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# Geo-spatial variability in soil health of Biwan watershed located at Mewat district of Haryana, India

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ABSTRACT

A study was carried out to evaluate the geo-spatial variability of soil health parameters in Biwan watershed located in the Mewat district of Haryana in 2012-13. The main objective of this study was to determine spatial variability of selected soil health parameters that influence crop growth and yield. Soil samples (100) with GPS co-ordinates were collected on random basis from Tapkan, Biwan, Shonkh, Palla and Palladi villages of Biwan watershed during pre-monsoon period (May 2012). Soil health parameters such as pH2, electrical conductivity (EC2), organic carbon, available NPK and micronutrient (Zn, Fe, Cu and Mn) were analyzed from each sample by the standard methods. The spatial variability maps for different soil health parameters were prepared through GIS software (ArcGIS 9.0). Results indicated that the pH2 (6.0-8.59) and EC2 (<1.0 dS/m) were normal in about 80% of soil samples in watershed area. Comparatively, higher soil salinity was observed in Palladi village. Organic carbon and available nitrogen were low in the soils of whole watershed. The available phosphorous was low in 57% soil samples and rest was in medium. The lower concentration of available phosphorous was in most of the part of watershed, whereas medium concentration was in some part of Biwan and Palladi villages. The available potassium was low in 23%, medium in 67% and high in 10% soil samples. The higher concentration of available potassium was in some parts of Biwan, Shonkh and Palla villages. The Zn concentration was deficient (<0.6 mg/kg) in 70% of soil samples and 30% samples were in sufficient. The higher concentration of Zn was in Tapkan and Palladi villages. 84% soil samples showed the iron (Fe) deficiency. The sufficient Fe concentration was in the scattered patches of the watershed. The Cu and Mn concentrations in most of the soils of Biwan watershed were sufficient. It was concluded from the study that the soil health of Biwan watershed was poor.

**Key words**: Mewat, Micronutrients, Organic carbon, Soil health, Watershed

In the recent years, soil health is the major concern for agriculture system at national and international level. It is considered as one of the major indicator to represent the socio-economic condition of rural areas/farmers. Hence, the Government of India has recently initiated the soil health card scheme. For small holder farmers, a healthy soil is one which gives economically viable production of crops (Jat *et al.* 2015). However, soil health is best described by its biological, physical and chemical properties. Hence, soil health improvements practices are directly linked to socio-economic status of the region. Mewat district of Haryana is considered as one of the most backward regions of our country (Aggarwal 2004). The district is predominantly rural (95%) having total geographical area of 1.90 lakh ha (Lha) and cultivated area of about 1.5 Lha (C-DAP 2007). Mewat district lags behind the rest of Haryana on almost every yardstick of development. The economy is predominantly agriculture based with about 72% agriculture worker. Irrigated and rain-fed agriculture area of Mewat district is 35% and 65%, respectively. Cropping intensity of entire Mewat district is 150% (C-DAP 2007). Out of the total irrigated area, only 15% is irrigated by good quality water and rest is irrigated with poor quality (saline) groundwater. The agricultural productivity of Mewat district is comparatively and considerably low (C-DAP 2007). This is may be due to prevailing natural resource base, lack of education and awareness, low adoption of improved farm practices and poor socio-economic condition of people. Out of these factors, prevailing natural resource base (soil, water and vegetation) is mainly responsible for low agriculture productivity of the Mewat region. Poor soil health has been recognized as one of major factor responsible for low agricultural productivity as well as socio-economic backwardness of a particular region. Hence, the government of India has already initiated the soil health card scheme in the year 2015. Therefore, it was an urgent need to assess the soil health as quantitatively and geo-spatially in a representative area/watershed in Mewat district of

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Haryana for planning of sustainable land use pattern and its management to enhance the environmental quality, crop productivity and socio-economic condition of the farmers. The test watershed was Biwan watershed as it represents similar agro-climatic condition to the whole Mewat district. Keeping in view, the present study was undertaken to find out quantitative and geo-spatial variation in soil health status of Biwan watershed of Mewat for planning the strategies to be imposed the social and economical status of the farmers of Mewat district of Haryana, India.

## MATERIALS AND METHODS

Biwan watershed located in Nuh block of Mewat district in Haryana, India was selected as test area for the present study. It lies between $26^0$N and $30^0$N latitude and $76^0$E and $78^0$E longitude (Census of India 2011). The district falls under sub tropical semi arid zone II of agroclimatic zones of Haryana. There is no major industry (except mining) in Mewat district, and about 62% of its population lives below poverty line (Kaur *et al*. 2009). As compared to the literacy rate of Haryana state in general (75.55%), the literacy rate of Mewat is just 54.08%. Of this, the female literacy rate is a mere 36.60% (Census of India 2011). Biwan watershed, comprises the Tapkan, Biwan, Shonkh, Palla and Palladi villages, lies between $27^0$39' and $28^0$ 20' North latitude and $76^0$51' and $77^0$20' East longitudes. The Biwan watershed is also socio-economically backward. Agriculture, the base economic activity of the people is deprived of irrigation. The ground water is the major source of water in the district area as well as in Biwan watershed. There is no river and area is drained by artificial drains namely Nuh, Ujina and Kotla drains. They carry rain water into Yamuna river. The climate of Biwan watershed is semi arid and annual rainfall is about 594 mm. About 80% of this rainfall is received during July–September months. The cropping seasons are *kharif* (June–September) and *rabi* (October–March). No major crops were cultivated during the summer season (April–May). The principal crops grown during *kharif* and *rabi* seasons are pearl millet/sorghum/bottle gourd and wheat/mustard/tomato, respectively. These are primarily irrigated with tube well water. Quality of groundwater resources of Biwan watershed is as 45% good, 50% saline and 5% alkali conditions (Gurjar *et al.* 2015). Textural classification of soils of Biwan watershed is given in Fig 1.

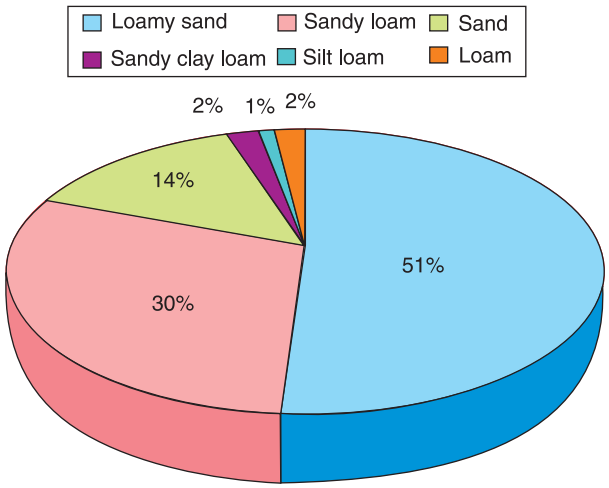


Fig 1 Textural classification of soils of Biwan watershed, Mewat, Haryana

Bulk (1 kg) top soil (0–15 cm) samples from four random spots around each sampling site were extracted by means of a tube auger. Total 100 soil samples (20 samples from each village) were collected from fields of villages of Biwan watershed. These soil samples, collected in labeled-polythene bags, were air dried, crushed and ground with a wooden mortar–pestle, passed through a 2-mm sieve, partitioned into three replicates and subjected to soil texture (Bouyoucos 1962). Soil pH and EC were determined at 1:2 soil–water ratios using a glass electrode and conductivity bridge, respectively (Jackson 1973). Soil organic carbon (SOC) was determined by dichromate oxidation (Walkley and Black 1934); available N by the alkaline potassium permanganate distillation method (Subbiah and Asija 1956). Available phosphorus (P) in soil was determined by extracting samples with 0.5 M $NaHCO_3$, and determining P colorimetrically using molybdate (Olsen *et al.* 1954). Available potassium was determined using 1 N ammonium acetate extraction followed by flame photometer (Jackson 1973). Bio-available (DTPA extractable) micronutrients, viz. zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) were also estimated as per the standard procedures (Page *et al.* 1982) through flame atomic absorption spectrometer.

Spatial variability in soil health status of the study area was assessed by collection of soil sampling site co-ordinates (i.e. latitudes and longitudes) with the help of Global Positioning System (GPS). Spatial variability maps of different soil health parameters were prepared by imported collected co-ordinates point in Arc-GIS 9.0 software and using kriging geospatial techniques (Franke 1982).

## RESULTS AND DISCUSSION

The minimum, maximum and mean values of soil health parameters such as pH, EC, OC, available NPK, and macro micronutrients (Cu, Fe, Mn, Zn) are given in Table 1 and are described village-wise. Geo-spatial variability of soil health parameters in whole Biwan watershed are discussed in this paper.

### *Tapkan village*

The pH of soil samples varied from 7.38 to 8.63 with mean value of 8.16 indicating that most of the soils were normal in category which does not require any type of reclamation. Salinity in terms of EC ranged from 0.16 to 2.17 with a mean value 0.73 dS/m. It also indicated that most of the soils in Tapkan village were normal soil except few samples that had marginal salinity (>2 dS/m). Organic carbon content (OC) varied from 0.07 to 0.38% with mean value of 0.26% indicated that the organic carbon content in soil is low. Available NPK ranged from 25.09 to 100.35, 4.48 to 13.44 and 94.08 to 203.84 with mean values of 60.84,

Table 1 Minimum, maximum and mean values of soil health parameters in the villages of Biwan watershed

| Village | Range | pH2 | EC2 (dS/m) | OC (%) | Avail. N (kg/ha) | Avail. P (kg/ha) | Avail. K (kg/ha) | Zn (mg/kg) | Cu (mg/kg) | Fe (mg/kg) | Mn (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tapkan | Minimum | 7.38 | 0.16 | 0.07 | 25.09 | 4.48 | 94.08 | 0.15 | 0.45 | 1.33 | 1.18 |
| | Maximum | 8.63 | 2.17 | 0.38 | 100.35 | 13.44 | 203.84 | 1.28 | 2.78 | 4.98 | 7.14 |
| | Mean | 8.16 | 0.73 | 0.26 | 60.84 | 8.06 | 150.70 | 0.76 | 1.29 | 3.17 | 4.76 |
| Biwan | Minimum | 7.45 | 0.15 | 0.04 | 25.09 | 6.72 | 80.64 | 0.05 | 0.09 | 1.14 | 0.58 |
| | Maximum | 8.66 | 1.64 | 0.38 | 87.81 | 15.68 | 331.52 | 0.69 | 1.30 | 6.58 | 9.87 |
| | Mean | 8.14 | 0.56 | 0.27 | 52.68 | 11.65 | 134.12 | 0.39 | 0.48 | 2.69 | 5.09 |
| Shonkh | Minimum | 7.68 | 0.26 | 0.11 | 25.09 | 4.48 | 80.64 | 0.08 | 0.18 | 1.56 | 2.45 |
| | Maximum | 8.78 | 2.12 | 0.30 | 62.72 | 13.44 | 512.96 | 0.76 | 3.75 | 4.78 | 9.58 |
| | Mean | 8.13 | 0.68 | 0.20 | 36.38 | 8.51 | 168.84 | 0.39 | 1.50 | 2.98 | 5.76 |
| Palla | Minimum | 7.17 | 0.08 | 0.04 | 12.54 | 2.24 | 75.04 | 0.11 | 1.11 | 1.87 | 2.24 |
| | Maximum | 8.67 | 2.75 | 0.20 | 62.72 | 8.96 | 262.08 | 0.32 | 2.92 | 4.67 | 7.34 |
| | Mean | 7.99 | 0.66 | 0.14 | 32.61 | 5.38 | 143.92 | 0.20 | 1.85 | 3.24 | 4.20 |
| Palladi | Minimum | 7.30 | 0.23 | 0.15 | 25.05 | 6.72 | 105.28 | 0.16 | 0.88 | 1.56 | 2.45 |
| | Maximum | 8.83 | 2.85 | 0.38 | 100.32 | 15.68 | 512.96 | 0.95 | 2.78 | 6.45 | 12.78 |
| | Mean | 8.19 | 1.02 | 0.28 | 58.92 | 11.76 | 243.99 | 0.51 | 1.86 | 3.16 | 7.18 |

8.06 and 150.70 kg/ha, respectively. It was indicated that the mean contents of available N and P were low, whereas available K content was medium in soils of Tapkan village. Micronutrients Zn, Cu, Fe and Mn ranged from 0.15 to 1.28, 0.45 to 2.78, 1.33 to 4.98, and 1.18 to 7.14 mg/kg, respectively with the mean values of 0.76, 1.29, 3.17 and 4.76 mg/kg, respectively. It indicated that micronutrients content in all the soil samples were above the critical level of deficiency of Zn (<0.6 mg/kg), Cu (<0.2 mg/kg), Fe (< 4.5 mg/kg) and Mn (<2 mg/kg).

*Biwan village*

The pH of soil samples varied from 7.45 to 8.66 with mean value of 8.14 indicating that most of the soils were normal in category which does not required any type of reclamation. Salinity in terms of EC ranged from 0.15 to 1.64 with a mean value of 0.56 dS/m. It also indicated that the soils of Biwan village are normal soil. Organic carbon content varied from 0.04 to 0.38% with mean value of 0.27% indicated that the organic carbon content in soil is low. Available NPK ranged from 25.09 to 87.81, 6.72 to 15.68 and 80.64 to 331.52 kg/ha with mean values of 52.68, 11.65 and 134.12 kg/ha, respectively. It also indicated that the low available N content whereas available K and P contents were medium in soils of Biwan village. Micronutrients Zn, Cu, Fe and Mn ranged from 0.05 to 0.69, 0.09 to 1.30, 1.14 to 6.58, and 0.58 to 9.87 mg/kg, respectively with the mean values of 0.39, 0.48, 2.69 and 5.09 mg/kg, respectively. It indicated that mean zinc (Zn<0.6 mg/kg) and iron contents (Fe<4.5 mg/kg) were deficient while copper (Cu<0.2 mg/kg) and manganese Mn (< 2 mg/kg) contents were sufficient in the soils of Biwan village.

*Shonkh village*

The pH of soil samples varied from 7.68 to 8.78 with mean value of 8.13 indicating that most of the soils were normal in category. Salinity in terms of EC ranged from 0.26 to 2.12 with a mean value of 0.68 dS/m. It also indicated that the soils of Shonkh village are normal soil. Organic carbon content varied from 0.11 to 0.30% with mean value of 0.20% indicated that the organic carbon content in soil is low. Available NPK ranged from 25.09 to 62.72, 4.48 to 13.44 and 80.64 to 512.96 kg/ha with mean values of 36.38, 8.51 and 168.84 kg/ha, respectively. It indicated that the contents of available N and P were low, whereas available K content was medium in soils of Shonkh village. Micronutrients Zn, Cu, Fe and Mn ranged from 0.08 to 0.76, 0.18 to 3.75, 1.56 to 4.78, and 2.45 to 9.58 mg/kg, respectively with the mean values of 0.39, 1.50, 2.98 and 5.76 mg/kg, respectively. It indicated that mean zinc (Zn<0.6 mg/kg) and iron (Fe<4.5 mg/kg) contents were deficient while copper (Cu<0.2 mg/kg) and manganese Mn (< 2 mg/kg) contents were sufficient in the soils of Shonkh village.

*Palla village*

The pH of soil samples varied from 7.17 to 8.67 with mean value of 7.99 indicates that most of the soils were normal in category which does not require any type of reclamation. Salinity in terms of EC ranged from 0.08 to 2.75 with a mean value of 0.66 dS/m. It also indicated that the soils of Palla village are normal soil. Organic carbon content varied from 0.04 to 0.20% with mean value of 0.14% indicated that the organic carbon content in soil is low. Available NPK ranged from 12.54 to 62.72, 2.24 to 8.96 and 75.04 to 262.08 kg/ha with mean values of 32.61, 5.38 and 143.92 kg/ha, respectively. It indicated that available N and P contents were low, whereas available K content was medium in soils of Palla village. Micronutrients, viz. Zn, Cu, Fe and Mn ranged from 0.11 to 0.32, 1.11 to 2.92, 1.87 to 4.67, and 2.24 to 7.34 mg/kg, respectively with the

mean values of 0.20, 1.85, 3.24 and 4.20 mg/kg, respectively. It indicated that mean zinc was deficient (Zn<0.6 mg/kg) while copper content (Cu<0.2 mg/kg), iron content (Fe< 4.5 mg/kg) and manganese content Mn (< 2 mg/kg) were sufficient in the soils of palla village.

*Palladi village*

The pH of soil samples varied from 7.30 to 8.83 with mean value of 8.19 indicating that most of the soils were normal in category which does not require any type of reclamation. Salinity in terms of EC of ranged from 0.23 to 2.85 with a mean value of 1.02 dS/m. It also indicated that the soils of Palladi village are normal soil. Organic carbon content varied from 0.15 to 0.38% with mean value of 0.28% indicated that the organic carbon content in soil is low. Available NPK ranged from 25.05 to 100.32, 6.72 to 15.68 and 105.28 to 512.96 with mean values of 58.92, 11.76 and 243.99 kg/ha, respectively. It also indicated the low available N and K content, whereas P content was medium in soils of Palladi village. Micronutrients, viz. Zn, Cu, Fe and Mn ranged from 0.16 to 0.95, 0.88 to 2.78, 1.56 to 6.45, and 2.45 to 12.78 mg/kg, respectively with the mean values of 0.51, 1.86, 3.16 and 7.18 mg/kg, respectively. It indicates that micronutrients content in all the soil samples were above the critical level of deficiency of Zn, Cu, Fe and Mn.

*Spatial variability in soil health of Biwan watershed as whole*

The spatial variability maps of soil health parameters such as pH, EC, OC, available NPK, and major micronutrients (Cu, Fe, Mn, Zn) were constructed using ArcGIS-9.0 software. The detail description of each parameter is given below.

*Spatial variation in soil reaction (pH) and salinity (EC)*

The pH of the 90 % soil samples was normal ($pH_2$ = 6.0 to 8.59) to most of the crops and soils, whereas pH of 7 % soil samples were in the category of progressive alkalinity and soils are less productive with a pH range of 8.60 to 8.70. The rest 3% soil samples had of pH >8.70 which may have the problems of sodicity subjected to analysis of ESP. pH of the soils of Biwan watershed were also quite spatially variable with higher soil pH in some part of Biwan, Shonkh and Palladi villages. The salinity in terms of electrical conductivity (EC) in about 79% soil samples was below 1.0 dS/m considered as normal soil, whereas 15% soil samples were in the category of marginal salinity ($EC_2$ = 1-2 dS/m) and 6% soil samples had an excessive salinity ($EC_2$ >2 dS/m). Excessive salinity in agricultural lands in Biwan watershed was confined to areas irrigated with poor quality (salinity rich) tube-well waters. Kaur *et al*. (2009) also reported that about 59 % salt affected area of Mewat district is associated with salt affected groundwaters. Salinity in soils of Biwan watershed was spatially variable with higher soil salinity in parts of Palladi village and lower salinity in the parts of Biwan, Shonkh and Palla villages.

*Spatial variation in organic carbon*

The 100 % soil samples from Biwan watershed were low in organic carbon which had less than 0.5% organic carbon. It also spatial varied in the different villages of watershed with lowest values in Palla village where soils are sandy in texture. Comparatively higher values of organic carbon were found in the areas of Biwan village of the watershed. The low organic carbon content in soils of test watershed may be due to coarse soil texture. The same was also found during texture analysis of the collected samples in the present study. C-DAP (2007) also stated that 90% soils of the Mewat district have coarse texture and textural classes vary from sandy to loamy sand.

*Spatial variation in available nitrogen, phosphorous and potassium*

The available nitrogen content in 100 % soil samples of Biwan watershed was low (<280 kg/ha) which may be due to presence of low organic carbon content in soils of watershed. Comparatively, available N content was quite spatially variable with higher values in the areas of Biwan and Palladi villages, whereas lower content was observed in the areas of Palla village (Fig 2a). Content of available P was also spatially variable in the area of Biwan watershed with 57% soil samples were low (<10 kg/ha) and rest were medium (10-25 kg/ha) in available P content. Comparatively, higher values of available P content (>25 kg/ha) were in the areas of Biwan and Shonkh villages and lower values in Palla village (Fig 2b). The available K content was low (<120 kg/ha) in 23%, medium (120-280 kg/ha) in 67% and high (>280 kg/ha) in 10% soil samples of Biwan watershed. Moreover, it was quite spatially variable with higher content in areas of Tapkan, Biwan, Shonkh and Palla villages, whereas lower content in the area of Palladi village (Fig 2c). Being coarse textured, the soils are poor in water as well as in nutrient retention. Low level of organic carbon, nitrogen and phosphorus in soils of test watershed may be due to coarse soil texture. C-DAP (2007) also reported that almost all the soils of the Mewat district are low in organic carbon, Nitrogen and phosphorus contents.

*Spatial variation in bio-available micronutrients*

Bio-available Zn concentration was deficient (<0.6 mg/kg) in 70% of soil samples, whereas 30% soil samples were sufficient in Zn content (0.6 to 10 mg/kg). Zn toxicity (Zn >10 mg/kg) was not there in the soils of watershed while Zn concentration was quite spatially variable with higher content in the area of Tapkan, Biwan, Shonkh and some part of Palladi villages (Fig 3a). Kaur *et al.* (2009) also reported that about 90% of agricultural land of Mewat district is zinc deficient (<0.6 mg/kg). Adriano (2001) concluded that precipitation of most of the available Zn fractions into unavailable (carbonate) forms under high soil pH (>8.20) conditions could be the main cause of acute zinc deficiency in a particular area. Bio-available copper content was sufficient (Cu 0.2-5 mg/kg) in 93% soil samples whereas rest 7% soil samples were deficient (Cu<0.2 mg/

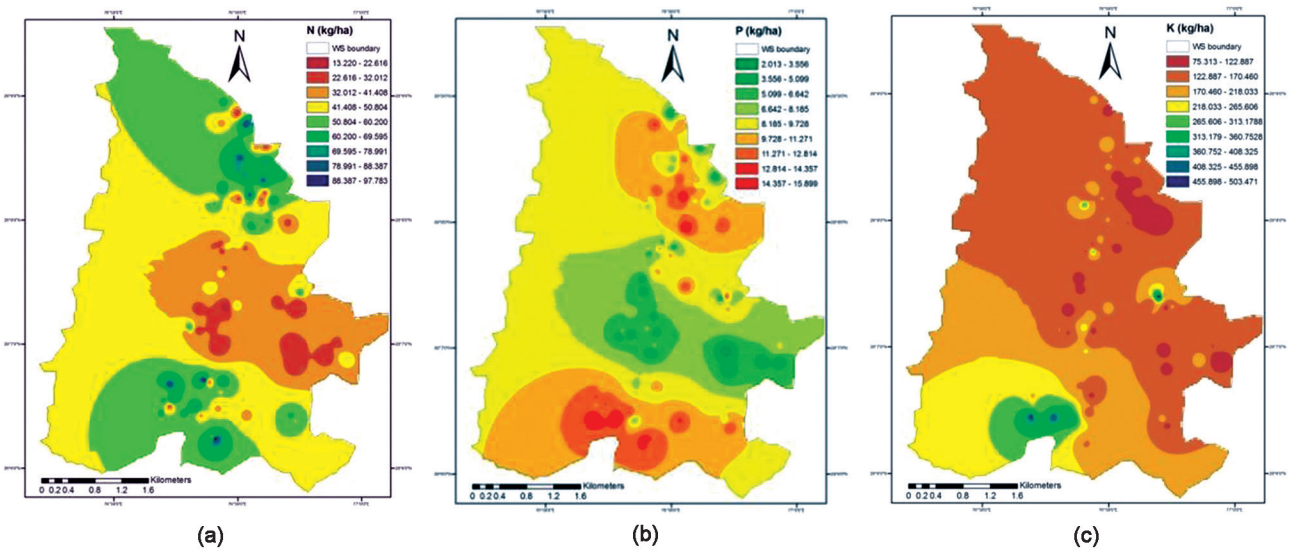


Fig 2 Spatial variability maps of available (a) nitrogen, (b) phosphorous and (c) potassium

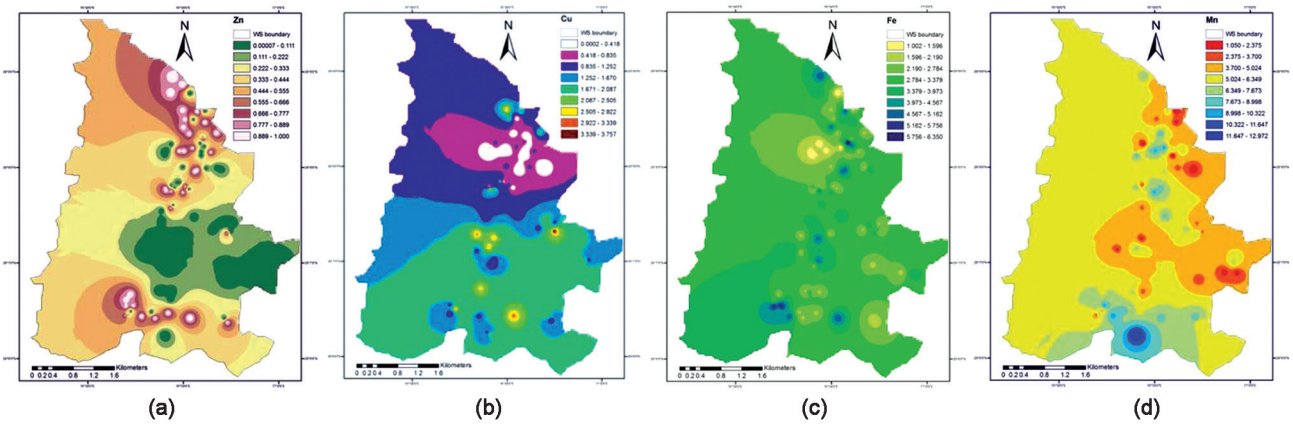


Fig 3 Spatial variability maps of bioavailable (a) Zn (b) Cu (c) Fe and (d) Mn

kg) in copper content. It was also quite spatially variable in the soils of watershed with comparatively higher values in some part of Palladi village (Fig 3b). Bio available iron content was deficient (Fe<4. mg/kg) in 84 % soil samples and rest were sufficient in iron content. Iron content in soils of watershed was also quite spatially variable with higher values in Palladi village (Fig 3c). Bio-available Mn concentration was deficient (Mn<2 mg/kg) in 6% soil samples, whereas 92 % and 2 % soil samples showed the sufficient (Mn 2-10 mg/kg) and toxic (Mn >10 mg/kg) level of Mn contents, respectively. Mn content was also quite spatially variable in the soils of Biwan watershed with higher values in the area of Palladi village (Fig 3d). Mewat regions soils are derived from sedimentary rocks and such soils are rich in Fe and Mn contents in general (Adriano 2001).

Biwan watershed soils were observed to be of poor health particularly due to lower level of organic carbon content, available N and P, Zn and Fe. The study provide the information on geo-spatial variations in the form of areas of deficient, sufficient and toxic for particular nutrients by which recommended dose of fertilizers can be adjusted within the test watershed. As an overall, the study indicated an urgent need for improving soil health status of Biwan watershed for enhancing crop productivity and rural income from agriculture leading to enhanced socio-economic status of local community/farmers of the study area.

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REFERENCES

Adriano D C. 2001. Trace elements in terrestrial environment: Biogeochemistry, bioavailability and risks of metals. Springer, New York.

Aggarwal M. 2004. Call of Mewat. Spectrum Published in The Tribune Newspaper, 31 October 2004.

Bouyoucos G J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agronomy Journal* **54**: 464–5.

C-DAP. 2007. Comprehensive District Agriculture Plan report for Mewat district of Haryana for Rastriya Krishi Vikash Yojana (RKVY) of XI Five Year Plan.

Census of India. 2011. District Census Handbook Mewat, Haryana, Directorate of Census Operations, Haryana. Ministry of Home Affairs, Government of India.

Franke R. 1982. Scattered data interpolation: Tests of some methods. *Mathematics of Computation* **38**(157): 181–200.

Gurjar D S, Sudhishri S, Mishra A K, Kaur R and Khanna M. 2015. Quality characterization of groundwater in biwan watershed of the mewat district, Haryana, India. *International Journal of Tropical Agriculture* **33**(4): 3239–46.

Jackson M L.1973. *Soil Chemical Analysis.* Prentice Hall of India Pvt Ltd, New Delhi.

Jat M L, Majumdar K, McDonald A, Sikka A K and Paroda R S. 2015. Book of extended summaries. National Dialogue on Efficient Nutrient Management for Improving Soil Health, 28-29 September 2015, New Delhi, India, p 56.

Kaur R, Minhas P S, Jain P C, Singh P and Dubey D S. 2009. Geo-spatial analysis of land–water resource degradation in two economically contrasting agricultural regions adjoining national capital territory (Delhi). *Environmental Monitoring and Assessment* **154**: 65–83.

Olsen S R, Cole C V, Watanable F S and Dean L A.1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. *Circulation USDA* 939.

Page A L, Miller R H and Keeney D R. 1982. Methods of Soil Analysis Part 2—Chemical and Microbiological Properties, 2nd Edn. ASA/SSSA Series No. 9, Madison.

Subbiah B V and Asija G L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Current Science* **25**: 259–60.

Walkley A and Black I A. 1934. An examination of the different method for determination of soil organic matter and proposed modification of chromic acid titration method. *Soil Science* **37**: 29–38.