Agropedology 2022, 32 (02), 211-218
doi.org/10.47114/j.agroped.2022.dec6

Mapping of Soil Fertility in Paddy-growing Soils of KRP Dam Catchment of Tamil Nadu Using GIS

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Abstract : Soil Fertility mapping are helps in reducing the cost of fertilizer and environmental risks. In KRP Dam catchment, 92 surface soil samples collected from major paddy-growing soils were used for soil fertility mapping in a GIS environment. Soil properties *viz*, pH ranged from highly acidic to strongly alkaline, with the maximum area being slightly alkaline (19.98%) and moderately alkaline (26.16%), but soils were non-saline (<2 dSm^{-1}). Organic carbon (OC) varied from low (<0.5%) to high (>0.75%) occupied 20.01% and 44.90%, respectively. The soils were high (> 22 kg ha^{-1}) in available phosphorus (P), occupying 42.55% area followed by low P in 19.35% area and medium P in 18.72% area. There soils were medium to high in available potassium (K) and available sulphur (S). DTPA-Cu was found to be above the critical limit, but deficient in iron, manganese, zinc and boron. The extent and distribution of soil nutrients will help in site-specific fertilizer recommendations for paddy farming in the KRP dam catchment.

Keywords: *KRP dam, soil properties, fertility status, mapping, GIS*

Introduction

The demand for food increases along with the global population, placing greater challenge on limited soil resources for the survival of mankind. Thus is our responsibility to maintain fertile soil through appropriate crop management techniques and soil amendments (MacCarthy *et al.* 2013). Indigenous nutrient-supplying capacity and fertilizer management may make the soil fertile for one type of crop but could be deficient for others. So, the determination of soil fertility range would be important not only for producing healthy crops economically but also for maintaining productivity for future generations.

Soils of paddy-growing soils are exposed to alternate wet and dry conditions and flooding situations. Excess water generally imbalanced ionic ratio and movement (Srinivasan *et al.* 2019). Paddy soils outstretch in an unique management system that changes of soil moisture affect the microbial activity by changing the potential of redox and subsequently determine bioavailability of nutrients. Regardless of the microbial activity in paddy soils, changes in the redox potential due to changes in the presence of oxygen, alone can affect the availability, deficiency, and toxicity of the plant nutrients. Regular paddy cultivation without balanced fertilization (Biswas *et al.* 2008) will cause great economic losses. New nutrient deficiencies are emerging (Saha *et al.* 2016), and there might be potential hidden hunger for many others that need to be identified for efficient paddy crop production in the catchment.

Soil fertility varies among regions indicating that variable amounts of fertilizers need to be applied for different types of crop production. The management of

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different rice fields certainly affects the level of fertility in the paddy fields (Supriyadi 2018). The inadequate dose will impair crop yield, while an overdose can cause not only economic losses but also could be responsible for environmental pollution (Yang and Zhang 2008). So, broad knowledge of soil fertility can provide a better perception of current nutrient status, distribution patterns and trends (Dafonte *et al.* 2010) that can be obtained through geostatistical and geospatial analyses and finally mapped in a GIS environment (Behera and Shukla 2015; Srinivasan *et al.* 2021). Such analyses help in decision-making processes for precision agriculture and thus for the improvement of crop productivity (Rahman *et al.* 2016).

An approach towards justifying such concerns is site-specific nutrient management which considers spatial variations in nutrient status, thus cutting down the possibility of over or under-use of fertilizer. Geographic information system (GIS) is a powerful tool that helps to integrate many types of spatial information such as agro-climatic zone, land use, soil management, etc. to derive useful information (Adornado and Yoshida 2008). Furthermore, GIS-generated soil fertility maps may serve as a decision-support tool for nutrient management (Prabhavati *et al.* 2015; Khaki *et al.* 2017). In this background, a study was initiated to map the spatial distribution of soil fertility parameters in major paddy-growing soils in the KRP Dam catchment of Tamil Nadu.

Materials and Methods

Study area

Krishnagiri Dam, known as Krishnagiri Reservoir Project (KRP) Dam was built across the Thenpennai river fall in Dhuduganahalli village, Krishnagiri district of Tamil Nadu. A case study was conducted during 2019-21 in the KRP dam catchment in Kaveripattinam block, Krishnagiri district of Tamil Nadu. The study area (21°29'37.44" N; 78°10'41.51" E), belongs to the agro-ecological sub-region (AESR) of 8.2

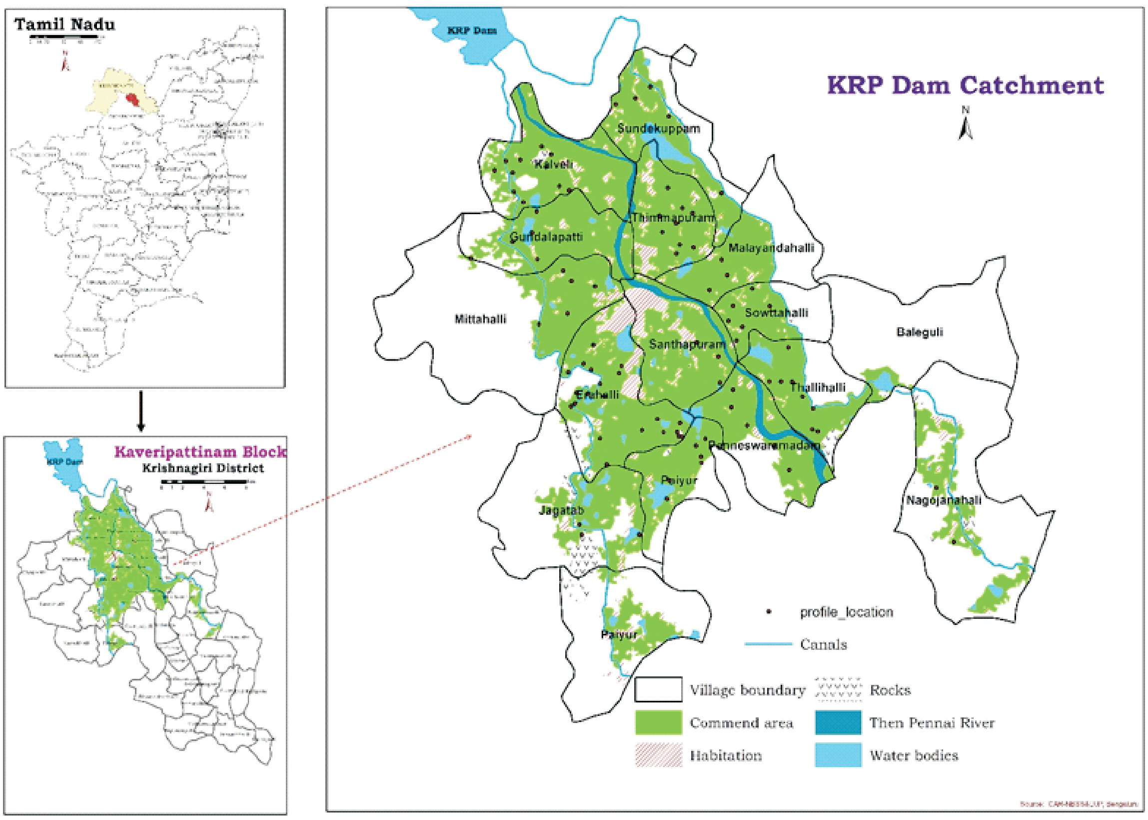

Fig. 1. Location map of the study area

and covers an area of 12483 ha (Fig. 1). The reservoir has two main canals, one on the left side, and another one on the right side, almost parallel to the Ponnaiyar river. About 16 villages directly benefit from this reservoir for irrigation and other purposes. There is a water supply from the reservoir for 10 months a year, which ensures successful cultural operations.

Climate and land uses

The mean annual rainfall varied from 750 to 900 mm and more than 60-70% is received during the north-east monsoon (October-December) with a 150 - 180 days growing period (LGP). The mean maximum temperature in summer is 37°C and the mean minimum temperature is 25.5°C. The soil temperature class is hyperthermic. The moisture regime is "ustic" lying in the Deccan Plateau, a hot semi-arid eco-region with mixed red loamy soils. In the dam catchment, paddy is the main crop cultivated in triple, double and single seasons and some parts of the land are under coconut, jasmine, ragi and pulses.

Field studies

A detailed soil survey at 1:10,000 scales was carried out in the KRP dam catchment during 2019-21. Soil profiles 92 were studied based on the different landforms (Denudural Hills, Isolated hills, Foothills, Pediments, Valley fringe and Valley fringe) and slope variability. The surface soil samples were used to map the nutrient variability and their locations were recorded using a handheld global positioning system (GPS).

Laboratory analysis

Surface soil samples were collected, processed and analysed. Soil pH and EC were determined using the procedures described by Jackson (1973) and Page *et al.* (1982), respectively. The wet oxidation method of Walkley and Black (1934) was used to determine the soil organic carbon. Available phosphorus (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Olsen and Sommers 1982). Available potassium was estimated by flame photometer after extraction with Neutral normal ammonium acetate solution (pH 7.0) (Hanwayan and Heidal 1952). The available sulphur was extracted with 0.15% $CaCl_2$ and estimated the sulphate content by turbidimetric procedure (Williams and Steinbergs1964). Available boron was estimated using Azomethine-H reagent (Jackson 1973). The available micronutrients (Fe, Mn, Cu and Zn) were extracted using DTPA (Lindsay and Norvell 1978) and their concentrations were determined with atomic absorption spectrophotometer.

Map preparation

The maps of pH, EC, OC (P, K, S, B, Fe, Mn, Cu and Zn) were prepared using Arc GIS software 10.3 environment.

Results and Discussion

Soil properties

Depending on the variation in pH, the soil was classified as acidic, neutral, or alkaline. Most of the nutrients will be available to plants at a neutral pH. Some nutrients will be fixed in acid or alkaline soils and unavailable to plants. The soil reaction is acidic in the uplands and alkaline in the lowland soils (Fig. 2a). Around 30% of the area is moderately alkaline (7.8- 8.4 pH) and 20% is a slightly alkaline reaction (7.3-7.8 pH). Alkaline condition is largely distributed in the dam catchment (Table 1) due to paddy cultivation in anaerobic conditions.

EC is a measure of the amount of salts present in the soil. Though EC does not affect plant growth directly, it has been used as an indirect indicator of nutrient availability. High EC of the soil indicates soil salinity (EC >4 dS m^{-1}) which impede crop growth and microbial activity. Due to high sodium concentration, soils with high EC generally have poor structure and drainage, and high sodium-rich becomes toxic to plants. Soils of the area have been grouped into non-saline (<2 dS m^{-1}) classes.

Table 1. Distribution of soil characteristics in KRP Dam catchment

Soil Reaction (pH)	Area (ha)	% TGA	EC (dS m^{-1})	Area (ha)	% TGA	OC (%)	Area (ha)	% TGA
Strongly acidic (5.0 -5.5)	40.2	0.32	Non saline (< 2)	10063.1	80.61	Low (< 0.5)	2498.0	20.01
Moderately acidic (5.5 - 6.0)	240.6	1.93				Medium (0.5 – 0.75)	1959.6	15.70
Slightly acidic (6.0 -6.5)	1152.6	9.23				High (> 0.75)	5605.4	44.90
Neutral (6.5 -7.3)	1373.3	11.00						
Slightly alkaline (7.3 -7.8)	2493.9	19.98						
Moderately alkaline (7.8 - 8.4)	3265.1	26.16						
Strongly alkaline (8.4 - 9.0)	1497.5	12.00						

Soils of the catchment have been grouped into three organic carbon classes. Data in (Table 1 and Fig 2c) indicate that high (>0.75%) and medium (0.5-0.75%) levels of organic carbon occupy 44.90% and 15.70% of the area respectively, whereas about 20.01% of the area have low (<0.5%) organic carbon content. The single cropped zones, which remain 5-6 months under water in a year in any country. Regular addition of organic manures and fertilizers to paddy soil could improve the organic matter (Srinivasan *et al.* 2021).

Available P status in the Dam catchment was found to be adequate in 60% of the area and low in 20% respectively. It is observed that soils of high available P (>22 kg ha^{-1}) are occupying 42.55% area followed by

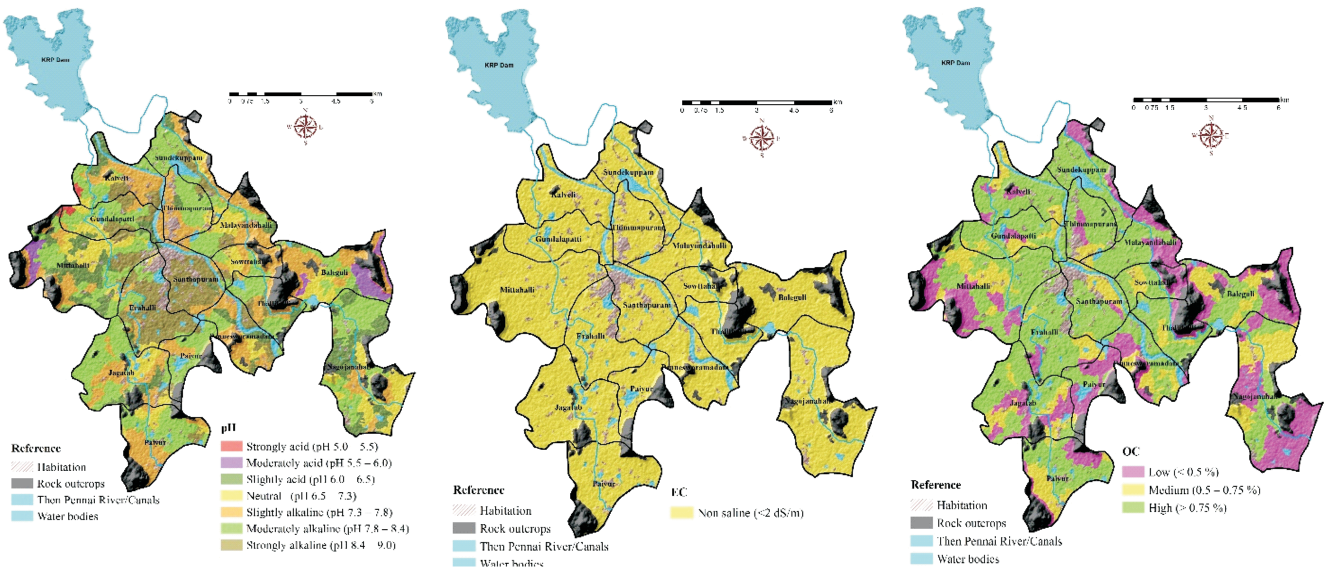

Fig. 2. Distribution of a) soil reaction b) EC c) soil OC in KRP dam catchment

medium (11-22 kg ha^{-1}) and low (<11 kg ha^{-1}) in 18.72% and 19.35%, respectively. The extent and distribution of available P are shown in fig 3a and presented in table 2. High available might be due to because of the regular addition of fertilizer to paddy-based cropping system and inherent characteristics of parent materials (Biswas *et al.* 2019).

Available K in Dam catchment is medium to high in more than 80% of the area. It is observed that soils of medium available K (118-280 kg ha^{-1}) occupy 37.30% area followed by high (>280 kg ha^{-1}) in 29.08% and low (<118 kg ha^{-1}) in 14.22% of the area (Fig. 3b; Table 2).

The availability of sulphur is influenced by several soil factors, and as a result, the status of various forms of sulphur in soils differs significantly with soil type. It is observed that soils of medium available S (10-20 mg kg^{-1}) occupy 35.43% area followed by high S (>20 mg kg^{-1}) is 31.48% and low S (<10 mg kg^{-1}) in 13.70% of the area. (Fig 3c, Table 2).

Iron is a critical micronutrient for several crops as deficiency of Fe is known to occur in different regions of India. Fe deficiency occurs when the soil concentration is below 4-5 mg kg^{-1} in rice production, while toxicity occurs when the soil Fe concentration is above 300 mg kg^{-1} (Dobermann and Fairhurst 2000). In KRP Dam catchment 2507 ha (20.08%) was deficient (<4.5 mg kg^{-1}) and sufficient (>4.5 mg kg^{-1}) area was 60% (Table 3 and Fig. 4a). This low content of Fe might be due to precipitation of Fe^{2+} by calcium carbonate concretions in calcareous soils and higher pH of the soils, which decreases the availability of Fe (Vijaya Kumar *et al.* 2013).

Table2. Distribution of major soil nutrients in KRP Dam catchment

Nutrients	Class	Area (ha)	% TGA
	Low (< 11 Kg ha^{-1})	2415.3	19.35
Available P	Medium (11 – 22 Kg ha^{-1})	2336.3	18.72
	High (> 22 Kg ha^{-1})	5311.5	42.55
	Low (<118 Kg ha^{-1})	1775.2	14.22
Available K	Medium (118 – 280 Kg ha^{-1})	4656.6	37.30
	High (> 280 Kg ha^{-1})	3631.1	29.08
	Low (<10 mg kg^{-1})	1710.1	13.70
Available S	Medium (10 – 20 mg kg^{-1})	4423.1	35.43
	High (> 20 mg kg^{-1})	3929.9	31.48

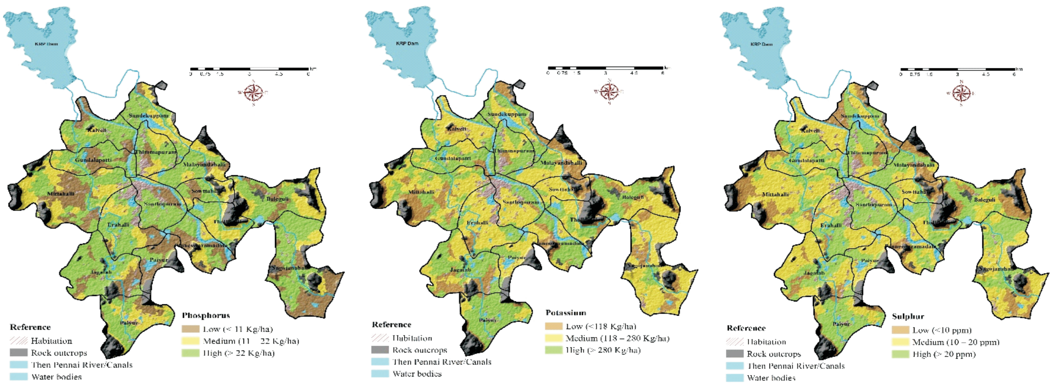

Fig. 3. Distribution of a) Available P b) K and c) S in KRP dam catchment

Manganese functions primarily as part of enzyme systems in crops. It is required to activate important metabolic reactions and plays a direct role in photosynthesis. Mn deficiency (<3.0 mg kg^{-1}) was found in 5728 ha (45.89%) area and 34.73% of the area was sufficient (>3.0 mg kg^{-1}) (Table 3, Fig. 4b).

About 31.03% of the area was sufficient (>0.8 ppm) in Zn in the KRP Dam catchment. Available Zn status in most of the soils (<0.8 mg kg^{-1}) was deficient (Table 3 and Fig. 4c).

Available boron is low (<0.5 mg kg^{-1}) in 7603 ha (61%) and medium (0.5-1.0 mg kg^{-1}) in 2460 ha (20%). The extent and distribution of available B are shown in fig 4d and presented in table 3.

Table 3. Area wise distribution of different micronutrients in KRP Dam catchment

Nutrients	Class	Area (ha)	% TGA
Iron (Fe)	Deficient (< 4.5 mg kg^{-1})	2506.9	20.08
	Sufficient (> 4.5 mg kg^{-1})	7556.1	60.53
Manganese (Mn)	Deficient (< 3.0 mg kg^{-1})	5727.9	45.89
	Sufficient (> 3.0 mg kg^{-1})	4335.2	34.73
Zinc (Zn)	Deficient (< 0.8 mg kg^{-1})	6189.5	49.58
	Sufficient (> 0.8 mg kg^{-1})	3873.6	31.03
Boron (B)	Low (< 0.5 mg kg^{-1})	7603.0	60.90
	Medium (0.5-1.0 mg kg^{-1})	2460.0	19.70

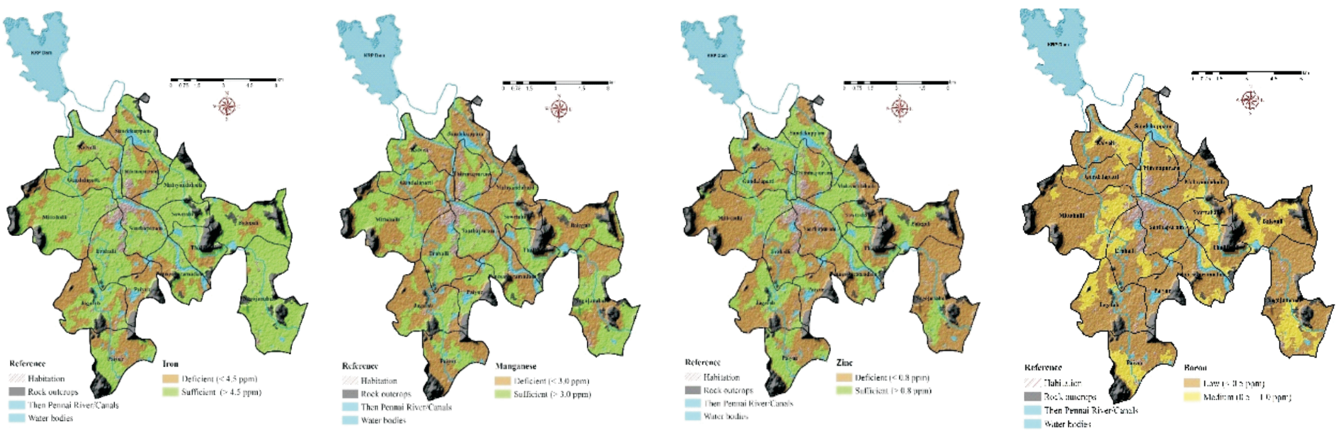

Fig. 4. Distribution of a) Available Fe, b) Mn, c) Zn and d) B in KRP dam catchment

Conclusion

Soil fertility assessment and mapping helped to identify the nutrient-critical zones and remediation. The soils of KRP dam catchment were high in nearly 40 percent area and low in about 19 per cent area. These soils were medium to high in available K and S but different in available Fe, Mn and Zn. The knowledge of extent and distribution of soil fertility will help in chalking out help to implement appropriate nutrient management for specific crops in the KRP dam catchment area.

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Received: June, 2022 *Accepted: November, 2022*