dabra block (11.29 Cmol (P^+)/kg) and the lowest in the Ghatigao Block (4.85 Cmol (P^+)/kg). The carbonate concentration in Gwalior Distict ranged from 0.80 to 4.50 Cmol (P^+)/kg, with an average value of 1.77 Cmol (P^+)/kg, a standard deviation of 0.83, and a variation of 46.68%, as shown in table 2 and fig. 8. Soil carbonate contents ranged from 0.90 to 1.80 Cmol (P^+)/kg in Bhitarwar, 0.40 to 1.60 Cmol (P^+)/kg in Ghatigao, 0.80 to 2.80 C mol (P^+)/kg in Morar, and 0.90 to 4.50 C mol (P^+)/kg in Dabra.

The calcium content of soils in the Gwalior district varied widely, with a range of 1.90 to 27.60 Cmol (P^+)/kg, as shown in Table 3 and Figure 14. The mean value was 8.89 Cmol (P^+)/kg, with a standard deviation of 6.65 and a coefficient of variation of 73.88%. Looking at the data in Table 2, we see that the calcium content in soils across the different blocks of Gwalior (Bhitarwar, Ghatigao, Morar, and Dabra) ranged from 1.90 to 8.10 Cmol (P^+)/kg, 3.60 to 13.70 Cmol (P^+)/kg, 3.20 to 9.50 Cmol (P^+)/kg, and 3.50 to 8.50 Cmol (P^+)/kg, respectively. Among these, Ghatigao village had the highest calcium content (7.32 Cmol (P^+)/kg), while Bhitarwar Block had the lowest (3.91 Cmol (P^+)/kg). pH of the soils increased with Increase in the availability of Ca and Mg. Table No. 2 and Fig. 13 present data on magnesium levels in the soil of the Gwalior District, which ranged from 0.60 to 9.50 Cmol (P^+)/kg, with an average value of 2.76 Cmol (P^+)/kg, a standard deviation of 1.91, and a coefficient of variation of 69.08%. The four blocks in the district (Bhitarwar, Ghatigao, Morar, and Dabra) exhibited magnesium levels that varied from 0.70 to 3.10 Cmol (P^+)/kg, 0.60 to 3.90 Cmol (P^+)/kg, 0.80 to 3.20 Cmol (P^+)/kg, and 1.00 to 2.60 Cmol (P+)/kg, respectively.

Table 2: **Status of Physical properties of soils of different blocks of Gwalior district**

Blocks		Sand %	Silt%	Clay %	Bulk density (Mg/m^3)	Porosity %
Bhitarwar	Min	52.40	20.10	20.30	1.29	43.77
	Max	59.40	24.10	24.00	1.49	51.32
	Mean	56.27	22.02	21.71	1.41	46.89
	SD	2.03	1.38	1.14	0.06	2.15
	CV	3.61	6.29	5.24	4.04	4.58
Ghatigao	Min	51.30	20.50	19.00	1.26	38.11
	Max	60.10	23.90	25.40	1.64	52.45
	Mean	56.27	22.37	21.37	1.43	46.11
	SD	2.48	1.11	1.96	0.09	3.51
	CV	4.40	4.98	9.19	6.51	7.60
Morar	Min	30.30	33.20	24.30	1.28	40.38
	Max	40.20	39.50	33.40	1.58	51.70
	Mean	36.09	36.18	27.73	1.43	46.11
	SD	2.97	2.03	2.09	0.09	3.49
	CV	8.22	5.61	7.54	6.47	7.56
Dabra	Min	33.20	32.20	27.10	1.28	40.38
	Max	39.60	38.20	30.60	1.58	51.70
	Mean	36.03	35.07	28.91	1.42	46.49
	SD	1.74	1.88	0.99	0.09	3.21
	CV	4.83	5.36	3.44	6.00	6.91

The maximum magnesium level (2.03 Cmol (P^+)/kg) was reported in the Ghatigao block, while the minimum (1.66 Cmol (P^+)/kg) was reported in the Morar block. As the data indicate, magnesium levels significantly affected the soil health and agricultural productivity.According to Table 3, the soil in the Gwalior District has a sodium content that ranges from 0.80 to 88.80 Cmol (P^+)/kg, with an average value of 21.28 Cmol (P^+)/kg, a standard deviation of 24.07, and a coefficient of variation of 113.10%. The exchangeable sodium content of the soil also varied across the four blocks of the district. Specifically, Bhitarwar had a range of 6.30 to 26.39 Cmol (P^+)/kg, Ghatigao had a range of 4.40 to 21.60 Cmol (P^+)/kg Morar had a range of 8.20 to 27.60 Cmol (P^+)/kg, and Dabra had a range of 5.60 to 88.80 Cmol (P^+)/kg. It is important to note that high levels of exchangeable sodium in soil can negatively impact soil structure and plant growth, and therefore it is important for farmers and land managers to be aware of the sodium levels in their soil.The nitrogen content in the soil of different blocks in the Gwalior District, including Bhitarwar, Ghatigao, Morar, and Dabra, varied from 194.00 to 295.00, 195.00 to 314.00, 194 to 336.00, 198.00 to 298.00 kg/ha, with average values ranging from 257 to 274.67 kg/ha (Fig. 9). The results also indicate that the minimum and maximum values of nitrogen in the soil were found in Bhitarwar and Morar blocks, respectively. Similar findings were also reported by Talib and Verma (1990), indicating low to medium levels of available nitrogen in all soil profiles, with a decreasing trend in nitrogen content with depth due to a reduction in organic matter content.

In the different blocks of the Gwalior District (Bhitarwar, Ghatigao, Morar, and Dabra), the nitrogen level in the soil varied from 194 to 295, 194 to 314, 194 to 336, and 198 to 298 kg/ha, with average values ranging between 257,258.07 and 274.67,258.20 kg/ha. Additionally, according to the findings, the Bhitarwar and Morar Blocks had the minimum and maximum soil nitrogen values. Talib and Verma (1990), who also reached similar conclusions, concluded that all of the soil profiles contained low to medium levels of available nitrogen, and due to the decline in organic matter with increasing depth, all of the profiles displayed a decreasing trend.

Table 3: Status of Chemical properties of soils of different blocks of Gwalior district

Blocks		pH	EC (dS/m^1)	OC (%)	N	P	K	Co3	Hco3	Ca	Mg	Na	Sar
					(Kg/ha)			Cmol (P$^+$) kg^1					
Bhitarwar	**Min**	7.20	0.21	0.23	194.00	15.00	69.89	0.90	3.50	1.90	0.70	6.30	6.26
	Max	8.90	0.75	0.36	295.00	43.00	340.70	1.80	8.70	8.10	3.10	31.30	26.39
	Mean	8.26	0.59	0.27	257.40	26.60	169.48	1.20	6.45	3.94	1.77	17.58	15.21
	SD	0.56	0.16	0.03	31.77	8.92	66.10	0.44	1.73	1.75	0.75	7.29	6.38
	CV	6.75	26.86	12.32	12.34	33.53	39.00	36.60	26.77	44.41	42.39	41.49	41.95
Ghatigao	**Min**	7.50	0.27	0.35	195.00	14.00	227.14	0.90	1.40	3.60	0.60	4.40	2.40
	Max	8.90	0.83	0.49	314.00	45.00	393.12	1.90	6.90	13.70	3.90	21.60	18.42
	Mean	8.15	0.57	0.41	258.07	27.53	308.67	1.45	4.85	7.32	2.03	11.31	7.76
	SD	0.45	0.19	0.05	36.43	10.11	49.93	0.46	1.48	2.91	0.92	5.18	3.99
	CV	5.46	33.84	11.76	14.12	36.73	16.18	31.98	30.53	39.74	45.37	45.82	51.37
Morar	**Min**	7.40	0.30	0.45	194.00	6.10	192.19	0.80	5.00	3.20	0.80	8.20	5.91
	Max	8.90	0.61	0.98	336.00	44.00	751.30	2.80	9.70	9.50	3.20	27.60	22.50
	Mean	8.35	0.49	0.65	274.67	19.08	416.42	2.00	7.80	5.39	1.66	18.15	14.04
	SD	0.46	0.08	0.17	41.06	11.70	149.85	0.68	1.50	1.93	0.78	6.24	5.18
	CV	5.50	17.33	26.31	14.95	61.31	35.99	33.96	19.20	35.84	46.82	34.37	36.93
Dabra	**Min**	7.10	0.28	0.32	198.00	13.00	139.78	0.90	1.80	3.50	1.00	5.60	3.96
	Max	8.50	0.64	0.48	298.00	43.00	716.35	4.50	27.40	8.50	2.60	88.80	76.43
	Mean	7.72	0.50	0.39	258.20	28.87	408.26	2.43	11.29	6.13	1.84	54.57	38.96
	SD	0.45	0.12	0.05	30.58	10.20	187.82	1.01	7.93	1.46	0.47	25.29	18.80
	CV	5.88	23.89	12.22	11.84	35.32	46.00	41.72	70.23	23.85	25.56	46.34	48.25

Phosphorus level in the soil of different blocks (Bhitarwar, Ghatigao, Morar, and Dabra) varied from 15.00 to 43.00, 14.00 to 45.00, 6.10 to 44.00, and 13.00 to 43.00 kg/ha with average values ranging from the results showed that the Morar and Dabra Blocks had the lowest and highest soil phosphorus ,respectively (Fig. 10). Surface soils are categorised as medium in terms of accessible P concentration, exactly as N. Similar results have also been reported byTodmal *et al.*, (2008).

The range of the available potassium status (kg/ha) in the study area was 69.89–751.30 kg/ha, with an average value of 363.14 kg/ha (Fig. 11). These results are consistent with those of Prasad and Rokima (1991), who found that potassium accumulation is due to its stable buildup, as a result of its addition through fertilizers, organic manures and bio-fertilizers.

Conclusion

It was determined that the prevalent soil texture in the Gwalior district is sandy loam, with a pH range that varies from neutral to alkaline. The soils were classified as having low organic carbon levels, low to medium accessible levels of nitrogen and phosphorus, and medium to high levels of available potassium. The research findings indicate that the soils in the Gwalior district suffer from extensive nutrient deficiencies, with some regions also facing salinity and alkalinity problems. To express the geographic variability, nutrient scarcity, and availability in key blocks, GIS-based maps were created, which will be beneficial in developing crop planning and providing advice on nutrient use efficiency.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Bhardwaj, S., Khanna, D. R., Ruhela, M., Bhutiani, R., Bhardwaj, R., & Ahamad, F. (2020). Assessment of the soil quality of Haridwar Uttarakhand India: A comparative study. *Environment Conservation Journal*, *21*(3), 155-164.

Boke, S. (2004). Soil phosphorus fractions as influenced by different cropping systems in Andosols and Nitosols in Kembata-Tembaro and Wolayta Zones, SNNPRS. *Alemaya University,(AU) Ethiopia*.

Cambule, A. H., Rossiter, D. G., Stoorvogel, J. J., & Smaling, E. M. A. (2014). Soil organic carbon stocks in the Limpopo National Park, Mozambique: Amount, spatial distribution and uncertainty. *Geoderma*, *213*, 46-56.

Chima, U. D. (2007). Effects of tropical rainforest modification on soil quality of Omo biosphere reserve in Ogun State, Nigeria. *Master of Forestry (MF) Dissertation, University of Agriculture, Abeokuta, Ogun state, Nigeria*.

Dilliwar, P., Puri, G., Singh, R., Amule, F. C., & Choudhary, B. K. (2014). To evaluate the soil quality of Kheri series under Jawaharlal Nehru Krishi Vishwa Vidyalaya soil of Maharajpur Farm. In *National conference on soil health: A key to unlock and sustain production potential September* (pp. 3-4).

Franzen, D. W., Hopkins, D. H., Sweeney, M. D., Ulmer, M. K., & Halvorson, A. D. (2002). Evaluation of soil survey scale for zone development of site-specific nitrogen management. *Agronomy Journal*, *94*(2), 381-389.

Jackson, M. L. (1962). Soil Chemical Analysis: Basic Procedures and Instrumental Techniques (No. 5.1 J14). Madison, WI: Soil Science Society of America.

Jackson, M. L. (1967). Soil chemical analysis: advanced course (No. 2nd ed. 7). Madison, WI: Soil Science Society of America.

Jackson, M. L. (1973). Soil Chemical Analysis: Advanced Course (No. SSSA-3). Madison, WI: Soil Science Society of America.

Li, X. F., Chen, Z. B., Chen, H. B., & Chen, Z. Q. (2011). Spatial distribution of soil nutrients and their response to land use in eroded area of South China. *Procedia Environmental Sciences*, *10*, 14-19.

Liu, Z. P., Shao, M. A., & Wang, Y. Q. (2013). Spatial patterns of soil total nitrogen and soil total phosphorus across the entire Loess Plateau region of China. *Geoderma*, *197*, 67-78.

Long, X. H., Zhao, J., Liu, Z. P., Rengel, Z., Liu, L., Shao, H. B., & Tao, Y. (2014). Applying geostatistics to determine the soil quality improvement by Jerusalem artichoke in coastal saline zone. *Ecological engineering*, *70*, 319-326.

Mandal, U. K., Ramachandran, K., Sharma, K. L., Satyam, B., Venkanna, K., Udaya Bhanu, M., ... & Venkateswarlu, B. (2011). Assessing soil quality in a semiarid tropical watershed using a geographic information system. *Soil Science Society of America Journal*, *75*(3), 1144-1160.

Maniyunda, L. M., Raji, B. A., & Gwari, M. G. (2013). Variability of some soil physicochemical properties on lithosequence in Funtua North-Western Nigeria. *Int J Sci Res*, *2*, 174-180.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.

Prasad, B., & Rokima, J. (1991). b. Integrated nutrient management–III. Transformation of applied K into various K fractions in relation to its availability and uptake in calcareous soils. *J. Indian Soc. of Soil Sci*, *39*(4), 722-726.

Ruhela, M., Bhardwaj, S., Garg, V., & Ahamad, F. (2022). Assessment of soil quality at selected sites around Karwi town, Chitrakoot (Uttar Pradesh), India. *Archives of Agriculture and Environmental Science*, *7*(3), 379-385.

Sahu, C., Basti, S., Pradhan, R. P., & Sahu, S. K. (2016). Physicochemical properties of soil under different land use practices located near Bhawanipatna town in Odisha, India. *International journal of environmental sciences*, *6*(6), 941-953.

Singh, R. P., & Mishra, S. K. (2012). Available macro nutrients (N, P, K and S) in the soils of Chiraigaon block of district Varanasi (UP) in relation to soil characteristics. *Indian Journal of Scientific Research*, *3*(1), 97-100.

Singh, Y. V., Kant, S., Singh, S. K., Sharma, P. K., Jat, L. K., Kumar, M., ... & Yadav, R. N. (2017). Assessment of Physico-Chemical Characteristics of the Soil of Lahar Block in Bhind District of Madhya Pradesh (India). *International Journal of Current Microbiology and Applied Sciences*, *6*(2), 511-519.

Sireesha, P. V., & Naidu, M. V. S. (2013). Studies on genesis, characterization and classification of soils in semi-arid agro-ecological region: A case study in Banaganapalle Mandal of Kurnool district in Andhra Pradesh. *Journal of the Indian Society of Soil Science*, *61*(3), 167-178.

Srinivasan, R., Natarajan, A., Kumar, K. S., & Kalaivanan, D. (2013). Distribution of available macro and micronutrients in cashew growing soils of Dakshina Kannada District of Coastal Karnataka. *Madras Agricultural Journal*, *100*(1-3), 747-750.

Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. Current Science, 25(8), 259-260.

Talib, A. R., & Verma, S. D. (1990). Relationship between different forms of potassium and particle size in benchmark soils of Kashmir. *Indian Journal of Agricultural Sciences*, *60*(9), 643-644.

Thangasamy, A., Naidu, M. V. S., Ramavatharam, N., & Reddy, C. R. (2015). Characterisation, classification and evaluation of soil resources in Sivagiri micro-watershed of Chittoor District in Andhra Pradesh for sustainable land use planning.

Todmal, S. M., Patil, B. P., & Tamboli, B. D. (2008). Characterisation and classification of soils in Agriculture College Farm, Kolhapur. *J. Maharashtra agric. Univ*, *33*(3), 287-291.

Tomar, V. S. (1968). *Studies on magnesium in Madhya Pradesh* (Doctoral dissertation, M. Sc. Thesis, JNKVV, Jabalpur (MP)).

Wakley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science, 37(1), 29-38.

Wang, J., Fu, B., Qiu, Y., & Chen, L. (2001). Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in China. *Journal of arid environments*, *48*(4), 537-550.

Yadav, T. C., Rai, H. K., Tagore, G. S., Chaubey, D., & Dhakad, R. (2018). Assessment of spatial variability in physico-chemical properties of soils in Alirajpur district of Madhya Pradesh using Geo-statistical approach. *Journal of soil and water conservation*, *17*(4), 317-324.

Yadav, T. C., Rai, H. K., Tagore, G. S., Chaubey, D., & Dhakad, R. (2018). Assessment of spatial variability in physico-chemical properties of soils in Alirajpur district of Madhya Pradesh using Geo-statistical approach. *Journal of soil and water conservation*, *17*(4), 317-324.