

Prediction of Soil Properties at Field-scale Using Multispectral UAV and Satellite Imagery

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Introduction: High-resolution soil maps are critical for precision agriculture, yet conventional surveys (e.g., SSURGO) generalize spatial variability and cannot capture change over time. Digital soil mapping (DSM) fills this gap, and its accuracy depends on both the imagery source and the prediction algorithm. This project therefore compared two imagery platforms, unmanned aerial vehicle (UAV) and Sentinel-2 satellite, with four prediction models (random forest (RF), gradient boosting machine (GBM), extreme boosting machine (XGBoost), and regression kriging (RK)) on accuracy and per-hectare cost to determine suitable remote sensing platform for field-scale soil mapping.

Methodology: Soil samples were collected at two depths (0–7.5 and 7.5–15 cm) at ACRE, DPAC, and SEPAC and analyzed for soil organic matter (SOM), total nitrogen (N), phosphorus (P), potassium, cation exchange capacity (CEC), and pH. UAV multispectral imagery (DJI Mavic 3M) and free Sentinel-2 imagery were acquired to capture pre-plant bare soil, peak-season crop vigor, and post-harvest bare soil. Vegetation indices (e.g., NDVI) and soil indices (e.g., SBI), combined with terrain attributes (e.g., slope), served as predictors for four models (RF, GBM, XGBoost, RK) evaluated under nested cross-validation. Results were compared on prediction performance and per-hectare mapping cost.

Results:

- Sentinel-2 imagery-derived prediction outperformed UAV imagery-derived prediction in 22 of 36 R^2 comparisons across properties, sites, and depths.
- Satellite-based maps cost about \$141.69 per-hectare versus \$210.67 per-hectare for UAV-based maps.
- The hybrid method (RK) was the most robust model compared with other machine learning models.
- The higher cost of UAV sensing was not matched by a consistent accuracy gain over Sentinel-2 sensing.

FOR FURTHER READING:

Zhao, L., Jamshidi, S., Krupke, C., Rui, Y., & Paul, S. S. (2026, July). Cost-performance analysis of satellite and UAV-based remote sensing for field-scale digital soil mapping [Poster presentation]. ASABE Annual International Meeting.

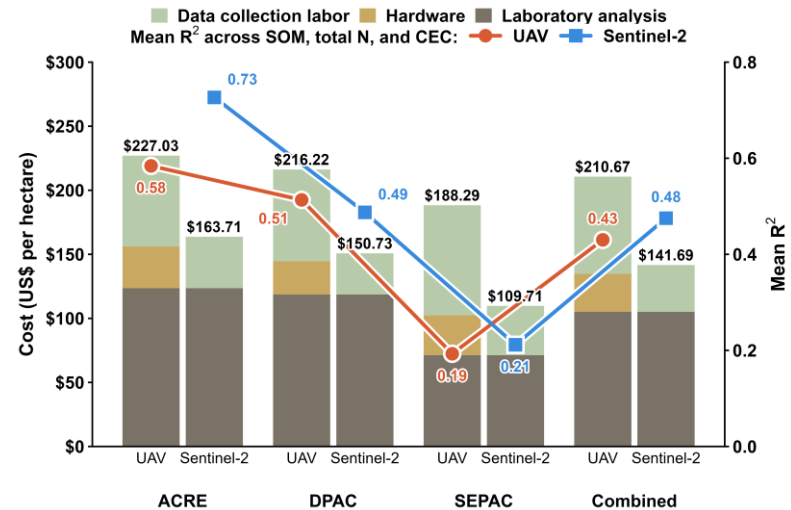


Figure 1. Per-hectare mapping cost and model performance of UAV and Sentinel-2 at each site and for all sites combined. Bars (right axis) show the cost from data-collection labor, hardware, and laboratory analysis. Lines (right axis) show the mean R^2 of the best-performing models for soil organic matter (SOM), total nitrogen (N), and cation exchange capacity (CEC) across two soil depths (0–7.5 cm and 7.5–15 cm).

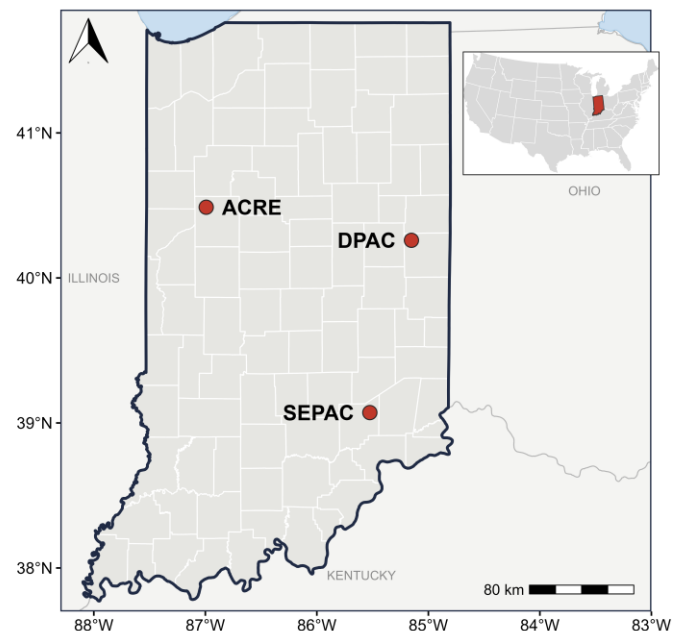


Figure 2. Location of the three study sites across Indiana, USA. The Agronomy Center for Research and Education (ACRE), the Davis Purdue Agriculture Center (DPAC), and the Southeast Purdue Agricultural Center (SEPAC).