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Spatial variability of soil chemical property in Ramagarh village in Purna Valley of Vidarbha

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Abstract
An investigation was conducted at Ramagarh village in Daryapur tehsil of Amravati District to quantify the spatial variability of soil chemical property (pH, EC, OC, Ca and Mg). Based on the result obtained, the soil pH was varied from 8.20 to 9.82 while at the same time Electrical conductivity was varied from 0.13 to 0.68. The available Ca and Mg varied from 30.8 to 41.2 cmol (p^+) kg^{-1} and 10.8 to 23.6 cmol (p^+) kg^{-1} with a mean value of 36.85.and 16.66 respectively. In case of OC it was ranged between 0.24 to 0.95 per cent with mean of 0.56.

Keywords: spatial variability, soil pH, available Ca and Mg and organic carbon

Introduction
Soil is most precious natural resource of any nation. It is finite resource and its judicious management is of paramount importance. It provides a basic support to agriculture and largely governs the success of crop production. The ever increasing need for food to support the growing population demand, efficient management and utilization of limited and precious land resources is highly essential. However, the progress in this aspect is slowed down mainly because of some negative factors which cause deterioration and degradation of these precious resources. Out of several factors the problem of salinity/sodicity is of great concern which is mostly confined to arid and semi arid region of country.

Vidarbha has two major river basins. Amongst these two rivers Purna river rises in Satpura hills in Betul district of MP, meanders its course first southwards and then north-westwards to eventually meet Tapi river near Edlabad in Jalgaon district. The elliptically shaped Purna basin is about 170 in E - W and about 55 km NS. Its geographic area is 7500 sq km. The basin lies in Akola, Amravati and Buldhana districts of Vidarbha, bound in the north by Satpura hills. The basin comprises of alluvial soils deposited over centuries. Out of 7500 sq km area of the basin, 2700 sq km has severe problems of salinity. This belt is called "Kharpanpatta" in Marathi (meaning the tract of saline soil and ground water).

The Purna basin lying in western Vidarbha has unique features, which has extremely high innate soil and water salinity. The saline belt of the Purna basin covers 894 villages of 16 tehsils of the 3 districts. Prior to this estimate made in the nineties, it was assessed 545 villages as suffering from the problem of salinity in 14 tehsils in the 3 districts. The soil is classified as sodic haplusterts and sodic calciusterts (Padole *et al* 1998). The clay content in these soils is ranges from 52-70 per cent. The pHs, ECe and ESP ranges from 7.7 to 9.4, 0.90 to 5.20 dS m^{-1} and 2.57 to 33.78, respectively. The soils are mostly normal at surface horizon and problems of salinity / sodicity increases with depth. (Padole *et al.* 1998). The soils in Purna valley have been extensively studied during 1990 to 1993 by several workers, Nimkar (1990), Magar (1990), Kadu (1991) and Balpande (1993). The salinity / sodicity problems have been diagnosed in these soils although most of the soils are found to have good production potential. Knowledge of spatial variation of soil properties is important in precision farming and environmental modeling (Santra *et al.* 2008). The concept of management zones was evolved in response to large variability with the main purpose of efficient utilization of agricultural inputs with respect to spatial variation of soil properties. Therefore, understanding of spatial variation of soil properties is very essential for refining farm management practices, modeling at landscape level and assessing the impact of agriculture on environment. The application of parametric statistics is inadequate for analysis of spatially dependant variables because, they assume that measured observations are independent in spite of their distribution in space. Geostatistics provide a tool for improving sampling design by utilizing the spatial dependence of soil properties within a sampling region and useful to illustrate the spatial interrelationship of soil data which reduces error, biasness and increase the accuracy of data for interpolation (Oliver 1987). The information on spatial variability of soil properties at village or watershed level, particularly, in soils of basaltic terrain is meager. Therefore, the present study was planned.

Materials and Methods

Purna valley of Vidarbha region is an east west elongated basin with slight convexity to south, occupying the part of Amravati, Akola and Buldana district of Vidarbha and extends from $20^0$45’ and $21^0$15’ N latitude and 75^0 15’ to $77^0$45’ E longitude with east west length of about 100-150 km having width of about 10-60 km, covering an area of 2.74 lakh hectare in 892 villages.

The study area comprises part of Purna valley of Vidarbha region of Maharashtra. Geographically, the Ramagarh village is located between 77^o 12’ 36” to 77^o 13’ 50” E longitudes and 20^o 50’ 46” to 20^o 53’ 59” N latitudes. Ramagarh village is located in Daryapur tehsil in Amravati District Maharashtra. The total area of the village is 324 ha. The study area falls in the Survey of India (SOI) toposheet No. 55 H/1. The river Purna rises from the Satpuda ranges and flows nearly through the centre of the valley. Many tributaries flows from northern and southern sides form a parallel to sub parallel type of drainage. The river channel is as deep as 30 meters and as wide as 200 meters in many places. The gradient of the alluvial plain is 1 to 10 meters per kilometer. Locally the slope may reach up to 3 per cent. The whole tract looks flat with very gentle undulations there. The elevation of the alluvial plain varies from 248 to 360 meters above mean sea level. Cadastral map (1:8000 scale) collected from *Patwari* of the village was used for identification of field boundaries, survey numbers and for planning the traverse in the field for soil sample collection and used as base map. In addition to this Survey of India (SOI) Toposheet No. 55 H/1 (1:8,000 scale) was used to collect topographic information.

Then the cadastral map was georeferenced with toposheet using maximum GCP in the GIS environment using Arc GIS vers. 10.1 software. The best soil sampling design to quantify spatial variability is somewhat difficult to determine because measured variability and sample spacing were dependent on each other (Eltaib et al. 2002). In the present study, grid sampling was selected which reduces a large degree of uncertainty. A grid size of 250 X 250 m was chosen and established on SOI toposheet as well as on cadastral map of the village. A total 82 soil samples were collected at a depth of 0-20 cm covering the entire study area. Nearly 1.0 kg of representative soil sample from each grid was collected for laboratory studies. The hydrogen ion concentration expressed as pH was measured with a pH meter using a 1:2 soil water suspension and saturated paste and EC of 1:2 soil water extract and saturation extraction of soil was determined as described by Richard (1954). The soil water suspension prepared for measuring pH was also used for measuring electrical conductivity. It was measured by ELICO conductivity bridge meter (Jackson, 1973). Organic carbon was determined by the Walkley and Black titration method (Jackson, 1967). Ground soil samples passed through 80 mesh sieve were used for estimating organic carbon. Soil samples were oxidized by 1*N* potassium dichromate and the conc. H_2SO_4 acid to generate the heat of dilution. The amount of unutilized dichromate was determined by back titration with 0.5 *N* ferrous ammonium sulphate solutions.

Results and Discussion

Descriptive statistics of soil chemical properties

The descriptive statistics of soil chemical properties are presented in (Table 1). The pH varied from 8.27 to 9.28 and EC varied from 0.13 to 0.68 with a mean value of 8.56 and 0.25 respectively. Organic carbon varied from 0.24 to 0.95 per cent with a mean value of 0.56. Ca and Mg varied from 30.8 to 41.2 per cent and 10.8 to 23.6 with a mean value of 36.84 and 16.66 per cent respectively. Among the chemical properties Mg was found to be highly variable (CV = 6.42) followed by Ca (CV = 4.72), on the other hand pH was found least variable with CV of 0.02.

Among the chemical properties organic carbon, EC, Ca and Mg were not normally distributed. Logarithmic transformation function was applied to fit normal distribution.

Table 1: Descriptive statistics of soil chemical properties

Soil property	Minimum	Maximum	Mean	SD	CV	Skewness	Kurtosis
pH	8.27	9.28	8.56	0.19	0.02	0.46	3.95
EC	0.13	0.68	0.25	0.15	0.02	1.75	1.59
OC (%)	0.24	0.95	0.56	0.09	0.17	0.20	7.00
Ca (C mol (p+)kg^{-1})	30.8	41.2	36.85	2.18	4.72	-0.78	0.69
Mg (C mol (p+)kg^{-1})	10.8	23.6	16.66	2.55	6.42	-0.26	0.87

Correlation and regression of soil properties

The interrelations in between the nutrients were identified and placed in (Table 2).The results indicate that there was a significant and negative correlation between Ca and mg at 5% (r=-0.579*, p=0.05) followed by pH and EC at 5% (r= -0.529*, p= 0.05). pH and mg has at 5% (-0.419*,p=0.05), Mg and K at 5% (r= -0.378*, p= 0.05), mg and Zn at 5% (r= -0.342*, p=0.05). The regression equation are presented in Table 4.3 and depicted in Fig. 1, 2, 3 and 4. The results indicate that 27 percent (R^2=0.27) of variability in pH was expressed by EC and 17% (R^2=0.17) of variability in pH was expressed by mg and 33% (R^2= 0.33) of variability in Ca was expressed by mg and 14% (R^2=0.14) of variability in mg was expressed by K and 11% (R^2=0.11%) of variability in mg was expressed by Zn.

Table 2: Correlation between soil properties

Soil properties	Coefficient correlation(r)	Regression equation	Regression coefficient (R^2)
pH – EC	-0.529(*)	y = -0.411 + 3.776x	0.27
pH- mg	-0.419(*)	y = -0.030 + 9.075x	0.17
Ca – mg	-0.579(*)	y = -0.675 + 41.57x	0.33
mg – K	-0.378(*)	y = -11.62 + 847.3x	0.14
mg- Zn	-0.342(*)	y = -0.022 + 0.952x	0.11

*indicate Significance at 5%, (p=0.05) Table value 1.99

Semivariogram of soil chemical properties

Semivariogram parameters for soil chemical properties with the best fitted model are presented in (Table 3). Among the three different theoretical model tested, the spherical model was found best fit for pH, EC, and OC whereas, Gaussian model was found best fit for Ca and Mg. The range varied from 1067 m to 2500 m. The highest range was observed for EC, OC, Ca and Mg (2500 m) and lowest range was observed for pH (1067 m). It indicates those EC, OC, Ca, and Mg were spatially correlated for longer distance than pH. The values of nugget variance ranged from 0.002 (OC) to 6.365 (Mg). The values of sill i.e. total variance varied from 0.01 (OC) to 6.37 (Mg). Out of total variation (sill), nugget component was 32.0, 54.62, 27.7, 86.71 and 100 per cent for pH, EC, OC, Ca and Mg respectively. All the chemical properties of soils viz., pH, EC, organic carbon, Ca and Mg displayed moderate spatial dependence, with nugget-sill ratios of 27.7 to 54.6%, respectively (Hou-Long *et al.* 2010). The semivariogram of soil pH, EC, Organic carbon, Ca and Mg are depicted in Fig. 5 to 9.

Table 3: Semivariogram parameters of soil chemical properties

Soil property	Semivariogram model	Range (m)	Nugget (C_0)	Partial sill (C)	Sill (C_0+C)	Nugget/ Sill Ratio (%)
pH	Spherical	1067	0.008	0.017	0.03	32.0
EC	Spherical	2500	0.013	0.0108	0.024	54.62
OC	Spherical	2500	0.002	0.005	0.01	27.7
Ca	Gaussian	2500	4.394	0.6733	5.07	86.71
Mg	Gaussian	2500	6.365	0.0	6.37	100

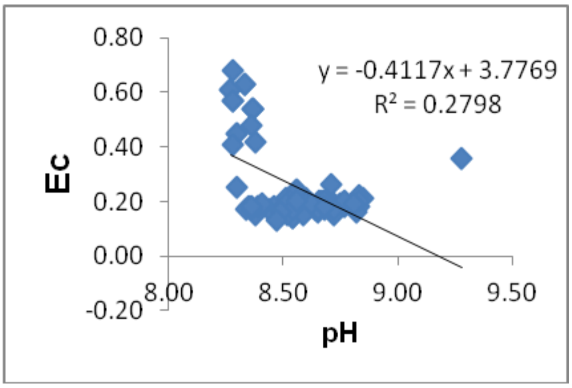

Fig 1: Relationship between pH and Ec

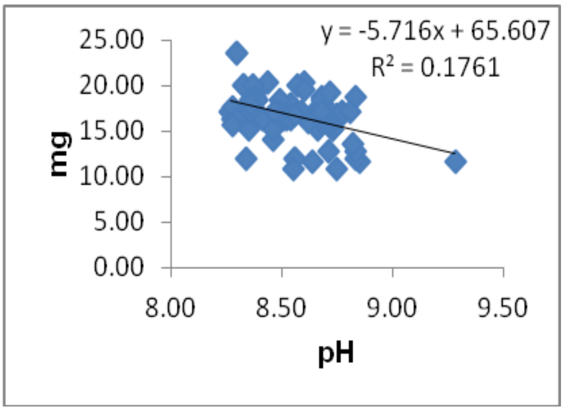

Fig 2: Relationship between pH and mg

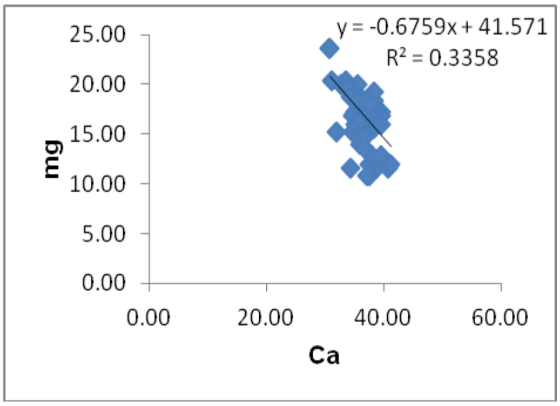

Fig 3: Relationship between Ca and mg

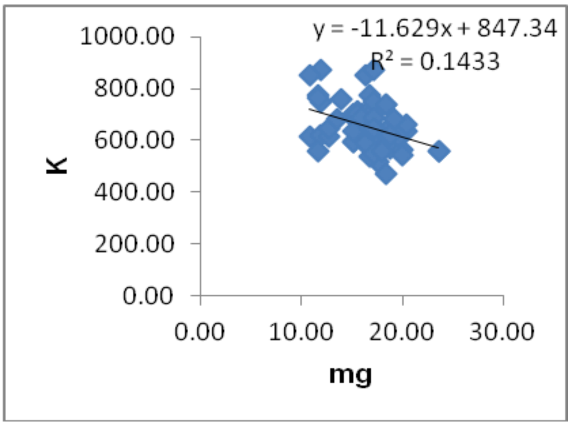

Fig 4: Relationship between mg and K

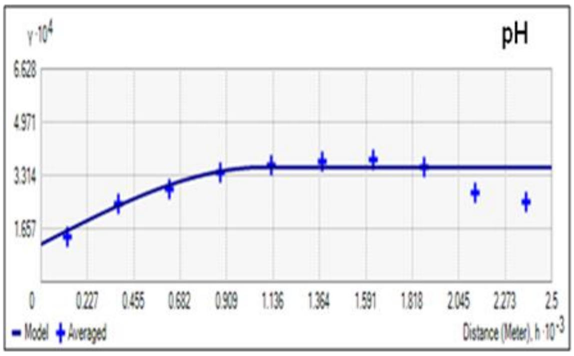

Fig 5: Semivariogram of pH

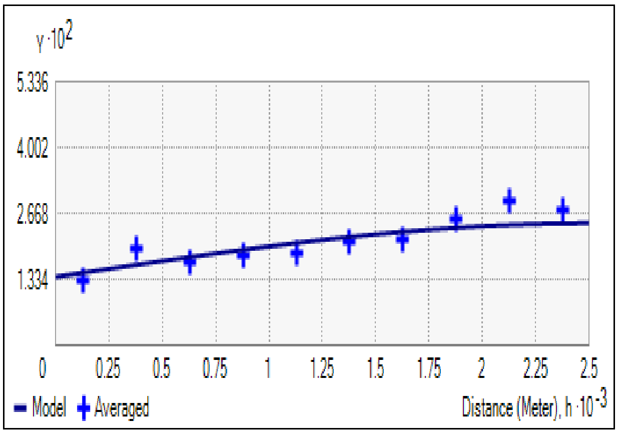

Fig 6: Semivariogram of EC

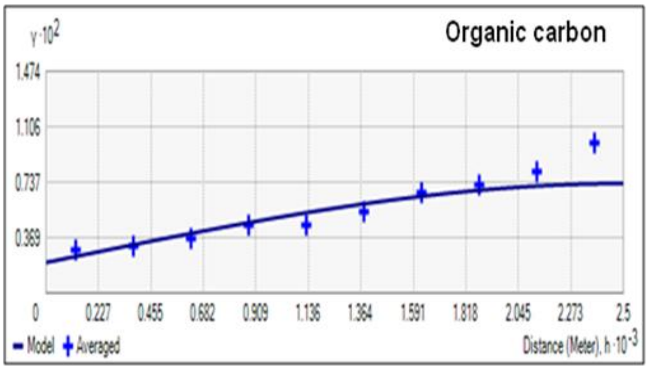

Fig 7: Semivariogram of Organic carbon

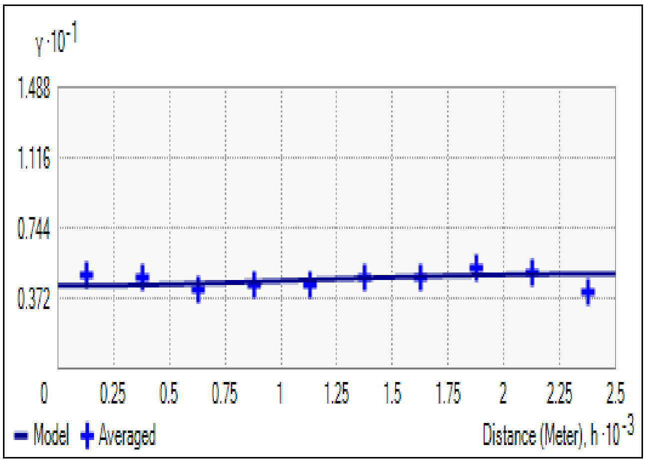

Fig 8: Semivariogram of Ca

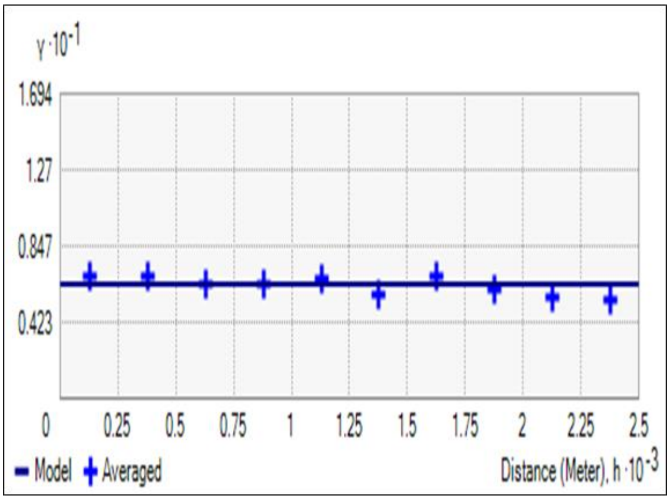

Fig 9: Semivariogram of Mg

Kriged maps of soil chemical properties

The spatial variability maps of pH, EC, Organic carbon, exchangeable Ca, and mg were prepared through ordinary kriging and presented in Fig. 10 to Fig. 14, respectively. Spatial map of pH shows that the soils are moderately alkaline in central and slightly alkaline in southern and northern east part of the village. While spatial map of EC shows that the major area under the range of 0.22 to 0.34 followed by central of the village area (0.18 to 0.22). Some western south part of the village was under the range of 0.17 to 0.18.

In respect of organic carbon the spatial map shows that the range of organic carbon content was 2.28 to 5.92 kg ha^{-1} and the major area was under high organic carbon content because of addition of manure and crop residues by the farmer.

The spatial map of exchangeable calcium shows that the major area was under 30.8 - 37.37 C mol (p+) kg^{-1} and some area under 37.37-41.2 C mol (p+) kg^{-1}. Spatial map of exchangeable Magnesium shows that the major area under North and south content 10.8 - 16.6 C mol (p+)kg^{-1} and more exchangeable magnesium content in some part of western and northern east area of the village as compared to north and south area of the village.

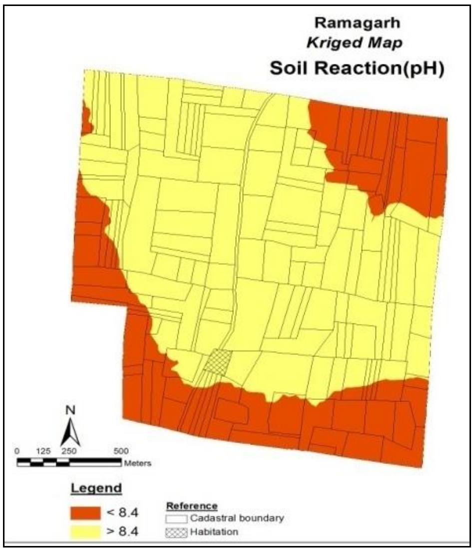

Fig 10: Kriged map of soil pH

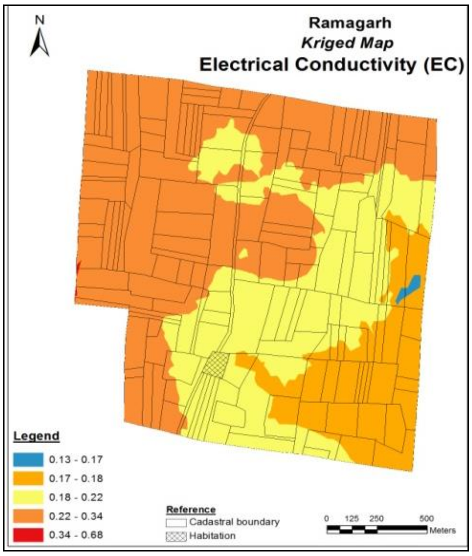

Fig 11: Kriged map of soil

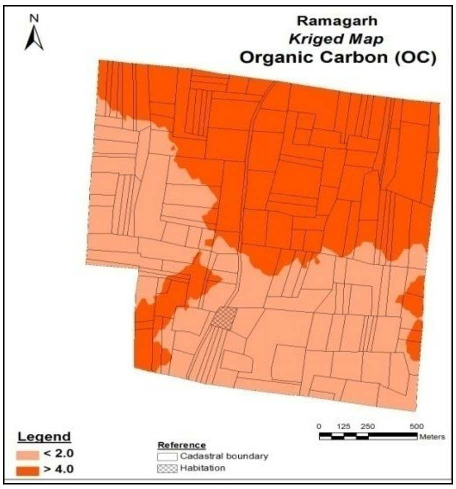

Fig 12: Kriged map of available OC

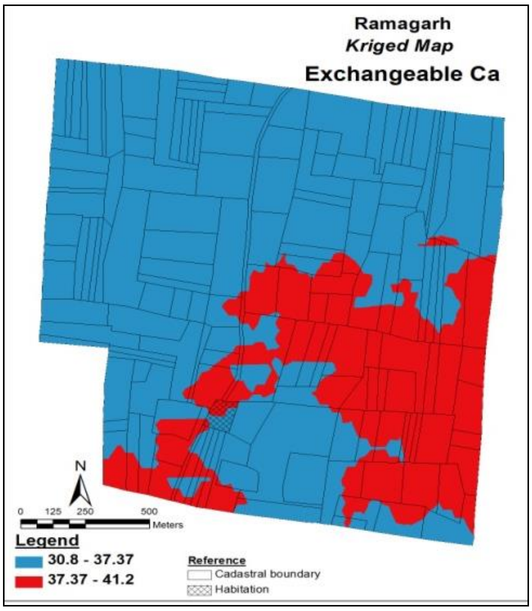

Fig 13: Kriged map of available Ca

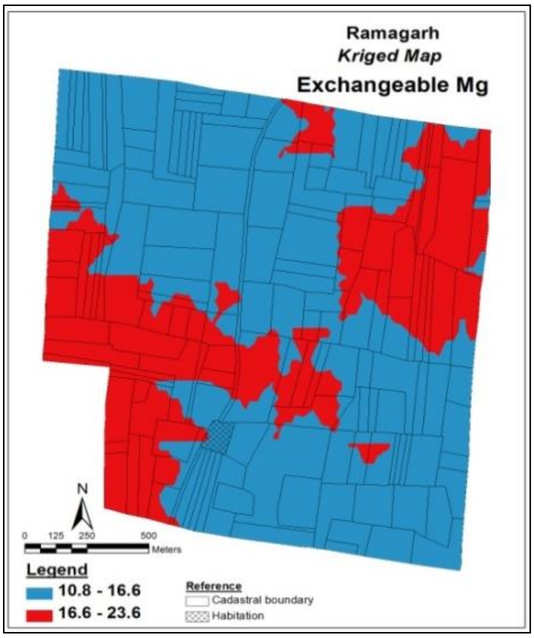

Fig 14: Kriged map of available mg

Cross validation of soil chemical and soil fertility properties

Evaluation parameters of kriged map of soil chemical and soil fertility properties are presented in (Table 4). Among the chemical properties of soils higher RMSE value was observed for pH (0.12) and the lowest RMSE values were observed for electrical conductivity (0.015). Highest coefficient of determination (R^2) value was observed for pH (0.36) compared to organic carbon (0.29) whereas lowest R^2 was found for EC (0.18).

Table 4: Evaluation parameters of kriged map of soil chemical and soil fertility properties

Soil property	RMSE	R^2
pH	0.12	0.36
EC	0.015	0.18
OC	0.06	0.29

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