

Integrating Tropical Soil-Calibrated Pedotransfer Functions with Sentinel-1 for Site-Specific Soil Moisture Retrieval in Zambia

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HYBRID CONFERENCE

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CONCLUSIONS

- Tropical soil-calibrated PTFs provide a practical approach for estimating SWRCs where direct measurements are limited.
- Combining PTF-derived SWRC parameters with Sentinel-1 backscatter enables site-specific soil-moisture retrieval in tropical maize-soybean systems.

INTRODUCTION

Soil water retention curves (SWRCs) are essential for soil-crop-atmosphere models and accurate remote sensing of soil moisture. Direct measurement of SWRCs requires costly equipment and expertise that are scarce in most tropical countries. Pedotransfer functions (PTFs) provide a practical alternative by estimating SWRCs from routinely measured properties (texture, bulk density, organic carbon). Combined with Sentinel-1 backscatter, they enable wider spatial assessment of soil water status, critical for precision agriculture.

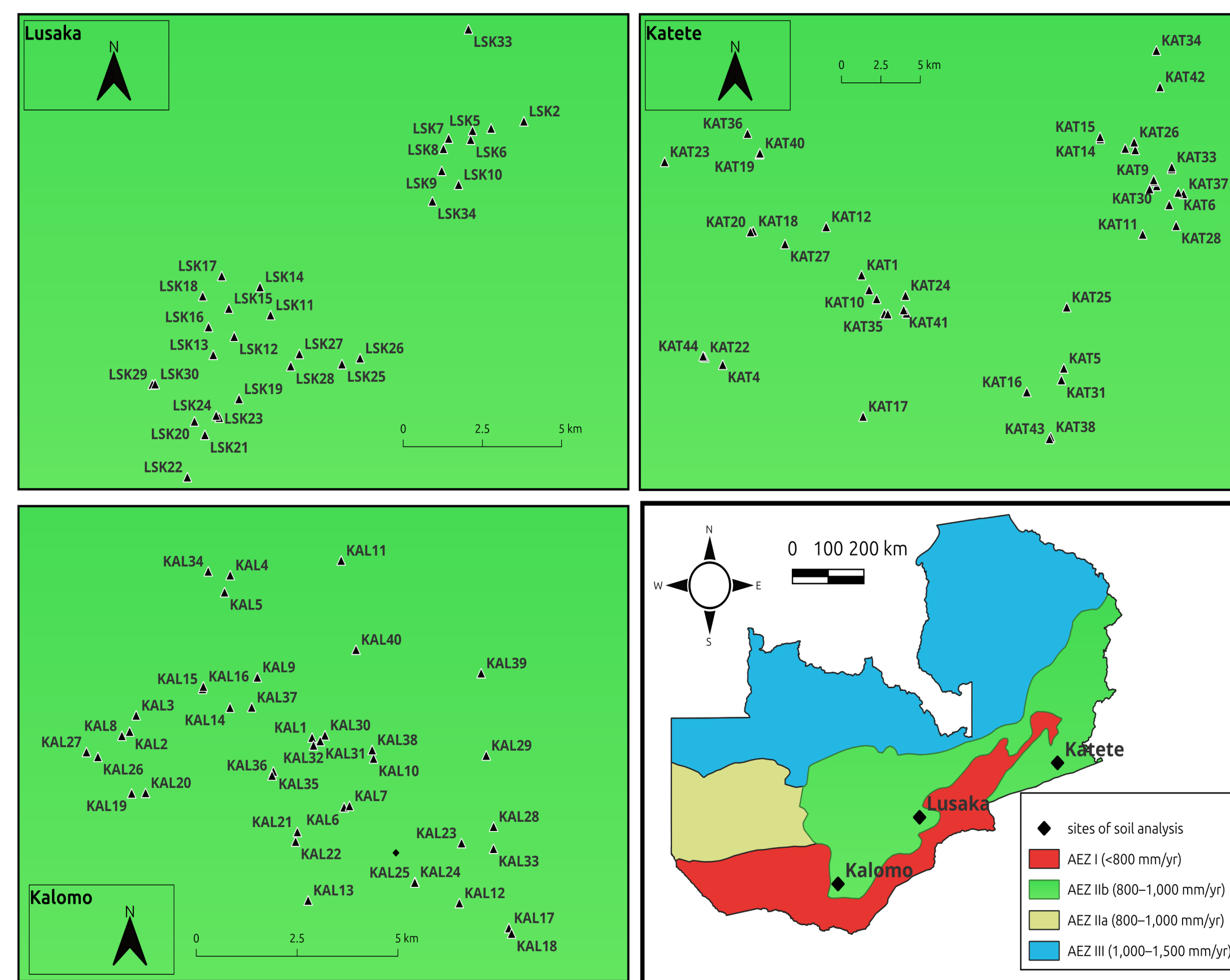


Figure 4: Map of maize-soybean fields sampled in Lusaka, Kalomo, and Katete in Zambia.

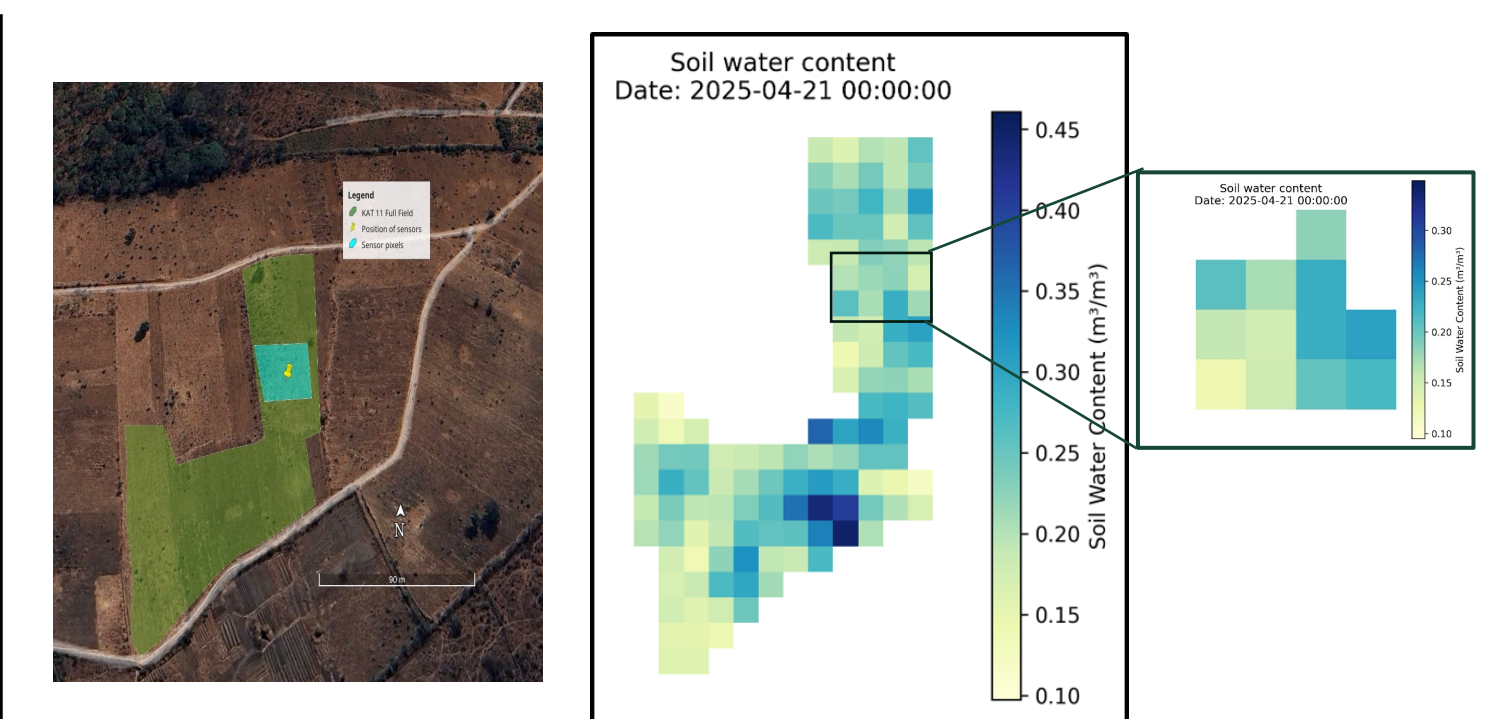


Figure 6: Comparison of remote sensed versus TMS-4 sensor soil moisture of a field in Katete.

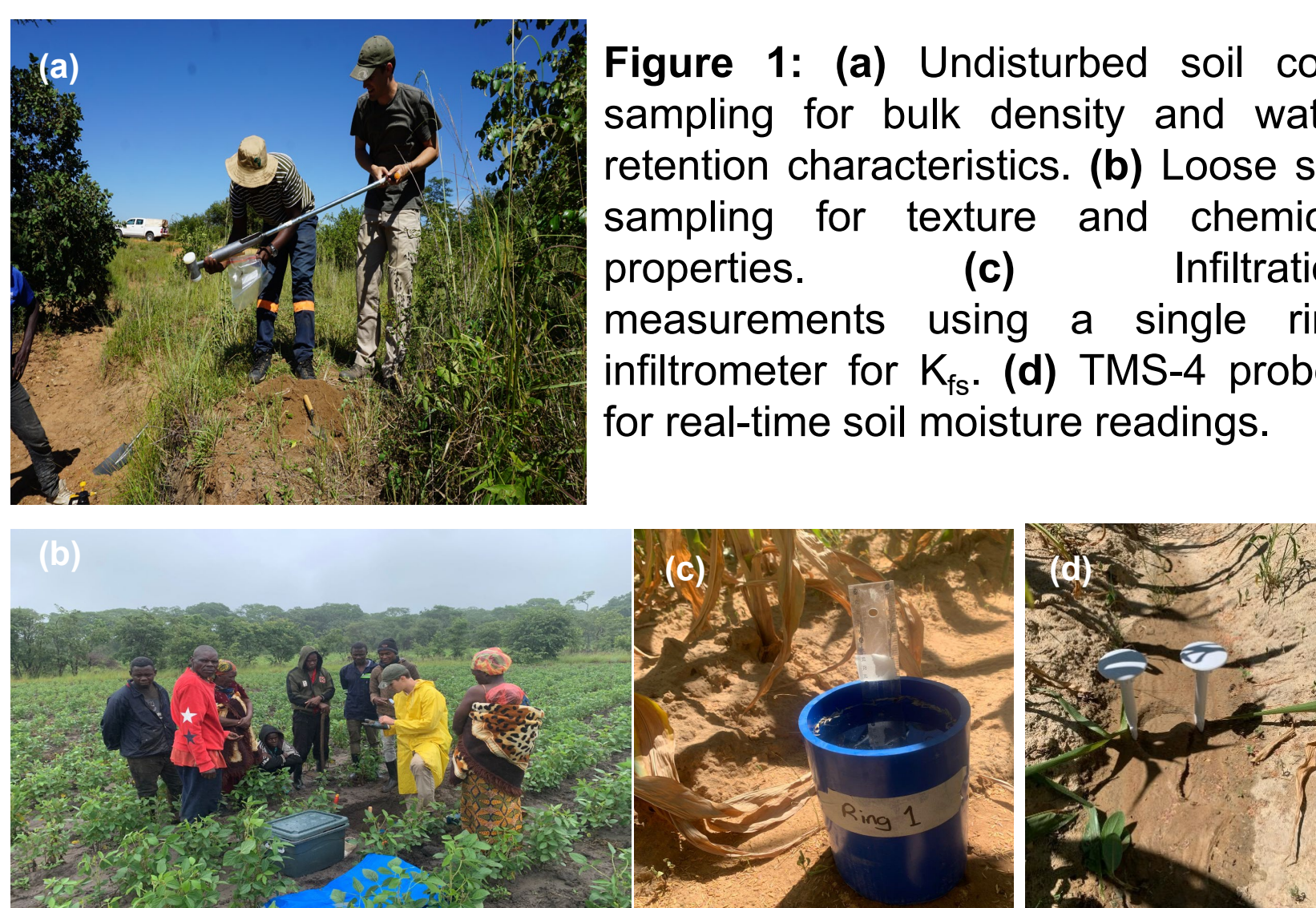


Figure 1: (a) Undisturbed soil core sampling for bulk density and water retention characteristics. (b) Loose soil sampling for texture and chemical properties. (c) Infiltration measurements using a single ring infiltrometer for K_{fs} . (d) TMS-4 probes for real-time soil moisture readings.

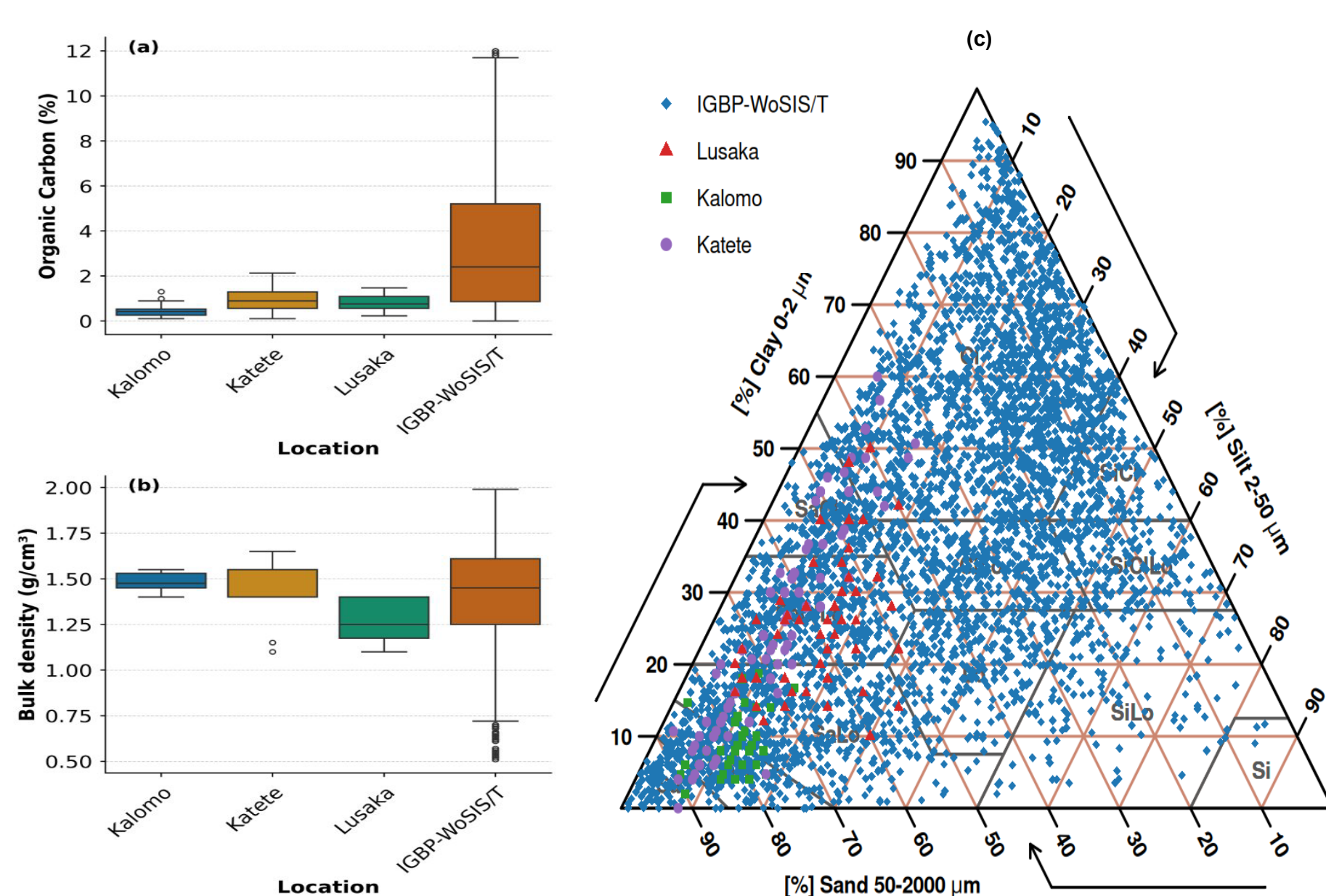


Figure 2: (a) OC, (b) Bulk density, and (c) soil texture distribution at the 3 Zambian sites relative to the IGBP-WoSIS/T dataset.

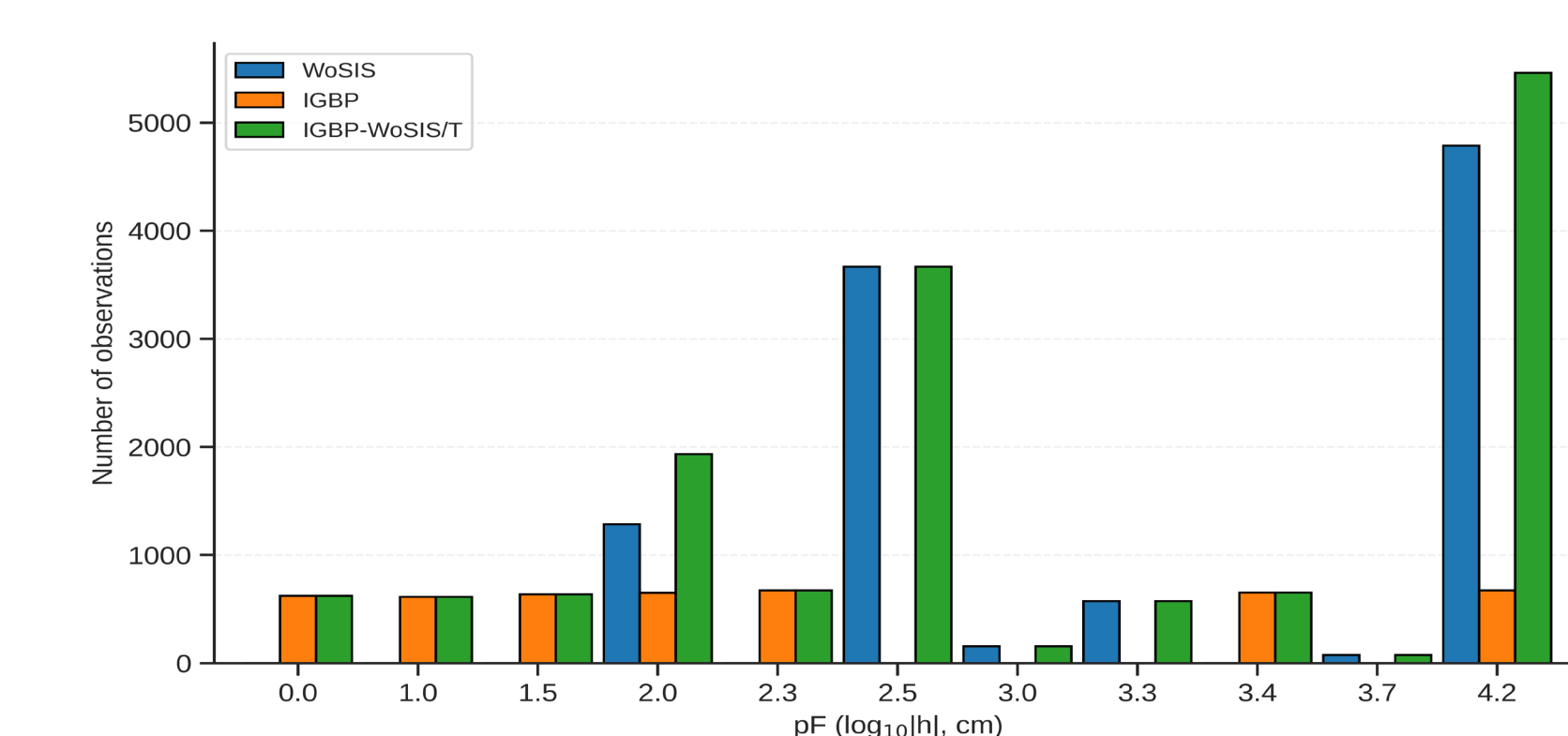


Figure 3: Distribution of WoSIS, IGBP and IGBP-WoSIS/T datapoints relative to matric potentials.

RESEARCH QUESTION

How can soil hydraulic information be estimated and integrated with Sentinel-1 where laboratory measurements are limited?

SITE SELECTION AND DATA COLLECTION

Random Forest (RF) based PTFs were trained on tropical subsets of the combined WoSIS-IGBP soil database (IGBP-WoSIS/T). Validation was performed at three Zambian sites: Lusaka (commercial), Kalomo and Katete (small-scale); representing different farming systems and agroclimatic conditions. Soil sampling followed the Land Degradation Surveillance Framework and included:

- physical, chemical, and hydraulic properties of top- and subsoil,
- single ring infiltrometer measurements of saturated hydraulic conductivity (K_{fs}),
- Continuous in-situ soil moisture with TMS-4 probes (Figure 1).

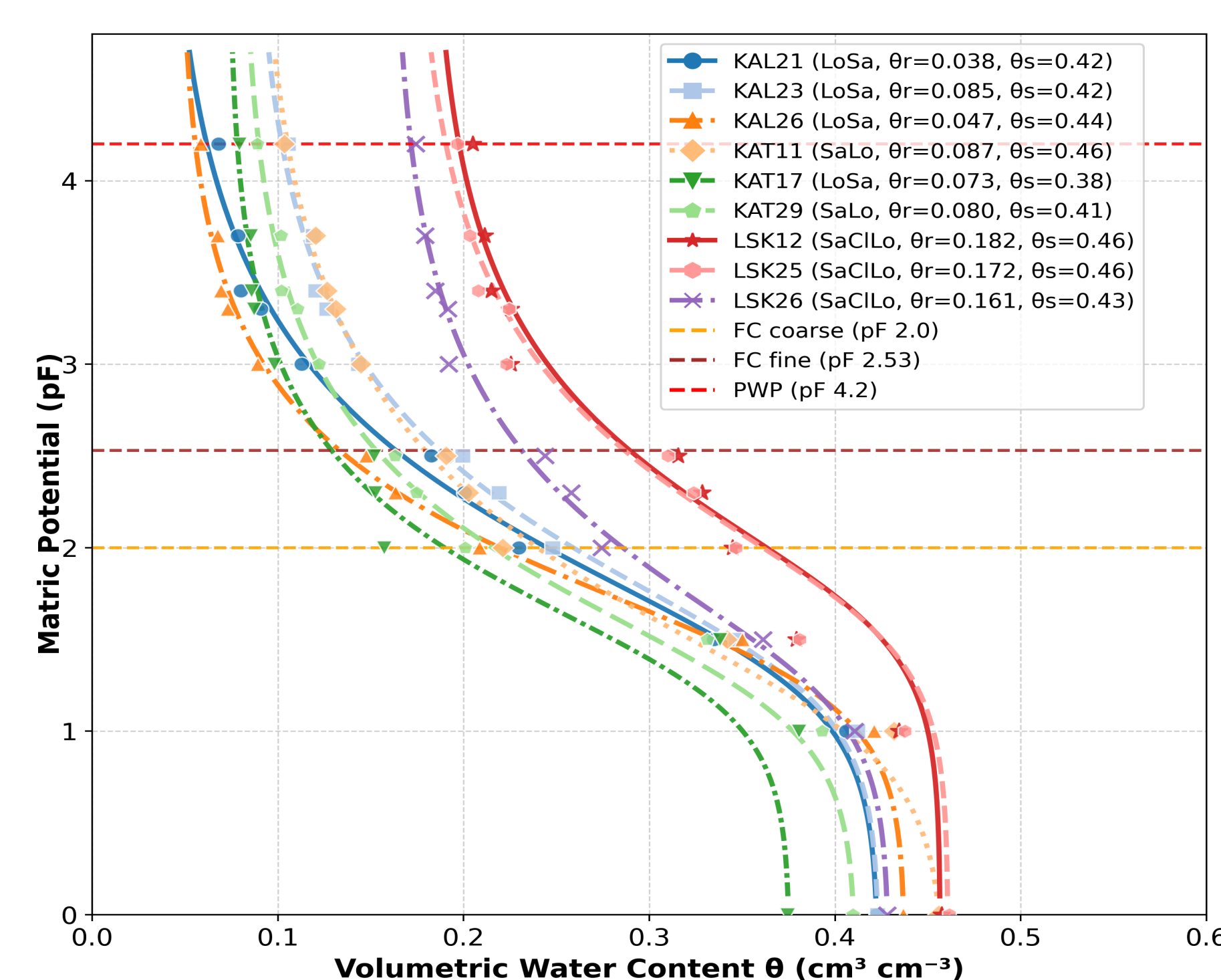


Figure 5: van Genuchten SWRC of topsoils in maize-soybean fields of interest in Kalomo Katete and Lusaka.

Saturated and residual water contents derived from the SWRCs were used to calibrate Sentinel-1 backscatter for site-specific soil moisture retrieval.

RESULTS & DISCUSSION

Lusaka and Katete farmers practiced maize-soybean rotation; Kalomo farmers monocropped maize. Topsoil OC and clay were higher in Lusaka and Katete (median OC $\approx$ 1.0-1.1, median clay $\approx$ 21%) than in Kalomo (OC 0.5 %, clay 8 %) (Figure 2).

Laboratory measured available water capacity (AWC) was highest in Lusaka (0.21 cm^3/cm^3), followed by Kalomo (0.19) and Katete (0.12). K_{fs} was also highest in Lusaka (134 mm h^{-1}) versus 72 mm h^{-1} (Kalomo) and 46 mm h^{-1} (Katete).

PTF-derived SWRCs showed the expected sigmoidal shape (Figure 5). Calibrated Sentinel-1 backscatter correlated with in-situ TMS-4 moisture ($R^2 = 0.24-0.72$). PTF derived AWC agreed moderately with laboratory values ($r=0.64$ $R^2=0.41$), giving site means of 0.15 (Lusaka), 0.17 (Kalomo) and 0.12 cm^3/cm^3 (Katete).

KEY TAKE HOME MESSAGES

- Tropical soil-calibrated PTFs provide scalable SWRC estimates.
- PTF-derived hydraulic parameters support Sentinel-1 soil-moisture retrieval.
- This approach is promising for data-scarce tropical agricultural systems.



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