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Identification of Soil Fertility Constraints of Erstwhile Warangal District, Telangana, India, using GIS for their Precise Management for Sustainable Crop Productivity

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out to identify soil fertility constraints and map the fertility status of erstwhile Warangal District, Telangana, India using geographic information system (GIS) and global positioning system (GPS). 241 geo-referenced surface soil samples (0-20 cm) from the study area were analyzed for their fertility parameters. Soil fertility maps were prepared for each parameter under GIS environment using Arc-GIS v 10.8.2. The soils in study area were slightly

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acidic to slightly alkaline in reaction (6.16 - 8.34), non saline in nature (0.14 to 1.00 dS m^{-1}) and low to high (0.12 - 1.14%) in organic carbon (OC%) content. The soils were low in available nitrogen (136 to231 kg ha^{-1}), low to high in available phosphorus (14.00 to 166.00 kg P_2O_5 ha^{-1}) and medium to high in available potassium (199 to 997 kg K_2O ha^{-1}). The wide variation from deficient to sufficient was observed in the status of available zinc (0.13 to 2.05 mg kg^{-1}), iron (0.09 to 11.80 mg kg^{-1}), copper (0.14 to 2.14 mg kg^{-1}) and manganese (0.18 to 10.30 mg kg^{-1}). The soil fertility status in study area revealed that soil organic carbon, available nitrogen and zinc are important soil fertility constraints in the erstwhile Warangal District Telangana India. To build up organic matter, zinc content, native nitrogen and maintain nutrient balance in the soil the farmers are advised to adopt farmyard manure (FYM) and $ZnSO_4$ application regularly.

Keywords: Digital soil mapping; soil fertility; GIS; sustainable crop productivity.

1. INTRODUCTION

"Digital soil mapping (DSM) is a procedure for generating model informed maps of soil variability and function and may be used for optimizing soil management and use. There are global concerns on reduction of limited fertile land due to desertification and land degradation processes. Increasing population is putting pressure on our finite land resources. Inappropriate land use and agricultural practices viz., over-cultivation, overgrazing, deforestation, poor irrigation practices, indiscriminate mining, increasing urbanization are some of the major causes leading to loss of fertile agricultural and forest covered land. The vegetal degradation, erosional processes, water logging and salinization, and loss of soil fertility are the major processes responsible for desertification worldwide" [1]. In case of India, an increasing human as well as livestock population exerting huge pressure on land resources, which have led to very significant land degradation. Out of India's total geographical area (TGA) of 328 Mha, about 228 Mha (69%) is under dry conditions (arid or semiarid or dry sub-humid), and these lands are highly populated and more vulnerable to environmental stress. Sehgal and Abrol [2] reported that "57% of land area in India has been degraded in one way or the other, and lands under cultivation are the most degraded followed by grazing land and forests. In India, low fertility of soils is the major constraint to achieving high productivity goals". "However, there is a grim need to develop and prepare a systematic soil fertility database at regional level at specified time intervals, to assess status of available nutrients for grouping of soils in homogenous units for better fertilizer management and avoidance of excessive and imbalanced use of fertilizers. There is still a large gap in knowledge about the spatio-temporal distribution of the available nutrients (macro and micronutrients) in the soils" [3,4]. "The situation called for a systematic benchmarking of the soil nutrient status under different agricultural land use systems, followed by spatio-temporal monitoring of the nutrient input and losses at fixed time intervals" [5,6,7]. "It was felt that the spatial data on the distribution of the major and the micronutrients in the erstwhile Warangal district could be better mapped and stacked for future analyses if the data points are tagged through precise GPS locations, and integrated on a GIS plat form" [8]. This paper reports on identification of soil fertility constraints in erstwhile Warangal district and results can be useful in recommending optimum soil management practices, crops and cropping systems for ensuring sustained yields in the region.

2. MATERIALS AND METHODS

2.1 Study Area

The soils of Warangal district classified as red earths, black soils (shallow to deep) and forest soils extend over an area of 12,834 Km^2. Warangal district lies between 17º 19' & 18º 36'N latitude and 78º 49' & 80º 43' E longitude and the topography of the district consists of isolated hills, rainfed tanks, lakes and shrubby forests. The geological formation of the district mainly developed from the granite and genesis of Arachean period and Dharwars of Precambrian period. Prevailing climatic condition of Warangal district was very hot in Summers even mercury sometimes touching 45ºC and in winter's temperature, it dips to 13ºC in during the months of December and January. This district receives annual rainfall of 994 mm. Hence, the study area qualifies for hyperthermic soil temperature and ustic soil moisture regimes V. Rajagopal et.al. [8]. The soils were classified upto family level as per USDA taxonomy [9].

2.2 Soil Sampling and Laboratory Analysis

A total of 241 surface composite soil samples of 0-20 cm depth were collected, the coordinates of sampling sites were collected using a hand held GPS in the study area. Standard methods were followed to estimate soil pH, electrical conductivity (EC), available nitrogen (N), phosphorus (P), potassium (K) and micronutrients (Zn, Cu, Fe and Mn) [10]. To quantify the level of deficiency or sufficiency of soil micronutrients the analyzed soil nutrient data were classified into 'very low' to 'high' level of availability, using the classification suggested by Singh [11] that is now followed by majority of soil testing laboratories in India [12]. The limits used for the study are provided in Table 1.

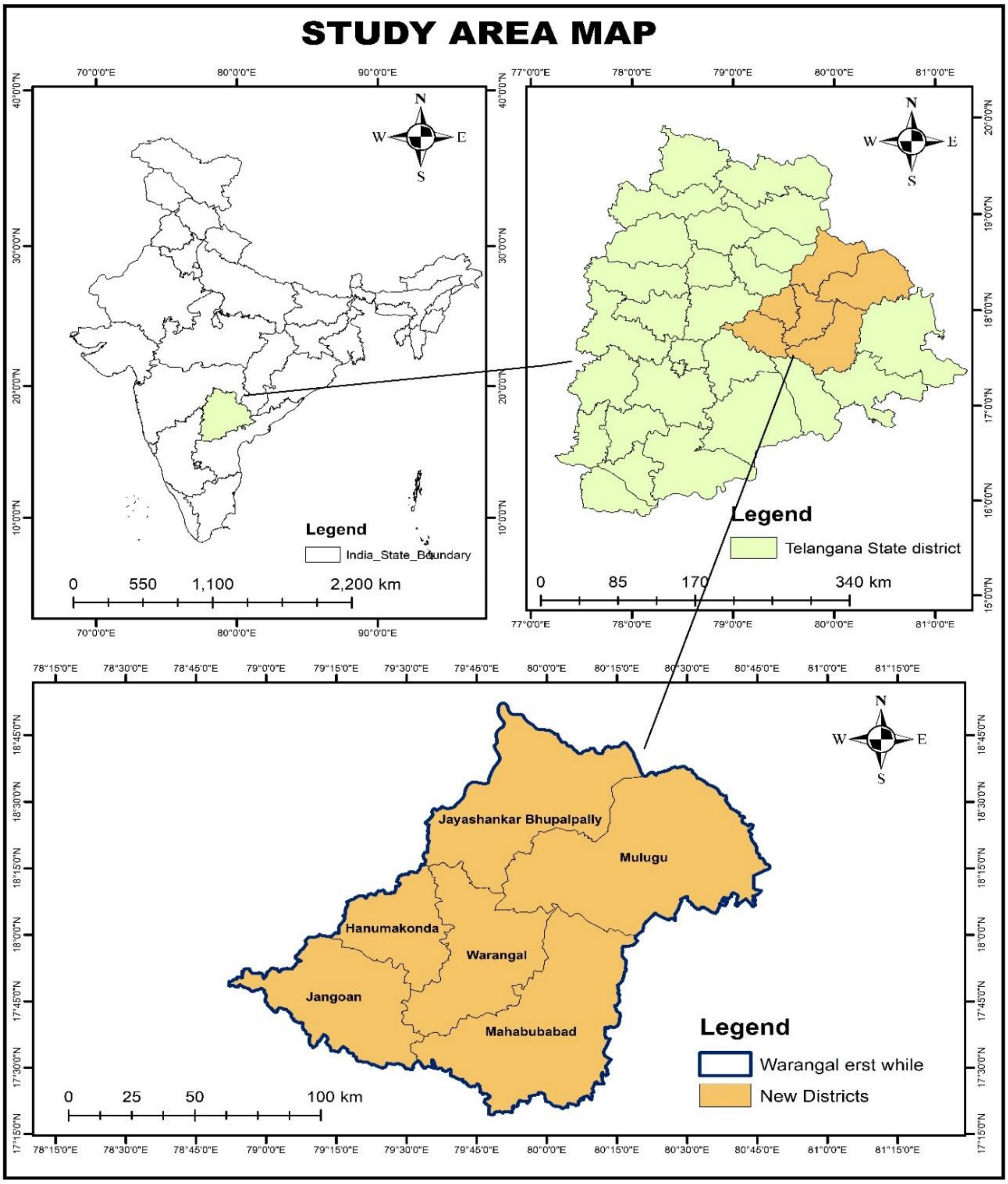

Fig. 1. Study area map of erstwhil Warangal district and recently formed new districts

Table 1. Soil test rating chart used for interpretations

Nutrients	Fertility ratings for available nutrients					
	Low		**Medium**		**High**	
Organic carbon (g kg-1)	<5		5-7.5		>7.5	
			Macronutrients			
Available N (kg ha-1)	<280		280-560		>560	
Available P_2O_5 (kg ha-1)	<22.5		22.5-55.0		>55.0	
Available K_2O (kg ha-1)	<140		140-330		>330	
			Micronutrients			
Micronutrients (mg kg-1)	**Very low**	**Low**	**Marginal**	**Adequate**	**Moderately adequate**	**High**
Available Zn	<0.30	0.31-0.60	0.61-1.20	1.21-1.80	1.81-2.40	>2.40
Available Fe	<0.10	0.11-0.20	0.21-0.40	0.41-0.80	0.81-1.20	>1.20
Available Cu	<2.50	2.51-4.50	4.51-9.00	9.01-18.0	18.1-27.0	>27.0
Available Mn	<1.00	1.01-2.0	2.01-4.0	4.01-8.00	8.01-16.0	>16.0

2.3 Statistical Analysis

The mean, standard deviation (SD) and coefficient of variation (CV%) for each soil physicochemical and chemical parameters were determined using OP stat analysis soft where.

2.4 Mapping

To map the frequency distribution pattern of different soil nutrients, the data analyzed from sample sites were first fed into geographic information system (GIS) as point-based and geo-referenced data through table management. The software used for this study was Arc-GIS v.10.8.2 (ESRI Co, Redlands, USA). The data were then processed through IDW interpolation method, and classified into homogenous groups of availability status of nutrients as contours in vector maps, as per the classification in Table 1. Their approximate area coverage in the study area was calculated. Based on the level of adequacy of each nutrient for plants, the units in the individual vector maps were then aggregated into low, medium and high categories for macronutrients, whereas for micronutrients, aggregated into very low, low, marginal, adequate, moderately adequate and high.

3. RESULTS AND DISCUSSION

The present study was conducted with an objective of assessing the soil fertility status and to prepare the thematic maps of erstwhile Warangal district of Telangana state. Based on the soil test results of laboratory analysis a total of ten soil fertility maps were generated using the Arc-GIS software.

3.1 Soil Reaction (pH) and its Spatial Variability

The soil reaction (pH) in the erstwhile Warangal district was slightly acidic to slightly alkaline in reaction (6.16 - 8.34) with mean pH value of 7.46, standard deviation of 0.34 with coefficient of variation is low (4.53%) (Table 2). Higher soil reaction in the study area is mainly because of calcareousness nature of the soils. The interpolation of pH data between 241 sample locations resulted in three soil reaction classes. They are slightly acidic (6.16-6.80), neutral (6.81-7.30) and slightly to moderately alkaline (7.31-8.34) in reaction. Major portion of the study area was slightly to moderately alkaline (75%) and remaining area was neutral (23%) and slightly acidic (2%) in soil reaction (Table 3 and Fig. 2). Our results corroborated with the findings of Satyavathi and Suryanarayana Reddy [13] who have reported that the soils of Warangal district were slightly to moderately alkaline in reaction.

3.2 Soil EC and its Spatial Variability

The soil electrical conductivity (EC) in the erstwhile Warangal district was non saline in nature though varied from 0.14 to 1.00 dS $m^{-1}$with an average value of 0.40 dS m^{-1}, standard deviation of 0.17 with coefficient of variation is moderate (43.32%) (Table 2). Electrical conductivity (EC) of soils of erstwhile Warangal district was below the critical limits. The normal EC may be ascribed to leaching of salts to lower horizons due to the light textured nature of the soils. Similar results were also reported earlier by Surendra Babu, et.al. (2019) and Rajagopal et.al. [8] for the soils of erstwhile Warangal district. Though the entire study area comes under non saline in nature and the interpolation of Ec data between 241 sample locations categorized into three classes. They are very low soluble salt content (0.14-0.25 dS m^{-1}), low soluble salt content (0.26-0.75 dS m^{-1}) and moderately soluble salt content (0.76-1.0 dS m^{-1}). Major portion of the study area (87%) comes under low soluble salt content, and remaining area comes under very low soluble salt content (9%) and moderately soluble salt content (4%) (Table 3 and Fig. 2).

3.3 Soil Organic Carbon and Available Macronutrients and their Spatial Variability

3.3.1 Soil organic carbon

The soil organic carbon content in erstwhile Warangal district was ranged between 0.12 - 1.14% with mean value of 0.57% with standard deviation value of 0.17 and coefficient of variation (CV%) is moderate (29.50%) (Table 2). Mapping of organic carbon by GIS revealed that they are categorised into three classes. They are low (0.12-0.50%), medium (0.51-0.75%) and high (0.76-1.14%). Major portion of the study area was medium (66%) and remaining area was low in 21% and high in 13% (Table 3 and Fig. 2). The values obtained in the present study are in agreement with those reported by Rajagopal et.al. [8] and Surendra Babu, *et.al.* (2019). The reason for medium organic carbon content in these soils may be attributed to the addition of organic manures regularly though the prevalence of arid condition in the study area.

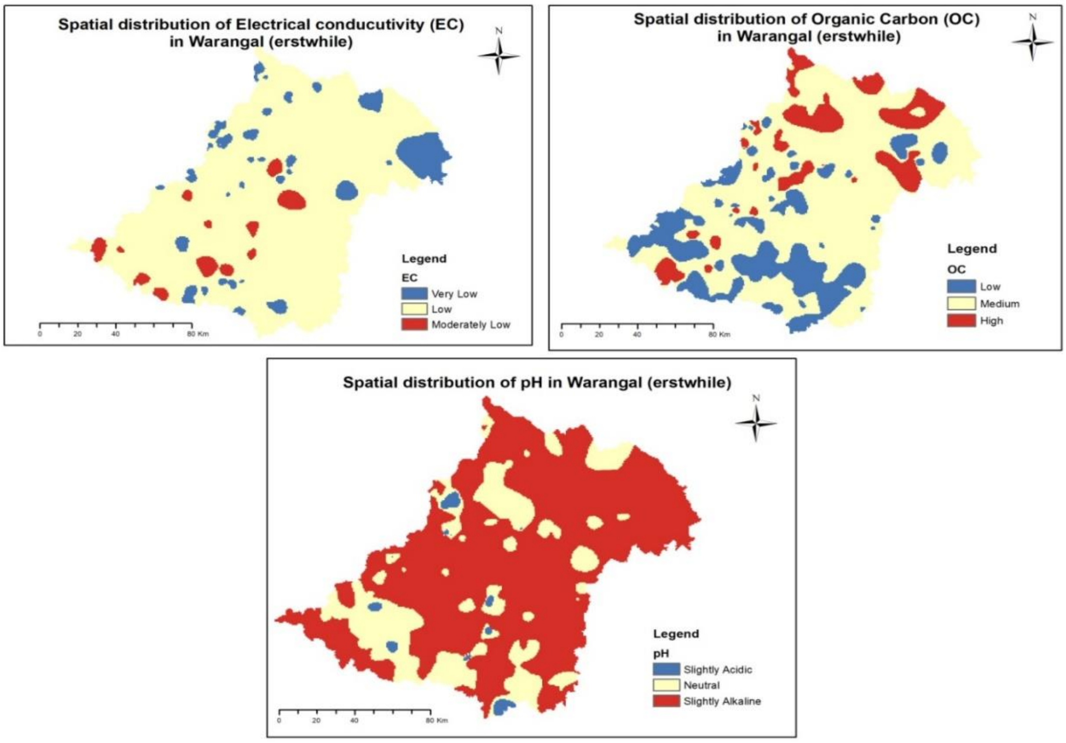

Fig. 2. Spatial distribution of soil pH, Ec an d organic carbon (OC %) in erstwhile Warangaldistrict, Telangana state, India

3.3.2 Soil available nitrogen

The entire study area in erstwhile Warangal district was characterized as low in soil available nitrogen and it is ranged between 136 to 231 kg ha^{-1}with an average value of 178 kg ha^{-1}with standard deviation of 15.50 and coefficient of variation is low (8.72%) (Table 2). The interpolation of available nitrogen data between 241 sample locations resulted in three classes. They are very low (136-160 kg ha^{-1}), low (161-180 kg ha^{-1}) marginally low (181-200 kg ha^{-1}) and medium low (201-231 kg ha^{-1}). Major portion of the study area was low in 52%, remaining area was marginally low in 40%, medium low in 4% and very low in 3% (Table 3 and Fig. 3). Similar results were reported earlier by Surendra Babu et.al. (2019) and Vijay kumar et al. [14] in case of Warangal soils. "Inspite of having medium organic carbon content, soils of erstwhile Warangal district being light in texture are prone to be degradation. Also tropical temperatures of the region aid in rapid mineralization of organic matter when compared to its rate of accumulation which is the main source of nitrogen in the soil. Under tropical conditions, organic carbon is lost in the form of carbon dioxide due to accelerated activity of microorganisms. The only way to improve nitrogen content in the soils is to apply organic manure in judicious quantities" Prabavathi et.al. [15].The entire district was interpreted as low in soil available nitrogen.

3.3.3 Soil available phosphorus

The soil available phosphorus in entire study area of erstwhile Warangal district varied between 14.00 to 166.00 kg ha^{-1}, with an average value of 54.53 kg ha^{-1}with standard deviation of 31.35 with coefficient of variation is moderately varied (56.80%). The interpolation of available phosphorus data between 241 sample locations resulted in three classes.They are low (14-23 kg ha^{-1}), medium (23-55 kg ha^{-1}) high (55-100 kg ha^{-1}) and very high (100-166kg ha^{-1}).The major portion of the study area was high in 53%, remaining area was medium in 34%, very high in 10% and low in 3%(Table 3 and Fig. 3).Similar type of results were reported earlier by Surendra Babu *et.al.* (2019) and very low soil available phosphorus in erstwhile Warangal district was reported earlier by Vijay kumar *et.al.* (1994). "Higher availability of phosphorus in the soils may be attributed to excess application of phosphatic fertilizers than the recommended doses in almost half of the study area. Further, residual activity of phosphorus is well known, which might have resulted in increased amount of available phosphorus in the soil. Thus, it would be best to supplement the crop with phosphorus only after taking into account of the available soil phosphorus" (Sushma Sannidi et.al. (2021).

3.3.4 Soil available potassium

The soil available potassium in erstwhile Warangal district varied between 199 to 997 kg ha^{-1} with an average value of 469 kg ha^{-1} with standard deviation of 189 and CV is moderately varied (40.19%). The GIS map of soil available potassium in 241 sample locations results three classes. They are medium (140-330 kg ha^{-1}) high (330-600 kg ha^{-1}) and very high (600-997 kg ha^{-1}). The major portion of the study area was high in 50%, remaining area was very high in 36% and medium in 14% (Table 3 and Fig. 3). Soils are able to maintain a sufficient or even high level of exchangeable K and provide a good supply of K to plants for many years Prabavathi et.al. [15]. The higher content of available K in soils of study area may be due to the predominance of potash rich micaceous and feldspar minerals in parent material. Similar type of results were reported earlier by Surendra Babu et.al. (2019) and medium soil available potassium in erstwhile Warangal district was reported earlier by Vijay kumar et.al. [14].

3.4 Soil Available Micronutrients Status and their Spatial Variability

3.4.1 Soil available Zinc (Zn):

The soil available zinc in the erstwhile Warangal district was ranged between 0.13 to 2.05 mg kg^{-1}, with a mean value of 0.67 mg kg^{-1} and standard deviation of 0.38 with coefficient of variation was moderate (57.81%). The interpolation of soil available zinc data between 241 sample locations resulted in five classes. They are very low (0.13-0.30 mg kg^{-1}), low (0.31-0.60 mg kg^{-1}), marginal (0.61-1.20 mg kg^{-1}), adequate (1.21-1.80 mg kg^{-1}) and moderately adequate (1.81-2.05 mg kg^{-1}). The major portion of the study area was marginal in 62%, remaining area was low in 26%, very low in 6%, adequate in 6% and moderately adequate in 0.47% (Table 3 and Fig. 4). Regardless of the localized natural endowment, Zn deficiency was found over large parts of the region and therefore, there is a need for Zn fertilization at recommended doses for rational crop yields. The soil available Zn increased with low pH and high organic carbon content but decreased with increase in soil pH. Since, most of the soils are neutral to moderately alkaline and low in organic carbon, Zn may be precipitated as hydroxides and carbonates and as a result their solubility and mobility might have decreased and reduced the availability. Similar type of results was reported earlier by Surendra Babu et.al. (2019), Vijay Kumar et.al. [14] and Satyavathi and Suryanarayana Reddy [13] in case of erstwhile Warangal district soils. McLeod MK et al. [5] also reported similar type of results in Indonesia.

3.4.2 Soil available Ferrous (Fe):

The soil available iron in erstwhile Warangal district was ranged between 0.09 to 11.80 mg kg^{-1}, with a mean value of 3.36 mg kg^{-1} with standard deviation of 2.20 and coefficient of variation is moderate (66.93%). The interpolation of available iron data between 241 sample locations resulted in four classes. They are very low (0.09-2.50 mg kg^{-1}), low (2.51-4.50 mg kg^{-1}), marginal (4.51-9.00 mg kg^{-1}), adequate (9.01-11.80 mg kg^{-1}). The major portion of the study area was low in 44%, remaining area was marginal in 28%, very low in 26% and adequate in 2% (Table 3 and Fig. 4) and need to be taken care of. Similar type of results were reported earlier by Surendra Babu *et.al.* (2019), Vijaykumar et al. [14] and Satyavathi and Suryanarayana Reddy [13] in case of erstwhile Warangal district soils. Patil PL et al. [6] reported similar type of results in case of northern transitional zone of Karnataka.

3.4.3 Soil available Copper (Cu):

The soil available copper in erst while Warangal district was ranged between 0.14 to 2.14 mg kg^{-1}, with a mean value of 0.72 mg kg^{-1} with standard deviation of 0.33 and coefficient of variation is moderate (46.39%). The interpolation of available copper data between 241 sample locations resulted in five classes. They are low (0.14-0.20 mg kg^{-1}), marginal (0.21-0.40 mg kg^{-1}), adequate (0.41-0.80 mg kg^{-1}), moderately adequate (0.81-1.20 mg kg^{-1}) and high (1.20-2.14 mg kg^{-1}). The major portion of the study area was adequate in 56%, remaining area was moderately adequate in 32%, high in 6%, marginal in 6% and low in 0.41% (Table 3 and Fig. 4). Similar type of results was reported earlier by Surendra Babu *et.al.* (2019), he reported that DTPA extractable Cu in soils of

Telangana ranged from 0.09 15.81mg kg^{-1} soil with an average of 1.91 ± 0.02 mg kg^{-1} with using 0.20 mg Cu kg^{-1}as critical limit and overall deficiency was 1.35 % while in erstwhile Warangal district Cu deficiency was recorded to the extent of less than 1%.

3.4.4 Soil available Manganese (Mn):

The soil available manganese in erstwhile Warangal district was ranged between 0.18 to 10.30 mg kg^{-1}, with a mean value of 3.82 mg kg^{-1} with standard deviation of 1.93 and coefficient of variation is moderate (51.51%). The interpolation of available manganese data between 241 sample locations resulted in five classes. They are very low (<1.0 mg kg^{-1}), low (1.0-2.0 mg kg^{-1}), marginal (2.0-4.0 mg kg^{-1}), adequate (4.0-8.0 mg kg^{-1}) and moderately adequate (8.0-10.3 mg kg^{-1}). The major portion of the study area was marginal in 48%, remaining area was adequate in 40%, low in 7%, moderately adequate in 5% and very low in 0.79% (Table 3 and Fig. 4). Similar type of results were reported earlier by Surendra Babu *et.al.* (2019), he mentioned that based on critical limit of 2.00 mg Mn kg^{-1} soil, most of the soils are sufficient in Mn and on an average less than 4% soils are deficient in DTPA-extractable Mn.

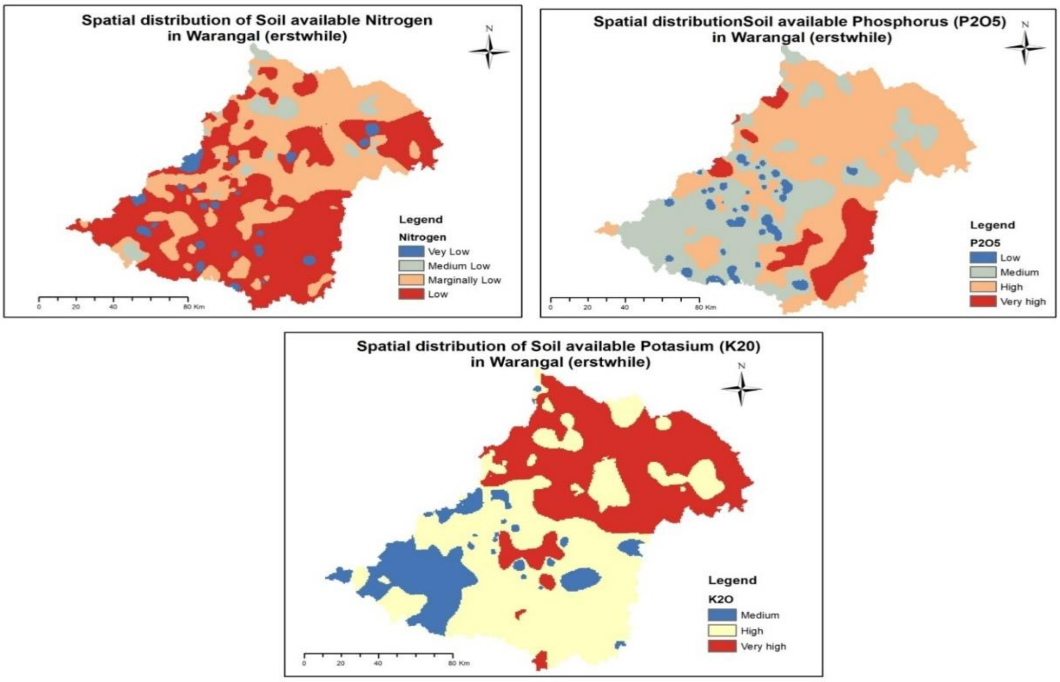

Fig. 3. Spatial distribution of soil available nitrogen, P_2O_5 and K_2O in erstwhile Warangal district, Telangana, India.

Table 2. Physico-chemical and chemical properties of soils of erstwhile Warangal District, Telangana, India

Soil parameter	Range	Mean	Standard deviation	Coefficient of variation (CV %)
Soil pH	6.16-8.34	7.46	0.34	4.53
Ec (dS m^{-1})	0.14-1.00	0.40	0.17	43.32
OC (%)	0.12-1.14	0.57	0.17	29.50
Available Nitrogen (kg ha^{-1})	136-231	178	15.50	8.72
Available P_2O_5 (kg ha^{-1})	14.00-166.00	54.53	31.35	56.80
Available K_2O(kg ha^{-1})	199-997	469	189.21	40.19
Available Zn (mg kg^{-1})	0.13-2.05	0.67	0.38	57.81
Available Fe (mg kg^{-1})	0.09-11.80	3.36	2.20	66.93
Available Cu (mg kg^{-1})	0.14-2.14	0.72	0.33	46.39
Available Mn(mg kg^{-1})	0.18-10.30	3.82	1.93	51.51

Table 3. Soil classification under different parameters as per the classes assigned for soil fertility mapping of the study area

Soil parameter	Number of classes assigned and obtained	Particulars of the classes obtained	Class (Value)	Percentage of total geographical area covered under each class
Soil pH (1:2.5)	3	Slightly acidic	6.16-6.80	2.18
		Neutral	6.81-7.30	23.03
		Slightly alkaline	7.31-8.34	74.79
Soil EC (dSm^{-1})	3	Very low saline	0.14-0.25	8.97
		Low saline	0.26-0.75	87.05
		Moderately low Saline	0.76-1.00	3.98
Soil organic carbon (OC %)	3	Low	0.12-0.50	21.13
		Medium	0.51-0.75	66.13
		High	0.76-1.14	12.74
Soil available nitrogen (kg ha^{-1})	4	Very low	136-160	3.44
		Low	161-180	51.87
		Marginally low	181-200	40.24
		Medium low	201-231	4.46
Soil available phosphorus (P_2O_5) (kg ha^{-1})	4	Low	14-23	3.82
		Medium	24-55	33.73
		High	56-100	52.66
		Very High	100-166	9.79
Soil available potassium (K_2O) (kg ha^{-1})	3	Medium	140-330	28.60
		High	331-600	62.90
		Very High	601-997	8.57
Soil available zinc (mg kg^{-1})	5	Very low	0.13-0.30	6.47
		Low	0.31-0.60	25.70
		Marginal	0.61-1.20	61.56
		Adequate	1.21-1.80	5.79
		Moderately adequate	1.81-2.05	0.47
Soil available iron (mg kg^{-1})	4	Very low	0.09-2.50	25.67
		Low	2.51-4.50	44.29
		Marginal	4.51-9.00	28.21
		Adequate	9.01-11.80	1.83
Soil available copper (mg kg^{-1})	5	Low	0.14-0.20	0.41
		Marginal	0.21-0.40	5.73
		Adequate	0.41-0.80	55.52
		Moderately adequate	0.81-1.20	32.44
		High	1.21-2.14	5.91
Soil available manganese (mg kg^{-1})	5	Very low	<1.00	0.79
		Low	1.00-2.00	6.51
		Marginal	2.00-4.00	48.30
		Adequate	4.00-8.00	39.87
		Moderately adequate	8.00-10.30	4.53

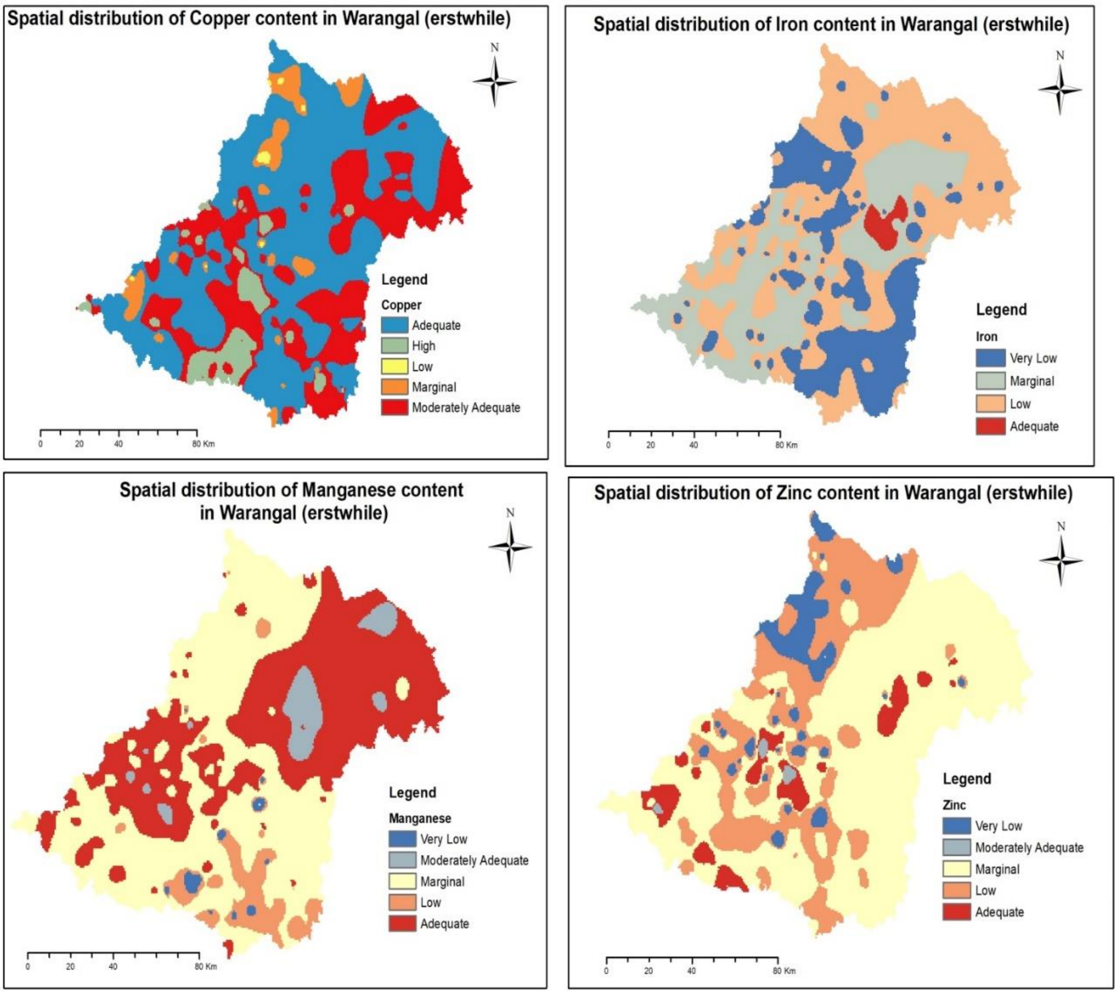

Fig. 4. Spatial distribution of soil available Zinc (Zn), Ferrous (Fe), Copper (Cu) and manganese (Mn) in erstwhile Warangal district, Telangana, India

4. CONCLUSION

Soils of erstwhile Warangal district of Telangana were slightly acidic to slightly alkaline in reaction, non-saline in nature and low to high in organic carbon content. The soils were low in available N, low to high in available P_2O_5 and medium to high in available K_2O. Major portion (66%) of the study area was medium in organic carbon content. The entire area of erstwhile Warangal district is deficient (low) in available N, The major portion (53%) of the study area was high in available P_2O_5, and major portion (50%) of the study area was high in available potassium. The available Zn, Iron, Copper and Manganese were marginal, low, adequate and marginal in 62%, 44%, 56% and 48% of area respectively. Deficiency of Cu, Mn and Fe is negligible. The fertility status of available nutrients in study area revealed that organic carbon, available N and Zn are important soil fertility constraints for sustained crop production and hence need immediate attention by planners and policy makers for more focused programmes in these areas. The study also helped to identify and delineate critical areas under deficiencies of N, OC and Zn for prioritization and site specific nutrient management. Based on the status of nutrients the recommendation for fertilizers can be made which may be of immense useful in enhancing the yields of crops and reducing the cost of excessive fertilizer in addition to providing balanced nutrition to the crops. To build-up organic matter and native N and maintain nutrient balance in the soil, farmers are advised to adopt FYM and $ZnSO_4$ application. Besides these, crop rotation can enhance crop production and soil fertility in erstwhile Warangal district.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dregne HE, Chou NT. Global desertification dimensions and costs. In degradation and restoration of arid lands. Lubbock: Texas Tech. University; 1992.
2. Sehgal J, Abrol IP. Soil degradation in India: Status and impact. New Delhi, India, Oxford and IBH. 1994;80p.
3. Singh SK, Mahesh Kumar, Sharma BK, Tarafdar JC. Depletion of organic carbon, phosphorus and potassium under pearl millet based cropping system in the arid region of India. Arid Land Research and management. 2007;21:119-131.
4. Mahesh Kumar, Santra P, Singh SK, Raina P, Kar A, Ram B, Moharana PC. Identifying sensitive soil properties as a function of land use change in thar Desert of India. Agricultural research. 2018;7:187-199.
5. McLeod MK, Sufardi S, Harden S. Soil fertility constraints and management to increase crop yields in the dryland farming systems of Aceh, Indonesia. Soil Research. 2020 Aug 28;59(1):68-82.
6. Patil PL, Pulakeshi HB, Dasog GS. Identification of soil fertility constraints by geographic Information system (GIS) technique and response of crops to identified nutrient constraints in northern transitional zone of karnataka. In the Third National Conference on Agro-Informatics and Precision Agriculture. 2012;232-236.
7. Kumar M, Kar A, Raina P, Singh SK, Moharana PC, Chauhan JS. Assessment and mapping of available soil nutrients using gis for nutrient management in hot arid regions of North-Western India. Journal of the Indian Society of Soil Science. 2021;69(2):119-32
8. Rajagopal V, Prabhu Prasadini P, Pazanivelan S, Balakrishnan N, Characterisation and classification of soils in Warangal District of Central Telangana Zone. Madras Agricultural Journal. 2013;100(4-6):432-437.
9. Soil Survey Staff, Keys to Soil Taxonomy. (II ed), National Resource Conservation Centre, USDA, Virginia; 1998.
10. Jackson ML, Soil chemical analysis-advanced course. Second Edition. University of Wisconsin, Madison; 1979.
11. Singh MV. Micro and secondary-nutrients and pollutant elements research in India. Coordinator Report, AICRP Micro- and Secondary-Nutrients and Pollutant Elements in Soils and Plants. Indian Institute of Soil Science, Bhopal. 2008;31:1-77.
12. Dwivedi BS. Revamping soil testing service: A pre-requisite for effective implementation of soil health card scheme. Journal of the Indian Society of Soil Science. 2017;65(Supplement):S 62-S71.
13. Satyavathi PLA, Suryanarayana Reddy M. Distribution of DTPA extractable micronutrients in soils of Telangana, Andhra Pradesh. Agropedology. 2004;14(1):32-37.
14. Vijay kumar T. Suryanarayan Reddy M, Gopalakrishna V. Characteristics and classification of soils of northern telangana'zone of Andhra Pradesh. Agropedology; 1994.
15. Prabhavathi M*, Adhikari RN, Raizada1 A, Biswas2 H, Mohan Kumar P, Naik BS, Muralidhar W. Identification of soil fertility constraints using GIS for sustainable crop production in the watershed of semi-arid tropics. Journal of the Indian Society of Soil Science. 2023;71(2):159-171.

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