

DecLaRe: Decision support for strengthening land resilience in the face of global challenges
(Presented during the Status Seminar held in Accra, Ghana on 2-6 June, 2025)

Assessment of The Micronutrient Dynamics of Northern Ghana, Supported by Gamma Ray Measurement

Chike O. Madueke¹, Amisu Mohammed², Mouinou A. Igue⁺³,
Vincent K. Avorny², Karsten Vennemann¹, Ludger Herrmann¹

Sponsored by the



Federal Ministry
of Research, Technology
and Space



UNIVERSITÄT
HOHENHEIM





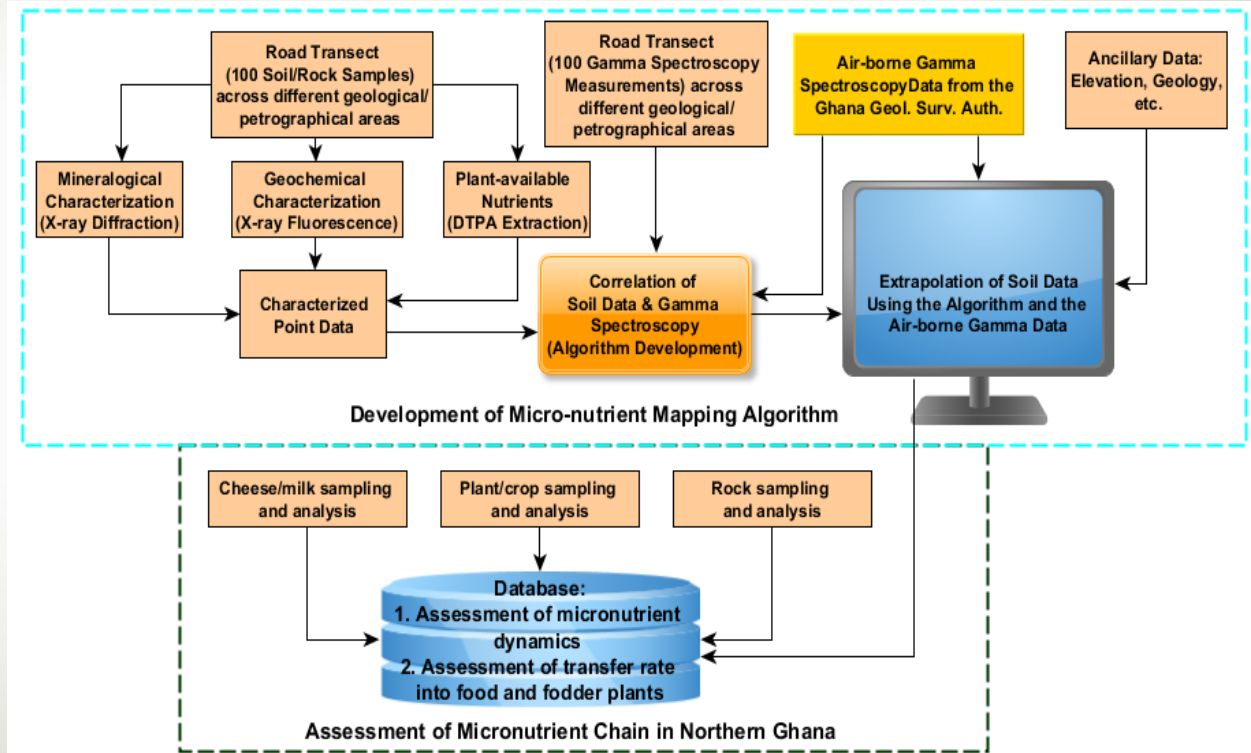
Introduction

- ❑ Moderate to severe **food insecurity**, including **hidden hunger**, (*particularly among children*) is as high as **67 %** in sub-Saharan Africa (FAO, *et al.*, 2023).
- ❑ Hidden hunger, is attributable in part, to micronutrient deficiency
- ❑ However, no consistent data exist that systematically cover the micro-nutrient transfer from the soil over plants to humans and animals.
- ❑ In particular, **information on the soil micronutrient status are virtually non-existent in sub-Saharan Africa**, necessitating the development of an efficient and site-specific mapping approach.
- ❑ This will provide the basis to better understand the **micro-nutrient dynamics** in the region.



Framework/Hypothesis

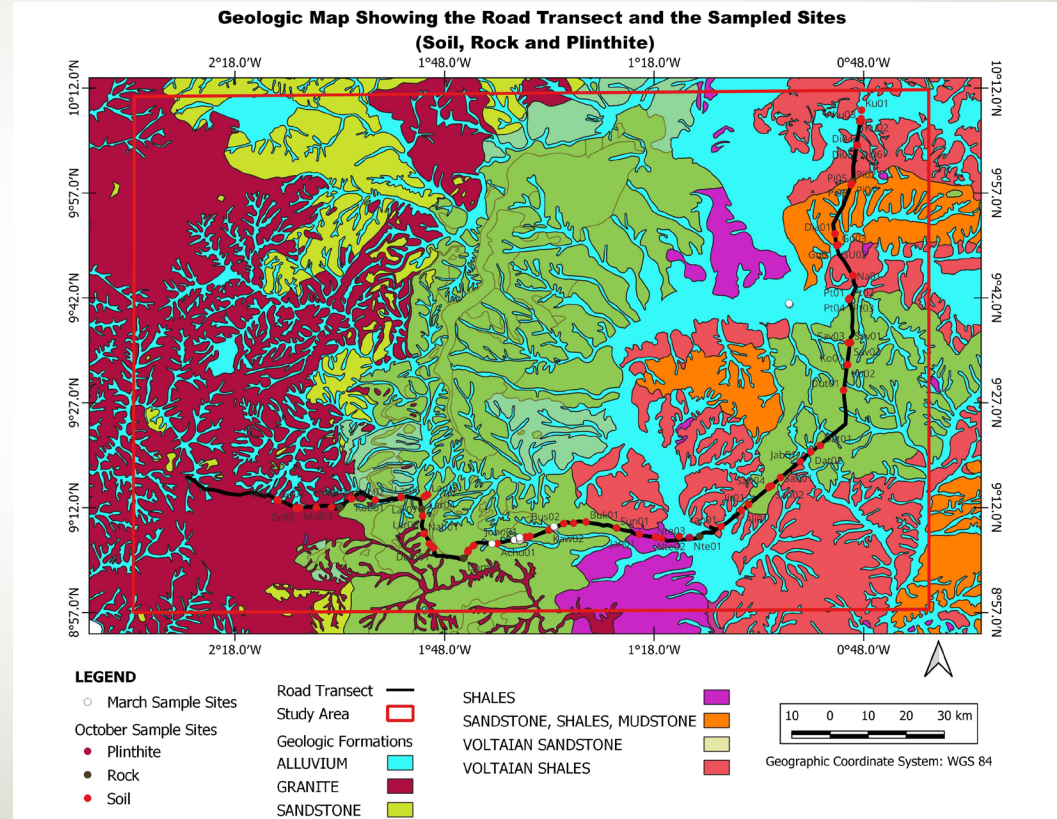
- ❑ The **original sources of micro-nutrients** in the landscape are the **parent rocks**. This non-available stock is **transformed via soil formation** (weathering) into **plant available forms**.
- ❑ Different plants accumulate different amounts of this available fraction. Therefore, finally the consumption pattern is decisive for the total micro-nutrient uptake of humans and livestock.
- ❑ Site-specific soil management and fertilization for proper and improved nutrition is crucial.





Sampling Transect

- ❑ Samples were collected along a transect cutting across different geological formations in the DecLaRe intervention zone.
- ❑ Rock, soil and plinthite samples were taken.





Analytics

Laboratory Analytics

1. X-ray Diffraction: *Mineral composition*
2. X-ray Fluorescence: *Total element content including micro-nutrients*
3. DTPA (“CAT”) Extraction: *Plant available micro-nutrient fraction*
4. Elementary analysis: *Total/organic carbon and total nitrogen*
5. Combined sieve and pipette analysis: *Grain size distribution*
6. Potentiometry: *Soil pH in a 1:2.5 soil to 0.01 M CaCl₂ solution*

Statistical Analytics

1. Descriptive statistics (box plots, histograms, correlation and linear regression).
2. Multilinear regression and inter-/extrapolation of the data still ongoing



Results

Overview of Available Micronutrients in the Study Area

- Iron and manganese are available in optimum to very high ranges.
- *Copper content ranges from moderate to high.*
- *Zinc and molybdenum are generally deficient.*

SN	Nutrient	Range (mg kg ⁻¹)	Average Rating	Mean (mg kg ⁻¹)	CV (%)
1	Iron	16-695	Adequate	84	12
2	Manganese	8-625	Adequate	131	21
3	Copper	0-3	Moderate-Adequate	1	30
4	Zinc	0-10	Deficient	1	8
5	Molybdenum	0-1	Deficient	0	-



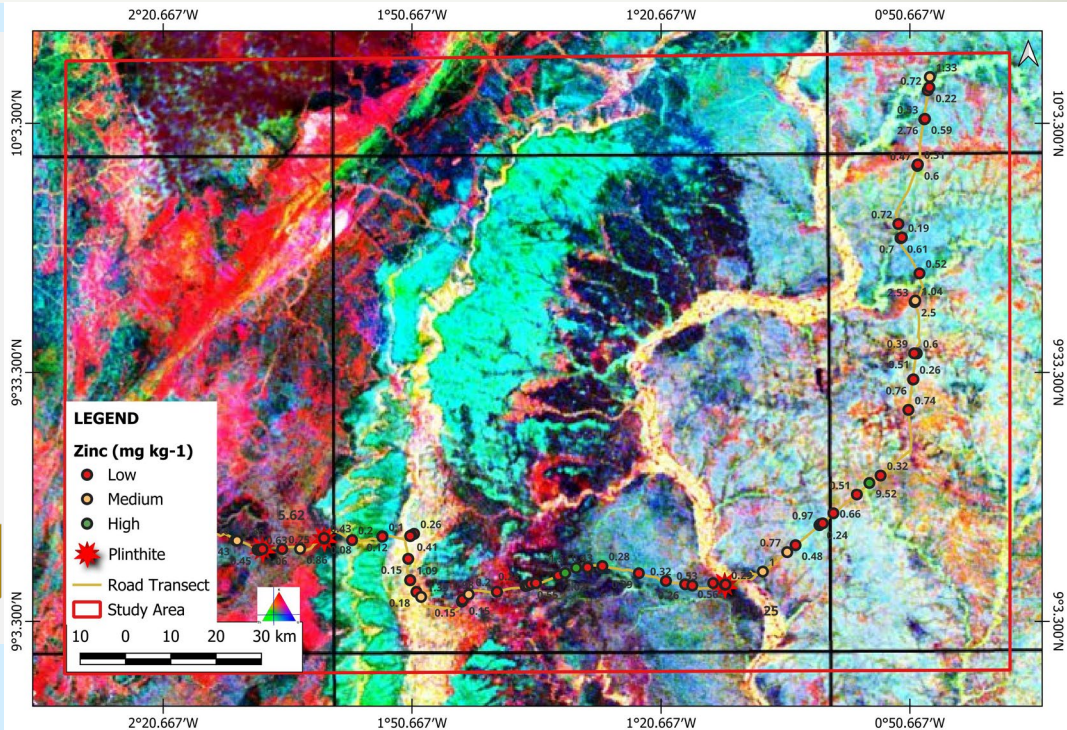
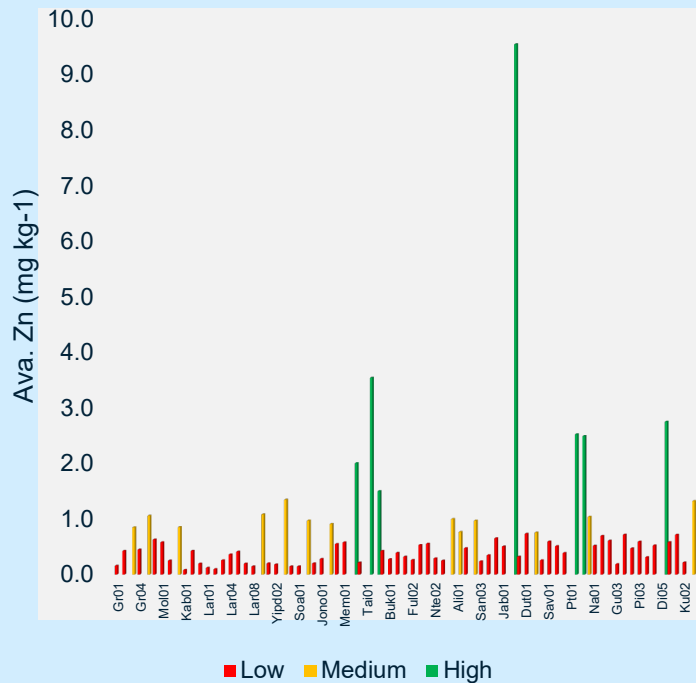
Distribution of Plant-Available Micronutrient Ratings

		Low	Medium	High
Iron	(mg kg ⁻¹)	<4.5	4.5–7.5	>7.5
	Proportion (%)	0	0	100
Manganese	(mg kg ⁻¹)	<2.0	2.0–4.0	>4.0
	Proportion (%)	0	0	100
Copper	(mg kg ⁻¹)	<0.20	0.20–0.40	>0.40
	Proportion (%)	6	32	61
Zinc	(mg kg ⁻¹)	<0.75	0.75–1.50	>1.50
	Proportion (%)	74	17	9
Molybdenum	(mg kg ⁻¹)	<0.1	0.1-0.2	>0.2
	Proportion (%)	95	1	4

The ratings were i.a. adapted from Reddy *et al.* (2017) and VDLUFA (1991)

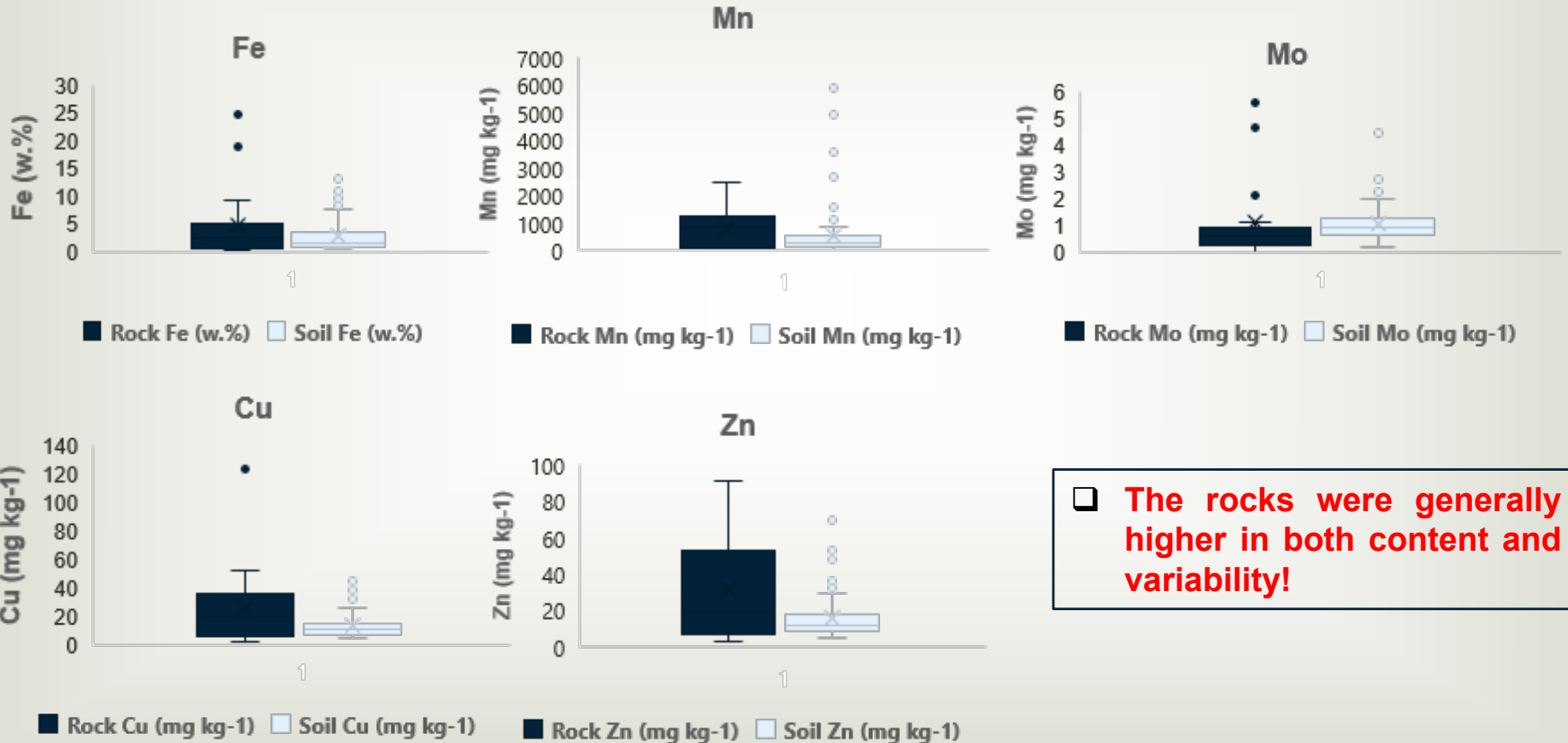


Spatial Variability of Micronutrients





Comparative Analysis of **Total** Micro-nutrient Content of Soils and Rocks



The rocks were generally higher in both content and variability!



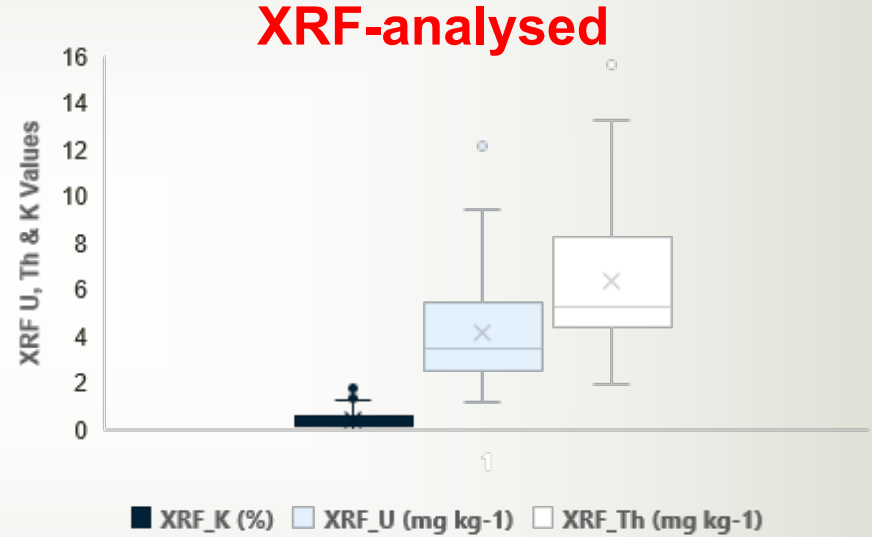
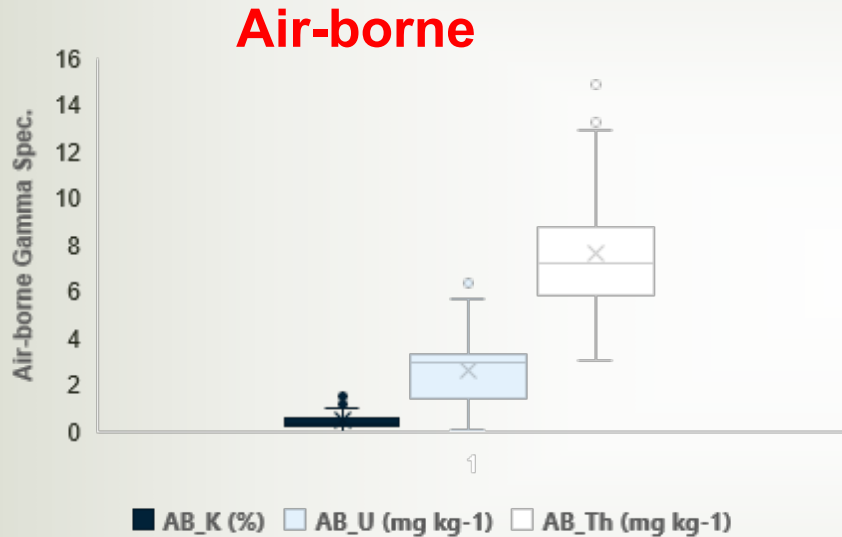
Comparative Analysis of **Total and Available** Micronutrient Content of Soils

	Fe	Mn	Cu	Zn	Mo
Average Total Content (mg kg ⁻¹)	22621.6	384.3	11.2	14.6	1.0
Average Available Content (mg kg ⁻¹)	75.1	114.3	0.7	0.7	0.02
Proportion of Total that is Available (%)	0.03 - 4.30	5.0 - 77.7	1.5 - 18.8	0.4 - 18.0	0.2 - 53.9

- ❑ **The available share is quite variable: What are the key determinants?**
 - **A higher proportion of the total Mn and Mo tend to be available in sites with relatively low total content**



Comparison of remotely-sensed gamma K, U, Th and soil content as determined by XRF



NB: AB = airborne, XRF = x-ray diffraction

Good News: The value ranges for both datasets are quite similar

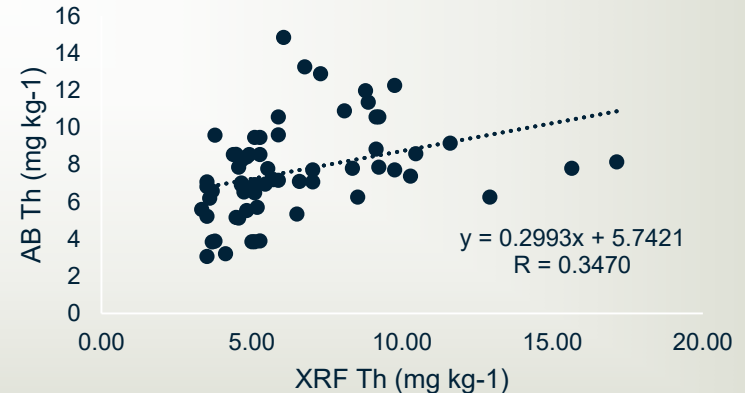
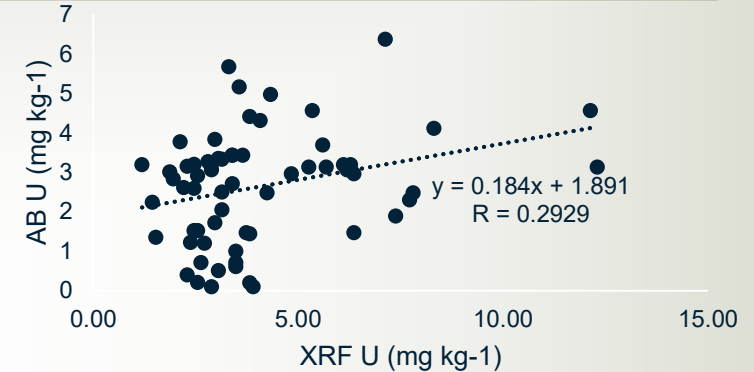
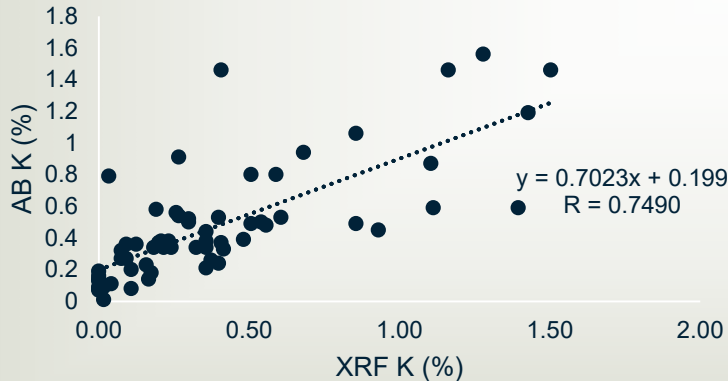


Correlation of Air-borne and XRF Data

Correlation for U and Th is quite poor

Reasons are still to be explored. Potentially, the soil water content at time of flight was variable.

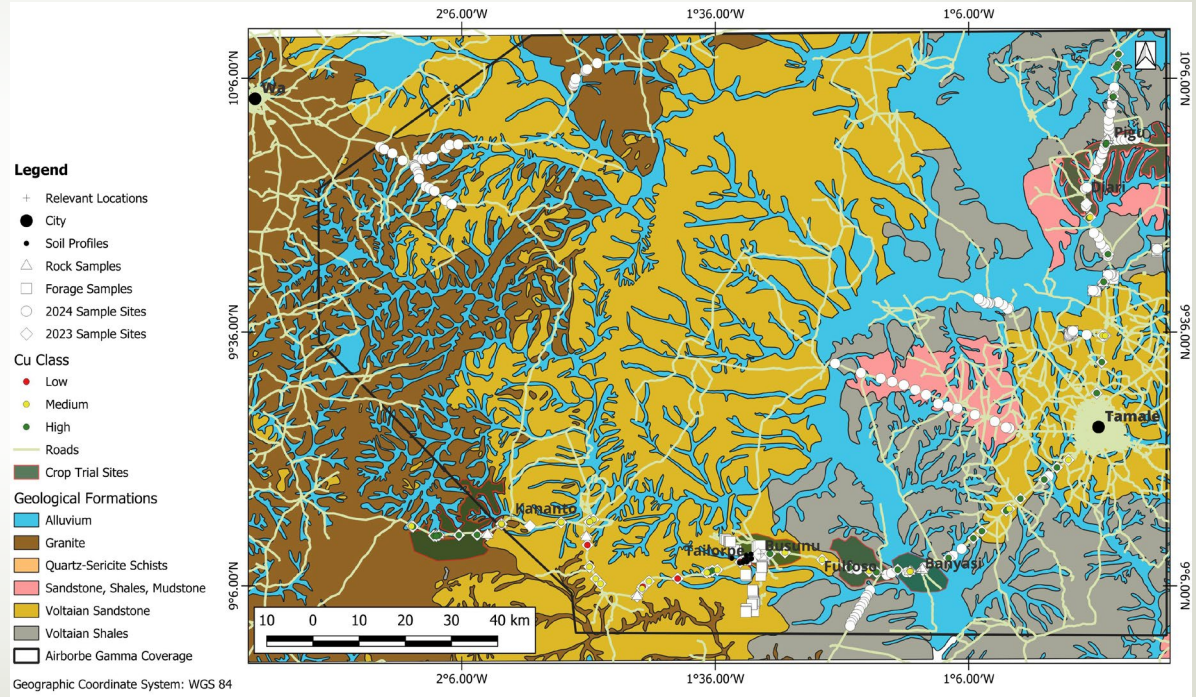
Dealing with individual geologic formation may improve the model



Improving the Sampling Scheme

- ❑ In 2024,
 - Up to 30 soil samples were taken per geological formations (at 3 depths)
 - **Forage** also taken at 55 sites in the region.
 - **Crop** samples (maize and groundnut) collected
 - **Milk** and **wagashi** (local cheese) collected
 - **Food** (TZ and soup) collected.

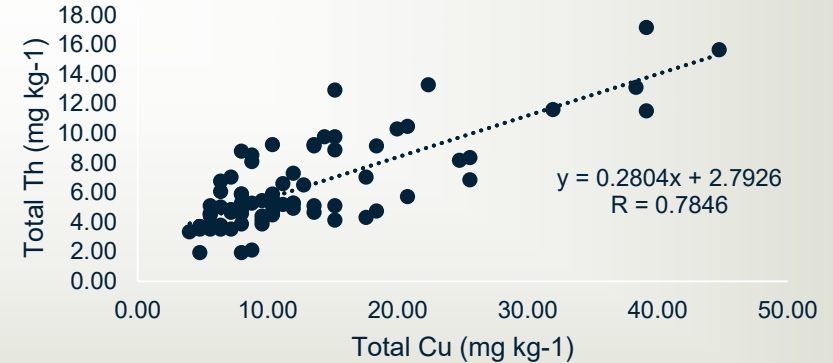
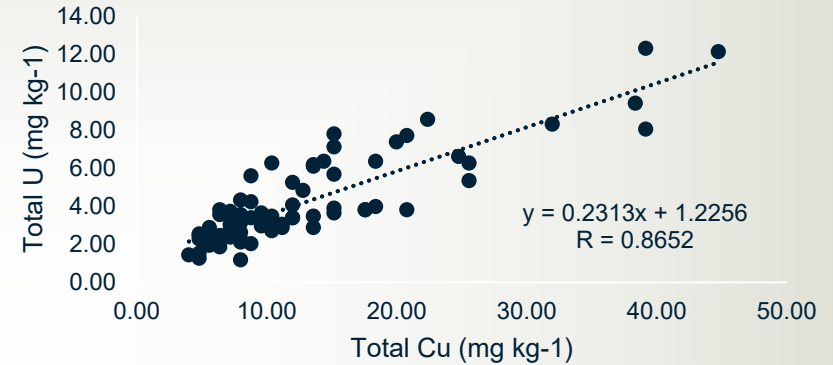
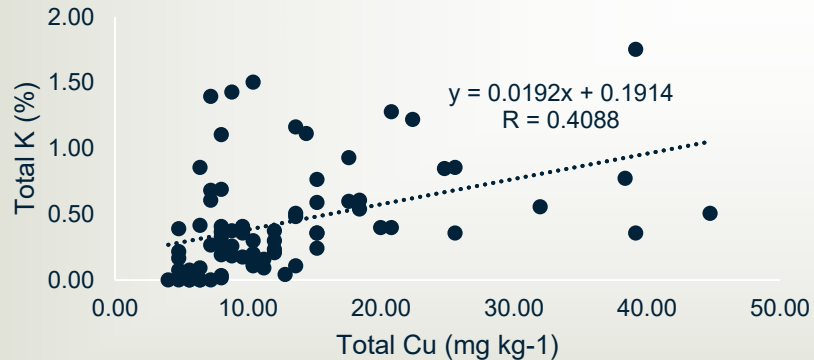
- ❑ 5 sites on 5 geologic formations set aside for micronutrient fertilizer trials





Correlation of K, U, and Th to Cu

- ❑ **A strong linear correlation exists between U and Th against Cu.**
- ❑ Relatively poor correlation between K and Cu.

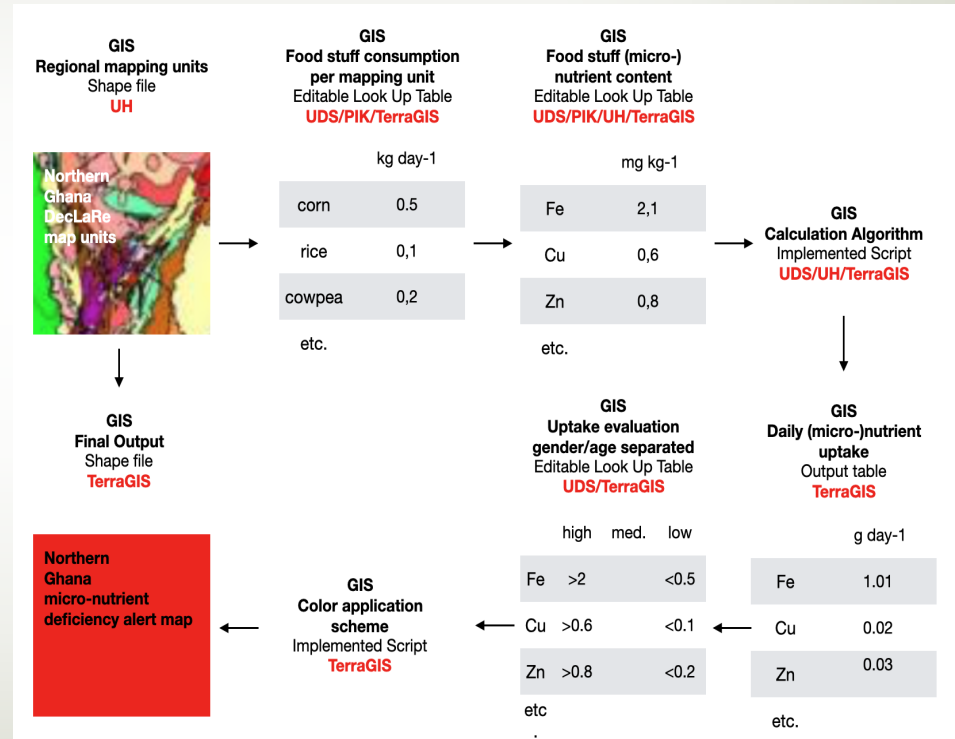




Conclusion

- ❑ Plant available micronutrients in topsoils are variable across the study area, particularly for **Cu** and **Zn**, with **Zn** and **Mo** being most limiting.
- ❑ The soil micro-nutrient status can be mapped using gamma ray spectroscopy, but the model is still being fine-tuned to enhance efficiency.
- ❑ Transfer rates from soils over plants to humans and animals will be assessed in the next step of the project.

Transition from Soil to Human Nutrition





References

FAO. (2021). Standard operating procedure for soil pH determination. Rome, Italy: FAO.

FAO. (2022). Standard operating procedure for soil available micronutrients (Cu, Fe, Mn, Zn) and heavy metals (Ni, Pb, Cd), DTPA extraction method. Rome, Italy: FAO.

Harris, W. and White, G.N. (2008). X-ray diffraction techniques for soil mineral identification (Chapter 4). *In*: A. L. Ulery, L. R. Drees (eds.) *Methods of Soil Analysis Part 5—Mineralogical Methods*. Madison, Wisconsin, USA: Soil Science Society of America. Pp. 81–115.

Hengl, T., Mendes De Jesus, J., Heuvelink, G.B.M., Ruiperez, G.M., Kilibarda, M., Blagotić, A., Shangguan, W., Wright, M.N., Geng, X.Y., Bauer-Marschallinger, B., Guevara, M.A., Vargas, R., MacMillan, R.A., Batjes, N.H., Leenaars, J.G.B., Ribeiro, E., Wheeler, I., Mantel, S. and Kempen, B. (2017). SoilGrids250m: Global gridded soil information based on machine learning. *PLOS ONE*. **12**: e0169748.

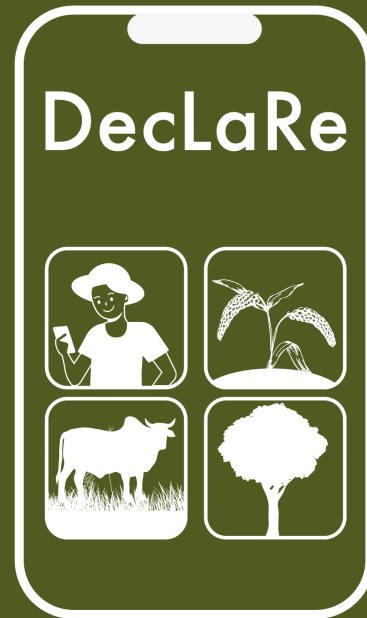
Karathanasis, A. D. and Hajek, B. F. (1996). Elemental analysis by X-ray fluorescence spectroscopy (Chapter 7). *In*: D.L. Sparks, A.L. Page, P.A. Helmke, R.H. Loeppert, P.N. Soltanpour, M.A. Tabatabai, C.T. Johnston, M.E. Sumner (eds.) *Methods of Soil Analysis: Part 3 Chemical Methods*. Madison, Wisconsin, USA: Soil Science Society of America. Pp. 161-223.

Olmstead, L.B., Alexander, L.T. and Middleton, H.E. (1930). A pipette method of mechanical analysis of soils based on improved dispersion procedure. *Technical Bulletin* No. 170. Washington, DC., USA: United States Department of Agriculture.

Pitt, J.L., Provin, T.L., Hons, F.M., Dou, F. and Waskom, J.S. (2003). Use of a total carbon/nitrogen analyzer for the determination of organic and inorganic carbon in soils, manure, and composts. 2003 Meeting of ASA, Denver, CO, USA.

VDLUFA (Hrsg.) (1991). Methodenbuch I: Die Untersuchung von Böden. 4. Auflage. Gesamtwerk einschl.1. - 7. Teillieferung; Darmstadt.

Thankyou for your attention!



Decision support for strengthening Land Resilience in the face of global challenges