Journal of Soil Salinity and Water Quality 17(1), 59-67, 2025
DOI: https://doi.org/10.56093/jsswq.v17i1.166600

Soil Fertility Assessment in Sirsa District of Haryana Using Geo-spatial Techniques

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Abstract

This study was conducted to evaluate the soil fertility status of Sirsa district of Haryana state, India for sustainable soil management, enhancement of nutrient use efficiency and crop productivity. In 2022, a soil survey carried out which involved the collection of 350 surface soil samples from a depth of 0–15 cm using a systematic sampling method with GPS coordinates. The samples were analyzed for soil pH, electrical conductivity (EC), and the available of nitrogen (N), phosphorus (P), potassium (K), and sulfur (S). The Sulfur Availability Index (SAI) and Soil Nutrient Index (SNI) were calculated based on previously established indices. High-resolution spatial distribution maps of the Sirsa district were prepared to depict the fertility status. The soils were non saline, and slightly to moderately alkaline in nature. Out of total area (4276 km^2), entire area was low in available N, about 62% and 51% area were medium in OC and available K, respectively, while about 56% and 58% area were high in available P and S, respectively. Nutrient index values of the district for OC and available K were medium, available N was low and available P and S were high. Sulfur availability index of the district was 8.17. Based on the study, it can be concluded that farmers are encouraged to apply chemical fertilizers based on the soil test results, complemented by bio-fertilizers and organic manures. This integrated nutrient management (INM) approach offers an effective strategy for maintaining soil fertility and promoting sustainable crop production in the region.

Key words: Soil survey, Soil fertility, Soil Nutrient Index, Sulfur Availability Index, Integrated Nutrient Management

Introduction

World human population was estimated to increase by 19.7 percent from 8.1 billion in 2023 to 9.8 billion in 2050 (FAO, 2009; United Nations, 2017). In order to feed constantly growing population, it is essential to increase the anticipated food production either through area expansion or productivity enhancement. The soil fertility status is the backbone of high agricultural productivity in input-driven systems (Marschner, 2008; Parnes, 2013). Soil is the cradle for all crops and plants, so it is utmost important resource. (Desavathu *et al.,* 2018). Additionally, diminishing soil health limits the production potential of the available resources (Fagodiya *et al*., 2023; Gathala *et al*., 2020). The assessment of soil fertility is essential for the optimization of agricultural ecosystems and sustainability (Yageta *et al*., 2019).

Haryana is an agrarian state of India having only 1.33% of the geographical area (TGA) of the country and contributes around 7% to nation's food grain production. The production of food grains has increased five-fold over the past 67 years, and this, combined with an insufficient and imbalanced usage of nutrients, has resulted in an over-mining of all the essential nutrients (Pathak and Fagodiya, 2022). Nutrient over-mining needs to be ceased when soil health is to be maintained, which is urgently needed to sustain the nation's food and nutritional security. (Raj *et al*., 2020). Soil health has declined as a result of intensive agriculture, which relies on the production of high-yielding cereals and other crops, resulting in nutrient depletion from the soil and use of chemical fertilizers and pesticides without any appropriate dosage. (Singh *et al*., 2019). Therefore, a thorough knowledge of soil fertility provides a better identification of soil nutrient patterns and their trends in the current situation (Dafonte *et al*., 2010). A precise measurement of the soil fertility and degradation is necessary to formulate and carry out national agricultural policies for decision makers (Cahn *et al*., 1994). The soil fertility maps aid in predicting deficiencies or sufficiencies, based on which crop-specific fertilizer recommendations can be made to maintain crop productivity and also discourage the overuse of fertilizers (Sathyanarayana *et al*., 2021). Keeping all the above-mentioned points in view, this study was conducted in Sirsa district of Haryana state, India with the objectives: (i) to evaluate the status of soil pH, EC, organic carbon (OC), and available nitrogen (N), phosphorus (P), potassium (K), Sulfur (S), and (ii) to analyze the spatial distribution of soil fertility parameters.

Material and Methods

Description of the study area

Sirsa is the north western district of Haryana State and located between 29°14′ to 30°0′ N latitude and 74°29′ to 75°18′ E longitudes. It has a total geographical area of 4276 km^2 and a total cultivated area of 4050 km^2. The study area includes all seven blocks of the district viz. Nathusari Choupta, Rania, Sirsa, Baragudha, Odhan, Ellenabad and Dabwali (Fig. 1). The climate of Sirsa district is tropical desert type arid and hot. The mean maximum and minimum temperature is 41.1°C (May-June) and 5.1°C (January), respectively. The annual average rainfall of the district is 318 mm and the monsoon rainfall is 253 mm. The soils of the district are sandy (S) to sandy loam (SL) in texture. Major cropping systems growing in the area were cotton- wheat, rice – wheat, groundnut – mustard, pearl millet – wheat, guar – mustard, mungbean – wheat and guava.

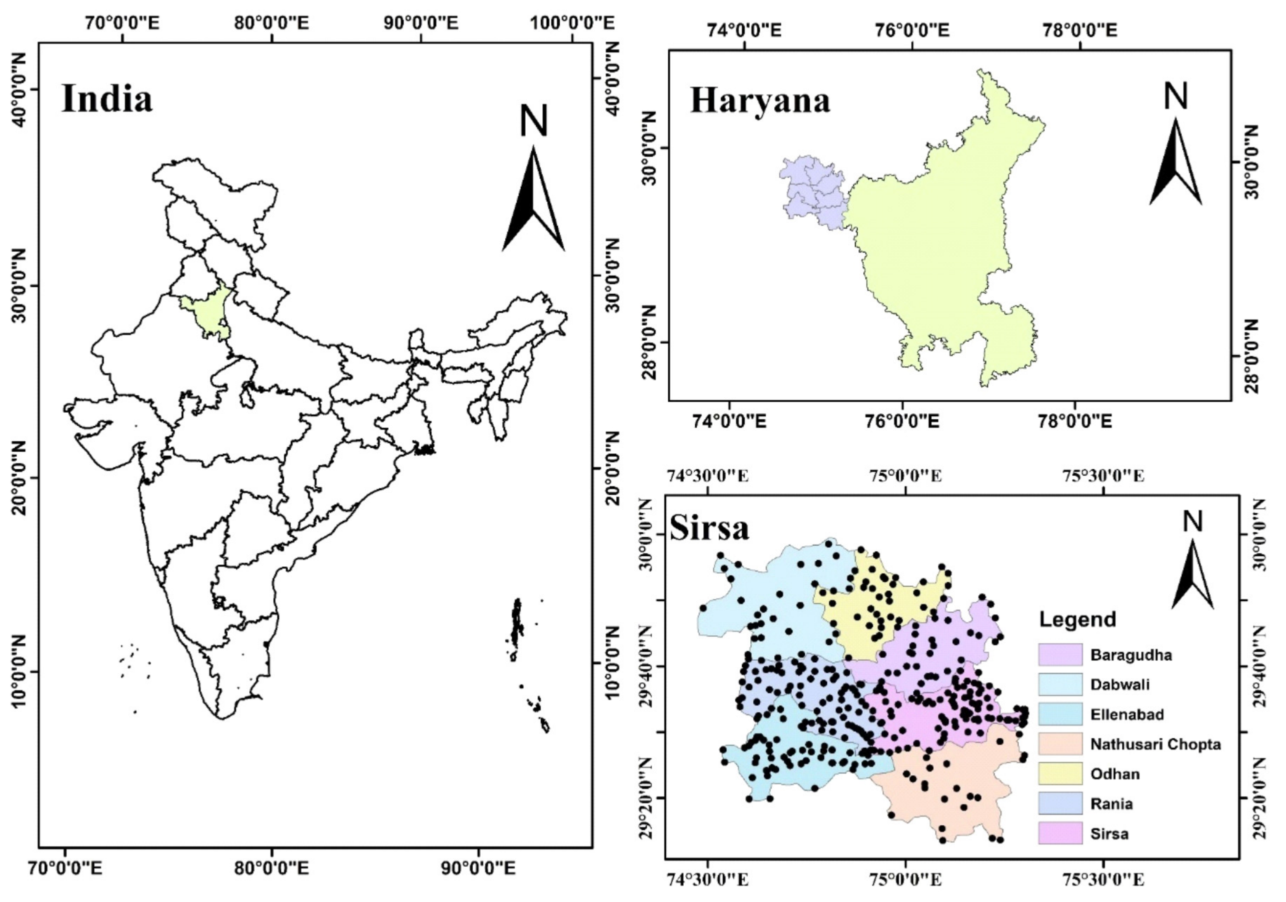


Fig. 1 Location map and spatial distribution of sampling sites of study area

Soil sampling and laboratory analysis

Total 350 surface soil samples (0-15 cm depth) were randomly collected from all seven blocks of the Sirsa district. In order to prevent the effects of recent fertilization during the crop growing season, the samples were taken after harvest (of rabi crops) and before the following cropping season (kharif crops) (2022). A handheld Global Positioning System (GLandMeasure) was used to record the co-ordinates. All of the samples were brought into the lab, air-dried, manually crumbled to remove the root materials, and then passed through 2 mm sieve. The samples were sieved through 100 mesh sieve (0.5 mm) for determining organic carbon (OC). The pH and electrical conductivity of soils were measured using 1:2 soil-water suspension following the standard procedures as outlined by Jackson (1973). Organic carbon (OC) was determined through the rapid titration method (Walkley and Black, 1934). Available nitrogen (N) was estimated by alkaline permanganate method outlined by Subbiah and Asija (1956). The Olsen method (1954) was used to measure available phosphorus (P), utilizing sodium bicarbonate ($NaHCO_3$) as the extracting agent. Available potassium (K) was determined using the ammonium acetate extraction method while available sulfur (S) was measured using 0.15% calcium chloride ($CaCl_2$) as an extract described by Chesnin and Yien (1950).

Statistical analysis and map creation

Descriptive statistics of the analysed soil data viz., minimum, maximum value, mean and standard deviation were determined using SPSS software (29.0.1.0). The spatial variability of soil fertility parameters were estimated using ArcGIS 10.8 for windows, while the interpolation method was employed for ordinary kriging. Kriging is one of the best interpolation techniques for spatial interpolation of soil parameters (Malla *et al.*, 2020).

The nutrient index was developed by Parker et al. (1951) to assign a single value to each nutrient and enable the comparison of soil fertility levels between different regions.

$$\text{Nutrient index} = \frac{(N_l \times 1) + (N_m \times 2) + (N_h \times 3)}{N_t}$$

where,

N_t = Number of samples analyzed for a particular nutrient in give area;

N_l = number of samples with low nutrient status (low category);

N_m = number of samples with medium nutrient status (medium category); and

N_h = number of samples with high nutrient status (high category)

Additionally, according to NI, the soil fertility level was divided into three categories: low (1.67), medium (1.67–2.33), and high (>2.33).

The formula described by Donahue *et al.* (1977) was used to calculate the Sulfur Availability Index (SAl) as follows:

SAI = (0.4 × $CaCl_2$ extractable SO_4^{2-} in mg kg^{-1} soil + % organic matter)

Results and Discussion

Physico-chemical properties of soil

The descriptive statistics values indicating maximum, minimum, mean, and standard deviation for the soil fertility parameters of Sirsa district are provided in Table 1. The pH_2 range of Sirsa district was 7.41–8.70 with mean value of 8.27 indicated the slightly to moderately alkaline soils. Among all different blocks of Sirsa the highest pH_2 value was observed in Odhan block (8.35) whereas, minimum pH_2 was observed in Sirsa block (8.20) (Fig. 2a). The use of basic fertilizer, which causes the reaction of basic cations on the exchangeable complex, might be the cause of the alkaline pH_2 (Meena *et al.*, 2006). In addition, this was also might be due to the presence of basic parent material and high degree of base saturation (Gora, 2013). The range of electrical conductivity (EC_2) of the district was normal and varied non-significantly between 0.12 and 0.95 dS m^{-1} with average value of 0.45 dS m^{-1} (Table 1 and Fig. 2b).

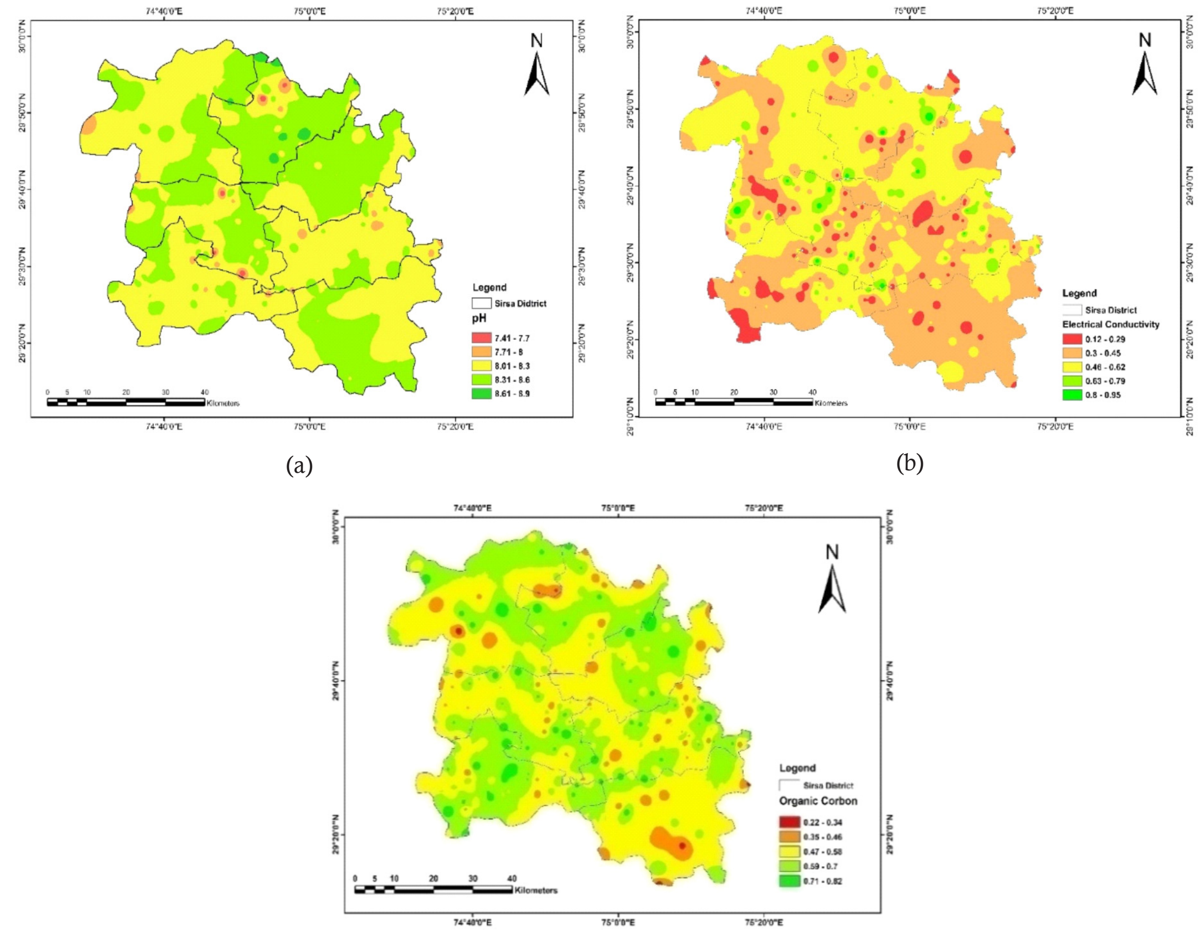
Sirsa district showed variation in organic carbon (OC) ranged from from 0.22 to 0.82%, with a mean value of 0.57%. About 28.86%, 63.42% and 7.71 % area of the district was in low, medium

Table 1. Descriptive statistics of soil chemical properties of various blocks of Sirsa district

Indicators	pH_2	EC_2 (dS m^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	SAI
Sirsa district (N=350)								
Maximum	7.41	0.12	0.22	79.14	5.90	96	8.59	1.80
Minimum	8.70	0.95	0.82	225.80	51.03	637.62	89.15	16.63
Mean	8.27	0.45	0.57	144.39	26.06	247.09	42.6	8.17
SD	0.2	0.19	0.12	18.19	9.34	106.66	17.07	3.11
Block –Nathusari Choupta (N=20)								
Minimum	8.10	0.15	0.27	79.14	7.39	96	8.59	1.80
Maximum	8.40	0.49	0.76	156.65	40.63	409	59.83	11.32
Mean	8.29	0.35	0.50	134.74	21.93	203.35	37.43	7.18
SD	0.10	0.10	0.13	18.27	10.08	91.24	15.07	2.80
Block -Rania (N=79)								
Minimum	7.41	0.14	0.37	119.17	8.57	116	8.89	2.08
Maximum	8.60	0.95	0.80	225.80	51.03	637.62	84.37	15.81
Mean	8.30	0.46	0.58	151.68	26.97	253.06	44.31	8.49
SD	0.27	0.23	0.12	20.93	10.14	115.93	16.68	3.04
Block -Sirsa (N=94)								
Minimum	7.61	0.18	0.31	108.99	6.62	110	8.65	2.07
Maximum	8.40	0.90	0.78	179.07	47.03	563	89.15	16.63
Mean	8.20	0.47	0.56	145.64	26.84	232.61	42.81	8.21
SD	0.18	0.19	0.13	16.39	9.25	98.02	19.36	3.49
Block -Baragudha (N=33)								
Minimum	7.90	0.14	0.31	107.32	7.03	107	8.79	1.88
Maximum	8.50	0.89	0.77	172.64	45.80	543	67.80	12.66
Mean	8.34	0.47	0.57	136.56	24.99	280.42	39.24	7.58
SD	0.14	0.18	0.12	15.48	9.73	101.81	15.93	2.88
Block -Odhan (N=38)								
Minimum	7.41	0.15	0.33	91.10	7.85	100.06	8.89	2.02
Maximum	8.70	0.92	0.78	160.52	36.75	485	72.2	13.6
Mean	8.35	0.49	0.56	142.83	24.58	284.13	40.15	7.73
SD	0.29	0.21	0.12	15.02	7.97	108.24	13.75	2.54
Block -Ellenabad (N=56)								
Minimum	7.90	0.12	0.32	102.72	8.99	117	8.69	1.87
Maximum	8.40	0.69	0.82	212.62	41.73	570	75.69	14.15
Mean	8.27	0.39	0.57	144.52	27.93	242.86	46.78	8.93
SD	0.11	0.17	0.11	17.63	8.12	110.81	16.96	3.09
Block -Dabwali (N=30)								
Minimum	7.85	0.16	0.22	89.32	5.90	115	8.65	1.86
Maximum	8.45	0.75	0.77	158.64	41.12	490	74.21	14.02
Mean	8.23	0.45	0.56	138.04	23.59	230.23	39.88	7.68
SD	0.15	0.18	0.13	15.94	9.45	96.65	15.86	2.94

EC: Electrical Conductivity; OC: Organic Carbon; N: Available Nitrogen; P: Available Phosphorus; K: Available Potassium; S: Available Sulfur; SAI: Sulfur Availability Index

and high in OC status, respectively. Rania (0.58%) block showed highest OC followed by Baragudha (0.57%) and Ellenabad (0.57%) blocks, whereas Nathusari Choupta (0.50%) block showed lowest OC (Table 1). These results are further confirmed by a comparison of the estimated nitrogen values with the critical limits for determining soil fertility, which showed that about 31% of study area was low and 62% area was medium in OC status, respectively (Fig. 2c). Low to medium organic carbon content in all blocks was likely due to higher rates of decomposition of organic matter



(c)

Fig. 2 Spatial variability of soil (a) pH and (b) EC and (c) soil organic carbon (%) Sirsa district

in hyperthermic temperature regime and good soil aeration owing to sandy and sandy loam soil texture, which results in extremely high oxidizing conditions (Antil *et al.*, 2016; Gora, 2013).

Available nutrients

It was observed that the soils of Sirsa district were low in available nitrogen (100% area) and varied form 79.14-225.80 kg ha^{-1} and their mean value was 144.39 kg ha^{-1}. Among different blocks, Rania block (151.68 kg ha^{-1}) had highest available N while Nathusari Choupta had lowest available N (134.74 kg ha^{-1}) content (Table 1 and Fig. 3a). Leaching and volatilization losses of applied N from nitrogenous fertilizers are likely to be responsible for the low status of available nitrogen (Meena *et al.*, 2006; Singh *et al.*, 2011, 2014). The significant correlation (R^2 = 0.5725) between the organic carbon content and the available nitrogen can be used to further hypothesize that because the OC content of these soils is on the lower side, it may be interpreted as lower values of available N (Fig. 4a).

It was found that the available phosphorus of district ranged between 5.90 and 51.03 kg ha^{-1} with a mean of 26.06 kg ha^{-1}. Among the blocks, Ellenabad block had 27.93 kg ha^{-1} as highest average value and Nathusari Choupta block had 21.93 kg ha^{-1} as lowest value of available P. About 13%, 31% and 56% of study area was low, medium and high in available P status, respectively (Table 1 and Fig. 3b). The variations in the status of available P in these soils might be due to continuous application of phosphate fertilizers (Singh *et al.*, 2011). The regression coefficient (R^2 = 0.6334) between organic carbon content and available phosphorus was also higher (Fig. 4b). The soil properties that affect the availability, fixation, and transformation of phosphorus in the soil are pH, texture, organic carbon content and

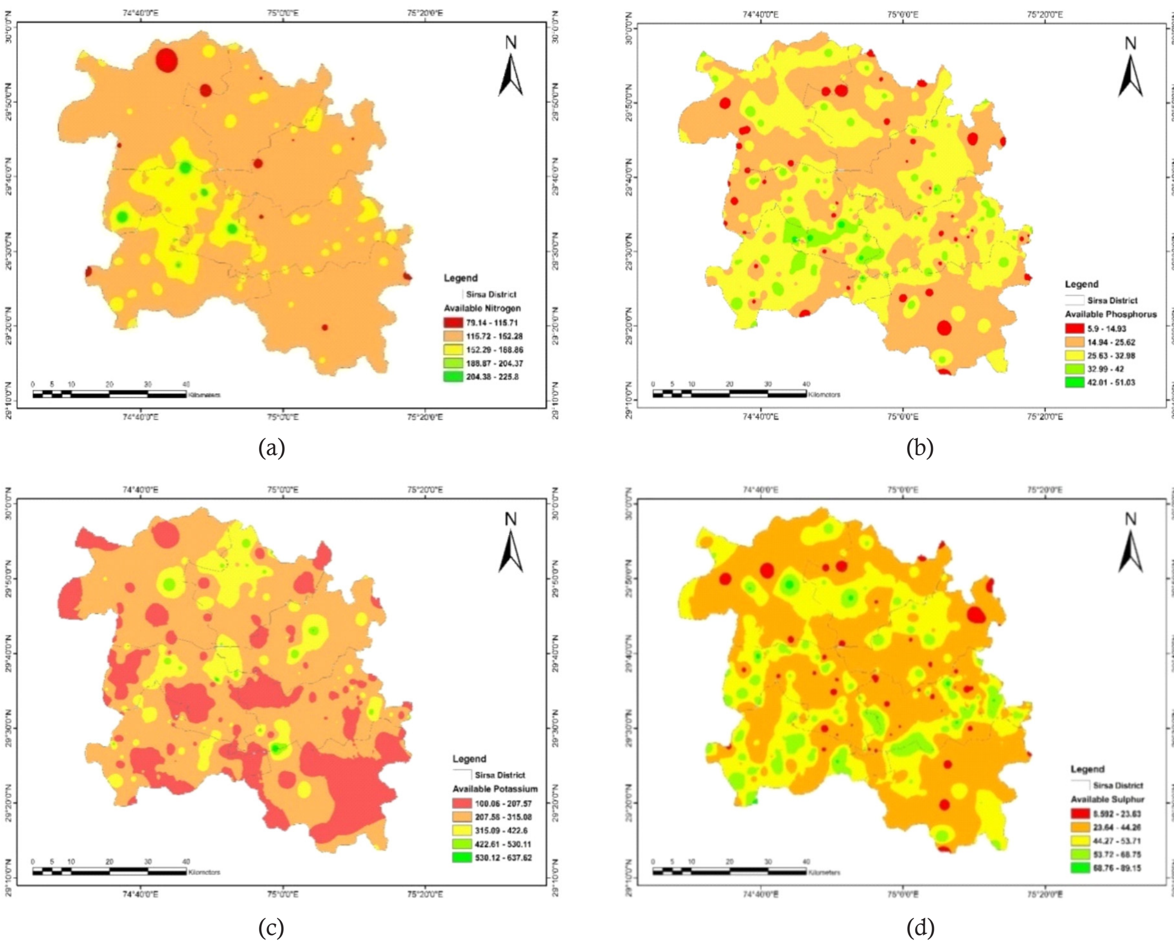


Fig. 3 Spatial variability of available (a) nitrogen (kg ha^{-1}), and (b) phosphorus (kg ha^{-1}), (c) potassium (kg ha^{-1}) (d) Sulfur (kg ha^{-1}) status of Sirsa district

various management practices (Singh *et al.*, 2011). The available K varied from 96 to 637.62 kg ha^{-1} with a average value of 247.09 kg ha^{-1}. Highest value of available K was observed in Rania block (637.62 kg ha^{-1}) whereas lowest value was observed in Nathusari Choupta block 203.35 kg ha^{-1}. About 18, 51 and 31% of study area had low, medium and high levels of available K, respectively (Table 1 and Fig 3c). The medium to high amount of available K in soil might be due to parent material like feldspar and illite, which contain significant amounts of potassium (Sharma *et al.*, 2012). The lower value of available K might be due to intensive cultivation and long-term continuous uptake of potassium by field crops without application of potassium fertilizer (Singh *et al.*, 2011).

The available S values of district ranged in between 8.59-89.15 kg ha^{-1} with a mean value of 42.6 kg ha^{-1}. Highest and lowest mean values of available S were recorded in Ellenabad (46.78 kg ha^{-1}) and Nathusari Chuopta blocks (37.43 kg ha^{-1}), respectively. Similarly, Sulfur availability index (SAI) of the district varied from 1.18-16.63 with mean value of 8.17. Highest and lowest SAI was recorded in Ellenabad (8.93) and Nathusari Chuopta block (7.18) blocks, respectively. Out of total area about 29 and 58% of study area was medium and high in available S status (Table 1 and Fig. 3d). The elevated level of available sulphur in these rice growing soils might be due to sulphur rich parent material and the routine application of zinc sulphate as a common recommendation to address zinc deficiency in rice-wheat cropping system (Narwal *et al.*, 2011). The significant correlation (R^2 = 0.5585) between the organic carbon content and the available sulfur might also be reason of such variation (Fig. 4c).

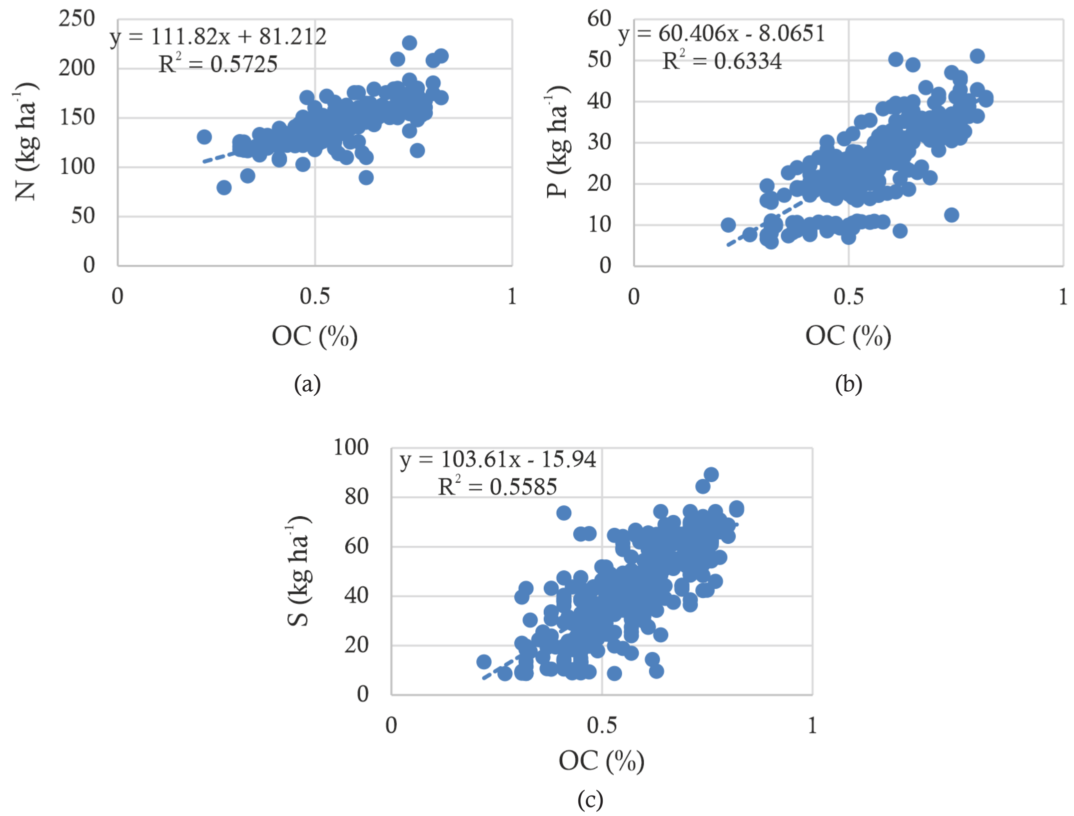


Fig. 4 Correlation between soil organic carbon and (a) available nitrogen, (b) available phosphorus, and (c) available Sulfur

Nutrient index value

Nutrient index (NI) values were calculated to evaluate the overall nutritional status of organic carbon (OC), available nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) in the study area. The NI values of different blocks of the Sirsa district are presented in Table 2. NI values of OC were found medium in all the blocks except Nathusari Choupta block where it was low. Available N was low in all the blocks and overall district. In Rania, Sirsa, Baragudha, Odhan and Ellenabad blocks, available P was high whereas Nathusari Choputa and Dabwali blocks it was medium. Overall district was high in available P status. In a similar manner, NI values of available potassium were medium for all the blocks and overall district. Similarly, NI value of available sulfur for all the blocks was high except Nathusaru Choupta block where it was low.

Table 2. Nutrient index value of various blocks of Sirsa district

S.No.	Block	OC	N	P	K	S
1.	Nathusari Choupta	1.65	1.00	2.15	1.95	2.30
2.	Rania	1.76	1.00	2.39	2.19	2.56
3.	Sirsa	1.77	1.00	2.65	2.07	2.37
4.	Baragudha	1.88	1.00	2.39	2.27	2.36
5.	Odhan	1.79	1.00	2.34	2.34	2.37
6.	Ellenabad	1.88	1.00	2.64	2.11	2.59
7.	Dabwali	1.83	1.00	2.23	2.07	2.35
	Overall district	1.76	1.00	2.42	1.84	2.44

OC: Organic Carbon; N: Nitrogen; P: Phosphorus; K: Potassium; S: Sulfur

Conclusion

The study emphasized that soil fertility assessment helps in identifying areas requiring targeted soil and crop management strategies, thereby enhancing soil health and agricultural productivity. From the study, it can be concluded that the soils of Sirsa district were mostly non saline and slightly to moderately alkaline in the reaction. Soil fertility attributes showed low levels of available N, medium levels of OC and high levels of available K and available P and S. Application of organic manures needs to be encouraged in these soils apart from crop residue incorporation as the soils has low to medium organic carbon content. The Judicious use of fertilizers along with organic inputs in the soils particularly nitrogen and potassium is need of hour. Therefore, farmers are encouraged to use chemical fertilizers according to soil test results combined with bio-fertilizers, and organic manures as a part of integrated nutrient management (INM) approach for maintaining soil fertility and promote sustainable crop production in this area.

Acknowledgements

The authors are thankful to the Chaudhary Charan Singh Haryana Agricultural University, Hisar 125004, Haryana, India for providing platform for research work and internal review of the manuscript.

Conflict of interest: On the behalf of all authors, the corresponding author states that there is no conflict of interest.

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Received: May 13, 2025; Accepted: June 25, 2025