Original Research Article

Mapping of micronutrients in soils of Kishtwar district (Jammu and Kashmir) - A GIS approach

Abstract

A study was conducted to evaluate the status of DTPA extractable micronutrients of Kishtwar district soils and generate their prediction maps. The Kishtwar district of Jammu and Kashmir covers an area of 7737 sq. km. and falls in the temperate zone of the state. It is an upland valley in the northeast corner of the Jammu region. A total of 167 soil samples were collected from the entire Kishtwar district in a stratified random manner. The digitization and generation of maps were carried out with ArcGIS 10.0 software following Inverse distance weight (IDW). DTPA-Zn content of soils of Kishtwar varied widely as low as 0.13 mg Zn kg^{-1} and as high as 1.6 mg Zn kg^{-1} with a mean value of 0.64 mg Zn kg^{-1}. DTPA ranged from 0.11 mg Cu kg^{-1} to 2.3 mg Cu kg^{-1} with a mean value of 0.77 mg Cu kg^{-1}. DTPA-Fe ranged from 5.40 mg Fe kg^{-1} to 42.4 mg Fe kg^{-1}, with a mean value of 22.05 mg Fe kg^{-1}. DTPA- Mn ranged from 7.4 mg Mn kg^{-1} to 36.2 mg Mn kg^{-1} with a mean value of 18.59 mg Mn kg^{-1}. Available boron (B) ranged from 0.05 to 3.6 ppm with a mean value of 0.70 ppm. Among micronutrients tested, Cu, Zn and B were mainly deficient; a regular supply of organic matter and pH correction is advised. Micronutrient deficiency and erosion are major hindrances in the agriculture of the district. The spatial maps on micronutrient status created throughout the study will be useful for farmers or researchers for the site-specific repair of nutrient deficiency and for assisting farmers in choosing the amount and type of nutrient to apply for the best results.

Keywords: Agriculture, Geographic Information System (GIS), Mapping, Micronutrients, Soil, Temperate Zone

Introduction

"The soil micronutrient constraints to productivity and other related aspects have been studied since the post-green revolution era because of the widespread deficiencies in soils in the majority of the agriculturally progressive states of our country. Micronutrient deficiencies in soils have increased in recent years" (Rattan & Sharma, 2004; Singh, 2003), and the trend is changing from single to multiple nutrient deficiencies. The elements (B, Cu, Fe, Mn, Mo, and Zn) are called "trace elements" (Alloway, 1990; Brady et al., 2008). "The group of essential elements includes both macro and trace elements. Essential trace elements are often called "micronutrients" because they are required in small but critical concentrations by living organisms. In the growth and development of crops, soil micronutrients play a pivotal role instead of being present in small quantities. These elements also govern the availability of other nutrients" (Kosmas et al., 1993). "Parent material, climate, and geological history are of major importance in affecting regional and continental soil properties. However, landscape position and land use may be the dominant factors of soil properties under a hillslope and small catchment scale. Landscape positions influence runoff, drainage, soil temperature, erosion, and soil formation" (Sillanpää, 1982). "Differences in soil formation along a hill slope result in differences in soil properties, which can affect the pattern of plant production, litter production, and decomposition" (Brubaker et al., 1993). "Micronutrient quantities required by plants are minimal, and the thresholds for sufficient, deficient, and toxic levels are also very close. Several review studies have summarized and suggested the micronutrients range based on extraction methods" (Brady et al., 2010). "Significant sources of soil micronutrients are inorganic forms from parent material and organic forms within humus, though deficiency or toxicity can mainly be attributed to the parent material" (Brady et al., 2010). Furthermore, factors that play essential roles in regulating micronutrients include soil pH, oxidation state, organic matter, mycorrhizae, organic compounds, and the stability of chelates.

Micronutrient deficiency profoundly affects humans, domestic animal health, and plant yield and quality (Cakmak, 2002; Welch, 2003). Extensive research on the effects of micronutrient fertilizers on crop yield and quality (Malakouti et al., 2005). In India, about one-half of all soils are low in zinc (Katyal & Vlek, 1985; Welch et al., 1991), with as much as 74% of the rice-growing soils of the Andra Pradesh (a southern state in India) being zinc deficient and 69% of the wheat-growing soils (Rathore et al., 1980). With the arrival of information technologies like the Global Positioning System (GPS), Geographical Information System (GIS) organized a collection of georeferenced samples, and producing spatial data about the distribution of nutrients is possible (Wani et al., 2014). Delineation of homogenous units to decide sampling size is to be generated with the help of remote sensing hence, saving a lot of time. Changes in micronutrient status can be monitored over time as georeferenced samples can be revisited, which is otherwise difficult in the conventional sampling approach (Sood et al., 2004).

Keeping this in view, the present study was taken up in the Kishtwar district of Jammu and Kashmir to explore micronutrient-related constraints to soil health by assessing the micronutrient status of the soils and their spatial variability in soils.

Material and Methods

Study Area

Kishtwar District is in the Jammu Division of Jammu and Kashmir state of India. It lies between 32°53' and 34°21' N latitude and 75°1' and 76°47' E longitude (Figure 1). Altitude in the district diverges from 900 to 6575 meters above mean sea level. It has an average elevation of 1107 meters (3361 feet) from mean sea level, experiencing a wide range of climates. Commonly known as the 'Land of Saffron and Sapphire,' it is also rich in forest products. Kishtwar is surrounded by the Anantnag and Doda districts of J&K and also borders Himachal Pradesh. High altitudes of this district hardly receive monsoon; hence there is less rainfall in those areas. The average annual rainfall in the district is 887.8 mm. Due to topographic variation, rainfall varies from place to place in the district. The coldest month is January, with a mean maximum temperature of about 6°C and a mean minimum temperature of about -3°C. The minimum temperature sometimes drops to below -10°C, and in an extremely hilly part of the district minimum temperature may drop down to about -30° to -

40°C. The increase in human and cattle population puts tremendous pressure on the state's resources, especially forests, soil, and water. Soil erosion is the major problem because of its hilly terrain, undulating topography, fragile ecosystem, climatic conditions, and loss of vegetation cover due to excessive grazing, lopping, illicit felling, and encroachments. Land degradation is further aggravated by triggering landslides, earthquakes, and development activities including road constructions, railway lines, hydroelectric projects, etc. In 2007, district Kishtwar was carved out, commonly known as the 'Land of Sapphire and Saffron'; it is also rich in forest products.

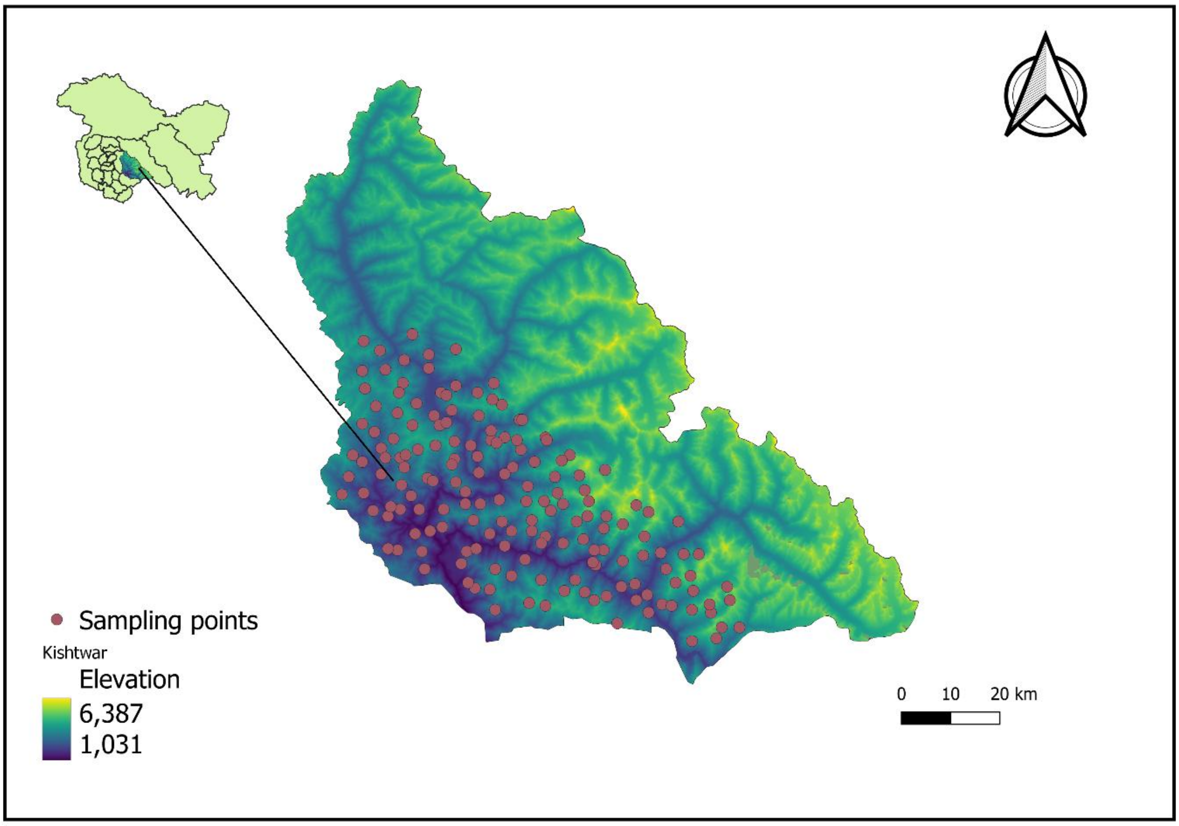


Figure 1. Map of the study area and sampling points

Collection of soil samples and analysis of samples

A total of 167 composite soil samples were taken randomly across the whole district. Soil samples were taken using a stratified random sampling technique. The collected soil samples were air-dried, grounded with a wooden pestle and mortar, sieved (2-mm sieve), labeled, stored, and analyzed for DTPA extractable micronutrients (Zn, Cu, Mn, and Fe) as determined by the method suggested by (Lindsay & Norvell, 1978) and for available boron by improved Azomethine- H method (Wolf, 1974).

Mapping and interpolation

Mapping the spatial distribution of soil properties requires spatial interpolation methods. In the present study, the interpolation technique inverse distance weighting (IDW) was employed, and soil maps of each property were generated. These interpolation techniques have been commonly used in mapping soil properties (Nayak et al., 2006; Schloeder et al., 2001).

Results and Discussions

DTPA-extractable Zn

DTPA-Zn content of soils of Kishtwar varied widely as low as 0.13 mg Zn kg^{-1} and as high as 1.6 mg Zn kg^{-1} with a mean value of 0.64 mg Zn $kg^{-1,}$ and also high variation was observed as depicted by Coefficient of variation % (CV) 40.18% (Table 2). The frequency distribution curve of Zn was positively skewed (0.82) and kurtosis (1.93) (Fig 3(a)). DTPA-Zn content of soils was divided into three categories. With an average value of 0.64 mg Zn kg^{-1} soil, the first category of Zn (< 0.6 mg Zn kg^{-1}) with an average value of 0.41 mg Zn kg^{-1} represented 39.5% of total samples taken (Table 1 and Figure 4(a)). The second category (0.6-0.8 mg Zn kg^{-1}), with an average value of 0.69 mg Zn kg^{-1}, represented 41.9% of the total samples. The third category (> 0.8 mg Zn kg^{-1}), with an average of 1.00 mg Zn kg^{-1}, represented 18.5% of the total samples. The contents of DTPA Zn in soils showed considerable variation across different transects of the Kishtwar district. The deficiency of Zn was mainly present in the eastern part of the district and the central patch extending from north to south (Fig 2(a)). Zn deficient sporadic patches were also present, mainly concentrated on the eastern side of the district, where land is predominantly under rice cultivation. Zn deficiency is mostly in soil low in OM and coarse in texture (Takkar & Randhawa, 1978). (Jalali et al., 1989) reported that the DTPA-extractable zinc varies from 0.35 to 0.65 mg kg^{-1} in the high-altitude soils of Kashmir. At high altitude soil, there is strong sorption of Zn by OM than at low altitude; therefore, lower content of Zn in high altitude soils (Lahiri & Chakravarti, 1989). During crop growth, a small fraction of the total Zn is at the disposal to plant roots leading to Zn deficiency. Zn deficiency is mainly prominent in soils derived from parent materials such as quartz sand contains low total and available Zn. Coarse textured soils high in free $CaCO_3$ and low organic matter have frequent Zn deficiencies (Singh & Abrol, 1985).

DTPA-extractable Cu

DTPA-Cu content of soils of Kishtwar varied widely as low as 0.11 mg Cu kg^{-1} and as high as 2.3 mg Cu kg kg^{-1} with a mean value of 0.77 mg Cu kg^{-1} also, high variation was observed as depicted by the Coefficient of variation % (CV) 50.74% (Table 2). The frequency distribution curve of Cu was positively skewed (0.98) and kurtosis (2.33) (Fig 3(b)). DTPA-Cu content of soils was divided into three categories (Table 1 and Figure 4). With an average value of 0.77 mg Cu kg^{-1} soil, the first category of Cu (< 0.2 mg Cu kg^{-1}) with an average value of 0.14 mg Cu kg^{-1} represented 9.5% of the total samples taken. The second category (0.2-0.4 mg Cu kg^{-1}), with an average value of 0.34 mg Cu kg^{-1}, represented 6.5% of the total samples taken. The third category (> 0.4 mg Cu kg^{-1}), with an average of 0.91 mg Cu kg^{-1}, represented 83.8% of the total samples. Copper deficient soils were mainly present on the southern side of the Kishtwar tehsil and the area adjoining Kishtwar. Chatro and Marwah tehsils recorded the highest content of copper in soils (Fig 2(b)). Coarse textured soils have low Cu content compared to fine-textured soils (Mansoor et al., 2021; Sharma et al., 2015). With an increase in clay and OM content also increases. Soils with OM lead to Cu complexation into insoluble forms hence low Cu levels and consequently deficiency in some plants (Jan et al., 2020; Moraghan & Mascagni Jr, 1991; Wani, 2016). Available Cu increases with an increase in organic matter and clay content but decreases with an increase in pH and $CaCO_3$ content of the soil (Gull et al., 2020; MAHDI et al., 2021). The build-up of copper can be associated with regular sprays of Cu-containing fungicides in orchards and agricultural fields, which leads to Cu toxicity (Singh & Abrol, 1985).

DTPA-extractable Fe

DTPA-Fe content of soils of Kishtwar varied widely as low as 5.40 mg Fe kg^{-1} and as high as 42.4 mg Fe kg^{-1}, with a mean value of 22.05 mg Fe kg^{-1}. Also, high variation was observed, as depicted by the Coefficient of variation % (CV) of 30.66% (Table 2). The frequency distribution curve of Fe was near normal with skewness (0.05) and kurtosis (0.32) (Fig 3(c)). DTPA-Fe content of soils was divided into three categories (Table 1 and Fig 4). With an average value of 22.05 mg Fe kg^{-1} soil, the first category of Fe (< 6 mg Fe kg^{-1}) with an average value of 5.40 mg Fe kg^{-1} represented 0.5% of the total samples taken. The second category (6-10 mg Fe kg^{-1}), with an average value of 9.02 mg Fe kg^{-1}, represented 2.9% of the total samples taken. The third category (> 10 mg Fe kg^{-1}), with an average of 22.41 mg Fe kg^{-1}, represented 96.6% of the total samples. Soils on the eastern side of the district had lower Fe than on the western side. However, on the southern side of the Kishtwar tehsil, specific patches had very high Fe content in soils (Fig 2(c)). (Lahiri & Chakravarti, 1989) observed that due to acidic pH in high altitudes, there is an increased iron and organic matter level compared to low altitudes. An inverse relationship exists between Fe availability of soil and pH hence, irregular distribution in the soil (Misra et al., 1990). However, a minuscule portion of total samples showed iron deficiencies, which can be attributed to calcareous soils (Calciorthents), compact soils with restricted aeration, low organic matter, and high permeability (Nayak et al., 2006).

DTPA-extractable Mn

DTPA-Mn content of soils of Kishtwar varied widely as low as 7.4 mg Mn kg^{-1} and as high as 36.2 mg Mn kg^{-1} with a mean value of 18.59 mg Mn kg^{-1}. High variation was observed as depicted by the Coefficient of variation % (CV) of 27.87% (Table 2). The frequency distribution curve of Mn was positively skewed (0.36) and kurtosis (0.73) (Fig 3(d)). DTPA-Mn content of soils was divided into three categories (Table 1 and Fig 4). With an average value of 18.59 mg Mn kg^{-1} soil, the first category of Mn (< 3 mg Fe kg^{-1}) represented none of the total samples taken. The second category (3-5.5 mg Mn kg^{-1}) also represented none of the total samples. The third category (> 5.5 mg Mn kg^{-1}), with an average of 18.59 mg Mn kg^{-1}, represented 100% of the total samples taken, indicating that all samples had Mn in the high range. Kishtwar tehsil had higher Mn than others (Fig 2(d)). (Nazif et al., 2006) have reported DTPA-extractable Mn to vary from 4.59 to 21.08 mg kg^{-1} at different locations in Jammu and Kashmir soils. Moreover, the variability in soil Mn can be attributed to the wide variation of geological parent material, weathering processes, soil pH, age and contents of organic matter, clay $CaCO_3$ contents, leaching, and submergence in the soil of study area (Lal & Biswas, 1973). Altitude also plays a remarkable role in available Mn (Sakal & Singh, 1995) as the area under study has hilly topography hence, wide variations.

Available boron

Available boron (B) content of soils of Kishtwar varied widely as low as 0.05 ppm and as high as 3.6 ppm, with a mean value of 0.70 ppm. Also, high variation was observed, as depicted by the Coefficient of variation % (CV) of 82.11% (Table 2). The frequency distribution curve of B was positively skewed (1.93) and kurtosis (6.16) (Fig 3(e)). The soil B content was divided into three categories (Table 1 and Fig 4). With an average value of 0.70 ppm soil, the first category of B (< 0.5ppm) with an average value of 0.28 ppm represented 47.30% of total samples. The second category (0.5-1.0 ppm), with an average value of 0.74 ppm, represented 32.3% of the total samples. The third category (> 1.0 ppm), with an average of 1.59 ppm, represented 20.37% of the total samples. The area adjoining Marwah and Kishtwar tehsil had lower B than other district areas (Fig 2(e)). The availability of B in soil depends on the concentration of borate in solution, organic matter, texture, pH, Cation exchange capacity, the mineral coating on the clays, and type of clay (Hingston, 1964). Furthermore, moisture, wetting and drying, temperature, and soil texture influence the amount of B fixation (Eaton & Wilcox, 1939; Jan et al., 2020). Thus, it is not surprising that soils differed considerably in available B. The first category of B (< 0.5 ppm) represented 47.30% of total samples, indicating a widespread soil deficiency. This might be due to coarse-textured and leached soils (Haplustalfs) it also depends on $CaCO_3$ content in soils (Sakal & Singh, 1995).

Table 1. Critical ranges and distribution of Zn **(**mg kg^{-1}**)**, Cu **(**mg kg^{-1}**)**, Fe **(**mg kg^{-1}**)** , Mn**(**mg kg^{-1}**)** and B **(**ppm**)** of Kishtwar soils

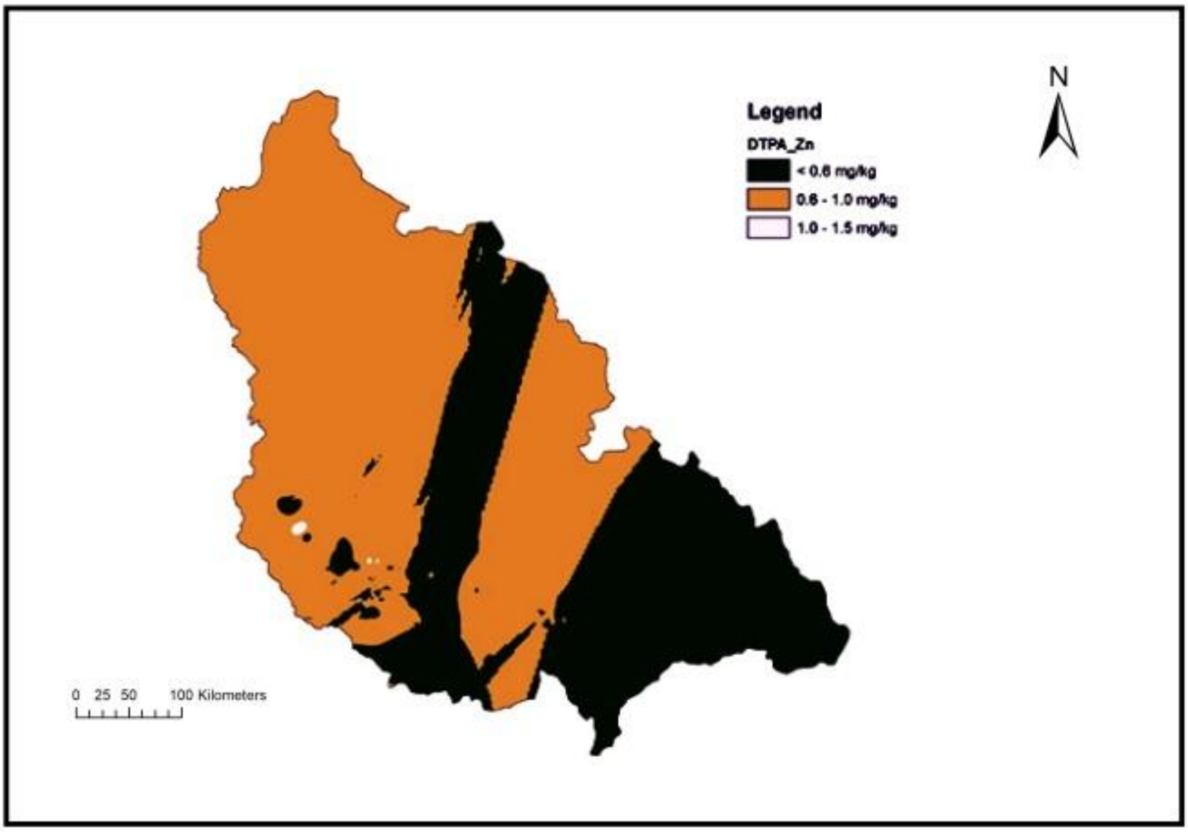
Categories range	**Mean**	**Percentage of samples out of the total number of samples**
Zinc (mg kg^{-1}**)**		
Low(<0.6)	0.41	39.5
Medium (0.6-0.8)	0.69	41.9
High(>0.8)	1.00	18.5
Copper (mg kg^{-1}**)**		
Low(<0.2)	0.14	9.4
Medium (0.2-0.4)	0.34	6.5
High (>0.4)	0.91	83.8
Iron (mg kg^{-1}**)**		
Low (<6)	5.40	0.5
Medium (6-10.5)	9.02	2.9
High (>10)	22.41	96.6
Manganese (mg kg^{-1}**)**		
Low (<3)	0.00	0.00
Medium (3-5.5)	0.00	0.00
High (>5.5)	18.59	100
Boron (ppm)		
Low (<0.5)	0.28	47.30
Medium (0.5-1.0)	0.74	32.33
High (>1.0)	1.59	

Table 2. Descriptive statistics of Zn (mg kg^{-1}), Cu (mg kg^{-1}), Fe (mg kg^{-1}), Mn(mg kg^{-1}) and B (ppm) of Kishtwar soils

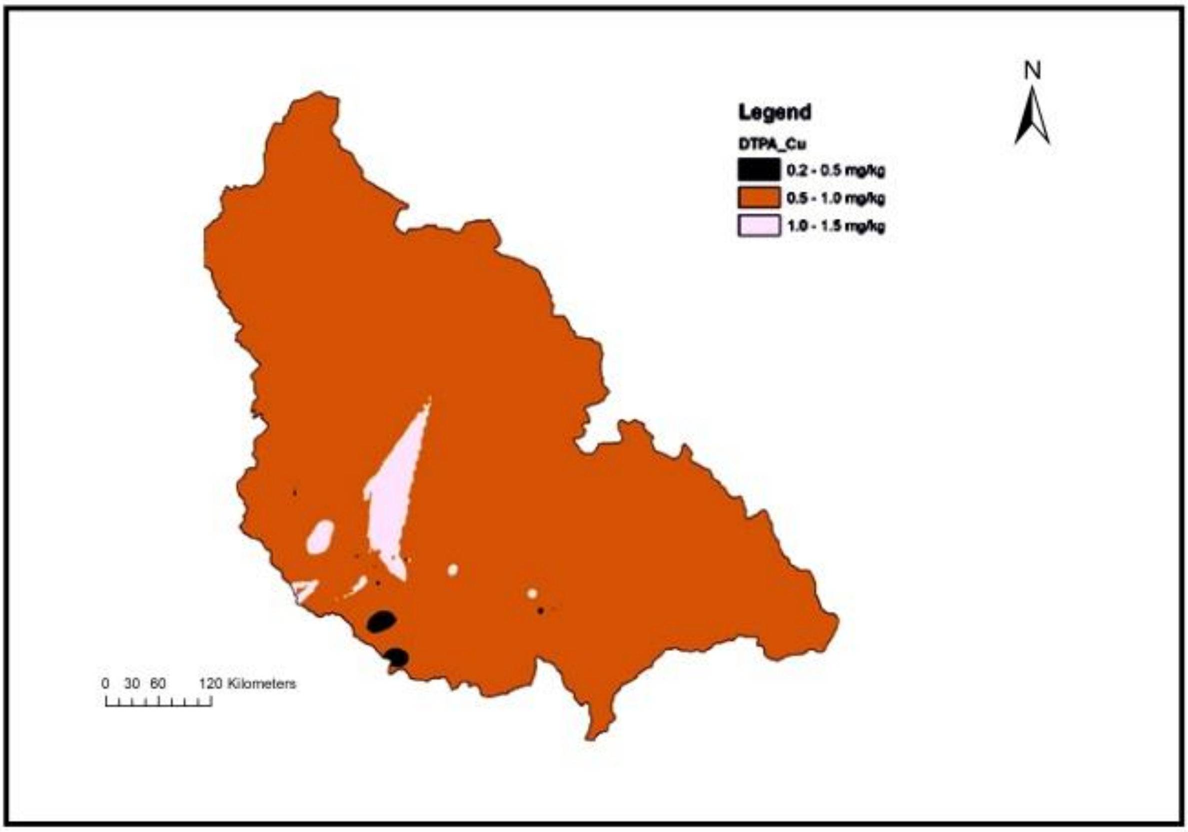
Name of parameter	Minimum	Maximum	Range	Mean	Coefficient of variation (%)	Standard Error	Skewness	Kurtosis
Zinc	0.13	1.60	0.13-1.6	0.64	40.11	0.02	0.82	1.92
Copper	0.11	2.30	0.11-2.3	0.76	50.08	0.03	0.97	2.32
Iron	5.40	42.40	5.4-42.4	22.04	30.01	0.52	0.05	0.32
Manganese	7.40	36.20	7.4-36.2	18.59	27.80	0.40	0.35	0.73
Boron	0.05	3.60	0.05-3.6	0.70	82.11	0.04	1.93	6.16

Figure 2. Thematic maps of Zn (a), Cu (b), Fe(c), Mn (d), and B (e) of Kishtwar soils

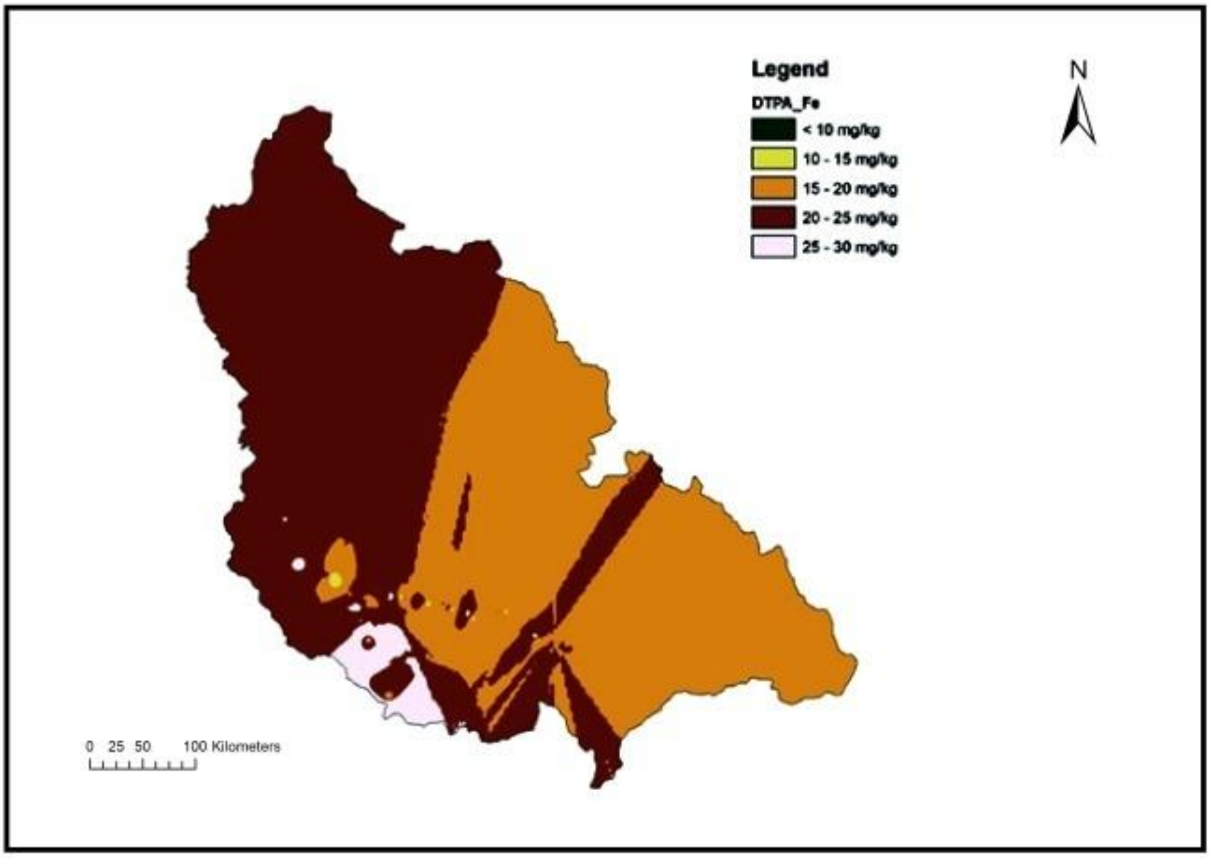
Zn (a)



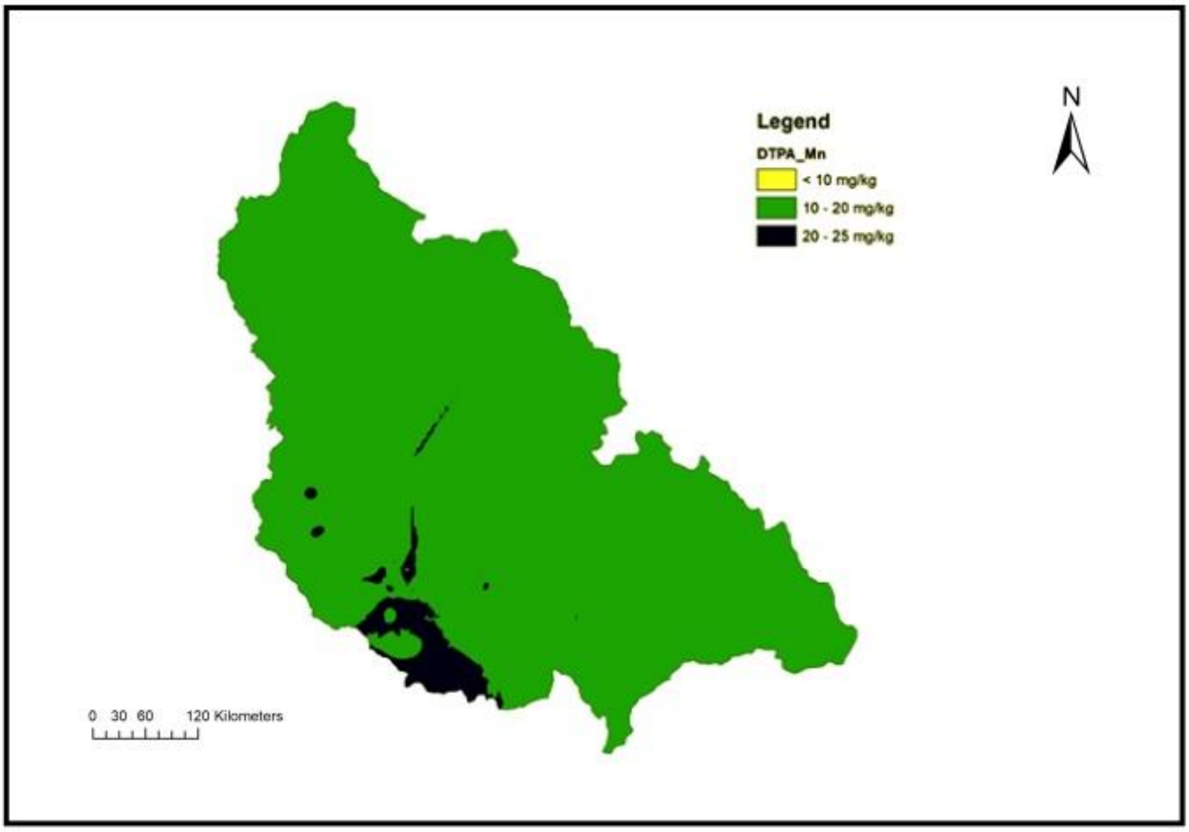
Cu (b)


Legend
DTPA_Cu
0.2 - 0.5 mg/kg
0.5 - 1.0 mg/kg
1.0 - 1.5 mg/kg
N
0 30 60 120 Kilometers

Fe(c)


Legend
DTPA_Fe
< 10 mg/kg
10 - 15 mg/kg
15 - 20 mg/kg
20 - 25 mg/kg
25 - 30 mg/kg
N
0 25 50 100 Kilometers

Mn (d)



Legend
DTPA_Mn
< 10 mg/kg
10 - 20 mg/kg
20 - 25 mg/kg
N
0 30 60 120 Kilometers

B (e)

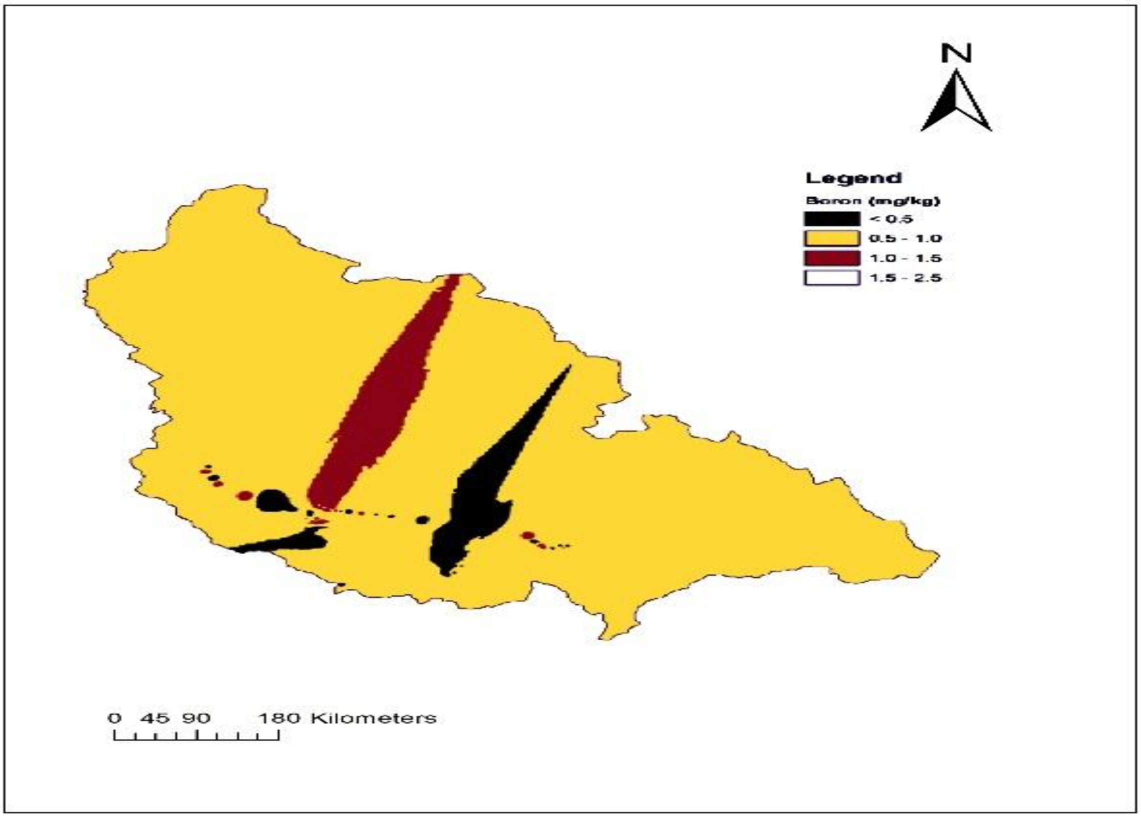
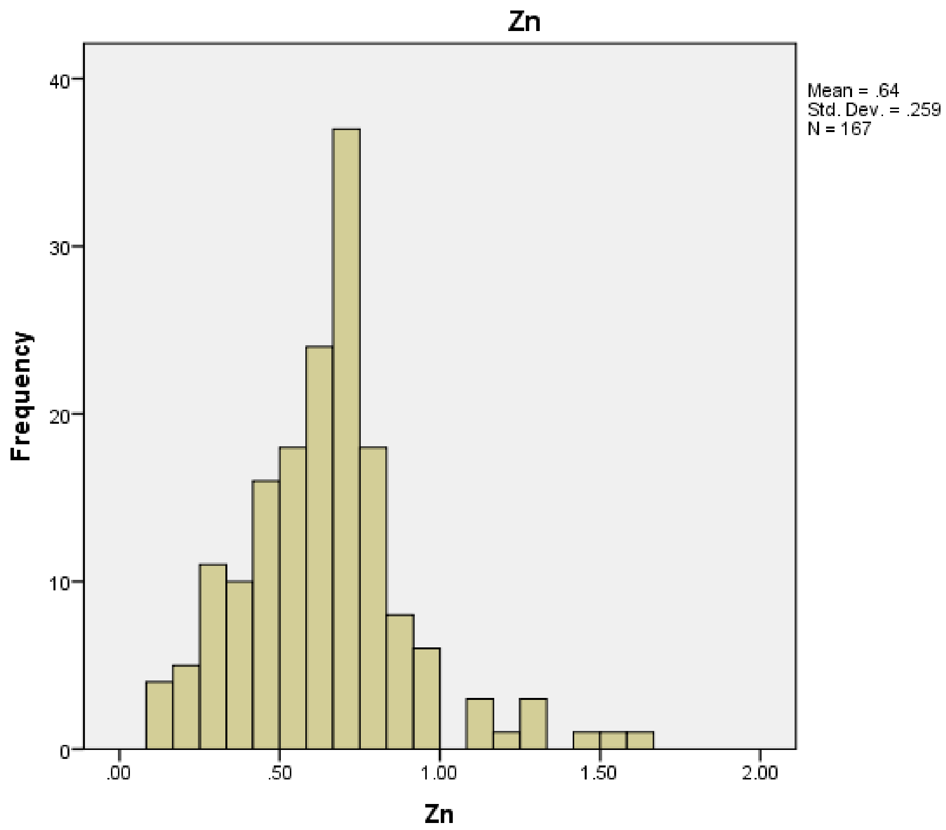
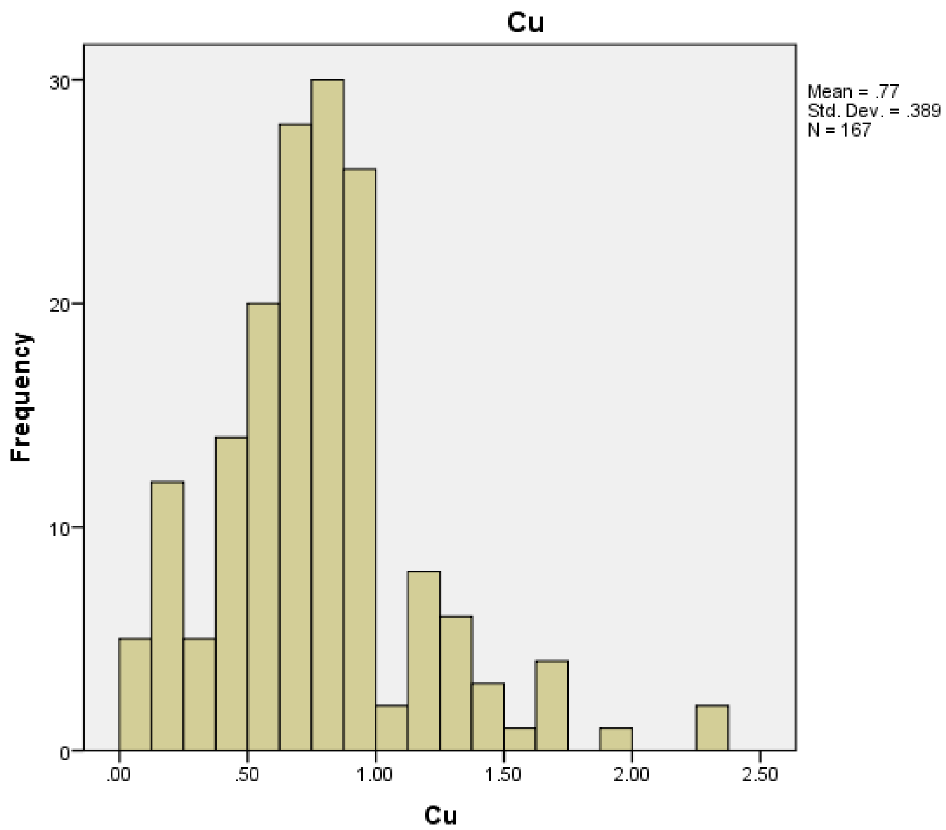


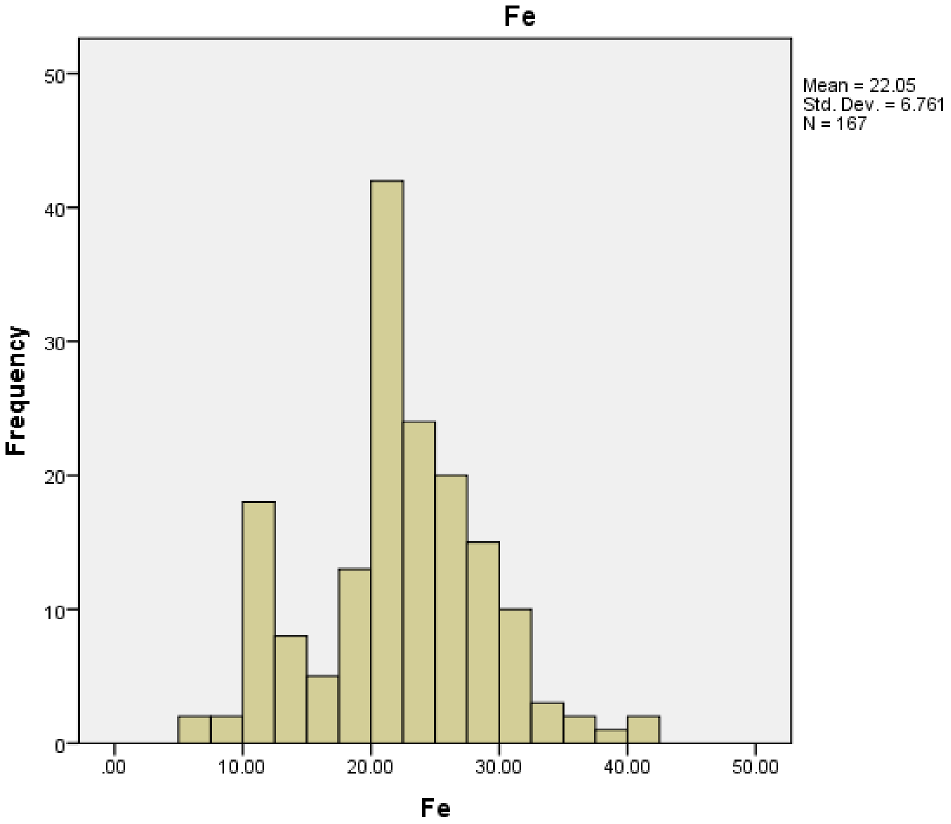
Figure 3. Frequency distribution of Zn (a), Cu (b), Fe (c), Mn (d), and B (e) of Kishtwar soils

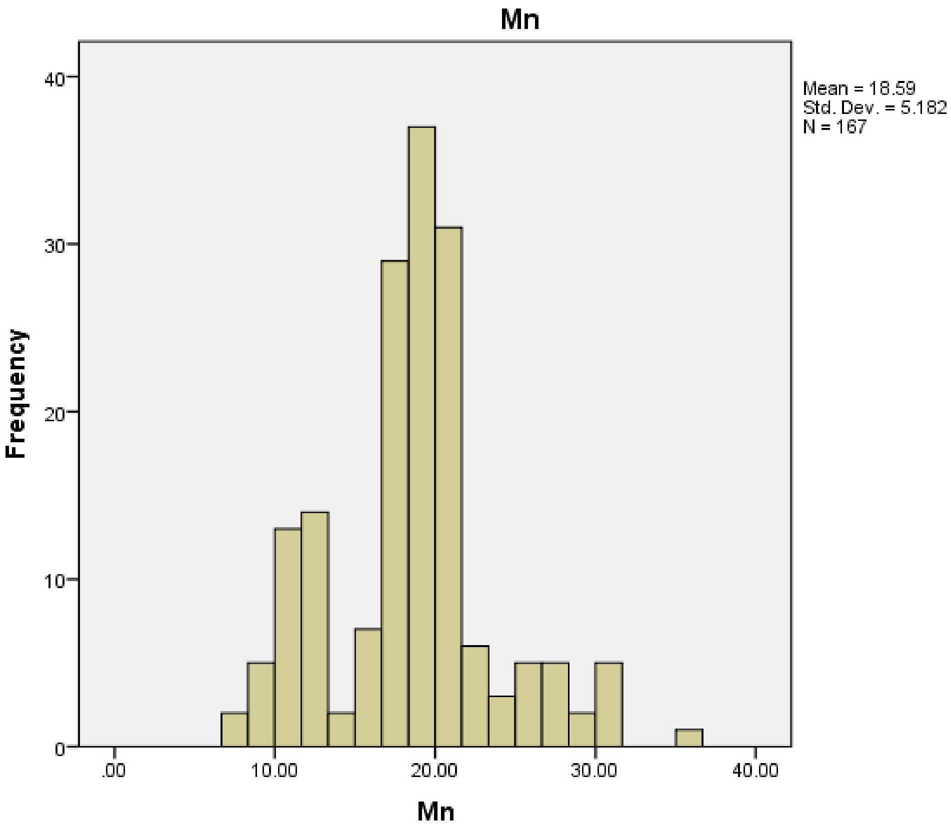


Zn
Frequency
0
10
20
30
40
.00
.50
1.00
1.50
2.00
Zn
Mean = .64
Std. Dev. = .259
N = 167



Cu
Frequency
0
10
20
30
.00
.50
1.00
1.50
2.00
2.50
Cu
Mean = .77
Std. Dev. = .389
N = 167


Fe
Mean = 22.05
Std. Dev. = 6.761
N = 167
Frequency
0
10
20
30
40
50
.00
10.00
20.00
30.00
40.00
50.00
Fe


Mn
Mean = 18.59
Std. Dev. = 5.182
N = 167
Frequency
0
10
20
30
40
.00
10.00
20.00
30.00
40.00
Mn

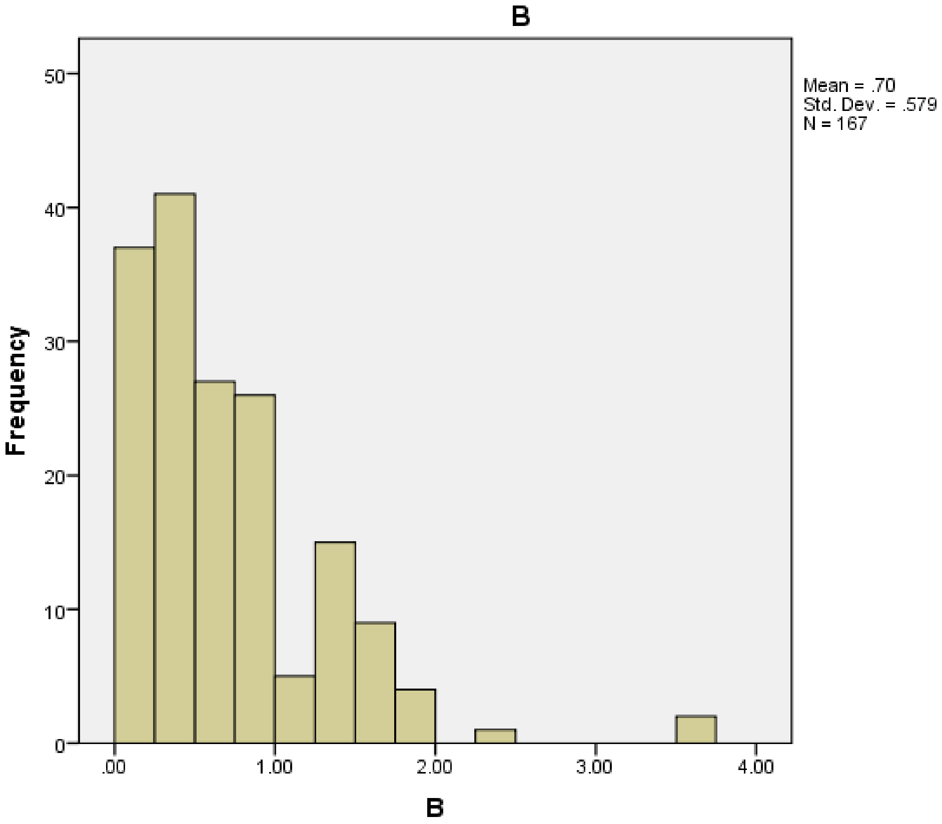
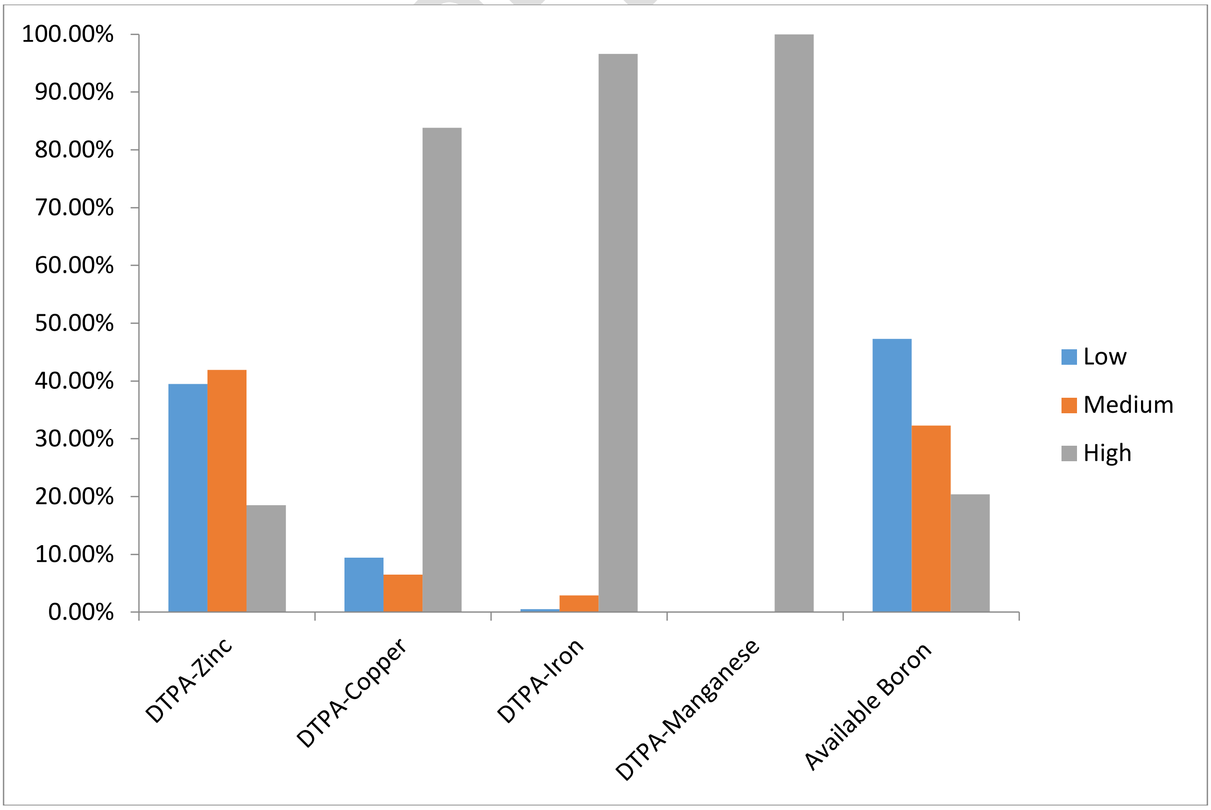


Figure 4. Percentage distribution of different micronutrient categories in soils of Kishtwar district



Conclusion

In modern Indian agriculture setup, micronutrients are the essential nutrient elements for the growth and productivity of crops. Among micronutrients tested, Cu, Zn and B were mainly deficient; a regular supply of organic matter and pH correction is advised. Micronutrient deficiency and erosion are major hindrances in the agriculture of the district. The spatial maps on micronutrient status generated during the study will be useful for farmers as well as researchers for the site-specific correction of nutrient deficiency and to guide farmers in the application of amount and type of nutrients to achieve a potential yield of crops, as there will be different nutrient management where there are multiple nutrient deficiencies. Furthermore, it will be helpful to assess the temporal changes in micronutrient status in the soils in the future. Although, a sufficient portion of the area in the district is under saffron cultivation which requires adequate micronutrients to meet international quality standards.

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