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Land Restoration Effectiveness Assessed by Satellite-Based Remote Sensing Technologies as a New Monitoring Approach

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Abstract

The Mediterranean region requires effective land restoration monitoring methods to face increasing land degradation, desertification, and climate change threats. Traditional assessments are often time-consuming and subjective. This study addresses this need by focusing on two sites in Israel: the restored food forest in Beit Lehem of the Galilee and the adjacent Alonie Aba natural forest. Within Beit Lehem of Galilee, we compare the restored food forest to a non-restored area where traditional farming practices remain. By comparing these sites, the study aims to assess how well the restored area mimics the ecological functions of a natural forest and how it contrasts with areas under continued traditional agriculture. This assessment leverages satellite-based remote sensing, specifically Sentinel-2 and Sentinel-1 data, to provide a comprehensive and objective approach to monitoring restoration initiatives. Sentinel-2 high-resolution multispectral imagery enables detailed tracking of vegetation health through indices like SAVI, PSRI, and NDWI.

Additionally, Sentinel-1 SAR data offers insights into microtopography changes and soil moisture monitoring. Our comparative analysis of the restored and natural forest areas, alongside the non-restored agricultural areas, reveals significant improvements in vegetation health, soil moisture, and microtopographic stability in restored sites.

Furthermore, this work employs a Hidden Markov Model (HMM) to examine the temporal dynamics of restoration indicators such as SAVI, PSRI, and NDWI. The HMM models the observed satellite-derived indices as emissions. These emissions originate from underlying hidden states, representing different ecosystem conditions (e.g., degraded, transition, restored). We estimate the transition probabilities between these states over time by training the model on multi-temporal satellite data. This probabilistic approach allows us to predict the likelihood of restoration success by estimating transition probabilities between states, identifying stable restoration trajectories, and detecting potential regression or stagnation.

The HMM thus provides a robust, interpretable, and scalable framework for long-term monitoring and decision support in restoration planning.

This study offers a detailed assessment of long-term restoration processes in the Mediterranean region, contributing to sustainable land management and ecosystem restoration practices.

Keywords: Restoration actions, Mediterranean, Land Degradation, Satellite Imagery

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