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"Reconcile land system changes
with planetary health"

From data to decisions: Improving land use models with machine learning for sustainable land management

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Abstract

Accurate simulations of land system changes are crucial for designing sustainable management pathways and to maintain planetary health for future generations. Spatiotemporal land use and land cover change (LULCC) models such as CLUMondo offer decision support to policy-makers and land managers by simulating scenario narratives of future land use. Such models allow users to also perform impact assessments of future ecosystem change. Yet, LULCC models often rely on traditional statistical approaches such as logistic regression, which have been proven to be outperformed in similar tasks, such as species distribution modelling. In this study, we present a novel Python-based adaptation of CLUMondo, integrating machine learning (ML) algorithms (Random Forest, XGBoost, Support Vector Machines, and Multi-Layer Perceptron) to improve CLUMondo's ability to model location suitability and land use allocation. To showcase our novel approach, we select the Federal State of Mato Grosso, Brazil, as a case study area simulating scenarios for the period of 2022 to 2040. Mato Grosso is a major producer of agricultural commodities, e.g., soy, cattle, corn, while aiming to reconcile agricultural production with nature conservation and forest protection goals.

Our findings confirm that ML significantly enhances the predictive accuracy of the LULCC model in terms of location suitability and spatial allocation performance compared to conventional logistic regressions. The results reveal that better location suitability modelling not only increases the precision of current land change simulations but substantially alters future projections of agricultural expansion and ecosystem dynamics. Our work contributes to a growing community of open science focussing on transparency and reproducibility in modelling. Moreover, by bridging advances in ML with spatially explicit LULCC models, we enhance the reliability of modelling outputs. Both, transparency of modelling processes and enhanced reliability of results contribute to better applicability of LULCC models to support policy processes for sustainable land governance.

Keywords: Agricultural expansion, deforestation, land use change, land use modelling, machine learning, Mato Grosso , spatiotemporal modelling

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