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Study of potassium fractions under different land use systems of Alnavar taluk of Dharwad district and their correlation with soil properties

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Abstract
In Alnavara Taluk of Dharwad District, the distribution of various potassium (K) forms were examined in four land use systems, including paddy, maize, sugarcane, and forest-based land use systems. The soils were acidic to neutral in reaction (5.35 to 6.10) in surface layer and slightly low pH was noticed in the soils of forest ecosystem. The EC is normal in range and the cation exchange capacity of the soils were low to medium (13.54 to 28.28 cmol (p+) kg^{-1}) and increased with depth in all the land use systems. The soils of the taluk were low to medium in organic carbon and medium to high in potassium contents. Higher SOC (1.88 to 10.52 g kg^{-1}) was recorded in the soils of forest ecosystem followed by sugarcane, maize and paddy based land use system. Among different land use systems sugarcane-based land use system recorded higher potassium fractions content i.e. WS-K (3.58 to 5.10 mg kg^{-1}), exchangeable-K (102.73 to 170.68 mg kg^{-1}), lattice-K (10222 to 11198 mg kg^{-1}) and total-K (10750 to 11750 mg kg^{-1}). All fractions of K were significantly and positively correlated with CEC except water soluble K. The water soluble-K was significantly and positively correlated with OC in all the land use systems. Vertical distribution of different forms of K revealed under different soil profiles, the water soluble, exchangeable, available and non exchangeable forms of potassium decreased with depth. Whereas, non-exchangeable K, total-K and lattice-K did increased with depth.

Keywords: Potassium fractoins, soil properties, water soluble-K, different land use systems

Introduction
The main nutrient and most abundant element in soil is potassium, however the amount of potassium in each soil varies depending on the physico-chemical properties of the soil. In soil, potassium may be found in a variety of forms, including water soluble, exchangeable, non-exchangeable, mineral, lattice, and total forms. In soils, these forms are dispersed in a variety of ways. Its concentration in soil is influenced by the parent substance and level of weathering. In contrast to water soluble K and exchangeable K, the levels of non-exchangeable K and total K in the soil are higher. The dynamics of potassium in soil are primarily controlled by the physico-chemical characteristics of the soil and depend on the degree of equilibrium between distinct forms. The majority of soil potassium (about 98% of the total K) often occurs in secondary (illite group) clay minerals and primary minerals (micas and feldspars) in an unusable state. Plants have easy access to accessible K and exchangeable K in general.

Material and Methods
Site description
Alnavar is located at 15.43°N 74.73°E. Its mean elevation is 563 metres (1847 feet)**.** The area falls under North Transition Zone (zone 8) of Karnataka and the average rainfall of Alnavar is 2423 mm.

Collection and analysis of soils
In each land use system one soil profiles were excavated from the identified area representing sugarcane, paddy, maize and forest-based land use systems in Alnavar taluk, respectively. Soil samples were collected and air dried in shade, ground with wooden mortar, passed through a 2 mm sieve and stored in polythene bags for analysis from different horizons to study physical and chemical properties and different fractions of potassium *viz;* water soluble-K, exchangeable-K, Non-exchangeable-K, lattice-K and total-K.

Results and Discussion

Physicochemical properties of soils

The data presented in Table 1 clearly revealed that, the particle size composition in soil profile under different land use systems was dominated by higher sand and clay content than silt content throughout the depth in all the land use systems. However, the sand content decreased with increasing depth, but clay content increased with increase in depth of soil profile of all land use system except forest-based land use system and silt content did not follow any trend.

The ranges of sand, silt and clay contents were 38.24 to 46.96 percent, 20.72 to 27.43 percent and 25.6 to 39.04 percent, respectively in profile of maize-based land use system. The range of sand, silt and clay observed in paddy-based land use system were 35.52 to 49.12 percent, 14.72 to 26.88 percent and 27.44 to 43.76 percent, respectively. On the contrast, the profile of the sugarcane-based land use system recorded higher sand content in the range of 38.96 to 57.28 percent, followed by clay in the range of 28.88 to 49.04 percent and silt with 6.72 to 13.84 percent, whereas in forest-based land use system the range of sand, silt and clay contents were observed to be 38.24 to 43.68 percent, 19.43 to 26.88 percent and 32.88 to 36.88 percent, respectively.

The pH values of profile soil samples ranged from 5.95 to 6.25 in maize-based land use system, 5.35 to 6.04 in paddy-based land use system, 6.10 to 6.79 in sugarcane-based land use system and 5.85 to 6.25 in forest-based land use system at different depth of profile. The soil pH of all the land use system increased with the depth of profile. The surface horizon soils recorded soil pH of 5.95, 5.35, 6.10 and 5.85 in maize, paddy, sugarcane and forest-based land use system, respectively indicating surface horizon soils were found to be acidic to neutral pH.

The electrical conductivity at different depths of profile varied from 0.52 to 1.05 dSm^{-1} in maize-based land use system, 0.38 to 0.93 dS m^{-1} in paddy-based land use system, 0.44 to 0.95 dS m^{-1} in sugarcane-based land use system and 0.29 to 1.01 dS m^{-1} in forest-based land use system. The electrical conductivity of all the land use system increased with the depth of profile. The surface soil under maize, paddy, sugarcane and forest-based land use systems recorded the EC values of 0.52 dS m^{-1}, 0.38 dS m^{-1}, 0.44 dS m^{-1} and 0.29 dS m^{-1}, respectively which showed within the normal range throughout the depth of profile.

Table 1: Physical and chemical properties in selected soil profiles of different land use systems in Alnavar taluk

Profile depth (cm)	Sand	Silt	Clay	Textural class	pH (1:2.5)	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	CEC [cmol(p+) kg^{-1}]
	%							
Maize-based land use system								
0-18	46.96	27.43	25.6	Sandy clay loam	5.95	0.52	5.31	17.70
18-45	44.96	24.88	30.16	Clay loam	6.03	0.74	3.22	23.34
45-80	42.96	20.72	36.32	Clay loam	6.11	0.97	1.98	23.99
80-120	38.24	22.72	39.04	Clay loam	6.25	1.05	1.33	28.28
Paddy-based land use system								
0-25	45.68	26.88	27.44	Sandy clay loam	5.35	0.38	6.80	17.06
25-60	49.12	14.72	36.16	Sandy clay	5.67	0.49	4.82	17.58
60-90	42.40	17.28	40.32	Clay	5.99	0.85	3.11	19.96
90-140	35.52	20.71	43.76	Clay	6.04	0.93	1.99	21.95
Sugarcane-based land use system								
0-27	57.28	13.84	28.88	Sandy clay loam	6.10	0.44	8.09	12.67
27-52	51.84	13.28	34.88	Sandy clay loam	6.19	0.53	5.63	16.57
52-95	49.12	6.72	44.16	Sandy clay	6.35	0.61	5.05	17.58
95-140	38.24	12.71	49.04	Clay	6.79	0.95	1.64	20.14
Forest-based land use system								
0-18	43.68	19.43	36.88	Clay loam	5.85	0.29	10.52	13.54
18-40	40.96	25.28	33.76	Clay loam	6.01	0.35	5.50	16.54
40-80	40.96	26.16	32.88	Clay loam	6.12	0.82	4.98	22.86
80-110	38.24	26.88	34.88	Clay loam	6.25	1.01	1.88	26.25

The status of organic carbon in profile soils at different depths ranged from 1.33 to 5.31 g kg^{-1} in maize-based land use system, 1.99 to 6.80 g kg^{-1} in paddy-based land use system 1.64 to 8.09 g kg^{-1} in sugarcane-based land use system and 1.88 to 10.52 g kg^{-1} in forest-based land use system. With the surface horizons, organic carbon content of maize, paddy, sugarcane and forest-based land use systems were 5.31 g kg^{-1}, 4.80 g kg^{-1}, 6.09 g kg^{-1} and 7.52 g kg^{-1}, respectively indicating higher organic carbon content is surface than in the sub-surface horizons.

The status of cation exchange capacity in profile soils at different depths ranged from 17.70 to 28.28 cmol(p+)kg^{-1} in maize-based land use system, 17.06 to 21.95 cmol(p+)kg^{-1} in paddy-based land use system, 12.67 to 20.14 cmol(p+)kg^{-1}in sugarcane-based land use system and 13.54 to 26.25 cmol(p+) kg^{-1} in forest-based land use system. With the surface horizons, CEC of maize, paddy, sugarcane and forest-based land use systems were 17.70 cmol(p+)kg^{-1}, 17.06 cmol(p+)kg^{-1}, 12.67 cmol(p+)kg^{-1} and 13.54 cmol(p+)kg^{-1}, respectively indicating low to medium CEC content is surface and sub-surface horizons.

Distribution of different forms of potassium in soils (Table 2)

1. Water soluble K

In general, water soluble potassium decreased with depth in all the profiles of different land use systems. The higher water soluble K ranging from 3.58 to 5.10 mg kg^{-1} was recorded in profile of sugarcane-based land use system followed by maize-based land use system profile 2.05 to 3.40 mg kg^{-1} and forest-based land use system 0.99 to 3.85 mg kg^{-1}. The lowest water soluble K was recorded in paddy-based land use system 1.08 to 2.99 mg kg^{-1}. Similar findings were reported by Das *et al*. (2000) [2] and Tarafdar and Mukhopadhyay (1986) [10]. In all the profiles, the surface horizon contained more water soluble K than the sub-surface. This may be due to application of K fertilizers or presence of higher organic matter content in the surface soil. In general, the vertical distribution pattern showed somewhat gradual decrease in depth of the profiles.

The water soluble potassium was high in surface soil of forest-based land use system as compared to sub-surface soils. The reason could be an upward translocation of K by capillary rise (Anil *et al*., 2009) [11] further, due to vegetation, litter fall, and high organic matter content in surface.

Among the different land use systems sugarcane recorded higher water soluble potassium due to frequent addition of potassic fertilizers and of organic manures and residues and incorporation of sugarcane trash under intensive cultivation might have led to higher water soluble K in these soils (Hebsur, 1997) [5].

2. Exchangeable potassium

This fraction was found to be maximum in samples of sugarcane-based land use system profile wherein it varied from 102.73 to 170.68 mg kg^{-1}. In maize and paddy-based land use system the exchangeable K content decreased up to certain depth thereafter it increased and lower depth showed higher content of exchangeable potassium wherein it varied from 98.45 to 158.55 mg kg^{-1} and 99.02 to 129.71 mg kg^{-1}, respectively. The irregular distribution of exchangeable K was observed in forest-based land use system profile which varied from 95.39 to 134.53 mg kg^{-1}.

When compared to sub-surface soil, sugarcane-based land use systems had more exchangeable potassium in the surface soil. This was mostly because K+ ions moved by capillary action from sub-surface to surface sites, which reduced exchange sites and increased compactness at lower depths. Due to increased agricultural residue levels and humus aggregation, surface soil has a larger exchangeable potassium concentration than subsurface soil. Application of potassium fertiliser to the surface soil and variations in the amount of clay. Similar findings were reported by Jagadeesh, Hebsur, and Gali (2011) [4], as well as Kaptan *et al* (2003) [9].

Higher Ex- K in surface soils of forest-based land use system may be due to the fact that rich organic matter and continuous litter fall.

3. Non-exchangeable K

The non-exchangeable K in soil under the maize, paddy, sugarcane and forest land use systems varied from 340.80 to 428.94 mg kg^{-1}, 354..30 to 548.87 mg kg^{-1}, 376.10 to 512.37 mg kg^{-1} and 385.49 to 432.83 mg kg^{-1}, respectively. The higher non-exchangeable potassium was recorded in profile of sugarcane-based followed by, forest, maize and paddy-based land use system, respectively.

Table 2: Vertical distribution K fractions (mg kg^{-1}) of selected soil profiles of different land use systems

Profile depth (cm)	Water soluble K	Exchangeable K	Non-exchangeable K	Lattice K	Total K
Maize-based land use system					
0-18	3.40	158.55	340.80	10747	11250
18-45	2.98	156.82	369.20	11271	11800
45-80	2.45	116.49	405.06	12676	13200
80-120	2.05	98.45	428.94	13370	13900
Paddy based -land use system					
0-25	2.99	129.71	354.30	7663	8150
25-60	2.75	118.58	398.67	8730	9250
60-90	2.54	110.19	548.87	9988	10650
90-140	1.08	99.02	527.90	11672	12300
Sugarcane-based land use system					
0-27	5.10	170.68	376.10	11198	11750
27-52	4.95	153.25	428.70	11763	12350
52-95	4.98	128.65	512.37	11304	11950
95-140	3.58	102.73	421.69	10222	10750
Forest based-land use system					
0-18	3.85	134.53	385.49	9076	9600
18-40	1.85	123.26	437.45	10187	10750
40-80	1.05	95.39	417.56	11436	11950
80-110	0.99	105.08	432.83	13211	13750

4. Lattice potassium

The lattice potassium content increased with depth in all the land use system wherein it varied from 10747 mg kg^{-1} to 13370 mg kg^{-1} in maize, 7663 to 11672 mg kg^{-1} in paddy, 10222 to 11763 mg kg^{-1} in sugarcane and 9076 to 13211 mg kg^{-1} in forest-based land use system, respectively.

5. Total potassium

The total K in profiles of different land use systems varied from 11250 to 13900 mg kg^{-1} in maize, 8150 to 12300 mg kg^{-1} in paddy, 10750 to 12350 mg kg^{-1} in sugarcane and 9600 to 13750 in forest-based land use system, respectively. However the total K increased with depth in profiles of maize, paddy and forest-based land use systems. However, depth-wise distribution of total K was irregular in profile of sugarcane-based land use system. The variation in the depth-wise distribution of total potassium depends on the relative effects of factors like soil texture, the rate of weathering of surface soils, the amount of organic carbon present, and the release of soluble potassium from organic residues, as well as the use of potassic fertilisers and the leaching of potassium to lower horizons. The outcomes are contrasted with study findings by Hebsur and Gali (2011) [4] and Jagmohan and Grewal (2014) [8].

Correlation between different forms of K and soil properties in profile of different land use system (Table 3)

In the profile distribution water soluble K was significantly

and positively correlated with sand and organic carbon this might be because of these soils were coarse textured in nature dominated by kaolinitic type of clays and had relatively higher amount of organic carbon compared to fine textured soils and, hence, had relatively higher water soluble K. These findings corroborate the findings of Adhikhari and Ghosh (1991) [12].
Exchangeable K shown a positive relation with CEC and pH, which may be explained by the fact that rising pH levels are likely to enhance CEC, which in turn may have raised exchangeable K. The relationship between EC and the non-exchangeable K was significant and positive. It appears that potassium soluble salts may have contributed to the EC. These outcomes concur with Tripathi *et al*. (1992) [13] conclusions.
The exchangeable, non-exchangeable, lattice and total K showed positive and significant correlation with pH in all the land use systems which was indicative of higher fixation of K at high pH values.
The sand fraction had a negative and significant correlation with total K, lattice K, and non-exchangeable K. It might be because sand particles lack fixation sites since they are coarse. The lattice K was significantly and positively correlated with clay, pH and CEC which may be due to presence of K bearing minerals in clay and as pH increases CEC also increases which in turn might have increased lattice K. Similar pattern was seen for total K, as shown by the correlation coefficients, which show that lattice K contributes significantly to total K as do finer fractions of soils rich in K-bearing minerals.

Table 3: Correlation between different forms of K and soil properties in profile of sugarcane-based land use system

Parameters	Sand	Silt	Clay	pH	EC	OC	CEC	K
Water soluble K	0.868*	0.547	-0.944*	-0.588	-0.376	0.862*	-0.597	0.215
Exchangeable K	0.011	0.576	0.720*	0.728*	-0.061	0.067	0.716*	0.989**
Non-exchangeable K	-0.412	-0.359	0.826*	0.866*	0.854*	-0.456	0.813*	0.215
Lattice-K	-0.755	-0.165	0.706*	0.846*	0.535	-0.582	0.731*	-0.141
Total –K	-0.765	-0.158	0.717*	0.855*	0.543	-0.589	0.745*	-0.151

Conclusions

The findings of this research revealed that, in comparison to other land use systems, sugarcane-based land use systems had higher potassium fractions content. WS-K and exchangeable-K fractions were also found to be higher in surface soil and lower in sub-surface soil, whereas non-exchangeable-K, lattice-K, and total-K were found to be higher in sub-surface layer in all land use systems. Water soluble K was significantly and positively correlated with sand and organic carbon. The exchangeable K showed a positively correlated with CEC and pH which may be due to fact that increases in pH results in increase in CEC, which in turn might have increased exchangeable K. The non-exchangeable K was significantly and positively correlated with EC. It seems that soluble salts of potassium may be contributed to the EC.
The sand fraction was negatively and significantly correlated with non-exchangeable K, lattice K and total K. The lattice K was significantly and positively correlated with clay, pH and CEC which may be due to presence of K bearing minerals in clay and as pH increases CEC also increases which in turn might have increased lattice K.
With the exception of water soluble potassium, clay and CEC have a substantial and favorable association with all types of potassium.

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