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Soil physical and physico-chemical properties under major cropping systems of Chittoor district, Andhra Pradesh

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Abstract
A study was undertaken carried out during 2020-21 in Chittoor district of A.P. to know the impact of major cropping systems on soil physical and physico-chemical properties. A total of 60 soil samples (15 from each cropping system) under four major cropping systems *viz.,* groundnut-redgram intercropping system, sugarcane-sugarcane sequence cropping system, paddy monocropping system and perennial fodder system were collected and studied. Soils from paddy monocropping system (1.56 Mg m^{-3}) recorded significantly highest bulk density than other cropping systems whereas, lowest in perennial fodder system (1.33 Mg m^{-3}). The texture of soils in all four cropping systems was almost similar ranging from sandy loam to sandy clay loam. Majority of the samples in perennial fodder and paddy monocropping systems epitomized under sandy clay loam texture. Soils were found to be neutral to slightly alkaline in reaction, non-saline, low to medium in organic carbon and non-calcareous in all the cropping systems studied. Slightly alkaline pH was recorded in perennial fodders (8.31) and neutral in groundnut-redgram intercropping system (7.22). Soils under perennial fodder system recorded higher electrical conductivity (0.20 dSm^{-1}), organic carbon (0.58%) and lime content (5.8%) than other cropping systems.

Keywords: Cropping systems, non-saline, non-calcareous and slightly alkaline

Introduction

Soil physical and physico-chemical properties are important for favourable crop growth and maintaining soil quality. Cropping systems exert significant impacts on soil physical and physico-chemical properties, which ultimately affect crop yield. In some cases, however, continuous monocropping has detrimental effects on soil quality. Soil health is negatively affected by unsuitable management practices, which decrease crop productivity (Ranamukhaarachchi and Begum, 2005) [14]. Soil physical properties are positively influenced by cropping systems and management practices, i.e., residue retention and tillage (Bhushan and sharma, 2006) [1]. Many practices like crop type, cultivation, and application of organic residues are known to influence soil properties. Therefore sustainable cropping and land management practices are essential for maintaining crop productivity while enhancing various soil properties. Better crop rotations, reduced tillage, intensive use of cover crops and efficient use of animal manures offers a powerful combination of practices to improve soil and agro-ecosystem health. Whereas, continuous use of inorganic fertilizers under intensive cropping systems leads to deterioration of soil properties resulting in decline in soil productivity. Hence, this study will provide a better understanding on how various cropping systems influences the physical and physico-chemical properties of soil.

Material and Methods

The present study was carried out in Chittoor district of Andhra Pradesh which falls under southern Agro-climatic zone (NARP-AP-3) and geographically, located between 12°37’ to 14°08’ N Latitude and 78°03’ to 79°55’ E Longitude with mean elevation of 53 to 183 m from MSL. The onset of S.W. monsoon in first week of June which continues till third week of September whereas; N.E monsoon enters first week of October continues upto last week of December with an average annual rainfall of 934 mm. The rainfall received during south west monsoon (June- Sep) is 438 mm (47%) and north east monsoon (Oct- Dec) contribute 396 mm (42.3%) rainfall, winter period (Jan-Feb) receives only 12 mm and 88 mm of rainfall received during summer period (March-May). The western parts of the study area received maximum rainfall through S-W monsoon. Whereas, eastern parts received through N-E monsoon and the amount of rainfall received is gradually decreased from eastern mandals to western mandals of study area. In summer, the temperature varies between 24.4 and 38.0°C and sometimes reaches to 42.0°C, whereas, in winter the temperature varies from 17.4 to 31.6°C. The study area witnessed divergent major land use and cropping systems *viz.*, 1. Rice based cropping system, 2. Sugarcane based cropping system, 3. Vegetable based cropping system 4. Groundnut based cropping system, 5. Casuarina and Eucalyptus plantations, 6. Mango orchards, 7. Mulberry based cropping system, 8. Perennial fodder based, 9. Flower crops based, 10. Forest land use, 11. Fallow land use, 12. Waste lands etc.

The soil samples were collected by selecting three villages from a Mandal and 5 soil samples from the predominant cropping system of that village were collected. Fifteen soil samples from each cropping system *viz.*, groundnut-redgram intercropping system, sugarcane-sugarcane sequence cropping system, paddy monocropping system and perennial fodder system at 0-15cm depth were collected. The bulk density was measured with soil core sampler by taking undisturbed soil samples in stainless steel rings of 60mm diameter with capacity of 100cc internal volume. This metallic core was inserted at 0-15 cm depth and sample retained within the core was transferred to pre weighed aluminium box and kept in oven at 104°C for 48 hrs. The soil bulk density (Mg m^{-3}) was calculated by dividing the oven dry weight of undisturbed soil sample with volume of metallic core. The collected soil samples brought to the laboratory and separated the plant debris, roots, stones etc. The samples were air dried, pounded and passed through the 2 mm sieve. This fine earth is again pounded with pestle and mortar and passed through 0.2 mm sieve for estimation of soil organic carbon percentage

These soil samples were processed and analysed for various physical properties (bulk density and texture) and physico-chemical properties (pH, EC, OC and lime content). Bulk density and texture were analysed by adopting standard procedures as outlined by Jackson (1973) [7] and Bouyoucos (1962) respectively. pH of soil samples was determined in 1:2.5 soils: water suspension using a glass electrode pH meter (Jackson, 1973) [7]. Electrical conductivity of soil samples was determined in 1:2.5 soils: water suspension with conductivity meter by Richards *et al.* (1954) [15] and is expressed as dSm^{-1}. Organic carbon content of soil samples was determined by chromic acid wet digestion method (Walkley and Black, 1934) [17] and expressed as percentage. Lime content was determined by titration method (Piper, 1966) and expressed as percentage.

Results and Discussion

Physical properties

Bulk density

The data revealed that the bulk density (Table 1 and 2) of soils under major cropping systems of Chittoor district varied from 1.33 Mg m^{-3} (perennial fodder system) to 1.56 Mg m^{-3} (paddy monocropping system). Significantly the highest bulk density was recorded in paddy monocropping system (1.56 Mg m^{-3}) followed by sugarcane–sugarcane sequence cropping system (1.51 Mg m^{-3}) while the lowest in perennial fodder system (1.33 Mg m^{-3}) and was on par with groundnut-redgram intercropping system (1.35 Mg m^{-3}). The lower bulk density of the soils in fodder systems might be attributed to high SOM and less disturbance of land.

Selassie and Ayanna (2013) [16] reported that lower bulk density in uncultivated land might be due to high organic matter making the soil loose, porous and well aggregated. In contrast to fodder systems, though paddy fields exhibited higher SOM content, due to compaction of the top soil by repeated ploughing and puddling, these soils resulted in higher bulk density. Similar results were obtained by Celik (2004) who concluded that soils under cultivation had higher bulk density than that of uncultivated land.

Texture

The texture (Table 3) of soils under different cropping systems was almost similar ranging from sandy loam to sandy clay loam. In perennial fodder and paddy monocropping systems majority of the samples fell under sandy clay loam textural class whereas, in groundnut-redgram intercropping and sugarcane-sugarcane sequence cropping systems more number of samples fell under sandy loam textural class.

Physico-Chemical Properties

pH

pH is an important electrochemical property of soil which helps in understanding processes and speciation of chemical element in soil. pH (Table 4 and 8) of soils under major cropping systems ranged from 7.22 (CS_1: groundnut-redgram intercropping system) to 8.31 (CS_3: perennial fodder system) which are neutral to slightly alkaline in reaction. Significantly the highest pH was recorded with perennial fodder system (8.31) followed by paddy monocropping system (8.17) while the lowest was recorded with groundnut-redgram intercropping system (7.22) and was on par with soil pH of sugarcane-sugarcane sequence cropping system (8.17).

The results are in accordance with findings of Surya Krishna *et al*. (2021) [9] who reported that the pH of surface soils in Chittoor district ranged from 7.42 in sugarcane monocropping system to 8.11 in paddy-paddy system. Predominance of exchangeable bases in surface soils results in higher pH in paddy monocropping system (Kiflu and Beyene, 2013) [8]. Loria *et al.* (2016) [11] mentioned that slightly acidic pH in various land use systems may be due to long- term use of acid forming fertilizers.

Electrical conductivity

Electrical conductivity (EC) is a measure of the amount of salts in soil. Electrical conductivity (Table 5 and 8) of soils under major cropping systems of Chittoor district ranged from 0.12 dSm^{-1} (CS_1: groundnut-redgram intercropping system and CS_2: sugarcane-sugarcane sequence cropping system) to 0.20 dSm^{-1} (CS_4: perennial fodder system). The highest electrical conductivity was recorded with perennial fodder system (0.20 dSm^{-1}) followed by paddy monocropping system (0.17 dSm^{-1}) while the lowest was recorded with groundnut-redgram system (0.12 dSm^{-1}) and sugarcane-sugarcane sequence cropping system (0.12 dSm^{-1}). However, the results conclude that the EC was normal under all the cropping systems indicating major cropping systems of the district have not influenced the salt concentration of the soils.

These results are in accordance with the findings of Govardhan *et al*. (2017) [6] who inferred that the soils of cultivated fields of Chittoor district do not suffer from any salt content problems because the district has neither major rivers of perennial nature nor any irrigation canals to influence the soluble salt content of the soils in general.

Table 1: Bulk density in soils under major cropping systems of Chittoor district

Cropping systems	Bulk density (Mg m^{-3})															Mean
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	
CS_1:Groundnut-redgram intercropping system	1.43	1.48	1.38	1.58	1.36	1.43	1.19	1.25	1.22	1.25	1.36	1.26	1.32	1.31	1.42	1.35
CS_2:Sugarcane - sugarcane sequence cropping system	1.32	1.57	1.38	1.49	1.62	1.37	1.44	1.54	1.62	1.68	1.66	1.38	1.50	1.71	1.45	1.51
CS_3:Paddy monocropping system	1.56	1.47	1.70	1.32	1.52	1.58	1.78	1.44	1.28	1.44	1.68	1.58	1.55	1.85	1.64	1.56
CS_4:Perennial fodder system	1.51	1.27	1.36	1.50	1.10	1.19	1.28	1.47	1.25	1.24	1.47	1.46	1.39	1.34	1.12	1.33

Table 2: Bulk density in soils under major cropping systems of Chittoor district

Cropping system	Bulk density (Mg m^{-3})	
	Range	Mean
Groundnut-redgram intercropping system	1.19 - 1.58	1.35
Sugarcane-sugarcane sequence cropping system	1.32 – 1.71	1.51
Paddy monocropping system	1.28 – 1.85	1.56
Perennial fodder system	1.10 – 1.51	1.33
S.Em ±		0.03
CD (at 0.05)		0.09

Table 3: Textural class of soils under major cropping systems of Chittoor district

Cropping System	Texture			
	Sand (%)	Silt (%)	Clay (%)	Textural class
Groundnut-redgram intercropping system	65 - 78	5 – 18	14 - 21	Sandy loam (12), Sandy clay loam (3)
Sugarcane-Sugarcane Sequence crop system	60 - 82	6 – 15	6 - 28	Sandy loam (9), Sandy clay loam (4), Loamy sand (2)
Paddy Monocrop system	55 - 75	3 – 25	13 – 30	Sandy loam (7), Sandy clay loam (8)
Perennial Fodder system	55 - 76	7 - 25	12 - 23	Sandy loam (9), Sandy clay loam (6)

Table 4: pH of soils under major cropping systems of Chittoor district

Cropping systems	pH															
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	Mean
CS_1: Groundnut-redgram intercropping system	8.29	7.48	7.18	6.87	7.75	8.26	8.02	8.08	6.8	6.95	5.64	6.64	7.35	6.7	6.36	7.22
CS_2:Sugarcane-sugarcane sequence cropping system	7.44	7.61	8.35	7.3	7.22	6.59	8.32	8.22	7.67	8.2	8.56	7.57	8.05	7.22	7.67	7.73
CS_3:Paddy monocropping system	8.21	8.37	8.27	8.33	8.51	8.35	8.12	7.94	8.32	8.29	8.42	8.42	7.75	7.96	7.36	8.17
CS_4:Perennial fodder system	8.38	8.36	8.23	8.29	8.36	8.47	7.69	8.33	8.41	8.44	8.42	8.39	8.19	8.52	8.3	8.31

Table 5: Electrical conductivity of soils under major cropping systems of Chittoor district

Cropping systems	EC (dSm^{-1})															
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	Mean
CS_1:Groundnut-redgram intercropping system	0.1	0.07	0.18	0.11	0.11	0.12	0.14	0.2	0.15	0.13	0.14	0.13	0.09	0.07	0.08	0.12
CS_2:Sugarcane-sugarcane sequence cropping system	0.08	0.08	0.13	0.05	0.09	0.08	0.15	0.23	0.14	0.17	0.11	0.05	0.12	0.25	0.09	0.12

CS$_3$:Paddy monocropping system	0.16	0.12	0.23	0.25	0.12	0.28	0.56	0.09	0.52	0.13	0.13	0.15	0.12	0.08	0.07	0.17
CS$_4$:Perennial fodder system	0.14	0.15	0.23	0.12	0.34	0.2	0.08	0.14	0.19	0.13	0.17	0.29	0.14	0.19	0.16	0.20

Table 6: Organic carbon in soils under major cropping systems of Chittoor district

Cropping systems	Organic carbon (%)															
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	Mean
CS$_1$:Groundnut-redgram intercropping system	0.25	0.39	0.46	0.52	0.4	0.45	0.66	0.43	0.47	0.46	0.54	0.55	0.41	0.61	0.52	0.47
CS$_2$:Sugarcane-sugarcane sequence cropping system	0.69	0.53	0.44	0.47	0.36	0.42	0.59	0.63	0.44	0.54	0.32	0.43	0.46	0.41	0.68	0.49
CS$_3$:Paddy monocropping system	0.61	0.68	0.68	0.71	0.66	0.5	0.45	0.51	0.57	0.62	0.62	0.53	0.57	0.51	0.45	0.57
CS$_4$:Perennial fodder system	0.58	0.51	0.65	0.46	0.74	0.56	0.63	0.69	0.59	0.66	0.28	0.67	0.59	0.57	0.59	0.58

Table 7: Lime content ($CaCO_3$) in soils under major cropping systems of Chittoor district

Cropping systems	Lime content (%)															
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	Mean
CS$_1$:Groundnut-redgram intercropping system	6.5	5.5	4.5	6.0	4.0	4.0	2.0	5.0	6.5	6.5	6.5	6.5	6.0	7.0	7.0	5.5
CS$_2$:Sugarcane-sugarcane sequence cropping system	5.0	5.0	3.0	2.0	3.0	2.5	1.4	9.5	3.5	3.5	6.5	2.0	4.0	6.0	5.0	4.1
CS$_3$:Paddy monocropping system	6.0	9.0	7.0	2.0	8.0	6.0	2.5	3.5	4.0	1.0	2.5	3.5	1.1	3.0	1.5	4.0
CS$_4$:Perennial Fodder system	5.0	6.5	6.5	7.0	7.0	7.5	6.5	2.5	4.0	5.0	9.0	8.0	3.0	4.0	5.5	5.8

Table 8: Physico-Chemical properties of soils under major cropping systems of Chittoor district

Cropping System	pH		EC (dSm^{-1})		Organic C (%)		$CaCO_3$ content (%)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Groundnut-redgram intercrop system	5.64 - 8.29	7.22	0.07 – 0.20	0.12	0.25 – 0.66	0.47	2.0 – 7.0	5.5
Sugarcane-sugarcane sequence cropping system	6.59 -8.56	7.73	0.05 – 0.25	0.12	0.32 – 0.69	0.49	1.4 – 9.5	4.1
Paddy monocropping system	7.36 -8.51	8.17	0.07 – 0.56	0.17	0.45 – 0.71	0.57	1.0 – 9.0	4.0
Perennial fodder system	7.69 - 8.52	8.31	0.08 – 0.34	0.20	0.28 – 0.74	0.58	3.0 – 9.0	5.8

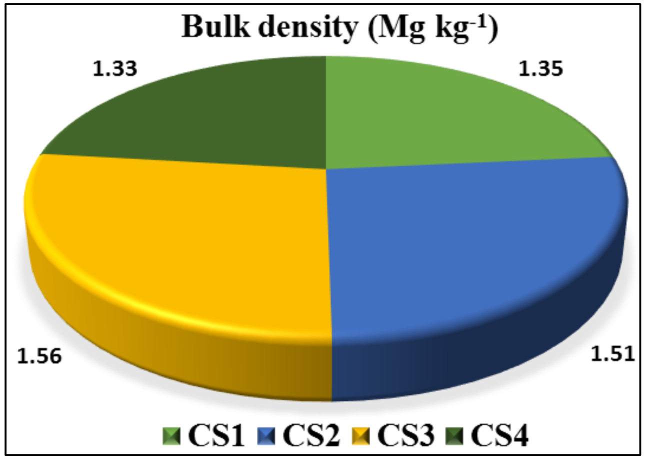

Fig 1: Bulk density in soils under major cropping systems of Chittoor district

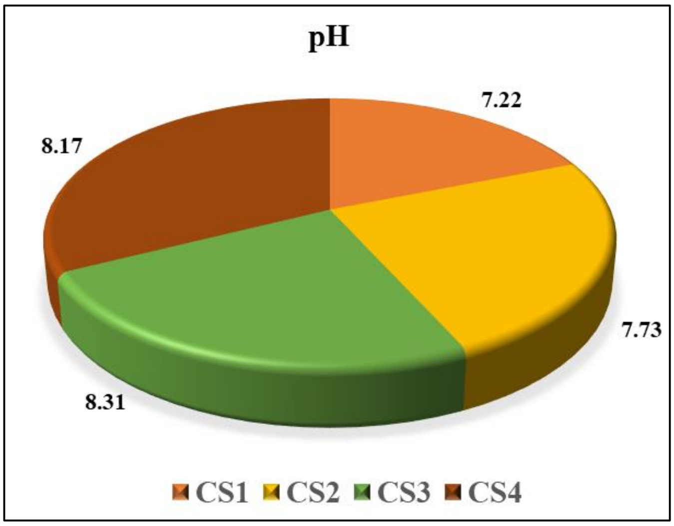

Fig 2: Soil pH in soils under major cropping systems of Chittoor district

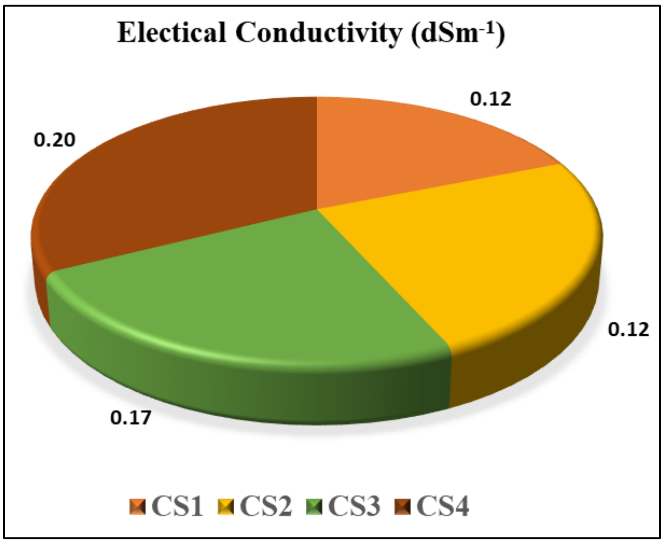

Fig 3: Electrical conductivity (dSm^{-1}) in soils under major cropping systems of Chittoor district

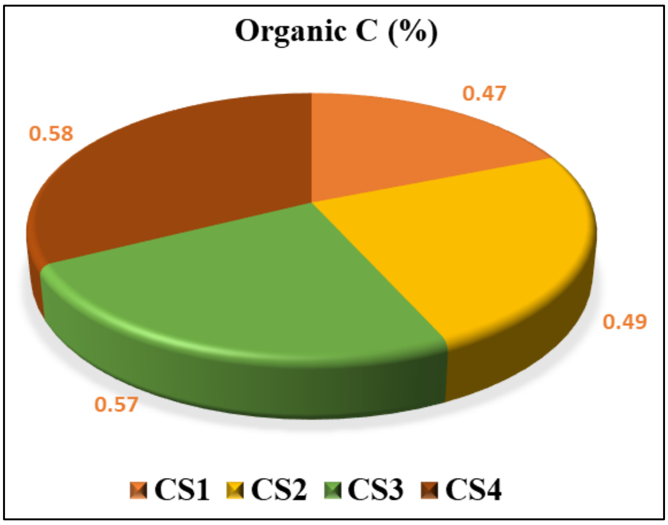

Fig 4: Organic carbon (%) in soils under major cropping systems of Chittoor district

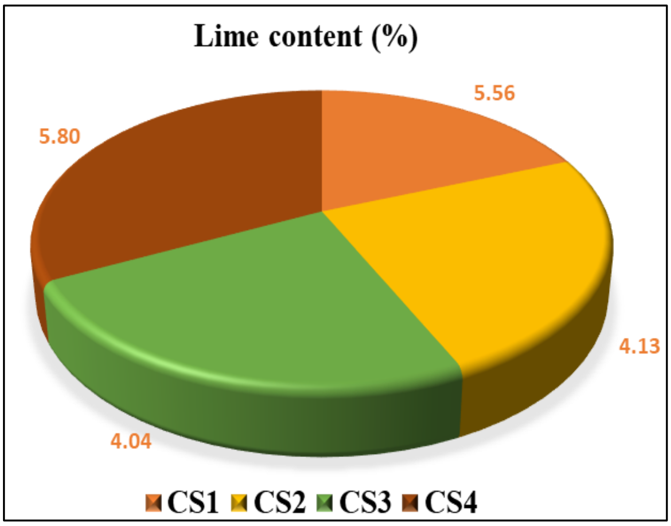

Fig 5: Lime content (%) in soils under major cropping systems of Chittoor district

Organic carbon

Soil organic carbon (SOC) is one of the most important characteristics of soil that result from the interplay of net primary producers, decomposers, and mineralogy. The data on organic carbon (Table 6 and 8) in soils under major cropping systems revealed significant differences between cropping systems of the study area. The organic carbon of soils under major cropping systems ranged from 0.47% (CS_1: groundnut-redgram intercropping system) to 0.58% (CS_4: perennial fodder system) which represent low to medium organic carbon. Significantly the highest OC was recorded with perennial fodder system (0.58%) and was on par with paddy monocropping system (0.57%) while the lowest was recorded with groundnut-redgram intercropping system (0.47%) and was on par with that of sugarcane-sugarcane sequence cropping system (0.49%). Long-term cultivation has been frequently associated with decreasing SOC (Gaudin *et al.*, 2015) [4]. Similar relationships between cultivation and SOC status in agricultural soils are reported by Ghosh *et al.* (2020) [5].

It was interesting to note that none of the samples recorded higher OC content *i.e.* > 0.75%. The reason for low organic carbon content in these soils may be attributed to the prevalence of semi-arid condition, where the degradation of organic matter occurs at a faster rate coupled with little or no addition of organic manures and low vegetation cover on the fields, there by leaving less chances of accumulation of organic carbon in the soils. The sugarcane – sugarcane cropping system has recorded lower SOC stocks due to repeated burning of sugarcane trash, a common practice which might be attributed to loss of sequestered carbon.

The perennial fodders significantly have high organic carbon status due to the profuse branched root system and more root biomass with in surface layers and root exudates might favors higher carbon sequestration than other arable cropping systems like groundnut-groundnut in the study area (Mohan *et al.*, 2020) [12].

Lime content

The data on lime content (Table 7 and 8) in soils of major cropping systems revealed no significant differences between cropping systems of the study area. The lime content of soils ranged from 4.0% (CS_3: paddy monocropping system) to 5.8% (CS_4: perennial fodder system) which represent that the soils are non-calcareous. The highest $CaCO_3$ content was recorded in perennial fodder system (5.8%) and was on par with groundnut-redgram intercropping system (5.5%) while the lowest was in paddy monocropping (4.0%) and was on par with that of sugarcane –sugarcane sequence cropping system (4.13%).

Lower values of free $CaCO_3$ might be due to dissolution effect in respective cropping systems. Presence of high $CaCO_3$ content might be due to semi-arid climate which is responsible for the pedogenic processes resulting in the depletion of Ca^{2+} ions from the soil solution in the form of calcretes (Ashok kumar and Jagdish Prasad, 2010) [10].

Conclusion

The present investigation revealed that cropping systems has a significant effect on soil physical and physico-chemical properties. Based on this study, physical and physic-chemical properties particularly bulk density and organic carbon content, the perennial fodder system found to be good among all the four cropping systems in terms of soil health.

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