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"Reconcile land system changes
with planetary health"

Grounded perspectives vs. aerial views: Enhancing soil health monitoring through mixed methods

Zahra Shiri[1], Quang Bao Le[2], Veronique Alary[3]

[1]*International Center for Agricultural Research in the Dry Areas (ICARDA), Social, Economic, and Policy Research Team (SEPRT), Tunisia*
[2]*International Center for Agricultural Research in the Dry Areas (ICARDA), Egypt*
[3]*SELMET, CIRAD, INRAE, Institut Agro, Université Montpellier, France*

Abstract

Assessing soil health is essential for sustainable land management but is often constrained by limited financial and technical resources. Remote sensing offers a cost-effective and scalable solution, using indices such as the Normalized Difference Vegetation Index (NDVI), Soil Moisture Index (SMI), Normalized Difference Salinity Index (NDSI), Soil Organic Carbon (SOC), and others to monitor soil conditions. Meanwhile, farmers frequently rely on observable soil traits like colour, fertility, and moisture retention to guide their agricultural decisions. This study explores the complementarity between remote sensing indicators and farmers' perceptions to enhance soil health monitoring strategies. Conducted in six villages in northwestern Tunisia, the research involved 78 farmers who evaluated soil health at three georeferenced points per plot based on visible characteristics. Simultaneously, Sentinel^{-2} satellite imagery was processed to derive biophysical soil health indicators, which were spatially and temporally aligned with field survey points. A combined dataset was constructed, and statistical analyses, including the Kruskal-Wallis test, were used to compare the two approaches. Findings revealed that NDVI, SMI, and NDSI were the most informative indices, with NDVI showing strong correlations ($p < 0.01$) with crop growth, disease presence, weed infestation, residue cover, and soil organic matter. SMI effectively indicated soil moisture status, erosion, and crop health, while NDSI captured soil salinity and organic matter variations. SOC was significantly related ($p < 0.05$) to soil depth, moisture, erosion, and biological activity, confirming its role as a core indicator of soil quality. Soil compaction also showed relevant associations with NDSI and SMI, while NDVI remained sensitive to vegetation type and management practices. However, soil structure did not significantly correlate with any spectral index, and some properties like soil depth were only relevant to SOC. The study concludes that integrating remote sensing with farmers' assessments enhances the accuracy and applicability of soil monitoring. Remote sensing contributes spatial detail and repeatability, while farmers' insights provide contextual understanding. A mixed-methods approach combining high resolution imagery with participatory field observations is recommended to develop robust, inclusive soil health monitoring systems, especially in data-scarce or resource limited environments.

Keywords: Farmers' perceptions, mixed-methods, remote sensing, soil health, sustainable land management

Contact Address: Zahra Shiri, International Center for Agricultural Research in the Dry Areas (ICARDA), Social, Economic, and Policy Research Team (SEPRT), Av. Hedi Karray, 2049 Tunis, Tunisia, e-mail: z.shiri@cgiar.org