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The Study of Soil Physical Properties of the Rice-dominated Cropping Area of Tangi Choudwar

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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

Wetland rice agriculture includes puddling practices, which facilitate transplanting and weed control easier and lowers water and nutrient loss through percolation. However, in addition to these benefits, the puddling alters the soil's physical properties, which is harmful to subsequent rice crops.100 gridded soil sample was collected from 24 panchayats of Tangi Choudwar. In this study, soil physical properties like texture, water holding capacity (WHC), and bulk density (BD) were measured in twenty-four panchayats in Tangi Choudwar, Odisha. It was recorded that BD varied from 1.32 to 1.63 Mg/m^3 and the WHC of soil varied from 36.70 to 64.70%. The proportion of sand, silt, and clay varied from 35 to 84%, 6 to 34%, and 12 to 38%, respectively. From the correlation study, WHC showed a positive correlation with clay content and a negative correlation with sand

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content, whereas BD showed negative correlation with the clay content (r=-0.261, P=0.01) and positive with sand content (r=0.167, P=0.05). The findings of this study may provide guidance for effective cultivation management techniques and assist in enhancing crop productivity and soil quality.

Keywords: Rice; soil texture; bulk density; water holding capacity.

1. INTRODUCTION

In India, rice is cultivated on 43.86 million hectares, producing 104.80 million tonnes with average productivity of roughly 2390 kg/ha [1]. It is raised in several types of soil and climatic situations. Rice (*Oryza sativa*) cultivation regularly uses puddling, or tillage in saturated soil conditions. The soil's physical characteristics changed as a result of puddling. Puddling caused changes in pore size distribution by causing the formation of hardpans at shallow depths and the breakdown of soil aggregates. It also increased bulk density (BD), decreased hydraulic conductivity, and decreased the cone index. The cone index increased during the subsidence stage of the puddled soil [2]. In order to decrease deep percolation water losses, puddling tries to decrease the proportion of water-transmitting macrospores while increasing the number of water-retaining microspores [3]. Thus, puddling allows the soil to retain any standing water in the field, which may also result in a reduction in the quantity and frequency of irrigation [4]. Continuous flooding is used to produce rice, but it may also affect the soil's physical characteristics through other processes, such as the shearing action of tillage tools during puddling and the impact of the field moisture regime on soil structure during the growing season.

The physical characteristics of soil are a key factor in evaluating its viability for engineering, environmental, and agricultural applications. The physical characteristics of the soil directly affect its capacity for support, movement, retention, and availability of water and nutrients to plants, the ease with which roots can penetrate the soil, and passage of heat and air [5]. Chemical and biological qualities are also influenced by physical properties. Generalizations like "a loam soil having intermediate bulk density, good aggregation, a good infiltration rate, and no impedance to drainage represent a soil with good physical conditions, and good production could be expected on such soil if chemical factors were not limiting" could be used to deter the majority of inquiries [5]. In regularly rice-cultivated areas, changes in soil physical qualities are a complicated process that is impacted not only by the soil's initial characteristics and crop growth but also by farmers' production and management procedures. The relationship between the main paddy soil groups and their physical characteristics is discussed in this research with the goal of enhancing those characteristics.

2. MATERIALS AND METHODS

Tangi Choudwar's coordinates are 20° 29' N to 20° 38' N' latitudes and 85° 81' E to 86° 04' E' longitudes. The average annual rainfall is 1400 mm. This block has 24 panchayats, and 55.7% of the population is directly and indirectly dependent on farming. Rice green gram cropping systems predominate in this region.

An extensive grid-based soil sampling was done to gather soil samples from the study area. 100 soil sample were collected. Using a screw-type sampling auger, soil samples were taken from the top 15 cm of the soil based on coordinates on GPS and placed in plastic zip-top bags. After being air dried, soil samples were put through a 2-mm sieve. The soil texture was determined by the hydrometer method [6], the water holding capacity (WHC) by gravimetric method [7]. The bulk density of the soil in situ was determined by the core method [8]. The descriptive statistical analysis of these soli physical properties were analyses using “agricolae packages” and pearson correlation matrix among these physical properties were calculated using “corrr package” in R studio.

3. RESULTS AND DISCUSSION

3.1 Soil Particle Distribution in Rice Paddies

Measured variables in the data set were analyzed to obtain the minimum, maximum, mean, and standard deviation (SD). The summaries of the descriptive statistics of the proportions of sand, silt, and clay percentages in twenty-four panchayat rice paddies were

Table 1. Descriptive statistics of soil particles distribution in rice paddies

Panchayat of Tangi Choudwar	Sand (%)				Silt (%)				Clay (%)			
	Max.	Min.	Avg.	SD	Max.	Min.	Avg.	SD	Max.	Min.	Avg.	SD
Kakhadi	76	70	72.4	2.94	18	6	10.0	4.38	20	12	17.6	2.94
Kayalpada	77	58	69.0	6.73	21	6	13.8	6.01	22	12	17.2	3.29
Indranipatna	66	58	61.5	2.81	26	16	20.3	2.92	22	11	18.2	3.67
Banipada	70	62	64.7	3.77	20	18	19.3	0.94	18	12	16.0	2.83
Agrahat	70	50	62.0	6.80	20	16	18.7	1.33	32	12	19.3	6.25
Sankarpur	70	50	65.3	7.69	18	14	16.8	1.81	32	12	17.6	7.27
Badasamantarapur	70	56	63.2	5.96	24	14	19.7	3.14	22	11	17.0	4.55
Mangarajpur	70	61	66.4	4.41	23	14	18.4	4.03	16	12	14.8	1.47
Berhampur	61	46	53.8	4.87	24	18	21.0	2.19	36	16	25.2	6.85
Garudagaon	76	46	58.4	10.9	24	14	19.4	2.29	37	12	23.8	9.23
Safa	76	46	56.7	12.4	22	16	18.6	1.76	37	12	26.1	11.7
Kanheipur	76	46	55.2	10.0	21	12	16.8	3.10	36	14	28.9	7.51
Uchapada	76	46	57.3	10.8	21	4	16.5	4.84	36	14	26.9	9.11
Govindapur	76	46	57.3	10.8	21	4	16.5	4.84	36	14	26.9	9.11
Jaripada	65	44	54.0	5.31	22	12	3.63	3.77	36	16	5.89	6.53
Kotasahi	58	35	48.3	8.11	34	14	22.3	6.75	38	15	29.3	6.45
Salagaon	66	35	50.1	11.2	34	14	23.9	7.39	34	12	26.1	7.66
Nakhara	63	35	45.6	7.80	34	22	25.3	4.68	34	13	30.6	7.25
Harianta	61	35	46.9	8.63	34	16	29.1	4.67	34	14	29.1	7.13
Napanga	84	35	50.9	13.2	34	4	25.7	8.71	34	12	28.3	8.12
Bhatimunda	81	37	54.6	16.5	29	7	23.8	8.45	34	12	21.6	10.1
Magura dhanamandal	70	39	57.2	11.3	29	16	22.5	5.59	32	12	20.2	7.95

Note Max: maximum; Min: minimum; Avg: average; SD: Standard deviation

Table 2. Descriptive statistics of bulk density and water holding capacity

Panchayat of Tangi Choudwar	Bulk density (Mg /m^3)				Water holding capacity (%)			
	Max.	**Min.**	**Avg.**	**SD**	**Max.**	**Min.**	**Avg.**	**SD**
Kakhadi	1.51	1.45	1.49	0.02	44.03	41.63	42.71	0.82
Kayalpada	1.61	1.47	1.56	0.05	56.45	41.51	46.05	5.18
Indranipatna	1.64	1.53	1.56	0.04	55.46	46.30	49.71	3.14
Banipada	1.51	1.45	1.48	0.02	46.75	41.23	44.40	2.33
Agrahat	1.62	1.58	1.59	0.01	57.52	41.40	50.12	5.63
Sankarpur	1.51	1.49	1.50	0.01	58.45	42.22	47.10	6.62
Badasamantarapur	1.62	1.52	1.58	0.04	57.39	42.22	50.22	6.10
Mangarajpur	1.62	1.52	1.58	0.04	48.70	41.22	45.79	3.03
Berhampur	1.62	1.48	1.52	0.05	59.40	48.95	56.15	3.73
Garudagaon	1.56	1.32	1.49	0.07	60.60	42.22	53.81	6.05
Safa	1.48	1.32	1.43	0.07	60.60	42.40	55.87	5.65
Kanheipur	1.5	1.32	1.38	0.08	58.60	41.80	53.85	4.75
Uchapada	1.56	1.41	1.48	0.05	60.60	41.60	51.42	7.15
Govindapur	1.56	1.41	1.48	0.05	60.60	41.60	51.42	7.15
Jaripada	1.49	1.38	1.44	0.04	60.67	38.80	2.95	4.85
Kotasahi	1.48	1.37	1.43	0.03	64.40	44.60	57.84	5.68
Salagaon	1.63	1.43	1.55	0.06	64.40	42.40	55.40	7.08
Nakhara	1.61	1.58	1.60	0.01	62.40	42.40	58.46	6.61
Harianta	1.6	1.43	1.47	0.06	65.20	42.40	57.32	7.08
Napanga	1.47	1.42	1.44	0.01	64.70	46.40	59.12	6.15
Bhatimunda	1.46	1.43	1.44	0.01	64.60	36.70	49.59	11.56
Magura Dhanamandal	1.61	1.44	1.54	0.07	52.15	44.60	47.67	2.82

Note Max: maximum; Min: minimum; Avg: average; SD: Standard deviation

Table 3. Correlation between soil physical properties

	WHC (%)	Clay (%)	Silt (%)	Sand (%)	BD (Mg/m^3)
WHC (%)	1				
Clay (%)	0.777*	1			
Silt (%)	0.508*	0.316*	1		
Sand (%)	-0.825*	-0.861**	-0.694**	1	
BD (Mg/m^3)	-0.169*	-0.261**	-0.021	0.167*	1

n= Number of soil sample 100.
*** Correlation is significant at the 0.01 level (2-tailed)*
** Correlation is significant at the 0.05 level (2-tailed)*

presented in Table 1. The sand percentage varied from 35 to 84%, the silt percentage from 4 to 34%, and the clay percentage from 12 to 18%, respectively, among the panchayats of Tangi Choudwar. Kakhadi panchayat had the highest average sand percentage, followed by Kayalpada, and Kotasahi panchayat had the lowest. The silt percentage was highest in Harianta panchayat, followed by Napanga, and lowest in Badasamantarapur panchayat. The clay percentage was highest at Nakhara, followed by Kanheipur, and lowest in Jaripada. Although sandy clay loam, sandy loam, loamy sand, clay loam soil textural classes present in these panchayats, but sandy clay loam soil textural classes predominated in these areas. In general, soil texture is a fixed characteristic and cannot be changed unless a significant volume of these components is added or subtracted [9]. The results of this study confirmed that the different farming practices did not change the soil texture However, soil aggregates bearing on other soil properties may be highly affected by the farming practices [9]. In rice paddies, an intensive tillage system followed by puddling operations breaks the soil aggregates and peds into fine plastic mud. Fine-textured soils, which have a high proportion of expanding clay minerals, disperse rapidly after submergence, even without wet tillage. Puddling produces fewer changes in their physical qualities on its own [10]. Coarse-textured soils are very permeable and have a single-grain, loose structure with little soil agglomeration [10].

3.2 Bulk Density and Water Holding Capacity in Rice Paddies

The bulk density of rice paddies in different panchayats of the Tangi Choudwar block varied from 1.32 to 1.64 Mg/m^3. The average maximum bulk density was recorded in Nakhara followed by Badasamantarapur and Mangarajpur and the lowest in Kanheipur. The water-holding capacity of rice paddies in Tangi Choudwar block panchayats ranged from 36.7 to 65.2%. The average maximum water holding capacities were recorded in Napanga, followed by Nakhara and Kotasahi, and the lowest in Kakhadi. This may be due to in these area proportion of clay content was more compared to sand content which increases total number of micro pores of soil that lower BD and increases WHC. Bulk density was higher throughout the 0–30 cm profile under rice-wheat than under maize-wheat in silt loam, silty clay loam, and silty clay soils [11]. Bulk density increased by 2 to 6% and a decrease in porosity of 8 to 9% under the rice monoculture system [12].

3.3 Correlation between Soil Physical Properties in Rice Paddies

Pearson correlations among the soil properties were presented in Table 3. There were strong positive correlations between soil clay content and water holding capacity (r = 0.777, P = 0.05), whereas soil sand content showed a negative correlation with clay, silt content, and water holding capacity (r = -0.861, -0.694, and -0.825, respectively, P = 0.05). Correlation analysis indicated that with increased in clay content, water WHC increased and BD decreased and vice versa in case of proportion of sand dominated soil. This is because the fine textured soils tend to organize in porous grains especially because of adequate organic matter content. This results in high pore space and low bulk density. However, in sandy soils, organic matter content is generally low, the solid particles lie close together and the bulk density is commonly higher than in fine textured soils. Soil bulk density correlated positively with soil sand content (r = 0.167, P = 0.05). Bulk density showed a negative correlation with the clay content [13]. A similar correlation ship (r) between clay content (Clay), average slake aggregate (ASA), wet aggregate stability index (WASI), bulk density (BD), and intact core available water holding capacity (IAWHC) was reported [14].

4. CONCLUSIONS

Soil physical properties varied in their relationships to soil parent material and the management practices followed for crop production. Proportions of sand, silt, and clay, bulk density, and water holding were associated with most soil physical, chemical, biological, and biochemical properties. As soil texture is an important parameter that enhances water infiltration, carbon sequestration, microbial activity, and root growth while decreasing soil erosion, it was recorded that BD varied from 1.32 to 1.63 Mg/m^3. and the water-holding capacity of soil varied from 36.70 to 64.70%. The proportion of sand, silt, and clay in different panchayats of Tangi Choudwar varied from 35 to 84%, 6 to 34%, and 12 to 38%, respectively. From the correlation study, WHC showed a positive correlation with clay content and a negative correlation with sand content, whereas BD showed the opposite. These findings will help farmers and stockholders make suitable decisions for crop production and maintain soil health.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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