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RESEARCH PAPER

Total elemental composition and primary particle size distribution of soils in relation to parent rocks and landforms

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Abstract: A study on total elemental composition of soil primary particles in relation to parent rocks and landforms in Gadag (*taluk*), Karnataka was conducted during 2018-19. Horizon-wise soil samples were collected and analysed for major and trace elements content in sand, silt and clay. Granite gneiss derived upland soils were higher in sand fractions than schist and decreased with depth. The silt fraction in lowland soils of granite gneiss were higher than schist. The depth wise silt distribution was irregular. Clay fraction was higher in schist derived lowland soils than granite gneiss and increased with depth in most of the pedons. The sand fraction had higher total content of Si and K, while total content of Al, Fe, Ca, P, Mg, S and Mn were higher in clay fraction and these elemental contents increased with depth except Si, which remained higher in surface horizons. Total content of Si, Al and K were higher in granite gneiss derived lowland soils than schist, whereas total content of Fe, Ca, P, Mg, S and Mn were higher in schist derived lowland soils than granite gneiss. The relative dominance of elements in granite gneiss derived soil particles in decreasing order was, Si followed by Al, Fe, K,Ca, Mg, P, S and Mn.Whereas in schist, Si was followed by Al, Fe,Ca,K,Mg, P, Mn and S. The total content of all the elements in soil particles increased from upland to lowland irrespective of parent rocks.

Key words: Landforms, Parent rocks, Soil primary particles, Total elemental composition

Introduction

Soil may be defined as a natural body, synthesized in profile from a variable mixture of broken weathered minerals and decayed organic matter. Soils cover the earth in a thin layer and which supplies nutrients, air and water and provide mechanical support to plants. Soil formation is influenced by four factors, which interact with the parent material to produce the soil profile during the soil formation process (Harlan and Franzmeier, 1977). Climate, time, topography, organisms (both plants and animals) and the parent material interact amongst each other to develop a vertical section of the soil called a profile. It is important to study the chemical and physical composition of the soil in order to outline their origin, characters and economical usage.

A holistic understanding of environmental behaviour of major elements in soils should not only be limited to total element content in bulk soils but also include their concentration in different solid phases in soils. The physical fractionation separates the bulk soil into three groups like clay (<2 µm), silt (2-50 µm) and sand (>50 µm) according to the particle size. Elemental distribution into various particle size groups depends on several factors including the presence of sorption site, composition of parent material and landforms (Hardy and Cornu, 2006). Therefore, total major elemental composition in virgin soil is generally dependent on the lithology of soil parent material, geochemical, geomorphic (up-mid-lowland) and pedological processes responsible for the formation of the soils. Elemental composition of soil particles and bulk soil will allow a better understanding of the presence of major elements in available form.In this context, the information on the total elemental composition of soils is essential not only for the evaluation of inherent soil fertility and soil quality from an agricultural point of view, but also for the understanding of the stock and flow of elements through a variety of natural and anthropogenic processes.

Material and methods

Gadag district with a geographical area of 4,656 sq km was selected for the study. The study area falls under northern dry zone (Zone-3) of Karnataka. The geographical coordinates of the area are 15° 25’ 47.17” N latitude and 75° 37’ 46.56” E longitude. Black soils occupy major portion of the area and in some places, red soils occur in association with black soils. The district has diversified topography, landforms, soil scapes, land use and geology. Therefore, varied kind of soil is being seen in the district and their elemental composition is bound to change spatially and depth wise.

The samples were collected from each master and sub-horizons of soil profiles that belonged to different parent materials, topography and landforms and their morphological characters were recorded by describing the profile.Granite gneiss derived upland pedon was (P 1) Chikkopa (CKP) and lowland pedon was (P 3)-Hirekoppa (HKP). While, the schist derived upland pedon(P 2) - Kabalaykatti (KLK) and lowland pedon (P-4) -Jelligeri (JLG) (Table1).

Collected soil samples were dried in shade. The air-dried samples were ground with a wooden pestle and mortar and passed through a 2 mm sieve to separate the coarse fragments (> 2 mm). Particle size-distribution of soil samples was determined by International pipette method as described by Piper (2002) using sodium hexametaphosphate as a dispersing agent for separation of sand, silt and clay. Each soil fractions

(0.25g) were subjected for microwave digestion with concentrated nitric and hydrofluoric acids at 220° C for 2 hours and immediate cooling for >30 minutes (Silva *et al*., 2016). The digested solution was filtered by grade 40 paper and stored in polyethylene bottle and kept in refrigerator.

Total content of major elements was determined by feeding extractant to ICP-OES (inductively coupled plasma optical emission spectroscopy), AAS (atomic absorption spectroscopy), flame photometer and spectroscopy for total silicon and aluminium, total iron and manganese, potassium and phosphorus and sulphur, respectively. The total calcium and magnesium content were determined by adopting Versnate titration method. The experimental data was subjected to statistical analysis for mean and range as outlined by Gomez and Gomez (1984).

Results and discussion

Distribution of soil fractions in pedons of different parent rocks and landforms (Table 1)

The sand content decreased with depth in pedons 1, 2 and 4. whereas in pedon 3, it followed an irregular trend. However, the highest sand content was noticed in Ap horizon of all pedons except pedon 3 (C horizon). The sand content of granite gneiss derived soil pedons ranged from 32.1 to 51.1 per cent while it ranged from 25.7 to 49.7 per cent in schist derived soil pedons. The mean highest sand content was observed in upland soil pedons 1and 2 (47.9 and 48.4 %) and the least in case of the lowland soil pedons 3 and 4 (36.1 and 27.5 %).

In pedons 1 and 2 silt content decreased with depth, whereas in pedon 3 and 4, it followed an irregular trend. The highest silt content was recorded in Ap and Br horizons of pedons 1, 2, 3 and pedon 4, respectively. The silt content of granite gneiss derived soil pedons ranged from 11.6 to 16.4 per cent while it ranged from 8.8 to 13.8 per cent in schist derived soil pedons. The mean highest silt content was observed in lowland soil pedons 3 and 4 (15.1 and 13.0 %) and least in case of the upland soil pedons 1 and 2 (12.9 and 10.3 %).

The clay content increased with depth in pedons 1, 2 and 4, whereas in pedon 3, it followed an irregular trend. The silt content was lower than sand and clay content in all pedons. Higher clay content was recorded in Bck horizon of pedons 1 and 2, but, Bc horizon of pedon 3 recorded the highest clay. The pedon 4 had the highest clay in Br horizon. The clay content of schist derived soil pedons ranged from 38.9 to 60.5 per cent while it ranged from 35.5 to 51.8 per cent in granite gneiss derived soil pedons. The mean highest clay content was observed in lowland soil pedons 3 and 4 (48.8 and 59.5 %) and the least in case of the upland soil pedons 1 and 2 (40.2 and 59.5 %).

In most of the pedons, the surface horizons exhibited higher sand content than the subsurface horizons. This might be due to the removal of finer fractions and consequent enrichment by sand fractions on the upper horizons. Removal of finer particles *viz.,* clay, humus, oxides and hydroxides by eluviation and surface runoff is a continuous process. Similar results were reported by Satyavathi and Reddy (2003) and Dasog and Patil (2011). The irregular trend in silt content might be due to variation in weathering of parent material and coarse nature of silt than clay, which restricts its movement with percolating water. Similar observations were made by Sharma *et al.* (2001).The subsurface horizons exhibited higher clay content as compared to the surface horizons due to the illuviation process occurring during soil development. The surface enrichment of sand fraction in the soils was also due to the removal of finer particles by clay eluviation and surface runoff.

Sand content in granite gneiss derived soils was higher than schist. This might be due to the higher content of quartz in granite gneiss and slower degree of weathering of parent rocks (Maniyunda *et al.,* 2012).In most of the soils, silt fractions tend to have irregular distribution with soil depth. Similar findings were reported by Obi and Akinbola (2009). The parent materials indicated a highly significant difference in silt content. This implied that, parent material influenced silt content of soils formed on different basement parent rocks in the study area.The partially weathered feldspar grains weather completely forming fine

Table 1. Particle size distribution (per cent) of granite gneiss and schist derived soils in different landforms

Horizon	Depth (cm)	Sand	Silt	Clay	Horizon	Depth (cm)	Sand	Silt	Clay
		Granite gneiss						Schist	
					Upland				
		Pedon -1					Pedon -2		
Ap	0-12	51.1	13.4	35.5	Ap	0-15	49.7	11.4	38.9
Bw	12-30	48.9	12.7	41.6	Bw	15-25	48.2	10.6	41.2
Bck	30-75	43.7	12.7	43.6	Bck	25-100	47.4	8.8	43.9
Pedon range	43.7-51.1	12.7-13.4	35.5-43.6		Pedon range		47.4-49.7	8.8-11.4	38.9-43.9
Pedon mean	47.9	12.9	40.2		Pedon mean		48.4	10.3	41.3
					Lowland				
		Pedon -3					Pedon -4		
Ap	0-11	37.7	16.4	45.9	Ap	0-20	30.1	12.5	57.4
Bw_1	11-38	36.4	15.7	47.9	Bw_1	20-43	28.3	12.3	59.4
Bw_2	38-71	36.2	15.7	48.1	Bw_2	43-89	26.1	13.7	60.2
Bc	71-86	32.1	16.1	51.8	Br	89-130	25.7	13.8	60.5
C	86-130	38.1	11.6	50.3					
Pedon range	32.1-38.1	11.6-16.4	45.9-51.8		Pedon range		25.7-30.1	12.3-13.8	57.4-60.5
Pedon mean	36.1	15.1	48.8		Pedon mean		27.5	13.0	59.5

grained clay minerals which takes more time, this leads to lower clay content in granite gneiss derived soils and the total clay content of schist derived soils was high than granite gneiss. In turn, platy and sheet-like grains oriented in schist leads higher rate of weathering. This was due to high rate of weathering with high specific surface of particles than granite gneiss. This statement is supported by Meribeng *et al.* (2007) findings.

The upland soils exhibited higher sand content compared to the lowland soils irrespective of soil parent rocks due to their location in the sloping upland. These soils were easily eroded than midland and lowland soils. The eroded finer soil fractions from the uplands accumulated at the midland and lowland soils. Similar findings were also reported by Reddy *et al.* (2013) in basaltic terrain of Central India.

Horizon-wise distribution of total major elemental content in different series (Tables 2 and 3)

Chikkopa (CKP) series

The mean content of Al, Fe and Mn were higher in Bw horizon (12 to 30 cm) followed by Bck (30-75 cm) horizon and Ap (0-12 cm) horizon and these elemental contents increased with increasing depth up to 30 cm, further decreased with increasing the depth (Table 2). The mean content of Al, Fe and Mn varied from 44.79 to 69.34, 25.52 to 40.86 and 0.82 to 1.44 g kg^{-1}, respectively. However, the mean value of silicon varied from 143.24 to 169.43 g kg^{-1} and the maximum content of silicon (169.43 g kg^{-1}) was recorded in Ap horizon and decreased with increasing depth. The mean content of K, Ca, Mg, P and S in CKP series ranged from 8.31 to 10.00, 2.67 to 4.16, 1.54 to 3.19, 1.84 to 2.43 and 0.98 to 1.23 g kg^{-1}, respectively. These elements increased with increasing depth.

Kabalaykatti (KLK) series

Except Si, all the major elements were higher in Bw horizon (15-25 cm), while Si was higher in Ap horizon (0-15 cm). The mean values for Si, Al, Fe, K, Ca, Mg, P, S and Mn ranged from 102.94 to 117.96, 37.08 to 60.81, 26.94 to 71.73, 2.43 to 4.95, 5.30 to 6.73, 1.87 to 4.11, 0.69 to 1.61, 0.79 to 0.95 and 1.06 to 2.02 g kg^{-1}, respectively (Table 2). All the elements, except Si increased with increasing depth up to Bw horizon, further decreased with increasing depth.

Hirekoppa (HKP) series

The mean content of Si, Al, Fe, K, Ca, Mg, P, S and Mn in HKP series ranged from 176.61 to 219.08, 70.19 to 106.41, 44.04 to 81.45, 9.30 to 12.07, 6.06 to 8.47, 1.97 to 4.27, 2.60 to 4.26, 1.95 to 4.67 and 1.85 to 3.78 g kg^{-1}, respectively (Table 3). Among the five horizons, mean content of Si (219.08 g kg^{-1}) and Mg (4.27 g kg^{-1}) was higher in Ap horizon (0-11 cm), while remaining elements *viz.*, Al (106.41 g kg^{-1}), Fe (81.45 g kg^{-1}), K (12.07 g kg^{-1}), Ca (8.47 g kg^{-1}), P (4.26 g kg^{-1}), S (4.67 g kg^{-1}), and Mg (3.78 g kg^{-1}) were higher in Bc horizon (71-86 cm). Except Si and Mg, all the elements increased with increasing depth up to Bc horizon, thereafter the content decreased with increasing depth, while Si and Mg decreased with increasing depth.

Table 2. Distribution of major elements in granite gneiss (CKP) and schist (KLK) derived series of upland soil pedon

Horizon	Depth(cm)	Soil fraction	Si	Al	Fe	K	Ca	Mg	P	S	Mn
					Pedon 1: Granite gneiss derived soil series						
								g kg^{-1}			
Ap	0-12	Sand	210.17	36.77	20.55	10.13	1.98	1.36	1.15	0.58	0.59
		Silt	169.75	44.86	26.45	8.13	2.52	1.59	1.98	0.95	0.64
		Clay	128.37	52.75	29.56	6.68	3.51	1.69	2.40	1.40	1.25
		Mean	169.43	44.79	25.52	8.31	2.67	1.54	1.84	0.98	0.82
Bw	12-30	Sand	187.30	56.34	35.95	10.98	2.88	2.77	1.22	0.62	0.86
		Silt	155.65	72.71	41.31	6.99	3.82	3.30	1.38	1.06	0.88
		Clay	120.82	78.96	45.32	7.63	4.58	3.50	1.79	1.55	2.59
		Mean	154.59	69.34	40.86	8.53	3.76	3.19	1.46	1.08	1.44
Bck	30-75	Sand	171.97	47.36	32.41	12.81	3.45	2.11	1.91	0.76	0.59
		Silt	140.12	57.45	39.36	10.13	4.14	2.49	2.55	1.26	0.64
		Clay	117.65	62.54	42.42	7.07	4.88	3.09	2.84	1.65	1.25
		Mean	143.25	55.78	38.06	10.00	4.16	2.56	2.43	1.23	0.82
					Pedon 2: Schist derived soil series						
Ap	0-15	Sand	154.53	32.84	37.90	3.02	3.85	3.18	0.83	0.50	1.38
		Silt	106.48	35.26	46.92	3.64	5.10	3.79	0.84	0.83	1.85
		Clay	92.88	43.15	61.70	4.27	6.95	4.78	1.10	1.06	2.80
		Mean	117.96	37.08	48.84	3.64	5.30	3.92	0.92	0.79	2.01
Bw	15-25	Sand	140.55	49.34	55.85	3.92	5.30	3.10	1.16	0.52	1.59
		Silt	114.47	62.74	76.23	4.86	6.57	3.98	1.58	0.93	1.65
		Clay	91.94	70.36	83.10	6.06	8.33	5.23	2.09	1.41	2.82
		Mean	115.65	60.81	71.73	4.95	6.73	4.11	1.61	0.95	2.02
Cr	25-100	Sand	123.93	31.69	19.26	1.95	4.69	1.56	0.59	0.46	1.06
		Silt	99.09	37.99	26.09	2.51	5.42	1.68	0.63	0.80	0.79
		Clay	85.79	42.49	35.49	2.83	6.54	2.38	0.85	1.13	1.33
		Mean	102.94	37.39	26.94	2.43	5.55	1.87	0.69	0.80	1.06

Table 3. Distribution of major elements in granite gneiss (HKP) and schist (JLG) derived series of lowland soil pedon

Horizon	Depth(cm)	Soil fraction	Si	Al	Fe	K	Ca	Mg	P	S	Mn
					Pedon 3: Granite gneiss derived soil series						
								g kg^{-1}			
Ap	0-11	Sand	260.31	73.42	44.55	11.74	4.95	3.59	2.16	1.36	1.83
		Silt	235.43	78.49	46.15	10.98	5.85	3.73	2.49	1.75	2.13
		Clay	161.51	88.95	60.48	8.81	7.38	5.49	3.16	2.72	2.68
		Mean	219.08	80.29	50.39	10.51	6.06	4.27	2.60	1.95	2.21
Bw_1	11-38	Sand	240.97	75.45	48.48	11.57	5.48	3.32	2.42	1.88	2.06
		Silt	223.29	77.56	49.62	10.85	6.54	3.37	2.65	1.98	0.73
		Clay	147.73	102.45	63.48	8.81	8.32	5.15	4.13	3.83	2.98
		Mean	204.00	85.15	53.86	10.41	6.78	3.95	3.07	2.56	1.92
Bw_2	38-71	Sand	235.32	79.35	49.48	13.09	6.18	2.83	2.99	1.83	2.18
		Silt	213.66	79.95	51.65	13.73	7.21	3.43	3.18	3.65	2.48
		Clay	140.33	115.35	69.95	9.23	9.19	4.63	4.83	4.49	3.09
		Mean	196.44	91.55	57.03	12.01	7.53	3.63	3.67	3.32	2.58
Bc	71-86	Sand	220.11	95.75	69.10	14.24	7.21	3.17	2.98	2.65	4.12
		Silt	210.63	101.73	71.45	12.25	8.21	4.07	4.16	6.47	3.02
		Clay	128.23	121.75	103.79	9.74	9.98	5.02	5.65	4.89	4.19
		Mean	186.32	106.41	81.45	12.07	8.47	4.08	4.26	4.67	3.78
C	86-130	Sand	215.96	63.66	38.20	10.89	5.15	1.50	2.46	2.01	1.51
		Silt	195.46	60.34	37.94	9.35	5.87	1.93	2.98	2.26	1.74
		Clay	118.40	86.56	55.97	7.67	7.37	2.50	4.38	3.92	2.31
		Mean	176.61	70.19	44.04	9.30	6.13	1.97	3.28	2.73	1.85
					Pedon 4: Schist derived soil series						
Ap	0-20	Sand	200.31	54.87	76.96	6.17	6.95	3.72	2.39	1.32	1.79
		Silt	134.13	58.76	78.52	7.82	8.40	4.95	4.22	1.82	2.09
		Clay	117.59	78.64	103.34	9.17	13.67	8.34	4.98	2.49	3.20
		Mean	150.68	64.09	86.27	7.72	9.68	5.67	3.86	1.88	2.36
Bw_1	20-43	Sand	192.79	66.73	79.34	6.39	7.67	3.50	2.65	1.65	1.85
		Silt	129.68	69.13	80.46	9.25	9.89	4.29	2.72	1.75	2.21
		Clay	112.26	85.46	104.96	10.30	14.49	6.26	4.42	3.16	3.48
		Mean	144.91	73.77	88.25	8.65	10.68	4.68	3.26	2.19	2.51
Bw_2	43-89	Sand	188.08	84.33	107.51	6.93	7.67	4.34	2.19	1.84	2.63
		Silt	127.72	85.97	116.61	12.47	10.96	4.94	2.32	2.65	3.26
		Clay	109.95	119.93	156.75	12.17	16.32	7.13	3.49	3.98	4.84
		Mean	141.92	96.74	126.96	10.52	11.65	5.47	2.66	2.83	3.58
Br	89-130	Sand	183.71	69.35	87.64	7.97	8.50	3.33	1.78	2.16	2.21
		Silt	123.50	69.59	91.46	9.32	12.28	3.49	2.15	2.16	2.67
		Clay	105.58	120.57	126.58	12.97	17.85	5.04	2.92	4.11	3.17
		Mean	137.59	86.50	101.89	10.09	12.88	3.95	2.28	2.81	2.68

Jelligeri (JLG) series

The total content of Si, Al, Fe, K, Ca, Mg, P, S and Mn in JLG series soil particles varied from 137.59 to 150.68, 64.09 to 96.74, 86.27 to 12.96, 7.72 to 10.52, 9.68 to 12.88, 3.95 to 5.67, 2.28 to 3.86, 1.88 to 2.83 and 2.36 to 3.58 g kg^{-1}, respectively (Table 3). Among the horizons, the higher mean content of Si, Mg and P were recorded in Ap horizon (0-20 cm) followed by Bw_1 (20-43 cm), Bw_2 (43-89 cm) and Br (89-130 cm) horizons, while Al, Fe, K, S and Mn were found higher in Bw_2 horizon followed by Br, Bw_1 and Ap horizon. Only the mean content of Ca was higher in Br horizon followed by Bw_2, Bw_1 and Ap horizon. All the major elements, except Si, Mg and P increased with increasing depth up to Bw_2 horizon, further decreased with increasing depth, whereas Si, Mg and P decreased with increasing depth.

Total silicon content showed that maximum concentration is in surface horizons (Ap) as compared to lower horizons and sharp decrease with increasing depth in all pedons, this might be attributed to desilication of SiO_2 in the lower horizons of soils during intense weathering process. This finding is supported by Maniyunda *et al.* (2012).

Total Al, Fe, Mg and Mn content showed maximum concentration in lower horizon (B) and minimum in surface horizon (Ap) in all pedons, this could be due to translocation of elements released during weathering of the minerals, and the relative abundance of quartz in surface. Moreover, the weathering of quartz is very low (Jackson and Sherman, 1953) as compared to other minerals. Beside this, the concentration of Al, Fe, Mg and Mn in B horizon could either be due to enhanced weathering or illuviation of elements along with the finer particles as structural components or as coatings or as discrets oxide particles. The higher content of the K, P, and Ca in B horizon than surface (Ap) might also be due to the downward movement of dissolved P, K, Ca and organic carbon with percolating water and thereby their accumulation in the B horizon. These results were on par with the results of Yawson *et al.* (2011). The dominance of Ca followed by Mg was seen in soils. This may be due to variation in adsorption sites offered by respective soils (Pichu*,* 2016). Ruhal and Paliwal (1978) reported that most of the sulphur appears as insoluble sulphate or sulphate occluded in calcium carbonate in subsurface soils.

Conclusion

The sand content was higher in granite gneiss derived from upland than lowland soils, while clay content were higher in schist derived lowland than upland with depth wise increasing trend in all the pedons. All the element content in soil particles was higher in deeper horizons in all pedons, except Si, content which was higher in surface horizons and these elements are higher in schist derived from lowland soils than granite gneiss derived from lowland soil with similar trend was noticed in upland soils.

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