Mapping of Micronutrients in Soils under Rice and Maize Ecosystems of northern District in Kashmir –A GIS Approach

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Abstract:

Mapping of DTPA-extractable cationic micronutrients were carried out by random grid sampling, collected geo-referenced surface (0.2 m) soil samples representing different soils (as per soil map prepared on 1:50,000 scale) from 625 sites in Kupwara district (Northwest Kashmir, India) using Global Positioning System (GPS) before the crops sown. The plant samples were also collected simultaneously from every 5th soil sampling site. These soil and plant samples were analyzed for micro nutrients (Fe, Mn, Zn and Cu). The DTPA-Zn in soils varied from 0.12 to 5.10 mg kg^{-1}, DTPA-Cu from 0.26 to 3.90 mg kg^{-1}, DTPA-Fe from 0.89 to 51.18 mg kg^{-1} and DTPA-Mn from 0.51 to 33.30 mg kg^{-1}. The contents of Zn in plants varied from 16.3 to 73.7 mg kg^{-1}, Fe from 22.4 to 585.0 mg kg^{-1}, Cu from 7.6 to 20.1mg kg^{-1} and Mn from 7.3 to 649.3 mg kg^{-1}. None of the samples were found to be deficient in iron. The relationship between micronutrient contents in soil and plant was significant. There is a need to refine the critical level of deficiency for DTPA-Fe with reference to growing environment, certain soil characteristics and pre-defined plant parts of specific crops. Soil micronutrient maps prepared in Arc Info GIS clearly delineated the specific locales where micronutrient problem constrained crop production. Multi-micronutrient map suggested that deficiency of individual element is more prevalent as compared to that of two or three micronutrients. DTPA extractable micronutrients showed positive correlation with organic carbon and clay. The positive influence of organic carbon on micronutrient availability was maximum for DTPA-Cu. These results indicated that Zn is likely to constraint crop production, followed by Mn in the soils of Kupwara district.

Keywords: DTPA extractable micronutrients, GIS, GPS, rice, maize

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Introduction:

The soil micronutrient related constraints to productivity and other related aspects are being studied since the post-green revolution era because of their widespread deficiencies in soils in majority of the agriculturally progressive states of our country. The Zn deficiency was first noticed in rice in *Tarai* soils during the 1960s (Nene 1965). Later on the deficiency of Fe in rice, sugarcane, chickpea, groundnut *etc.* on sandy soils (Takkar and Nayyar 1979) and that of Mn in wheat-rice system on light textured soils (Takkar and Nayyar 1981) were reported. The deficiency of Cu and B is also emerging out in some pockets. Therefore, there is a need for correcting deficiency of micronutrients through efficient sources.

Several researchers have indicated that the availability of micronutrients in soils depends on soil pH, organic matter content, adsorptive surfaces and other physical, chemical and biological conditions in the rhizosphere (Jiang *et al*. 2009). Large hectares of arable land in Kashmir have been reported to be deficient in micronutrients and many of these deficiencies were brought about by the continuous use of inorganic fertilizers particularly nitrogen, phosphorus, and potassium by farmers, limited use of organic manures as well as non-recycling of crop residues are some of the other factors contributing towards rapids exhaustion of micronutrients in soils.

In the present era of precision farming, the inputs such as fertilizer, crop varieties and management practices are matched precisely with the variability in soil and climatic conditions so that inputs are applied as per the location specific requirements of the crop. The advent of information technology have provided tools like Global Positioning System (GPS), Geographical Information System (GIS) which helps in collecting a systematic set of georeferenced samples and generating the spatial data about the distribution of nutrients (Sharma 2004). The maps generated through remote sensing helps in delineating the homogenous units to decide the sampling size and thereby saving a lot of time. This will also help to monitor the changes in micronutrient status over a period of time as geo-referenced sampling sites can be revisited with the help of GPS which is otherwise difficult in the random sampling (Sood *et al. 2004).* The availability of micronutrients to plants is influenced by certain soil characteristics (Singh *et al.* 1989).

Keeping this in view, the present study was taken up in Kupwara district of Jammu and Kashmir to diagnose micronutrient related constraints to productivity by assessing micronutrient status of the soils and their spatial variability in soils and plants.

Study Area:

The Kupwara district (Fig. 1) forming a part of Kashmir valley is located in north-western part of J&K, India. Physiographically, this district is an undulated area. It has been divided into three major physiographic units *viz.,* low altitude, mid altitude and high altitude zone. High altitude zone constitutes the major part of the study area. The soils in the Kupwara district were medium to heavy in texture at the surface, slightly acidic to alkaline in reaction, devoid of salts, as majority (99%) of the samples having EC < 0.8 d S m^{-1}. The soils were medium to high in organic carbon contents, medium in available N, low to medium in available P and K.

Materials and Methods:

i. Collection of Soil and Plant Samples

The available satellite data on 1:50,000 scale was interpreted to delineate various physiographic units. A soil map of Kupwara district on 1:50,000 scale prepared by NBSS&LUP, Nagpur was also used to design sampling plan. These maps were overlaid in the Arc/ Info GIS to delineate the homogenous units at (1:50,000 scale) and were taken as basis for collecting soil and plant samples in the field. Georeferenced surface (0.2 m) soil samples representing different soils were collected at a grid size varying from 2 to 2.5 km^2, depending on the homogeneity of the area from mid-October to first week of November 2010. The plant samples from almost every 5th soil sampling site were also collected. Location of soil and plant sampling sites (x, y coordinate(s) of the district was recorded with the help of GPS used during collection of soil samples.

ii. Analysis of Soil and Plant Samples

The soil samples were ground, passed through 2 mm sieve and analyzed for DTPA extractable micronutrients (Fe, Mn, Zn and Cu) as per the method proposed by Lindsay and Norvell (1978) and the concentrations of Fe, Mn, Zn and Cu were determined using atomic absorption spectrophotometer. The samples were categorized as deficient and sufficient in micronutrients (Fe, Mn, Zn and Cu) as per rating limits given in table 1. Rice/maize plant samples collected were washed successively with tap water, 0.1 *N* HCl, distilled water and de-ionized water. The samples after drying in shade were dried in hot air oven at 70±2 °C and ground in a stainless steel mill and stored for analysis. Plant samples were digested in di-acid mixture (Nitric acid and perchloric acid in the ratio 3: 1) and the concentrations of Fe, Mn, Zn and Cu were determined using atomic absorption spectrophotometer. These plant samples were categorized as sufficient and deficient in particular micronutrient according to the criteria laid down in table 1.

iii. Preparation of Maps

Maps for soil sampling sites were generated based on x, y coordinates recorded in the field using Arc-info GIS. Maps showing the spatial distribution of deficient and sufficient area for individual DTPA extractable micronutrients were also generated and digitized using the same GIS package.

Results and Discussion:

i. Chemical Properties of Soils

The soils of Kupwara district are slightly acidic to alkaline in reaction. All of the soils are free from the problem of salinity and alkalinity. The organic carbon (OC) in these soils ranged between 0.49 and 2.81% with a mean value of 1.49%. The $CaCO_3$ content in soils of Kupwara district varied from nil to 2.35% with an average value of 0.71%. The soils of Kupwara district are medium to heavy in texture at the surface. There is a wide variation in clay content, which varied from 20.8 to 36.5% with a mean value of 33.2%. Similarly, silt content varied between 27.2 and 52.6% with a mean of value of 41.5%. The sand content varied from 16.6 to 35.3% with mean of 25.2%. The available phosphorus (P) content of soils varied from 6.3 to 34.0 kg ha^{-1} averaging to 13.5 kg ha^{-1} thereby indicating the accumulation of P in soils over the years (Sharma *et al.* 2004).

ii. DTPA Extractable Micronutrients

The DTPA-Zn in soils varied considerably and ranged from 0.12 to 5.10 mg kg^{-1} (Table 2). The results are in line with those of Talikdar *et al.* 2009 and Mahashabde and Patel (2012). The mean value (0.79 mg kg^{-1}) of the available Zn was more than the critical limit of Zn deficiency (0.6 mg kg^{-1}) as suggested by Bansal and Takkar (1986). Out of 625 soil samples, 53.3% samples were found to be deficient in DTPA-Zn. The samples falling under sufficient category (more than 0.6 mg kg^{-1}) were further segregated into three sub-classes namely sufficient (0.6 to 1.2 mg kg^{-1}), adequate (1.2 to 2.4 mg kg^{-1}) and high (2.4 mg kg^{-1}) in DTPA-Zn and the corresponding samples in these classes were 26.6, 17.8, and 2.4%, respectively (Table 3). There was a great variation in the Fe content (0.89 to 51.18 mg kg^{-1}) in the soils of the district. Similar results wre reported by Sharma *et al.* 2005. The average content of DTPA extractable Fe was 23.80 mg kg^{-1}. The deficiency of Fe was not a serious problem in the district as only 3.4% samples were found to be deficient in Fe. The samples sufficient in available Fe were further categorized into four sub-classes having limits of DTPA-Fe between 4.5-9.0, 9.0-18.0, 18.0-27.0 and >27.0 mg kg^{-1} and the samples under these categories were found to be 10.1, 25.0, 17.9 and 43.7%, respectively (Table 3). Majority of the soils (97%) are not deficient in Fe as the amount of iron required by crops is being released by iron bearing minerals viz. hematite and goethite in these soils. The DTPA-Cu of the investigated soils ranged from 0.26 to 3.90 mg kg^{-1} with a mean value of 1.65 mg kg^{-1} (Table 2). The results are in conformity with those of Arokiyaraj *et al.* 2011. The data further showed that Cu deficiency was not a problem in these soils as no samples were found to be below the critical limit (Table 3). The samples falling in sufficiency categories were further categorized into five subclasses *viz.,* 0.2 to 0.4, 0.4 to 0.8, 0.8 to 1.6, 1.6 to 3.2 and > 3.2 mg kg^{-1}. The corresponding percentage of samples under these categories was found to be 0.7, 7.8, 42.7, 36.0 and 12.8%, respectively (Table 3). It indicates that majority of soils of Kupwara district are adequate in Cu content. The DTPA-Mn status of soils ranged from 0.51 to 33.3 mg kg^{-1} (Table 2). Considering 3.5 mg kg^{-1} DTPA extractable Mn as the critical limit (Nayyar *et al.* 1985), 22% soil samples (category I and II) were deficient in Mn

(Table 3). The samples belonging to sufficient category were further categorized as sufficient (3.5-7.0 mg kg^{-1}) and adequate (> 7.0 mg kg^{-1}) and percentage samples in these categories were found to be 19.8 and 57.8%, respectively (Table 3). These results corroborate with the findings of Bansal and Takkar (1986) and Chahal *et al.* 2005. As rice-brown sarson is the major cropping system in Kupwara district, Mn deficiency was not observed in major parts of the district because the soils are dominantly medium to fine in texture and Mn is mobilized under reduced conditions during rice cultivation which resulted in higher availability of Mn to rice (MandaI and Haldar 1980). At the same time, there is no possibility of Mn leaching in fine textured soils. Therefore, fine textured soils are not expected to become deficient in Mn for rice. Based on soil test, it was found that deficiency of Zn was highest among all the DTPA extractable micronutrients. There is a need for Zn fertilization at regular interval to maximize yield. Otherwise, the deficiency of Zn will gradually become a major constraint to productivity of crops.

iii. Micronutrient Status in Plants

Zn content in rice/maize leaves varied from 16.3 to 73.3 mg kg^{-1} with an average content of 39.9 mg kg^{-1} (Table 2). Considering 20 mg kg^{-1} as the critical limit, the Zn deficiency was found in 2.1% samples (Table 3). Therefore, it is advisable that Zn fertilizers should be added in such soils for sustainable agricultural production. Analysis of both soil and plant samples showed that these soils are deficient in Zn but relatively higher percentage of deficiency of Zn was observed in plant samples. The soils of Kupwara district are low to medium in available P (Sharma *et al.* 2004) there is little possibility of antagonistic effect between P and Zn which resulted in less deficiency of Zn in plants as compared with other micronutrients. The Zn content in plants was significantly correlated with Zn status of soil (r = 0.521*). The Fe, Cu and Mn content in plant ranged from 22.4 to 585.0, 7.6 to 20.1 and 7.3 to 649.3 mg kg^{-1} with mean values of 236.8, 14.0 and 149.4 mg kg^{-1}, respectively (Table 2). Considering critical limit for Fe and Mn, only 6.3 and 12.5% of plant samples were deficient in these nutrients, respectively (Table 3). None of the samples were found to be deficient in Cu. The failure of plant analysis to indicate analogue information as that of soil test may be due to relatively higher degree of deficiency of Zn in rice plants, thereby increasing Cu levels from marginal to sufficiency. This might have resulted in high concentration of Cu in plants. Therefore, there is an urgent need to take up the research studies on this line. The DTPA-Fe, Cu and Mn contents in soils were significantly correlated with the respective micronutrient content in plants (r= 0.376* for Fe, 0.524* for Cu and 0.365* for Mn). These findings are in conformity with those of Chahal *et al.* 2005; Shaheen *et al.* 2007; Kumar *et al.* 2009 and Kobraee *et al.* 2013.

iv. Spatial Distribution of DTPA Extractable Micronutrients

A perusal of data in Table 4 indicated that 14.8% (45063.7 ha) of the total geographical area of the district was deficient in Zn, whereas the remaining area was sufficient with respect to Zn availability. The soil samples having sufficient amount of Zn were further subdivided into three graded levels and the area under sufficient, adequate and high categories was 110433 ha (36.3%), 148187 ha (48.7%) and 893.7 ha (0.3%), respectively (Fig. 4). The spatial distribution of Fe in the study area indicated that 0.2% of area of the district was having Fe content below the threshold limit (4.5 mg kg^{-1}) whereas, the remaining area (99.8%) had sufficient amount of Fe (Table 4, Fig. 3). The segregation of sufficient category revealed that 45.3 and 34.5% area of the district was having Fe content in the range of 9-18 and 18-27 mg kg^{-1}, respectively. An area of 304.577 thousand hectares of Kupwara district was sufficient in Cu (Table 4). A further subdivision of sufficient category revealed that majority of the area (97.7%) of the district was having adequate (0.8-1.6 & 1.6-3.2 mg kg^{-1}) amount of Cu (Fig. 2). Therefore, the farmers can avoid spraying the copper sulphate to such soils. Spatially, small area (4.8%) of the district was deficient in available Mn whereas, 95.2% area had sufficient amount of Mn (Table 4 and Fig. 5). The further classification of samples having sufficient Mn into different categories indicated that majority of area (57.9%) in the district had adequate amount of Mn. Similar findings were reported by Nayak *et al.* 2006 and Akbas *et al.* 2009

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v. Multi-micronutrient Deficiencies

Major portion of the area has all the micronutrients above the critical limit. Also, deficiency of individual elements is more prevalent rather than combination of two or more micronutrients. The micronutrient Cu is sufficient in all the areas of the district. Only a small portion of the district has multi-micronutrient deficiency *i.e.* deficiency of two or three micronutrient elements. Nearly 80.4% (244736 ha) area of the district has all the three micro nutrients (Zn, Fe, Mn) above the critical limit as represented by category SSS (Table 5). This is followed by category DSS representing soils suffering from deficiency of Zn alone at a particular place (Fig. 6). Other micronutrients like Fe and Mn are above critical limit. The area covered under this category was 14.7% (44716.1 ha) of the district. Other category like SDS i.e area having sufficiency of Zn and Mn and deficient in Fe, occupied 4.6% of the district. The rest of the categories like SSD i.e. areas having deficiency of Mn alone and DDS i.e areas having deficiency of Zn and Fe, occupied very small area of the district ranging from 0.2 to 0.1% of the district. The results revealed that maximum area of the district faffs under Zn deficiency, followed by Fe deficiency.

vi. Effect of Different Physico-chemical Properties on DTPA extractable Micronutrients

The availability of micronutrients is influenced by several factors such as pH, organic carbon, calcium carbonate and texture *etc.* The soil samples were categorized into different levels of pH (<7.0 and >7.0), OC (<0.50, 0.50-0.75 and >0.75%), clay (<20, 20-30 and >30%) and calcium carbonate (<1, 1-2 and >2%). The mean values of micronutrients in different categories of soil properties were plotted against soil parameters (Fig. 7 to 10).

i. Zinc

The Zn availability is positively correlated with all the soil properties but the influence of organic carbon is more pronounced as seen from highest coefficient of correlation of OC with Zn (r = 0.645) (Table 6). The Zn availability increased with increase in OC and $CaCO_3$ content of soil and decrease in Zn availability with increase in pH but there was a tremendous increase in availability of Zn with increasing OC content from 0.5 to 0.75% followed by pH (Fig. 9). Takkar *et al.* (1977) also reported increase in availability of Zn with increasing OC content and reverse with increasing pH. An increase in availability of Zn with increasing pH has been reported by Lal and Mathur (1989) and Khan *et al.* (1997). At the same time, it can be inferred that uptake of Zn by plants is not merely a function of pH but it is controlled by other physiological factors and associated nutrients. The increase in clay content from less than 20% to more than 30% resulted in a non-significant increase in DTPA-Zn content (Table 6).

ii. Iron

Soil pH did not have a consistent effect on DTPA extractable Fe content of soils. However, organic carbon had a marked influence on the DTPA-Fe content of soils (Fig. 8). The mean DTPA-Fe was 10.89, 18.33 and 24.30 mg kg^{-1} in soils having OC less than 0.5, between 0.5 and 0.75 and greater than 0.75%, respectively (Fig. 8). The extent of increase was higher from shifting of OC from low to medium category. These results find support from positive and significant coefficient of correlation (r= 0.470) of DTPA-Fe with organic carbon. A similar relationship between DTPA-Fe and OC was also reported by Dolui and Mustafa (1997). DTPA-Fe increased from 17.94 mg kg^{-1} in soils having clay less than 20% to 25.56 mg kg^{-1} in soils with clay content greater than 30%. A positive and significant correlation between DTPA-Fe with clay (r = 0.459) also supported these results (Table 6).

iii. Copper

Statistically there was no relationship of DTPA-Cu with pH but increasing OC content had a prominent effect on Cu availability as it is evident from a highly significant coefficient of correlation (r = 0.678) between OC and DTPA extractable Cu. The increase in copper content was 0.78 to 1.68 mg kg^{-1} with increasing OC content from 0.5 to more than 0.75% (Figure 7). It may be due to the fact that complexing agents are generated by organic matter which in turn promoted Cu availability in soils. Similar relationship was also reported by Karim *et al.* (1976). The DTPA-Cu increased from 1.18 mg kg^{-1} in soils having clay less than 20% to 1.78 mg kg^{-1} in soils with clay content greater than 30%. A positive and significant correlation between DTPA-Cu with clay (r=0.628) (Table 6). Katyal and Vlek (1985) also obtained a positive relationship between DTPA-Cu and clay content of soils.

iv. Manganese

The availability of Mn decreased with increase in pH (Frierch and Catalano 2012; Schwab *et al.* 1990). DTPA-Mn of the soil was positively correlated with organic carbon and the availability of Mn increased with increase in OC content. Its content in soils increased from 6.29 to 9.55 mg kg^{-1} when the OC content of the soils rise from less than 0.5% to more than 0.75%. The extent of increase was higher (3.26 mg kg^{-1}) with increasing OC content from less than 0.5% to more than 0.5% but it was lower (1.87 mg kg^{-1}) when OC increased from less than 0.75% to more than 0.75%. The availability of Mn decreased with increasing

$CaCO_3$ content from less than 1 to 2% but again it increased with increasing $CaCO_3$ content from less than 2% to more than 2% (Fig. 10). The mean DTPA-Mn was 5.58, 7.86 and 8.42 mg kg^{-1} in soils having clay less than 20, between 20 and 30 and greater than 30%, respectively. These results also supports a significant positive relationship of Mn with clay (r =0.468).

Acknowledgement:

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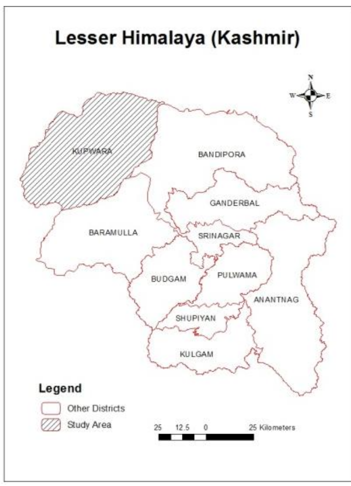
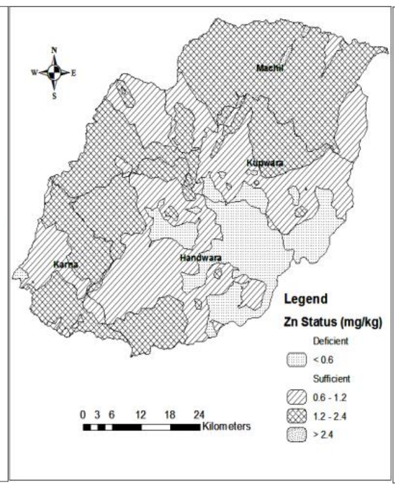




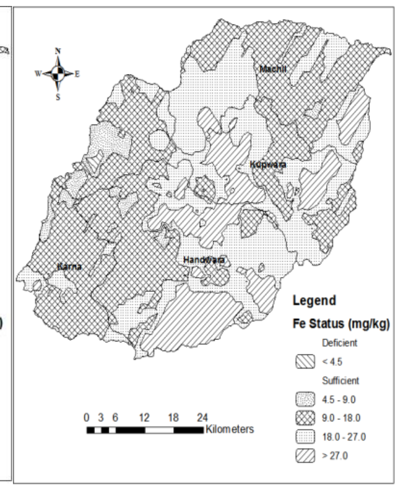
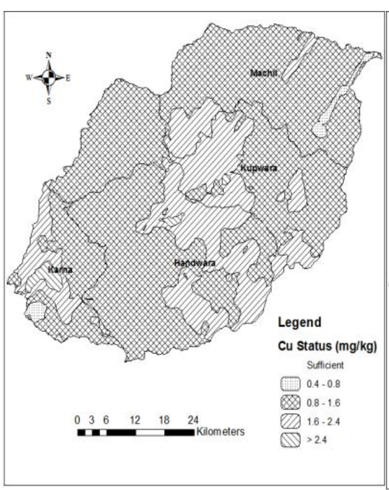
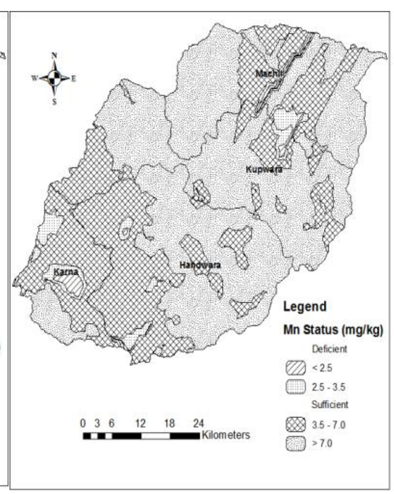


Fig 1. Location Map

Fig 2. Zinc status

Fig 3. Iron status





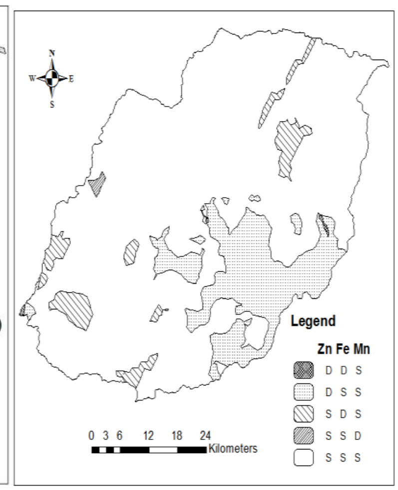


Fig 4. Copper status

Fig 5. Manganese status

Fig 6. Multi-micronutrient deficiency

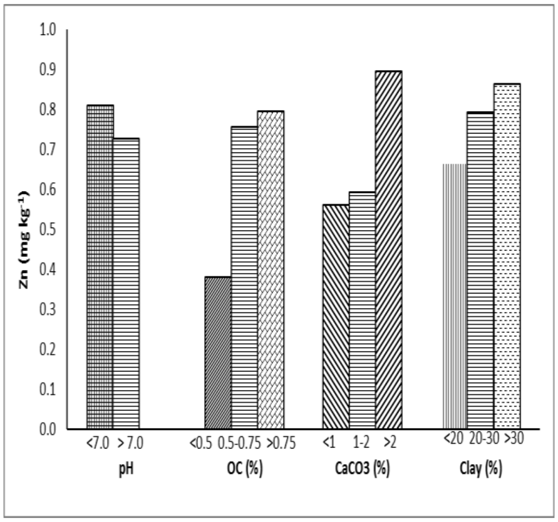


Figure7. Soil Zn as affected by pH, organic carbon, CaCO3 and clay content

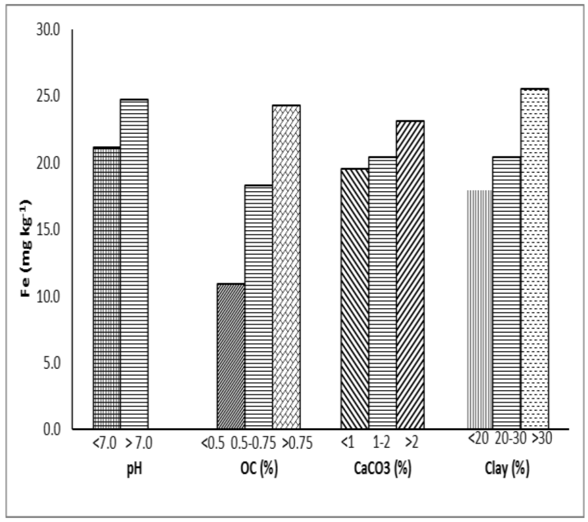


Figure 8. Soil Zn as affected by pH, organic carbon, CaCO3 and clay content

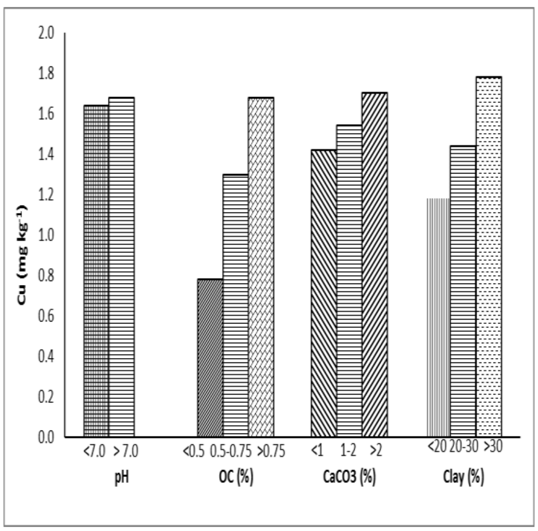


Figure9. Soil Cu as affected by pH, organic carbon, Carbon, CaCO3 and clay content

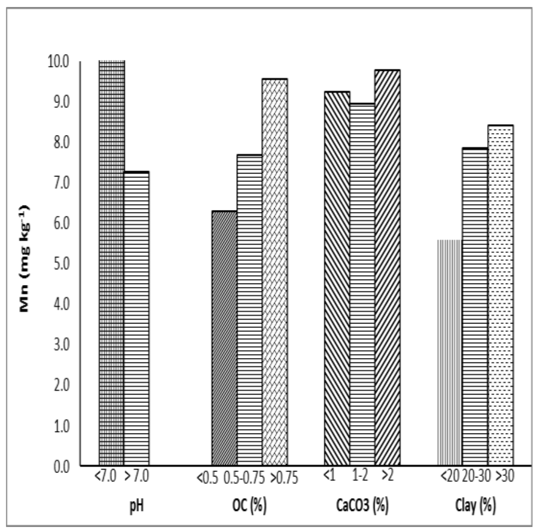


Figure 10. Soil Mn as affected by pH, organic CaCO3 and clay content

Table 1
Criteria for assessment of micronutrients in soils and plants

Nutrients (mg kg^{-1})	Soil						
	Deficient		Sufficient				
Zn	(I) < 0.6		(II) 0.6 – 1.2	(III) 1.2 - 2.4	(IV) > 2.4	-	-
Fe	(I) < 4.5		(II) 4.5 – 9.0	(III) 9.0 – 18.0	(IV) 18.0 – 27.0	(V) > 27.0	(VI) NA
Cu	(I) < 0.2		(II) 0.2 – 0.4	(III) 0.4 – 0.8	(IV) 0.8 – 1.6	(V) 1.6 – 3.2	(VI) > 3.2
Mn	(I) < 2.5	(II) 2.5 - 3.5		(III) 3.7 – 7.0	(IV) > 7.0	-	-
	Plant						
Zn	< 20					> 20	
Fe	< 50					> 50	
Cu	<5.0					>5.0	
Mn	< 20					> 20	

Table2. Micronutrient (mg kg-1) status of soils and plants (rice/maize) in Kupwara district

Nutrient	Minimum	Maximum	Mean	S.D
Soils				
Zn	0.12	5.10	0.79	0.62
Fe	0.89	51.18	23.80	12.43
Cu	0.26	3.90	1.65	0.67
Mn	0.51	33.30	9.34	6.83
Plants				
Zn	16.3	73.3	39.9	10.1
Fe	22.4	585.0	236.8	137.7
Cu	7.6	20.1	14.0	2.6
Mn	7.3	649.3	149.4	146.7

Table3. Percentage of samples falling in different ranges of micronutrient

Nutrients ($mg\ kg^{-1}$)	Soil					
	I	II	III	IV	V	VI
Zn	53.3	26.6	17.8	2.4		
Fe	3.4	10.1	25.0	17.9	43.7	
Cu	0.0	0.7	7.8	42.7	36.0	12.8
Mn	16.5	5.9	19.8	57.8		
	Plant					
Deficient			**Sufficient**			
Zn	2.1			97.9		
Fe	6.3			93.7		
Cu	0.0			100		
Mn	12.5			87.5		

Table4. Area (ha) under different categories of nutrients

Category	Area (ha)			
	Zn	Fe	Cu	Mn
I	45063.7 (14.8)	657.3 (0.2)	0.0 (0)	2910.8 (1.0)
II	110433.0 (36.3)	11894.2 (3.9)	327.5 (0.1)	11557.6 (3.8)
III	148187.0 (48.7)	137860.0 (45.3)	3539.0 (1.2)	113693.0 (37.3)
IV	893.7 (0.3)	105041.0 (34.5)	220148.0 (72.3)	176416.0 (57.9)
V		49124.9 (16.1)	77213.0 (25.4)	
VI			3349.9 (1.1)	

Note: Figures in parenthesis are the percentage of the total geographical area of the district

Table5. Area under various micronutrient categories in Kupwara district

Category			Area	
Zn	Fe	Mn	(ha)	(%)
D	D	S	347.6	0.1
D	S	S	44716.1	14.7
S	D	S	14120.4	4.6
S	S	D	657.3	0.2
S	S	S	244736.0	80.4

D-Deficient, S-sufficient

Table6. Correlation between micronutrients and chemical properties of soil

Soil properties	Zn	Fe	Cu	Mn
pH	0.461*	NS	NS	-0.413*
EC	0.475*	0.417*	NS	NS
OC	0.645**	0.470*	0.678**	-0.458*
$CaCO_3$	0.445*	0.471*	NS	NS
Clay	0.342	0.459*	0.628**	0.468*

*** Significant at 5% level NS = Non-significant**

Conclusion:

The rice-brown sarson growing soils of Kupwara district require zinc fertilizers for better crop growth and productivity of crops. Apart from Zn, deficiency of Mn may cause a nutritional problem in these soils in near future. The spatial maps generated under the study will be useful for guiding the farmers to decide the amount and kind of nutrient to be applied for optimum/economic returns, as the nutrient management will be different for areas having deficiency of one or more nutrients than those having the sufficient nutrients.

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