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promoting climate resilient futures"

Assessing deforestation risk and carbon emission mitigation in commodity frontiers through integrated land system modelling

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Abstract

Global agricultural trade dynamics increasingly displace production across world regions. This is particularly relevant for trade relationships connecting the EU-27 with Southern America and Southeast Asia where export-oriented agriculture can intensify pressure on forests that serve as critical terrestrial carbon pools. This study investigates how alternative land use scenarios can mitigate deforestation risk and reduce associated carbon emissions in two tropical production frontiers with a strong export orientation: Mato Grosso state, Brazil, dominated by soy and cattle production, and Kalimantan, Indonesia dominated by palm oil and industrial pulp production.

For the purpose of study, future production demands for both regions are derived from the MAGNET global economic model while scenarios focused on the period of 2025 to 2050. Drawing on these projections, we conducted stakeholder interviews with actors in both study regions to identify preferences of locally grounded mechanisms for reconciling agricultural production with conservation objectives. Stakeholder insights were integrated into scenario parameterisation within CLUinPy (a novel open-access in-house Python implementation of the CLUMondo land-use model). Carbon emission impacts resulting from future land-use change were assessed using a spatially-explicit carbon accounting framework.

Across both regions, stakeholders consistently identified multifunctional and integrated production systems, including agroforestry and cattle ranching combined with silviculture, as important mechanisms to achieve sustainable land-use futures. Modelling results indicate that transitions towards such integrated systems reduces the probability of future deforestation compared to a reference scenario, with corresponding reductions in carbon emissions. However, the magnitude of these benefits is highly sensitive to assumptions about the productivity of integrated systems and their capacity to meet future production demand without displacing agricultural expansion into remaining forest areas.

From a modelling perspective, improved spatial mapping of agroforestry and silvopastoral systems, together with broader empirical datasets on their productivity, is essential to better constrain scenario outcomes. This study contributes to the evidence base for designing climate-resilient, multifunctional agro-ecosystems capable of meeting production needs while safeguarding tropical carbon stocks. More broadly, it provides a transferable modelling framework for assessing deforestation and carbon-emission trade-offs in export-oriented tropical agriculture–forest mosaics.

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