J. Farm Sci., 37(2): (143-146) 2024

RESEARCH PAPER

Total elemental composition of soil primary particles in vertisols of northern Karnataka

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(Received: November, 2023 ; Accepted: June, 2024)

DOI: 10.61475/JFS.2024.v37i2.07

Abstract: A study on total elemental composition of soil primary particles in Belavadi micro-watershed of Belagavi district, Karnataka was conducted during 2022-23. Horizon-wise soil samples were collected and analysed for major and trace elemental content in sand, silt and clay. *Vertisol* pedons 1 and 2 revealed the various patterns in elemental composition across horizons and soil fractions. In the uppermost (Ap) horizon, the sand fraction contained relatively higher concentrations of Si, Al, Fe and K, while significant amounts of Si, Al and Fe were also present in the silt and clay fractions. However, as soil depth increased (Bss1, Bss2 and Bss3) there was an overall decrease in the total concentration of these major elements. The sand fraction exhibited higher content of Mn, Cu and V. With increasing depth, the concentrations of trace elements did not follow any pattern.

Key words: Clay, Elemental composition, Sand, Silt

Introduction

The total elemental composition of soil primary particles in *Vertisols* could be complex and highly variable, depending on the landscape and environmental conditions. Total major and trace elemental composition in virgin soil generally depends on geochemical, geomorphic and pedological processes and the lithology of the soil parent material. The elemental composition of soil particles is influenced by weathering of parent material, secondary mineral formation, organic matter decomposition and leaching. The breakdown of rocks and minerals in the parent material through weathering releases various elements into the soil. Organic matter decomposition contributes to the release of carbon, nitrogen and other nutrients. Leaching, the movement of water through the soil profile can lead to the loss of certain elements, especially in areas with high rainfall.

The total elemental composition of soil particles and bulk soil will allow a better understanding of the presence of major and trace elements in available form (Sanjay and Kuligod, 2020). 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. Vertical distribution of major and trace elements in soil particles gets affected by plant cycling relative to leaching, weathering, dissolution and atmospheric deposition. As the interface between the atmosphere, biosphere and lithosphere, soil undergoes an intense vertical exchange of materials resulting in steep chemical and physical gradients from surface to bedrock. The present study helps to understand pedological evolution of *vertisols* of Northern Karnataka.

Material and methods

Belavadi microwatershed of Bailhongal taluk, Belagavi district is located between 15^0 43'-15^0 45' North latitudes and 74^0 53'- 74^0 55' East longitudes. Belavadi micro-watershed comes under Agro-climatic Zone 8: Northern Transitional Zone of Karnataka. Most of the zone is at an elevation of 747 m above MSL. The average annual rainfall of the zone ranges from 550 to 1025 mm. The soils are medium and deep black, light red and shallow soils. The main cropping season is *kharif*. Maize, soyabean, groundnut, cotton, wheat, sugarcane and some vegetable crops like chilli, potato, peas and onion are the major crops. Pedons 1 and 2 belong to the black soils with schist geology of Belavadi micro-watershed.

The samples were collected from each master and sub-horizons of soil profiles and their morphological characters were recorded by describing the profile. 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 hexameta phosphate 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 220º 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 Versanate titration method. The experimental data was subjected to statistical analysis for mean as outlined by Gomez and Gomez (1984).

Results and discussion

A comprehensive overview of the distribution of major and trace elements within the pedons of *vertisol* is presented across different horizons, depths and soil fractions. Soil primary particle contents include major elements like silicon (Si), aluminum (Al), iron (Fe), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), sulfur (S), manganese (Mn) and trace elements like zinc (Zn), lead (Pb), strontium (Sr), chromium (Cr), copper (Cu), vanadium (V), nickel (Ni), cobalt (Co), rubidium (Rb) and arsenic (As), with their concentrations reported in (g kg^{-1}) for major elements and (mg kg^{-1}) for trace elements.

Total elemental composition of pedon 1 of *Vertisol*

In pedon 1 across the various studied horizons (Ap, Bss1, Bss2 and Bss3) there was a clear variation in the elemental composition (Table 1). The soil fractions sand, silt and clay exhibited differences in their elemental composition. This is expected since each soil fraction has distinct physical and chemical properties, which affect the retention and molecular availability of different fractions. Total elemental composition varied across different soil horizons. This is attributed to differences in the processes that occur at different soil depths. Similar findings were reported by Kothandaraman and Krishnamoorthy (1979).

The Ap horizon which is the uppermost layer of the soil, showed significant variation in the elemental composition of soil fractions. The sand fraction had relatively higher concentrations of Si, Al, Fe and K (223.89, 80.65, 46.46 and11.81 g kg^{-1}, respectively) and trace elements like Mn, Cu and V (1.44, 47.33 and 26.56 mg kg^{-1}, respectively). The silt fraction showed substantial levels of Si, Al and Fe (144.63,103.18 and 76.89 g kg^{-1}, respectively), while the clay fraction had lower concentrations of Si and Al (207.12 and 91.09 g kg^{-1}) and trace elements compared to silt fraction. Horizons closer at surface (Ap) tend to have higher concentrations of certain elements due to the accumulation of organic matter, biological activity, weathering processes, vegetation and crop management practices. The uppermost horizon was rich in elements like Si, Al, Fe and K. These elements are often associated with minerals like quartz, clay minerals and iron oxides. The presence of trace elements (Mn, Cu and V) indicated the influence of both primary minerals and external sources like weathering or deposition.

In the Bss1 horizon variations in the elemental composition of soil fractions was observed. The sand fraction remained rich in Si, Al and Fe (215.49, 88.45 and 54.95 g kg^{-1}, respectively) and trace elements such as Zn, Cu, V, Ni and Sr. The silt fraction displayed elevated levels of Si, Al and Fe content indicating the persistence of primary minerals. The clay fraction also retained significant Si and Al content (199.25 and 100.08 mg kg^{-1}) compared to other elements.

In the Bss2 horizon, there was a decrease in the overall concentration of mean Si, Al and Fe (173.61, 107.21 and 81.86 g kg^{-1}, respectively) in all soil fractions compared to the upper horizons. The sand fraction contained notable amounts of these elements, as well as trace elements like Mn and Cu. The silt and

Table 1. Distribution of elements (major and trace) in soil fractions of pedon 1 of *Vertisol*

Horizon	Soil fraction	Major elements									Trace elements									
		Si	Al	Fe	K	Ca	Mg	P	S	Mn	Zn	Pb	Sr	Cr	Cu	V	Ni	Co	Rb	As
		(g kg^{-1})									(mg kg^{-1})									
Ap	Sand	223.89	80.65	46.46	11.81	3.37	0.80	0.78	1.17	1.44	64.10	8.44	21.26	6.37	47.33	26.56	26.41	16.05	2.42	3.48
	Silt	144.63	103.18	76.89	7.74	5.12	3.39	3.27	2.56	0.22	118.53	8.53	46.44	7.53	85.72	63.20	57.53	43.63	6.88	Tr
	Clay	207.12	91.09	58.73	13.60	7.41	5.26	4.93	4.19	3.31	77.54	10.21	47.48	Tr	58.60	36.23	33.69	24.56	6.56	Tr
	Mean	191.88	91.64	60.69	11.05	5.30	3.15	2.99	2.64	1.66	86.72	9.06	38.39	6.95	63.88	42.00	39.21	28.08	5.29	3.48
Bss1	Sand	215.49	88.45	54.95	14.33	10.83	5.30	6.15	4.49	4.24	78.60	19.30	37.91	2.83	65.74	35.34	32.88	21.63	7.69	6.87
	Silt	140.29	127.84	83.92	11.04	10.95	5.73	6.79	6.20	4.43	140.11	16.93	36.92	2.62	95.28	71.04	64.63	49.54	3.04	Tr
	Clay	199.25	100.08	62.83	13.28	9.60	4.69	5.37	4.14	3.60	89.36	17.09	37.78	Tr	66.28	38.86	36.03	25.91	9.43	Tr
	Mean	185.01	105.46	67.23	12.88	10.46	5.24	6.10	4.94	4.09	102.69	17.77	37.54	2.73	75.77	48.41	44.51	32.36	6.72	6.87
Bss2	Sand	130.11	122.02	111.81	12.73	11.02	7.12	7.96	6.96	5.85	195.66	14.78	22.09	2.98	134.52	73.54	68.22	56.59	6.44	1.09
	Silt	183.23	111.27	82.83	14.85	9.97	5.80	6.43	6.09	4.84	125.28	13.60	31.92	6.44	89.65	40.44	38.96	30.51	3.18	Tr
	Clay	207.49	88.34	50.95	16.63	9.51	3.00	4.66	3.15	2.58	55.24	13.44	21.46	9.56	41.14	11.19	11.53	8.85	6.17	Tr
	Mean	173.61	107.21	81.86	14.74	10.17	5.31	6.35	5.40	4.42	125.39	13.94	25.16	6.33	88.44	41.72	39.57	31.98	5.26	1.09
Bss3	Sand	222.35	102.88	64.55	15.33	7.39	3.20	3.49	5.49	2.75	71.01	13.42	20.30	8.45	50.80	10.69	10.96	7.66	5.49	3.04
	Silt	194.23	105.92	69.13	13.48	8.49	4.07	4.83	2.83	2.92	106.16	19.59	30.36	4.88	80.62	34.10	34.70	24.27	4.62	Tr
	Clay	128.31	120.22	110.01	10.93	9.22	5.32	6.16	5.16	4.05	193.86	12.98	20.29	1.18	132.72	71.74	66.42	54.79	4.64	Tr
	Mean	181.63	109.67	81.23	13.25	8.37	4.20	4.83	4.49	3.24	123.68	15.33	23.65	4.84	88.05	38.84	37.36	28.91	4.92	3.04

clay fractions showed a similar trend, with lower Si and Al concentrations compared to clay fractions.

The Bss3 horizon, representing the deeper layers of the soil, registered an increase in mean Si, Al and Fe (181.63, 109.67 and 81.23 g kg^{-1}, respectively) concentrations this was slightly higher compared to Bss2 across all soil fractions. The sand fraction contained significant amounts of Si, Al and Fe as well as trace elements like Zn, Mn and Cu. The silt and clay fractions had lower Si and Al concentrations but retain relatively high levels of trace elements. This horizon is also marked by a decrease in essential total elements like K, Ca and Mg. The decline in essential total elements like K, Ca and Mg with depth is likely due to their increased leaching and depletion as water moves through the soil profile (Blaser *et al.*, 2000). The mean composition of Fe, K and Cu decreased with soil depth while the other elements Si, Ca, Mg, P, S, Mn, Zn Sr, Cr, Cu, Co and Rb showed an erratic distribution across the depths.

Total elemental composition of pedon 2 of *Vertisol*

In pedon 2, across the various horizons (Ap, Bss1, Bss2 and Bss3) there was a clear variation in the elemental composition and the data is represented in Table 2. Top of FormIn the Ap horizon, the major elements such as Si, Al, Fe and K were present in varying amounts among different soil fractions. Notably, Al and Fe (93.71 and 80.18 g kg^{-1}, respectively) concentrations were the highest in the clay fraction, while K (17.77 g kg^{-1}) was higher in the sand fraction. 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. Similar observations were made by Sharma *et al.* (2001).

The trace elemental composition of Zn, Pb, Sr, Cr, Cu, V, Ni, Co and Rb were higher in silt fractions followed by clay and sand fractions. The highest mean content of Si (224.88 g kg^{-1}) was observed in top soil horizon. The enrichment of elements like Zn, Cu, V, Ni and Sr in the silt fraction could be due to preferential retention and accumulation in these finer particles as influenced by mineral sources and weathering materials. Si, Al and Fe concentrations decreased across the soil fractions compared to upper horizon due to reduced weathering and biological activity at greater depth. These findings were in confirmity with (Satyavathi *et al.*, 2006).

In the Bss1 horizon, a similar trend continued with variations in the distribution of elements across the soil fractions. Interestingly, the concentrations of elements such as Al, Fe, and Ca (107.08, 80.79 and 9.02 g kg^{-1}, respectively) and total trace elements Zn, Sr, Cu, V, Ni and Co composition were noticeably higher in the clay fraction.

In the Bss2 and Bss3 horizons of *Vertisol,* a comparable pattern persisted. Notably, the concentrations of certain elements, such as Si, Al and Fe, tend to decrease with depth. The major elements Si, Al, and Fe and trace elements Zn, Sr, Cu, V, Ni and Co were consistent in exhibiting higher concentrations.

Table 2. Distribution of elements (major and trace) in soil fractions of pedon 2 of *Vertisol*

Horizon	Soil fraction	Major elements (g kg^{-1})									Trace elements (mg kg^{-1})									
		Si	Al	Fe	K	Ca	Mg	P	S	Mn	Zn	Pb	Sr	Cr	Cu	V	Ni	Co	Rb	As
Ap	Sand	260.31	51.85	47.81	17.77	43.09	8.27	7.14	5.76	6.22	39.97	11.42	20.05	8.64	37.43	15.16	13.04	10.08	8.66	8.29
	Silt	240.76	50.29	49.38	13.35	7.86	6.12	5.18	3.88	4.52	60.50	15.52	11.24	6.81	50.70	33.67	28.75	19.82	4.99	Tr
	Clay	173.58	93.71	80.18	8.71	8.96	6.53	4.74	4.49	3.86	113.71	12.97	38.93	0.96	89.46	57.71	54.15	44.85	8.38	Tr
	Mean	224.88	65.28	59.12	13.28	19.97	6.97	5.69	4.71	4.87	71.39	13.30	23.41	5.47	59.20	35.51	31.98	24.92	7.34	8.29
Bss1	Sand	247.23	83.85	47.24	15.64	8.15	5.99	5.14	4.59	4.55	44.39	18.07	19.13	7.61	37.14	13.32	11.54	8.39	6.77	5.98
	Silt	227.59	84.35	50.16	15.51	7.07	4.50	4.48	3.53	3.26	67.80	12.14	14.96	0.07	51.03	30.26	30.11	19.75	4.12	Tr
	Clay	148.53	107.08	80.79	11.64	9.02	7.29	7.17	6.46	4.12	122.43	12.43	20.34	1.43	89.62	67.10	61.43	47.53	0.78	Tr
	Mean	207.78	91.76	59.40	14.26	8.08	5.93	5.60	4.86	3.98	78.21	14.21	18.14	3.04	59.26	36.89	34.36	25.22	3.89	5.98
Bss2	Sand	222.35	102.88	64.55	15.33	7.39	3.20	3.49	5.49	2.75	71.01	13.42	20.30	8.45	50.80	10.69	10.96	7.66	5.49	3.04
	Silt	194.23	105.92	69.13	13.48	8.49	4.07	4.83	2.83	2.92	106.16	19.59	10.36	4.88	80.62	34.10	34.70	24.27	4.62	Tr
	Clay	128.31	120.22	110.01	10.93	9.22	5.32	6.16	5.16	4.05	193.86	12.98	30.29	1.18	132.72	71.74	66.42	54.79	4.64	Tr
	Mean	181.63	109.67	81.23	13.25	8.37	4.20	4.83	4.49	3.24	123.68	15.33	20.32	4.84	88.05	38.84	37.36	28.91	4.92	3.04
Bss3	Sand	224.47	105.00	66.67	17.45	9.51	5.32	5.61	9.61	4.87	73.13	15.54	22.42	0.57	52.92	11.81	13.08	9.78	7.61	5.16
	Silt	196.35	108.04	71.25	15.60	10.61	8.19	7.95	4.95	5.04	107.28	11.71	13.48	8.00	82.74	41.22	36.82	28.39	6.74	Tr
	Clay	130.43	122.34	112.13	15.05	11.34	7.44	8.28	12.8	6.17	197.98	15.10	32.41	3.30	135.84	73.86	68.54	56.91	6.76	Tr
	Mean	183.75	111.79	83.35	16.03	10.49	6.98	7.28	8.95	5.36	126.13	14.12	22.77	3.96	90.50	42.30	39.48	31.69	7.04	5.16

in the clay fraction, while certain trace elements like Zn and Cu demonstrated variability across horizons and fractions. These deeper horizons showed a decrease in overall elemental concentrations, which could be attributed to leaching processes where elements were washed down through the soil profile (Acosta *et al*., 2011). The persistence of Si, Al and Fe in the clay fraction could be due to their strong associations with clay minerals, while the decrease in these elements with depth might be related to mineral dissolution and leaching. Mean total content of elements showed an irregular trend in distribution across the horizons. The irregular distribution of elements such as Si, Ca, Mg, P, S, Mn, Zn, Sr, Cr, Cu, Co and Rb could be attributed to complex interactions between mineral weathering, organic matter decomposition, leaching and the availability and mobility of these elements in the parent material as reported by Saiborne *et al.* (2012). The variations in elemental composition observed between the two pedons can be attributed to differences in factors like parent material, climate, vegetation and land use history. These factors can influence mineral weathering rates, organic matter inputs and elemental mobility (Erick *et al.,* 2015).

Conclusion

In upper Ap horizon of *Vertisol* (Pedons 1 and 2) the sand fraction contained relatively high concentrations of Si, Al, Fe and K, while significant amounts of Si, Al and Fe were also present in the silt and clay fractions. However, as depth increased (Bss1, Bss2 and Bss3) there was an overall decrease in the concentration of these major elements. Additionally, the distribution of trace elements such as Mn, Zn, Cu, V, Ni, Co, Pb, Sr and Cr varied across horizons and fractions. The sand fraction had higher concentrations of certain trace elements like Mn, Cu and V. However, there was a noticeable decrease in the concentrations of essential nutrients like K, Ca and Mg with soil depth, particularly in the Bss3 horizon.

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