Annals of Plant and Soil Research 24(4):606-610 (2022)
https://doi.org/10.47815/apsr.2022.10216

GIS-based soil fertility assessment of a micro-watershed of semi-arid tropics in southern India

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Received: May, 2022; Revised accepted: August, 2022

ABSTRACT

Available macronutrient status in the soil of Chotanahalli micro-watershed (468 ha) in Kunigal Taluk, Tumkur district was studied with the aid of GIS. Forty three surface soil samples at 320 m grid were collected from Chotanahalli micro-watershed and assessed for the soil organic carbon, available nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. Results revealed that the ranges of SOC, available N, P and K were 2.1 to 7.5 g kg^{-1}, 282.2 to 526.8 kg N ha^{-1}, 8.0 to 67.6 kg P_2O_5 ha^{-1} and 124.3 to 338.5 kg K_2O ha^{-1}, respectively. Spatial interpolation revealed that majority (321 ha) of the watershed was low in SOC, whereas the whole watershed was medium in available N, P and K. In case of secondary nutrients, available S was found to be medium in majority (423.4 ha) of the area, whereas, exchangeable Ca and Mg were found sufficient in the whole watershed. The Nutrient Index values indicated that the micro-watershed was under “medium” category for available nitrogen, phosphorus, potassium and sulphur, whereas, it fell under “low” category with respect to organic carbon. Measures to improve the status of SOC should be taken up in the study area for sustainable production of crop.

Key words: Macronutrient, GIS, micro-watershed

INTRODUCTION

Karnataka has the biggest share of drought-prone terrain (79%) of all major states in the country and the second largest area under dry land after Rajasthan. Intensive tillage, monocropping year after year, use of high yielding varieties, imbalanced application of nutrients coupled with limited use of organic manures, less recycling and burning of crop residues, soil erosion, undulated topography, and indiscriminate use of irrigation water are all repercussions of current agricultural system degenerating soil health. In dry lands, erosional soil loss and dwindling water supply cause faster deterioration of soil fertility and stagnant crop yield. In comparison to the ideal 4:2:1, the present NPK fertiliser consumption ratio in Indian drylands is 10:2.9:1. This imbalance has resulted in the emergence of multi-nutrient deficiencies, which is currently a real challenge to manage at the farm level. The need of balanced plant nutrition for long-term agricultural production has been well established. In future, neglected nutrient deficiencies will only worsen the situation by jeopardising productivity and sustainability. Geospatially aided natural resource monitoring in watersheds has the potential to play critical role in achieving higher productivity and agricultural sustainability. In the present study, we have studied the spatial variability of key fertility parameters and available primary and secondary nutrients in the soil of Chotanahalli micro watershed using field survey and GIS.

MATERIALS AND METHODS

The survey was conducted during 2018-19 with the objective to study soil fertility status of Chotanahalli micro-watershed of Nagasandra sub-watershed located in the Kunigal Taluk of Tumkur District (at North latitude 13° 3' 24.866" and 13° 5' 26.744", East longitude 76° 54' 9.083" and 76° 55' 23.623" and 772 m MSL, covering an area of 468 ha; spread across Chotanahalli, Jeddigere, Vogaragere and Hampapura villages). Cadastral map at 1:7,920 scale

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showing parcel boundaries was used as the base map. Out of 468 ha (total watershed area), cultivable land area was 427.9 ha. A grid of 320 m spacing was overlaid on the cadastral map for this study. Forty three grids-points, covering the whole micro-watershed, were identified by following standard procedure (Liu *et al.,* 2006). A total 43 surface field-soil samples were collected from the fields along the GPS points falling nearest to the grid points and locations were geo-tagged. Soil samples were analysed for physico-chemical parameters. The pH (1:2.5) and electrical conductivity (EC) (1:2.5) of soils were measured by pH meter and EC meter, respectively. Available N (Subbiah and Asija, 1956), available P (Olsen *et al.*, 1954), available K (Jackson, 1973), SOC (Walkley and Black, 1934), available S (Chesnin and Yien, 1951) and extractable Ca and Mg (Jackson, 1973) contents were analysed by following the standard protocol. Correlation among soil properties and available nutrients was assessed using R 3.6 (R Core Team, 2018). For the assessment of variability, mean and standard deviation for each set of data were used. The data, after analysis, were linked with the grid numbers and respective GPS locations to run interpolation (Krigging) for soil fertility mapping (Liu *et al.,* 2006 and Mirzaee *et al.,* 2016). Thematic maps were prepared using Arc GIS 10.4 software by considering the standard soil fertility ratings mentioned by NBSS&LUP.

RESULTS AND DISCUSSION

Physico chemical properties

The results of the investigation with respect to the status of pH, EC, organic carbon, major nutrients and secondary nutrients in the soils are presented as range, mean and standard deviation in Table 1.

Table 1: Range, mean and standard deviation of soil properties and macronutrient status in Chotanahalli micro-watershed of Tumkur District

Property	Range	Mean	SD
pH	4.31–7.42	6.01	0.72
EC (dS/m)	0.06–0.61	0.16	0.12
OC(%)	0.21–0.75	0.42	0.15
N (kg/ha)	282.2–526.8	376.1	62.49
P_2O_5 (kg/ha)	8.01–67.6	41.56	17.32
K_2O (kg/ha)	124.3–338.5	217.8	37.77
S (mg/kg)	9.71–20.8	15.20	3.06
Ca (meq/100g)	1.45–6.35	3.90	1.38
Mg (meq/100g)	0.9–3.65	2.13	0.74

Village-wise descriptive statistics of the analytical result of the soil samples is depicted in Table 2 for better perusal. In Chotanahalli micro-watershed, soil pH value ranged from 4.3–7.4 but most of area fell under three major classes with range of pH 5–6.5 strongly acidic to slightly acidic in nature. Out of cultivable 427.9 ha, 4.1 ha area come under strongly acidic condition, 176.5 ha come under moderately acidic condition and 246.7 ha was slightly acidic. Area under these classes were 1.0, 37.7 and 52.7 %, respectively. The variation in pH value was related to its parent material, relief and topography. Relatively high pH value was observed in black soils due to the increase of high amounts of basic cations in solum as they were poorly drained. In red soil, pH was relatively lower due to the presence of iron hydroxide and other species which generate H^+. The observations were in conformity with the findings of Dasog and Patil (2011) and Seth *et al.* (2017). Soil EC values ranged from 0.06–0.61 dS m^{-1} but the whole cultivable area (427.9 ha) came under one major class–non saline (< 2.0 dS m^{-1}). This may be owing to the undulating type of the terrain attached with moderately good drainage environment, which promoted removal of salts with the drainage water. These observations were in compliance with the findings of Taje *et al.* (2022). Although SOC in the micro-watershed varied widely from 2.1–7.5 g kg^{-1} but most of the area came under two major classes—low and medium. Out of the cultivable 427.9 ha, 321.0 ha area came under low and 106.9 ha came under medium SOC content. Per cent area under these classes were 68.6 and 22.8% of the whole watershed (Table 3). Similar observations were reported by Patil *et al.* (2011) that the soils prevailing under semi-arid climate with high temperature show low to medium organic carbon.

Table 2: Village-wise range, mean and standard deviation of soil properties and macronutrient status in Chotanahalli micro-watershed of Tumkur District

Property	Hampapura (10)			Chotanahalli (14)			Vogaragere (18)		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
pH	4.77–6.72	5.82	0.63	4.76–7.35	6.20	0.75	4.31–7.42	5.95	0.75
EC (dS m^{-1})	0.06–0.44	0.16	0.12	0.06–0.39	0.14	0.11	0.06–0.61	0.17	0.14
OC (g kg^{-1})	2.4–4.0	3.2	0.05	2.8–7.5	4.8	0.15	2.1–7.5	4.3	0.16
N (kg ha^{-1})	282.2–417.1	345.5	38.43	304.1–523.7	396.9	66.67	282.2–526.8	378.0	67.36
P_2O_5 (kg ha^{-1})	15.25–58.23	37.20	14.31	8.01–66.24	40.0	18.67	16.0–67.6	44.04	18.01
K_2O (kg ha-^{1})	163.3–338.5	218.1	53.92	179.2–231.0	212.3	15.93	124.3–301.3	222.5	41.64
S (mg kg^{-1})	10.40–18.02	12.69	2.17	9.71–19.41	14.06	3.03	14.56–20.80	17.64	1.47
Ca (meq 100 g^{-1})	1.45–5.80	3.69	1.31	2.05–6.35	4.12	1.64	1.85–6.25	3.89	1.29
Mg (meq 100 g^{-1})	0.95–3.45	1.93	0.68	1.10–3.65	2.37	0.92	0.90–3.45	2.07	0.62

**One sample was collected from Jeddigere village*

Soil fertility

Soil fertility analysis revealed that the available N content was medium in all the cultivable portion of Chotanahalli micro-watershed with the value ranging from 282.2–526.8 kg ha^{-1} (Table 1). Most of the portion of available N is contributed by organic matter that showed low to medium content in the study area due to a few obvious causes–low rainfall, higher temperature, and very low vegetation which facilitated faster degradation of organic matter, leading to nitrogen deficiency. Similar observations were also made by Seth *et al.* (2017). Phosphorus availability was medium in Chotanahalli micro-watershed with the values ranging widely from 8.0–67.6 kg P_2O_5 ha^{-1}. However, most of the area came under one major fertility class–medium (10–25 kg P ha^{-1}) (Table 1). The large standard deviation (17.3 kg P_2O_5 ha^{-1}) was due to the variation in soil properties namely, clay, SOC, CEC and P fixation capacity. Medium availability of P in these soils, despite farmers applying very high doses of P-fertilizer, is due to the conversion of available phosphorus (orthophosphates) to unavailable form (Tricalcium-phosphates) owing to the higher lime content and acidic soil reaction. This is in accordance with the study of Patil *et al.* (2011). Available K was medium in Chotanahalli micro-watershed with the values ranging from 124.3 to 338.5 kg K_2O ha^{-1}. Whole of the cultivable 427.9 ha fell under medium available K category. This is due to predominance of K rich micaceous and feldspar minerals in the parent material as reported by Dasog and Patil (2011).

Table 3: Area under different fertility classes and Nutrient Index classes of major nutrients and sulphur in Chotanahalli micro-watershed

Nutrients	Area (ha) under classes of nutrients			Nutrient Index	Nutrient Index class
	Low	Medium	High		
Organic carbon	321	106.9	0	1.25	Low
Available N	0	427.9	0	2.00	Medium
Available P	0	427.9	0	2.00	Medium
Available K	0	427.9	0	2.00	Medium
Available S	0	423.4	4.5	2.01	Medium

**40.1 ha (8.6%) area is occupied by habitation and waterbodies*

The exchangeable calcium was sufficient in Chotanahalli micro-watershed with its values ranging from 1.45–6.35 cmol (p^{+}) $kg^{-1.}$ Similar result was reported by Seth *et al.* (2017) for adjoining micro-watershed. Exchangeable magnesium too was sufficient in the said micro-watershed with its values ranging from 0.90–3.65 c mol (p^{+}) $kg^{-1.}$ This might be due to high clay content in the lower horizon compared to the upper horizon, which led to impeded leaching, consequently, accumulation of calcium and magnesium in the lower horizon. Similar results were reported by Narsaiah *et al.* (2018) and Basumatary *et al.* (2021). It was clear that

Mg^{2+} was present in lower amount than Ca^{2+} because of the higher mobility of the former ion. Krishna *et al.* (2017) reported similar results. Available S was present in medium to high category in Chotanahalli micro-watershed with values ranging from 9.71—20.80 mg kg^{-1}. Most of area was assigned two major classes—high (> 20 mg kg^{-1}) and medium (10—20 mg kg^{-1}). Out of 468 ha, 4.5 ha (1%) came under high, and 423.4 ha (90.4%) came under medium available S category, remaining 40.1 ha (8.6%) was occupied by roads, waterbody vegetation etc. The medium amount of available S at surface soil samples was mainly because of the acidic reaction, low to medium SOC values in this mixture of black and red soils (Satish *et al.*, 2018), lack of S addition and gypsiferous nature of S which is less available in black soils. Krishna *et al.* (2017) reported similar results. The village-wise perusal of data (Table 2) showed that the soils of Chotanahalli village were superior in terms of average pH, SOC, available N, Ca and Mg in comparison with Hampapura and Vogaragere. Whereas, the soils of Vogaregere village showed highest average EC. It also contained the highest average amount of available P, K and S. Nutrient Index (NI) values for SOC, available N, P, K and S came 1.25, 2.0, 2.0, 2.0 and 2.01, respectively. Except SOC, which came under 'low' NI class, all the above-mentioned nutrients were assigned under 'medium' NI class (Table 3). Correlation analysis (Table 4) indicated that pH had a positive significant correlation with Ca (r= 0.51**) and Mg (r= 0.57**) contents and also available N had positive significantly higher correlation with SOC contents (r= 0.94***).

Table 4: Correlation coefficient (r) among soil properties and available nutrients

Parameters	N	P	K	S	Ca	Mg
pH	0.11	0.05	0.06	0.05	0.51**	0.57**
EC	-0.10	-0.05	0.22*	0.26*	0.17*	0.12
OC	0.94***	-0.03	0.05	0.17	0.06	0.20

**significant at 5% level of significance **significant at 1% level of significance ***significant at 0.1% level of significance*

CONCLUSION

From the present study, it can be concluded that in Chotanahalli micro-watershed of Nagasandra sub-watershed at Tumkur District, around 90.4% of cultivatable area were moderately to slightly acidic in reaction. A major part of soils (68.6%) in that area had low SOC content, whereas available soil nutrients status (N, P and K) was found to be sufficient. Among secondary macro-nutrients, available S was medium in 90.4% of soils and exchangeable Mg^{2+} and Ca^{2+} also remained sufficient. Therefore, application of organic matter either through FYM, compost or crop residues in conjunction with judicious inorganic fertilizers is important to support the crop productivity and maintenance of soil health for long term sustainability of this area. The information collected can be useful in developing management practices for cultivated soils of Tumkur district.

ACKNOWLEDGMENT

Authors acknowledge WDD (Watershed Development Department), Government of Karnataka and World Bank for providing financial support to carry out the study under Sujala-III project. The technical support provided by NBSS&LUP Regional Centre, Bangalore and the staff of Sujala is greatly acknowledged.

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