Nicolas Tarasewicz

Expressing ecosystem model output and Swedish forestry goals with composite indicators

Forest ecosystems provide a wide range of services necessary for maintaining environmental health and human well-being. Ecosystem models help inform how various management strategies respond in different regions to changing climate conditions. They contribute to mitigation and adaptation policy measures and support private forest owners in deciding ideal practices to implement. The complex nature of model output and how ecosystem services have many synergies and trade-offs between environmental, economic, and social sustainability dimensions make communicating findings outside of scientific cohorts difficult. Composite indicators are mathematical simplifications of complex phenomena widely applied to promote and communicate findings to stakeholders. This study developed a composite with existing ecosystem model results for 19 forestry management strategies across three ecoregions and climate scenario projections in Sweden.

Multiple composites were generated around a central framework that considered domestic and international sustainability policy goals by employing several multivariate techniques to account for variation in targets and ecosystem services. Ten ecosystem service indicators were sorted into theoretical sub-component groups based on whether they addressed biodiversity, climate change mitigation and risk management, or production policy aims. A combination of principal component analysis, exploratory factor analysis, Cronbach's coefficient alpha, and hierarchical cluster analysis was used to re-sort indicators. These hybrid groupings accounted for meaningful statistical relationships between modeled values. Eight composites were generated with either theoretical or hybrid sub-components, two normalization approaches (z-score and min-max), and two weighting schemes. The two weighting schemes were based on policy prioritizations between sub-components that reflect 1) current policy standards and 2) explored a scenario following international recommendations to focus on biodiversity and climate change above forest production.

The eight composite structures were systematically evaluated across all regions and climate scenarios for each structural aspect (i.e., the sub-component grouping, normalization approach, and weighting scheme) to determine significant differences between structures and the ideal combination for representing the original model output. Z-score normalization with hybrid sub-components and both weighting schemes were selected as the most suitable composite. This combination best captured the variation between management strategies and the relationships between ecosystem indicators while offering more than one policy perspective. The final composite agreed with original model findings: a combination of continuous cover and broadleaf-mixture strategies are best for balancing goals under changing climate conditions for all modeled ecoregions. Results highlighted areas of refinement in the model's parameterization of spruce management strategies. As with all other composites, the subjective nature of decisions made when designing its framework must be justified and clear when applied, especially when dealing with multidimensional model output.

Keywords: Physical geography, ecosystem analysis, forest management, multifunctionality, LPJ-GUESS, composite indicator, climate change adaptation, biodiversity, SDGs, Sweden

Advisor: **Anna Maria Jönsson**
Master degree project 30 credits in Physical Geography and Ecosystem Science, 2021
Department of Physical Geography and Ecosystem Science, Lund University. Student thesis series INES nr 540