Annals of Plant and Soil Research 24(4):625-630 (2022)
https://doi.org/10.47815/apsr.2022.10219

Spatial variability of soil properties of intensively cultivated rice soils of selected command areas of Karnataka

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

ABSTRACT

The spatial distribution of soil properties and plant available Si was studied in three important rice producing command areas of Karnataka by collecting random georeferenced surface (0-15cm) soil samples using GPS and GIS techniques. The soil samples were analysed for different soil properties and plant available Si and the data along with GPS reading were used for the preparation of soil thematic maps using interpolation method and the interpolated maps were analysed with geostatistical parameters and the corresponding kriging maps for pH, electrical conductivity (EC), soil organic carbon (SOC), available nitrogen, phosphorus, potassium and plant available Si (CCSi and AASi) were prepared. These soil samples were categorized as low, medium and high as per criteria followed by soil testing laboratories. The content of soil pH, EC, OC, CEC, sand, silt and clay in surface soils varied from 5.2- 8.7, 0.05-0.49 dS m^{-1}, 2.2-17.5 g kg^{-1}, 3.6- 26.5 c mol (p^+) kg^{-1}, 20.4-85.6, 0.9-59.7 and 1.9-47.8%, 15.7-65.4 mg g^{-1} and 19.2-106.7 mg g^{-1}, respectively. The available nitrogen (89.6-313.6 kg ha^{-1}) was low whereas, phosphorus (10.4-206.9 P_2O_5 kg ha^{-1}) and available K_2O (68.9-516.9 K_2O kg ha^{-1}) were low to medium in range. The CCSi and AASi content ranged from 15.7-65.4 mg g^{-1} and 20.0-106.7 mg g^{-1}, respectively.

Keywords: GIS, GPS, nutrients, soil fertility, rice soils, Karnataka

INTRODUCTION

Spatial variability of soil physical and chemical properties on a regional scale is affected by intrinsic (geological and pedological soil forming factors) and extrinsic (Tillage, soil management practices, crop rotation and fertility status) factors. In recent years, spatial variability map of soil properties has been increasingly used by soil scientists for planning and management of the soil for sustainable crop production. Geographic information system (GIS) is a powerful technique to characterize and model spatial variability of soils. Despite the ease of determination of various soil physical and chemical properties through conventional methods, spatial variability maps are produced to represent the variability of soil within or among the agricultural field, which adequately represents their distribution. In agroeco systems, GIS technique is a cost effective and accurate alternative to evaluate the spatial variation of soil properties (Seema *et al.*, 2020). Rice is the dominant crop in Karnataka, covering an area of 1.19 mha with an annual production of 3011 kg ha^{-1}.The study area three different command areas, viz., Tungabhadra (TCA), Bhadra (BCA) and Cauvery (CCA). The study area accounts for over 50% of rice cultivation in Karnataka and over 75% of the total rice produced in Karnataka (Anjum and Prakash, 2021).With the invention of GIS and global positioning system (GPS) changes in the fertility status of the soil can be monitored by revisiting the georeferenced maps. Keeping this in view, an attempt was made to develop a digital database of estimated soil properties and PASi for rice growing command areas viz., Tungabhadra, Bhadra and Cauveryusing GIS and GPS.

MATERIAL AND METHODS

The study area comprises 3 important rice-producing command area of Karnataka (viz., Tungabhadra, Bhadra and Cauvery) which accounts for over 50% of rice cultivated area and over 75% of the total rice production in Karnataka. The soil samples were collected from these command areas at the crop maturity stage between November and December, 2018. Soil and plant samples were collected based on the availability and area of rice growing ecosystems in each command area and simultaneously recorded the geographical location (latitude and

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longitude) and altitude for each sample using GPS (Global Positioning System).The collected soil samples were thoroughly mixed, shade dried, powdered and sieved through a 2.0 mm sieve and stored separately. The soil samples were analysed for pH (1: 2.5) and EC (1:2.5) (Jackson, 1973), organic carbon (Walkley and Black, 1934), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Bray and Kurtz, 1945 and Olsen *et al.*, 1954), and available potassium using flame photometry (Jackson, 1973). The plant available Si were extracted by 0.01 M $CaCl_2$ (Haysom and Chapman, 1975) and 0.5 M acetic acid (Narayanaswamy and Prakash, 2009) and estimated using a UV visible spectrophotometer. The base map of Karnataka was digitized and geo-referenced. Polygons were superimposed on the geo-referred map. Then latitude and longitude of the sampling location collected from the GPS were transformed into polygon data using the kriging interpolation technique in Arc GIS software 10.4 for making thematic soil fertility maps.

RESULTS AND DISCUSSION

Physico - chemical properties

The soil reactivity (pH) and electrical conductivity (1:2.5 water)in soils of three command areas are presented in Table 1.Soil pH ranged from 5.2- 8.7with a mean value of 7.00±1.3 (Table 1).Analysis of soil samples of three command areas of Karnataka revealed that 36% were acidic, 5% were neutral and 59% were alkaline in reaction. Soil samples of TCA recorded higher pH because of presence of medium to deep black clayey soil which is derived from the basaltic-pedisediment with the accumulation of bases and poor drainage (Basumatary *et al.*, 2021). Few samples of BCA recorded high pH of the soil which might be due to the use of basic fertilizers as well as poor drainage (Ranjita *et al.*, 2019). The sampling location of CCA falls under the southern dry zone. Jena and Natarajan (2013) reported that the soils of Cauvery command area are predominantly alkaline with pockets of acidic soils.

Table 1: Physicochemical properties of rice soils collected from different command areas of Karnataka

Command Area	Location	pH	EC (dS m^{-1})	OC (g kg^{-1})	CEC (cmol (p^+) kg^{-1})	Sand	Silt %	Clay
Tungabhadra	Range	6.1-8.7	0.2-0.5	2.2-8.7	5.2-24.0	38.2-76.0	7.04-43.3	5.2-37.8
	Mean	7.9±1.0	0.4±0.1	5.5±2.6	11.9±7.1	58.9±14.9	19.5±14.9	21.6±14.4
Bhadra	Range	5.2-8.5	0.1-0.5	5.9-16.7	4.14-26.5	20.4-74.2	8.8-59.7	1.9-40.0
	Mean	6.8±0.02	0.2±0.2	9.8±3.6	9.20±8.0	52.1±19.0	32.9±18.2	14.6±13.0
Cauvery	Range	5.9-8.7	0.1-0.5	11.3-17.5	3.6-26.5	46.9-76.7	8.7-31.9	0.60-24.7
	Mean	7.5±1.2	0.2±0.2	13.5±2.2	13.0±8.6	65.7±22.1	17.5±10.0	16.78±8.6
	CD ($p \leq 0.05$)	0.8	0.1	2.0	NS	NS	NS	NS
	CV (%)	15.0	50.0	28.0	70.5	34.6	56.7	54.9

The electrical conductivity (dSm^{-1}) of TCA, BCA and CCA ranged from 0.24-0.49, 0.05-0.40 and 0.06-0.46 dS m^{-1}, respectively with a mean of 0.39±0.12, 0.23±0.15 and0.24±0.15 dS m^{-1}, respectively (Table 1). Significantly higher EC was recorded in TCA, whereas, the soil of BCA and CCA were on par with each other. The EC values of all soil samples under the study were normal in the range which indicates non-saline nature. Soils were with low salt content because calcium and magnesium were the dominant cations rather than sodium and potassium (Pulakeshi *et al.*, 2014). The variation in soluble salts content in soilsamples may be credited to poor drainage and leaching variation of salts from soils due tohigh rainfall (Ranjitha *et al.*, 2019). The organic carbon (OC) content of the soil under study ranged from 2.2-17.5 g $kg^{-1}$with a mean value of 10.2±3.9 (Table 1). Analysis of soil samples of different command areas of Karnataka revealed that 13% were low, 17% were medium and 73% were high in OC status. In situ incorporation of crop residue by the combined harvesters into the field resulted in higher OC status of soil (Meunier *et al.*, 2018). Significantly, higher OC content was recorded in the soil samples of CCA followed by BCA. The status of OC was lowest in TCA. The variation in the OC status in the soil samples is due to the variation in the crop management on the fields. In CCA, the high OC status in the soil is due to crop rotation of rice with the maize and pulse crops (mung bean, cowpea) and application of green manure crops such as *sesbania aculateae*. The higher OC status of the soil samples in BCA was due to in situ incorporation of crop residue by the combined harvesters into the field (Meunier *et al.*, 2018; Ranjitha *et al.*, 2019). Half of the collected samples in TCA were low in OC, which was due to intensive cultivation (rice-rice cropping sequence), lack of incorporation of crop residues or organic manure application.

The CEC of soil samples collected from TCA ranged from 5.2-24.0 cmol $(p^+)kg^{-1}$ with a mean value of 11.9±7.1 cmol (p^+) kg^{-1}, whereas, BCA soils recorded aminimum and maximum of 4.1-26.5 cmol (p^+) kg^{-1} with the mean value of 9.2±8.0cmol (p^+) kg^{-1} (Table 1). CCA soil samples recorded the CEC values ranged from 3.6-26.5 cmol (p^+) kg^{-1} with a mean of 13.0±8.6 cmol (p^+) kg^{-1}. Irrespective of the command area, CEC ranged from 4.1-26.5 cmol (p^+) kg^{-1}. The result indicated that the soils with higher clay content recorded higher CEC. In general, higher CEC was recorded in the soils with higher clay content. Comparatively, low CEC was recorded in BCA which falls under the Southern Transition Zone (STZ), which is characterized by the soil with poor clay content. Tungabhadra and Cauvery command areas recorded comparatively higher CEC due to the presence of high silt and clay content. The results are consistent with Pallavi and Prakash (2019) and Majumdar and Prakash (2020).

Particle size analysis

The data (Table 1) revealed that the textural class of the soil samplecollected from the rice fields varied greatly from sandy to clay. The results revealed that sand, silt and clay content of the three-command area varied from 20.41-76.73, 7.04-59.66and 1.88-39.97%, respectively. The soil samples collected from TCA recorded38.16-75.95% sand, 7.04- 43.29% silt and 5.23-37.80% clay. The sand, silt and clay content of soil samples of BCA ranged from 20.41-74.23, 8.83-59.66 and 1.88-39.97% clay, respectively. The soil samples collected from CCA recorded 46.90-76.73% sand, 8.72-31.86% silt and 0.60-24.65% clay. In general, the soils of TCA and CCA were higher in clay content due to the presence of basaltic parent material and the presence of 2:1 smectite parent material. The soil samples collected from BCA were low in clay fraction due to *in situ* conditions of high rainfall, with alternate dry and wet periods. On account of heavy rainfall, there was excessive leaching of soil colloids andsilica and hence the soils are porous and sandy. Similar results were reported by Pallavi and Prakash (2019) and Majumdar and Prakash (2020).

Available primary nutrients

The available N content of surface soil samples of the command areas varied from 89.6-313.6 kg ha^{-1} with a mean 133.4 $kgha^{-1}$, available P ranged from 10.3-206.9P_2O_5 kg ha^{-1} and available K_2O content varied from 68.8-516.8 K_2O $kgha^{-1}$ (Table 1).The available nitrogen content was low in analysed soil samples of command areas *i.e.*, nitrogen content below 280 kg ha^{-1}, which might be due to low organic matter content in these soils (Patil *et al.*, 2018).A significant and positive correlation was observed between available nitrogen and organic carbon (r = 0.534**) confirms the N is closely associated with organic matter. Similar results were reported by Basumatary *et al.* (2021) and Sahoo *et al.* (2020). A large variation in the available N status in soil was noticed within as well as among command areas. According to Amara *et al.* (2016), such variation in N content may be related to soil management, application of FYM and fertilizer to previous crops. In addition, intensive rice cultivation leading to high crop removal together with insufficient replenishment might be the reason for the high degree of nitrogen deficiency in these soils. A significant and positive correlation was observed between available nitrogen and organic carbon (r = 0.534**) confirms the N is closely associated with organic matter. Similar results were reported by Patil *et al.* (2017).

Data (Table 2) showed that available P ranged from 10.4-207.0 P_2O_5 kg ha^{-1} and found to be in medium to high. The lower P in some locations can be attributed to the lower pH. This was evident form a positively significant correlation between available P with soil pH (r =

0.583**). Soil pH governs the availability of the phosphorus which was previously reported by Basumatary *et al.* (2021) and Maqbool et al (2018). Some of the low pH soil showed comparatively high P_2O_5 with other which can be attributed to the application of fertilizers (Phillip and Anil Kumar, 2021). Available K_2O content of surface soil samples was found to be medium to high (68.9-516.9 K_2O kg ha^{-1}) (Table 2). The available potassium was significantly and positively correlated to the pH (0.42*) that is higher pH soil having predominance of K rich micaceous and feldspar minerals are having higher K. The water soluble and exchangeable potassium has been the major contributor to available pool of potassium in soil. In addition to this, potassium contained in fertilizers might have resulted in higher exchangeable potassium in soils as reported by Patil *et al.* (2017).

Table 2: Fertility status of rice soils collected from different command areas of Karnataka

Command Area	Location	Available N Kg ha^{-1}	Available P Kg ha^{-1}	Available K Kg ha^{-1}	CCSi (mg kg^{-1})	AASi (mg kg^{-1})
Tungabhadra	Range	100.8-134.4	29.5-207.0	133.3-516.9	15.7-32.6	28.8-98.2
	Mean	119.5013.6	104.11±72.8	283.6±136.7	23.7±6.0	66.1±43.6
Bhadra	Range	112.2-156.8	14.2-192.4	70.0-428.4	17.7-46.5	19.2-151.3
	Mean	129.1±19.0	74.7±76.1	189.2±126.5	25.6±9.5	69.4±35.0
Cauvery	Range	100.8-313.7	19.6-142.4	68.9-491.7	18.4-65.4	32.1-106.7
	Mean	179.7±80.2	59.3±48.5	221.9±152.3	35.9±14.3	71.8±5.3
	CD($p \leq 0.05$)	NS	NS	NS	7.5	NS
	CV (%)	38.1	86.0	61.3	36.3	50.0

Plant Available Silicon (PASi)

Data presented in Table 2 indicates the dissolved silicon (CCSi) content of the soil samples of the different command areas of Karnataka. Out of total studied samples 27 % were low, 59 % were medium and only 14% of samples were high in PASi (CCSi and AASi). The CCSi content of Tungabhadra, Bhadra and Cauvery command area ranged from 15.7-32.6,17.7-46.5 and 18.4-65.4mg g^{-1}, respectively, with a mean of 23.7±5.9, 25.6±9.5and 35.9±14.3 mg g^{-1}, respectively. Significantly higher CCSi was recorded in CCA (Table 2), whereas, BCA and TCA were on par with each other. The lower value of the CCSi in this soil might be due to intensive cultivation, persistent ploughing and complete removal of biomass which reduces the CCSi content in the soil (Majumdar and Prakash, 2015). CCSi of CCA was higher due to crop rotation, green manuring, in-situ incorporation of rice residue as well as burning. This is consistent with the results recorded by Vandevenne *et al.* (2015).

Table 3: Correlation coefficient (r) among soil properties and available nutrients

	pH	EC	OC	CEC	Sand	Silt	Clay
Available N	0.437*	0.284	0.534*	0.417	0.153	-0.066	-0.119
Available P	0.582**	0.174	0.067	0.341	0.119	-0.217	0.112
Available K	0.416	0.679**	-0.048	0.109	-0.170	-0.079	0.319
CCSi	0.322	-0.099	0.299	0.296	0.068	-0.155	0.102
AASi	.677**	0.225	0.153	0.588**	-0.163	-0.064	0.292

**, ** significant at 0.05 and 0.01 probability level, respectively*

The AASi content in TCA varied from 28.8-to 98.2 with a mean of 66.1±43.6mg g^{-1}. In BCA, the AASi content varied from 19.19-151.25 mg g^{-1} with a mean69.4±35.0 mg g^{-1}. AASi content of CCA ranged from 32.13-106.69 mg g^{-1} with a mean71.8±5.3 mg g^{-1}, but there was no significant difference among the command area. AASi is a common method for estimating Si adsorbed on the mineral surfaces such as the Fe and Al oxides (Klotzbucher *et al.*, 2016). Empirically, higher AASi content was recorded in CCA (Table 5) followed by BCA. The lowest AASi content was recorded in the TCA. The larger variation in AASi within as well as among command areas was observed, which may be attributed to variation in climate, water management, crop residue management and agricultural intensification. Klotzbucher *et al.* (2016) reported that the capacity factor of soil *i.e*., the ability to replenish the Si and above-ground plant biomass and plant Si uptake during growth period differs between fields which might be the reason for the variation in AASi.

AASi showed significant positive correlation with the pH (0.677**), CEC (r=0.588**) and CCSi (r=0.541**) (Table 3). Whereas the CCSi noticed positive significant correlation only with the AASi (r=0.47**) and showed no significant correlation with the other soil physicochemical properties. Positive correlation between AASi and CCSi are inagreement with the previous studies (Meunier *et al.*, 2018) which showed that the two pools of the Si are dependent. The strong correlation between AASi and CCSi also indicates that, AASi act as an immediate source of CCSi (Pokrovski *et al.*, 2003). The positive correlation between PASi and CEC indicated that higher AASi will be observed in soils having higher CEC. The content of PASi pools is likely to be significantly influenced by the soil pH and control silica dissolution kinetics (Fraysse *et al.*,2006).

Present study showed that the soils of Tungabhadra, Bhadra and Cauvery command areas varied from acidic to alkaline and are non-saline. The OC content was in high to medium range. Available N content was low, available P and K content varied from medium to high. The PASi (CCSi and AASi) content was low to medium.

ACKNOWLEDGEMENTS

The first author acknowledges the Indian Council of Agricultural Research (ICAR), New Delhi, Government of India, for awarding her Senior Research Fellowship (SRF), for pursuing her doctoral degree programme.

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