

Spatial Distribution of DTPA-Extractable Micronutrients in Arid Soils of Jhunjhunun District, Rajasthan

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Received: December 2013

Abstract: Based on 252 georeferenced surface soil samples (0-30 cm), the spatial variability of DTPA-extractable micronutrients viz., Zn, Fe, Mn, and Cu, in four major land uses in Jhunjhunun District, has been mapped in a GIS environment, and their adequacy determined as per the criteria followed in the soil testing laboratories. Zn content in soils varied from 0.28 to 3.6 mg kg⁻¹, Fe from 3.2 to 30.4 mg kg⁻¹, Mn from 3.4 to 40.5 mg kg⁻¹ and Cu from 0.12 to 4.8 mg kg⁻¹. About 18% area (106704 ha) of the district is deficient in Zn, and 6.3% area (37346.4 ha) in Fe. Deficiency of Mn and Cu is negligible. Individual micronutrient deficiency is more prominent than deficiency of micronutrients in combinations. A broad positive correlation of the DTPA-extractable micronutrients is found with soil organic carbon and clay, while soil pH and CaCO₃ has negative influence on the availability of Zn, Mn and Fe.

Key words: Micronutrients, spatial variability, land use, GIS.

Micronutrients have an important role in balanced plant nutrition and stabilization of crop production. Their availability is influenced mainly by the soil properties, particularly pH, organic matter, CaCO₃, soluble salts, cation exchange capacity and soil texture. Micronutrient deficiencies in soils get enhanced due to mining by the plants (Rattan and Sharma, 2004; Shukla, 2011). Long and continuous mining can change the status from single-nutrient deficiency to multi-nutrient deficiencies. In India deficiencies of Zn and Fe are most widespread, followed by Mn and B, mostly because of the characteristics of some specific soil groups, intensity of cropping and climatic conditions (Shukla, 2011). The deficiencies have been found to get aggravated especially under the exploitative nature of modern agriculture that involves continuous and excessive use of chemical fertilizers with high concentration of macronutrients, but without organic matter input through organic sources, as well as due to the extremely low amount of crop residues recycling (Nayyar *et al.*, 2001). In arid region, the soils are generally coarse textured, alkaline in reaction and mostly poor in fertility, but systematic information on

the content and distribution of micronutrients is meager and mostly based on some random sampling (Sharma *et al.*, 1985). Considering the above, and the apprehension that continuous cropping in the region might lead to enhanced deficiency of the soil micronutrients, a systematic mapping of the soil fertility status was undertaken in the arid western part of Rajasthan.

The present study was conducted in Jhunjhunun District (5928 km²) in the north eastern fringe of Thar Desert, where the mean annual rainfall is 444.5 mm, received mainly during summer monsoon. Spatially, the rainfall decreases from 484 mm in the east to 331 mm in the west. The potential mean annual evapo-transpiration is 1578 mm, which always exceeds the precipitation and thus compel a short growing period of rainfed crops. Air temperature during summer vary between 39.8°C and 41°C while during winter the mean minimum temperature vary between 4.2 and 5.3°C.

The soils of the district are coarse textured, light brown, sandy, sandy loam to sandy clay loam, very deep, non-calcareous and well-drained. These are classified under Typic Torripsamments and Typic Haplocambids. Pearl millet, clusterbean, moth bean, mung bean and sesame are the important kharif crops. Wheat and mustard are grown with groundwater

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irrigation, while gram is cultivated with the support of conserved moisture and winter rains (*Mawat*).

Materials and Methods

Soil samples (0-30 cm) were collected from 252 random sites in the district, covering the following four major land uses: (a) irrigated croplands, (b) rainfed croplands, (c) grazing lands (permanent) and (d) grazing lands (sand dunes). Location of the sampling sites was recorded with the help of a Global Positioning System (GPS). The air-dried samples (<2 mm) were analyzed for DTPA-extractable micronutrients (Zn, Fe, Mn, Cu) using Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). The pH, EC, and organic carbon were determined as per Jackson (1973). Particle size analysis and CaCO₃ content in soils were estimated following Piper (1966). The CEC was determined following saturation of soils with 1N sodium acetate (pH 8.2) as per Richards (1954). Available phosphorus was determined by Olsen extraction method (Olsen *et al.*, 1954),

and available potassium by flame photometer after extraction with neutral normal ammonium acetate solution (pH 7.0) following Jackson (1973). Soil samples were classified as sufficient or deficient as per the critical limits for Fe, Mn, Zn and Cu given by Lindsay and Norvell (1978). Spatial distribution maps for different micronutrients were prepared using Arc Info GIS. Polygons showing different combinations of micronutrients either as sufficient (S) or deficient (D) were extracted using Arc/GIS spatial analyst module. The sufficiency or deficiency of the micronutrient contents was determined using the classification proposed by Sharma *et al.* 2006; Table 1.

Results and Discussion

Physico-chemical characteristics of soils

The soils of the district are fine sand to clay loam in texture (Fig. 1) in the sampling depth of 0-30 cm from the surface (sand 50-94%; clay 2.7-32.5%). These are mostly alkaline in reaction, pH ranging from 7.2 to 9.7 and EC from 0.05

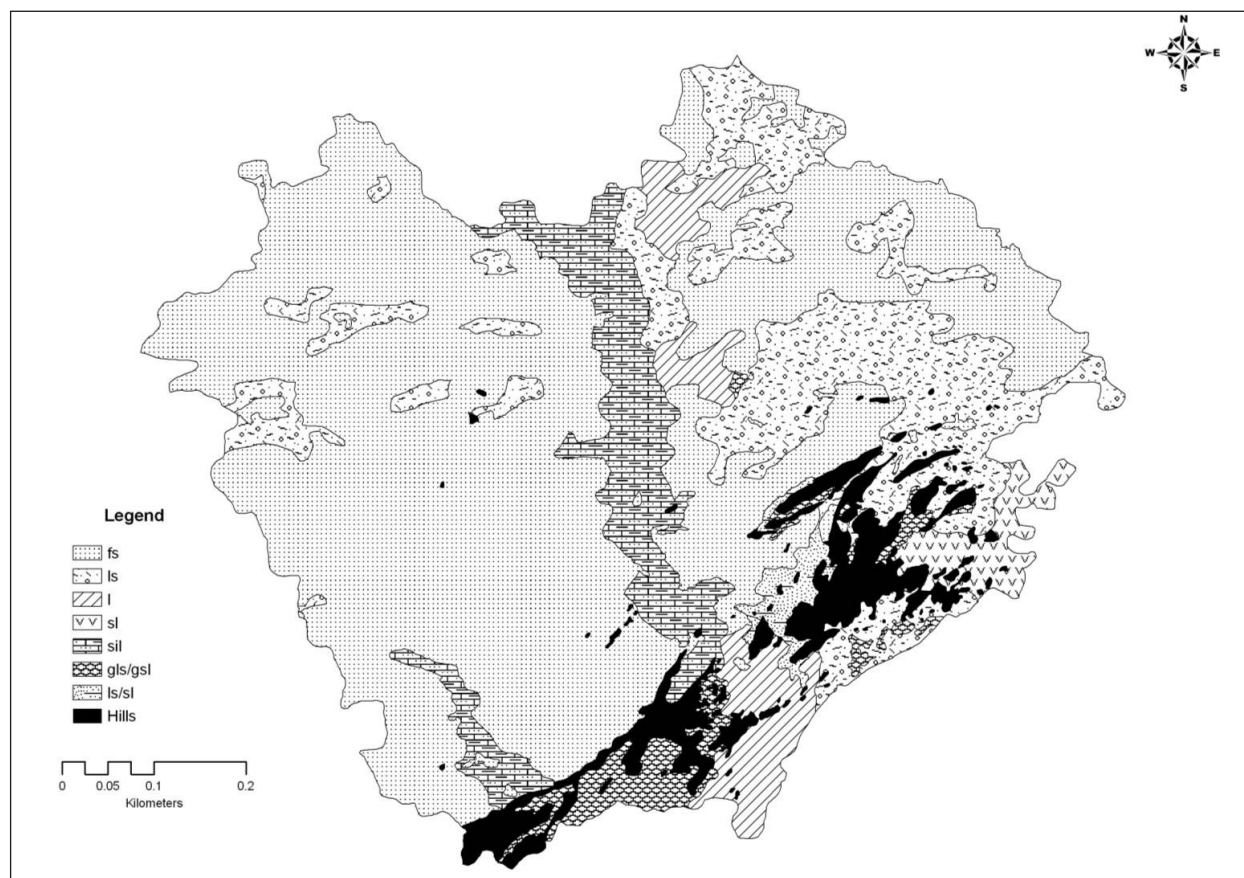


Fig. 1. Broad soil textural classes (surface soil) in Jhunjhunun District (where, fs-fine sand; ls-loamy sand; sl-sandy loam; l-loam, sil-silty loam; gls-gravelly loamy sand; gsl-gravelly sandy loam).

Table 1. Criteria for assessment of micronutrient deficiencies in soils (mg kg^{-1})

Nutrients	Category					
	Deficient			Sufficient		
	I	II	III	IV	V	VI
Zn	<0.6	0.6-1.2	1.2-2.4	>2.4		
Cu	<0.2	0.2-0.4	0.4-0.8	0.80-1.6	1.6-3.2	>3.2
Fe	<4.5	4.5-9.0	9.0-18.0	18.0-27.0	>27.0	
Mn	<2.5	2.5-3.5	3.5-7.0	>7.0		

Source: Sharma *et al.*, 2006.

Deficient category (class I) and Sufficient category (class II-VI) used in maps.

to 2.5 dS m^{-1} . Soil organic carbon (SOC) ranges from 0.03 to 0.62% (mean 0.16%). The CaCO_3 content in the soils varies from nil to 8.5%.

Available phosphorus (P) in the soils ranges from 2.7 to 58.2 kg ha^{-1} (mean 14.7 kg ha^{-1}). The high content is most likely due to the carry-over effect of continuous phosphorus fertilization over a long period of time as large parts of the district are under irrigated double cropping for many decades (Anon., 2007). Available potassium (K) in the soils varies from 84 to 616 kg ha^{-1} , but shows some deficiency in small scattered pockets across the district.

DTPA extractable micronutrients and their spatial distribution

The DTPA-extractable Zn in the soils shows wide variability of 0.28 to 4.50 mg kg^{-1} , with a mean of 0.94 mg kg^{-1} (Table 2, Fig. 1). The higher contents ($>1.2 \text{ mg kg}^{-1}$ soil) are dominantly found along the Kantli River valley, running south to north in the eastern half of the district, other smaller stream valleys, as well as in the shallow intermountain plains of the Aravallis in the south-east. The minimum contents ($<0.6 \text{ mg kg}^{-1}$ soil) are found in the sandy undulating terrain in the NW, especially in the sandy hummocks. Considering the critical limit to be 0.6 mg kg^{-1} soil, 18.0% area (106704 ha) of the district is deficient in Zn content (which represent 24% of the samples analyzed). Deficiencies of Zn have also been

Table 2. Micronutrients (mg kg^{-1}) status in soils of Jhunjhunun District

Micro-nutrients	Range	Mean	SD
Zn	0.28-4.50	0.94	0.534
Cu	0.12-4.80	1.00	0.845
Fe	3.20-30.40	7.70	3.550
Mn	3.40-40.50	12.10	6.750

reported from other arid and semi-arid areas of the country (Dhir, 1977; Gupta *et al.*, 2000; Sakal, 2001; Mahesh Kumar *et al.*, 2011). The mapping also reveals that dominantly the contents are sufficient ($0.6-1.2 \text{ mg kg}^{-1}$) in the sandy alluvial plains, adequate ($1.2-2.4 \text{ mg kg}^{-1}$) in large parts of the younger alluvial plains and the intermontane plains, and high ($>2.4 \text{ mg kg}^{-1}$) in parts of the Kantli River valley. The areas under the above three sufficiency categories are 61.7%, 15.4% and 4.9% of the district area, respectively (Fig. 2). The mapping suggests that large part of the district is now under the threat of slipping below the critical limit if Zn fertilization is not taken up on the basis of recommended practices.

The DTPA-extractable Cu in the soils varies from 0.12 to 4.80 mg kg^{-1} (mean 1.0 mg kg^{-1} ; Table 2). As in the case of Zn, the higher values of Cu ($>1.6 \text{ mg kg}^{-1}$) are along the stream valleys and the intermontane plains of the Aravallis

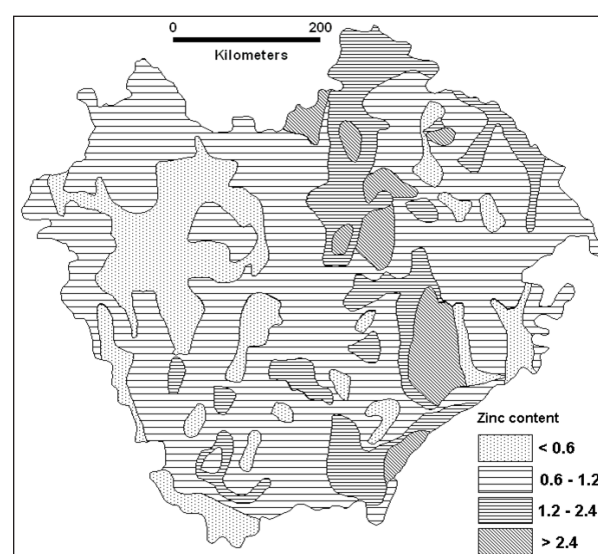


Fig. 2. Spatial distribution of Zn in the soils of Jhunjhunun District.

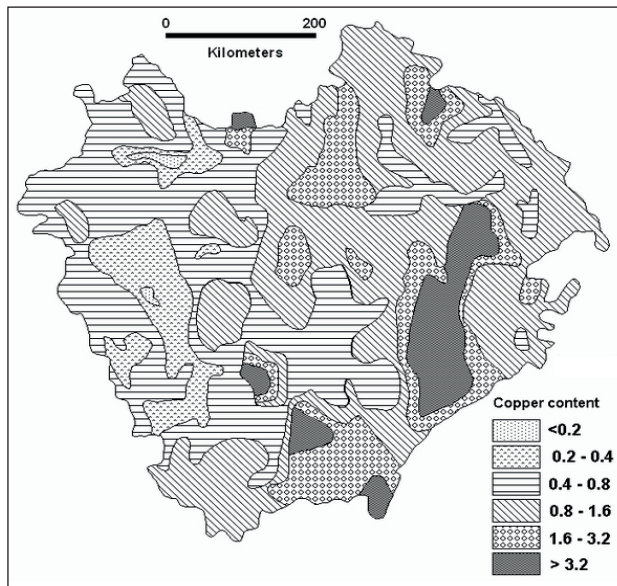


Fig. 3. Spatial distribution of Cu in the soils of Jhunjhununu District.

in the south-east, while the lower values ($<0.04 \text{ mg kg}^{-1}$) are associated with the sandy hummocks. Mapping based on Sharma *et al.* (2006) classification of sufficiency (Table 1), about 72.5% area of the district has soils with Cu content of $0.80\text{--}3.20 \text{ mg kg}^{-1}$, 6.6% area with $>3.2 \text{ mg kg}^{-1}$, 13.2% area with $0.40\text{--}0.80 \text{ mg kg}^{-1}$, and 7.5% area with $0.20\text{--}0.40 \text{ mg kg}^{-1}$ content (i.e., deficient; Fig. 3). Thus, Cu deficiency is not a problem for agriculture in the area. Considering the critical limit of Cu as 0.2 mg kg^{-1} , the soils are mostly sufficient in Cu, and only 0.20% area (1185.6 ha) is found deficient.

The DTPA-extractable Fe varies from 3.2 to 30.4 mg kg^{-1} (mean 7.7 mg kg^{-1}). The intermontane plains of the Aravallis and its foothills in the SE, the dune-covered areas in the NW and parts of the younger alluvial plains of the Kantli River are dominated by a content of $>9.0 \text{ mg kg}^{-1}$, while large parts of the older sandy alluvial plain have a content of $4.5\text{--}9.0 \text{ mg kg}^{-1}$. The sandy hummocks in the west mostly have a content $<4.5 \text{ mg kg}^{-1}$ (i.e., deficient). The mapping reveals that 70.3% area has a content of $4.5\text{--}9.0 \text{ mg kg}^{-1}$, 21.2% area has $9.0\text{--}18.0 \text{ mg kg}^{-1}$, 1.8% area $18.0\text{--}27.0 \text{ mg kg}^{-1}$, and 0.4% area $>27.0 \text{ mg kg}^{-1}$ (Fig. 4). Only 6.3% area is deficient in Fe ($<4.5 \text{ mg kg}^{-1}$).

The DTPA-extractable Mn ranges from 3.4 to 40.5 mg kg^{-1} (mean 12.1 mg kg^{-1}). Mapping reveals that most part of the district has a content of $>7.0 \text{ mg kg}^{-1}$, while small areas

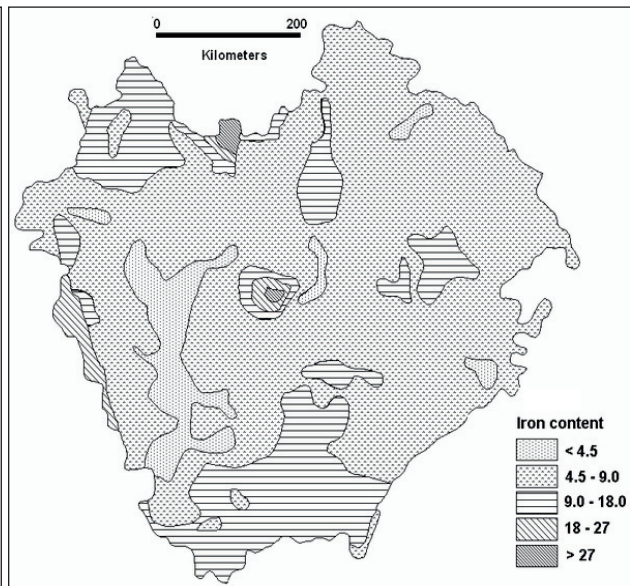


Fig. 4. Spatial distribution of Fe in the soils of Jhunjhununu District.

stretching NE-SW along the foothills of the Aravallis have a content of $3.5\text{--}7.0 \text{ mg kg}^{-1}$, with isolated islands of $2.5\text{--}3.5 \text{ mg kg}^{-1}$ within them (Fig. 5). Considering 2.5 mg kg^{-1} soil as the critical limit (Lindsay and Norvell, 1978), none of the area of the district was found below critical in Mn content. The results conform the findings of Sharma *et al.* (1985) and Gupta *et al.* (2000).

Multi-micronutrient deficiencies

The study did not find a combined deficiency of all the four micronutrients (Zn, Cu, Fe and

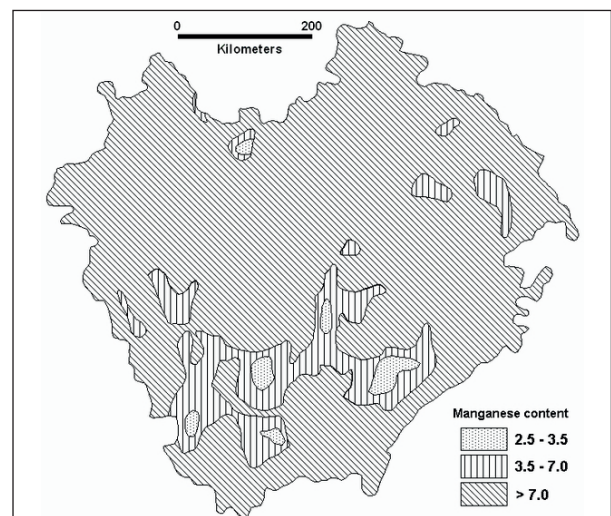


Fig. 5. Spatial distribution of Mn in the soils of Jhunjhununu District.

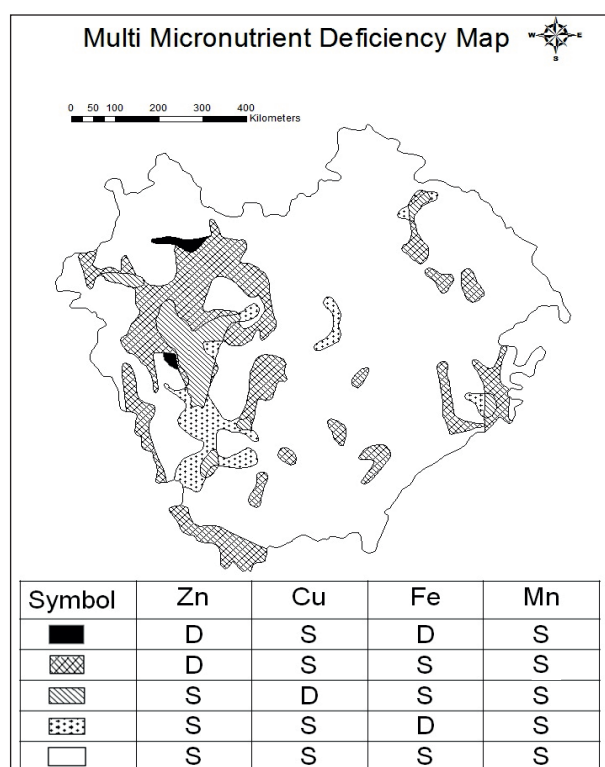


Fig. 6. Multi-micronutrients deficiencies in Jhunjhunu District.

Mn) at any one site. Even, the deficiency of more than two micronutrients is rarely present in the district. Individually, Zn is the most common micronutrient found deficient at a particular site, followed by Fe.

Mapping reveals that 78.5% area of the district (465348 ha) has all the four micronutrients above the critical limits, (i.e., sufficiency of Zn, Cu, Fe and Mn, marked in the order as SSSS in Fig. 6), followed by 14.4% area (85363.2 ha) having deficiency of Zn, but sufficiency of Cu, Fe and Mn (marked as DSSS), 3.30% area (19562 ha) having deficiency of Fe, but sufficiency of others (SSDS), 0.40% area (2371 ha) having deficiency of Cu and sufficiency of others (SDSS), and

Table 3. Relationship (*r* value) between available micronutrients and soil properties

Soil property	Micronutrients			
	Zn	Cu	Fe	Mn
pH	-0.022	-0.152*	0.021	-0.006
CaCO ₃	-0.045	0.038	-0.059	-0.014
SOC	0.334**	0.336**	0.480**	0.272*
Clay	0.158*	0.182*	0.323**	0.234*

* Significant at 0.01 level significance,

** Significant at 0.05 level of significance.

3.40% area (20155 ha) having deficiency of Zn and Fe, but sufficiency of Cu and Mn (DSDS; Fig. 6). When seen in the background of major land uses, some interesting features emerge, as discussed below.

Impact of different land uses on micronutrients

The soils under irrigated cropping (intensively cropped) have the higher values of Fe (4.2-30.4 mg kg⁻¹; mean 8.2 mg kg⁻¹) and Zn (0.35-4.7 mg kg⁻¹; mean 1.2 mg kg⁻¹), followed by permanent grazing lands, which have higher Mn (6.9-40.5 mg kg⁻¹; mean 13.3 mg kg⁻¹) and Cu (0.48-4.5 mg kg⁻¹; mean 1.8 mg kg⁻¹) than the other dominant land uses in the district. The lower mean values of Zn (0.82 mg kg⁻¹), Cu (1.2 mg kg⁻¹), Fe (6.8 mg kg⁻¹) and Mn (7.6 mg kg⁻¹) are found in the open grazing lands of the sand dunes (Fig. 7).

The higher concentration of Fe and Zn in irrigated croplands, which are also double cropped in most of the years, could be attributed to the continuous use of FeSO₄ and ZnSO₄ for the crops as per the recommendations of the state agricultural departments, Krishi Vigyan Kendras, NGOs and other agencies working for the farming communities in the district. Both the irrigated and the rainfed croplands have comparatively lower levels of Mn and Cu than the grazing lands (both permanent and open), possibly due to continuous removal of these micronutrients by crops and apathy of the farmers to replenish the loss through external sources (Anon., 2006; Mahesh Kumar *et al.*, 2009).

Relationship between soil properties and available micronutrients

A faint hint of the dependence of available micronutrients on some important soil properties has been found from the broad statistical correlation between them (Table 3). The DTPA-extractable Zn, Cu, Fe and Mn show a positive correlation with organic carbon, although the relationship is not very strong. The significant and positive relationship noticed between Zn and SOC ($r=0.339$) has also been reported from other arid and semi-arid soils in the country (Mahesh Kumar *et al.*, 2011; Minakshi *et al.*, 2005; Sharma *et al.*, 2006). The available Zn in the soils of the district also shows a significant and positive correlation with the clay content of the soil ($r=0.158$), but

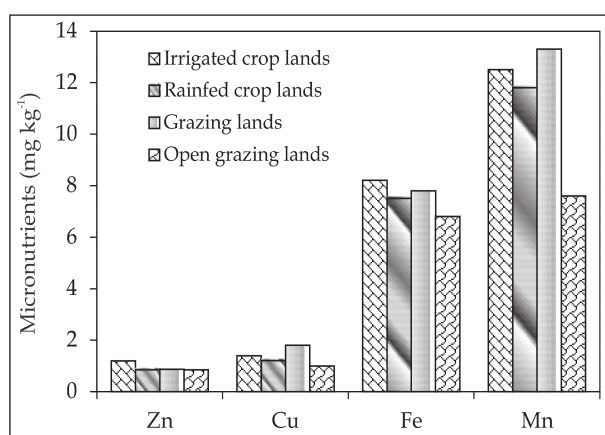


Fig. 7. Levels of available micronutrient under different land uses.

a faint negative relationship with soil pH and CaCO_3 ($r=-0.0211$). Takkar *et al.* (1977) observed similar results in sandy soils having high pH, CaCO_3 and low organic matter.

Among the other important relationships, available Cu has significant correlation with SOC ($r=0.337$), which agrees well with the results of Dhane and Shukla (1995) and Sharma *et al.* (1985). DTPA-extractable Fe is also found to be significant and positively correlated ($r=0.480$) with SOC, as has been reported from other areas also (Katyal and Sharma, 1991; Minakshi *et al.*, 2005). Clay content in the soils is also found to have some positive relationship with Fe ($r=0.323$). Overall, the results of relationship from the district are in broad agreement with the findings of Sharma *et al.* (2003) and Meena *et al.* (2006) from other parts of Rajasthan.

Conclusions

The GIS-based study on soil micronutrients in four major land uses in Jhunjhunun District reveals widespread Zn deficiency, which requires urgent attention and adequate fertilization. Deficiency of Fe in the soils is also an emerging phenomenon which, if neglected, may cause nutritional imbalance in the soils and consequently affect the crop yields. It is felt that a systematic monitoring of the soil micronutrient status, based on GIS mapping of the resource at periodic intervals, along with mapping and monitoring of the other soil properties, land use, cropping practices, and input management will help to determine the types of interventions required to maintain micronutrient adequacy in the soils, and to

provide timely guidance to the farmers on the fertilization needs.

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