



Assessment and Mapping of Nutrients in Soils of Babain and Ladwa Blocks of Kurukshetra using GIS

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study was conducted in 2021-22 to evaluate the soil fertility status and create geospatial thematic mapping of available macro and micronutrients using GIS, and their correlation with physico-chemical properties of the soils of the Babain and Ladwa blocks of Kurukshetra, India. A composite of 204 georeferenced soil samples was collected from different villages of both blocks and samples were analysed using standard procedures. The average pH of the soils of Babain and Ladwa had a mean value of 8.10 and 8.18. Among the total soil samples, 92 and 80 samples were found to be saline in Babain and Ladwa, respectively. The nitrogen, phosphorous, potassium and

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sulphur content in the soils of the Babain block ranged from 105-280, 6-32, 80-500 and 34-298 kg ha⁻¹, while in the Ladwa block nitrogen, phosphorous, potassium and sulphur content in the soils ranged from 89-287, 7-27, 65-510 and 45-430 kg ha⁻¹, respectively. The soil samples exhibited varying levels of zinc, iron, and copper, with some falling into the sufficient category and others into the deficient category. However, all samples had sufficient manganese and boron content. The observed deficiency of zinc, iron and copper can be replenished with the application of manures and fertilizers to improve soil fertility and crop productivity.

Keywords: Geospatial mapping; GIS; georeferenced samples; macronutrients; micronutrients; crop productivity.

1. INTRODUCTION

The rice-wheat cropping system is widely practised in the Indo-Gangetic plain zones of Haryana. The proportion of rice and wheat in the total food grain production of Haryana has shown a significant growth from 50 per cent in 1966-67 to more than 90 per cent in the recent period [1]. Kurukshetra, with a net sown area of 149000 hectares (88.69%) is one of the productive districts of the state accounting for 5.13 per cent of wheat and 12.4 per cent of the paddy of the total production of Haryana. Both of these crops have different edaphic requirements and need the application of substantial amounts of nutrients, specifically nitrogen (N), in order to achieve their maximum yield potential, which compelled farmers to use heavy doses of NPK fertilizers. Crops continue to draw more macro- and micronutrients from the soil even when additional fertiliser is applied to grow high-yielding, fertilizer-responsive crop varieties, which causes nutritional deficiencies in the soil. The rampant use of fertilizers over a period has led to the accumulation of elements like phosphorus (P) and caused the deficiency of sulphur (S) in many locations (Sharma, 2008). Soil fertility is a crucial factor affecting agricultural productivity [2], that can reveal considerable information about its prospective yield [3]. Characterization of soil with respect to the assessment of the fertility status of the soils of a certain area or region is an essential component of sustainable agriculture production.

It is imperative to safeguard and protect the base of natural resources with the application of relevant technologies that are socially acceptable, economically feasible and environmentally sustainable. The soil test-based nutrient administration plays a critical role in combating the deteriorating fertility of the soil by bridging the gap between the crop's fertiliser requirements and the soil's nutrient reserve [4]. Evaluating soil fertility has become a standard

routine for evaluating crop productivity and sustainable soil management. Conducting a soil study helps in making choices for sustainable use of agricultural land. An extensive understanding of land's capacity for sustainable use is necessary, given the changing nature of both human needs and environmental situations. This lessens the possibility of environmental deterioration while enabling every square inch of land to help feed millions of people [5]. With the development of advanced remote sensing, GIS, and GPS technology, it is now feasible to conduct systematic surveys for the purpose of monitoring soil and crop health. With crop nutrition tailored to the unique site, this will assist in monitoring the likelihood of fertility in the examined area. Correlation between physico-chemical characteristics and available macro- and micronutrients is necessary to comprehend the causes of the scarcity of available nutrients in soils. Hence, present study was undertaken to study the state of macronutrients, micronutrients and their association with important soil properties.

2. MATERIALS AND METHODS

2.1 General Description of the Study Area

The study was conducted on the two (Babain and Ladwa) blocks of the Kurukshetra district (Fig. 1) during 2021-22, which is located between 29°-52':30"-12'N latitudes and 76°26': 77°04'E longitudes, with an average elevation of 241m to 274 m above MSL (mean sea level). The land has a gradual slope from northeast towards southwest, mostly covered by the upper Ghaggar basin. The district has a variable climate with temperature as high as 47°C in summers to as low as 1°C in winters. Annually, the district receives 582 millimetres of rainfall, primarily during July and August which is distributed unevenly around the region. The soils composition ranges from fertile clay loam to sandy loam in texture.

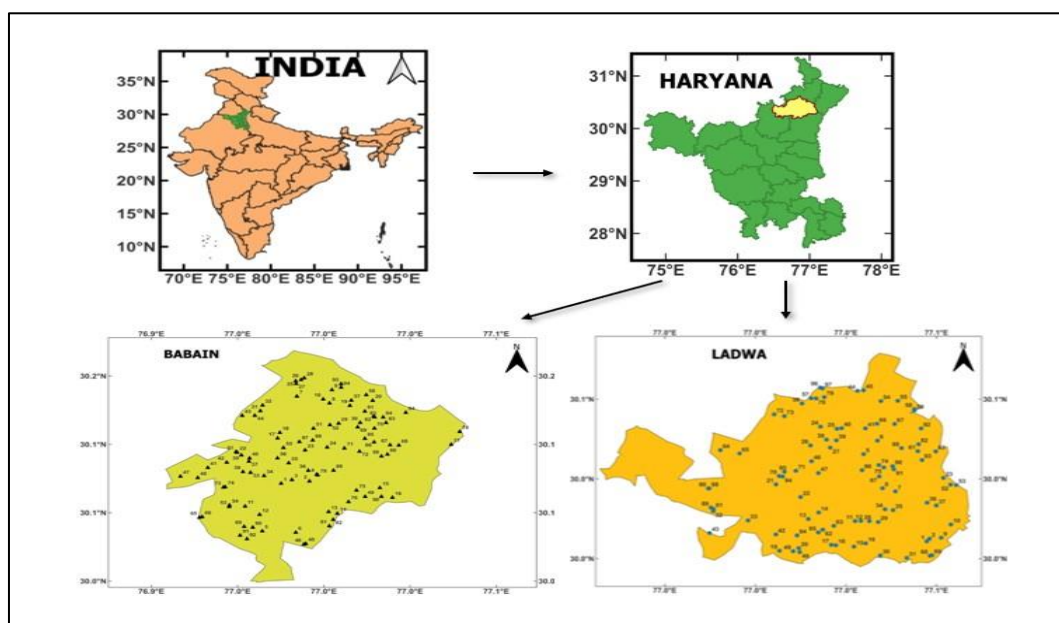


Fig. 1. Location map of Babain and Ladwa blocks of Kurukshetra

2.2 Soil Sampling and Analysis

204 composite surface soil samples were gathered from various villages in Babain and Ladwa blocks of Kurukshetra, ranging from 0 to 15 meters in depth. These samples, collected with an auger were air-dried, crushed and sieved through a 2mm sieve to determine their physico-chemical properties. The soil pH and electrical conductivity were estimated using a glass electrode Beckman pH meter and the conductivity meter, respectively [6]. Organic carbon content in soil was determined by Walkley and Black's [7] wet digestion method. The bulk density of soil samples was estimated from the mass of the soil and the volume of the soil cores. The available nitrogen, phosphorus, and sulphur were determined using the alkaline potassium permanganate method [8], Olsen's method [9] and Chensin and Yien method [10], respectively. The amount of potassium present in the extract was determined by a flame photometer as described by Jackson [6]. Lindsay and Norvell [11] method was used to determine DTPA extractable Zinc, Manganese, Copper and Iron. For the assessment of available boron in the soil, the hot water soluble boron method developed by Berger and Truog [12] was utilized.

Statistical analysis and soil mapping: The OPSTAT software [13] was utilized to conduct a descriptive analysis of the Pearson correlation between soil properties and nutrients. The analysed values (deficient and sufficient) for soil

samples were tagged with each geo-referenced point to be digitized for mapping. Subsequently, the maps were integrated using ArcGISv10.5 software.

3. RESULTS AND DISCUSSION

3.1 Soil pH and EC

The soil pH of the Babain block as shown in Table 1 ranged from 7.1 to 8.7, while in Ladwa it ranged from 7.4 to 8.6. The average pH values were 8.10 and 8.18 for Babain and Ladwa, respectively. The results indicating saline to alkaline soils in the examined area were also reported by Gora [14], Gyawali et al. [15], Shabnam [16] and Mohit Sharma [17]. The presence of basic parent material, excessive base saturation and uneven rainfall are the likely causes of the alkaline nature of soils. The electrical conductivity (EC) of Babain block soils ranged from 0.11-0.99 dS m⁻¹ and Ladwa soils ranged from 0.13-0.98 dS m⁻¹. The mean values of 0.38 dS m⁻¹ and 0.39 dS m⁻¹ respectively, indicating saline nature of soils, as also reported by Nazif et al. [18] in Bhimber (Jammu and Kashmir).

3.2 Bulk Density and Texture

The bulk density of two blocks of Kurukshetra district viz., Babain, Ladwa (as shown in Table 1) varied from 1.32-1.57 and 1.38-1.59 Mg m⁻³ with mean values of 1.45 and 1.50 Mg m⁻³

respectively, confirmed by the results of Gyawali et al. [15] and Gora [14]. The soil texture in both Babain and Ladwa blocks varied from sandy loam to loam, as also observed by Singh et al. [19] and Gyawali et al. [15] in the Kaithal district.

3.3 Available Nitrogen and Phosphorus

The available nitrogen content (as depicted in Table 1 and Fig. 2) of the soil of the Babain block varied from 105 to 280, while in Ladwa, it varied from 89-287, with a mean of 179.6 kg ha⁻¹ and 167 kg ha⁻¹, respectively. The data depicted in Table 2 showed that the majority of soil samples of the two blocks were found in the low category of soil nitrogen. In the Babain block, 92% of samples (88 samples) were classified as low, while 8% (8 samples) were categorized as moderate, with critical limits of <250 and 250-500, respectively. In Ladwa block, 101 samples (94%) were found to have low soil nitrogen levels, while 7 samples (6%) fell into the moderate category, as indicated in Table 2 and Fig. 3. The shortfall of nitrogen in most of the samples due to volatilization, runoff and denitrification was also observed by Shabnam [16] and Mohit Sharma [17] in Kaithal district. Similar results were also recorded by Hegde et al. [20], Tagung et al. [21], Singh et al. [22] and Jyothi and Hebsur [23] in their examined region.

The available phosphorus ranged from low to high for Babain (6 to 32 kg ha⁻¹) block with 26 (27%), 57 (58%) and 14 (15%) samples under low (<10), medium (10-20), and high (>20) categories, respectively. Ladwa (7 to 27 kg ha⁻¹) block had 29 (27%), 64 (59%) and 15 (14%) soil samples under the respective categories of low, medium, and high soil phosphorus. The mean phosphorus content was 14.09 kg ha⁻¹ for Babain and 14.47 kg ha⁻¹ for Ladwa. These results implying the moderate status of phosphorus in

soil samples were confirmed by the findings of Singh et al. [24] and Prem et al. [25].

3.4 Available Potassium and Sulphur Content

The range, as shown in Table 1 and Figs. 2 & 4, of available potassium in soils of the Babain block varied from 80 to 500 kg ha⁻¹, with a mean value of 245 kg ha⁻¹. In Ladwa, the available potassium varied from 65 to 510 kg ha⁻¹, with a mean value of 249 kg ha⁻¹. Upon analyzing the soil, it was found out that of 96 soil samples of Babain block, 12 samples (12%) fall under low status, 61 soil samples (64%) under medium and 23 (24%) under high potassium category. Scrutiny of data shown in Table 2 and Figs. 3 & 5 depicted that the available potassium content of Ladwa block for 14 (13%), 65 (60%) and 29 (27%) soil samples fall under low, medium, and high categories, respectively. The soil samples falling in the medium category of potassium might be due to the occurrence of illite and feldspar in parent material as also depicted by Mohit Sharma [17] in the Kalayat and Guhla blocks of Kaithal district. Similar results were also reported by Muralidharudu et al. [26], Motsara [27] and Singh et al. [28].

The available sulphur in the soils of Babain varied from 34-298 kg ha⁻¹, while that of Ladwa ranged from 45 to 430 kg ha⁻¹. The mean value of 130 and 120 kg ha⁻¹ respectively. The data depicted that available sulphur content of 0 (0%), 4 (4%) and 92 (96%) samples from Babain block fall under Low, medium and high category, whereas all soil samples from Ladwa were categorized as high. Similar results were observed by Gora [14], Shabnam [16] and Mohit Sharma [17] in Kaithal district of Haryana, attributing the use zinc sulphate as cause of high sulphur in soil samples.

Table 1. Physico-chemical properties and macro-nutrient status of Babain and Ladwa blocks of Kurukshetra

Physico-chemical properties	Babain		Ladwa	
	Range	Mean	Range	Mean
pH	7.1-8.7	8.10	7.4-8.6	8.18
EC (dS m ⁻¹)	0.11-0.99	0.38	0.13-0.98	0.39
Bulk density (Mg m ⁻³)	1.32-1.57	1.45	1.38-1.59	1.50
Texture	SL to L		SL to L	
Available nitrogen (kg ha ⁻¹)	105-280	179.6	89-287	167.0
Available phosphorus (kg ha ⁻¹)	6-32	14.09	7-27	14.47
Available potassium (kg ha ⁻¹)	80-500	245	65-510	249
Available sulphur (kg ha ⁻¹)	34-298	130	45-430	120
Organic carbon (%)	0.27-0.82	0.50	0.25-0.88	0.48

Table 2. Macro-nutrient status in Babain and Ladwa blocks of Kurukshetra district in terms of no. of soil samples and percentage of samples

Macro-nutrient	Babain (96)			Ladwa (108)		
	Low (%)	Medium	High	Low	Medium	High
Nitrogen	88 (92%)	8 (8%)	0	101 (94%)	7 (6%)	0
Phosphorus	26 (27%)	57 (58%)	14 (15%)	29 (27%)	64 (59%)	15 (14%)
Potassium	12 (12%)	61 (64%)	23 (24%)	14 (13%)	65 (60%)	29 (27%)
Sulphur	0	4 (4%)	92 (96%)	0	0	108 (100%)
Organic carbon	29 (30%)	61 (64%)	6 (6%)	40 (37%)	62 (57%)	6 (6%)

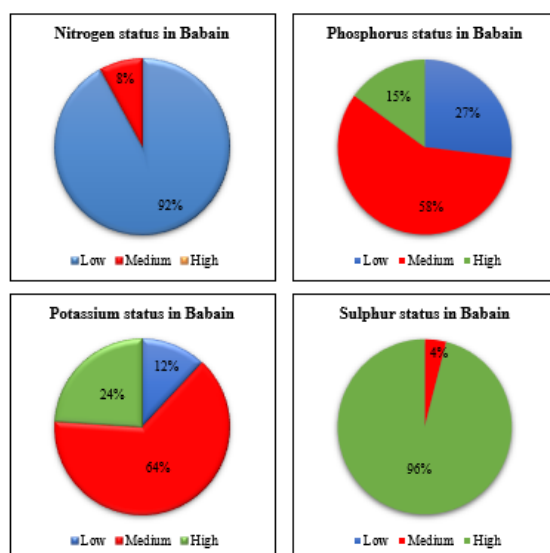


Fig. 2. Available macronutrient status in Babain block of Kurukshetra (% of soil samples)

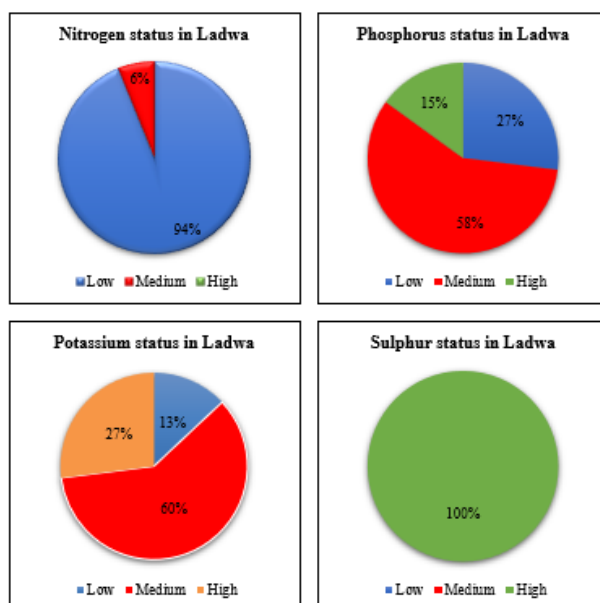


Fig. 3. Available macronutrient status in Ladwa block of Kurukshetra (% of soil samples)

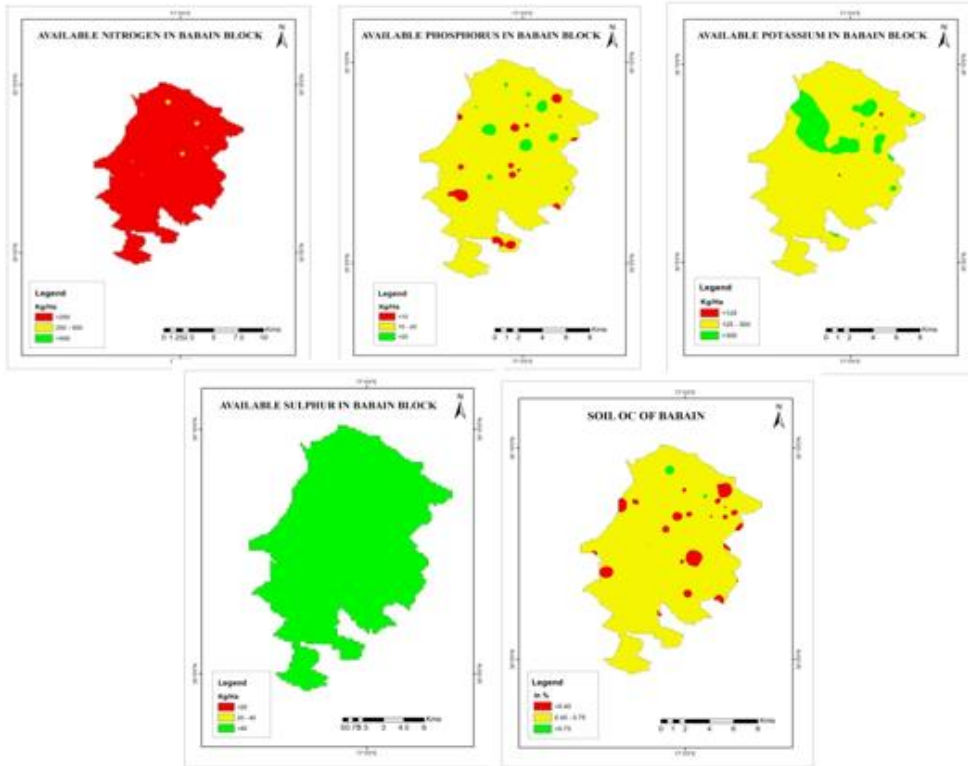


Fig. 4. Thematic map of soil nitrogen, phosphorus, potassium, sulphur, and organic carbon of Babain block of Kurukshetra

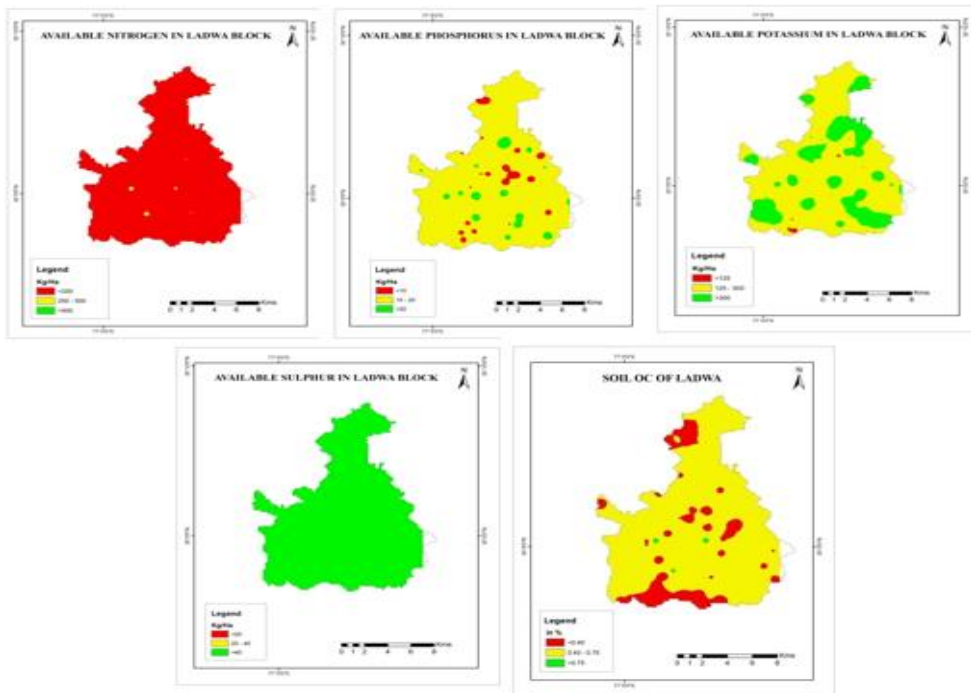


Fig. 5. Thematic map of soil macronutrients (nitrogen, phosphorus, potassium, sulphur) and organic carbon of Ladwa block of Kurukshetra

Table 3. Micronutrient status of Babain and Ladwa blocks of Kurukshetra

Location	Zn (mg kg ⁻¹)		Fe (mg kg ⁻¹)		Cu (mg kg ⁻¹)		Mn (mg kg ⁻¹)		B (mg kg ⁻¹)	
	Range	Mean	Range	mean	Range	mean	Range	Mean	Range	Mean
Babain	0.49-4.79	2.24	1.0-15.8	8.32	0.16-3.69	1.30	1.2-6.4	3.37	0.67-4.08	2.37
Ladwa	0.39-3.95	1.75	0.9-18.4	8.05	0.17-3.04	1.27	1.5-6.1	3.43	0.73-4.05	2.21

Table 4. Micronutrient status in Babain and Ladwa blocks of Kurukshetra (no. of soil samples)

Micronutrient	Babain		Ladwa	
	Sufficient	Deficient	Sufficient	Deficient
Zn	94 (98%)	2 (2%)	102 (94%)	6 (6%)
Fe	82 (85%)	14 (15%)	91 (84%)	17 (16%)
Cu	95 (99%)	1 (1%)	103 (99%)	1 (1%)
Mn	96 (100%)	0	108 (100%)	0
B	96 (100%)	0	108 (100%)	0

3.5 Organic Carbon

The data presented in Table 1 revealed that the organic carbon (OC) content of the soil of the Babain block varied from 0.27 to 0.82% and that of Ladwa ranged from 0.25 to 0.88%, with a mean value of 0.50 and 0.48 % respectively. A perusal of data revealed that 29 (30%), 61 (64%) and 6 (6%) soil samples of Babain (Fig. 4), while, 40 (37%), 62 (57%) and 6 (6%) soil samples of Ladwa block (Fig. 5) fall under low, medium and high organic carbon category, respectively. The soil samples falling in medium status of Organic carbon is attributed to the rice-wheat cropping system as also explained by Zhang and He [29]; Benbi and Brar [30]; Benbi et al. [31].

3.6 DTPA extractable Zn, Fe, Cu and Mn and Available B content

The data depicted in Table 3 and Figs. 6 & 8 revealed that the available zinc, iron, copper, manganese, and boron content in the soils in Babain varied from 0.49 to 4.79 mg kg⁻¹, 1.0 to 15.8 mg kg⁻¹, 0.16 to 3.69 mg kg⁻¹, 1.2 to 6.4 mg kg⁻¹ and 0.67 to 4.08 mg kg⁻¹, with a mean value of 2.24, 8.32, 1.30, 3.37 and 2.37 mg kg⁻¹, respectively. DTPA extractable status of zinc, iron, copper of 98 and 2%, 85 and 15% and 99 and 1% of samples were found sufficient and deficient for Babain block, respectively. Additionally, all soil samples were categorized as having sufficient levels of DTPA extractable manganese and available boron.

The Ladwa block's soils contained zinc, iron, copper, manganese, and boron content in the range of 0.39 to 3.95 mg kg⁻¹, 0.9 to 18.5 mg kg⁻¹, 0.17 to 3.04 mg kg⁻¹, 1.5 to 6.1 mg kg⁻¹, and 0.73 to 4.05 mg kg⁻¹, with mean values of 1.75, 8.05, 1.27, 3.43 and 2.21 mg kg⁻¹ respectively. DTPA extractable zinc, iron, and copper of 94 and 6%, 84 and 16%, 99 and 1% of samples fall under sufficient and deficient category, respectively. Meanwhile, 100% of samples fall under the sufficient category of DTPA extractable manganese and boron (Table 4 and Figs. 7 & 9). Shukla et al. [32], Shabnam [16], and Mohit Sharma [17] reported a similar micronutrient status in the soils of the Kaithal district.

3.7 Correlation between Soil Properties and Nutrient Status of Babain and Ladwa Blocks

The correlation matrix of the Babain block revealed that OC showed a significant positive correlation with N ($r = 0.794^{**}$), P ($r = 0.651^{**}$), K ($r = 0.545^{**}$) and S ($r = 0.419^{**}$). The significant positive correlation between OC and N had $R^2 = 0.6299$ (Fig. 10) as the value of the coefficient of determination. Data demonstrated that organic carbon had a significant positive correlation with available N ($r = 0.91^{**}$), P ($r = 0.688^{**}$), K ($r = 0.675^{**}$) and S ($r = 0.553^{**}$). Furthermore, coefficient of determination for the positive significant correlation between OC and N is $R^2=0.8277$ (Fig. 11). Similar results were found by Gyawali et al. [15], Shabnam [16] and Mohit Sharma [17] in Kaithal district of Haryana [33-35].

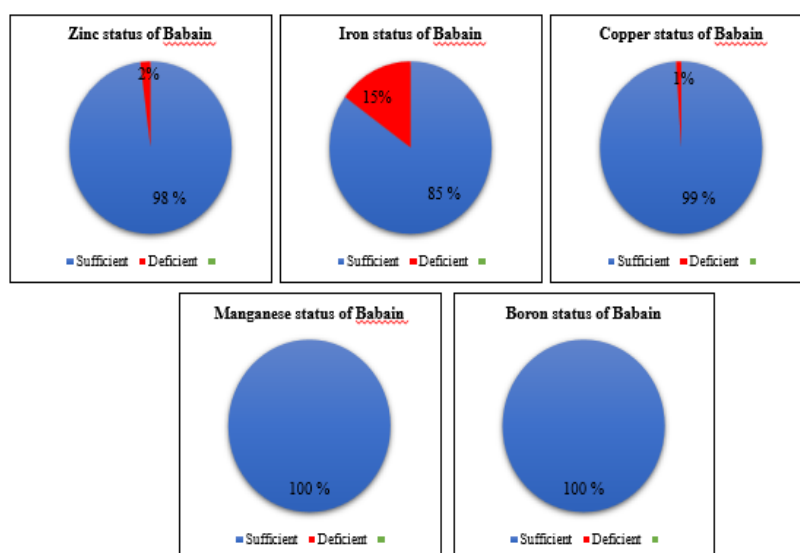


Fig. 6. Available micronutrient status in Babain block of Kurukshetra (% of soil samples)

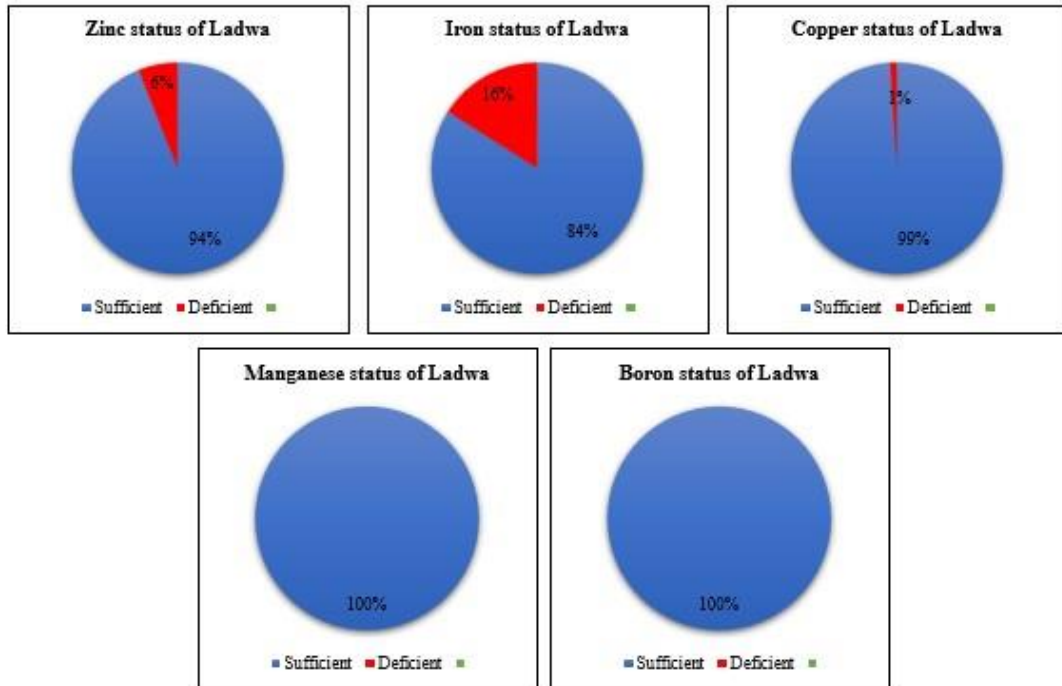


Fig. 7. Available micronutrient status in Ladwa block of Kurukshetra (% of soil samples)

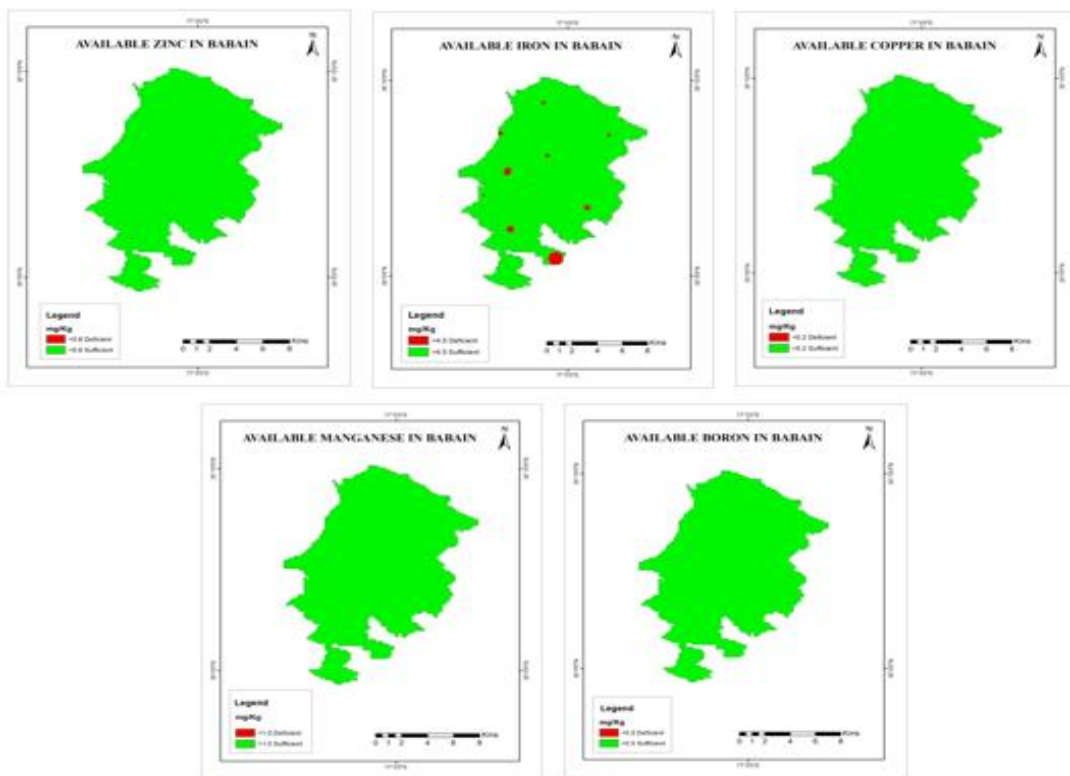


Fig. 8. Thematic map of soil micronutrients of Babain block of Kurukshetra

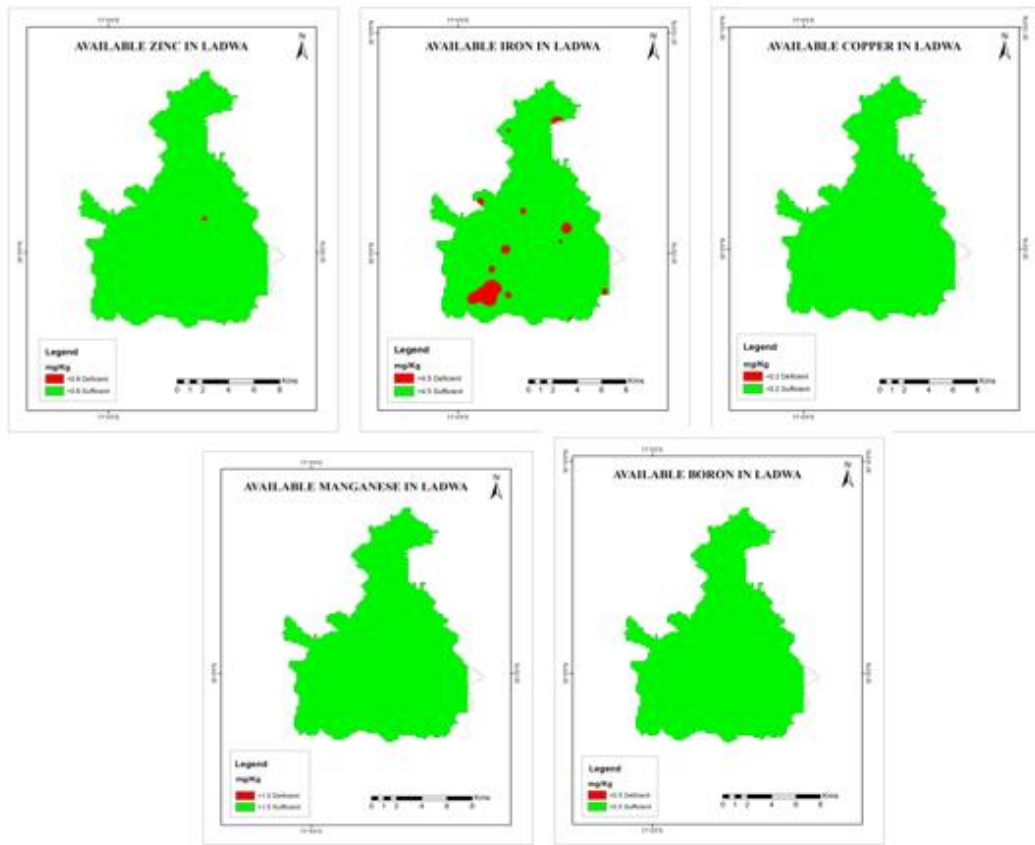


Fig. 9. Thematic map of soil micronutrients of Ladwa block of Kurukshetra

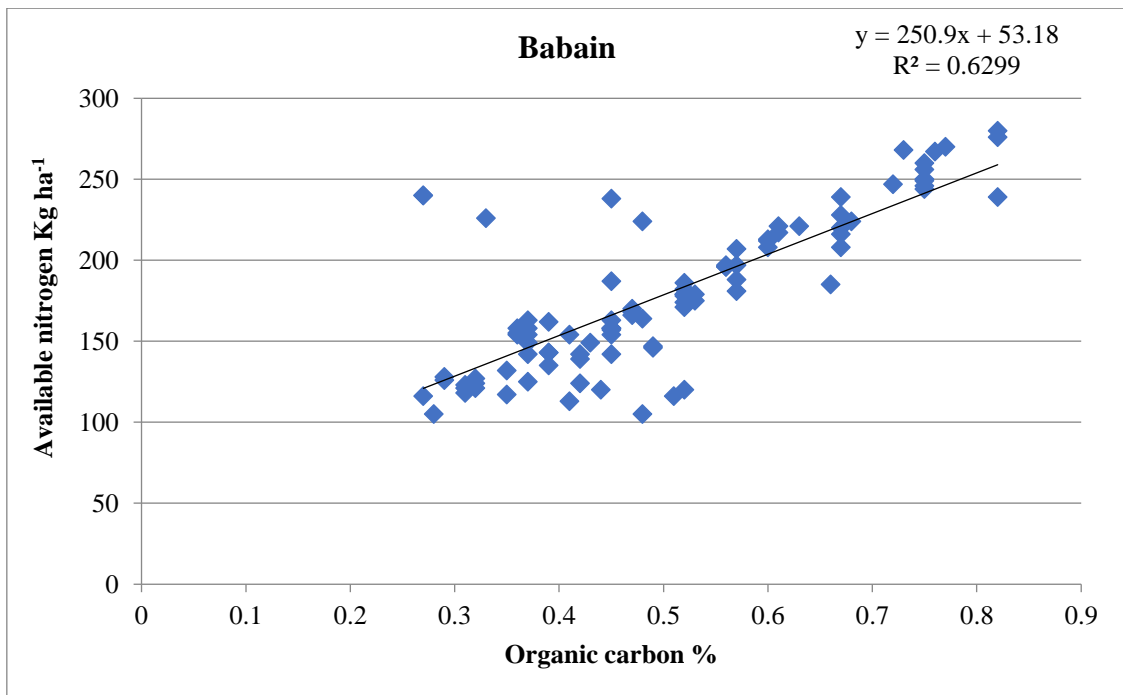


Fig. 10. Relationship between OC and available N Babain block

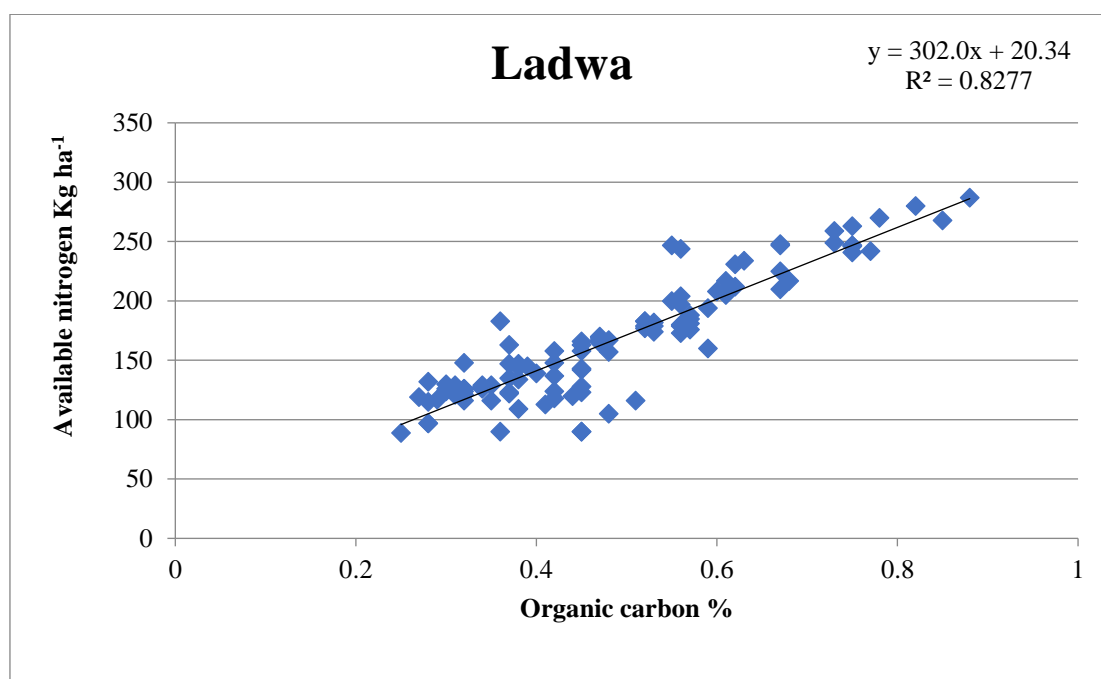


Fig. 11. Relationship between OC and available N in Ladwa block

4. CONCLUSION

The soils in the Babain and Ladwa blocks of Kurukshetra district were, exhibited a generally neutral to alkaline in reaction. They were non-saline, with low to medium organic carbon content and the soil texture varying from sandy loam to loam. The soils had low available nitrogen content, low to medium phosphorus, medium to high potassium and high sulphur content. A varying number of soil samples in both blocks fall in sufficient and deficient category for zinc, iron, copper. All the examined samples had sufficient amounts of manganese and boron.

In order to enhance soil fertility in the future, it is crucial to utilize organic fertilizers that are readily available to farmers instead of resorting to burning the paddy straw. This study provided the evident information of soil nutrients of Babain and Ladwa, that may be extended in future to examine crop land suitability in both the blocks.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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