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Soil quality of different rice-based cropping systems in a drought affected block of Odisha, India

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ABSTRACT

A work was undertaken to assess the soil quality of a drought affected block in Ganjam district of Odisha, India, namely Jagannathprasad, in five rice-based cropping systems viz. Rice-Rice (RR), Rice-Vegetable (RV), Rice-Pulse (RP), Rice-Oilseed (RO) and Rice-Fallow (RF). The results revealed that the soils were primarily red and black in color. On the basis of average value of various soil parameters analyzed, the trends observed for different rice-based cropping systems are: Moisture (%): RR (20.84%) > RV (16.77) > RP (15.10) > RO (14.60) > RF (14.01); pH: RF (6.34) > RF (6.29) > R0 (5.79) > RV (5.74) > RR (5.29); **EC** (mS/cm): RR (1.75) > RP (1.50) > RV (1.48) > RO (1.19) > RF (0.81); **OC (%):** RP (0.58) = RO (0.58) > RV (0.51) > RR (0.40) > RF (0.23); N (kg/ha): RP (363) > RO (279) > RR (230) > RV (175) > RF (126); P (kg/ha): RP (25.7) > RO (17.4) > RV (12.3) > RR (8.0) > RF (4.3); K (kg/ha): RP (185) > RO (138.8) > RR (102.8) > RV (68.2) > RF (36.1). The variation in soil parameters were in between the low and medium category according to the standard set by Tandan (1993). Further, from among the rice-based cropping systems, that RP and RO based crop rotation systems seems to be suitable option for cultivation in the drought affected block of Jagannathprasad. Therefore, such crop rotations should be carried out as a part of management practices, not only to restore the fertility of soil, but also to improve the socio-economic condition of farmers in these drought prone areas.

Key words: *Soil quality, Rice- based cropping system, Crop rotation, Drought affected areas*

Introduction

Natural calamities like drought can greatly affect the structure, function and productivity of agro-ecosystems and in consequence food security of that region. Losses caused by drought are generally measured by social and economic indicators like poverty, malnutrition, crop damage and yield, and nevertheless on sustainability of soil agroecosystems (Liu *et al.,* 2010).

Intercropping and crop rotation are considered as good practices so far agriculture is concerned. Rice is a major cereal crop in India as well as Odisha State. It is cultivated in 22% of the gross cropped area of India and 47% of the gross cropped area of Odisha (Jaiswal and Wadhwahi, 1984). Drought is of frequent occurrence in most parts of the country and during last few decades its severity has been increased by many folds (Gautam and Bana, 2014). Continuous cultivation of rice for longer periods of time not only lower the soil fertility and crop yield but also enhances the risk factor to both natural and manmade factors. Hence, selection of suitable crops on intercropping and /or crop rotation basis is likely to enhance efficient utilization of resource base and overall productivity against all odds (Anderson, 2005).

Based on the above facts, a work was under taken to assess the soil quality in different rice-based cropping systems of a drought affected block, i.e., Jagannathprasad block, in Ganjam district of Odisha, India and endorse the suitable rice-based crop rotation for the drought prone areas. The rice-based cropping systems chosen in the present study are as follows: Rice-Rice (RR), Rice-Vegetable (RV), Rice-Pulse (RP), Rice-Oilseed (RO) and Rice-Fallow (RF).

Materials and Methods

Description of study area

Jagannathprasad is a block situated in the Ganjam district of Odisha, India (Fig. 1). It lies between $19^{0}55'$ and $19^{0}99'$ of the Northern Latitude and $84^{0}44'$ to $84^{0}77'$ of Eastern Longitude. The geographical area of the block is 379 sq. kms. This block has 24 panchayats and 290 villages. Climate of this area varies from subtropical, hot and humid to hot, moist and sub-humid. Based on quantity, the rainfall ranges from very light rain (0.1 - 2.4 mm) to very heavy rain (> 124.5 mm) (Table 1). A total rainfall of 1276.2 mm per annum is considered as normal rainfall. From the rainfall data of last 3 years, it is evident that the area is suffering from moderate drought (Table 2). The temperature of the area reaches more than 40 ^{o}C during summer season while in winter it is as low as 5 ^{o}C. The soils of this block are mostly is alluvial, black laterite and red. The texture is sandy to sandy loam or clay to clayey loam.

Sampling and Processing of Soil

Soil samples (0 – 15 cm) using a standard core sampler, were drawn from five different rice-based cropping systems (viz. Rice- Rice (RR), Rice-Vegetable (RV), Rice-Pulses (RP), Rice-Oilseed (RO) and Rice-Fallow (RF)) from different village sites in Jagannathprasad block of Ganjam district. Twenty soil samples were collected from each rice-based cropping system in polythene bags and thereafter kept in ice container and quickly transported to the laboratory. The soil samples were air dried and

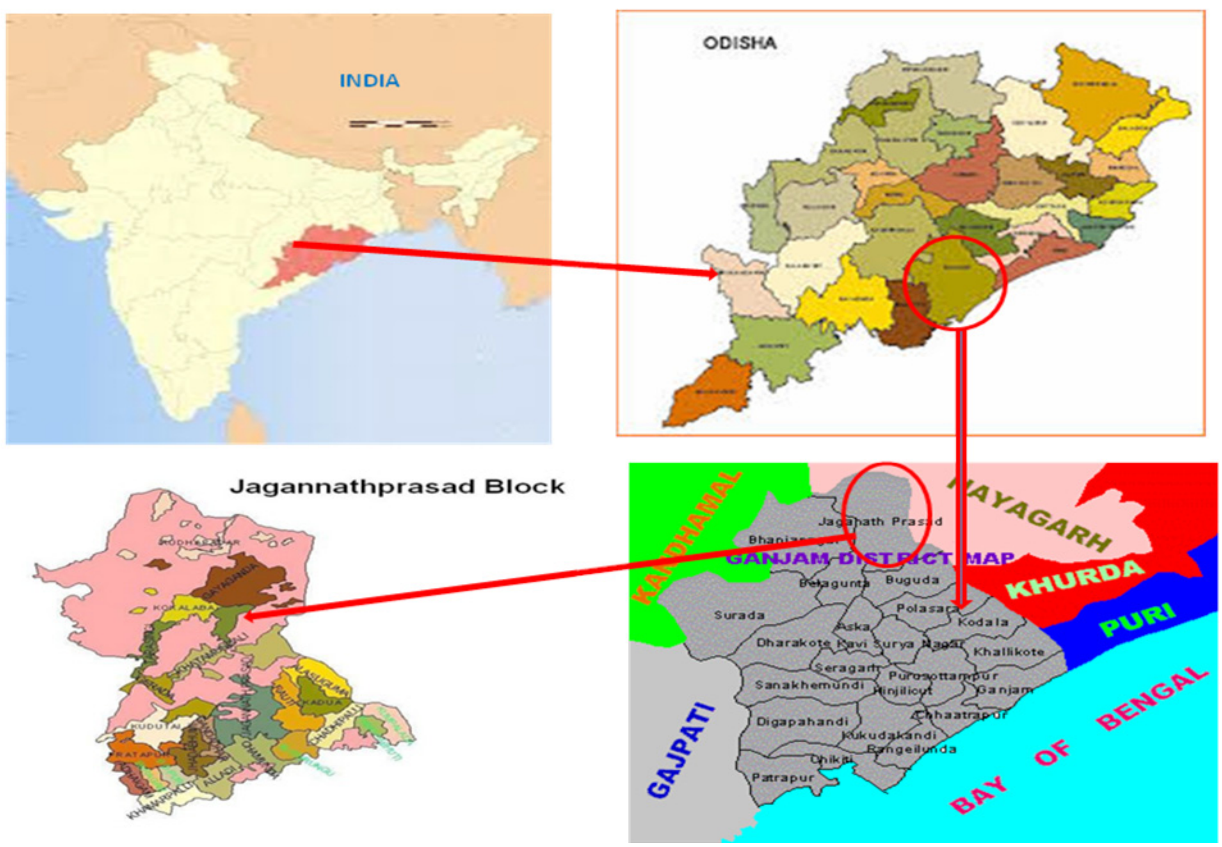

Fig. 1. Map of India (Inset Odisha state, Ganjam district and Jagannathprasad block)

sieved through a 2 mm sieve. The air dried, sieved samples were then used for physicochemical analysis as per the standard methods prescribed in IS: 2720.

Physicochemical Analysis of Soil

The color of the soil was judged after cross matching with Munshell color chart while the moisture content was measured gravimetrically by taking the fresh and oven dried weights of the soil samples and expressed in %. Similarly, the pH and electrical conductivity (EC in mS/cm) were measured electronically by dissolving the soil in double distilled water in the ratio 1 : 5 (w/v). The organic carbon and organic matter (%) contents were determined titrimetrically by oxidizing the soil in a strong oxidant and titrating against ferrous ammonium sulphate using diphenyl ammine indicator (Walkley and Black, 1934). The available nitrogen (kg/ha) was estimated by subjecting the soil extract to distillation process in Kjeldhal tube using magnesium oxide, Deverds alloys and NaOH solution and titrating the distillate against HCl. The available phosphorus (kg/ha) was determined spectrophotometrically at 660 nm after the development of color following the addition of chloro-molybdate and stannous chloride. Available potassium (kg/ha) on the other hand was determined with the help of a flame photometer following ammonium extraction method (Jackson, 1973).

Results

Soils are typically described on the basis of soil horizon, texture and color of the soil. Soils provide readily available nutrients to plants by converting dead organic matter into various nutrients through decomposition and mineralization. The color of soils in various rice-based cropping systems of different villages in Jagannathprasad block, as revealed from Munshell soil chart, are of Yellow, Red or Brown or black category with prevalence (> 70%) of red and black color.

Table 3 shows the physicochemical parameters of soil in various rice-based cropping systems at different sites. It is evident from the table that the moisture content varied from 15.38 - 25.26, 15.11 – 21.12, 14.11 – 16.14, 13.15 – 15.80 and 13.11 – 16.20 % in RR, RV, RP, RO and RF cropping systems, respectively. The pH and EC were in the range of 5.0 - 5.5 and 1.5 to 1.9 mS/cm in RR, 5.4 – 6.0 and 1.3 – 1.6 mS/cm in RV, 6.0 – 6.5 and 1.3 – 1.6 mS/cm in RP, 5.5 – 6.0 and 1.0 – 1.3 mS/cm in RO and 6.0 – 6.5 and 0.6 – 1.0 mS/cm in RF cropping systems, respectively. The OC and OM fluctuated respectively from 0.27 – 1.01 and 0.46 – 1.74 % in RR, 0.41 – 0.98 and 0.70 – 1.68 % in RV, 0.12 – 1.42 and 0.20 – 2.44 % in RP, 0.55– 0.62 and 0.94 – 1.06 % in RO and 0.11 – 0.20 and 0.18 – 1.31 % in RF cropping systems. The available Nitrogen (N), Phosphorus (P) and Potassium (K) contents ranged from 210 – 250, 6 – 10 and 80 – 118 kg/ha in RR , 150 – 200, 10 – 14 and 53 – 80 kg/ha in RV, 310 – 400, 20 – 30 and 160 – 210 kg/ha in RP , 250 – 300, 14 - 20 and 118 – 160 kg/ha in RO and 90 - 150, 2 – 6 and 22 – 50 kg/ha in RF cropping systems respectively.

On the basis of average value of various soil parameters analyzed, the following trends are observed for different rice-based cropping systems:

Table 1. Classification of rain fall (mm)

No Rain	Very Light Rain	Light Rain	Moderate Rain	Rather Heavy Rain	Heavy Rain	Very Heavy Rain
0	0.1 - 2.4	2.5 - 7.5	7.6 - 34.4	34.5 - 64.4	64.5 - 124.4	> 124.5

Source: Odisha Rainfall Monitoring System

Table 2. Rainfall data of Ganjam District during 2015-2018.

Year	Normal Rainfall (mm)	Actual Rainfall (mm)	Deviation (%)	Remark
2018 (June)	168.3	101.28	39.82	Moderate Drought
2017 (June-Sept.)	852.5	653.89	23.3	Moderate Drought
2016 (June-Sept.)	852.5	672.2	21.14	Moderate Drought
2015 (June-Sept.)	852.5	690.5	19.00	Normal

Source: Odisha Rainfall Monitoring System

Table 3. Physicochemical parameters of soil in various rice-based cropping systems of Jagannathprasad block

Parameter	RR		RV		RP		RO		RF	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Moisture (%)	15.38 – 25.26	20.84±3.21	15.11 – 21.12	16.77±1.78	14.11 – 16.14	15.10±0.65	13.15 – 15.80	14.60±0.77	13.11 – 16.20	14.01±0.93
pH	5.0 – 5.5	5.29±0.106	5.4 – 6.0	5.74±0.18	6.0 – 6.5	6.29 ±0.15	5.5 – 6.0	5.79±0.16	6.0 – 6.5	6.34±0.12
EC (mS/cm)	1.5 – 1.9	1.75±0.12	1.3 – 1.6	1.48±0.10	1.3 – 1.6	1.5±0.08	1.0 – 1.3	1.19±0.09	0.6 – 1.0	0.81 ±0.11
OC (%)	0.27 – 1.01	0.40±0.20	0.41 – 0.98	0.51±0.15	0.12 – 1.42	0.58±0.35	0.55 – 0.62	0.58±0.02	0.11 – 0.20	0.23 ±0.18
OM (%)	0.46 – 1.74	0.70±0.35	0.70 – 1.68	0.88±0.86	0.20 – 2.44	1.08±0.70	0.94 – 1.06	1.04±0.73	0.18 – 1.31	0.39 ±0.31
Avl. N (kg/ha)	210 – 250	230±12.65	150 – 200	175±12.65	310 – 400	363±29.52	250 – 300	279±15.52	90 - 150	126 ±15.58
Avl. P (kg/ha)	6 – 10	8±1.38	10 – 14	12.3±1.37	20 – 30	25.7±3.22	14 – 20	17.4±1.71	2 – 6	4.3 ± 1.02
Avl. K (kg/ha)	80 – 118	102.8±10.99	53 – 80	68.2±8.50	160 – 210	185±11.83	118 – 160	138.8±12.67	22 – 50	36.1 ± 8.23

RR (Rice-Rice), RV (Rice-Vegetable), RP (Rice-Pulse), RO (Rice-Oilseed), RF (Rice-Fallow)

Moisture (%): RR (20.84%) > RV (16.77) > RP (15.10) > RO (14.60) > RF (14.01)

pH: RF (6.34) > RF (6.29) > R0 (5.79) > RV (5.74) > RR (5.29)

EC (mS/cm): RR (1.75) > RP (1.50) > RV (1.48) > RO (1.19) > RF (0.81)

OC (%): RP (0.58) = RO (0.58) > RV (0.51) > RR (0.40) > RF (0.23)

N (kg/ha): RP (363) > RO (279) > RR (230) > RV (175) > RF (126)

P (kg/ha): RP (25.7) > RO (17.4) > RV (12.3) > RR (8.0) > RF (4.3)

K (kg/ha): RP (185) > RO (138.8) > RR (102.8) > RV (68.2) > RF (36.1)

Table 4 gives the two-way ANOVA for the soil parameters in different rice-based cropping systems of Jagannathprasad block. It is evident from the table that, while the organic carbon, organic matter, available nitrogen (N) and phosphorus (P) contents in the soil showed a significant variation both with respect to sites and cropping systems ($F_1 \geq 2.32$, $F_2 \geq 6.22$; $p < 0.05$); the soil moisture, soil pH, electrical conductivity and the available potassium (K) contents exhibited a significant variation with respect to cropping systems only ($F_2 \geq 26.21$; $p < 0.05$).

Discussion

Soil color has very often been considered as a guiding parameter to provide first-hand knowledge on the fertility status of soil. Grey to black colored lateritic soils is mostly preferred by the farmers for cultivation (Barrera-Bassols and Zinck, 2003). The soil moisture, pH and electrical conductivity are such parameters of soil, on which most of the biological and physicochemical activities of soil rely upon. Since, soil micro-flora and fauna execute up to their optimum capacity within a pH range and are influenced by the moisture content; the fertility status of soil is directly governed by decomposition of the existing organic matter sourced from biological origin (Sahu *et al.*, 2016a). An extreme acidic pH minimizes the soil organismal activity and as well as plant growth, whereas mild acidic pH reverses the situation (Sharma, 2015). In the present work, although RR cropping system had highest moisture content (standing water of 3-5 cm maintained throughout the cropping period), but pH was highly acidic (5.29). This might be due to reduced (anoxic) condition prevailed there in. Electrical conductivity is a measure of the ionic content of soil and difference in EC of various cropping systems might have been due to the differential applica-

Table 4. Two –way analysis of variance of soil parameters among various sites and rice-based cropping systems of Jagannathprasad block

Parameter	Source of Variation	SS	df	MS	$F_{cal\ at\ 0.05}$	$F_{tab\ at\ 0.05}$	S/NS
Moisture	Sites	33.75	9	3.75	1.29	2.15	NS
	Cropping Systems	304.81	4	76.20	26.21	2.63	S
pH	Sites	0.23	9	0.026	0.79	2.15	NS
	Cropping Systems	7.55	4	1.888	57.49	2.63	S
EC	Sites	0.13	9	0.015	1.18	2.15	NS
	Cropping Systems	5.17	4	1.291	104.04	2.63	S
OC	Sites	0.93	9	0.104	2.84	2.15	S
	Cropping Systems	0.91	4	0.227	6.22	2.63	S
OM	Sites	2.77	9	0.31	2.84	2.15	S
	Cropping Systems	2.70	4	0.68	6.22	2.63	S
Avl. N	Sites	8100.5	9	900.06	3.04	2.15	S
	Cropping Systems	337658	4	84414.50	285.02	2.63	S
Avl. P	Sites	79.62	9	8.85	2.32	2.15	S
	Cropping Systems	2803.72	4	700.93	184.08	2.63	S
Avl. K	Sites	2161.0	9	240.11	1.68	2.15	NS
	Cropping Systems	136417.7	4	34104.42	239.20	2.63	S

Table 5. A classification of agricultural soils according to Tandan (1993)

	LOW	MEDIUM	HIGH
pH	<6.5 (Acidic)	6.5 to 7.5 (Normal)	>7.5 (Alkaline)
EC (mS/cm)	<1 (Normal)	1 to 2 (Toxic)	>2 (Toxic)
OC (%)	<0.5	0.5 to 0.7	>0.75
N (kg/ha)	<250	250 to 500	>500
P (kg/ha)	<14	14 to 40	>40
K (kg/ha)	<118	118 to 280	>280

tion of fertilizers, mineralization of organic matter and salt content (Geetha *et al.*, 2017).

Organic matter is the primary raw material that supports the fertility of soil (Sahu *et al.*, 2016b) and is an index of metabolic activities in soil. The cultivated soil receives this organic matter mainly through the crop residues, animal manure, green manure, crop covers and sometimes organic fertilizers (Christ and David, 1996). The RF cropping system, in our observation, was with lowest OM content, which demonstrates that the fallow land received little or no organic matter. Whereas the other cropping systems underwent periodical turnover of the organic matter in them and resulted in higher contents of organic matter (Mohanty *et al.*, 2017). The mineralization of organic matter is the chief factor responsible for the availability of nitrogen and phosphorus to plants (Chen *et al.*, 2014; Hafsi *et al.*, 2014). Therefore, the lowest values of nitrogen, phosphorus and potassium content of soils in RF cropping system in comparison to other rice-based cropping systems further corroborates the presence of low organic matter in RF soil.

Table 6. Trend of various parameters and classification of soils of various rice-based cropping systems as per Tandan (1993)

Parameter	Classification of soils as per Tandan (1993)
pH	RF (6.34) > RP (6.29) > R0 (5.79) > RV (5.74) > RR (5.29)**Low**
EC(ms/cm)	RR (1.75) > RP (1.50) > RV (1.48) > RO (1.19) > RF (0.81)
	Medium **Low**
OC(%)	RP (0.58) = RO (0.58) > RV (0.51) > RR (0.40) > RF (0.23)
	Medium **Low**
N(kg/ha)	RP (363) > RO (279) > RR (230) > RV (175) > RF (126)
	Medium **Low**
P(kg/ha)	RP(25.7) > RO (17.4) > RV(12.3) > RR (8.0) > RF (4.3)
	Medium **Low**
K(kg/ha)	RP(185) > RO(138.8) > RR (102.8) > RV (68.2) > RF (36.1)
	Medium **Low**

RR (Rice-Rice), RV (Rice-Vegetable), RP (Rice-Pulse), RO (Rice-Oilseed), RF (Rice-Fallow)

A classification of agricultural soils according to Tandan (1993) is presented in Table 5. Further, the trend of various parameters and classification of soils of various rice-based cropping systems as per Tandan (1993) is also presented in Table 6. From the table, it is evident that all the soils were under low to medium category. However, the Rice-Pulse (RP) cropping system showed a relatively highest value in four out of six parameters (OC, 0.58 %; Available N, 363 kg/ha; available P, 25.7 kg/ha and available K, 185 kg/ha), followed by Rice – Oilseed (RO) cropping system (OC, 0.58%; available N, 279 kg/ha; available P, 17.4 kg/ha and available K, 138.8 kg/ha). Whereas, the Rice-Fallow (RF) cropping system showed relatively lowest value in five out of six parameters (EC, 0.81 mS/cm; OC, 0.23 %; available N, 126 kg/ha; available P, 4.3 kg/ha and available K, 36.1 kg/ha) under the defined category. This justifies that RP and RO based crop rotation systems seems to be suitable option for cultivation in the drought affected block of Jagannathprasad.

Conclusion

The study was undertaken to assess the soil quality of different rice-based cropping system of a drought affected block (Jagannathprasad) in Ganjam district of Odisha, India and endorse the suitable rice-based crop rotation for the drought prone areas. Our investigation revealed that (i) as the rice-based cropping system is altered; the soil quality of the system is also significantly affected and (ii) RP and RO based crop rotation systems seems to be appropriate choice for cultivation in the drought affected block of Jagannathprasad. Hence, such crop rotations should be carried out as a part of management practices, not only to restore the fertility of soil, but also to improve the socio-economic condition of farmers in these drought prone areas.

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