International Journal of Research in Agronomy 2024; SP-7(2): 24-34

International Journal
of
Research in Agronomy

Geospatial variability of micronutrient distribution in the Northern Himalayan Terrain of Kashmir

Ayman Javed, Shaista Nazir, Zahida Rashid, Yasir Hanif Mir, Shahid A Hakeem and Javid A Bhat

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
www.agronomyjournals.com
2024; SP-7(2): 24-34
Received: 02-12-2023
Accepted: 10-01-2024

Ayman Javed
Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Shaista Nazir
Division of Soil Science, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Zahida Rashid
Dryland Agriculture Research Station, Rangreth, Srinagar, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Yasir Hanif Mir
Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Shahid A Hakeem
Krishi Vigyan Kendra, Kupwara, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Javid A Bhat
Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Corresponding Author:
Yasir Hanif Mir
Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

DOI: https://doi.org/10.33545/2618060X.2024.v7.i2Sa.318

Abstract

The recognition of geographical variations in soil properties holds significant importance in the identification of polluted regions and the implementation of agricultural practices. The primary objective of this investigation was to generate nutrient maps that can be utilised for the implementation of site-specific nutrient management strategies. This was achieved by examination of geospatial interdependence and variability of micronutrients. Soil samples from district Kupwara were analysed to determine the particle size distribution, organic carbon (OC), and levels of accessible copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), and nickel (Ni). An atomic absorption spectrometer (AAS) was utilized for accurate measurement of element concentrations. The samples were collected utilising ArcGIS (10.2) with a randomised grid pattern. Microelements exhibited significant heterogeneity, as indicated by a coefficient of variation (CV) exceeding 28.05%. Descriptive statistics for the research region reveal noteworthy accumulations of DTPA-extractable Fe, Zn, Cu, and Mn, Ni concentrations were relatively lower. Probability distributions of soil microelements indicated that zinc and copper are the only elements that exhibit approximately normal distributions. The research underscores the significance of establishing nutrient management zones, particularly to optimise zinc availability in agricultural systems. The spatial variability maps generated holds the potential to serve as a valuable resource for precise and location-specific micronutrient management within the designated research region.

Keywords: Geospatial analysis, micronutrients, soil fertility, soil organic carbon, kriging

Introduction

Micronutrients play a pivotal role in ensuring soil health and optimizing crop productivity, with their scarcity being a natural occurrence. The provision of essential micronutrients by the soil is imperative for promoting plant development and producing nutritious food for human consumption. However, the widespread adoption of high-yielding crop varieties, advanced cropping techniques, and the extensive use of high-analysis NPK fertilizers have led to a decline in soil micronutrient levels, falling below acceptable agricultural output standards. This micronutrient deficit has significantly impacted agricultural productivity, sustainability, and stability.

Soil health, indicating the ability to support terrestrial ecosystem productivity, diversity, and environmental functions, is a crucial factor affecting plants, animals, humans, and the overall environment (Lal *et al.*, 2021) [10]. Concerns regarding soil deterioration are widespread globally, driven by factors such as erosion, waterlogging, salinity, alkalinity, acidity, and fertility loss. The main cause of these concerns is a decline in plant-available nutrients (Bhattacharyya *et al.*, 2015; Saljnikov, 2022) [2, 21]. Various regions, including hilly terrains, plains, arid and semi-arid areas, desert ecosystems, and peninsular, central, and coastal zones, are experiencing soil deterioration. The Indian Himalayan regions (IHR), encompassing 18% of the nation, are particularly significant, influencing critical ecosystem functions such as carbon sequestration and climate management. Anthropogenic activities, notably agricultural practices, stand out as the primary contributors to soil deterioration in these regions (Bhattacharyya *et al.*, 2015) [2]. With the decline in soil fertility and the increasing prevalence of nutrient shortages in cultivated soils worldwide (Hartemink, 2006; Jones *et al.*, 2013) [6-7], issues arise from factors such as high-yielding crops, excessive nutrient extraction, inadequate nutrient replenishment, and unsustainable soil-crop management practices. Numerous studies have identified micronutrient deficiencies, including zinc, iron, copper, manganese, boron, and molybdenum, in agricultural soils (Alloway, 2008; Shukla and Behera, 2019; Kihara *et al*., 2020) [1, 22]. Therefore, implementing effective soil management practices becomes imperative to preserve or improve soil parameters, thereby addressing global issues such as land degradation, global warming, poverty, and hunger (Keesstra *et al*., 2018) [8]. Therefore, comprehending the intricate dynamics and intrinsic properties of soil at local, regional, and national levels is essential to develop accurate and successful agricultural management strategies.

The spatial and temporal variations in soil fertility parameters are influenced by intrinsic soil features such as clay and iron oxide concentration, as well as human activities. Understanding the geographical and temporal variations in soil fertility parameters is vital for enhancing soil fertility management recommendations (Li *et al*., 2021; Tomaz *et al*., 2022) [12, 25]. Conducting soil surveys and creating geographical distribution maps to illustrate patterns and changes is essential for studying spatio-temporal variability in soil characteristics. Spatial variability maps of soil characteristics, facilitated by geostatistical methods, aid in implementing site-specific soil nutrient management strategies. Previous studies have demonstrated the efficacy of geostatistical methods, such as indicator kriging, in mapping the spatiotemporal variability of micronutrient concentrations in agricultural landscapes (Mohammadi *et al*. 2017; Tamburi *et al*. 2019) [16, 24]. However, limited information is available on the regional variability of soil fertility characteristics, particularly active soil organic matter and micronutrient availability, in farmed soils. Therefore, this study aims to assess and map the geographical variability of soil organic carbon and micronutrients (Zn, Fe, Mn, Cu, and Ni) under temperate climatic conditions in Kupwara (J&K), addressing the research gap regarding the regional variability of soil fertility characteristics in cultivated soils.

Materials and Methods

Study area

The current assessment was undertaken in the village of Sogam, situated within the Kupwara district. The geographical coordinates for the area are 34° 30'51.2" N Latitude and 74° 22'44.7" E Longitude (Figure 1). Sogam is positioned at an elevation of 1788 meters above mean sea level, encompassing a total area of 4510.90 hectares. Of this expanse, 71.92 per cent is deemed cultivable, and 63.09 per cent is designated as irrigated land. The region experiences a temperate climate characterized by mild summers and cold winters. The standard minimum annual temperature is recorded at 6.3 °C, with a maximum of 19.9 °C. The annual precipitation in this locale amounts to 1138.4 mm. Various land uses prevail in the area, including the cultivation of cereals such as rice, maize, wheat, barley, and oats. Additionally, oilseeds, fruits (Specifically apples), vegetables, forests, and pastures constitute the primary land utilization practices.

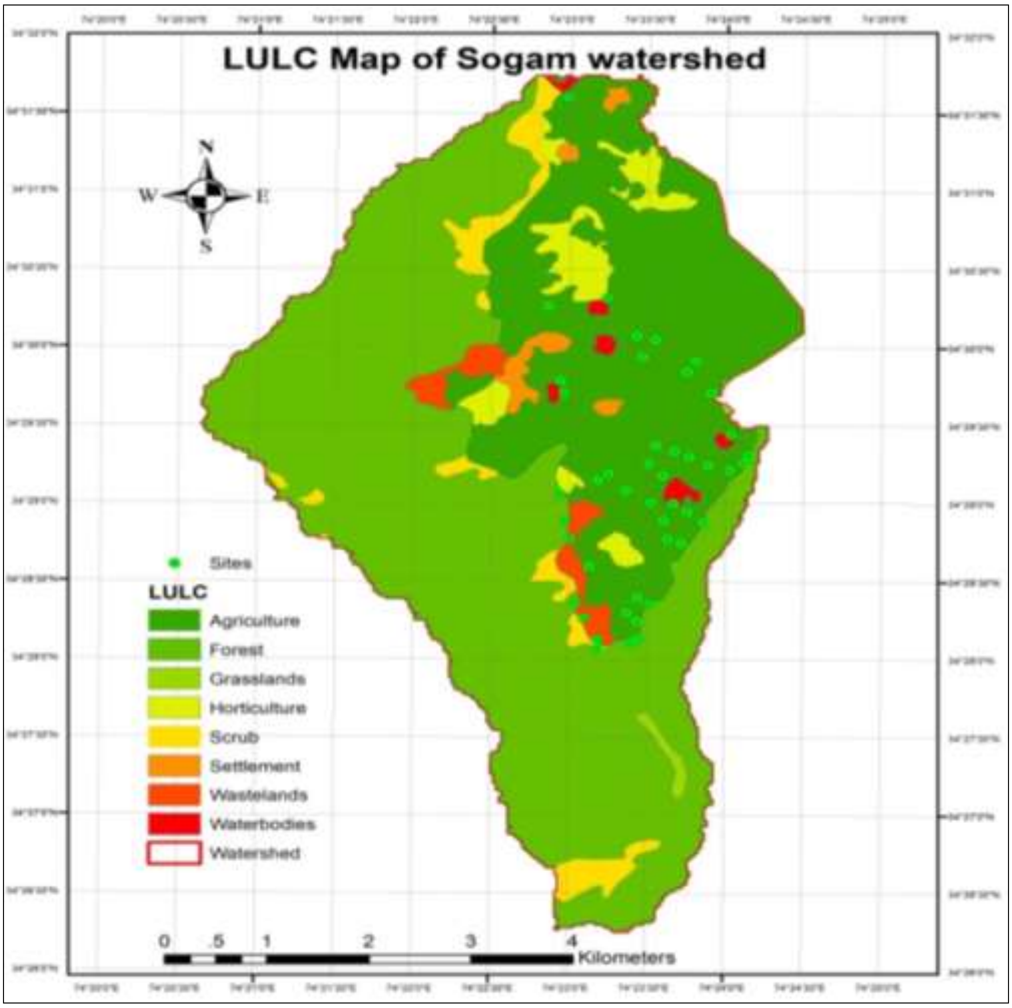


Fig 1: Spatial variability map of Land Use Land Cover (LULC) of Sogam watershed.

Soil Sampling and processing

Composite soil samples were systematically collected from the Kupwara district using ArcGIS (10.2) software, employing a randomized grid layout. Each grid was precisely measured at 50×50 m^2 and covered a depth range of 0 to 20 cm. Geographical Positioning System (GPS) technology was utilized to determine precise sampling points, enhancing accuracy and precision. The soil samples underwent thorough mixing, with manual removal of any large plant debris, roots, and stones from the composite mixture. The collected samples were meticulously bagged, tagged for identification, and transported to the laboratory for subsequent processing. Prior to chemical analysis, the materials were appropriately homogenized and pulverized to pass through a 2-mm filter system. The resulting specimens were then placed in polythene bags for storage. Subsequently, the samples underwent analysis to assess various soil properties. Table 1 illustrates the methodology and studied parameters of this investigation.

Table 1: Determination of soil parameters

S. No.	Soil parameter	Methodology	Reference
1.	Particle size distribution	Hydrometer method	Bouycous 1962
2.	OC	Rapid titration method	Walkley and Black, 1934
3.	Zinc	DTPA-extraction method	Lindsay and Norvell 1978 [11]
4.	Iron		
5.	Manganese		
6.	Copper		
7.	Nickel		

Statistical and Geostatistical Analysis of Collected Data

In the analysis, SPSS 2017 was utilized to examine the frequency distribution and assess the normality of the data. Descriptive statistical metrics, including the median, standard deviation, mean, coefficient of variation (CV), kurtosis, and skewness, were computed after converting the data. The CV primarily served to evaluate the variability within different datasets. Table 2 presents the micronutrient content ranges recommended by Takkar and Mann (1975) [23] and Lindsay and Norvell (1978) [11], forming the basis for assessing soil micronutrient distribution conformity to established norms.

To perform kriging interpolation within the geostatistical framework, ensuring a normal distribution of the dataset is imperative. A standard Quantile-Quantile (Q-Q) plot was employed using ArcGIS software (10.2) to evaluate the normality of the soil microelement data. In agricultural research, it is noteworthy that when sampling data closely resembles a normal distribution, a normal quantile-quantile (Q-Q) plot typically depicts a linear pattern. Addressing the non-normal distribution of the data necessitated the application of data transformation techniques (Fu *et al*., 2010) [5] for effective variability management.

Spatial analysis employed a geostatistical method (ArcGIS 10.2), where ordinary kriging and grid formation were executed in Geographic Information System (GIS). Contour functions were then applied to the map to visualize spatial variation, with a color legend distinguishing different levels of spatial variability. The traditional soil fertility evaluation method, in conjunction with ArcGIS (10.2), was employed to define management zones for various parameters within the area.

Table 2: Critical soil micronutrient limit values (Lindsay and Norvell 1978) [11]

	Micronutrients (mg kg^{-1})			
Content	**Cu**	**Fe**	**Mn**	**Zn**
Deficit	<0.2	<4.5	<2.5	<0.6
Marginal	0.2-0.4	4.5-9.0	2.5-3.5	0.6-1.2
Sufficient	0.4-0.8	9.0-18.0	3.0-7.0	1.2-2.4
High	0.8-1.6	18.0-27	>7.0	>2.4
Very High	1.6-3.2	>27.0		

Results and Discussions

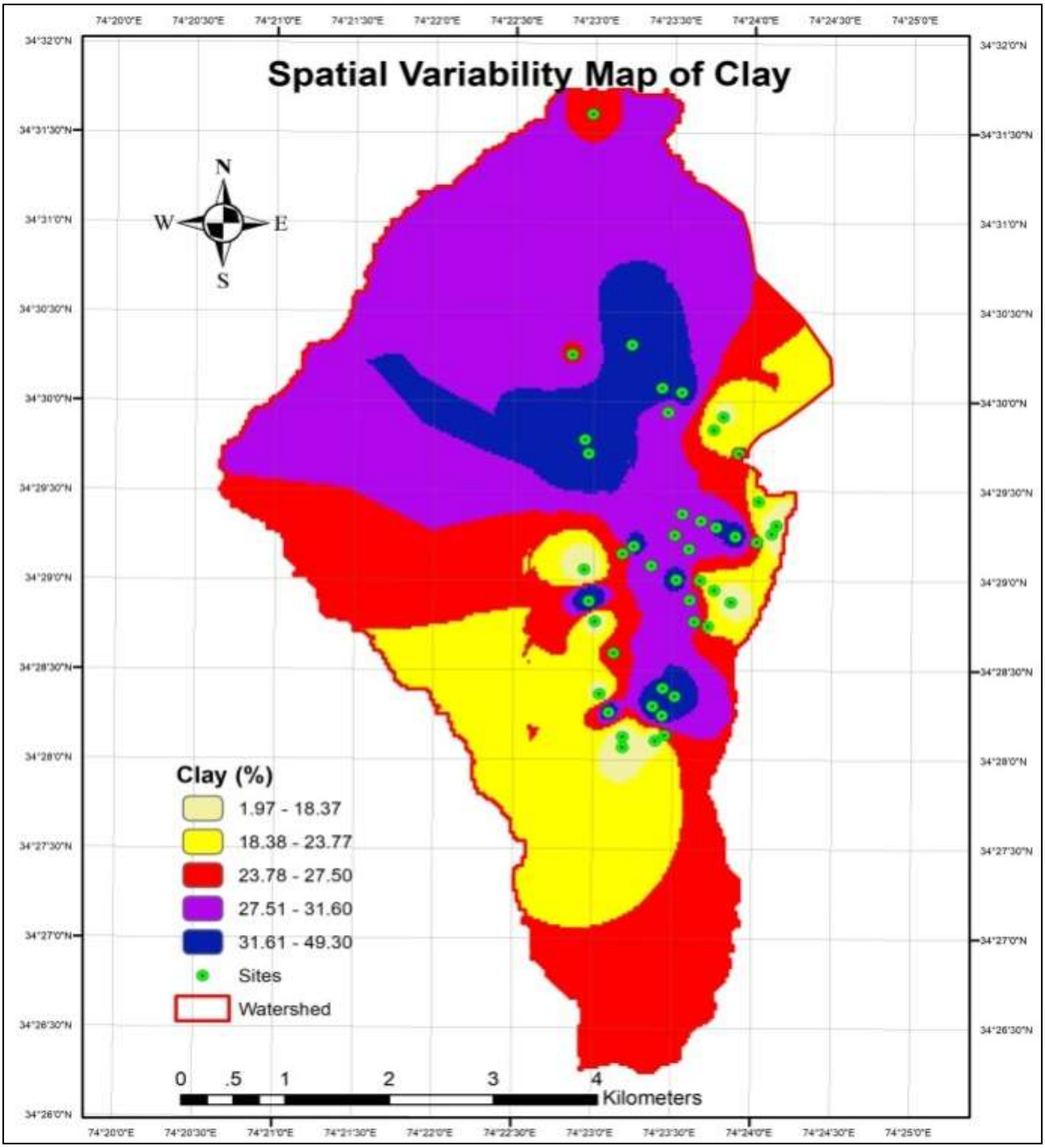
The mean values for sand, silt, clay were found to be 38.54%, 33.34%, and 29.2%, respectively (Table 3; Figure 3). The particle size distribution clearly categorized the soils under study as was clay loam soils. Comparable results have been documented by Ramzan *et al.* (2016) [19]. The OC levels varied from 6.84 to 11.34 with the mean value of 9.09 g kg^{-1} (Table 3; Figure 2), which was in the higher range as per the Walkley and Black (1934). The highest levels of OC are well supported by the reports of Nisar and Lone (2013) [18].

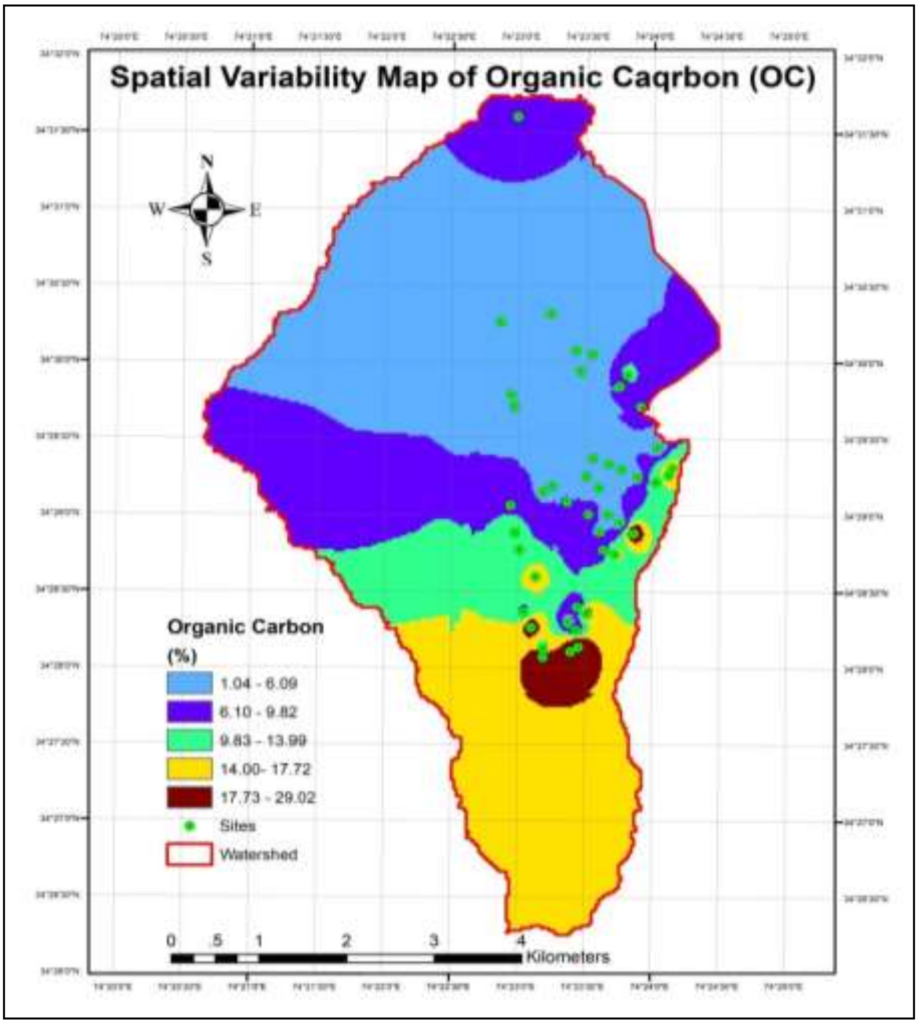
Descriptive statistics summarizing the soil micronutrients in the study region are presented in Table 3, showcasing coefficient of variation (CV) values ranging from 28.05% to 58.7%, following the sequence of Fe, Mn, Cu, Zn, and Ni (Table 3). Table 3 presents the varying concentrations of Zn, Cu, Fe, Mn, and Ni in the soil samples. Zn concentrations ranged from 1.14 to 3.57 mg kg^{-1}, Cu from 1.33 to 2.73 mg kg^{-1}, Fe from 31.28 to 33.17 mg kg^{-1}, Mn from 17.56 to 26.06 mg kg^{-1}, and Ni from 3.47 to 1.75 mg kg^{-1}. Notably, Fe, Cu, Zn, and Mn exhibit exceptionally elevated concentrations (Figure 3 and 4). The Ni content falls within the lower range according to Lindsay and Norvell (1978) [11]. Zn and Cu are the only micronutrients displaying a distribution closely resembling normal distribution, as evident in the probability distributions. The coefficient of variation for micronutrients shows a considerable range from 28.05% to 58.7%, signifying notable variability in micronutrient levels. These findings align with studies conducted by Vasu *et al.* (2021) [25].

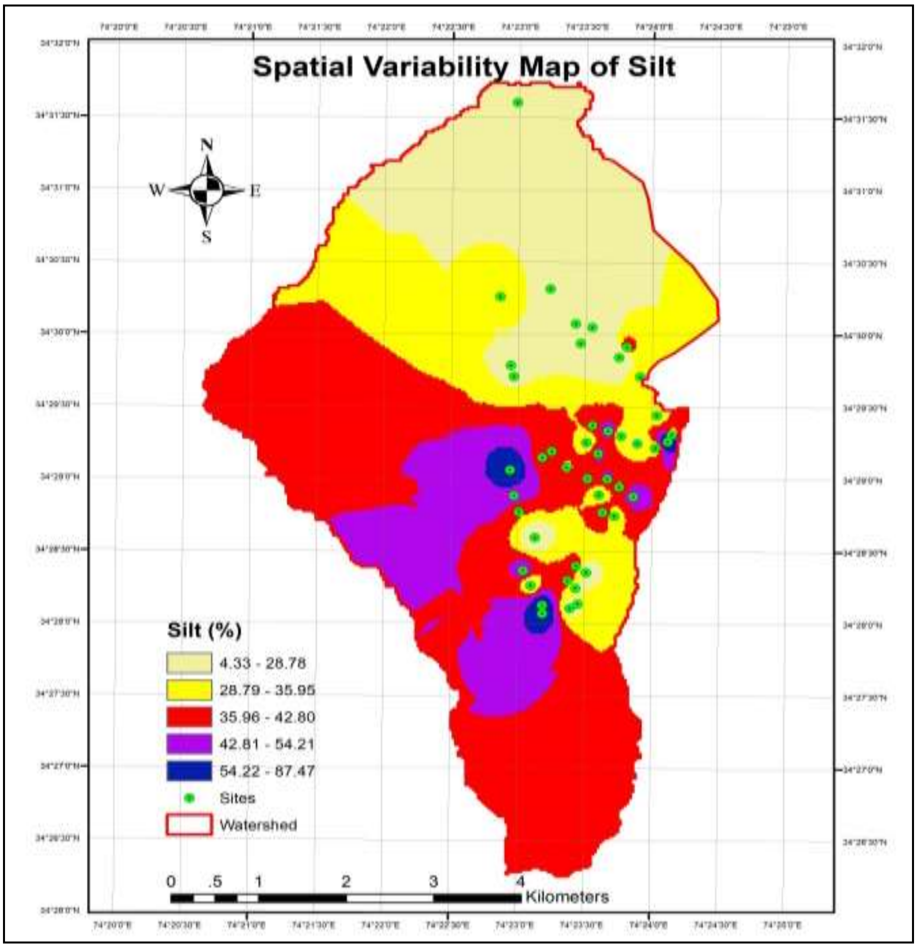
Overall, the observed values exhibit a lower magnitude in comparison to the findings reported by Foroughifar *et al.* (2013) [4]. However, they align with the outcomes documented by Mugloo *et al.* (2021) [17], Malik *et al.* (2022) [13], and Buttar and Sharma (2023) [3]. In addition, for variability categorization, Gomes and Garcia (2002) proposed a classification system based on CV values, categorizing up to 10% as low variability, 10-20% as medium variability, 20-30% as high variability, and above 30% as extremely high variability. This classification aids in understanding and identifying different levels of variability within datasets or populations.

Table 3: Statistical parameters of micronutrients in soil

Soil Element	Unit	Minimum	Maximum	Mean	CV (%)	Skewness	Kurtosis
Sand	%	35.08	42.01	38.54	29.9	0.31	0.7
Silt	%	28.72	35.97	33.34	37.3	0.23	0.38
Clay	%	25.86	30.84	28.35	29.2	-0.65	0.03
OC	gkg^{-1}	6.84	11.34	9.09	82.2	1.55	0.43
Zn	mg kg^{-1}	0.12	5.01	2.075	54.40	0.3922	-0.3425
Cu	mg kg^{-1}	0.26	3.8	1.938	38.9	0.1763	-0.4069
Fe	mg kg^{-1}	4	50.83	32.51	28.05	-0.2824	0.6975
Mn	mg kg^{-1}	0.51	33.2	21.02	33.8	-0.555	0.5936
Ni	mg kg^{-1}	0.15	6.14	2.065	58.7	2.06	5.05




Spatial Variability Map of Organic Caqrbon (OC)
N
W
E
S
Organic Carbon (%)
1.04 - 6.09
6.10 - 9.82
9.83 - 13.99
14.00- 17.72
17.73 - 29.02
Sites
Watershed
0
.5
1
2
3
4
Kilometers


Spatial Variability Map of Silt
N
W
E
S
Silt (%)
4.33 - 28.78
28.79 - 35.95
35.96 - 42.80
42.81 - 54.21
54.22 - 87.47
Sites
Watershed
0
.5
1
2
3
4
Kilometers

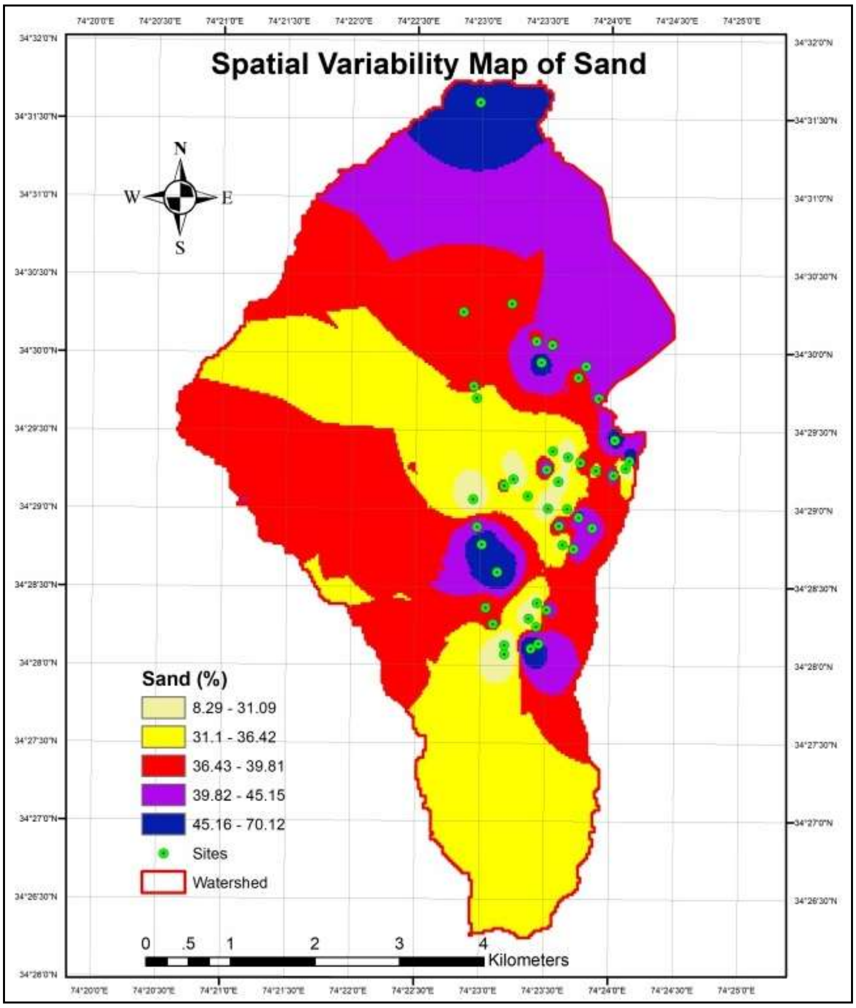
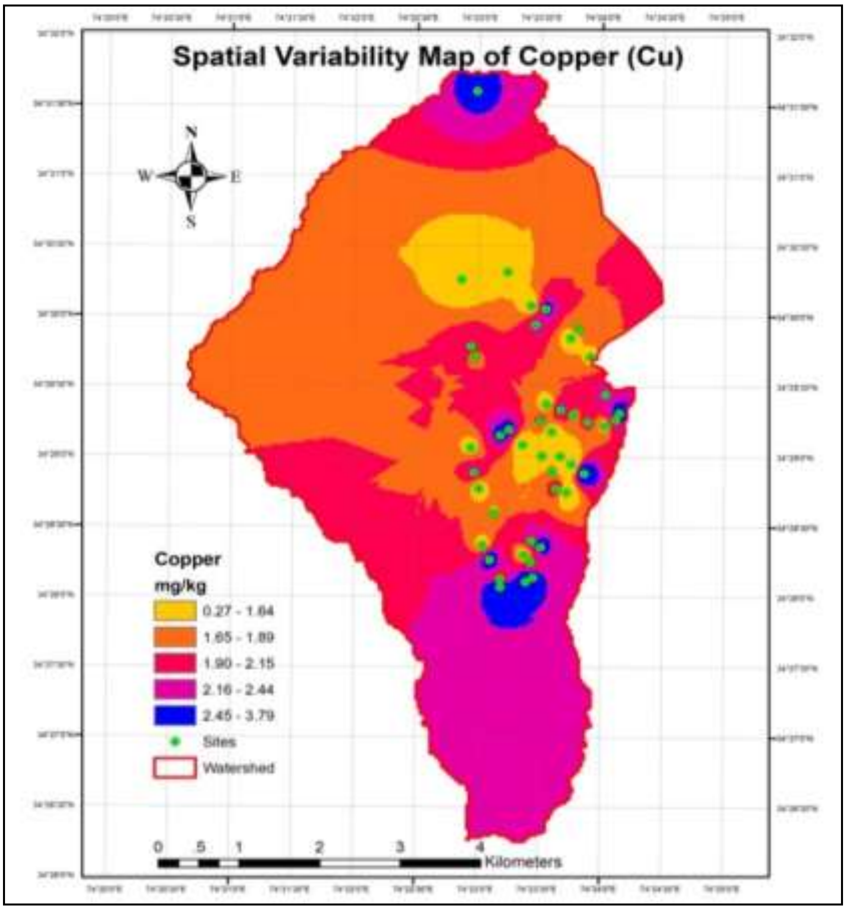


Fig 2: Spatial variability map of sand, silt, clay and organic carbon of Sogam watershed



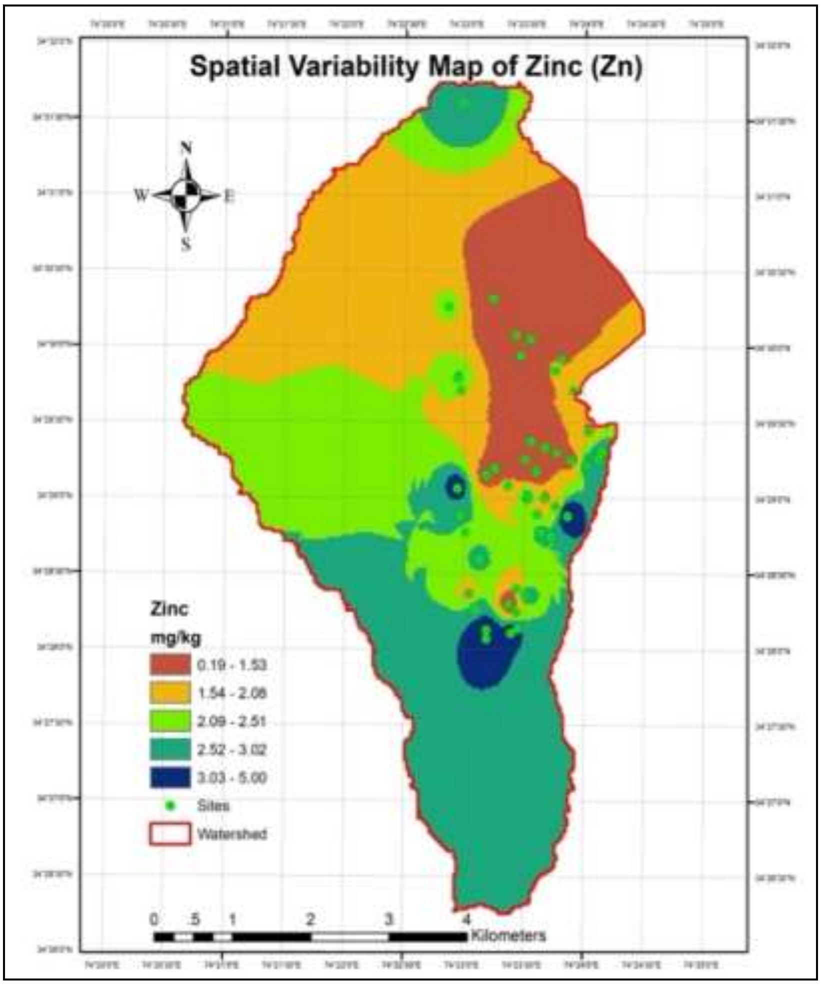
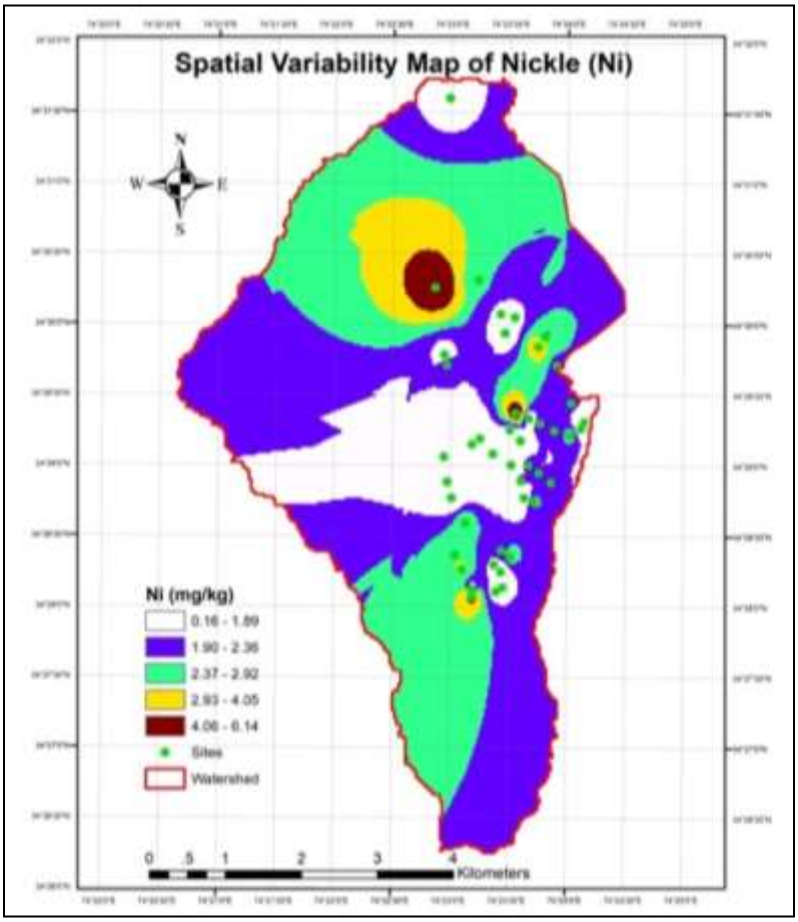


Fig 3: Spatial variability map of Zinc (Zn) and Copper (Cu) showing the very high levels of accumulation



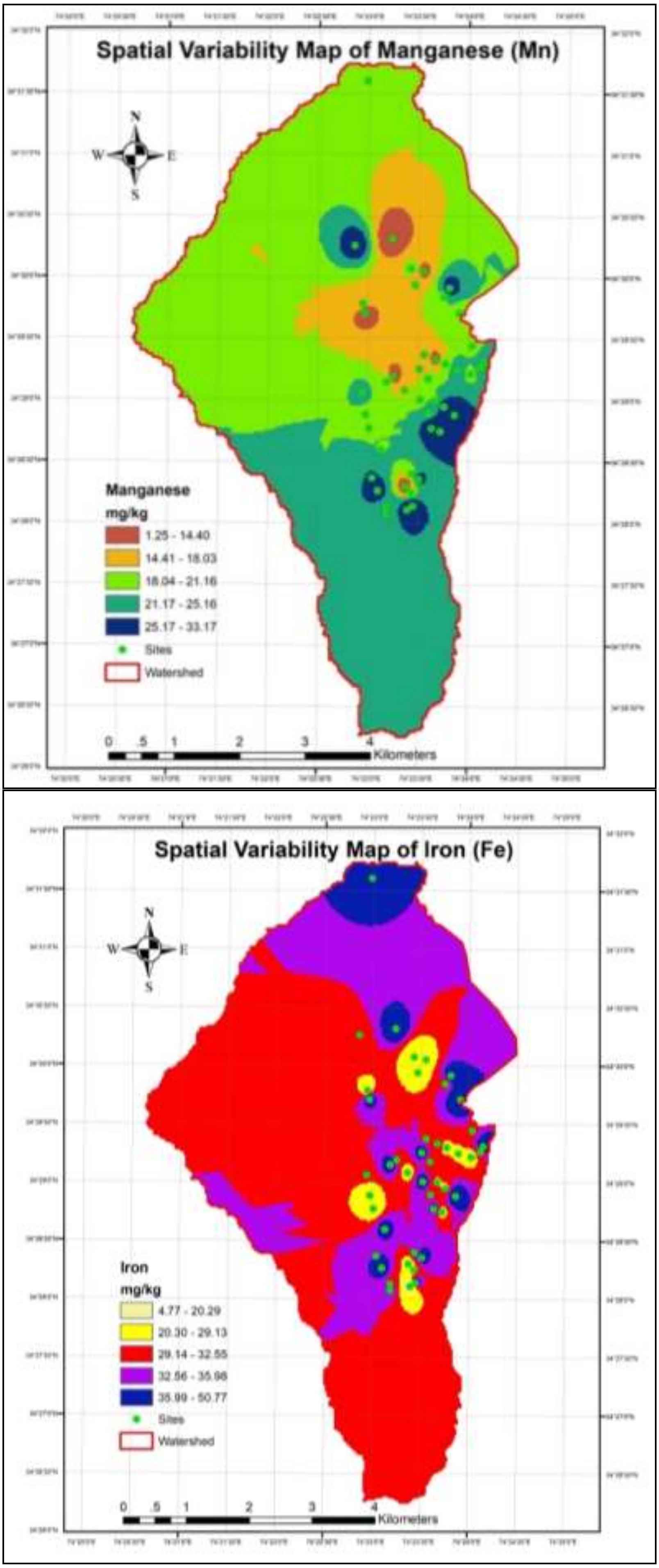
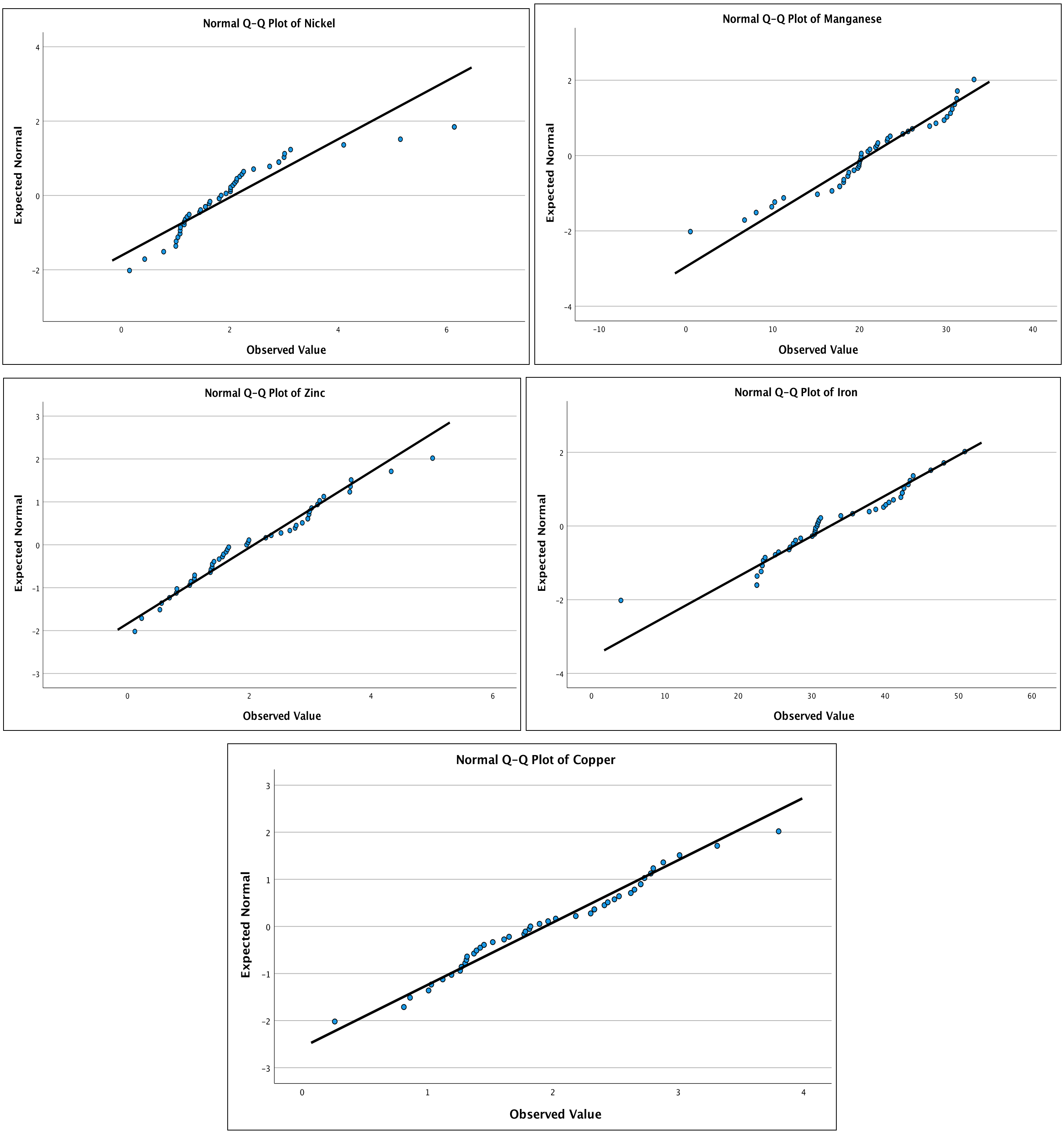


Fig 4: Spatial variability map of Iron (Fe), Manganese (Mn) and Nickel (Ni) showing the very high levels of accumulation in Fe and Mn and deficient in Ni

For a random variable with a regularly distributed distribution, the skewness and kurtosis coefficient is both equal to 0. To reduce the impact of extreme values on spatial analysis, it is common practice to alter data that deviate from a normal distribution (Webster and Oliver, 2001) [27]. Descriptive statistics show moderate to high skewness (-0.28 to 2.06) and kurtosis (-0.34 to 5.05) values, indicating a typical distributions for studied micronutrients. The distribution curves deviated from the straight lines, and the skewness brought on by outliers was the source of the deviation. Figure 5 demonstrates that Ni had a considerable deviation, which was justified by its high CV value (58.7%). Log-transformation of micronutrient data was applied to mitigate skewness and improve distribution for kriging mapping.

Soil management practices play a crucial role in contributing to variability in soil-related data, affecting parameters such as soil nutrient levels, moisture content and physical properties. Uneven distribution of fertilizers and manure, as well as soil disturbances from various land use changes, can induce spatial and temporal variability in soil characteristics (Ramzan and Mushtaq, 2016) [20]. Soil management practices and land use change also influence biological and chemical processes, including nutrient cycling, carbon dynamics (Mir *et al*. 2023a) [14], and microbial activity (Mir *et al*. 2023b) [15], impacting soil quality and ecosystem services. Therefore, adopting sustainable soil management practices is essential for minimizing variability and maintaining long-term soil health and productivity.


Normal Q-Q Plot of Nickel

Normal Q-Q Plot of Manganese

Normal Q-Q Plot of Zinc

Normal Q-Q Plot of Iron

Normal Q-Q Plot of Copper

Fig 5: Normal Q–Q plot for selected soil micronutrients

Conclusion

In conclusion, this study underscores the significance of employing GIS techniques for the analysis and interpretation of agricultural data. The descriptive statistics of soil micronutrients reveal elevated levels of DTPA-extractable Fe, Mn, Zn, and Cu in the research region, accompanied by comparatively lower concentrations of Ni. The observed CV values for micronutrients exhibits a notable range of variability, spanning from 28.05% to 58.7%. This variation can be attributed to a combination of anthropogenic activity and the inherent characteristics of the parent soil components.

The utilization of cartographic representations showcasing the spatial heterogeneity of soil micronutrient distribution enhances the facilitation of micronutrient critical zone delineation. These maps serve as valuable tools for optimizing soil input management, particularly in mitigating the potential contamination of soil by hazardous metals such as Ni. The findings of this investigation highlight the feasibility of partitioning the study regions into multiple segments based on their distinct management needs. Furthermore, the practicality of utilizing this spatial arrangement of soil micronutrients for site-specific micronutrient management is demonstrated, emphasizing the potential for targeted and efficient agricultural practices in the research region.

References

1. Alloway BJ. Micronutrient deficiencies in global crop production. Science and Business Media, Springer; c2008.
2. Bhattacharyya R, Ghosh BN, Mishra PK, Mandal B, Rao CS, Sarkar D, *et al*. Soil degradation in India: Challenges and potential solutions. Sustainability. 2015;7(4):3528-3570.
3. Buttar TS, Sharma V. Spatial variability of soil micronutrients under paddy (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system in irrigated plains. Indian Journal of Agricultural Sciences. 2023;93(4):403-408.
4. Foroughifar H, Jafarzadeh AA, Torabi H, Pakpour A, Miransari M. Using geostatistics and geographic information system techniques to characterize spatial variability of soil properties, including micronutrients. Communications in Soil Science and Plant Analysis. 2013;44(8):1273-1281.
5. Fu W, Tunney H, Zhang C. Spatial variation of soil nutrients in a dairy farm and its implications for site-specific fertilizer application. Soil Tillage Research. 2010;106:185–193.
6. Hartemink AE. Assessing soil fertility decline in the tropics using soil chemical data. Advances in Agronomy. 2006;89:179-225.
7. Jones DL, Cross P, Withers PJ, DeLuca TH, Robinson DA, Quilliam RS, *et al*. Nutrient stripping: The global disparity between food security and soil nutrient stocks. Journal of Applied Ecology. 2013;50(4):851-862.
8. Keesstra S, Mol G, De Leeuw J, Okx J, De Cleen M, Visser S. Soil-related sustainable development goals: Four concepts to make land degradation neutrality and restoration work. Land. 2018;7(4):133.
9. Kihara J, Bolo P, Kinyua M, Rurinda J, Piikki K. Micronutrient deficiencies in African soils and the human nutritional nexus: opportunities with staple crops. Environmental Geochemistry and Health. 2020;42:3015-3033.
10. Lal R, Bouma J, Brevik E, Dawson L, Field DJ, Glaser B, *et al*. Soils and sustainable development goals of the United Nations: An International Union of Soil Sciences perspective. Geoderma Regional. 2021;25:e00398.
11. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of America Journal. 1978;42:421–28.
12. Li P, Wang J, Liu M, Xue Z, Bagherzadeh A, Liu M. Spatio-temporal variation characteristics of NDVI and its response to climate on the Loess Plateau from 1985 to 2015. Catena. 2021;203:105331.
13. Malik MA, Wani AH, Jan N, Bhat MY. Assessment of Macro and Micronutrients in Rhizospheric Soil of two Medicinally Important Plants *Digitalis purpurea* L. and *Swertia petiolata* D. Don of Kashmir Himalaya. 2022.
14. Mir YH, Ganie MA, Shah TI, Aezum AM, Bangroo SA, Mir SA, *et al*. Soil organic carbon pools and carbon management index under different land use systems in North-western Himalayas. Peer Journal. 2023a;11:e15266.
15. Mir YH, Ganie MA, Shah TI, Bangroo SA, Mir SA, Shah AM, *et al*. Soil microbial and enzyme activities in different land use systems of the Northwestern Himalayas. Peer Journal. 2023b;11:e15993.
16. Mohammadi SJ, Esmaeelnejad L, Ramezanpour H. Geospatial modelling for optimum management of fertilizer application and environment protection. Modeling Earth Systems and Environment. 2017;3:1-12.
17. Mugloo JA, Khanday M, Dar M, Pala NA, Ahmad K, Bhat J. Spatial distribution of soil nutrients in high altitude alpine pastures of south Kashmir Himalaya, India. Range Management and Agroforestry. 2021;42(2):271-276.
18. Nisar M, Lone FA. Effect of landuse/landcover change on soils of a Kashmir Himalayan catchment-sindh. International Journal of Research in Earth & Environmental Sciences. 2013;1(1):13-27.
19. Ramzan S, Bhat MA. Chemical Partitioning and Distribution of Copper, Zinc and Nickel in Soils of Lesser Himalayas. The Indian Ecological Society. 2016;43(1):84-88.
20. Ramzan S, Wani MA. Geographic information system and geostatistical techniques to characterize spatial variability of soil micronutrients including toxic metals in an agricultural farm. Communications in Soil Science and Plant Analysis. 2018;49(4):463-477.
21. Saljnikov E, Lavrishchev A, Römbke J, Rinklebe J, Scherber C, Wilke BM, *et al*. Understanding and monitoring chemical and biological soil degradation. Advances in Understanding Soil Degradation; c2022. p. 75-124.
22. Shukla AK, Behera SK. All India coordinated research project on micro-and secondary nutrients and pollutant elements in soils and plants: Research achievements and future thrusts. Indian Journal of Fertilisers. 2019;15(5):522-543.
23. Takkar PN, Mann MS. Evaluation of analytical methods of estimation of available zinc and response of applied zinc in major soil series of Ludhiana, Punjab (India). Agrochemical. 1975;19:420–30.
24. Tamburi V, Shetty A, Shrihari S. Characterization of spatial variability of vertisol micronutrients by geostatistical techniques in Deccan Plateau of India. Modeling Earth Systems and Environment; 2019.
25. Tomaz A, Martins I, Catarino A, Mourinha C, Dôres J, Fabião M, *et al*. Insights into the spatial and temporal variability of soil attributes in irrigated farm fields and correlations with management practices: A multivariate

statistical approach. Water. 2022;14(20):3216.

26. Vasu D, Sahu N, Tiwary P, Chandran P. Modelling the spatial variability of soil micronutrients for site-specific nutrient management in a semi-arid tropical environment. Modeling Earth Systems and Environment. 2021;7:1797-1812.
27. Webster R, Oliver MA. Statistical methods in soil science and resource survey. New York, NY: Oxford University Press; c2001. p. 44.