Hyper-local Soil Management Made Possible: Handheld Reflectometer Informed by Bayesian Analysis of Local and Remote Data

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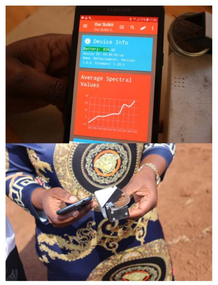
INTRODUCTION

- Soil health of smallholder farms is critical to food security in Africa.
- Stable and labile fraction of soil C pools are key variables of soil health and are indicators of various ecosystem services.
- Documentation of the current carbon status across a gradient of African smallholder farms will provide key insights.
- The Bayesian approach fills the gap of identifying the sensitive drivers as this method accommodates the domain specialist's expectation of uncertainty levels.

OBJECTIVES

1. to evaluate handheld inexpensive reflectometer device that estimates soil organic carbon (SOC)
2. to characterize the environment and practices of smallholder farms at regional and local site;
3. to integrate Bayesian statistical approach to better understand SOC drivers for hyper-local advice

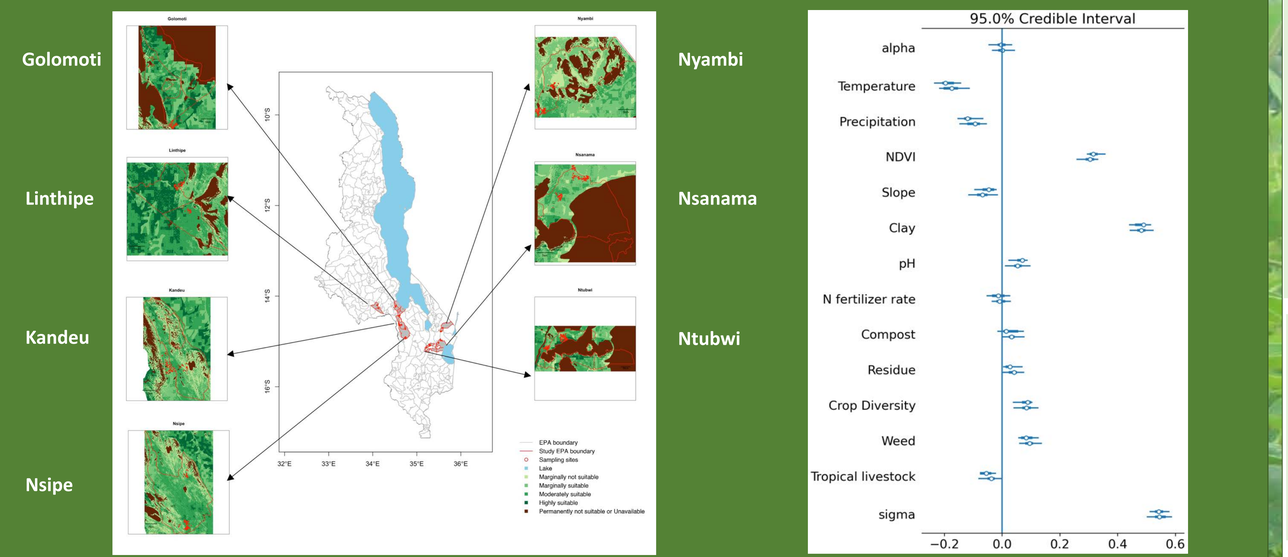
MATERIALS AND METHODS



On-Farm Study
Lab Analyses
Geospatial Data
Statistical Models

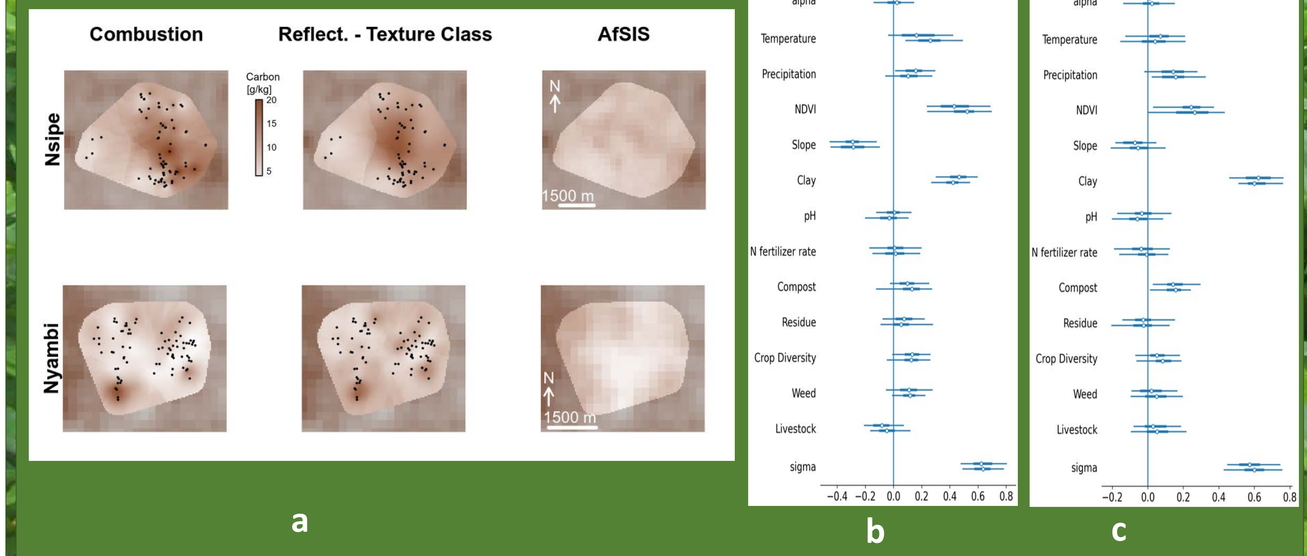
- Study sites (EPA) and focal plot (n = 1108) were chosen based on agricultural potential in Central and Southern Malawi (Fig.1). Village clusters under the 7 EPA were used for analysis at local scale.
- Survey and soil sampling were conducted in Oct, 2016 **(n=1108).** Survey instrument was carried out in a structured interview format.
- Management practices indicators (Survey): fertilizer N rate, compost adoption (Y/N), residue management (incorporated, removal, and burnt), and diversification (maize, maize/pigeon pea, and maize/other legumes).
- Handheld reflectometer is calibrated through lab analysis of pH, texture, and SOC (combustion).
- Climatic indicators are derived from multiple databases.
- Statistical analysis: Bayesian linear regression.

$$p(\theta|y) \propto p(\theta)p(y|\theta) \qquad y_i = \alpha + \beta_{ijk} + \sigma\varepsilon_{ijk}$$



a b

Fig.1. Locations of focal plots in Central and Southern Malawi, and maps of agricultural potentials of each EPA (a) based on Li et al,. (2017); and posterior results of Bayesian regression model with 2 chains of 10, 000 iterations explicit the 95% credible intervals associated with drivers of SOC for all focal plots (b).



a b c

Fig. 2. Interpolation of soil carbon across villages by different estimation methods. The foreground denotes a 250 m buffer around sample points (dots). Resolutions are 40 m (Nsipe), and 55 m (Nyambi) for combustion and reflectometer interpolations. AfSIS resolution is 250 m for all villages. AfSIS also provides the darker background (a); posterior results of Bayesian regression model with 2 chains of 10, 000 iterations explicit the 95% credible intervals associated with drivers of SOC at two central focal plot clusters, Nsipe in Central Malawi (b), and Nyambi in Southern Malawi (c).

RESULTS AND DISCUSSIONS

- Across the all study sites in Central and Southern Malawi, most indicators of organic inputs are positively related to SOC.
- Residue, crop diversity, and weed are positive drivers of SOC.
- NDVI that reflects the vegetation cover is a dominant driver of SOC variation at regional level. It is also widely used in studies to estimate spatial distribution of SOC.

- Handheld reflectometer provided promising hyper-local estimates of SOC. The correlation coefficient of SOC by combustion and SOC by reflectometer (with texture class) was 0.57.
- It provides in-situ quick estimation of SOC, and improved farmers' decision making.

- At local level, reflectometer was predictive of SOC, and much better than AfSIS database (which underestimated SOC at many farm sites, leading to erroneous recommendations).
- By village groups, we identified the distinct influence of each farm practice on SOC.
- Crop residue and crop diversity show positive effect overall, and at the Nyambi site compost was highly associated with SOC.

CONCLUSIONS

- Understanding **C pools as a key component of soil health** through Bayesian analysis of farmer management practices, soil properties and geospatial remote sensed data.
- **Handheld reflectometer** provides small farmers with in-time fine-scale estimation of SOC for first ever locally relevant decision making.
- **Residue management, compost/manure application,** and adoption of **crop diversity** have area-specific influence on SOC.

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