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Original Research Article

Secondary Nutrient Fractions and their Relationships with Soil Properties in Hebburu Micro-watershed of Chikkamagaluru District, Karnataka

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A B S T R A C T

Twenty five soil samples collected from six pedons under different land use were analyzed for different fractions of secondary nutrients. The exchangeable and total Ca increased with depth while water soluble Ca decreased with depth. The fractions of magnesium did not follow any trend with depth. The S fractions varied with a decreasing trend with depth of the profiles. Ca and Mg fractions showed positive and significant correlation with clay, pH, CEC and $CaCO_3$ and sulphur fractions showed positive and significant correlation with clay, PD, pH, OC and CEC.

Keywords

Secondary nutrient fractions, Soil properties, Clay, Organic carbon and CEC

Introduction

The distribution and forms of secondary nutrients accumulated in soils and their availability to plants has become important in recent years due to continued use of secondary nutrients free fertilizers and low rate of secondary nutrient fertilizer application. Under these conditions, mineralization of organic secondary nutrients will be the major source of secondary nutrients for crop production. Distribution of secondary nutrient forms and their interrelationship with few important soil characteristics decides the secondary nutrient supplying power of soil by governing their release and dynamics (Patel *et al.,* 2011).

Estimating status and depth wise distribution of secondary nutrient fractions and their relationship with soil physical and chemical properties are important to develop efficient secondary nutrient management strategies, especially in secondary nutrient deficient areas under different land uses. Since no work has been done regarding different fractions of secondary nutrients in Hebburu micro-watershed, the present study was undertaken to investigate the status and distribution of different fractions of secondary nutrients and their relationships with soil properties.

Materials and Methods

The study area is Hebburu micro-watershed of Ajjampura sub-watershed of Tarikere taluk, Chikkamagaluru district representing Southern Transition Zone of Karnataka, covering an area of 1037.59 ha. The climate of the study area is tropical climate with an average rainfall and elevation of the study area is 547 mm and 800.58 m above the Mean Sea Level (MSL), respectively. The relief is normally having nearly level (0-1%)

to very gently sloping (3-5 %) in the dominant black soils. The basalt, granite and schist rocks majorly cover the Hebburu micro-watershed area. The predominant mineral noticed in the area is chlorite schist.

Six representative soil profiles (pedons) P1, P2, P3, P4, P5 and P6 from the Hebburu micro-watershed under different land use *viz.*, coconut, arecanut, onion, chilli, ragi and bengal gram, respectively were exposed and the horizon-wise soils were studied and analyzed for physical and chemical properties of soils using standard procedures. The soil samples were analyzed for calcium and magnesium fractions *viz.,* exchangeable, Water soluble, Non-exchangeable and Total calcium and magnesium by using standard procedures (Jackson, 1973) and sulphur fractions *viz.,* sulphate, water soluble and heat soluble sulphur sulphur (Williams and Steinbergs, 1959), organic sulphur (Bardsley and Lancaster, 1965) and total sulphur (Tabatabai, 1982). The non-sulphate sulphur was obtained by substracting sulphate S, organic S, water soluble S and heat soluble S from total S. Simple correlations were worked out between secondary nutrient fractions and physical and chemical properties of the soil by standard statistical method (Sundararaj *et al.,* 1972).

Results and Discussion

The results on physical, chemical properties, calcium fractions, magnesium fractions and sulphur fractions of soils are given in the table 1, 2, 3, 4 and 5, respectively.

Calcium fractions

The exchangeable Ca was increased with increase in depth under different land use except under ragi land use. The exchangeable calcium content was higher in lower depths of profiles as compared to surface layers. This could be attributed to leaching of bases from surface to subsurface and adsorption of the cations by high clay content in the subsurface soils as reported by Ashok (1998), Anil *et al.,* (2008) and Mandal *et al.,* (2008). The water soluble Ca and non-exchangeable Ca was varied with a tendency of decrease in increase with depth under different land use. Total Ca increased with increase in depth of all the profiles under different land use. This could be attributed to leaching of bases from surface to subsurface and adsorption of the cations by high clay content in the subsurface (Ashok, 1998).

Exchangeable Ca showed a positive and significant correlation with clay, pH, CCE and CEC. Water soluble Ca showed a positive correlation with clay, PD, pH, OC, CCE, CEC and exchangeable Ca and negative correlation with BD. Non-exchangeable Ca showed a positive and significant correlation with clay, pH, CCE, CEC, exchangeable Ca and water soluble Ca Total Ca showed a positive and significant correlation with clay, pH, CCE, CEC, exchangeable Ca, and non-exchangeable Ca. Exchangeable Ca was positively and significantly correlated with exchangeable Mg, CEC and clay, while similar correlations both in magnitude and directions were observed between exchangeable Mg. Most of the soil properties correlated with exchangeable Ca which is attributed due to clay content in soils having higher base cations as observed the similar results of Gebeyaw (2015).

Magnesium fractions

Exchangeable Mg was second dominant cation after the calcium in soil exchange complex in all the profile soils. The exchangeable Mg content was higher in lower depths of profiles as compared to surface layers as also reported by Verma *et* *al.,* (2013). This could be attributed to leaching of bases from surface to sub surface and adsorption of the cations by higher content of clay in the sub surface similar results were made by Ashok (1998).The fractions of Mg did not follow definite trend with increase in depth of profiles under different land use. The irregular trend in the increase or decrease of exchangeable Mg content with soil depth under different land uses were also reported by Ashok (1998), Anil *et al.,* (2008) and Mandal *et al.,* (2008).

Exchangeable Mg showed a positive and significant correlation with clay, pH, and CEC and negatively significant correlation with PD. Water soluble Mg showed a showed a positive and significant correlation with PD and OC and negatively significant correlation with exchangeable Mg. Non-exchangeable Mg showed a negative and significant correlation with CCE. Total Mg showed a positive and significant correlation with clay, BD, pH, CEC, exchangeable Mg and non-exchangeable Mg and negatively significant correlation with water soluble Mg.

Sulphur fractions

The fractions of S varied with a decreasing trend in with increase depth of profiles under different land use. The lower values of suphate sulphur may be due to differences in soil and decreased with depth was due to low organic carbon content (Sarkar *et al.,* 2007) and also reported that reducing microbial population are the possible reasons for such decreasing trend. Similar results of decreases in sulphate S with depth are also reported by Patel and Patel (2008) and Patel *et al.,* (2011) in soils from Gujarath.

The results revealed that lower values of organic sulphur was generally recorded in sub-surface horizon than surface horizon as reported by Patel and Patel (2008) in South Gujarath and Jat and Yadav (2006) in Jaipur district of Rajasthan due to carbon bonded sulphur organic sulphur constituted 70 per cent of total indicate that it forms stable and reserve pool and could only be available after mineralization. Similar results were also reported by Sarkar *et al.,* (2007). Organic S was the dominant form followed by non-sulphate S and sulphate-S in all the profiles studied as reported by Singh and Room Singh (2007).

The lower content of water soluble sulphur with depth might be due to leaching loss of sulphate from the soils indicates that sulphate loosely bound to exchangeable sites which could be dissolved easily by distilled water and results of lower values of total sulphur in soils with depth might be associated with lower amounts of clay and organic carbon with depth of profiles were made by Patel and Patel (2008) and Patel *et al.,* (2011) in South Gujarath and Das *et al.,* (2012) in Assam. The results of heat soluble sulphur than water soluble with depth might be due to release of additional amount of sulphur from organic as well as clay particles on wet and dry heating of soil during extractions. Heating of soil may liberate greater amount of sulphate sulphur covalently bonded to organic matter. Similar observations have also been reported by Singh *et al.,* (2006), and Patel *et al.,* (2011).

The results found that total sulphur followed a decreasing trend with increase depth of profiles under different land use. These observations are in agreement with those of Patel *et al.,* (2011). The considerable variation in the total S values in the soils might be due to varying cropping system and parent materials as reported by Jat and Yadav (2006) and Patel *et al.,* (2011)

Lower non- sulphate S in the soils of high S category might be due to their slightly lower pH and higher organic matter contents.

Table.1 Physical properties of pedons under different land use

Horizon	Depth (cm)	Particle size distribution (%)			Textural class	Bulk density	Particle density
		Sand	Silt	Clay		← (Mg m^{-3})	→
Pedon 1 - Coconut land use							
Ap	0-18	42.97	13.01	44.02	Clay	1.31	2.59
Bt_1	18-48	33.56	12.11	54.33	Clay	1.60	2.40
Pedon 2 - Arecanut land use							
Ap	0-23	30.25	15.00	54.75	Sandy clay loam	1.49	2.65
AB	23-60	51.89	01.98	46.13	Sandy clay	1.65	2.59
Bt	60-102	53.16	04.88	41.96	Sandy clay loam	1.71	2.41
CB	102-132	68.30	09.10	22.40	Sandy clay loam	1.79	2.32
Pedon 3 - Onion land use							
Ap	0-11	45.92	11.50	42.58	Clay	1.78	2.51
B	11-49	44.20	11.40	44.40	Clay	1.54	2.28
Bt_1	49-79	44.00	08.00	48.00	Clay	1.45	2.19
Bt_2	79-110	36.37	09.25	54.38	Clay	1.45	2.18
Bt_3	110-131	34.69	08.45	56.86	Clay	1.27	1.97
Pedon 4 - Chilli land use							
Ap	0-17	34.70	19.00	46.30	Clay	1.23	2.28
Bw_1	17-36	32.98	18.60	48.42	Clay	1.25	2.21
Bs_1	36-67	32.60	17.80	49.60	Clay	1.65	1.99
Bs_2	67-96	28.91	10.50	60.59	Clay	1.77	1.95
Pedon 5 - Ragi land use							
Ap	0-16	59.57	03.33	37.10	Sandy clay	1.06	2.65
Bt_1	16-43	51.31	04.10	44.56	Sandy clay	1.19	2.19
Bt_2	43-76	68.60	13.70	17.70	Sandy loam	1.23	2.12
Bt_3	76-104	69.87	14.98	15.15	Sandy loam	1.36	1.96
Bt_4	104-131	70.40	15.40	14.20	Sandy loam	1.41	1.78
Pedon 6 – Bengal gram land use							
Ap	0-20	60.27	05.90	33.83	Clay	1.39	2.50
Bs_1	20-36	50.20	08.50	41.30	Clay	1.48	2.41
Bs_2	36-60	48.85	05.31	45.84	Clay	1.49	2.40
Bs_3	60-83	33.56	12.11	54.33	Clay	1.62	2.20
Bs_4	83-110	32.21	13.93	53.86	Clay	1.66	2.04

Table.2 Chemical properties of pedons under different land use

Horizon	Depth (cm)	pH	EC (dS m^{-1})	Organic carbon	CCE	CEC [cmol (p^+) kg^{-1}]
				← (g kg^{-1})	→	
Pedon 1 - Coconut land use						
Ap	0-18	7.44	0.30	9.00	50.01	62.50
Bt_1	18-48	7.89	0.31	6.60	21.50	82.11
Pedon 2 - Arecanut land use						
Ap	0-23	8.15	0.56	8.33	50.05	88.15
AB	23-60	7.99	0.43	7.25	41.23	63.80
Bt	60-102	8.17	0.54	5.98	22.10	57.20
CB	102-132	8.07	0.49	5.70	51.00	46.15
Pedon 3 - Onion land use						
Ap	0-11	7.71	0.48	7.80	80.19	34.95
B	11-49	7.97	0.41	6.60	72.50	60.20
Bt_1	49-79	8.03	0.36	4.40	80.11	61.35
Bt_2	79-110	8.02	0.35	4.40	71.00	77.20
Bt_3	110-131	8.05	0.40	3.39	71.51	79.45
Pedon 4 - Chilli land use						
Ap	0-17	8.42	0.27	6.00	60.12	75.45
Bw_1	17-36	8.25	0.25	6.00	70.33	74.23
Bs_1	36-67	8.21	0.31	4.40	50.02	82.19
Bs_2	67-96	8.04	0.32	3.80	81.24	83.47
Pedon 5 - Ragi land use						
Ap	0-16	5.45	0.13	6.90	52.31	15.76
Bt_1	16-43	5.45	0.09	4.20	51.22	13.64
Bt_2	43-76	5.41	0.07	4.20	51.05	13.20
Bt_3	76-104	4.99	0.09	3.10	51.01	12.55
Bt_4	104-131	4.84	0.09	2.30	50.09	12.44
Pedon 6 – Bengal gram land use						
Ap	0-20	8.01	0.45	6.60	80.36	78.92
Bs_1	20-36	8.18	0.33	6.60	72.65	79.13
Bs_2	36-60	8.22	0.34	6.60	71.66	80.58
Bs_3	60-83	8.27	0.37	5.10	81.37	81.62
Bs_4	83-110	8.34	0.45	5.30	70.09	79.99

Table.3 Calcium fractions in pedons under different land use

Horizon	Depth (cm)	Exch. Ca	Water soluble Ca	Non – exch. Ca	Total Ca
		← [cmol (p^+) kg^{-1}] →			
Pedon 1 - Coconut land use					
Ap	0-18	27.40	2.80	17.50	51.25
Bt_1	18-48	44.70	2.50	24.50	74.50
Pedon 2 - Arecanut land use					
Ap	0-23	12.20	2.00	03.60	22.51
AB	23-60	16.60	2.00	04.50	23.39
Bt	60-102	11.50	1.70	08.00	25.27
CB	102-132	17.80	1.70	14.80	36.91
Pedon 3 - Onion land use					
Ap	0-11	50.00	2.00	13.50	67.32
B	11-49	59.40	2.00	15.50	76.99
Bt_1	49-79	63.00	2.10	19.00	83.10
Bt_2	79-110	59.50	2.00	21.90	91.40
Bt_3	110-131	57.10	2.00	19.90	96.90
Pedon 4 - Chilli land use					
Ap	0-17	43.11	2.65	18.00	66.30
Bw_1	17-36	43.45	2.51	20.60	67.40
Bs_1	36-67	44.98	2.52	20.90	65.40
Bs_2	67-96	45.55	2.30	22.90	68.99
Pedon 5 - Ragi land use					
Ap	0-16	7.80	2.24	5.80	14.40
Bt_1	16-43	7.88	2.10	7.70	16.69
Bt_2	43-76	7.85	2.00	5.50	18.58
Bt_3	76-104	6.99	2.00	5.00	20.59
Bt_4	104-131	4.33	2.00	6.00	25.34
Pedon 6 – Bengal gram land use					
Ap	0-20	45.30	2.30	30.20	67.60
Bs_1	20-36	46.20	2.30	21.30	69.99
Bs_2	36-60	47.00	2.40	22.00	71.52
Bs_3	60-83	44.30	2.30	23.10	74.56
Bs_4	83-110	43.50	1.70	22.40	76.88

Table.4 Magnesium fractions in pedons under different land use

Horizon	Depth (cm)	Exch. Mg	Water soluble Mg	Non – exch. Mg	Total Mg
		←	[cmol (p^+) kg^{-1}]		→
Pedon 1 - Coconut land use					
Ap	0-18	7.10	1.70	7.00	14.85
Bt_1	18-48	7.40	1.50	5.30	16.23
Pedon 2 - Arecanut land use					
Ap	0-23	8.60	1.90	09.90	20.40
AB	23-60	8.60	1.90	10.10	20.60
Bt	60-102	8.80	1.30	18.10	28.20
CB	102-132	8.10	0.80	16.90	26.89
Pedon 3 - Onion land use					
Ap	0-11	16.80	1.40	2.80	19.10
B	11-49	12.60	1.40	7.70	21.50
Bt_1	49-79	10.10	1.20	6.80	19.82
Bt_2	79-110	19.70	1.00	7.30	30.70
Bt_3	110-131	24.00	1.10	8.10	33.30
Pedon 4 - Chilli land use					
Ap	0-17	15.00	0.70	6.40	24.50
Bw_1	17-36	13.30	0.70	8.20	23.61
Bs_1	36-67	23.70	0.80	6.90	31.51
Bs_2	67-96	24.20	0.70	2.60	32.15
Pedon 5 - Ragi land use					
Ap	0-16	3.50	1.60	8.70	13.90
Bt_1	16-43	6.60	1.60	5.10	12.50
Bt_2	43-76	7.20	1.50	3.50	11.85
Bt_3	76-104	4.80	1.33	2.30	08.69
Bt_4	104-131	4.30	0.98	0.60	05.80
Pedon 6 – Bengal gram land use					
Ap	0-20	04.30	1.70	2.60	08.60
Bs_1	20-36	04.80	1.56	4.40	10.76
Bs_2	36-60	09.80	1.41	5.90	17.11
Bs_3	60-83	13.90	1.40	3.60	19.98
Bs_4	83-110	18.00	1.10	9.10	28.68

Table.5 Sulphur fractions in pedons under different land use

Horizon	Depth (cm)	Sulphate S	Organic S	Water soluble S	Heat soluble S	Non – sulphate S	Total S
		← (mg kg^{-1}) →					
Pedon 1 - Coconut land use							
Ap	0-18	5.48	239.04	2.22	2.17	49.89	298.80
Bt_1	18-48	3.96	226.04	2.12	2.13	48.30	282.55
Pedon 2 - Arecanut land use							
Ap	0-23	7.33	248.11	3.69	2.22	39.74	301.09
AB	23-60	6.99	232.60	3.51	2.18	37.05	282.33
Bt	60-102	6.51	216.93	2.98	2.17	32.59	262.28
CB	102-132	5.59	196.15	2.60	2.12	32.14	241.60
Pedon 3 - Onion land use							
Ap	0-11	4.66	224.58	2.83	2.13	40.20	274.40
B	11-49	4.52	212.73	2.86	2.15	38.99	261.25
Bt_1	49-79	4.49	208.67	2.36	2.14	39.46	257.12
Bt_2	79-110	4.33	188.92	2.35	2.12	35.90	233.62
Bt_3	110-131	4.30	177.59	2.03	2.11	35.96	221.99
Pedon 4 - Chilli land use							
Ap	0-17	3.93	168.65	1.86	2.09	34.42	206.89
Bw_1	17-36	3.65	161.33	1.85	2.08	32.75	199.21
Bs_1	36-67	3.11	159.25	1.67	2.10	30.36	198.88
Bs_2	67-96	2.98	152.48	1.57	2.09	30.30	193.55
Pedon 5 - Ragi land use							
Ap	0-16	2.99	136.55	2.72	1.98	31.28	168.51
Bt_1	16-43	2.58	132.29	2.01	1.95	29.97	168.10
Bt_2	43-76	2.11	128.71	2.00	1.66	28.10	160.53
Bt_3	76-104	1.95	124.39	1.84	1.52	26.05	157.82
Bt_4	104-131	1.73	120.33	1.37	1.51	24.27	156.22
Pedon 6 – Bengal gram land use							
Ap	0-20	4.32	184.92	2.02	2.08	35.85	226.19
Bs_1	20-36	4.33	181.69	2.04	2.12	34.66	222.84
Bs_2	36-60	4.26	176.81	1.96	2.08	33.55	221.66
Bs_3	60-83	4.19	174.10	1.85	2.06	32.43	217.63
Bs_4	83-110	4.06	165.82	1.92	2.11	32.36	207.27

Table.6 Correlation co-efficient (r) between calcium fractions and selected soil properties under different land use

Parameters	Clay	BD	PD	pH	OC	CCE	CEC	Exch.Ca	WS-Ca	NE-Ca
BD	0.221	1.000								
PD	0.154	-0.016	1.000							
pH	0.707**	0.517**	0.262	1.000						
OC	0.282	-0.126	0.897**	0.433*	1.000					
CCE	0.248	0.008	-0.187	0.283	-0.091	1.000				
CEC	0.771**	0.364	0.143	0.907**	0.320	0.269	1.000			
Exch.Ca	0.619**	0.233	-0.098	0.698**	0.062	0.645**	0.677**	1.000		
WS-Ca	0.267	-0.340	0.167	0.152	0.239	0.082	0.319	0.267	1.000	
NE- Ca	0.497*	0.214	-0.109	0.644**	0.054	0.517**	0.713**	0.818**	0.423*	1.000
Total Ca	0.605**	0.221	-0.197	0.680**	-0.010	0.609**	0.699**	0.973**	0.260	0.864**

****** Correlation is significant at 1 per cent level of significance
***** Correlation is significant at 5 per cent level of significance

Table.7 Correlation co-efficient (r) between magnesium fractions and selected soil properties under different land use

Parameters	Clay	BD	PD	pH	OC	CCE	CEC	Exch. Mg	WS-Mg	NE- Mg
BD	0.221	1.000								
PD	0.154	-0.016	1.000							
pH	0.707**	0.517**	0.262	1.000						
OC	0.282	-0.126	0.897**	0.433*	1.000					
CCE	0.248	0.008	-0.187	0.283	-0.091	1.000				
CEC	0.771**	0.364	0.143	0.907**	0.320	0.269	1.000			
Exch. Mg	0.631**	0.338	-0.429*	0.507**	-0.232	0.395	0.503*	1.000		
WS-Mg	-0.057	-0.153	0.666**	-0.189	0.526**	-0.222	-0.139	-0.593**	1.000	
NE-Mg	0.134	0.253	0.340	0.383	0.311	-0.424*	0.166	0.013	-0.061	1.000
Total Mg	0.637**	0.420*	-0.195	0.647**	-0.058	0.117	0.555**	0.851**	-0.560**	0.517**

****** Correlation is significant at 1 per cent level of significance
***** Correlation is significant at 5 per cent level of significance

Table.8 Correlation co-efficient (r) between sulphur fractions and selected soil properties under different land use

Parameters	Clay	BD	PD	pH	OC	CCE	CEC	SO_4-S	Org. S	WS-S	HS-S	NS-S
BD	0.221	1.000										
PD	0.154	-0.016	1.000									
pH	0.707**	0.517**	0.262	1.000								
OC	0.282	0.126	0.897**	0.433*	1.000							
CCE	0.248	0.008	-0.187	0.283	-0.091	1.000						
CEC	0.771**	0.364	0.143	0.907**	0.320	0.269	1.000					
SO_4-S	0.386	0.414*	0.674**	0.648**	0.684**	-0.162	0.491*	1.000				
Org. S	0.436*	0.442*	0.662**	0.641**	0.725**	-0.134	0.503*	0.890*	1.000			
WS-S	0.138	0.209	0.726**	0.215	0.614**	-0.276	0.032	0.798**	0.708**	1.000		
HS-S	0.776**	0.370	0.554**	0.865**	0.642**	0.139	0.739**	0.755**	0.758**	0.478*	1.000	
NS-S	0.478*	0.123	0.605**	0.484*	0.698**	-0.083	0.446*	0.575**	0.843**	0.411*	0.660**	1.000
TS	0.445*	0.447*	0.641**	0.635**	0.714**	-0.134	0.508	0.873**	0.998**	0.679**	0.750**	0.860**

****** Correlation is significant at 1 per cent level of significance
***** Correlation is significant at 5 per cent level of significance

Under these conditions, there is possibility of continuous break down of the non-sulphate S in surface layer with its subsequent leaching to sub-horizons. Takkar, (1987), Kumar and Singh (1999), Jat and Yadav (2006) and Patel *et al.,* (2011) also reported similar findings in different soils.

All the forms of S, *viz.*, sulphate S, organic S, water soluble S, heat soluble S, non sulphate S and total S showed a positive and significant correlation with BD, PD, pH, OC and CEC, positive correlation with clay and negative correlation with CCE irrespective of different land use. The relationships studies between soil properties and various fractions of sulphur, revealed that, have a positive and significant correlation with organic carbon could be thought of as a good S-reservoir in the soils (Das *et al.*, 2012). Positive and significant relations of S fractions with soils properties are reported by Sarkar *et al.,* (2007) in Alfisols of West Bengal, Singh and Room Singh (2007) in soils of Uttar Pradesh and Patel *et al.,* (2011) in some soils of Gujarath.

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