Czech University of Life Sciences Prague
Faculty of Environmental Sciences

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Topic:

Chemical Signatures of Archaeological Soils

By

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RATIONALE

(a) Archaeological dark earth

(b) Necrosols

✓Past human activities are related to the accumulation of elements (e.g., P, K, Ca, Mn, Fe)

What is missing????

✓Comparison of chemical signatures of past settlements with arable fields applied with modern mineral fertilizers.

✓ Multi-elemental analysis of necrosols

✓Such soil analyses are pertinent in making inferences on;

(a) enrichment factors of elements and elements which well-reflect the footprints of ancient human impact within time and space.

(b) suitability of anthrosols for arable fields.

Positive crop mark

COMPOSITION OF THESIS

Composed of four (4) published articles;

(1) A medieval hillfort as an island of extraordinary fertile Archaeological dark earth soil in the Czech Republic. European Journal of Soil Science (Q1).

(2) Traces of German and British settlement in soils of the Volta Region of Ghana. Geoderma Regional (Q2).

(3) Human burials can affect soil elemental composition for millennia—analysis of necrosols from the Corded Ware Culture graveyard in the Czech Republic. Archaeological and Anthropological Sciences (Q1).

(4) Can Wood Ashes of Commonly Planted Tree Species in Ghana be Applied as Fertilizers? Waste and Biomass Valorization (Q2).

(1) A medieval hillfort as an island of extraordinary fertile Archaeological dark earth soil in the Czech Republic

Preamble

(i) Aerial view of Dřevíč Hillfort

(ii) Fertilizer experiment in Msec

Rationale of study

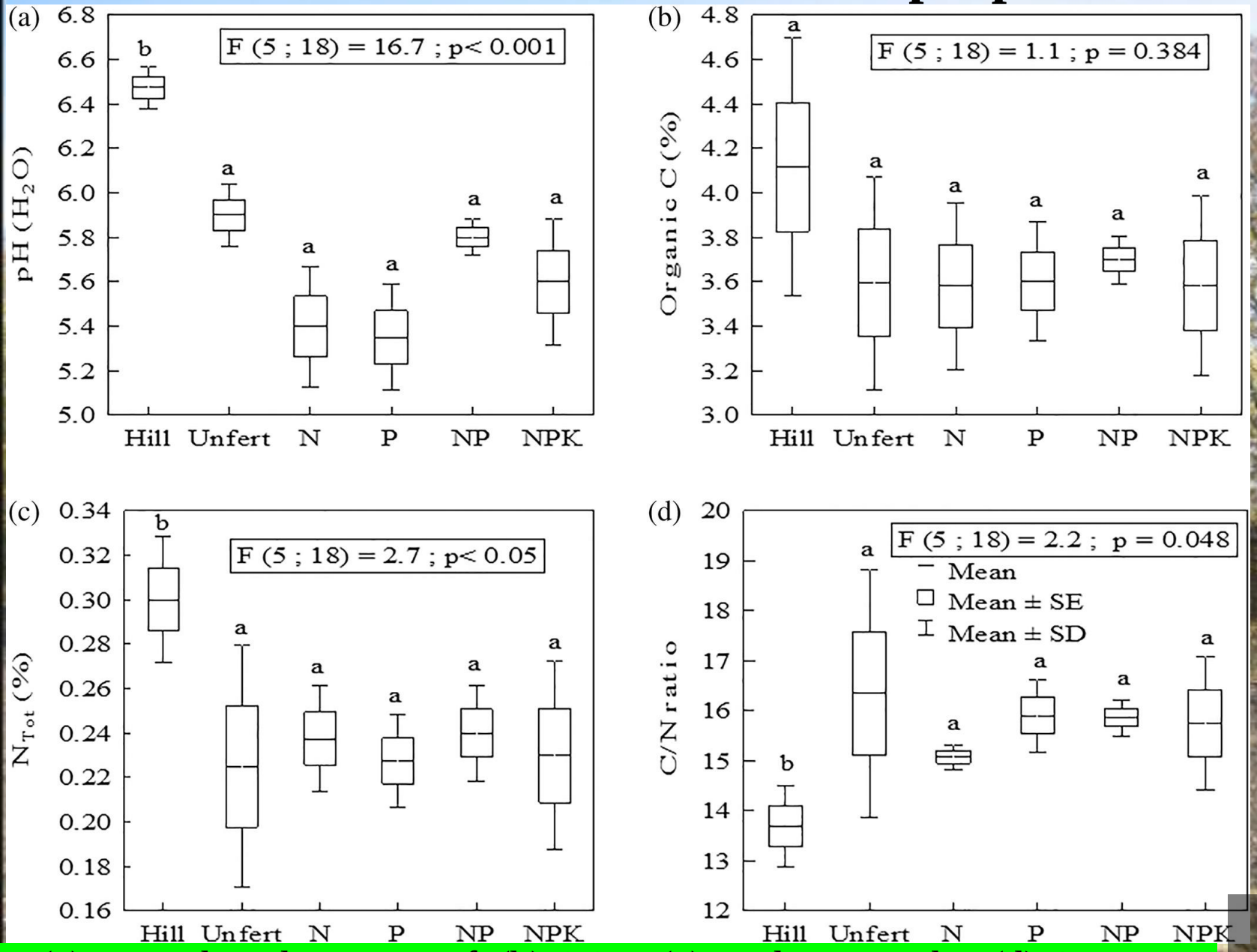
- ✓Enrichment of EDE by macro-, micro-, and trace elements compared to control soil.

- ✓whether intensive NPK fertilizer application increase the contents of anthropogenic elements to the same level as medieval settlement activities.

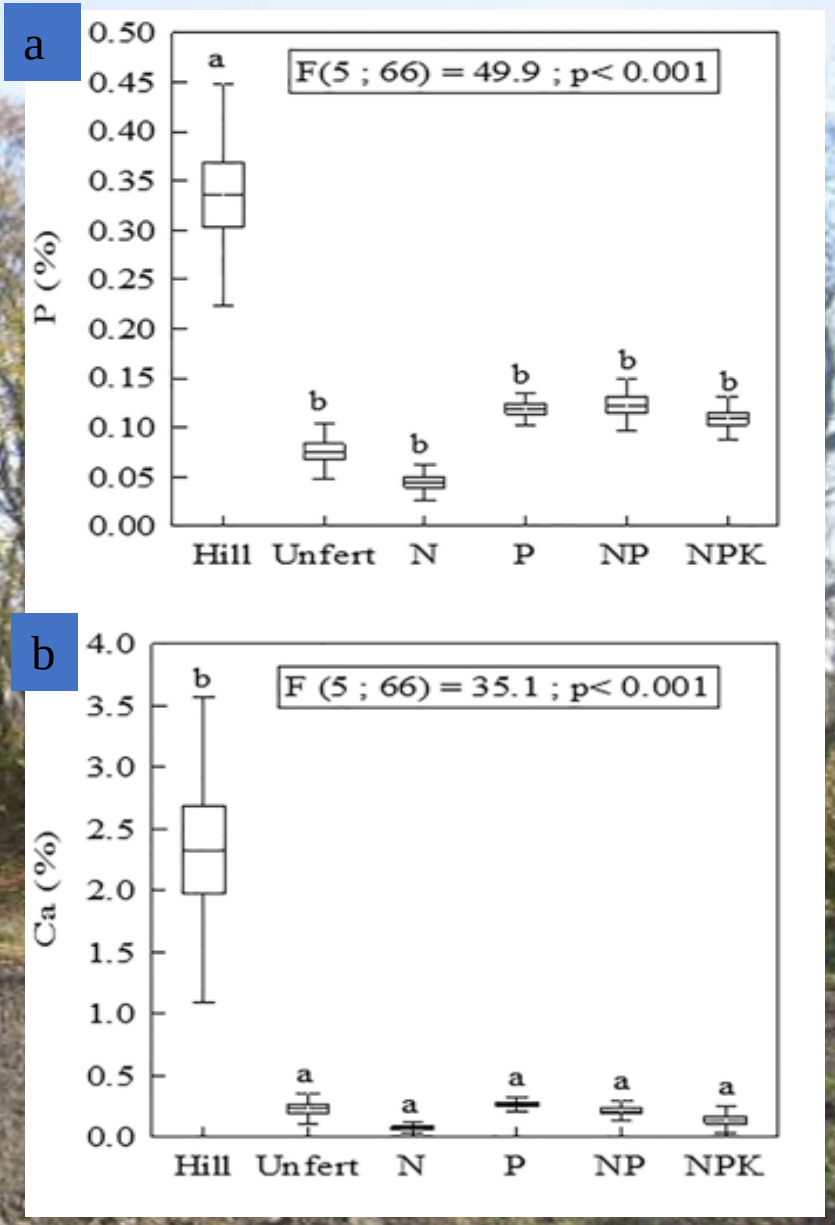
Question? ??? ????

- ✓In addition to P, Ca, Zn, and Cu in geo-archaeological studies, are there, other elements that can indicate medieval settlement activities?

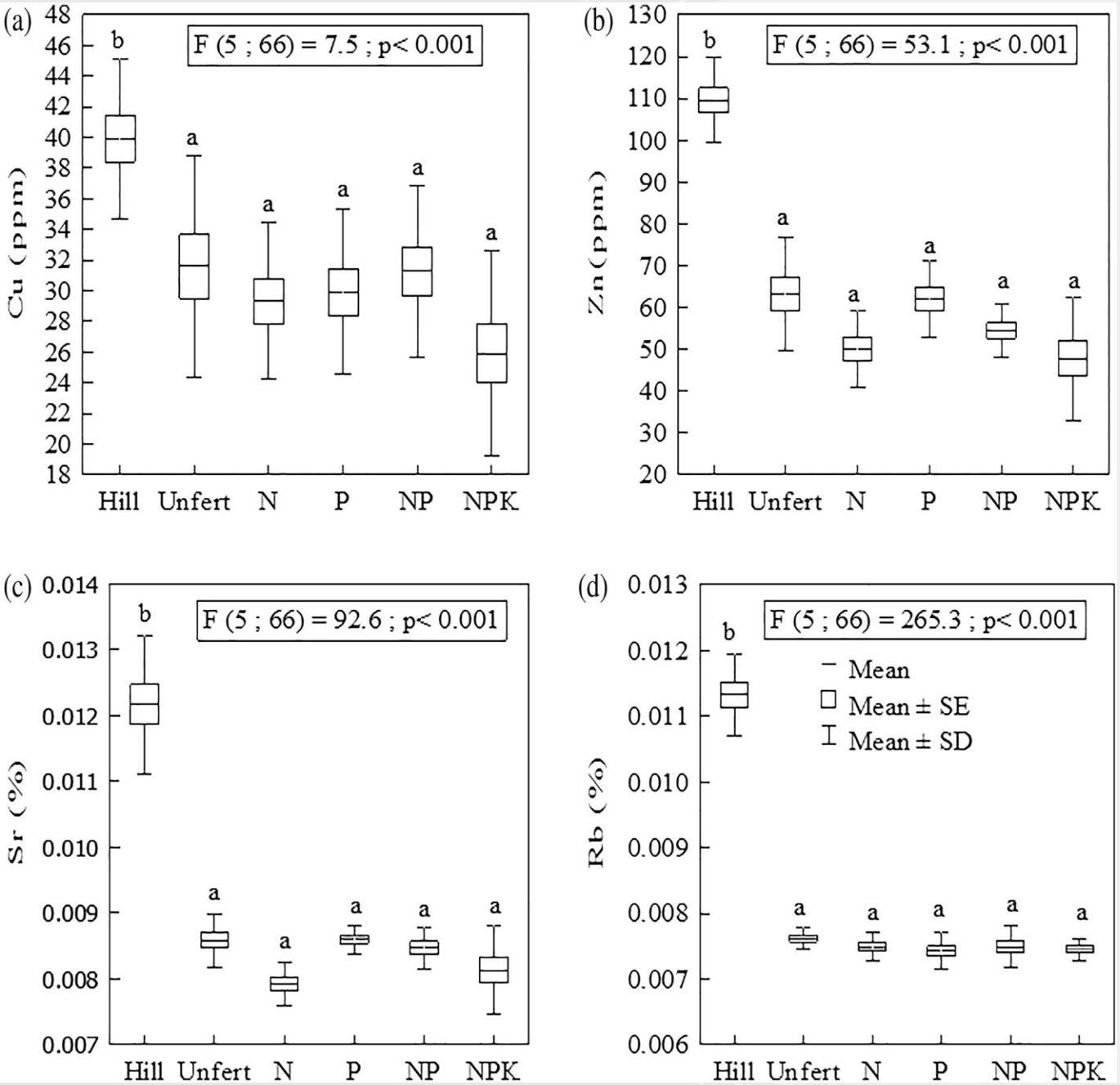
Soil chemical properties



1. (a) pH and total contents of (b) OC, (c) total N, and (d) C:N ratio6



2. Total content of (a) P and (b) Ca



Total content of (a) Cu, (b) Zn, (c) Sr, and (d) Rb

Relationship between P and other elements

Al, r = 0.84

Mn, r = 0.86

Fe, r = 0.84

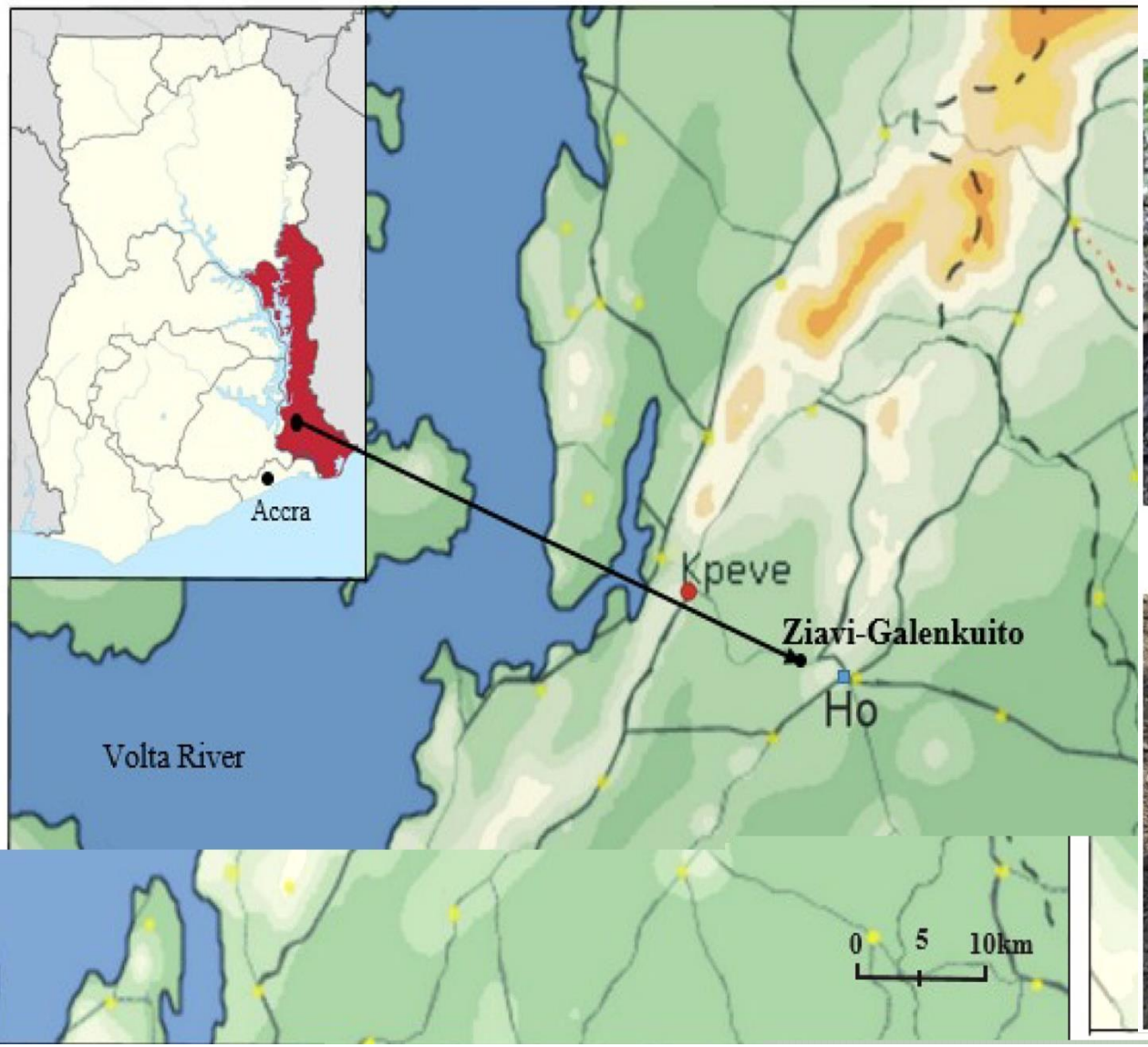
Cu, r = 0.59

Sr, r = 0.85

Rb r = 0.80

(2) Traces of German and British settlement in soils of the Volta Region of Ghana.

Preamble

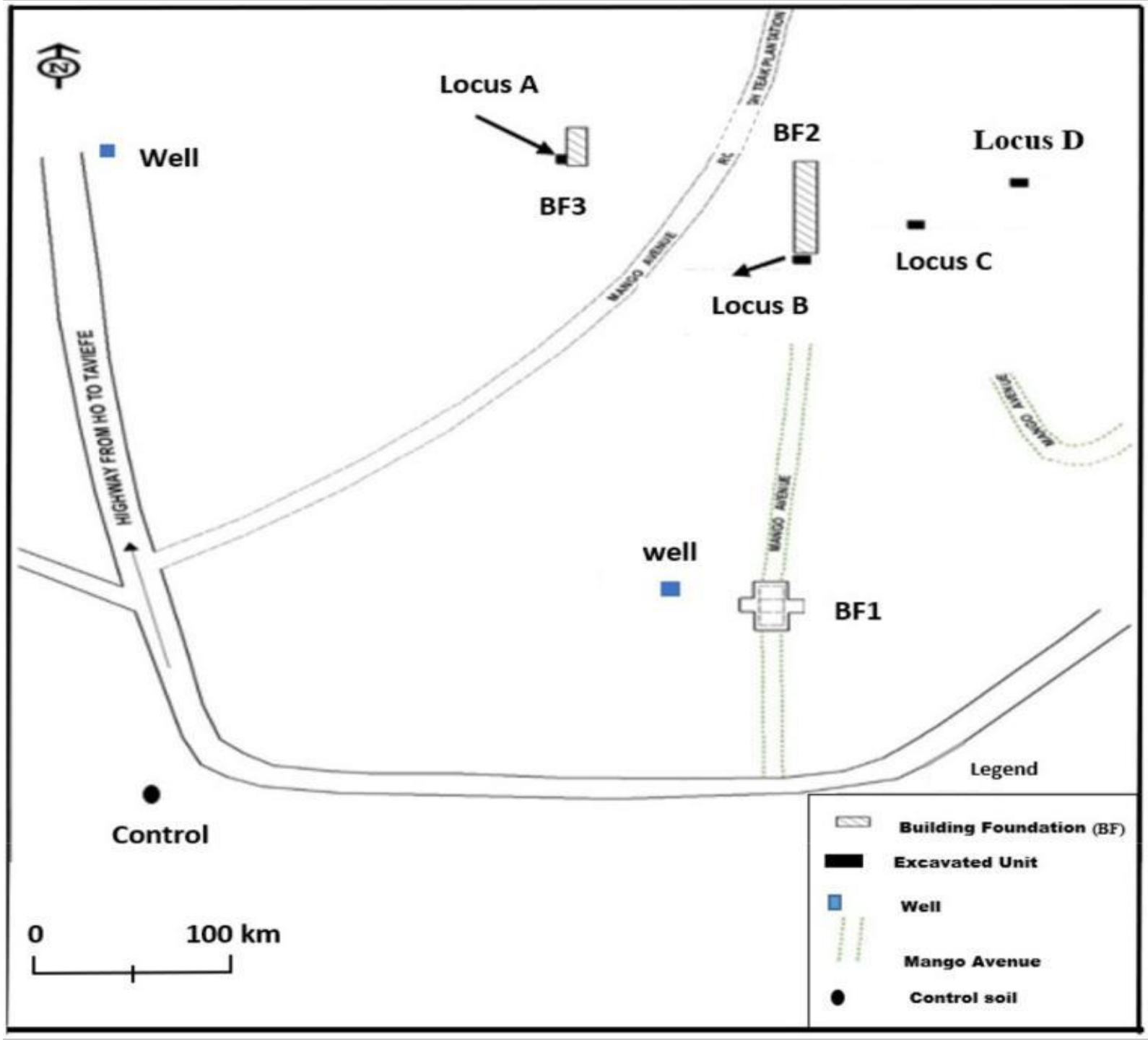


✓ Ziavi-Galenkuito in the Volta Region

✓ Relics of German and British settlements

What is the rationale behind this study?

- ✓ The extent of accumulation of anthropogenically-induced elements in <100 yrs of human settlement.
- ✓ Suitable elements as indicators of past settlement activities in the tropics.
- ✓ The relationship between total and plant-available elements and which is more suitable in estimating enrichment factors for geo-archaeological studies.



Soil physical attributes

- Grain size distribution (mean ± SD) and soil color (0 – 40 cm depth)

Sample location	≥ 2 mm (%)	< 2-1 mm (%)	< 1-0.5 mm (%)	< 0.5 mm (%)	Color
Locus A	7.7 ± 0.3a	25.4 ± 0.8a	30.4 ± 0.4a	36.4 ± 0.5a	7.5YR 2.5/1
Locus B	7.9 ± 0.2a	25.8 ± 0.6a	30.9 ± 0.4a	35.4 ± 0.5a	7.5YR 2.5/1
Control	7.6 ± 0.3a	29.2 ± 0.7b	31.1 ± 0.5a	**31.9 ± 0.6b**	7.5YR 3/3 7.5YR 4/3 7.5YR 4/6

Soil chemical attributes

pH and total element contents (mean ± SD) in the dark earth and control

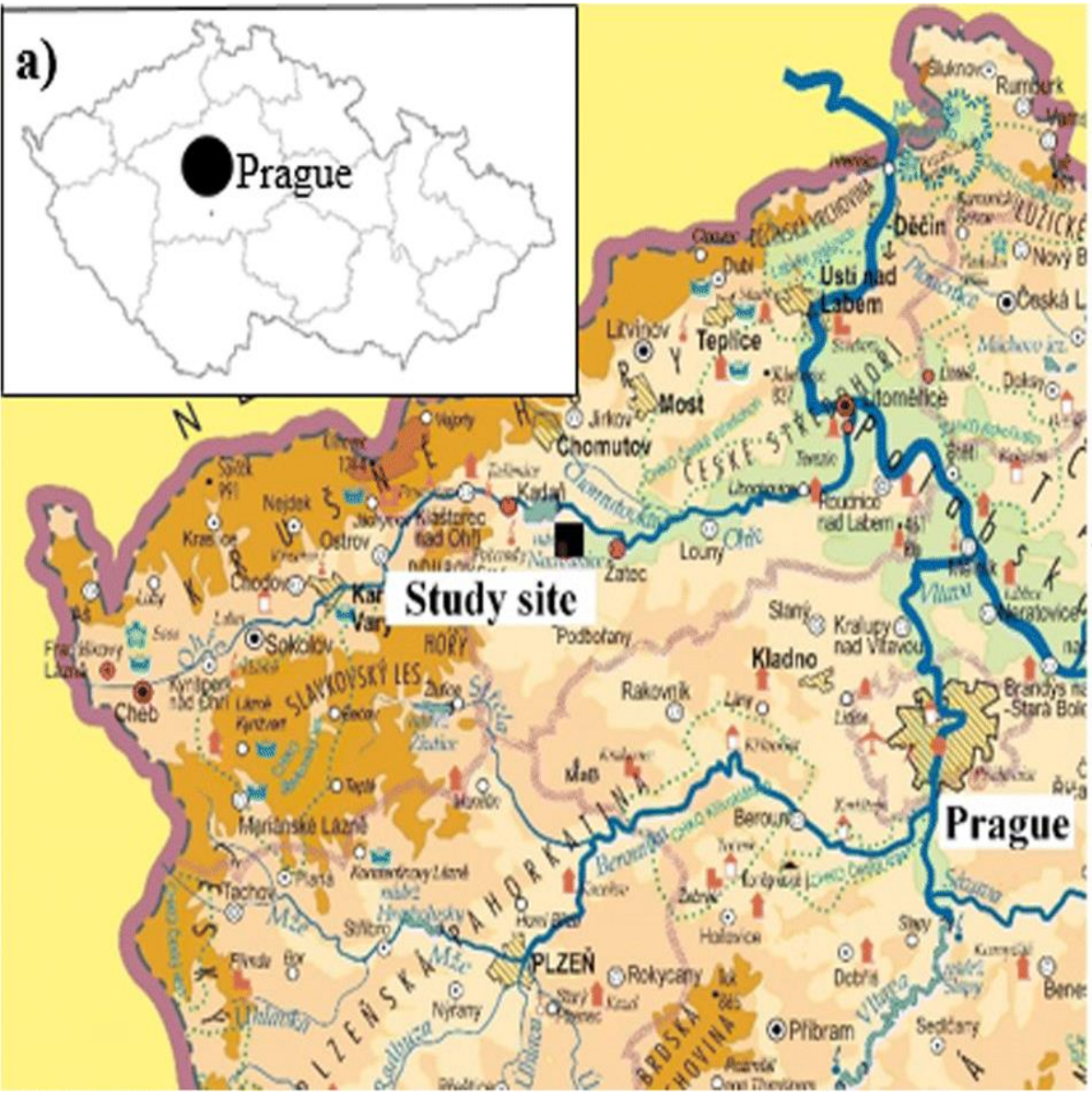
Sample location	pH (H_2O)	Org C (%)	Tot N (%)	C/N ratio	P (%)	K (%)	Ca (%)	Mn (%)	Cu (ppm)	Zn (ppm)	Rb (ppm)	Sr (ppm)
Locus A	6.6 ± 0.3a	4.5 ± 0.4a	0.32 ± 0.02a	14.9 ± 0.5a	0.51 ± 0.03a	1.31 ± 0.03a	4.67 ± 0.07a	0.25 ± 0.02a	33.2 ± 1.7a	60.1 ± 2.6a	39.8 ± 2.3a	149.2 ± 9.8a
Locus B	6.5 ± 0.1a	4.62 ± 0.2a	0.29 ± 0.01a	14.7 ± 0.3a	0.3 ± 0.02b	1.33 ± 0.03a	3.61 ± 0.3b	0.24 ± 0.0a	38.5 ± 3.7b	80.3 ± 3.6b	39.9 ± 2a	159 ± 4.2b
Control	4.3 ± 0.2b	1.76 ± 0.04b	0.09 ± 0.01b	20.2 ± 1.5b	0.01 ± 0.0c	0.06 ± 0.0b	0.17 ± 0.01c	0.03 ± 0.0b	17.2c ± 1.4	18.1 ± 3.7c	12.9 ± 1.2b	15 ± 2.2c

Relationship between total P and other elements

Parameter	Ca	Rb	Sr	K	Fe	Mn	Cu	Zn
Correlation coefficient (*r*)	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.6
p-value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

(3) Human burials can affect soil elemental composition for millennia—analysis of necrosols from the Corded Ware Culture graveyard in the Czech Republic.

Preamble



Graves before and after excavation

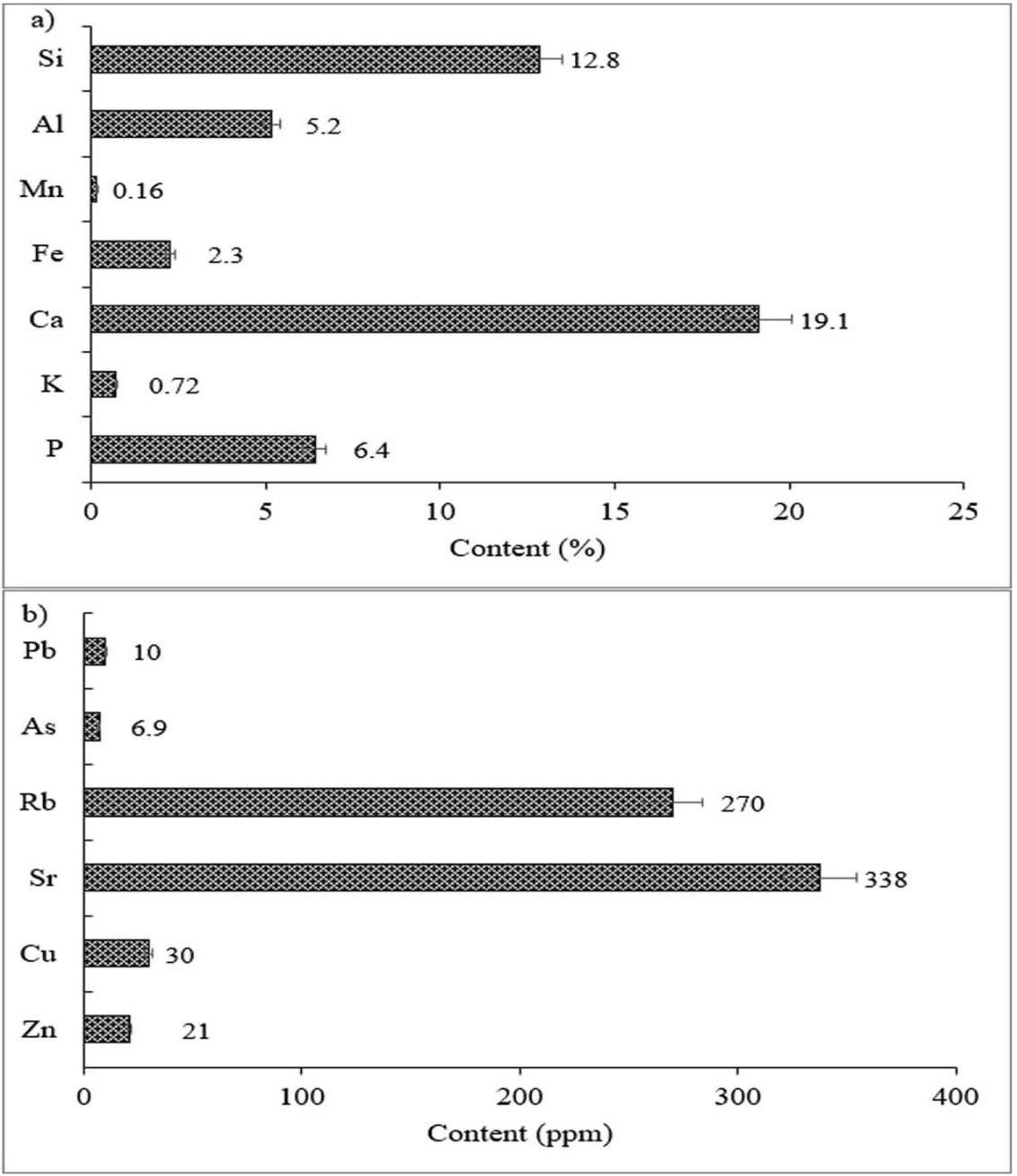
Rationale of study

Extent to which buried human bodies affect the elemental content (especially C, P, and Ca) of necrosols and whether the effects are visible even after several thousands of years.

Which elements are more suitable to indicate the decomposition of soft tissue and bone in an archeological perspective

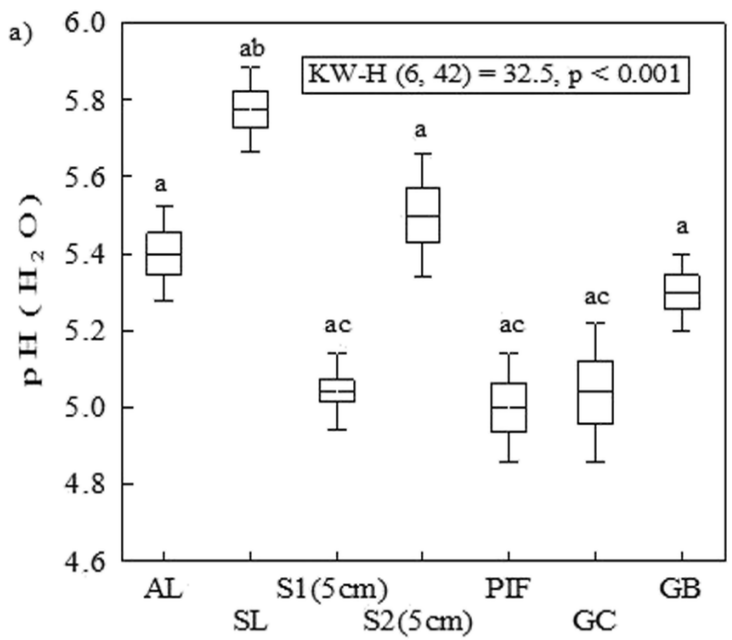
How the distance of bones in the grave affects the chemical composition of the substrate.

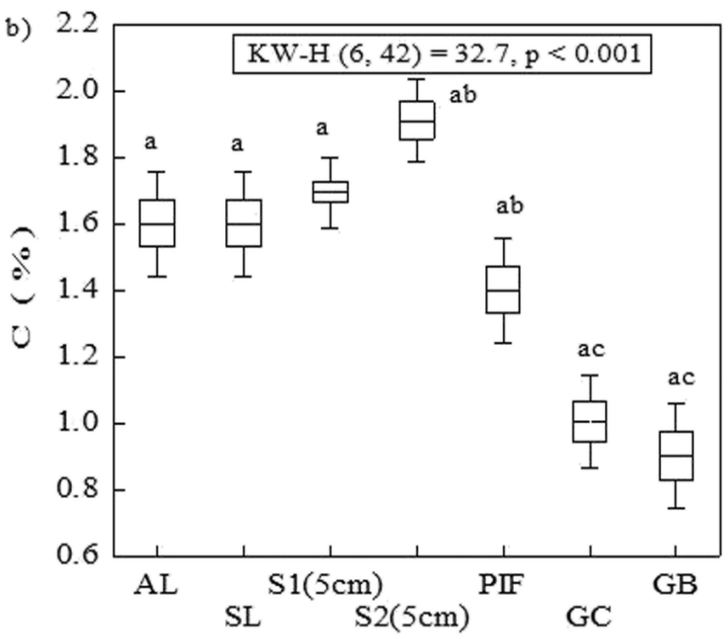
Content of elements in buried human bones



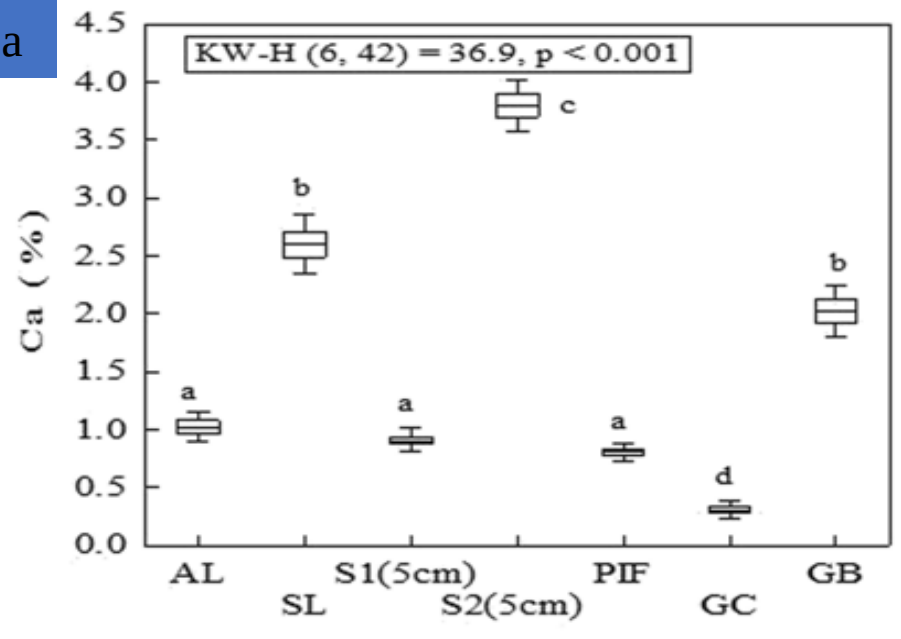
Description of sampled locations

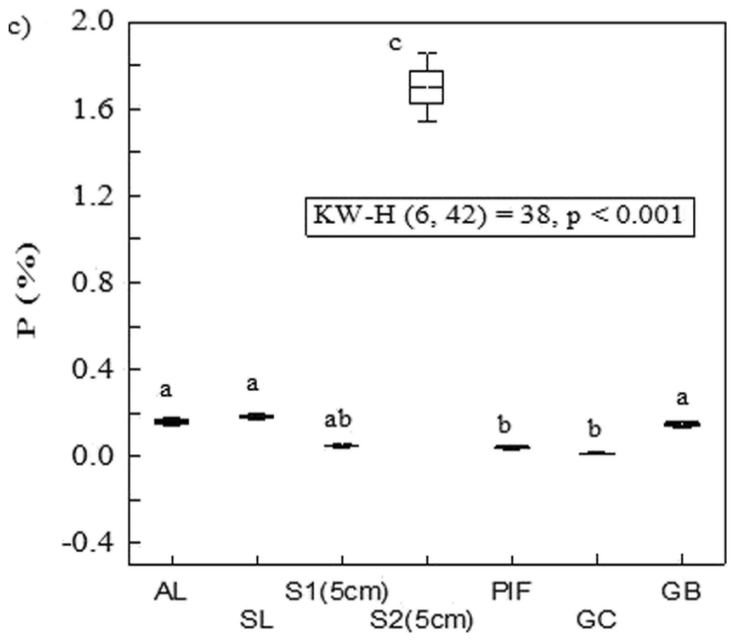
Soil layers	Abbreviation
Arable layer	AL
Subsoil layer	SL
Grave infill >5 cm to bones	S1 (5cm)
Grave infill ≤ 5 cm to bones	S2 (5cm)
Pot infill	PIF
Grave clay	GC
Grave bedrock	GB

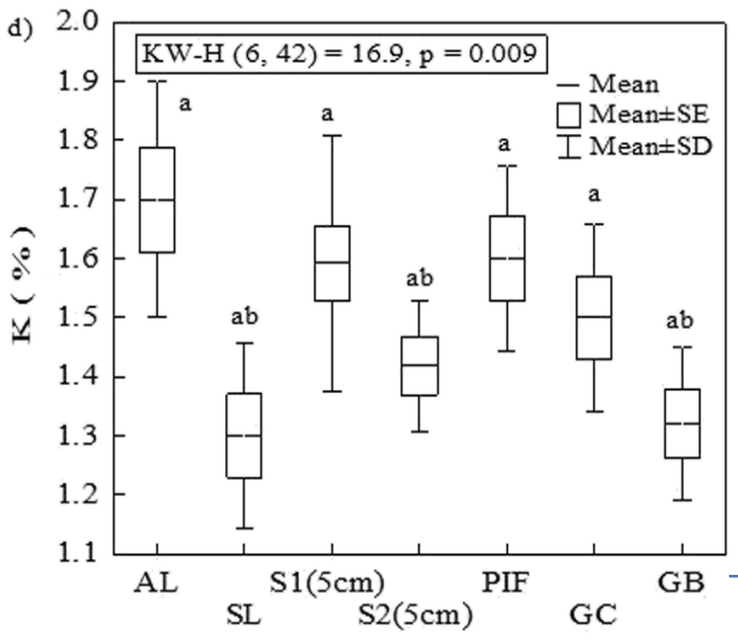




a







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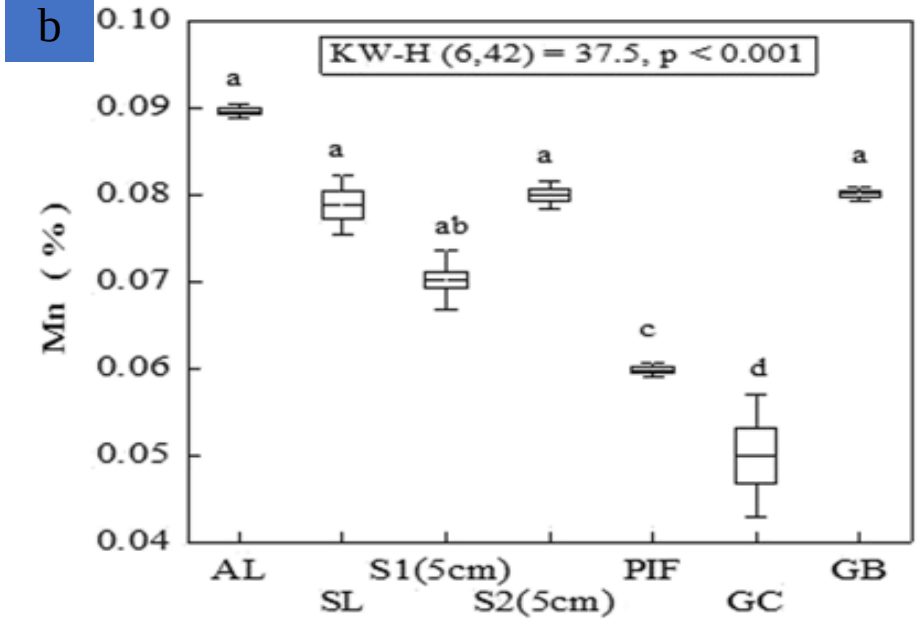
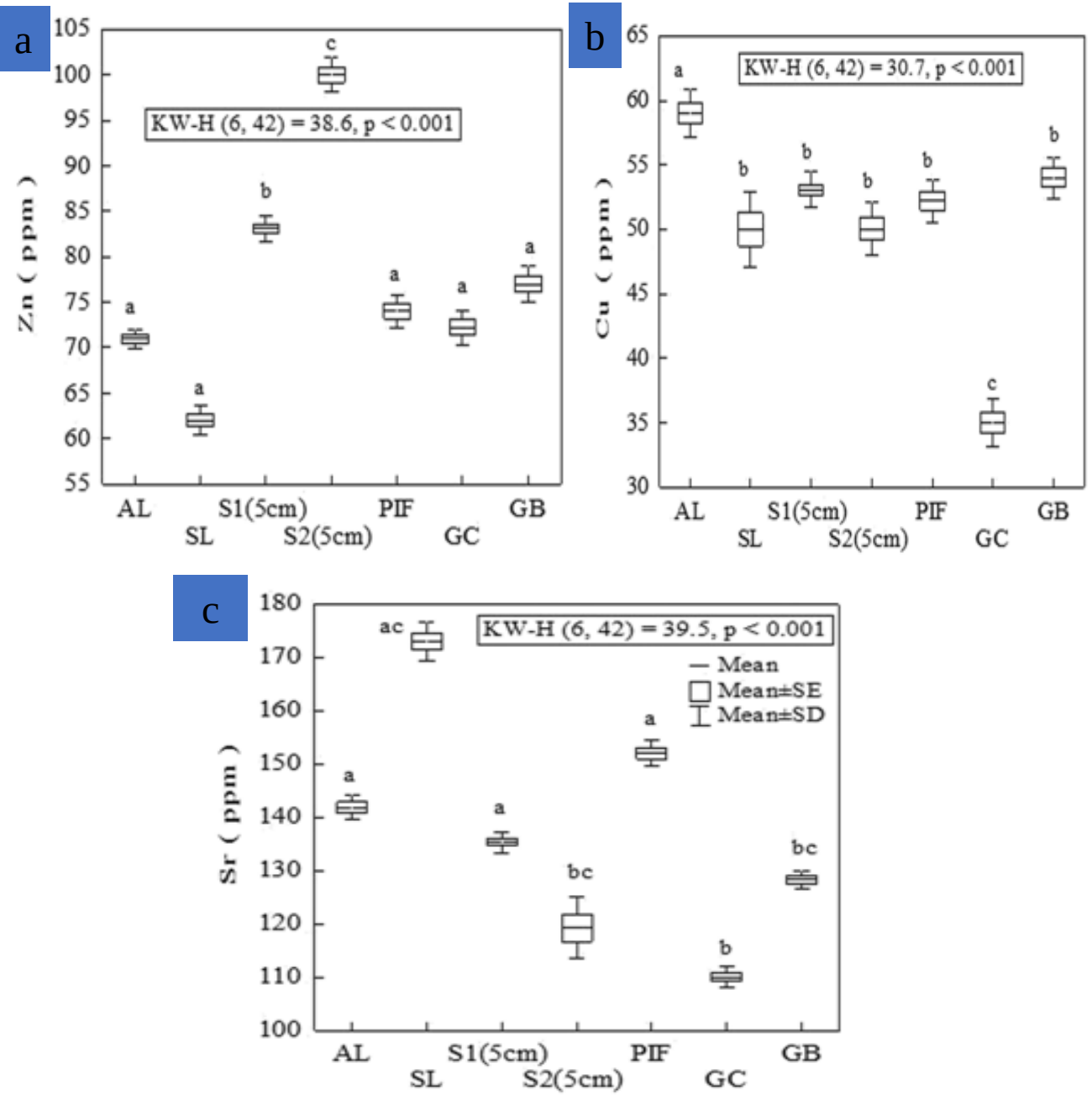


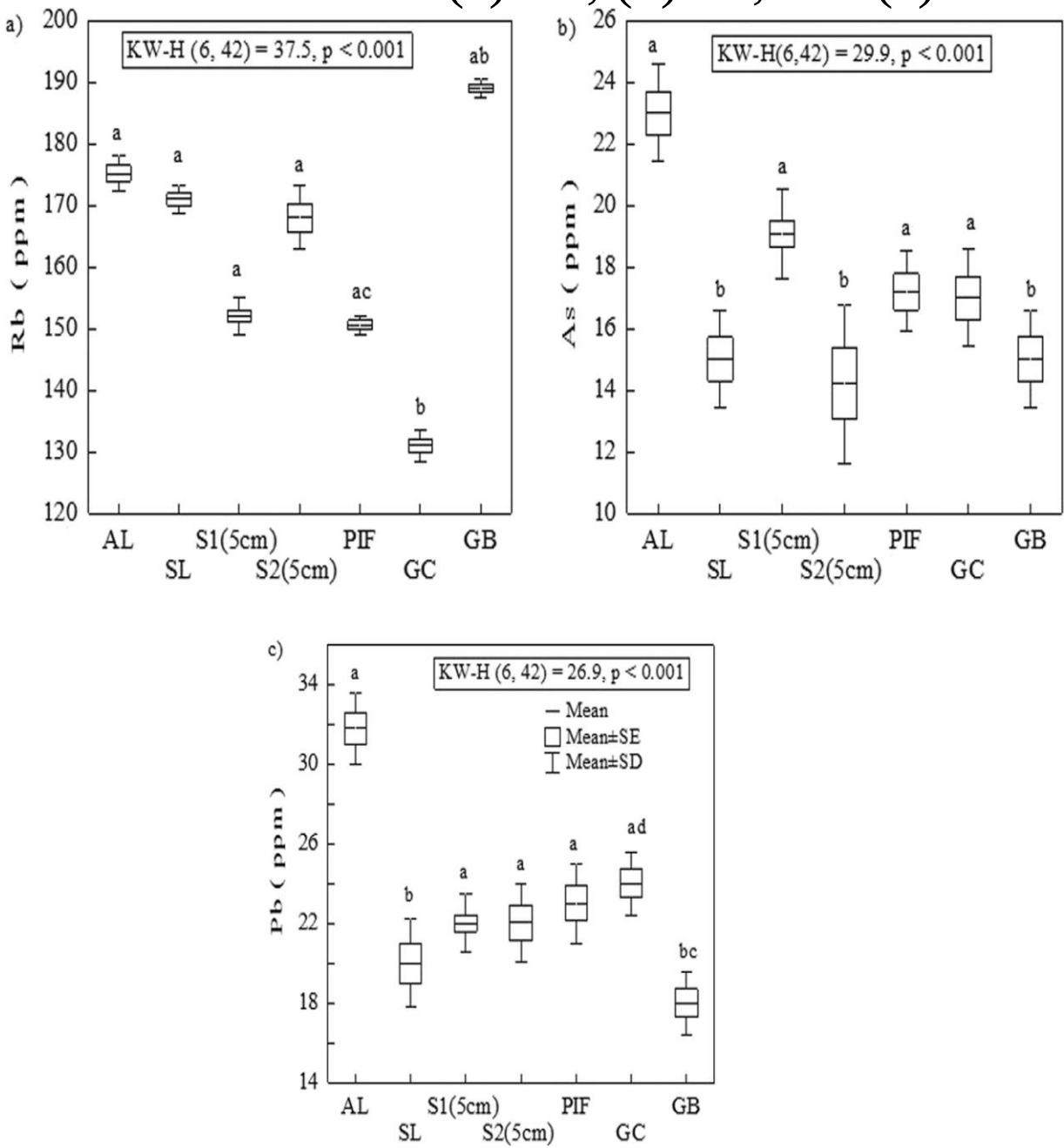
The pH (a) and total content of P (b), C (b), P (c), and K

Total content of Ca (a) and Mn (b)

Total content of (a) Zn, (b) Cu, and (c) Sr



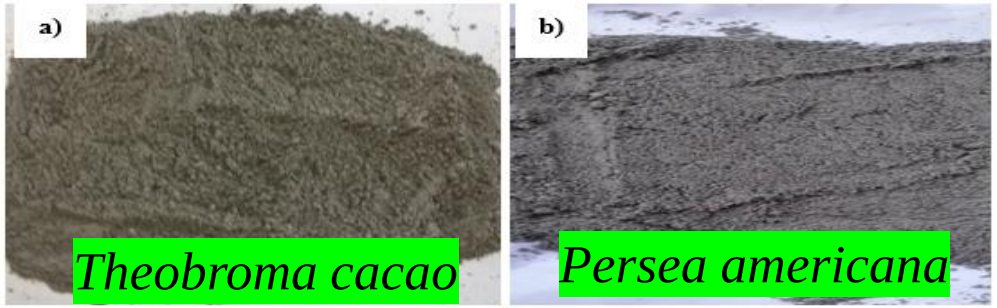
Total content of (a) Rb, (b) As, and (c) Pb

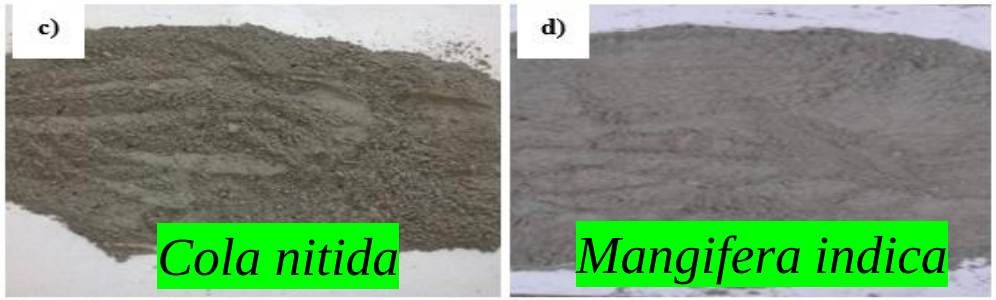


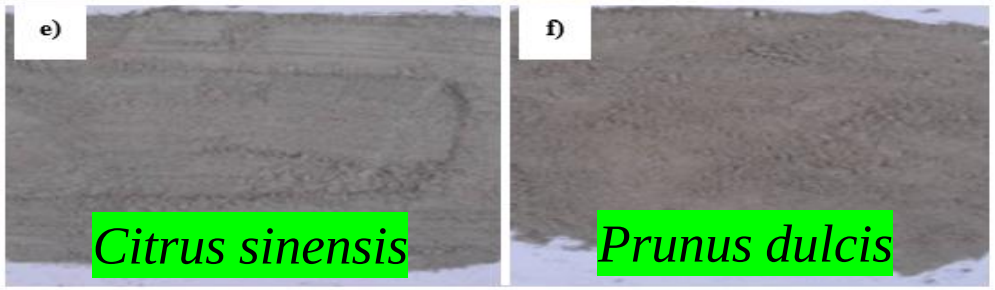
The pH and total content of elements below grave bedrock

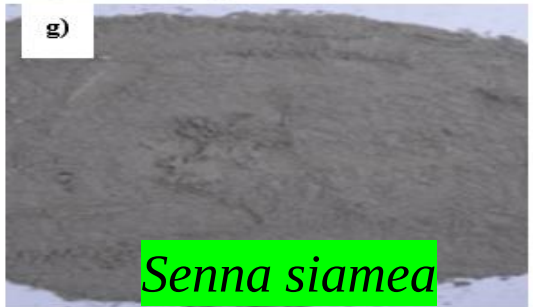
Sample no.	Depth (m)	pH (H2O)	P (%)	Ca (%)	Fe (%)	Mn (%)	Cu (ppm)	Zn (ppm)	Sr (ppm)	Rb (ppm)	As (ppm)	Pb (ppm)
57	0.9–1.4	5.4	0.09	0.71	2.7	0.21	29	34	97.2	143	11	16.3
58	1.4–2.4	5.5	0.11	0.33	1.6	0.04	55	47	118	138	8.7	23.6
59	2-4–3.4		0.15	0.48	2.5	0.04	23	27	121	169	13	18
60	3.4–4.4	4.8	0.29	0.42	2.8	0.08	48	38	122	173	14.7	23.6
61	4.4–5.4	5.8	0.32	1.46	4	0.38	63	42	126	232	27.7	25.6

(4) Can Wood Ashes of Commonly Planted Tree Species in Ghana be Applied as Fertilizers?









Study rationale;

ash yields, total and plant-available contents of macro, micro, and other elements among studied species

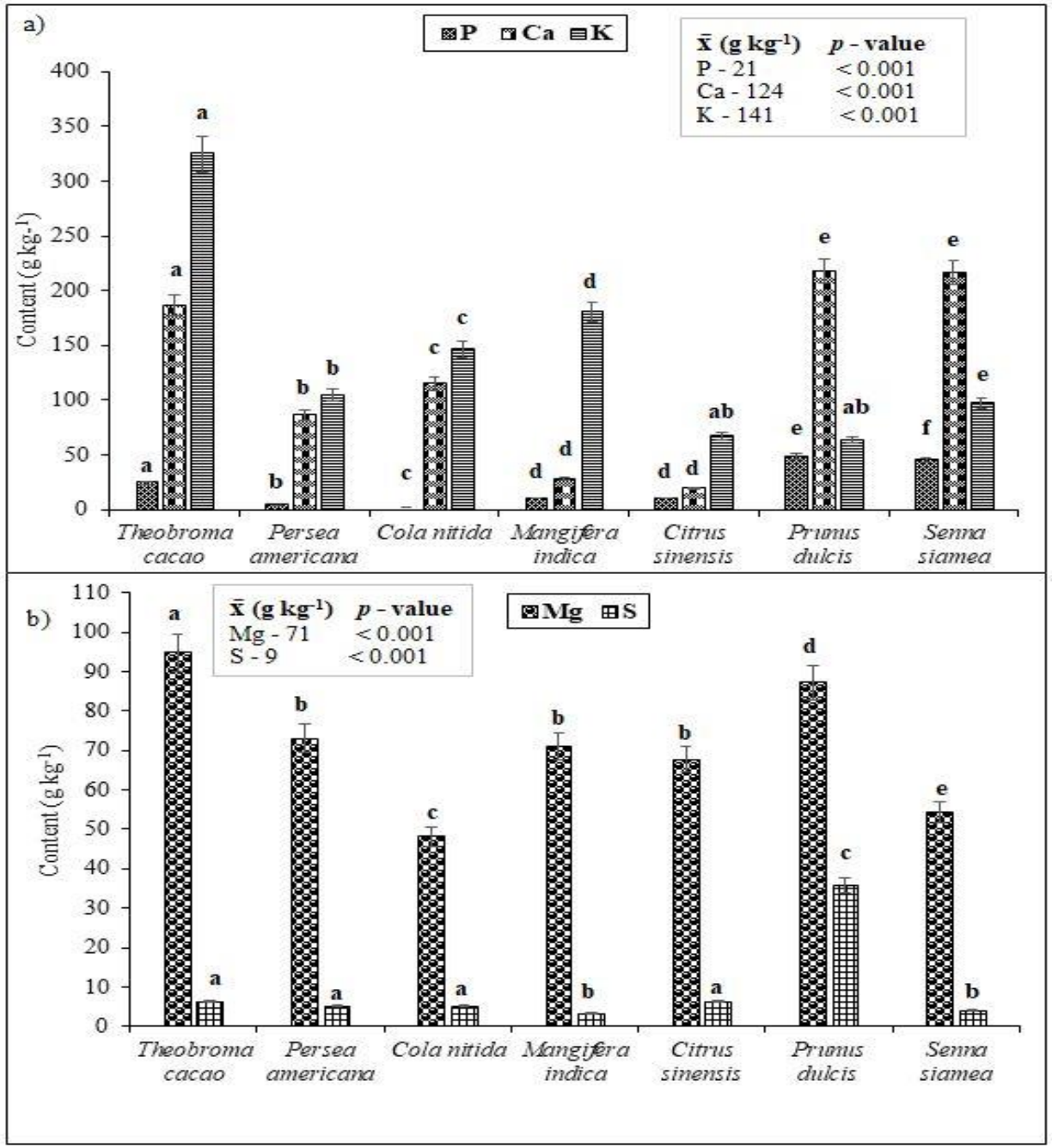
releasability of elements

if the studied ashes can be used as fertilizers

pH and ash yields

Species	pH	Ash yield (%wt)
T. cacao	12.9	7.1
P. americana	9.1	4.8
C. nitida	10.4	5.2
M. indica	10.2	5.7
C. sinensis	7.8	3.1
S. siamea	10.9	4.6

Total content of elements



Other elements include;
Mn, Cu, Zn, Na, Fe, Ni, Cr, Pb, Co, and As

Total element content of studied wood ashes

Element (mg/kg)	*T. cacao*	*P. americana*	*C. nitida*	*M. indica*	*C. sinensis*	*P. dulcis*	*S. siamea*	**Mean**
P	265	64	22	161	57	512	449	219
Ca	2948	19713	13610	16382	12923	17781	13827	13883
K	79086	88303	42394	63714	59671	44237	37491	59271
Mg	29001	15239	27265	13719	14627	24381	28478	21816
Mn	102	88	168	82	75	105	141	109
Cu	40	41	62	64	61	73	74	59
Zn	75	44	72	85	66	89	91	75
Na	941	6937	1171	6178	836	1027	1164	2608

Releasability (%) of element in wood ashes

Ash samples	P	Ca	K	Mg	Mn	Cu	Zn	Na	Fe
T. cacao	1.1	1.6	24.3	30.5	55.6	67.2	38	3.2	0.08
P. americana	1.6	22.9	84.3	20.9	50.6	76.1	23.5	75	0.9
C. nitida	1.1	11.8	29.1	56.8	48.4	79.1	30.2	14	0.24
M. indica	1.5	58.5	35.4	19.3	55.2	84.6	37.9	56.1	0.93
C. sinensis	0.5	68	88.5	21.5	52.6	85.9	32.7	23.2	0.71
P. dulcis	1.1	8.4	69.3	28	27	89.7	28.6	8.2	3.5
S. siamea	1	6.4	38.6	5.2	17.7	92.8	36.2	7.8	3.3
Mean	1.1	25.4	52.7	26	43.9	80.4	32.4	26.8	1.4

OVERALL CONCLUSIONS

- Intensive application of mineral fertilizers (N, P, and K fertilizers) can hardly mask the content of N, P, K, and other trace elements in EDE soil.
- Archaeological dark earth (European and African Dark Earths) is characterized by the accumulation of N, P, K, Ca, Mn, Fe, Cu, Zn, Sr, and Rb.
- Majority of archaeological soils are affected by ashes with a high accumulation of elements.
- Increased fertility of soils by ashes can be visible after thousands of years.
- The chemical signatures of necrosols can be preserved for centuries. However, in grave infills the Zn and P contents are the most suitable indicators of soft tissues and bone decompositions within space and time.
- Settlement activities affect nutrient availability and can affect the ecosystem for a long period