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Assessment of Fertility Status of Soils under Different Cropping Patterns in Rainfed Semi-Arid Eastern Plain of Rajasthan, India

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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

Soil fertility assessment is essential for effective land management practices. Therefore, this study was conducted to assess the physico -chemical characteristics of soil under different cropping systems (Pearl millet (S_1), Sorghum (S_2), Ground nut (S_3), Mung-bean (S_4), Maize (S_5), Pasture (S_6) and to test for significant differences in the nutrient in order to provide basis for recommending site

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specific land management practices in the study area. Soil samples under the aforementioned cropping systems were collected from 3 sites (Malpura Todaraisingh Piplu) in Tonk District. Collected soil samples were examined for various physico-chemical parameters which includes BD, PD, WHC, Porosity, pH, EC, OC, also macro nutrient like N, P, K, Ca, Mg, and S by using standard analytical methods. Results showed that lowest pH (6.3 to 6.7) observes in sorghum cropping land while highest PH observed in pearl millet (7.4 to 6.7), while Highest organic matter observed in Mung bean cropping system (1.52 and 1.10%) after that ground nut (1.29 and 0.88%). Highest values (568 Kg/ha and 480 Kg/ha) of Nitrogen was obtained from mung bean soil, while lowest in pearl millet and maize (260 Kg/ha and 329 Kg/ha) crop land.

Keywords: Cropping systems; pH; EC macro nutrient; bulk density particle density.

1. INTRODUCTION

Soil quality is highly dependent on soil management practices, and it influences crop production. Evaluating soil characteristics across varying cropping systems over extended periods is vital for maintaining soil quality. This is crucial as soil serves as a essential role within ecosystems, facilitating nutrient cycling, regulating water availability, and fostering optimal crop development [1]. As a developing country India not only faces water scarcity problems but also the challenge to maintain soil health and guarantee food security [2,3]. Changes in various cropping patterns can significantly impact soil properties, particularly with the increased use of fertilizers and low efficiency in nutrient utilization, thereby affecting soil quality. Multiple studies indicate that while there may be short-term gains in crop yield, over time, these changes can lead to soil chemical, physical, and biological alterations that are detrimental to sustainable agricultural practices [4,5,6,7] The modifications in soil are a reflection of various management approaches applied, including crop rotation and diversification. These alterations in soil quality are not solely attributed to tillage methods and fertilizer usage but also to factors such as crop varieties and planting techniques within agricultural patterns.

Crop diversification, often referred to as planned diversity in cropping systems, is essential not only for maximizing crop production but also for promoting soil health. By balancing soil biodiversity, enhancing nutrient use efficiency, and mitigating soil-borne pathogens, crop diversification plays a crucial role in sustainable agriculture [8]. The benefits of optimized crop diversification extend to growers and the environment like. Increasing crop diversity contributes to the heterogeneity of soil chemical nutrients, physical structures, and functional microorganisms across different spatial scales, ultimately leading to improved soil health and crop yields. However, the relationship between crop diversification and soil-borne pathogens can be complex [9,10,11,12]. While increased crop diversity generally reduces the prevalence of soil-borne diseases, there are instances where this relationship may not hold true. For example, [13] found that incorporating more pulse crops into rotations actually increased the pathogen index, potentially due to an increase in pulse-specific pathogens. Therefore, while crop diversification is generally beneficial, the impact on soil-borne diseases may vary depending on factors such as species redundancy and the host-specificity of pathogens [14,15]. Cropping systems are essential components of farming, illustrating the patterns of crops grown on a farm and their interactions with other aspects such as resources and available technology. There's a general acknowledgment that mycorrhizal fungi activity can enhance soil quality, and cropping systems play a role in promoting the inoculation of these fungi. Furthermore, mycorrhizal fungi contribute to early crop growth by establishing symbiotic relationships with plant roots, facilitating improved water and nutrient uptake

Rajasthan is segmented into three agro-climatic zones: Zone VI, covering the Trans-Gangetic Plains region; Zone VIII, encompassing the Central Plateau and Hills region; and Zone XIV, representing the Western Dry region. The soil in Rajasthan falls under various classifications according to the USDA Land Division program, including Aridisols, Alfisols, Entisol, Inceptisols, and Vertisol [16]. In India, The lack research data on this topic especially in the tropical and sub-tropical rainfed regions, is concerning, particularly regarding the environmental and economic impacts of conventional crop cultivation. Consequently, there's growing interest in alternative approaches like organic farming. However, there's a lack of comprehensive, long-term studies on how different crops (such as sorghum, pearl millet, groundnut, and green gram) and production systems (organic and integrated) affect soil physio-chemical properties, particularly in India's rainfed semiarid areas. These crops were selected based on their suitability for the study region, as they are well-adapted to the rainfed regions of semi-arid tropics and are commonly cultivated there. Therefore, our current research aims to assess the influence of various crops on soil physical and chemical properties in rainfed semi-arid areas.

2. MATERIALS AND METHODS

2.1 Present Study Area

Tonk is situated in North Eastern of Rajasthan, between 25°41' and 26°34' north latitudes and between 75°07' and 76°19' east longitudes (Fig. 1). It is bounded in the north by Jaipur district, in the south by Bundi and Bhilwara districts, in the west by Ajmer district and in the east by Sawai Madhopur district. It is situated in agro-climatic zone 3-A, specifically the semi-arid eastern plain zone the climate is different from typical semi-arid Rajasthan and is more sub-humid climate. The area does remain dry for almost part of the year and humidity increases only during the monsoon months. Summers are hot and during the peak summer months of May-June the temperature soars to more than 40°C. In winter months that stretch from November to February the mean temperature is low, around 20 °C but the lowest temperatures dip to around 5-6°C [17]. Rainfall is moderate as the average annual rainfall in this district is about 520 mm and rains are received during the monsoon months of July to September.

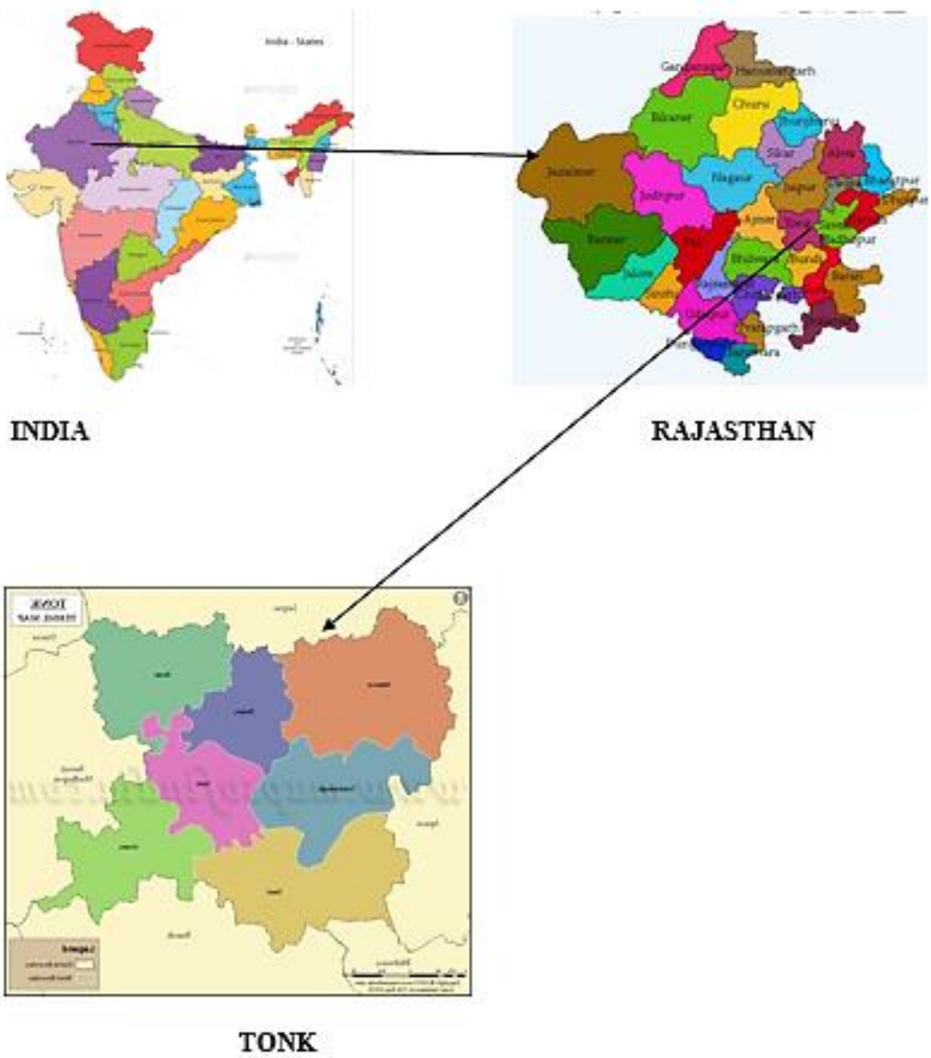


Fig. 1. Location of Tonk District in Rajasthan

Table 1. Procedure used for physical and chemical analysis of soil

S. No.	Parameters	Method	Scientist
		Physical properties	
1.	Bulk density (Mg kg^{-1})	Pycnometer	Black *et al*. (1965)
2.	Particle density (Mg kg^{-1})	Pycnometer	Black *et al*. (1965)
3.	Water holding capacity	Keen box	Piper (1966)
		Chemical properties	
4.	pH	Glass electrode pH meter	Jackson (1973)
5.	EC (dSm^{-1})	Electrical conductivity meter	Jackson (1973)
6.	Organic carbon (%)	Wet oxidation method	Walkey and Black [18]
7.	Available nitrogen	Alkaline Potassium permanganate	Subbiah and Asija (1956)
8.	Available phosphorus	Modified Olsen's method	Olsen *et al.*(1954)
9.	Available potassium	Extractable K_2O Ammonium acetate	Schollenberger and Simon (1945)
10.	Exchangeable calcium and magnesium	EDTA titration method	Jackson (1973)
11.	Available sulfur	Turbidimetric method	Chesnin and Yien (1950)

2.2 Soil Samples Collection Sites

A total of 72 samples were collected from Tonk district Rajasthan in the year of September 2021. The samples were from 6 cropping systems: Pearl millet (S_1), Sorghum (S_2), Ground nut (S_3), Mung-bean (S_4), Maize (S_5), and Pasture (S_6). 12 sample were collected from each cropping system in which six samples were taken from 0-15 cm and reaming 6 sample were taken from 15-30 cm depth with the help of soil auger and placed in a labelled polythene bags.

2.3 Process of Soil Sampling

The soil samples, after collection, taken to the laboratory for analysis. To begin with, these samples were carefully dried in the shade to ensure accuracy in subsequent processing steps. The first step in the processing involved removing any unwanted materials such as roots and stones from the samples. Additionally, any clods present in the samples were broken down using a wooden mallet. Following this, the samples were sieved using a 2 mm sieve to ensure uniformity (Table 1). The sieved samples were then carefully stored in polybags for later assessment of various physico-chemical parameters. Throughout this process, all necessary precautions were taken, adhering to the methodology outlined by [19]. Furthermore, the chemical properties of the soil were estimated using the standard procedure outlined by [20].

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties

The Table 2 show the summary the results of the laboratory analyses conducted on the soil samples for the crop farms under investigation and at the surface and the subsurface levels.

The pH of the soil is an important property because it affects nutrients availability and supply, microbial growth and the physical state of the soil [21]. The pH values represents, the combined effect of acid-base reactions occurring in the soil environment [22]. Soil pH of the different cropping system [Pearl millet (S_1), Sorghum (S_2), Ground nut (S_3), Mung-bean (S_4), Maize (S_5), Pasture (S_6)] on surface layer observed from 6.7 to 7.4 and subsurface layer from 6.3 to 7.2 respectively 7.4, 6.8, 6.7, 7.3, 6.9, 7, and 6.7, 6.3, 7.1, 6.5, 7.2, 6.9. The pH value Highest observed in surface layer as compare to sub surface layer. In same way highest EC observed in surface layer (0.88 dsm^{-1}) in sorghum cropping system and lowest EC observed (0.35 dsm^{-1}) in pasture land while in subsurface layer highest EC observed in pearl millet (0.84 dsm^{-1}) and lowest find in Mung bean (0.32 dsm^{-1}) that are significantly different from surface soil layer.

Soil Organic Matter of mung bean cropping system in highest observed in both surface and sub-surface layer respectively (1.52 and 1.10%), after that ground nut (1.29 and 0.88%) while lowest OM observed in sorghum crop system in both surface and sub- surface layer (0.74 and 0.60) this are non-significantly nearby pasture land OM content (0.71 and 0.84) show in Fig. 2.

The bulk density highest observed in pasture 1.48 and 1.57 g cm^{-3} on surface & subsurface layer while lowest BD observed in ground nut (1.34 and 1.32 g cm^{-3}) (Table 2 and Fig. 3). And in sorghum cropping system bulk density found (1.36 and 1.5 g cm^{-3}). In ground nut BD lowest observed because its pods increase the porosity and microbial activity most of surface layer also covered by plant parts (stem, leaves) due to moisture and temperature also maintain while BD highest observed in pasture land because animal feed on grasses and there weight compacts the land, which reduce the porosity and increase the bulk density [21].

Soil Porosity was observed to be increasing from surface to subsurface in pearl millet and sorghum land e. 38.12% to 41.22% and 37.09 to 42.31 but decreasing with increasing soil depths in groundnut and pasture land correspondingly 49.43 to 48.03% and 42.19 to 41.64% (Table 2 and Fig. 6). There is observed higher soil porosity with increasing the soil depth. The higher soil porosity with increasing soil depth on Maize and sorghum can be as a result of shallow root system of Maize and sorghum compared to groundnut and pasture [23].

Water holding capacity observed in surface layer ranged from 55.85 to 32.12%. Highest WHC observed in ground nut (55.85 %) and lowest observed in maize (32.12%), pasture (32.12%). in sub surface layer WHC observed in 47.51 to 28.21% (Table 2). The highest WHC in sub surface layer find out in sorghum 47.51% and lowest observed in Pasture land 28.21% because in compaction in pasture land and high in bulk density low in porosity due to WHC decrease [24].

Table 2. Soil physio-chemical parameters of Tonk District Rajasthan

Average Mean of Soil Under Different Depth									
parameters	**Depth**	**pH**	**EC(dsm^{-1})**	**OC (%)**	**OM (%)**	**BD (g cm^{-3})**	**PD (g cm^{-3})**	**Porosity (%)**	**WHC (%)**
Cropping patterns	**Surface and sub-surace**	**Mean±Std**	**Mean±Std**	**Mean±Std**	**Mean±Std**	**Mean±Std**	**Mean±Std**	**Mean±Std**	**Mean±Std**
Pearl millet (S_1)	0- 15 cm	7.4 (0.61)	0.59 (0.24)	0.53(0.21)	0.91(0.34)	1.38(0.06)	2.23(0.16)	38.12(3.15)	36.85(3.15)
	15-30 cm	6.7 (0.71)	0.84(0.27)	0.38(0.20)	0.66(0.33)	1.44(0.08)	2.45(0.18)	41.22(4.15)	45.87(3.43)
Sorghum (S_2)	0- 15 cm	6.8(0.63)	0.88(0.29)	0.43(0.25)	0.74(0.31)	1.36(0.06)	2.13(0.16)	37.09(5.25)	33.72(5.25)
	15-30 cm	6.3(0.65)	0.65(0.22)	0.35(0.24)	0.60(0.38)	1.5(0.09)	2.6(0.19)	42.31(12.2)	47.51(8.56)
Ground nut (S_3)	0- 15 cm	6.7(0.64)	0.56(0.24)	0.75(0.26)	1.29(0.37)	1.34(0.04)	2.65(0.13)	49.43(14.33)	55.85(3.43)
	15-30 cm	7.1(0.66)	0.76(0.27)	0.51(0.29)	0.88(0.34)	1.32(0.07)	2.54(0.16)	48.03(3.43)	45.87(3.15)
Mung-bean (S_4)	0- 15 cm	7.3(0.60)	0.41(0.25)	0.88(0.24)	1.52(0.32)	1.38(0.16)	2.59(0.14)	46.72(2.64)	50.12(5.25)
	15-30 cm	6.5(0.61)	0.32(0.29)	0.64(0.22)	1.10(0.34)	1.33(0.06)	2.54(0.16)	47.64(5.65)	44.21(3.15)
Maize (S_5)	0- 15 cm	6.9(0.68)	0.75(0.23)	0.56(0.26)	0.97(0.37)	1.4(0.05)	2.28(0.12)	38.60(8.56)	32.12(3.43)
	15-30 cm	7.2(0.6)	0.47(0.21)	0.63(0.24)	1.09(0.39)	1.43(0.12)	2.6(0.16)	45.00(7.92)	44.21(3.15)
Pasture (S_6)	0- 15 cm	7 (0.59)	0.35(0.29)	0.41(0.28)	0.71(0.34)	1.48(0.09)	2.56(0.11)	42.19(4.62)	32.12(8.56)
	15-30 cm	6.9(0.71)	0.54(0.30)	0.49(0.25)	0.84(0.31)	1.57(0.11)	2.69(0.13)	41.64(3.15)	28.21(5.25)

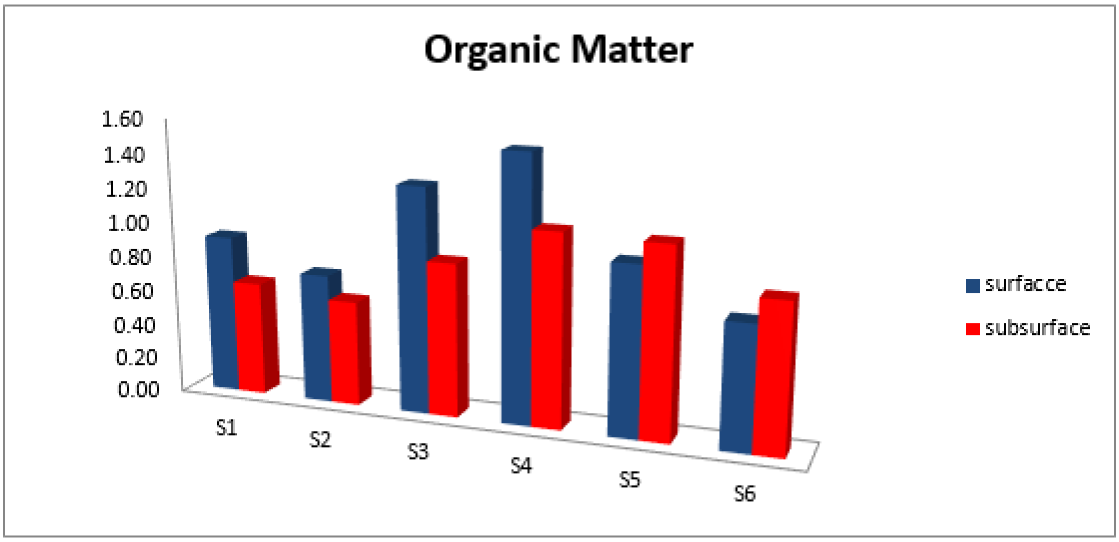


Fig. 2. Soil organic matter in different cropping system in surface and subsurface

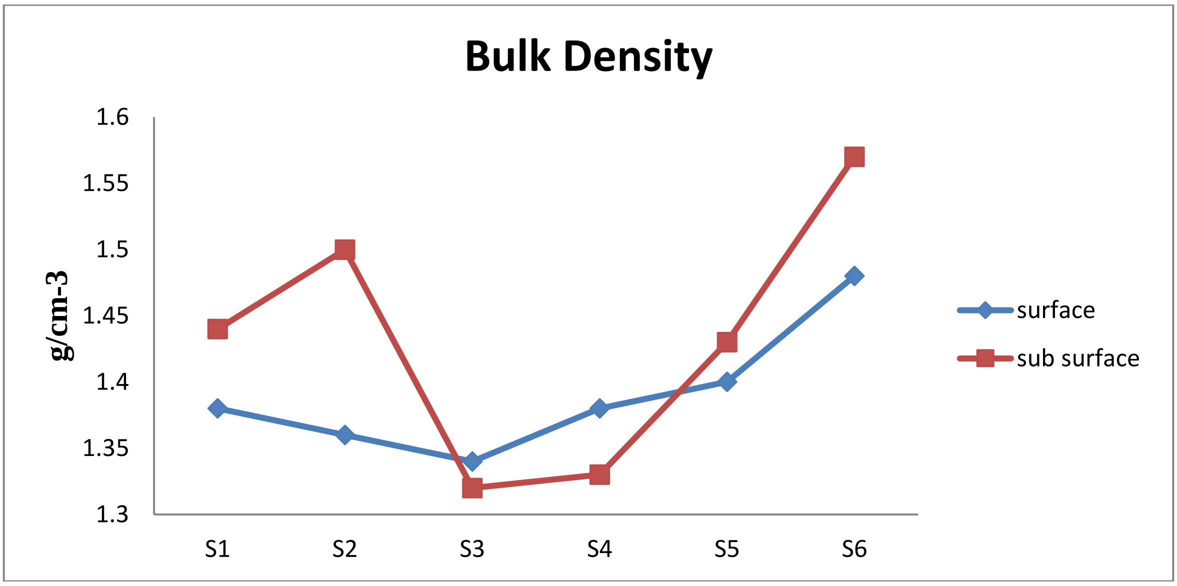


Fig. 3. soil bulk density in different cropping system

3.2 Status of Macronutrients

Highest values (568 Kg/ha and 480 Kg/ha) of Nitrogen was obtained from mung bean soil in the study area at the surface and subsurface soil levels (Table 4 and Fig. 4). Whereas, lowest values of Nitrogen were recorded in pearl millet and maize (260 Kg/ha and 329 Kg/ha) The highest values recorded in the mung bean because it is legumes crop those fix atmosphere N_2 and after harvesting crop roots also retained in soil those increase the N_2 level in soil [17]. Soil phosphorus of the different cropping system [Pearl millet (S_1), Sorghum (S_2), Ground nut (S_3), Mung-bean (S_4), Maize (S_5), Pasture (S_6)] varying surface layer from 26.5 to 14.2 Kg/ha and 26.4 to 15.9 Kg/ha in subsurface layer respectively 15.5 and 17.3 Kg/ha, 16.3 and 15.9 Kg/ha, 19.8 and 26.4 Kg/ha, 23.5 and 20.9 Kg/ha, 26.5 and 23.4 Kg/ha, 14.2 and 18.2 Kg/ha (Table 4 and Fig. 6). In surface layer highest phosphorus observed in Maize (26.5 Kg/ha) and subsurface in pasture (14.2 Kg/ha) while in subsurface highest observed in groundnut 26.4 Kg/ha and lowest observed in 15.9 Kg/ha [25].

Table 3. Nutrient rating of the soil test values

Parameters	Low	Medium	High
Organic carbon (%)	<0.5	0.5-0.75	>0.75
Available N (kg/ha)	<280	280-560	>560
Available P (kg/ha)	<12.5	12.5-25	>25
Available K (kg/ha)	<135	135-335	>335
Available S (kg/ha)	<10	10-20	>20
Deficient		Sufficient	
Calcium (Meq/100 g)	<1.0	>1.0	
Magnesium (Meq/100 g)	<1.5	>1.5	

Source: [25]

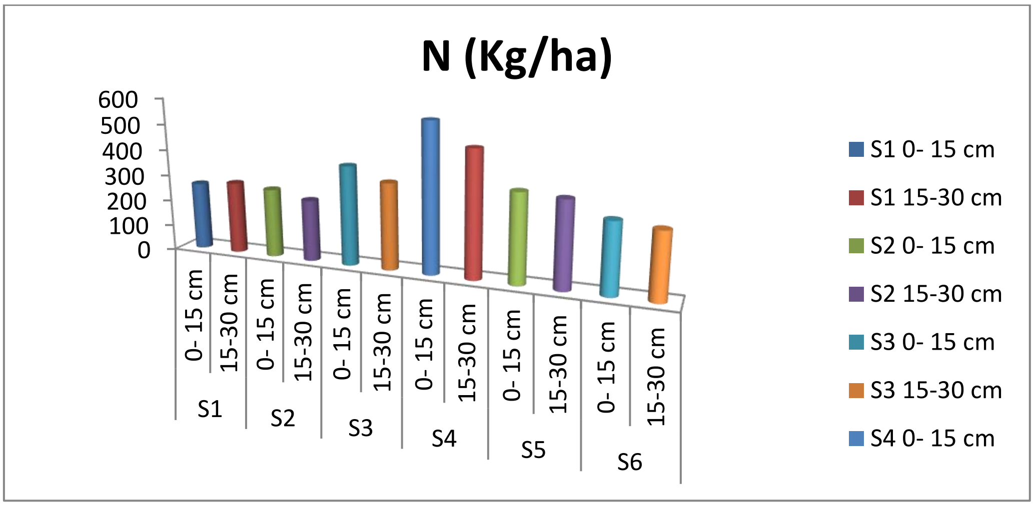


Fig. 4. Soil nitrogen status in different cropping system

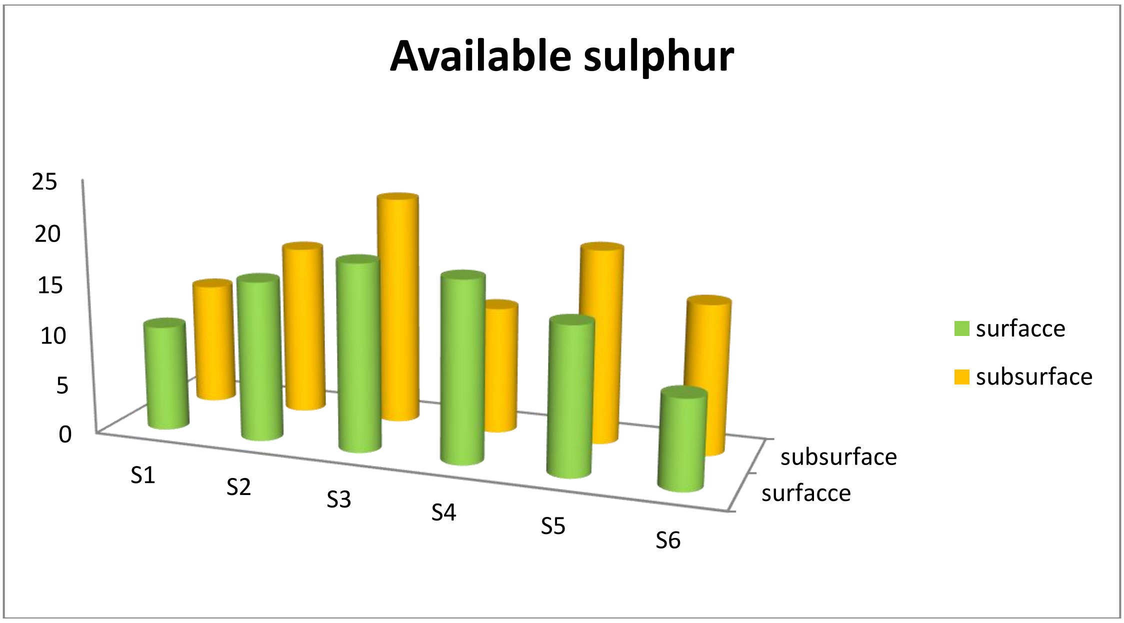
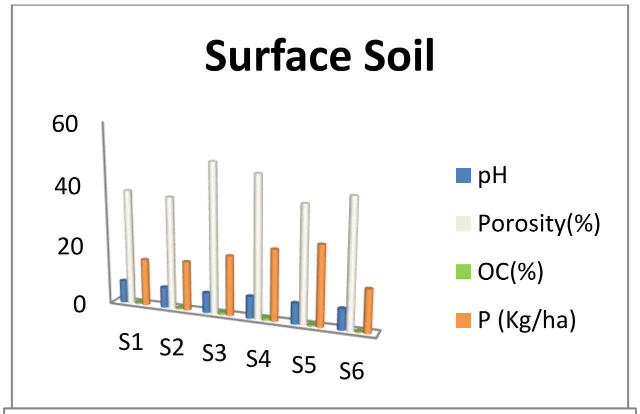


Fig. 5. Soil available sulphur in different cropping system

Table 4. Status of available macro nutrients viz. N, P, K, Ca, Mg, S, in the soil of Tonk District

Average Mean±Std of Soil Macro Nutrient Under Different Depth							
Cropping patterns	**Depth**	**N (Kg/ha)**	**P (Kg/ha)**	**K (Kg/ha)**	**S (Kg/ha)**	**Ca (Meq/100g)**	**Mg (Meq/100g)**
Pearl millet (S_1)	0- 15 cm	260(28.38)	15.5 (9.23)	315.21(28.48)	10.35(4.56)	14.06(5.55)	2.65(5.58)
	15-30 cm	275(22.35)	17.3(8.23)	310.75(33.58)	12.08(3.54)	8.24(8.45)	3.98(3.75)
Sorghum (S_2)	0- 15 cm	263(25.38)	16.3(3.67)	155.27(31.65)	15.69(2.79)	0.54(1.78)	5.06(4.46)
	15-30 cm	235(25.36)	15.9(8.69)	354.29(34.76)	16.76(5.37)	5.38(5.55)	4.06(1.78)
Ground nut (S_3)	0- 15 cm	380(28.33)	19.8(6.36)	174.92(32.56)	18.3(7.17)	2.56(3.26)	9.05(7.12)
	15-30 cm	330(29.37)	26.4(9.23)	224.02(43.56)	22.45(3.66)	16.43(2.93)	7.32(5.48)
Mung-bean (S_4)	0- 15 cm	568(26.34)	23.5(5.38)	124.36(31.56)	17.62(6.56)	8.04(5.48)	11.35(7.12)
	15-30 cm	480(27.32)	20.9(9.23)	254.95(35.39)	12.45(8.16)	12.09(6.23)	13.07(8.17)
Maize (S_5)	0- 15 cm	340(28.32)	26.5(9.23)	195.45(36.49	14.32(4.56)	0.45(4.17)	1.45(1.78)
	15-30 cm	329(23.39)	23.4(6.83)	310.85(38.48)	18.95(3.96)	5.36(7.12)	8.54(5.48)
Pasture (S_6)	0- 15 cm	270(22.30)	14.2(7.49)	145.98(33.87)	8.65(5.37)	0.48(7.32)	2.09(1.78)
	15-30 cm	254(21.31)	18.2(8.26)	198.45(33.13)	14.61(5.61)	19.54(7.24)	5.06(7.12)



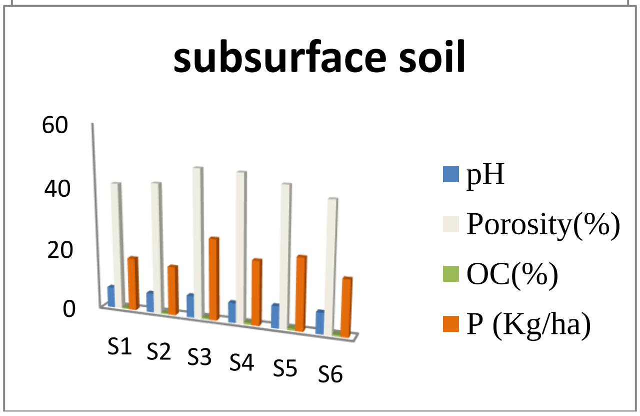


Fig. 6. physio- chemical characteristics of soil under different cropping system on surface and sub-surface layer

The sulphur content was found to be highest in the surface and subsurface layers of groundnut soil, with values of 18.3 Kg/ha and 22.45 Kg/ha respectively. On the other hand, the lowest sulphur content in the subsurface layer was observed in pasture soil, with 8.65 Kg/ha, and in pearl millet soil, with 12.8 Kg/ha. (Table 4 and Fig. 5). Because groundnut is an oily crop which has high sulphur requirements when sulphur fertilizers applied to it, some residue is left in the soil due to which the sulphur content was show high in groundnut soil sample [26].

The highest calcium and magnesium was observed in surface layer (14.06 Meq/100g and 11.35 Meq/100g) and lowest observed (0.45 Meq/100g and 1.45 Meq/100g) respectively. In subsurface layer, highest value observe (19.54 Meq/100g and 13.07 Meq/100g) and lowest note (5.36 Meq/100g and 3.98 Meq/100g) respectively.

3.3 Correlation between Physical and Chemical Properties of Soil

Correlation between physico-chemical properties and available macro-nutrients in soils shows in Table 5. The pH of the soil samples showed positive and significant correlation with EC (r = 0.548*) at 5% level of significance in overall sample observation and negative correlation with nitrogen (r = -0.162*) and phosphors (r = -0.256*). The EC of soil samples showed positive and significant correlation with nitrogen (r = 0.117*) and sulfur (r = 0.135**) at 5% and 1% level of significance in overall sample observation. OC of soil also showed positive and significant correlation with nitrogen (r = 0.874**), phosphors (r = 0.540**). The bulk density of soil samples showed negative and significant correlation with porosity (r = -0.319**), water holding capacity (r = -0.433**), calcium (r = -0.134**), at 5% and 1% level of significance. The particle density of soil samples showed positive and significant correlation with porosity (r = 0.745**) at 5% and 1% level of significance. The available nitrogen in soil samples showed negative and significant correlation with calcium (r = -0.624**) and potassium (r = -0.400**) and positively non-significant correlation with phosphorus (r = 0.547).

Table 5. Correlation between soil physico-chemical properties of Tonk District in Rajasthan

	pH	EC(ds/m)	OC (%)	BD (g cm^{-3})	PD (g cm^{-3})	Porosity (%)	WHC (%)	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	S (Kg/ha)	Ca (Meq/100g)	Mg (Meq/100g)
pH	1												
EC(ds/m)	0.548*	1											
OC (%)	0.381	-0.485	1										
BD (g cm^{-3})	-0.141	-0.140	0.444*	1									
PD (g cm^{-3})	-0.178	-0.567	0.276	0.394	1								
Porosity (%)	-0.081	-0.485	0.598	-0.319**	0.745**	1							
WHC (%)	-0.189	-0.095	0.480	-0.433	0.413**	0.738**	1						
N (Kg/ha)	-0.162*	0.499**	0.874**	-0.493	0.260	0.628	0.493	1					
P (Kg/ha)	-0.256*	0.039	0.540**	-0.407	0.128	0.435	0.241	0.547	1				
K (Kg/ha)	-0.244	0.160	-0.412	0.196	0.005	-0.125	0.190	-0.400	-0.169	1			
S (Kg/ha)	0.041	0.237**	0.351	-0.309	0.306	0.532	0.519	0.246	0.647**	-0.043	1		
Ca (Meq/100g)	0.211	-0.106	0.025	-0.134**	0.283	0.205	-0.056	-0.624**	0.109	0.258	0.122**	1	
Mg (Meq/100g)	-0.051	-0.481	0.720	-0.458	0.449	0.793	0.617	0.804**	0.390	-0.147	0.443	0.230	1

4. CONCLUSION

This study assessed the physico -chemical (pH, bulk density, available Nitrogen, Phosphorus, Potassium, organic matter, organic carbon and secondary nutrient) parameters of soil under different [Pearl millet (S_1), Sorghum (S_2), Ground nut (S_3), Mung-bean (S_4), Maize (S_5), Pasture (S_6)] cropping systems. According to result high macro nutrient observed in Ground nut and Mung-bean land as well as physical property also good as compare to other cropping system. Therefore, future land management practices should be such that will not impact these parameters as the bulk density currently recorded is above the tolerant limit for most crops cultivated in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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