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Quantifying ecosystem service potential in regenerative agriculture: A conceptual modelling framework

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Abstract

Regenerative agriculture (RA) has emerged as a sustainable approach to improving ecosystem health, particularly in soil fertility, carbon sequestration, and biodiversity. However, quantifying ecosystem services (ES) in RA is challenging due to its complex spatial and temporal dynamics. This study introduces a conceptual framework that integrates the Carnegie–Ames–Stanford Approach (CASA) model, remote sensing (RS), machine learning (ML), and the InVEST model to estimate Net Primary Productivity (NPP) and evaluate ES in RA systems. Applied to a multispecies cropping farm in Western Australia's Central Wheatbelt, the framework demonstrates that CASA, enhanced by ML, effectively estimates NPP in RA landscapes, offering a means to quantify ES at a fine scale. Field data from 2000 to 2023, along with satellite indices (NDVI, LAI), were used to calculate Photosynthetically Active Radiation (PAR) and Fraction of PAR Absorbed (FPAR), which were crucial for NPP estimation. The CASA model's ability to customize parameters for local conditions resulted in highly accurate NPP predictions ($R^2 = 0.72$, RMSE = ±0.43), outperforming traditional models such as MODIS. The InVEST model then quantified ES based on CASA-ML-derived NPP estimates, incorporating data on climate, land use, and soil properties. This integrated framework provides a scalable and data-driven approach to assessing RA's ecological impacts, including carbon storage, soil health, and biodiversity. The findings highlight the potential of CASA-derived NPP and remote sensing tools for monitoring RA's performance, enabling informed decision-making. This framework paves the way for future studies exploring economic trade-offs and the broader application of RA practices across different landscapes. By enhancing the precision of ES estimation, the framework can support sustainable agriculture and ecosystem service management at a global scale.

Keywords

Ecosystem services, Net Primary Productivity, CASA model, remote sensing, machine learning, InVEST model, multispecies cropping.

Recent Publications: Minimum 3 publications to be included (Not mandatory)

1. Jayasinghe, S. L., Thomas, D. T., Anderson, J. P., Chen, C., & Macdonald, B. C. (2023). Global Application of Regenerative Agriculture: A Review of Definitions and Assessment Approaches. *Sustainability*, *15*(22), 15941.
2. Jayasinghe, S.L, Thomas, D.T, Anderson, J., Chen, C., & Macdonald, B. (2024, October 21–24). A conceptual framework for modelling and economic assessment of regenerative

agriculture in Australian mixed farming. Australian Agronomy Conference, Albany, Western Australia.
3. Jayasinghe, S. L., & Kumar, L. (2023). Causes of tea land dynamics in Sri Lanka between 1995 and 2030. Regional Environmental Change, 23(4), 127.

Biography

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