Assessment and mapping of nutrients in soils of Babain and Ladwa blocks of Kurukshetra using GIS

Abstract

The study was conducted in 2021-22 to assess the soil fertility status along with 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 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 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 varied in the sufficient and deficient categories for the occurrence of zinc, iron and copper, while 100 % of 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 is a predominant cropping system 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 (Swaminathan, 2002). 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 these crops have different edaphic requirements and need the application of substantial amounts of nutrients, specifically nitrogen (N), to reach 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 resulted in the accumulation of elements like phosphorus (P) and caused the deficiency of sulphur (S) in many locations (Sharma, 2008). One of the key elements influencing agricultural yields is soil fertility (Kashiwar *et al*., 2020), that can reveal considerable information about its prospective yield (Nafiu *et al*., 2012). 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 (Srivastava and Singh, 2009). Assessment of soil fertility has now become a standard routine for evaluating crop productivity and sustainable soil management. 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 (Kashiwar *et al*., 2018). With the development of advanced remote sensing, GIS, and GPS technology, it is now feasible to conduct systematic surveys to monitor 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 (Figure 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 47ºC in summers to as low as 1ºC in winters. The district receives 582 millimetres of rain annually (during July and August), which is distributed unevenly around the region. The soils are fertile and vary from clay loam to sandy loam in texture.

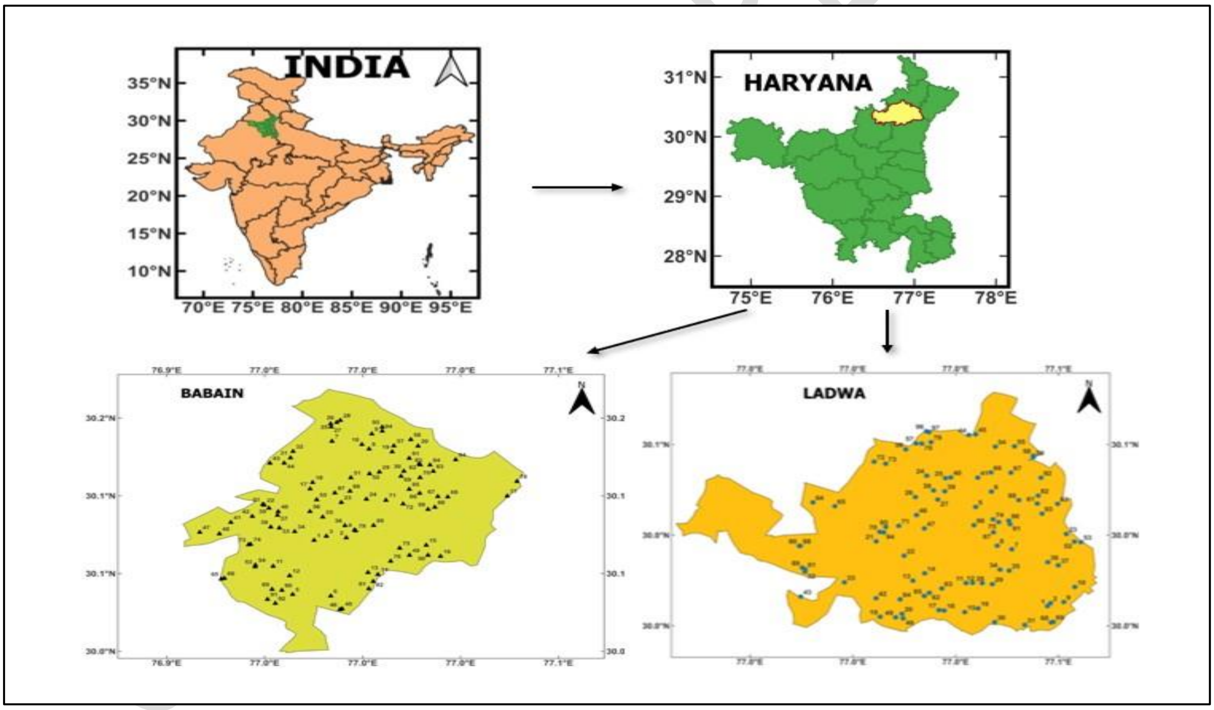

Figure 1: Location map of Babain and Ladwa blocks of Kurukshetra

2.2. Soil sampling and analysis

A total of 204 composite surface (0-15m depth) soil samples were collected from different villages of Babain and Ladwa blocks of Kurukshetra. The soil 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 (Jackson, 1973). Organic carbon content in soil was determined by Walkley and Black’s (1934) 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 (Subbiah and Asija, 1956), Olsen's method (Olsen et al., 1954) and Chensin and Yien method (Chensin and Yien, 1950), respectively. The amount of potassium present in the extract was determined by a flame photometer as described by Jackson (1973). Lindsay and Norvell, (1978) method was used to determine DTPA extractable Zinc, Manganese, Copper and Iron. The hot water soluble boron method of Berger and Truog (1939) was used to assess the available boron in soil.

2.3. Statistical analysis and soil mapping

The descriptive analysis for Pearson correlation between soil properties and nutrients was done using OPSTAT software (Sheoran *et al*., 1998). The analysed values (deficient and sufficient) for soil samples were tagged with each geo-referenced point to be digitized for mapping and maps were further 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 and Ladwa from 7.4 to 8.6, with a mean value of 8.10 and 8.18, respectively. The results indicating saline to alkaline soils in the examined area were also reported by Gora (2013), Gyawali *et al.* (2016), Shabnam (2021) and Mohit Sharma (2022). 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 the soils of the Babain block varied from 0.11-0.99 dS m^{-1} and Ladwa from 0.13-0.98 dS m^{-1}, with 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.* (2006) 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*. (2016) and Gora (2013). The soil texture of the Babain and Ladwa blocks varied from sandy loam to loam, as also observed by Singh *et al*. (2014) and Gyawali *et al*. (2016) in the Kaithal district.

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

Blocks	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 (kgha^{-1})	105-280	179.6	89-287	167.0
Available phosphorus (kgha^{-1})	6-32	14.09	7-27	14.47
Available potassium (kgha^{-1})	80-500	245	65-510	249

Available sulphur (kgha^{-1})	34-298	130	45-430	120
Organic carbon (%)	0.27-0.82	0.50	0.25-0.88	0.48

3.3. Available Nitrogen and Phosphorus

The available nitrogen content (as depicted in Table 1 and Figure 2) of the soil of the Babain block varied from 105 to 280 while that of Ladwa was 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 Babain block, 88 samples (92%) were found in the low category and 8 samples (8%) in the moderate category with a critical limit of <250 and 250-500, respectively. In Ladwa block, as shown in Table 2 and Figure 3, 101 (94%) samples were observed to be low in soil nitrogen and 7 samples (6%) were in the moderate category. The shortfall of nitrogen in most of the samples due to volatilization, runoff and denitrification was also observed by Shabnam (2021) and Mohit Sharma (2022) in Kaithal district. Similar results were also recorded by Hegde *et al*. (2021), Tagung *et al*. (2022), Singh *et al*. (2022) and Jyothi and Hebsur (2016) 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. Both blocks had a mean value of 14.09 kg ha^{-1} (Babain) and 14.47 kg ha^{-1} (Ladwa), respectively. The results implying the moderate status of phosphorus in soil samples were confirmed by the findings of Singh *et al.* (2011) and Prem *et al.* (2017)

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

Blocks/ No. of Samples	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%)

3.4. Available Potassium and Sulphur content

The range, as shown in Table 1 and Figures 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}. As per the analysis of soil, out 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 Figures 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 (2022) in the Kalayat and Guhla blocks of Kaithal district. Similar results were also reported by Muralidharudu *et al*. (2011), Motsara (2002) and Singh *et al*. (2014).

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}, with 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 of Babain block fall under Low, medium and high category, while that of 100% soil samples of Ladwa block fall under the high category. Similar results were observed by Gora (2013), Shabnam (2021) and Mohit Sharma (2022) in Kaithal district of Haryana, attributing the use zinc sulphate as cause of high sulphur in soil samples.

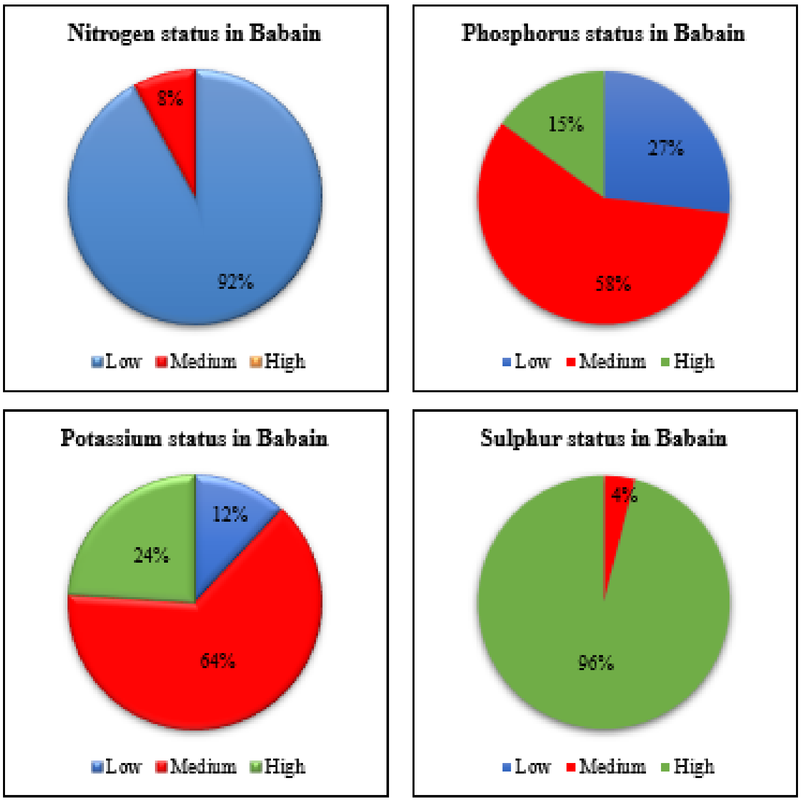

Figure 2: Available macronutrient status in Babain block of Kurukshetra (% of soil samples)

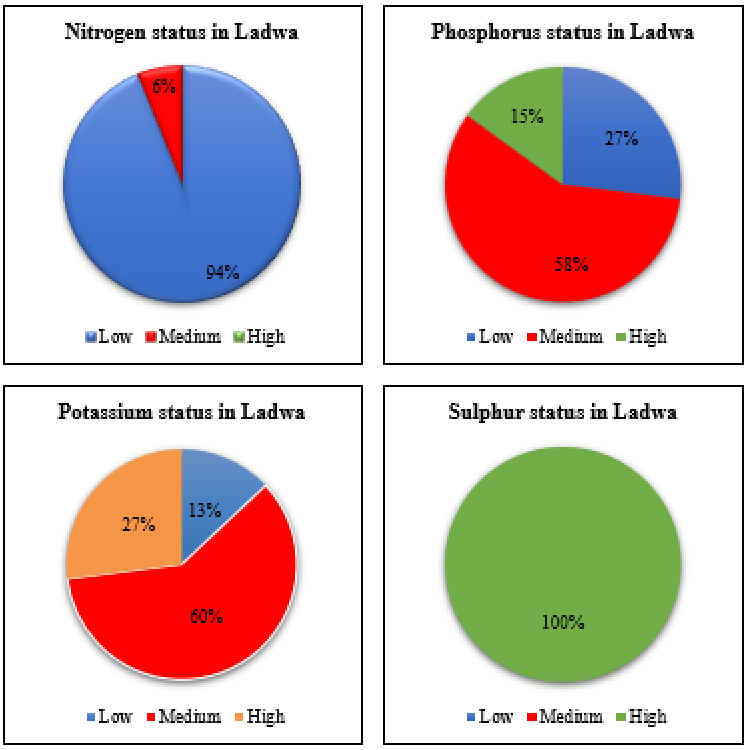

Figure 3: Available macronutrient status in Ladwa block of Kurukshetra (% of soil samples)

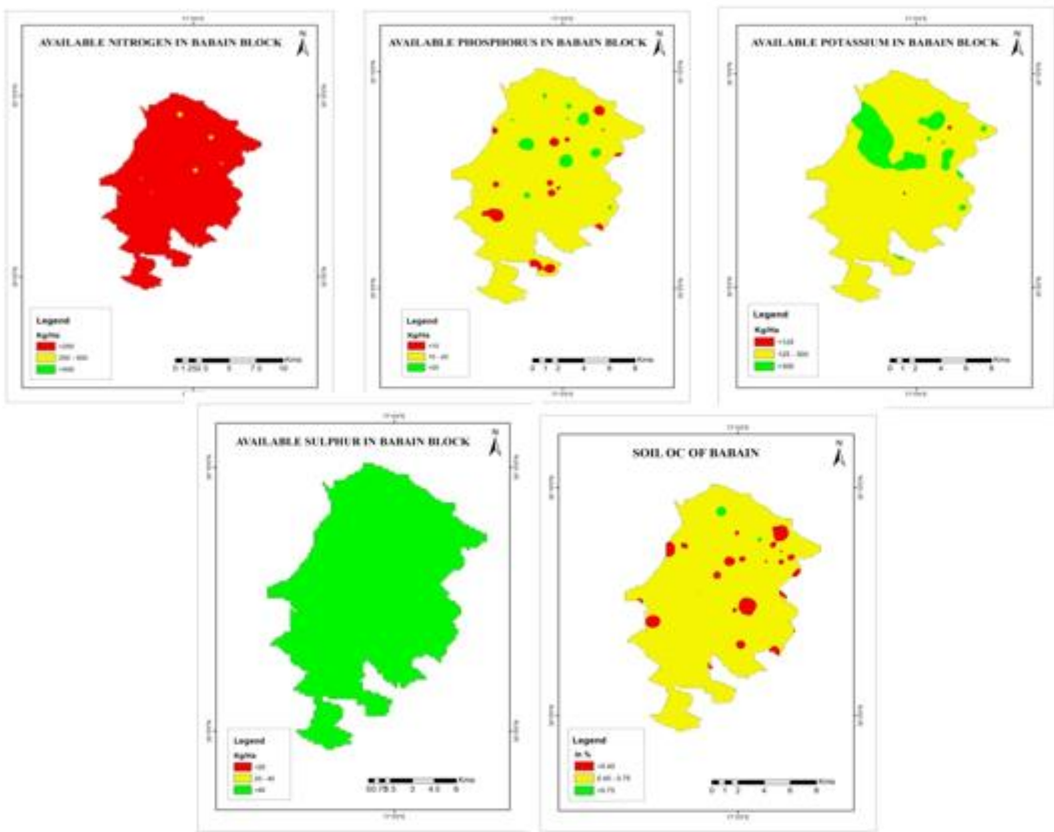

Figure 4: Thematic map of soil nitrogen, phosphorus, potassium, sulphur, and organic carbon of Babain block of Kurukshetra

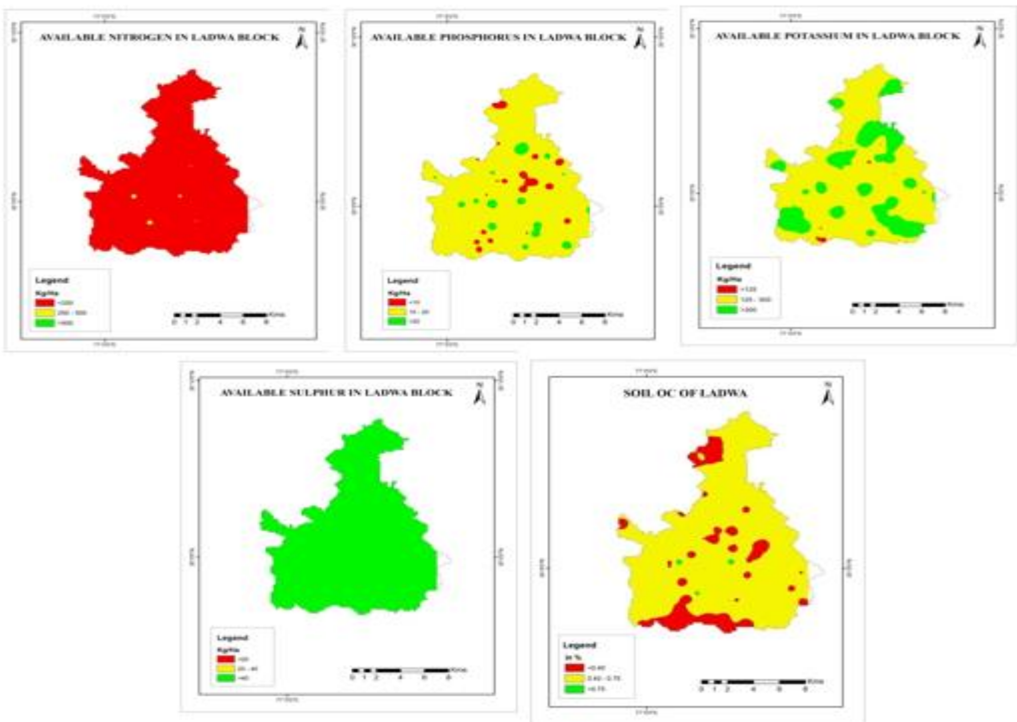

Figure 5: Thematic map of soil macronutrients (nitrogen, phosphorus, potassium, sulphur) and organic carbon of Ladwa block of Kurukshetra

3.5. Organic Carbon

The data presented in Table 1 revealed that 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 (Figure 4), while, 40 (37%), 62 (57%) and 6 (6%) soil samples of Ladwa block (Figure 5) fall under low, medium and high organic carbon category, respectively. The soil samples falling in medium status of Orgainc carbon is attributed to the rice-wheat cropping system as also explained by Zhang and He (2004); Benbi and Brar (2009); Benbi *et al*., 2012.

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

The data depicted in Table 3 and Figures 6 & 8 revealed that the available zinc, iron, copper, manganese, and boron content of 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, cooper of 98 and 2%, 85 and 15% and 99 and 1% of samples were found sufficient and deficient for Babain block, respectively while, DTPA extractable manganese and available boron had 100% of soil samples under sufficient category.

The soils of the Ladwa block had 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. While 100% of samples fall under the sufficient category of DTPA extractable manganese and boron (Table 4 and Figures 7 & 9). The similar status of micronutrients in the soils of the Kaithal district was reported by Shukla *et al*., 2015, Shabnam (2021) and Mohit Sharma (2022).

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

Block	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)

Blocks	Babain		Ladwa	
Micronutrient	**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

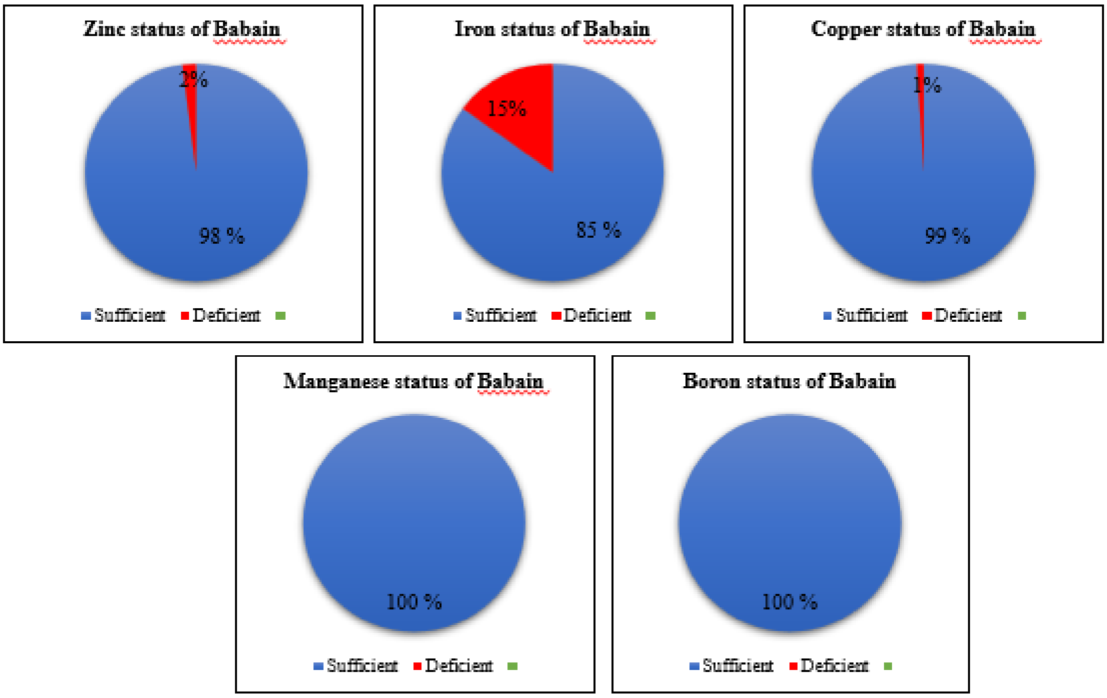

Figure 6: Available micronutrient status in Babain block of Kurukshetra (% of soil samples)

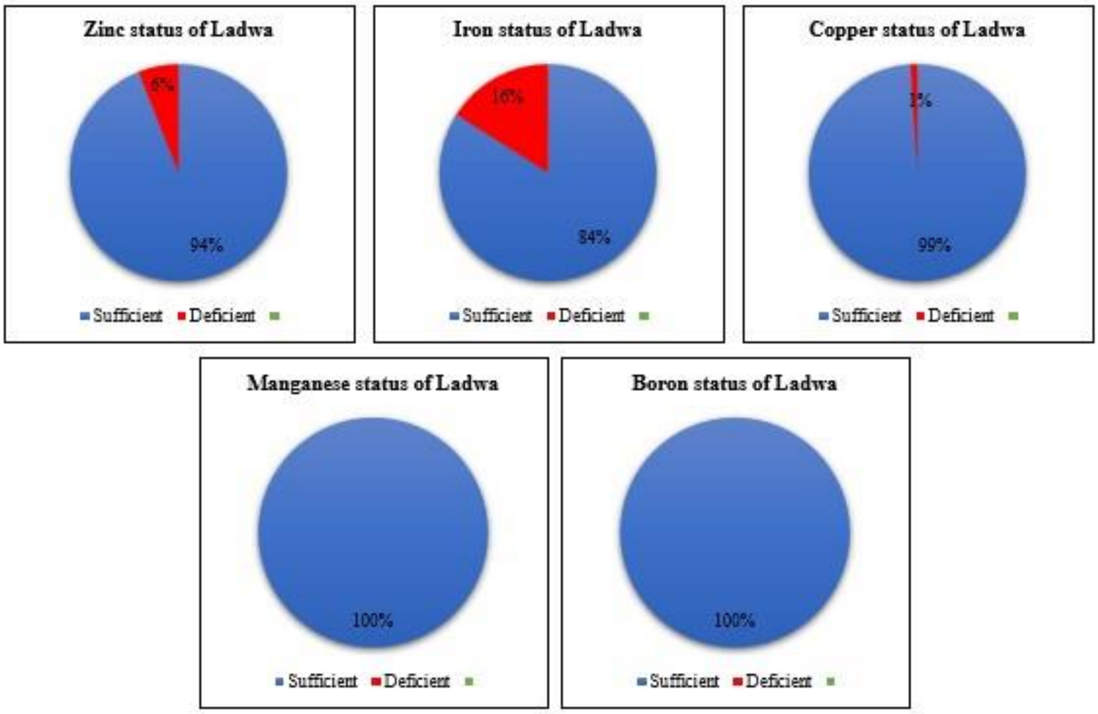

Figure 7: Available micronutrient status in Ladwa block of Kurukshetra (% of soil samples)

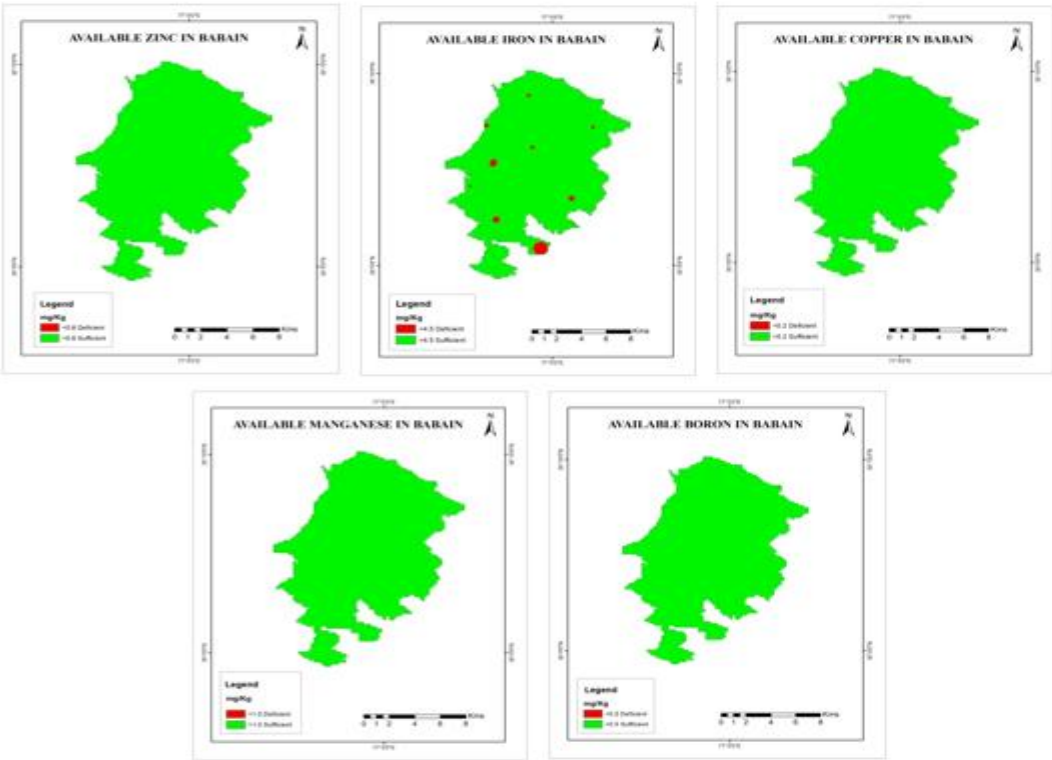

Figure 8: Thematic map of soil micronutrients of Babain block of Kurukshetra

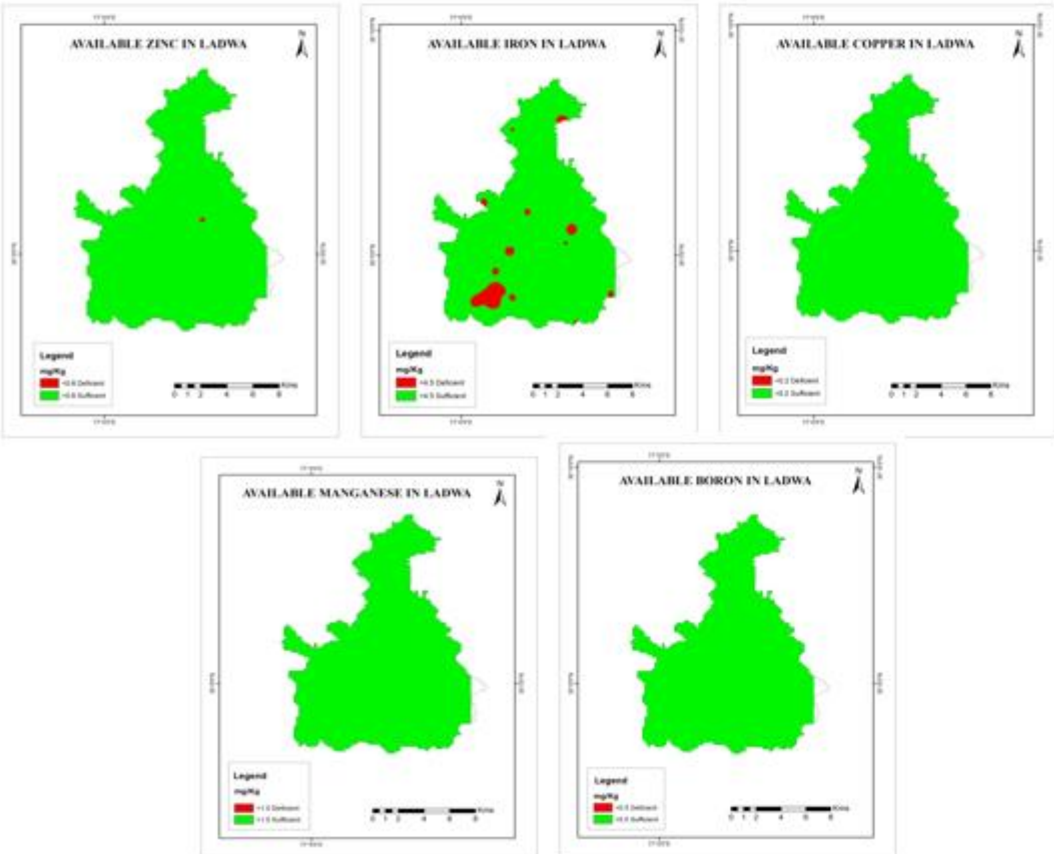

Figure 9: Thematic map of soil micronutrients of Ladwa block of Kurukshetra

3.7. Correlation between soil properties and nutrient status of Babain and Ladwa blocks

The correlation matrix for 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 (Figure 10) as the value of the coefficient of determination. Data showed 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**) and the value of the coefficient of determination for the positive significant positive correlation between OC and N is R^2=0.8277 (Figure 11). Similar results were found by Gyawali *et al.* (2016), Shabnam (2021) and Mohit Sharma (2022) in Kaithal district of Haryana.

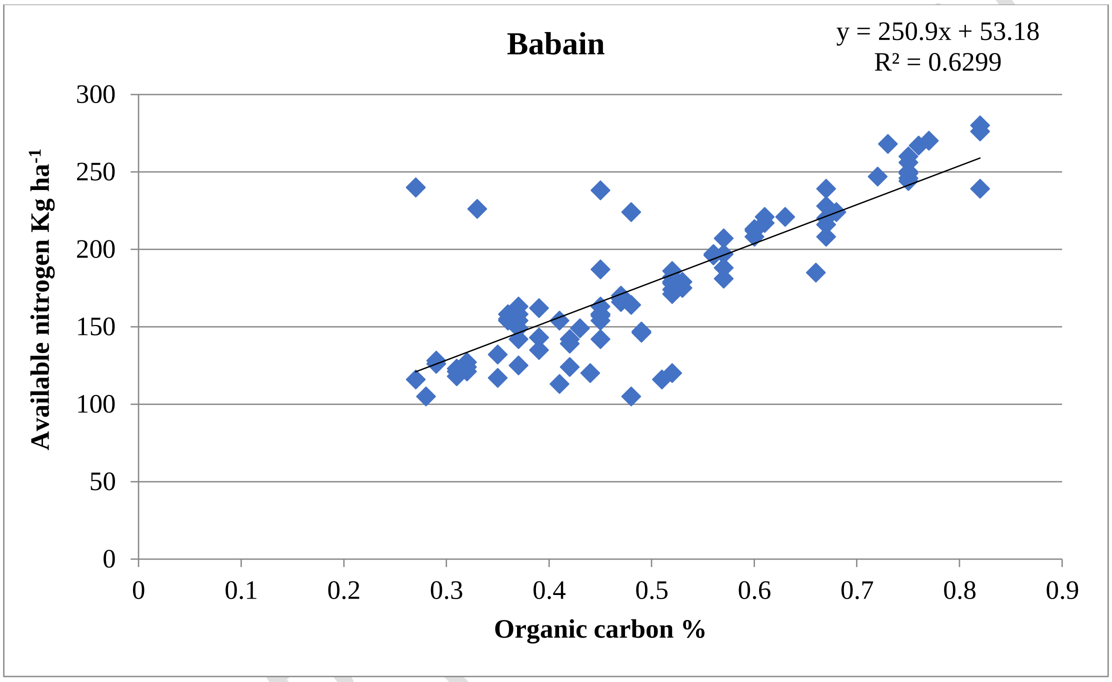

Figure 10: Relationship between OC and available N Babain block

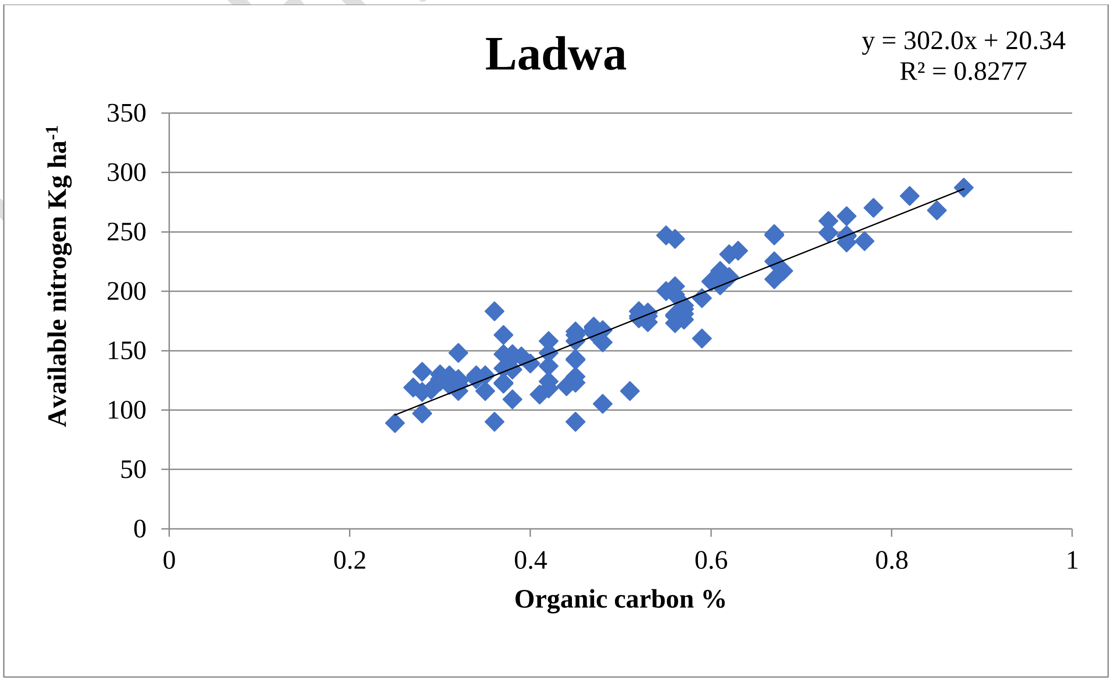

Figure 11: Relationship between OC and available N in Ladwa block

4. Conclusion

The soils of the Babain and Ladwa blocks of Kurukshetra district were, in general, neutral to alkaline in reaction, 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.

To improve soil fertility in future prospect, it is essential to use organic manures that are easily accessible to farmers rather than 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.

References

Benbi, D. K. & Brar, J. S. (2009). A 25-year record of carbon sequestration and soil properties in intensive agriculture. *Agronomy for sustainable development*, 29(2), 257-265.

Benbi, D. K., Toor, A. S., & Kumar, S. (2012). Management of organic amendments in the rice-wheat cropping system determines the pool where carbon is sequestered. *Plant and Soil*, 360(1), 145-162.

Berger, K. C. & Truog, E. (1939). Boron determination in soils and plants. *Industrial & Engineering Chemistry Analytical Edition*, 11, 540-45.

Chesnin, L. & Yien, C. H. (1950). Turbidimetric determination of available sulphates. *Proceedings of Soil Science Society of America Journal*, 14, 149-151.

Gora, V. (2013). Distribution of potassium and sulphur in soils under rice-wheat and cotton-wheat cropping systems of Haryana. M.Sc Thesis, CCS Haryana Agricultural University, Hisar, India.

Gyawali, C., Mohammad, B., Daljit, D., Dev, R. and Rishi, B. (2016). Spatial distribution of physico-chemical properties and macronutrients in rice growing soils of Haryana. *The Ecoscan*, 10, 365-370.

Hegde, R., Kumar, M., Niranjana M. B. K. V., Seema, K. V., and Dhanorkar, B. A. (2021) Study on the soil fertility and mapping in Ramasamudram-1 Microwatershed of Yadgir Taluk and district of Karnataka, India. *International Journal of Bio-resource and Stress Management*, 12(4), 348–360.

Jackson, M. L. (1973) Soil Chemical Analysis. Prentice Hall, New Jersey, USA.

Jyothi, T., & Hebsur, N. (2016). Evaluation of Fertility Status of Selected Bt Cotton Growing Soils of Northern Transition Zone (Zone 8) Of Karnataka. *The Ecoscan*, 10(3 & 4), 449-455.

Kashiwar, S. R., Nath, T., Kumar, D., Kundu, M. C., Dongarwa, U. R., Rajput, B. S., Pandey, S. K., & Dongarwar, L. N. (2018). Evaluation of soil fertility status of Rajiv Gandhi South campus (Banaras Hindu University), Mirzapur, Uttar Pradesh by using GIS. *International Journal of current Microbiology and applied Sciences*, 7, 3825-3836.

Kashiwar, S.R., Kundu, M.C., & Dongarwar, U.R. (2020). Soil fertility appraisal of Bhandara block of Maharashtra using geospatial techniques. *International Journal of Chemical Studies*, 7(5), 2312- 23188.

Lindsay, W. L. & Norvell, W. A. (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Science Society of American Journal*, 42, 421-428.

Mohit. Sharma. (2022). Assessment of soil fertility status of different blocks of Kaithal district, Haryana. M.Sc. Thesis, CCS Haryana Agricultural University, Hisar, India.

Motsara, M.R. (2002) Available NPK status of Indian soils as depicted by soil fertility maps. *Fertilizer News*, 47 (6), 5-21.

Muralidharudu, Y., SammI Reddy, K., Mandal, B.N. Subba Rao,A., Singh, K.N., & Sonekar, S. (2011) GIS. Based soil fertility maps of different status of India. AICRP-STCR IISS, Bhopal. 1-221

Nafiu, A. K., Abiodun, M. O., Okpara, I. M., & Chude, V. O. (2012). Soil fertility evaluation: A potential tool for predicting fertilizer requirement for crops in Nigeria. *African Journal of Agricultural Research*, 7(47), 6204-6214.

Nazif, W., Perveen, S., & Saleem, I. (2006). Status of micronutrients in soils of district Bhimber (Azad Jammu and Kashmir). *Agricultural and Biological Science*, 1(2), 35-40.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available P in soils by extracting with sodium bicarbonate. *Circular of United States Department of Agriculture*, 939.

Prem, G., Kumar, A., Choudhary, R., Singh, V. D., Kumar, R., & Kumar, A. (2017). Mapping of available nutrients in soils of Ambala district (Haryana)– A GIS approach. *Asian Journal of Soil Science*, 12(1), 86-93.

Shabnam. (2021). Status of macro and micro nutrient in soils of Kaithal and Siwan blocks, district Kaithal. M.Sc. Thesis, CCS Haryana Agricultural University, Hisar, India.

Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C., & Pannu R.S. (1998). Statistical software Package for agricultural research workers. Recent Advances in Information Theory, Statistics and Computer Applications by D.S Hooda and R.C. Hasija, Department of Mathematics and Statistics, CCSHAU, Hisar. 139-143.

Shukla, A. K., Malik, R. S., Tiwari, P. K., Prakash, C., Behera, S. K., Yadav, H., & Narwal R. P. (2015). Status of micronutrient deficiencies in soils of Haryana. *Indian Journal of Fertilizers*, 11(5) 16-27.

Singh, A., Phogat, V. K., Dahiya, R., & Batra, S.D. (2014). Impact of long-term zero till wheat on soil physical properties and wheat productivity under rice–wheat cropping system. *Soil and Tillage Research*, 140, 98-105.

Singh, M., Grewal, K. S., Panwar, B. S., & Narwal, R. P. (2011). GPS and GIS based fertility maps of major nutrients in soils of Haryana. Research Bulletin, Department of Soil Science, CCS Haryana Agricultural University, Hisar, 18-27.

Singh, S.K, Pal, S., Singh, P., Tiwari, S., Kashiwar, S.R., & Kumar, A., (2022). Spatial variability of soil chemical properties in Patna, Vaishali and Saran district adjoining the Ganga River, Bihar, India. *International Journal of Bio-resource and Stress Management*, 13(3), 283–291.

Singh, Y.P., Raghubanshi, B.P.S., Tomar, R. S., Verma, S.K., & Dubey, S.K. (2014) Soil fertility status and correlation of available macro and micronutrients in Chambal Region of Madhya Pradesh. *Journal of the Indian Society of Soil Science*, 62 (4), 369- 375.

Srivastava, A. K. & Singh, S. (2009). Citrus Decline: Soil Fertility and Plant Nutrition. *Journal of Plant Nutrition*, 32(2), 197–245.

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

Swaminathan, M. (2002). Excluding the Needy: The Public Provisioning of Food in India. *Social Scientist*, 30(4), 34-58.

Tagung, T., Singh, SK., Singh, P., Kashiwar, S.R., & Singh, S.K. (2022). GPS and GIS based soil fertility assessment and mapping in blocks of Muzaffarpur district of Bihar. *Biological Form- An International Journal,* 14(3), 1663–1671.

Walkley, A. & Black, I. A. (1934). An examination of Dagjareff methods for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37, 29- 37.

Zhang, M. & He, Z. (2004). Long-term changes in organic carbon and nutrients of an Ultisol under rice cropping in southeast China. *Geoderma,* 118(3-4)**,** 167–179.