



Elemental Composition of Soil Primary Particles in *Alfisols* of Northern Karnataka

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Abstract: Study on total elemental composition of soil primary particles in Bailmadapura micro-watershed of Gadag 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. *Alfisol* pedons 1 and 2 revealed the various patterns in elemental composition across horizons and soil fractions. Elemental analysis showed significant variations in the composition of major elements (Si, Al, Fe, Ca, Mg and K) and trace elements (Zn, Pb, Sr and Cu) among soil fractions (sand, silt, clay) at different depths. In Pedon 1, the upper horizon (Ap) showed higher concentrations of Si, Al and Fe in the sand fraction, with erratic distribution of Ca, Mg, P and S. The Bt1 horizon exhibited changes in element content, particularly in Fe concentration and the distribution of trace elements. The Bt2 horizon displayed further alterations, with Si and Al maintaining consistent patterns, while trace elements exhibited different distributions influenced by soil forming processes. In Pedon 2, similar trends were observed, emphasizing the influence of soil fraction and depth on elemental composition. The findings highlighted the complexity of interactions involving mineralogical composition, organic matter content, redox conditions, and pH in shaping elemental distribution in *Alfisols*.

Keywords: Alfisols sand, Silt, Clay, Soil primary particles

The total elemental composition of soil primary particles in *Alfisols* 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 *Alfisols* of Northern Karnataka.

MATERIAL AND METHODS

Bailmadapura MWS in Shirahatti taluk, Gadag district is located between 14° 59'-15° 10' North latitudes and 75° 34'-75° 37' East longitudes. Bailmadapura MWS comes under Agro-climatic Zone 3: Northern Dry Zone. Most of the MWS is at an elevation of 450-800 m above MSL. The average annual rainfall of the zone ranges from 464 to 785 mm. The soils are medium red soils in major areas, with sand loams in the remaining areas. The main cropping season is *Rabi*. Groundnut, chickpea, wheat, sorghum and sugarcane are the important crops of the zone.

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 using sodium hexametaphosphate as a dispersing agent for separation of sand, silt and clay (Piper 2002). 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 Versenate titration method. The experimental data was subjected to statistical analysis by using SPSS software (2002).

RESULTS AND DISCUSSION

Total elemental composition of pedon 1 of Alfisol: The comprehensive overview of the distribution of major and trace elements within the pedons of *Alfisol* is presented across different horizons, depths and soil fractions.

In pedon 1 across the various studied horizons (Ap, Bt1 and Bt2) there 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. In the uppermost horizon (Ap), the major elements Si, Al and Fe were significantly higher (110.92, 54.93 and 52.39 g kg⁻¹) in sand fractions and maintained relatively consistent and higher concentrations across the silt and clay soil fractions, indicating their widespread presence throughout the soil. The Ca, Mg, P and S concentrations showed an erratic distribution across the soil fractions. Trace elements like Zn, Pb and Sr (97.30, 18.22 and 56.83 mg kg⁻¹ respectively) exhibited diverse behaviour, with their concentrations varying between sand, silt and clay fractions. As the depth increased into the Bt1 horizon, there were changes in element content in different fractions. The major elements Si and Al (129.25 and 57.28 g kg⁻¹) continued to show consistent patterns, while Fe concentrations decline. The concentrations of Ca, Mg, P and S was lower in sand content. Trace elements, on the other hand, continued to display variability. Zn and Pb concentrations increased in the clay fraction. Similarly, Cu concentration rose in the clay fraction (79.67 mg kg⁻¹), indicating a distinct distribution pattern. Trace elements (Zn, Pb and Sr) recorded variable behaviour across different fractions, indicating complex interactions. This might have resulted from factors such as mineral adsorption, organic matter content, mineralogical

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

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	110.92	54.93	52.39	4.52	5.34	2.48	1.19	0.83	1.79	69.40	13.30	42.58	38.71	51.76	32.80	25.15	14.01	5.19	3.38				
	Silt	96.22	63.22	75.27	5.66	8.03	4.55	1.99	1.27	2.65	124.30	19.74	63.90	58.09	87.09	54.19	44.61	25.11	11.31	Tr				
	Clay	97.73	41.27	49.68	3.96	5.98	5.65	1.19	1.15	2.75	98.21	21.62	64.01	58.19	71.12	47.88	42.36	24.86	10.48	Tr				
	Mean	101.62	53.14	59.11	4.71	6.45	4.23	1.46	1.08	2.40	97.30	18.22	56.83	51.66	69.99	44.96	37.37	21.33	8.99	3.38				
Bt1	Sand	157.71	48.28	44.96	3.96	5.98	3.58	1.65	0.57	1.23	31.74	8.41	28.74	26.13	29.99	22.07	18.13	10.29	4.04	2.11				
	Silt	117.42	56.45	55.90	4.56	6.96	5.48	2.49	0.88	1.73	58.16	13.01	41.92	38.11	41.85	30.73	25.99	14.75	5.99	Tr				
	Clay	112.61	67.12	65.80	6.51	9.14	6.75	3.13	1.63	3.24	96.74	20.36	76.11	69.19	79.67	56.51	50.74	30.91	12.29	Tr				
	Mean	129.25	57.28	55.55	5.01	7.36	5.27	2.42	1.03	2.07	62.21	13.93	48.92	44.48	50.50	36.44	31.62	18.65	7.44	2.11				
Bt2	Sand	137.08	32.38	29.14	4.98	5.33	2.32	2.17	1.77	2.03	23.88	7.20	22.45	20.53	19.95	18.34	13.62	7.84	3.76	3.45				
	Silt	103.62	36.78	36.55	5.84	6.19	2.68	2.59	2.04	2.37	38.59	10.05	32.55	29.71	29.02	27.54	20.33	12.41	5.41	Tr				
	Clay	88.19	40.88	51.00	4.55	7.60	3.41	3.40	2.33	2.67	59.99	12.82	52.30	47.66	46.62	43.92	37.74	21.67	12.00	Tr				
	Mean	109.63	36.68	38.90	5.12	6.37	2.80	2.72	2.05	2.36	40.82	10.02	35.77	32.63	31.86	29.93	23.90	13.97	7.06	3.45				

Tr- Traces

composition and redox conditions in the soil. These findings were in conformity with Liu et al. (2002). The Bt2 horizon, representing deeper depths, showcased further changes in elemental content. Major elements Si, Al, Fe, Ca, Mg and K maintained consistent trends, while trace elements like Zn and Pb exhibited slightly different patterns compared to the shallower horizons. The mean concentration of total elemental composition indicated the erratic distribution of major and trace elements across the soil depth. In Bt2 horizon, major elements like Si and Al continued to display consistent and higher concentrations, while Fe remained lower than in the upper horizons due to mineralogical composition and weathering process affecting this element. Soil forming process transformation were influencing the distribution of these elements across different depths. This is typical as iron oxides are prone to reduction and leaching at greater depths. Similar distribution pattern and mobility of elements was observed by Dey (1999) in *Alfisols*. Trace elements (Zn and Pb) exhibited different patterns of content at deeper depth compared to shallower horizons. This kind of distribution was influenced by changes in pH, redox conditions, mineralogical content and the availability of colloids for adsorption

Total elemental composition of pedon 2 of *Alfisol*: In pedon 2, across the horizons (Ap, Bt1 and Bt2) there was a variation in the elemental composition (Table 2). In the uppermost horizon (Ap), the major elements Si, Al and Fe (101.62, 53.14 and 59.11 g kg⁻¹ respectively) displayed consistent patterns across soil fractions, suggesting their prevalence throughout the soil. Trace elements such as Zn, Pb and Sr (97.30, 18.22 and 56.83 g kg⁻¹, respectively) exhibited diverse behaviour, with varying concentrations among the fractions. Major elements (Si, Al and Fe) were significantly higher in the sand fraction of *Alfisols*. This pattern revealed that these major elements were prevalent in the coarser and primary mineral soil particles and are relatively consistent throughout the soil profile. This could be due to the presence of minerals like quartz (Si) and iron oxides (Fe) in the sand fraction. In the Bt1 horizon, there were changes in element concentration emerge. The major elements Si and Al maintained their consistent higher content, while Fe concentration showed a decrease. Concentration of Ca, Mg, P and S was lower in sand fraction. Trace elements exhibited intricate trends; Zn and Pb concentrations rose in the clay fraction. Cu concentration increased in the clay fraction, revealing distinct spatial patterns. Arsenic concentration was present in traces in silt and clay fractions across all the horizons. In Bt1 horizon major elements such as Si and Al maintained consistent patterns of distribution, while Fe concentrations declined.

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

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	156.86	35.17	40.23	5.35	6.18	5.51	3.16	2.83	3.71	38.72	12.14	30.03	27.51	30.92	22.01	18.02	10.72	5.7	0.32			
	Silt	108.81	37.59	49.25	5.97	7.43	6.12	3.17	3.16	4.18	71.79	16.6	44.45	40.62	45.91	30.98	25.34	14.91	7.67	Tr			
	Clay	95.21	45.48	64.03	6.6	9.28	7.11	3.43	3.39	5.13	104.77	15.14	66.25	60.44	74.68	48.44	43.75	28.03	13.75	Tr			
Bt1	Mean	120.29	39.41	51.17	5.97	7.63	6.25	3.25	3.13	4.34	71.76	14.63	46.91	42.86	50.50	33.81	29.04	17.89	9.04	0.32			
	Sand	127.38	40.14	32.71	6.4	8.14	5.01	4.04	3.91	4.51	36.12	10.02	24.22	22.33	22.87	18.85	15.55	10.46	6.83	4.58			
	Silt	112.54	40.9	32.54	6.96	9.87	6.13	6.08	5.25	6.24	51.65	11.51	46.48	35.48	27.89	29.27	22	15.03	9.81	Tr			
Bt2	Clay	90.24	51.94	38.94	6.28	9.99	5.83	4.3	4.58	4.78	65.87	17.38	56.18	51.39	48.96	44.94	39.74	22.7	15.18	Tr			
	Mean	110.05	44.33	34.73	6.55	9.33	5.66	4.81	4.58	5.18	51.21	12.97	42.29	36.40	33.24	31.02	25.76	16.06	10.61	4.58			
	Sand	123.93	36.69	29.26	2.95	4.69	1.56	0.59	0.46	1.06	32.67	6.57	20.77	18.88	19.42	15.4	12.1	7.01	3.38	1.13			
Tr- Traces	Silt	109.09	37.45	29.09	3.51	6.42	2.68	2.63	1.8	2.79	48.2	8.06	43.03	32.03	24.44	25.82	18.55	11.58	6.36	Tr			
	Clay	86.79	48.49	35.49	2.83	6.54	2.38	0.85	1.13	1.33	62.42	13.93	52.73	47.94	45.51	41.49	36.29	19.25	11.73	Tr			
	Mean	106.60	40.88	31.28	3.10	5.88	2.21	1.36	1.13	1.73	47.76	9.52	38.84	32.95	29.79	27.57	22.31	12.61	7.16	1.13			

This decline in Fe might be due to the reduction of iron oxides as one moves deeper into the soil profile. Trace elements (Zn, Pb and Cu) concentrations increased in the clay fraction, revealing occlusion and co-precipitation. This could be attributed to large surface area for adsorption and retention. Alekseeva et al. (2011) also made similar observation. Transitioning to the Bt2 horizon at greater depths, further shifts in element distribution become apparent. Major elements Si, Al, Fe, K, Ca and Mg continued to exhibit consistent and higher content, while trace elements such as Zn and Pb manifested distinct patterns compared to shallower horizons.

CONCLUSION

This study provides valuable insights into the total elemental composition of *Alfisols*, emphasizing the influence of soil depth and fractions on major and trace element distribution. The consistent patterns observed in major elements (Si, Al and Fe) across soil horizons and fractions indicate their prevalence in specific soil fractions, likely associated with primary minerals such as quartz and iron oxides. The variations in trace element distribution suggest intricate interactions influenced by factors like pH, redox conditions, and mineralogical content. The decline in Fe concentration with depth in both pedons indicated potential reduction of iron oxides. The study contributes to understanding the dynamic nature of elemental composition

in *Alfisols*, providing essential knowledge for soil management and environmental studies.

ACKNOWLEDGMENT

The author is thankful to 'The Karnataka Science and Technology Promotion Society (KSTEPS), Department of Science and Technology, Govt. of Karnataka with grant no AGR-13:2022-23/981 for providing financial assistance in the form of a stipend during the course of the investigation.

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