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Research Article

SOIL PHYSICAL AND HYDROLOGICAL PROPERTIES OF DIFFERENT LAND FORMS AND CROPPING SYSTEMS OF AGRICULTURAL COLLEGE FARM, NAIRA, ANDHRA PRADESH

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Abstract: Assessment of soil physical quality is essential for addressing issues of agro-ecosystem and optimizing soil productivity for sustainable land use. The Agricultural college farm, Naira has three different land forms *viz*., low lands, upland irrigated and upland rainfed. The different cropping systems followed are, Rice- rice, Rice- pulse, Rice-maize in upland irrigated system, Mesta- pulse, Mango, Sapota, Cashew, Coconut and Guava in upland rainfed system while in Low lands Rice- fallow system was followed. In each cropping system the soil physical investigations were made in three places and the mean values were interpreted. The results of the study revealed that soil depth was deep in low lands, moderate too deep in uplands. Soil texture was sandy clay to clay in lowlands, sandy clay loam in upland irrigated systems and sandy loam in upland rainfed systems. Clay content was relatively more in subsurface while sand content was relatively more in surface soil. In general surface soil recorded relatively low dry bulk density values (g/cm^3) compared to subsurface and the values ranged from 1.46 to 1.63 g/cm^3 in upland cropping systems and 1.44 to 1.53 in low land cropping system. The mean soil organic carbon content ranged from low to medium (2.57 to 7.31 g/kg soil). In general, higher soil organic carbon (SOC) was registered in surface soil and lower SOC in subsurface soil. Orchard cropping systems recorded higher SOC than agricultural systems. Coefficient of linear extensibility (COLE) was high in lowland rice- fallow system (0.094- 0.128) and low in upland irrigated systems (0.011- 0.021) and negligible in upland rainfed orchard system. Highest final infiltration rate of 23.5 mm/hr was recorded in the surface of coconut orchard and lowest of 5.7 mm/hr was in subsurface of low land rice- fallow system. The surface soil infiltration rates were relatively higher than subsurface soil. Saturated hydraulic conductivity values have also followed similar trend of infiltration rate. Water retention at field capacity was highest (24.3%) in subsurface of lowland rice system compared to other systems. Aggregate stability (mean weight diameter) index of soil in the form of mean weight diameter of water stable aggregates was ranged from 0.51(subsurface of Mesta-pulse cropping system) to 1.24 (surface of wetland rice system). The variations in soil physical and hydrological properties among cropping systems and land forms indicate the need for site specific crop planning and employing need based tillage and irrigation methods to optimize and maintain the favorable physical and hydrological properties of the soils.

Keywords: *Land forms, Cropping systems, Physical properties, hydrological properties*
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Introduction

Soil physical quality may be affected by soil texture, land form, land use and agriculture management practices like cropping pattern because these may cause alteration in soil characters [1]. Soil properties are responsible for change in the land use dynamics as soil properties are closely related to the different land use types and their associated management practices [2]. Spatial heterogeneity in soil properties might arise as a result of the differences in cropping systems and crop management despite under the same land use type [3]. Without maintaining soil physical health, one cannot talk about increment of agricultural production in feeding the alarmingly increasing population. In the last few decades, soil analysis and investigations of soil physical health has become an important topic of research. Analysis carried out in soils around Indore namely fores,' garden, barren land, farm of wheat and cemented frame making industry found that soil physical quality were comparatively low in cemented industrial areas and the quality was comparatively more in the forest area [4]. Similarly, soil physical properties were studied in the soils of Chiraigaon block of Varanasi district in relation to land use and found vast difference [5]. The information on soil physical quality of the present study area so far has not been studied. Therefore, the present investigation was undertaken to know the soil physical and hydrological properties in different land forms and in different cropping systems of Agricultural College Farm, Naira, Srikakulam District, Andhra Pradesh during dry season of 2019.

Materials and Methods

The study area is under sub-humid climate and is located in North Coastal agro-climate region of Andhra Pradesh, India located between 83°56.095 to 83°56.993 E and 18°23.045 to 18°26.988N, comprises red, black and associate soils in gently sloppy terrain of rainfed uplands to irrigated low lands. Major soil types of study area were red sandy loams on rainfed uplands, reddish yellow soils situated in upper elevations and medium black soils and deep black soils on irrigated low lands situated in lower elevations. The entire 250 acres land is practicing ten different cropping systems *viz*., In upland irrigated conditions, Rice- rice, Rice-pulse-green manure, Rice- maize, in upland rainfed conditions Mesta- pulse, Mango, Sapota, Cashew, Coconut and Guava while in low lands, Rice- fallow system was followed. The cropping systems followed were arbitrary and except low land field where in Rice-fallow system is followed. In uplands different cropping systems including orchards were grown. The climate belongs to semi-arid monsoon type with alternate wet and dry seasons as evidenced by past one decade meteorological data from 2012 to 2021. The mean annual temperature and rain fall were 26.48°C, 982.7mm, respectively.

Table-1 Mean values of Soil Physical properties in different land forms and cropping systems of Agricultural College farm, Naira.

N Cropping system	Soil depth (cm)	Sand (%)		Silt (%)		Clay (%)		Texture		B.D(d)* (g/cm^3)		Porosity (%)		SOC** (g kg^{-1})		COLE***		VE**** (%)	
		0 -15	15-30	0 -15	15-30	0 -15	15-30	0 -15	15-30	0 -15	15-30	0 -15	15-30	0 -15	15-30	0 -15	15-30	0 -15	15-30
Lowlands																			
Rice- Fallow	85.6	52.48	50.67	14.50	15.05	32.48	33.87	sc	c	1.44	1.53	45.7	42.3	6.13	3.38	0.094	0.128	19.50	26.50
Uplands- irrigated																			
Rice- Rice	53.3	64.24	61.13	13.64	14.18	20.12	21.50	scl	scl	1.58	1.62	40.4	38.9	4.67	2.57	0.018	0.021	8.13	9.48
Rice-Pulse	48.3	67.08	65.48	12.84	13.24	19.96	20.48	scl	scl	1.49	1.60	43.8	39.6	5.38	2.82	-	0.013	9.67	10.10
Rice- Maize	44.7	64.44	62.25	13.64	14.33	19.52	20.33	scl	scl	1.49	1.57	43.8	40.8	4.25	2.95	-	0.011	3.18	6.23
Uplands- rainfed																			
Mesta- Pulse	31.7	65.18	62.33	14.28	16.00	18.94	19.20	sl	sl	1.48	1.59	44.2	40.0	5.82	3.10	-	-	-	-
Mango	57.2	66.20	65.33	15.71	14.25	16.33	18.67	sl	sl	1.48	1.57	44.2	40.8	7.31	3.82	-	-	-	-
Sapota	43.5	68.52	67.33	10.52	11.33	18.08	19.30	sl	sl	1.50	1.58	43.4	40.4	6.23	2.95	-	0.019	-	2.85
Cashew	50.6	62.15	60.40	15.72	15.54	19.20	20.58	sl	sl	1.46	1.55	44.9	41.5	7.15	3.37	-	-	-	-
Coconut	28.1	69.50	66.33	11.21	12.83	15.82	17.18	sl	sl	1.49	1.63	43.8	38.5	5.08	3.20	-	-	-	-
Guava	37.5	67.33	63.58	13.90	15.11	16.48	18.67	sl	sl	1.46	1.56	44.9	41.1	6.88	3.52	-	-	-	-

: Bulk density (dry); **Soil Organic carbon; * Coefficient of Linear extensibility; ****Volume expansion*

Table-2 Mean values of Soil Hydrological properties in different land forms and cropping systems of Agricultural College farm, Naira

Cropping system	Final infiltration rate (mm/hr)		Saturated hydraulic conductivity (mm/hr)		MWHC* (%)		Water retention at FC* (%)		Aggregate stability (MWD***) (cm)	
	0 -15	15-30	0 -15	15-30	0 -15	15-30	0 -15	15-30	0 -15	15-30
Lowlands										
Rice- Fallow	7.5	5.7	12.1	7.5	45.2	45.0	22.7	24.3	1.24	0.97
Uplands- irrigated										
Rice- Rice	10.7	8.2	15.3	10.6	37.5	36.8	18.3	22.1	0.86	0.69
Rice-Pulse	19.2	11.7	21.7	12.1	39.7	37.0	16.9	17.5	1.17	0.91
Rice- Maize	15.3	10.1	22.6	10.8	37.5	36.2	16.2	17.6	0.72	0.56
Uplands- Rainfed										
Mesta- Pulse	21.4	12.4	28.4	12.1	35.3	37.8	14.8	16.2	0.66	051
Mango	18.7	10.8	26.7	14.8	35.8	37.6	13.9	15.5	0.65	0.58
Sapota	14.5	11.3	18.3	10.3	38.5	37.3	16.6	18.7	0.73	0.63
Cashew	20.3	12.6	31.6	12.8	36.2	36.9	15.4	17.8	0.61	0.55
Coconut	23.5	13.5	27.8	10.4	35.9	36.1	14.1	15.9	0.56	0.54
Guava	21.8	10.9	26.3	14.3	36.5	35.2	16.3	17.5	0.68	0.66

**Maximum water holding capacity; **Field Capacity; ***Mean weight diameter*

Soil sample collection: A total of 60 soil samples were collected at two depths *viz*., 3 surface samples (0- 15cm) and 3 subsurface samples (15-30cm) from random locations in each of cropping systems, constituting a total of 64 soil samples. Soil sampling was done during April, 2019 with the help of core sampler which comprises of volume 753.6 cm^3.

Laboratory analysis

Proportions of soil particles in fine earth fraction were determined by Bouyoucos hydrometer method [6]. Soil dry bulk density was determined by using core sampler method [7]. Particle density was determined by specific gravity bottle method, as described by [8]. Pore space was derived from the values of bulk density and particle density (2.65 g/m^3) and the results were expressed as percentage. Coefficient of linear extensibility (COLE) was determined by following the method outline in USDA, NRCS hand book 430 [10]. Undisturbed soil samples collected in cylindrical core samples from 0-15 cm soil depth were used for the determination of saturated hydraulic conductivity in the laboratory by constant head method [11].

The physical constants such as water holding capacity and volume expansion were determined by following Keen Raczkowski's method [12]. Final infiltration rate was determined using double ring infiltrometer following variable head method as suggested by Bertrand [9] and the results were expressed in mm hr-1. The mean values were used for interpretations.

Results and Discussion

Soil Depth

The soil depth was ranged from 28.1 to 85.6 cm, very deep in low lands, moderately deep to deep in upland soils. Soil transportation with eroded water from upland forms to lowland forms and more intense weathering in subsurface of low lands due to moisture availability for long time which favour intense weathering in subsurface of low lands which might cause for deeper soil depths in low lands compared to uplands [13].

Mechanical composition and soil texture

Relatively higher proportions of sand particles with mean value of 69.5% was recorded in surface horizon of coconut orchard and relatively low sand of 50.67% was observed in low land rice- fallow system [Table-1]. Highest silt content (16.0%) in sub surface of Mesta-pulse cropping and lowest (11.21%) in surface layer of coconut orchard. Highest clay of 33.86% in subsurface of lowland rice-fallow system and lowest clay of 15.82% in surface of coconut orchard. Higher proportions of clay were recorded in lowland rice-fallow cropping system and lower proportions of clay was recorded in rainfed upland orchard systems. The soil texture was sandy clay to clay in lowland rice-fallow cropping and sandy clay loam in upland irrigated cropping systems and sandy loam texture in rainfed orchard cropping. Presence of moisture in soil for longer periods and restricted drainage in soils with high clay percentage under irrigated cropping systems caused rapid weathering which resulted in finer textures [14].

Bulk density and Porosity

Perusal of the data [Table-1] represents that the bulk density ranged from 1.46 to 1.63 Mg/m^3 in upland cropping systems and 1.44 to 1.53 in low land cropping system. Further, the surface soil recorded relatively low bulk density values compared to subsurface.

The higher bulk density in subsurface might be due to more compaction of soil in deeper layers caused by over-head weight of the surface soil and decreased organic matter with depth. Similar observations were also made [15] and [16]. The statistical data showed a significant negative correlation of bulk density (r = -0.298**) with organic carbon [Table-3]. The soil porosity ranged from 42.3 to 45.7% in low land rice- fallow, while 38.5 to 41.5% in upland

Soil Organic Carbon (SOC)

The mean soil organic carbon content ranged from low to medium (2.57 to 7.31 g/kg soil). In general, higher SOC registered in surface soil and lower SOC in subsurface soil, which could be due to surface layer enriched with crop residue like left over roots mass and added FYM to the surface soil due to cropping activity.

Similar observations were made earlier [17] Further relatively higher SOC was found in orchard crops compared to agricultural crops. Addition of large amounts of leaf litter and less exposure of SOC by tillage in orchards could be the cause for relatively more SOC [18]. SOC is relatively higher in Rice-pulse system than Rice-rice and Rice-maize system.

COLE and Volume expansion

Coefficient of linear extensibility (COLE) was high in lowland rice- fallow system (0.094- 0.128) and low in upland irrigated systems (0.011- 0.021) and negligible in upland rainfed orchard system. The high COLE in lowlands might be due to presence of smectite type of clay [19]. The volume expansion of soil in lowland rice system ranged from 29.5% to 26.5%, while in upland irrigated system is from 3.18 to 10.10%. High volume expansion of soil in lowland is associated with presence of smectite type of clay.

Final infiltration rate and Saturated Hydraulic conductivity

Highest final infiltration rate of 23.5 mm/hr was recorded in the surface of coconut orchard and lowest of 5.7 mm/hr [Table-2] was in subsurface of low land rice-fallow system. In general, the surface soil infiltration rates are relatively higher than subsurface soil. Relatively higher organic matter in surface soil favoured aggregation and thus high infiltration rate in surface soils. Soil organic carbon content is positively correlated [Table-3] with infiltration rate (r=0.302**). Among landforms lowland soils recorded lowest infiltration rate compared to uplands. High clay content in lowlands (fine texture) restricted the water entry in to soil [13]. Infiltration rate and clay content were negatively correlated (r= -0.248**). Among the upland soils orchards recorded high infiltration rate than rice-based cropping systems. Relatively coarse texture in orchards (sandy loam) compared to rice-based systems (sandy clay loam) might be the reason for the difference. In general infiltration rate was relatively higher in surface soil compared to subsurface soil. High organic matter in surface soil favored soil aggregation and consequently improved infiltration rate. SOC and final infiltration rate were positively correlated (r= 0.302**). Saturated hydraulic conductivity also followed similar trends of final infiltration rate. Sand content and SOC were positively correlated (r=0.416** and r= 0.203*, respectively) and the clay content was negatively correlated (r= -0.217*) with saturated hydraulic conductivity of soil. Similar results were also reported earlier [13].

MWHC and water retention at Field capacity

Maximum water holding capacity (MWHC) of soil was ranged from 35.2% in subsurface of Guava orchard to 45.2% in surface layer of low land rice-fallow system. High MWHC in lowland rice cropping is due to fine texture and expanding type of clay mineral dominance in the soil. Water retention at field capacity (FC) was highest (24.3%) in subsurface of lowland rice system compared to other systems. High clay content in soils of lowland rice system might be the cause for high water retention [13]. Clay content and water retention has significant positively correlation (r= 0.361**). Lowest value of 14.1% water retention at FC was found in surface of coconut orchard.

Aggregate stability

Aggregate stability (structural stability) is index of soil in the form of mean weight diameter of water stable aggregates was ranged from 0.51(subsurface of Mesta-pulse cropping system) to 1.24 (surface of wetland rice system). High soil organic matter and high clay content in surface of wetland rice system favoured the formation of stable soil aggregates. Clay content and SOC positively correlated [Table-3] with the MWD (r=0.239*** and r= 00487**, respectively).

Conclusion

The data revealed that the difference in land forms and cropping systems (upland rainfed orchard, upland rice based cropping and lowland rice - fallow cropping) has variations in soil physical and hydrological properties. Lowland soils have fine texture (sandy clay to clay). Rainfed upland soils were relatively coarser textured than that of irrigated upland lands. Low land soils were deeper than irrigated uplands and rainfed upland soils. Bulk density was relatively higher in uplands compared to low lands while total porosity was higher in low lands than uplands. Relatively higher SOC was found in orchard crops compared to agricultural crops. SOC was relatively higher in Rice-pulse system than Rice-rice and Rice-maize system. High soil organic matter and high clay content in surface of wetland rice system favoured the formation of stable soil aggregates. Water retention at field capacity was highest in proportion of clay and organic matter in soil. From the present study, it could be concluded that the site-specific soil management is essential for maintaining favourable soil physical and hydrological environment in different cropping systems and land forms so as to optimize and sustain the soil quality through integrated soil management. Special emphasis should be given for the management of soil organic matter because many of the physical and hydrological properties are correlated with it.

Application of research: Research was carried out to arrive at a decision support system for optimizing soil physical properties in different land forms and cropping systems for sustainable land use of Agricultural college farm, Naira.

Research Category: Soil physical environment (NRM)

Abbreviations: SOC-Soil Organic Carbon, BD-Bulk density, COLE-Coefficient of linear extensibility, FC-Field Capacity, MWD-Mean weight diameter

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Study area / Sample Collection: Agricultural College Farm, Naira

Cultivar / Variety / Breed name: Nil

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