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Impact of land use systems on soil phosphorus and potassium in Khammam district, Telangana state

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Abstract
Land use systems can have a significant impact on the availability of important soil nutrients like phosphorus and potassium. This study was conducted to assess the impact of different land use systems on soil phosphorus and potassium in Khammam district, Telangana State. Soil samples were collected from three depths i.e., 0-15 cm, 15-30 cm and 30-45 cm of seven major land use systems *viz.*, rice-rice, rice-pulse, rice-maize, cotton-fallow, chilli-fallow, mango orchard and forest. Two-way analysis of variance used to analyse phosphorus and potassium under different land use systems. Results unveiled that maximum phosphorus (40.87 kg ha^{-1}) content and potassium (316.64 kg ha^{-1}) content was recorded under forest land use system. Lower phosphorus content (27.65 kg ha^{-1}) was observed in cotton-fallow and lower potassium content (243.11 kg ha^{-1}) recorded under rice-rice system. This study conclude that different land uses have significant effect on soil phosphorus and potassium which lead to change in soil nutrient status.

Keywords: Phosphorus, potassium, land use systems, nutrients

1. Introduction

Successful agriculture depends on the sustainable management of soil resources, as soils can quickly degrade in quality and quantity due to various factors. Agricultural practices, therefore, necessitate a fundamental understanding of sustainable land use. Land use is often a key factor affecting soil properties. Practices related to land use and soil management impact soil nutrients and processes such as erosion, oxidation, mineralization, and leaching. Consequently, these practices can alter the transport and redistribution of nutrients (Celik *et al.*, 2005; Liu *et al.*, 2010) [1, 2]. Soil fertility is crucial for both agricultural productivity and sustainability. Phosphorus (P) and potassium (K) are two essential nutrients that significantly impact plant growth and development. The availability of these nutrients in the soil is affected by various land use systems, including different cropping patterns, management practices, and land cover types (Guo *et al.*, 2010; Singh *et al.*, 2018) [3, 4]. Potassium is the seventh most abundant element, making up approximately 2.1–2.3% of the Earth's crust (Zorb *et al.*, 2014) [5]. It is a crucial nutrient, essential for maintaining ionic balance, enhancing crop quality, and improving resistance to pests and diseases. In fact, the potassium requirements of many crops are equal to or even exceed those of nitrogen (Das *et al.*, 2019) [6]. Phosphorus (P) is considered one of the most critical limiting factors affecting plant growth and productivity. Phosphorus is a crucial element for the management and sustainability of upland land use systems. understanding P availability and cycling processes, examining P fertilizer application rates and methods, exploring management options, and developing techniques to study its availability, uptake, and cycling (Nagassa and Gebrekidan, 2003) [7]. Grasping the connection between land use and the levels of available soil phosphorus (P) and potassium (K) is crucial for crafting effective nutrient management strategies and enhancing overall soil health (Edmeados, 2003; Guo *et al.*, 2016) [8, 9]. This research aims to explore how different land use systems affect the availability of phosphorus and potassium in the soil. The findings from this research will contribute to the broader understanding of soil nutrient management and provide practical recommendations for maintaining soil health and productivity in diverse land use contexts.

2. Materials and Methods

A survey was conducted during 2023 in different land use systems (i.e., rice-rice, rice-pulse, rice-maize, cotton-fallow, chilli-fallow, mango and forest) in Khammam district, Telangana State which is situated between 16"45' and 18"35' of Northern Latitude and 79"47' and 80"47' of Eastern longitude. The climate of the region is semi-arid climate which receives an average rainfall of 1041.1 mm. The district experiences an average maximum temperature of 35.3 ◦C and minimum temperature of 23.0 ◦C with annual max. relative humidity varying from 81% to 93% and min. of 33% to 66%. Total of 210 soil samples were collected from 70 different sites (10 from each land use system) in three depths i.e., 0-15 cm, 15-30 cm and 30-45 cm. GPS points were recorded for each sampling. The collected samples were shade dried, processed and sieved for further analysis.

Collected soil samples were analysed for phosphorus and potassium. Available phosphorus was extracted from soil by Olsen's reagent as described by (Olsen *et al*., 1954) [10]. The blue colour was developed following ascorbic acid method and the intensity of blue colour was measured at 660nm wavelength by using spectrophotometer. The available phosphorus content was calculated and expressed in kg ha^{-1}. Available potassium was extracted from soil using neutral normal ammonium acetate and was determined by using flame photometer as described by (Jackson, 1973) [11] and expressed in kg ha^{-1}. The data was statistically analyzed following the method of two-way analysis of variance (ANOVA) technique (Snedecor and Cochran, 1967) [12] at 5 percent level of probability. Land use systems are considered as one factor, soil depths as another factor and interaction between soil depths and land use systems were carried out.

3. Results and Discussion

3.1 Available phosphorus

The phosphorus content under different cropping systems with average values varied from 27.65 to 40.87 kg ha^{-1}, 24.37 to 38.86 kg ha^{-1} and 20.56 to 35.66 kg ha^{-1} at 0-15 cm, 15-30 cm and 30-45 cm respectively under different land use systems (Table 1 and Figure 1). Phosphorus content among land use systems in the order of forest (40.87 kg ha^{-1}) > mango (37.83 kg ha^{-1}) > rice-pulse (35.39 kg ha^{-1}) > rice-maize (32.65 kg ha^{-1}) > rice-rice (30.40 kg ha^{-1}) > chilli-fallow (30.25 kg ha^{-1}) > cotton-fallow (27.65 kg ha^{-1}). Maximum phosphorus content (40.87 kg ha^{-1}) was observed in forest system and lowest phosphorus content (27.65 kg ha^{-1}) was observed in cotton-fallow system. Significant interaction between land use systems and depths was observed. These results are in conformity with (Tesfahunegn and Gebru, 2020) [13] who reported that forest land showed higher available P compared to other cropping systems which involve regular harvesting and removal of biomass, which can deplete soil phosphorus over time. Intensive cropping systems and the need for nutrient replenishment through fertilizers can also lead to phosphorus depletion. Soil levels of available phosphorus are notably concentrated in the top five centimetres and tend to decrease with increasing soil depth (Kouelo *et al*., 2020) [14]. These results are in conformity with (Hammad *et al*., 2020) [15a].

3.2 Available potassium

The potassium content with average values varied from 243.1 to 316.64 kg ha^{-1}, 219.23 to 296.96 kg ha^{-1} and 196.76 to 277.29 kg ha^{-1} at 0-15 cm, 15-30 cm and 30-45 cm respectively under different land use systems (Table 2 and Figure 2). Potassium content among land use systems follow the order of forest (316.64 kg ha^{-1}) > rice-pulse (296.56 kg ha^{-1}) > mango (290.74 kg ha^{-1}) > chilli-fallow (272.41 kg ha^{-1}) > cotton-fallow (258.05 kg ha^{-1}) > rice-maize (253.79 kg ha^{-1}) > rice-rice (243.11 kg ha^{-1}). Maximum potassium content (316.64 kg ha^{-1}) was observed under forest system and lowest potassium content (243.11 kg ha^{-1}) was observed under rice-rice system. There is no interaction between land use systems and depths. Forests have varied root systems that contribute to potassium uptake and redistribution. These root systems can enhance soil potassium availability through their interactions with soil minerals and organic matter. Available K_2O decreases with increase in depth. (Kostrzewska *et al*., 2022) [16] reported that crop rotation promotes accumulation of K and continuous cropping reduced the accumulation of available K_2O. These results are in accordance with (Sofi *et al*., 2016) [17]. The availability of K is influenced by the density of biomass (Hammad *et al*., 2020) [15b].

Available P and K decreases with increase in depth this might be due to accumulation of these nutrients in the topsoil, adsorption, leaching and cycling of these nutrients through plant uptake and decomposition.

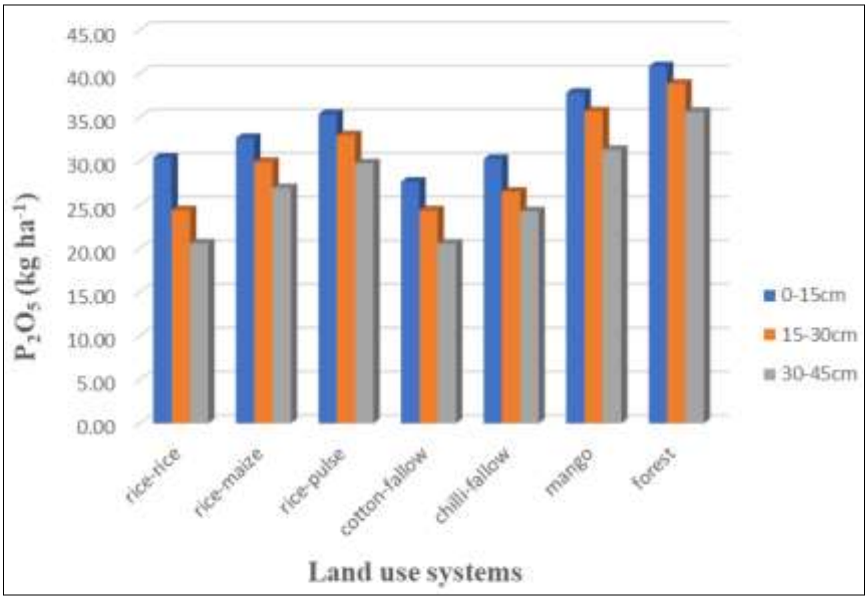

Fig 1: Available phosphorus (kg ha^{-1}) in soil under different land use systems

Table 1: Effect of different land use systems on available P_2O_5 (kg ha^{-1}) in soil at different depths

Land use system	Depth	1	2	3	4	5	6	7	8	9	10	Average
Rice-rice	0-15cm	25.93	36.37	29.43	27.45	34.3	33.21	32.43	23.08	37.46	24.29	30.40
	15-30cm	20.59	25.54	24.43	23.56	26.45	25.37	26.54	21.89	26.54	22.97	24.39
	30-45cm	17.94	20.54	20.79	20.74	20.32	20.93	21.64	19.76	23.24	19.98	20.59
Rice-maize	0-15cm	30.42	29.53	33.25	33.48	30.29	35.51	32.59	32.9	36.38	32.19	32.65
	15-30cm	27.87	26.54	30.26	30.21	28.61	33.28	29.9	28.45	33.28	30.68	29.91
	30-45cm	25.93	25.29	27.54	25.76	25.43	28.73	26.93	24.32	30.74	28.53	26.92
Rice-pulse	0-15cm	34.65	34.74	35.64	37.59	32.12	35.62	33.78	35.32	37.51	36.92	35.39
	15-30cm	33.29	31.83	31.84	34.52	29.79	33.96	30.41	33.84	35.64	34.61	32.97
	30-45cm	30.36	29.47	29.42	31.93	26.45	29.73	26.7	29.73	32.14	31.69	29.76
Cotton-fallow	0-15cm	28.9	25.75	27.65	28.6	25.76	29.69	25.84	26.09	30.7	27.56	27.65
	15-30cm	26.93	22.47	25.68	23.43	22.83	25.46	23.24	23.59	25.14	24.96	24.37
	30-45cm	22.32	20.56	22.89	19.64	19.74	20.15	20.19	19.54	20.32	20.23	20.56
Chilli-fallow	0-15cm	29.65	28.31	31.47	29.32	28.52	33.65	29.86	27.36	35.39	28.97	30.25
	15-30cm	25.83	24.02	26.59	27.74	25.14	29.01	26.18	23.43	30.67	26.52	26.51
	30-45cm	22.64	22.84	23.54	24.89	20.64	26.45	24.14	25.69	28.65	23.23	24.27
Mango	0-15cm	36.54	35.34	37.42	39.65	33.21	40.12	38.54	36.62	40.21	40.64	37.83
	15-30cm	35.98	33.89	32.13	37.91	30.28	38.73	36.15	34.75	38.69	38.57	35.71
	30-45cm	31.45	29.86	30.28	34.28	28.65	35.2	31.43	31.34	35.76	24.73	31.30
Forest	0-15cm	38.67	41.32	39.53	42.34	35.42	43.2	45.23	39.56	41	42.4	40.87
	15-30cm	36.45	39.98	37.23	40.54	33.13	40.32	43.21	37.45	39.54	40.75	38.86
	30-45cm	32.34	36.54	34.2	38.67	29.84	38.61	39.87	34.63	35.42	36.43	35.66
	S.Em ±	CD (5%)										
LUS	0.366	1.022										
Depth	0.240	0.669										
LUS X Depth	0.634	1.770										

Table 2: Effect of different land use systems on available K_2O (kg ha^{-1}) in soil at different depths

Land use systems	Depth	1	2	3	4	5	6	7	8	9	10	Average
Rice-rice	0-15cm	206.4	178.4	294.3	298.7	234.8	301.2	267.6	234.5	201.4	213.8	243.11
	15-30cm	191.5	160.8	223.1	273.4	219.6	289	234.2	219.2	188.1	193.4	219.23
	30-45cm	167.9	149.2	198.6	258.3	198.1	267.4	196.6	196.5	156.4	178.6	196.76
Rice-maize	0-15cm	298.6	287.5	201.4	276.3	276.4	209.1	256.4	302.1	198.7	231.4	253.79
	15-30cm	245	256.9	189.5	257.3	256.3	188.4	237.9	290.2	177.3	222.4	232.12
	30-45cm	234.2	239.6	165.4	239.3	239.5	168.4	214.5	269.5	156.8	204.3	213.15
Rice-pulse	0-15cm	347.4	334.8	300.1	298.5	276.7	269.4	267.9	278.4	289.2	303.2	296.56
	15-30cm	322.5	301.6	274.9	281.8	269	249.7	259.2	257.9	267.1	298.5	278.22
	30-45cm	305.4	278.1	249	267.5	243.5	228.4	222.4	234.6	245.6	267.4	254.19
Cotton-fallow	0-15cm	329.4	273.2	286.5	201.3	243.1	245.1	221.5	287.4	289.3	203.7	258.05
	15-30cm	309.5	243.7	266.8	189.6	220.5	221.4	209.6	265.4	273.5	188.6	238.86
	30-45cm	287.1	218.6	249.3	169.4	207.5	206.5	187.2	243.4	256.1	165.2	219.03
Chilli-fallow	0-15cm	332.1	289.5	256.4	267.4	267.4	257.6	245.9	269.4	293.2	245.2	272.41
	15-30cm	318.5	267.5	239.1	250.2	248.6	239.5	223.4	237.5	277.6	231.2	253.31
	30-45cm	298.6	249.2	219.7	239.5	229.7	205.4	212.3	218.6	263.1	219.5	235.56
Mango	0-15cm	278.4	314.3	324.4	267.4	298.6	284.4	278.5	280.5	258.5	322.4	290.74
	15-30cm	254.3	298.6	317.3	254.3	277.6	270.5	247.8	271.3	235.4	305.9	273.3
	30-45cm	236.5	267.2	300.9	235.2	258.3	258.5	217.3	260.4	214.5	295.4	254.42
Forest	0-15cm	357.4	300.5	336.8	298.5	278.4	316.7	301.7	323.7	320.2	332.5	316.64
	15-30cm	335.4	289.4	316.4	267.2	246.4	303.5	287.4	310.7	298.7	314.5	296.96
	30-45cm	314.8	267.8	298.6	245.1	231.3	287.1	267.5	294.6	276.4	289.7	277.29
	SEm ±	CD (5%)										
LUS	5.664	15.819										
Depth	3.708	10.356										
LUS X Depth	9.810	NS										

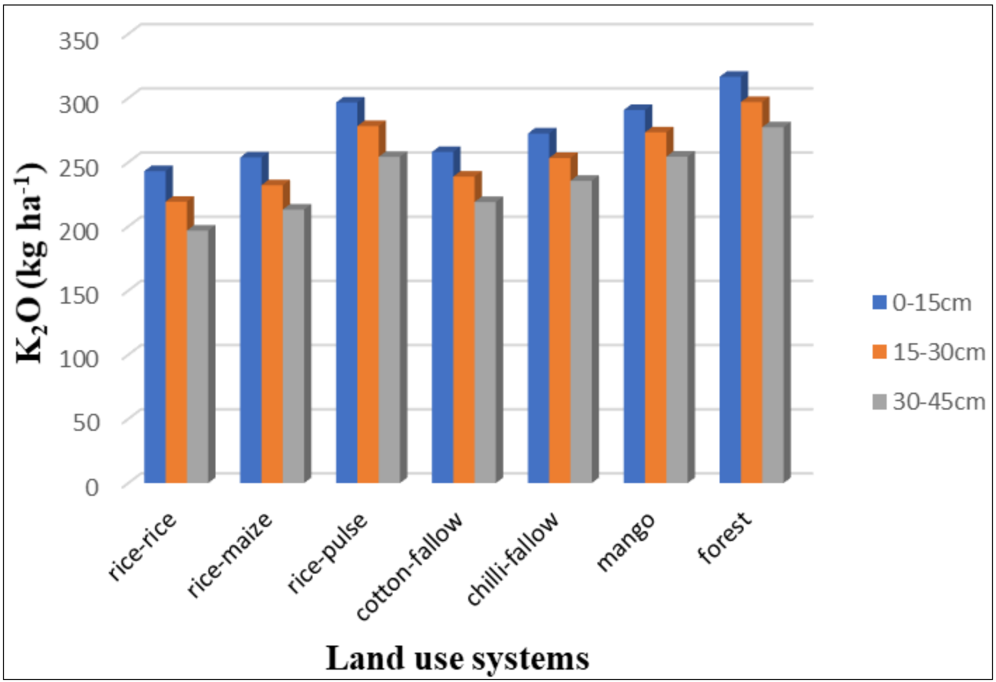

Fig 2: Available potassium (kg ha^{-1}) in soil under different land use systems

4. Conclusion

The results concluded that among the land use systems forest land use systems exhibited highest levels of available phosphorus and potassium. The cycling of nutrients through plant biomass, litter and soil organic matter helps to conserve soil P and K in forest ecosystems. These findings highlight the importance of preserving natural land cover such as forests to maintain soil fertility and nutrient cycling. Further research is needed to fully understand the complex interactions between land use systems and soil properties.

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