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Mapping soil moisture and organic carbon with Landsat 8 for productivity assessment in Boeny, Madagascar

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Abstract

The spatial characterisation of the Soil Moisture Index (SMI) is a valuable tool for numerous applications, including agriculture, soil conservation, ecological monitoring, climate analysis, and land degradation assessment. Despite its importance, access to SMI datasets at national and subnational scales remains limited. Yet such information is particularly crucial for developing countries like Madagascar, where land degradation, especially erosion and climate-related stresses such as recurrent drought are becoming increasingly severe.

The Soil Moisture Index (SMI) of the Boeny region in northwestern Madagascar was modeled using Landsat-8 OLI/TIRS imagery and two key parameters: the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST). Based on these outputs, potential soil productivity, an estimate of maximum yield potential, distinct from actual productivity, was assessed using a ΔSMI variation model combined with a Soil Organic Carbon (SOC) content model. Here, ΔSMI represents the change in soil moisture between April and August 2021 year of available data).

The analysis shows that SMI values in the Boeny region range from 0.23 to 0.36, depending on land use. These results indicate generally low soil moisture conditions, largely driven by the region's high temperatures and the predominance of sparsely vegetated savannah landscapes. In contrast, areas with dense vegetation, such as forests, mangroves, and wetlands, present significantly higher moisture levels.

Several studies highlight ΔSMI as a key indicator of potential soil productivity. In this study, the negative correlation ($R^2 = 0.05462$) between soil organic carbon (SOC) content and temporal variation in SMI (ΔSMI) confirms that ΔSMI can serve as a meaningful estimator of soil productivity potential. This relationship suggests that higher SOC levels in surface soils are associated with smaller fluctuations in soil moisture. The ΔSMI model, derived from the difference in SMI between the wet and dry periods of 2021, therefore provides a practical tool for identifying potential soil productivity at the subnational scale.

Keywords: Land surface temperature, Madagascar, normalised difference vegetation index, potential soil productivity, soil moisture index, soil organic carbon

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