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Co-designed scenarios to spatial futures: Integrating CLUMondo and invest to assess divergent multi-stakeholder land-use and NBS priorities

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Abstract

Conflicting land use demands and diverging interests among local and regional stakeholders remain persistent challenges for sustainable land use and forest management. This is of particular importance for the planning and implementation of Nature-based Solutions (NBS) in complex socio-ecological and forest-agricultural mosaics of tropical regions. Although participatory co-design land-use scenario approaches are increasingly used to capture stakeholder visions of the future, limited empirical studies have systematically traced how co-designed multi-stakeholder scenario narratives are translated into quantitative spatial model parameters. Less attention has also been given how divergent stakeholder-defined land-use and NBS priorities across jurisdictional scale shape future land use patterns and ecosystem service outcomes.

This study addresses these gaps by adopting a GeoAI-assisted parameterisation approach that systematically structures and translates co-designed stakeholder narratives into quantitative parameter sets for spatiotemporal land-use modelling. These scenario-specific inputs drive dynamic land-use simulations in the CLUMondo model. The resulting simulation results are coupled with the InVEST approach within a unified modelling environment, CLU-VEST, to assess ecosystem service trade-offs and synergies across alternative NBS-driven land use pathways developed with local and regional stakeholders. The study examines whether divergent stakeholder-defined land-use and NBS priorities produce distinct different future land use patterns and ecosystem service outcomes. Specifically, it addresses two core questions: (i) how can co-designed multi-stakeholder NBS-driven land use narratives be systematically translated into quantitative parameters sets? and (ii) what spatial overlaps and ecosystem service trade-off changes emerge when comparing local versus regional-driven CLU-VEST outcomes?

The research focuses on four landscapes of diverse socio-ecological contexts: Penablanca, Balasig Watershed, Maasin, and Silago, located in the Cagayan Valley and Eastern Visayas regions of the Philippines. These landscapes face compounding environmental and socio-economic pressures associated with forest degradation, agricultural expansion, and climate-related risks. By integrating participatory co-design, GeoAI-assisted parameterisation, and coupled land-use change and ecosystem service modelling, this study advances a replicable and transparent framework for linking multi-stakeholder narratives to spatially-explicit futures. The study provides decision-makers with empirically grounded evidence for reconciling competing land-use priorities, and offers a transferable methodological blueprint for inclusive land use and NBS planning in complex forest mosaic landscapes in the Philippines and other tropical regions.

Keywords: CLUMondo-InVEST coupled modelling, ecosystem service trade-offs, geoAI-assisted parameterisation, land use change, multi-stakeholder scenario narratives, nature-based solutions, Philippines