RESEARCH ARTICLE

SPATIAL VARIABILITY OF AVAILABLE SOIL NUTRIENTS AND USING GIS FOR NUTRIENT MANAGEMENT IN HOT ARID REGIONS OF NORTH-WESTERN INDIA

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Abstract: Present investigation was conducted to assess the spatial variability of available soil nutrients and using GIS for nutrient management in hot arid regions of North-Western India. Altogether, one hundred fifty surface soil samples were collected using global positioning system (GPS) from the farmer's field of Nagaur district area covering five villages.Soils of the district were found to be slightly to moderate alkalinity in reaction with a low organic carbon (OC) content and low in cation exchange capacity (CEC).The analysis of the soil samples revealed that majority of the soil samples fall under low to medium soil fertility.The soil samples were analyzed for macro and micro nutrient viz, available nitrogen (N), available phosphorus (P), Available potassium (K), copper (Cu),iron (Fe), manganese (Mn) and zinc (Zn), Results of the soil analysis revealed that Available N and Pwere low throughout the region, while available K, was medium. Among the micronutrients, Cu and Mn were adequately supplied in most areas, but Zn and Fe were inadequate in large parts. The spatial variability available plant nutrients viz., N, P, K, Cu, Fe, Mn and Zn in hot arid regions of Rajasthan across the land uses in region, has been mapped in a geographic information system (GIS), and their adequacy determined as per the criteria followed in the soil testing laboratories. Present study also showed that the hot arid regions of north western India not only deficient in individual nutrients but they also suffer from all plant nutrients deficiencies which warrants attention for soil test based soil fertility management.

Keywords: Geographic information system, Global positioning system, Macronutrients, Micronutrients, Soil laboratory

INTRODUCTION

Fertility status of the soils is most and importantly dependent on macro and micronutrient reserve of a cultivated land. Availability of nutrient in soils play pivotal role in determination of fertility status and sustainable productivity of soils. Hence, soil test based fertilizer recommendation could be an effective tool for optimizing soil fertility and productivity.In the arid north western part of Rajasthan, which contains the Desert, the soils are generally coarse textured, alkaline in reaction and are reported to be poor soil fertility and are prone to multi-nutrient deficiencies on intensive cultivation (Verma *et al.*, 2017; Kumar *et al.*, 2020).Increasing micronutrient deficiencies might be due to the continuous cropping, intensive cropping, and use of high grade chemical fertilizers, increased dry matter production and minimal use of organic manures.

Soil fertility and mapping of the spatial distribution of available soil nutrient status are important for location-specific crop management and sustainable agriculture, as well as for precision farming, but such geo-coded data is not available for in-depth studies. It was felt that the spatial data on the distribution of the macro and micronutrients under different land uses type could be better mapped and stacked for future analyses if the data points are tagged through precise GPS locations, and integrated on a GIS platform (Kumar *et al.*, 2019).

With use of information technology tools like GIS and GPS helps in generation of spatial data/maps on distribution of available plant nutrients with which we can precisely use the required input at right place (location site specific application of inputs). Information on spatial distribution of available macro and micronutrients enables grouping of the soils into homogenous units for better nutrient management (Kumar *et al.*, 2021).

MATERIALS AND METHODS

Study area

The area under study lied in the Agro climatic zone IIA (Internal drainage dry zone) of Rajasthan. The research site of study is located at 26°25′ and 27°40′ North latitude and 73°10′ and 75°15′ East longitude of Nagaur district, Rajasthan, India.

Collection of soil samples and analysis

One hundred fifty (150) surface soil (0-15 cm) samples were collected at representing five tehsils of Nagaur district viz., Nagaur, Jayal, Didwana, Ladnu and Nawa. The collected soil samples were processed and analyzed for macro and micro nutrients like available N by alkaline K permanganate method (Subbiah and Asija 1956),

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available P by Bray's method (Bray and Kurtz 1945), available K by flame photometric method (Jackson 1973). Available micronutrients namely, iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) were extracted by DTPA and measured by atomic absorption spectrophotometer as described by Lindsay and Norvell (1978). The analytical results of each soil samples was categorized as low, medium and high categories based on the critical limits for macro and micronutrients by following the criteria (Table 1).

Table 1. Categorization of different nutrients on basis of availability

Nutrient	Low	Medium	High
Available nitrogen (kg ha^{-1})	<250	250 - 500	>500
Available phosphorus (Kg ha^{-1})	<20	20-50	>50
Available potassium (Kg ha^{-1})	<125	125-300	>300
Available Cu (mg kg^{-1})	<0.2	0.2-0.4	>0.4
Available Fe(mg kg^{-1})	<4.5	4.5-9.0	>9.0
Available Mn(mg kg^{-1})	<2.0	2.0-4.0	>4.0
Available Zn(mg kg^{-1})	<0.6	0.6-1.2	>1.2

Source: Parker *et al.*, (1951).

The nutrient index was calculated by using the equation as proposed by (Parker *et al.*, 1951). In this method, the number of samples in each of the three categories, low (<1.67), medium (1.67-2.33) and high (>2.33) as obtained from the analysis was multiplied by 1, 2 and 3, respectively. The total of the figures thus obtained was divided by total number of samples.

$$\text{Nutrient index (NI)} = \frac{\{(L \times 1) + (M \times 2) + (H \times 3)\}}{\text{Total no. of samples}}$$

Where, L, M and H are the number of soil samples falling in category of low, medium and high nutrient status.

RESULTS AND DISCUSSION

Available nitrogen

The available nitrogen (N) content of the studied soils varied from 110.40 to 220.30 kg ha^{-1} with mean value of 168.95 kg ha^{-1} in Nagaur, 112.30 to 215.30 kg ha^{-1} with mean value of 158.66 kg ha^{-1} in Jayal, 112.10 to 218.20 kg ha^{-1} with mean value of 151.82 kg ha^{-1} in Didwana, 114.20 to 220.30 kg ha^{-1} with mean value of 153.77 kg ha^{-1} in Ladnu, 110.00 to 222.40 kg ha^{-1} with mean value of 149.90 kg ha^{-1} in Nawa, respectively. From the data (Table 2), it is clear that all the soils were low in available nitrogen. The low levels of nitrogen may mainly be ascribed low organic carbon content, resulting from sub-optimal vegetation, high temperature and high soil pH, favoring higher oxidation and volatilization losses (Kumar *et al.* 2014).

Available phosphorus

The available P in soils shows wide variability 14.41 to 20.90 kg ha^{-1} with mean value of 18.09 kg ha^{-1} in Nagaur, 14.80 to 21.23 kg ha^{-1} with mean value of 17.56 kg ha^{-1} in Jayal, 14.60 to 19.15 kg ha^{-1} with mean value of 16.92 kg ha^{-1} in Didwana, 14.60 to 21.23 kg ha^{-1} with mean value of 18.01 kg ha^{-1} in Ladnu, 13.23 to 19.61 kg ha^{-1} with mean value of 16.55 kg ha^{-1} in Nawa, respectively (Table 2). As a result,indicating low to medium in available P status in these soils. While, 137 soil samplesunder low category and 13 soil samples have medium (Table 3). The deficiency of P in arid soils may be attributed to their inherent low P status, low organic matter and formation of Ca-P, in soils containing high CaCO3 (Kumar *et al.*, 2021).

Available potassium

Available K ranged from 115.72 to 223.17 kg ha^{-1} with mean value of 158.50 kg ha^{-1} in Nagaur, 99.19 to 224.55 kg ha^{-1} with mean value of 134.00 kg ha^{-1} in Jayal, 95.05 to 223.17 kg ha^{-1} with mean value of 140.69 kg ha^{-1} in Didwana, 93.68 to 217.66 kg ha^{-1} with mean value of 140.47 kg ha^{-1} in Ladnu, 103.32 to 221.79 kg ha^{-1} with mean value of 157.00 kg ha^{-1} in Nawa, respectively.As a result, indicating low to medium available K status in these soils. While, 45 soil samples under low category and 105 soil samples have medium (Table 3). Low to medium content of available K in irrigated croplands is mainly due to continuous cultivation of the soils for climatically adapted crops like pearl millet, guar, mung beanand occasionally cotton, but without any replenishment of K to the soils. Depletion of available K in arid soils under intensive cultivation was also reported by Mahesh Kumar *et al.*, (2019) and Verma *et al.*, (2017). Consequently the stored K declined gradually. Generally, farmers of the region apply N and Pfertilizers like urea, DAP, SSP, sulphate and zinc sulphate to some extent, but they have not given any attention so far to replenish K through K-fertilizer.

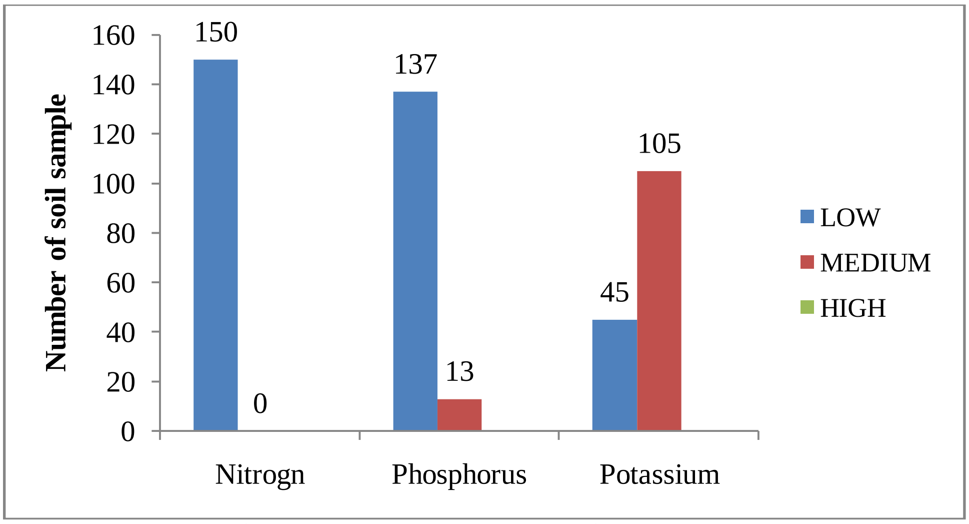

Fig.: 1. Categorization of available N, P and K on basis of availability in low medium and high

Micronutrients status and their spatial variability
The available micronutrient statuses are presented in table 2.

***Copper*:**The DTPA-extractable Cu in the soils varied from 0.25 to 0.76 ppm with the average value of 0.51 ppm in Nagaur, 0.24 to 0.75 ppm with the average value of 0.51 ppm in Jayal, 0.31 to 0.74 ppm with the average value of 0.54 ppm in Didwana, 0.28 to 0.80 ppm with the average value of 0.53 ppm in Ladnu, 0.25 to 0.82 ppm with the average value of 0.55 ppm in Nawa, respectively. In general, arid soils are not deficient in available Cu, and it varied from 0.21 to 4.28 ppm in arid soils of Rajasthan (Kumar *et al*., 2021).Considering the critical limits of Cu 0.20 ppm, all the soil have sufficient amount of available Cu(Fig. 2). Soils of almost all the tehsils have mean value for DTPA- extractable Cu greater than 0.5 ppm and 100% soil samples were found in sufficient categories for available Cu.

***Iron*:** The DTPA-extractable Fe ranged from 1.20 to 4.90 ppm with mean value of 3.22 ppm in Nagaur, 1.50 to 4.80 ppm with mean value of 3.06 ppm in Jayal, 1.80 to 5.70 ppm with mean value of 3.42 ppm in Didwana, 1.50 to 5.70 ppm with mean value of 3.52 ppm in Ladnu, 1.56 to 4.60 ppm with mean value of 3.29 ppm in Nawa, respectively. As a result, indicating low to medium iron status in these soils. Out of 150 soil samples 130 under low category and 20 soil samples have medium (Table 3). The less availability of iron in these soils is might be due to low organic matter content, loamy sand texture and high pH values. The calcium carbonate ($CaCO_3$) is present in soils get converted into bicarbonate, iron which reduces the availability of iron in soils and the chlorosis caused in this condition is known as “lime induced chlorosis” (Shukla *et al*., 2016).

***Manganese*:**The DTPA-extractable Mn in the soils of hot arid region of Rajasthan ranges from 1.40 to 4.50 ppm with the average value of 2.74 ppm in Nagaur, 1.20 to 4.50 ppm with the average value of 2.98 ppm in Jayal, 1.60 to 4.50 ppm with the average value of 2.90 ppm in Didwana, 1.40 to 4.40 ppm with the average value of 3.12 ppm in Ladnu, 1.50 to 4.30 ppm with the average value of 3.08 ppm in Nawa, respectively.The availability of manganese was found 100% in this area to be sufficient (Table 2). The relative high content of Mn in these soils could be due to the soils derived from basaltic parent material which contained higher ferromagnesium minerals.In the soil available form of manganese are mostly Mn^{2+}, Mn^{3+} and plants take up Mn^{2+} (reduced form). It can be bond to organic matter and prevent uptake 80 - 90% of Mn may be complexed with organic matter (Kumar *et al*., 2021).

***Zinc*:**The DTPA-extractable Zn in the soils of hot arid region of Rajasthan ranges from 0.21 to 0.67 ppm with the average value of 0.42 ppm in Nagaur, 0.14 to 0.78 ppm with the average value of 0.37 ppm in Jayal, 0.18 to 0.75 ppm with the average value of 0.44 ppm in Didwana, 0.16 to 0.84 ppm with the average value of 0.40 ppm in Ladnu, 0.18 to 0.84 ppm with the average value of 0.35 ppm in Nawa, respectively.These soils were deficient in available Zn. The low amount of available Zn was possibly due to high soil pH values which might be resulted in the formation of insoluble compounds of Zn or insoluble calcium zincate (Pandey*et al*., 2020).The low amount of available Zn was possibly due to high soil pH values which might be resulted in the formation of insoluble compounds of Zn or insoluble calcium zincate.The availability of zinc is low in sandy soils and highly leached in acidic soils. Mineral soils with low soil organic matter also exhibit zinc deficiency (Singh *et al*., 2021).

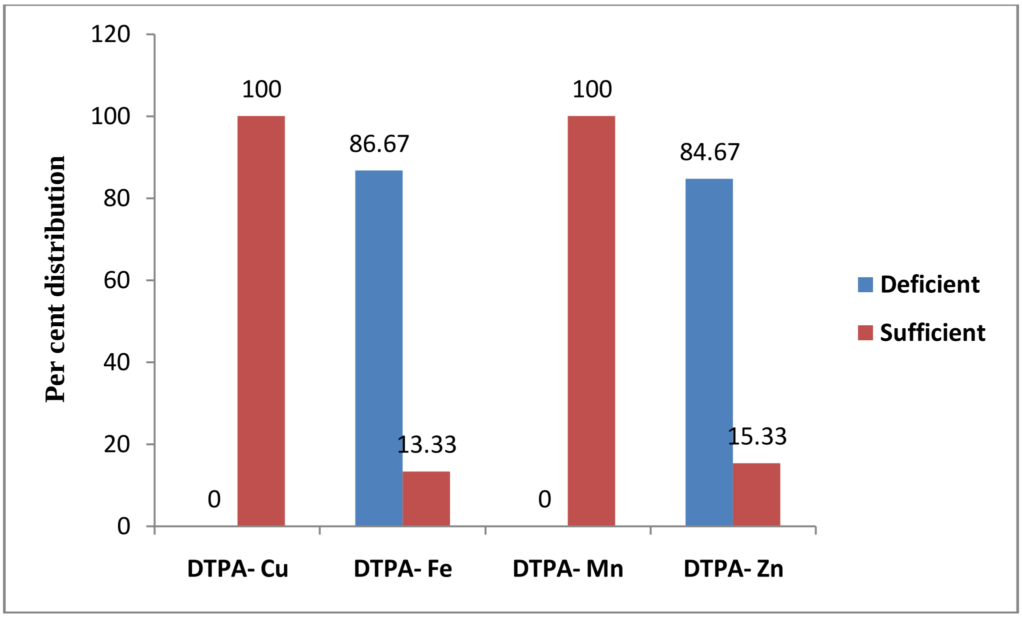

Fig.: 2. Per cent distribution of micronutrients (Cu, Fe, Mn and Zn) across the arid Rajasthan in deficient and sufficient category

Nutrient index

The nutrient index values (Table 3) were calculated as low for N, P, Fe and Zn, medium for K, Cu and Mn, indicate that there is wide spread deficiency of N, P, Fe and Zn in Nagaur area of north western Indiawhich might be due to low content of organic matter, coarse textured and no supplemental of N, P, Fe and Zn fertilizers. This may probability be due to loss of these nutrients in the anionic form from surface to lower depth through leaching.

Table 2. Soil available major and micronutrients content in Nagaur district

Tehsils	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})		Available Cu (mg kg^{-1})		Available Fe (mg kg^{-1})		Available Mn (mg kg^{-1})		Available Zn (mg kg^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Nagaur	110-220	168	14-20	18	115-223	158	0.25-0.76	0.51	1.2-4.9	3.22	1.4-4.5	2.74	0.21-0.67	0.42
Jayal	112-215	158	14-21	17	99-224	134	0.24-0.75	0.51	1.5-4.8	3.06	1.2-4.5	2.98	0.14-0.78	0.37
Didwana	112-218	151	14-19	16	95-223	140	0.31-0.74	0.54	1.8-5.7	3.42	1.6-4.5	2.90	0.18-0.75	0.44
Ladnu	114-220	153	14-21	18	93-217	140	0.28-0.80	0.53	1.5-5.7	3.52	1.4-4.4	3.12	0.16-0.84	0.40
Nawa	110-222	149	13-19	16	103-221	157	0.25-0.82	0.55	1.5-4.6	3.29	1.5-4.3	3.08	0.18-0.84	0.35

Sources: By research

Table 3. Classification of soils according to fertility status & their nutrient index

Soil available nutrients	Soil samples falling in each category of fertility level			Nutrient index value	Rating
	Low	Medium	High		
Available N	**150**	**0**	**0**	**1.00**	**Low**
Available P	**137**	**13**	**0**	**1.08**	**Low**
Available K	**45**	**105**	**0**	**1.7**	**Medium**
Available Cu	**0**	**150**	**0**	**2.0**	**Medium**
Available Fe	**130**	**20**	**0**	**1.13**	**Low**
Available Mn	**0**	**150**	**0**	**2.0**	**Medium**
Available Zn	**127**	**23**	**0**	**1.15**	**Low**

Sources: Muhr*et al*. (1965)

Table 4. Correlation coefficient (r) between soil properties and available nutrients

Parameters	pH	EC	OC	CEC
N	-0.341**	-0.044	0.931**	-0.240**
P	-0.158*	-0.132	0.143*	-0.091
K	-0.163*	0.001	0.088	-0.159*
Cu	-0.093	-0.048	0.013	-0.133
Fe	-0.161*	0.039	0.198*	-0.162*
Mn	-0.187*	-0.001	0.107	-0.090
Zn	-0.060	0.171*	0.044	-0.165*

*significant at 5% level, ** significant at 1% level

Correlation study

In general, pH shows significant correlation with nutrients like macro and micronutrients (Maqbool *et al*., 2017). Perusal of the data in table 4 showed significant and negative correlations between pH and N (r = -0.341**), P (r = -0.158*) and K (r = -0.163*). The OC showed positive significant correlation with N (r = 0.931**) and P (r = 0.143*) (Sharma *et al*. 2013). Negative significant correlation by CEC with N (r = -0.240**), K (r = -0.159*), Fe (r = -0.162*) and Zn (r = -0.165*) was found.

CONCLUSION

It is concluded from the present investigation that hot arid regions of North-Western India are slight to moderate to alkaline reaction with low content of organic matter. The proper diagnosis of nutrient deficiencies implies balance and judicious use of nutrients for sustainable agricultural production in the region.The contents of N, P, Zn and Fe are low in large areas, especially in the dune-covered west,while K Cu and Mn low to medium. Among soil properties, OC and CEC had a positive influence on the availability of macro and micronutrients whereas pH had negative influence on the availability of these nutrients. This information can be useful in developing management practices for cultivated soils of Nagaur district.

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