From Village to Region: Soil Micronutrient Dynamics Across Scales in Northern Ghana

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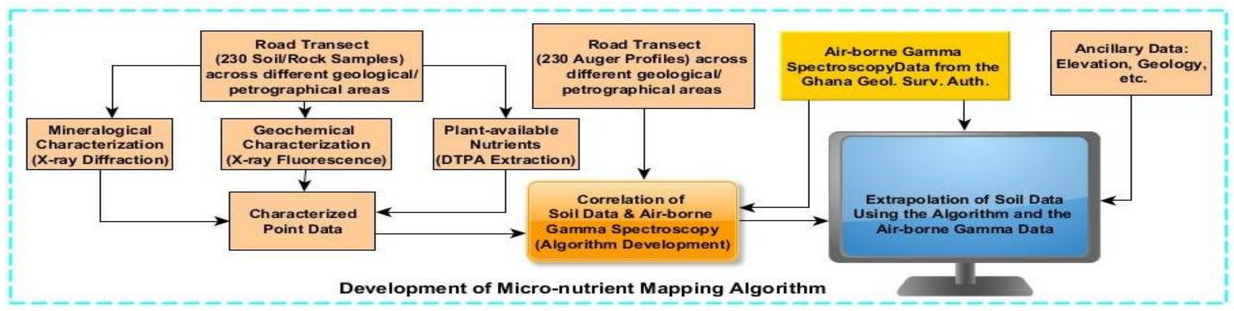
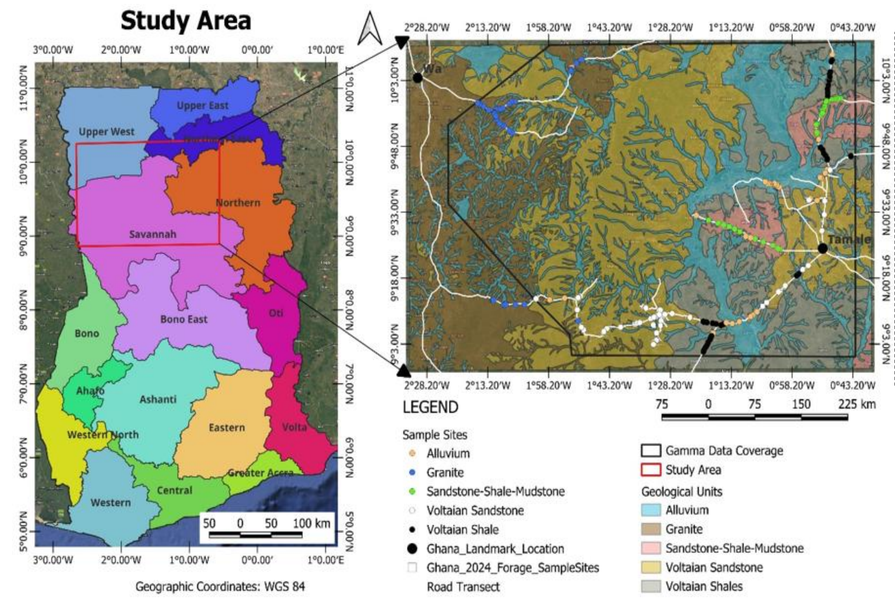
INTRODUCTION

- Soil **micronutrient** (Fe, Mn, Cu, Zn and Mo) **management** is fundamental for **sustainable crop production** and **increased agricultural productivity**.
- It also influences the **concentration** of minerals (**micronutrients**) in **edible plant tissues**, with immense implications for **nutrition security** and **hidden hunger**.
- As such, **understanding** the **spatial distribution** of soil micronutrients is essential for improving **crop productivity**, **food quality**, **and nutrition security** in Northern Ghana.
- Spatially explicit soil micronutrient **data** are, however, largely unavailable in the region
- **Regional-scale mapping** is **cheaper** and useful for **identifying broad nutrient patterns** and priority areas.
  - Coarse-scale mapping can, however, **mask important local variability**.
- **Village- and field-scale mapping** provides more **precise information** for fertilizer recommendations but
  - It is **substantially more expensive**.
- **Balancing cost** and **effectiveness** requires assessment of the **appropriate spatial scale** for soil **micronutrient assessment** and **management**.

APPROACH





- Over **200 soil** and **rock** samples were taken
  - along **road transects**
  - across **geological units**
- Over **200** soil **auger profiles**
- **Gamma spectrometry** data (air-borne)

RESULTS

Soil Micronutrient Variability across different Spatial Scales

Scale	Site	N	Available Micronutrients (mg kg^{-1}) Fe	Mn	Cu	Zn	Mo
Regional	Northern Ghana	238	98	135	0.78	0.99	b.d.
Medium	Granite	41	68	94	0.89	0.90	b.d.
	Alluvium	45	134	170	1.11	1.22	b.d.
	Sandstone-Shale-Mudstone	34	91	179	0.76	0.99	b.d.
	Voltaian Shale	39	122	171	0.89	0.95	b.d.
	Voltaian Sandstone	79	85	101	0.50	0.93	b.d.
Village	Bulenga	11	87	86	0.92	1.11	b.d.
	Busunu	16	143	123	1.33	1.56	b.d.
	Dalun Kukuo	10	170	122	1.24	1.42	b.d.
	Disiga	10	148	210	1.09	1.02	b.d.
	Fryfusu	10	99	109	0.53	1.40	b.d.
	Grupe	6	79	153	0.61	0.68	b.d.
	Kadia	7	95	132	0.49	0.73	b.d.
	Larabanga	7	89	100	0.55	0.85	b.d.
	Pigu	14	123	170	0.93	1.57	b.d.
	Pong Tamale	9	61	124	0.76	0.50	b.d.
	Tailorpe	14	80	103	0.53	0.72	b.d.
	Tarikpa	7	61	128	0.66	0.55	b.d.

NOTE: b.d. = below detection limit, Ava. = available, Fe = iron, Mn = manganese, Cu = copper, Zn = zinc, Mo = molybdenum

Micronutrient Availability: High | Medium | Low

- **Marked** spatial **variability** across all **scales**
- **Mo** was very **low, Fe** and **Mn** were **high**
  - Regional assessment is adequate and cost-effective
- **Cu** and **Zn** were variable across different scales
  - Moderate to **low Cu**
  - Predominantly **low Zn**
  - Medium to site-specific assessment may be required.

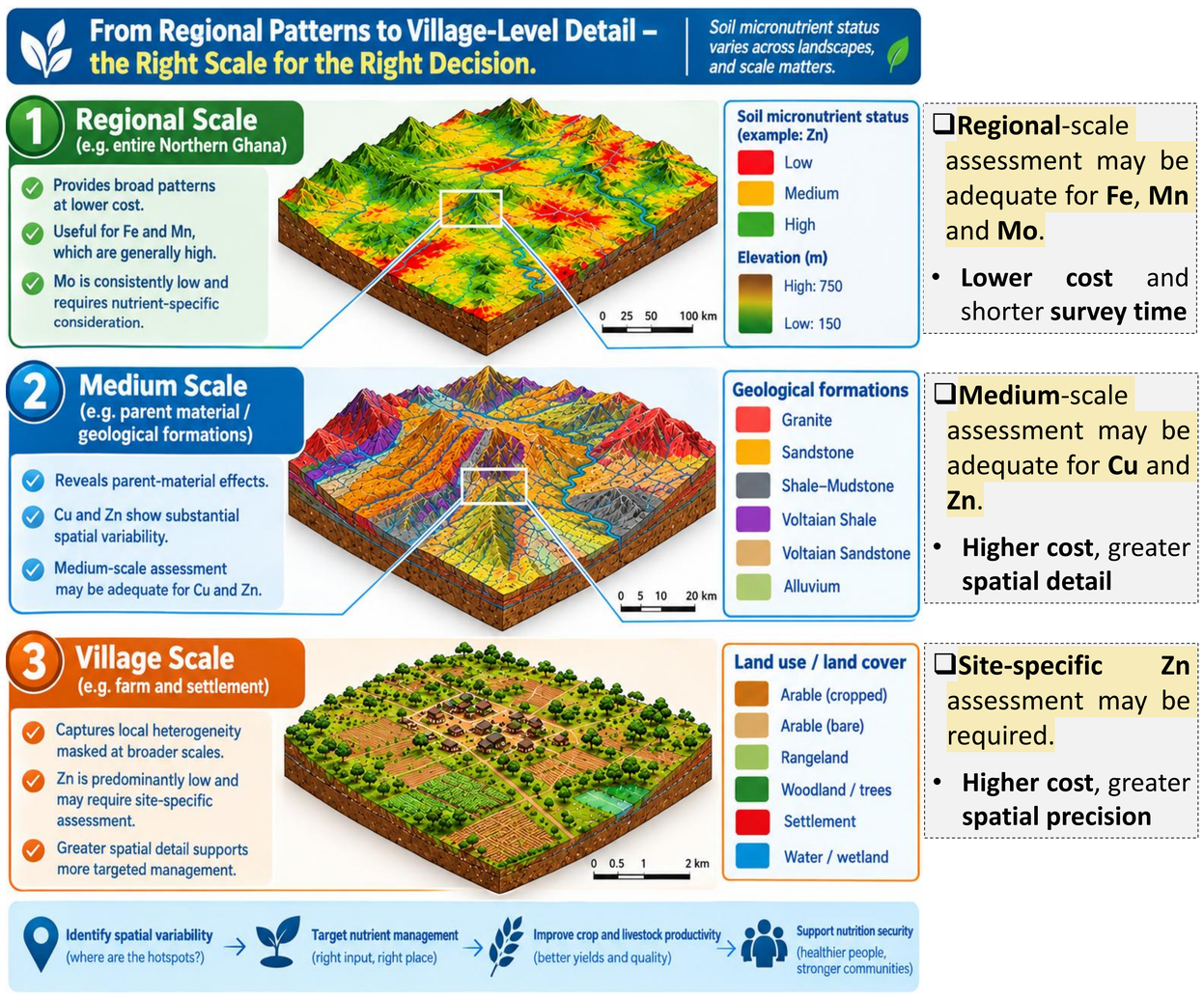
Total and Plant-available Micronutrients across different Geological Formations

Micronutrient Pool	Element	Statistic	df	P-value
Total	Fe	40.7	4	3.14e-08
Total	Mn	22.1	4	1.96e-04
Total	Cu	50	4	3.69e-10
Total	Zn	38.2	4	1.01e-07
Plant-available	Fe	27.8	4	1.37e-05
Plant-available	Mn	22.4	4	1.68e-04
Plant-available	Cu	44	4	6.32e-09
Plant-available	Zn	10.2	4	0.0367

Kruskal-Wallis tests results:

- **Total** and **plant-available** pools **differed** significantly among **geological formations**
- Differences were generally stronger for total pools
  - Highlighting the influence of parent material
- Plant-available Zn showed the least variability
  - **It** remained predominantly **low**, supporting **medium-** to **site-specific** assessment.

Micronutrient Variability Across Spatial Scales



- **Regional**-scale assessment may be adequate for **Fe**, **Mn** and **Mo**.
  - **Lower cost** and shorter **survey time**
- **Medium**-scale assessment may be adequate for **Cu** and **Zn**.
  - **Higher cost**, greater **spatial detail**
- **Site-specific Zn** assessment may be required.
  - **Higher cost**, greater **spatial precision**

CONCLUSION

The Importance of Spatially Explicit Soil Micronutrient Data in West Africa

Better data → Better decisions → Higher productivity → Improved nutrition

1 Reveals spatial variability
- Regional-scale models provide useful broad-scale insights but often mask local variability.
- Parent material-specific and site (village)-specific models give higher predictive accuracy, highlighting the importance of multi-scale assessment approaches.

2 Guides appropriate spatial scales
- Medium to village-scale soil assessment required for Cu and Zn.
- Regional-scale adequate for Fe, Mn and Mo.

3 Challenges generalised fertilizer recommendations
- Generalized fertilizer recommendations may inadequately address local Zn and Cu deficiencies, whereas regional management may be sufficient for Fe and Mn.

4 Enables better agricultural and nutritional outcomes
- Data availability enables improved **crop** and **forage** productivity to mitigate **hidden hunger**, and ensure efficient and sustainable **Mo, Zn** and **Cu** fertilization.

5 Improves food quality and nutrition security
- Improved micronutrient content and **food quality** would mitigate **hidden hunger** and **malnutrition.**

Spatially explicit soil micronutrient data provide the foundation for targeted, efficient and sustainable interventions in West Africa.

Take-home Message

- **Spatial variability matters**
  - Regional averages can mask important local micronutrient differences.
- **Scale should be nutrient-specific**
  - Regional assessment may suffice for Fe, Mn and Mo; Cu and Zn require finer assessment.
- **Better spatial data enable better decisions**
  - Targeted mapping supports more efficient and sustainable micronutrient management.

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