Landscape Analysis in EIA: A Biodiversity Ally?

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Abstract

EIA can be an important tool in reversing the current decline of biodiversity. To do so, it must effectively assess impacts of a project on biodiversity and translate that information into the decision-making process and post decision-making implementation. Tracking changes in landscape composition, structure and pattern provides windows into key processes that mediate biodiversity, but broad-scale landscape change is not always measured or translated into evidence-based decision-making. This paper presents a content analysis of 28 EIA reports prepared over the last ten years at the local to federal levels in Ontario, Canada and suggests areas where landscape analysis could fill gaps in biodiversity dimensions of EIA. The paper also introduces a simulation modelling experiment that expands landscape analysis capacity to assess cumulative impacts and assist with EIA decision-making. The simulation tests how accounting for scales of analysis that better relate to biodiversity could enhance project EIA and lead to better-informed decisions.

Introduction

The loss of biodiversity is a critical problem of our time. Major factors contributing to this decline include land use change and associated habitat loss and alteration (MEA 2005). Effective environmental planning, including assessing the impacts of potential land use changes, is important for the conservation of biodiversity. Environmental impact assessment (EIA) can be a useful tool for this purpose.

Biodiversity is both a component of and is influenced by the composition, structure and pattern of landscapes: it can be defined at an ecosystem, species and genetic level (UNEP 1992, Walz & Syrbe 2013). Biodiversity and ecology literature emphasize the importance of broader spatial scales and landscape context in mediating biodiversity (e.g., Walz & Syrbe 2013). Analyzing landscape structure, and linking it to ecological processes and components such as biodiversity, has been a large focus of landscape ecology. This discipline studies the relationship between spatial pattern and ecological processes, including how habitat structure and function change as land use changes, and how biodiversity responds to these changes. In this way, landscape ecology and the tools it offers can provide a scientific framework for linking land use patterns at a broader scale to components of biodiversity, and clues about predicted biodiversity response to land use changes (Mayer et al. 2016).

However, a landscape perspective is not common when assessing impacts of projects that affect land use; decisions are often made for individual projects, examining site-specific scales, with little attention paid to landscape context and ecology (Botequilha Leitão & Ahern 2002, Gontier 2006, Gagné et al. 2015). Possible reasons for this omission suggested by these authors include

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prohibitive data requirements and the complexity of ecological models and metrics at broader scales. Cumulative effects of such one-off decision-making often result in a loss or alteration of important habitat in the landscape and associated losses in biodiversity.

Our research focuses on the question of what landscape information EIAs might be missing that could enhance their effectiveness with respect to biodiversity. Where are the greatest gaps? How can we test how these gaps might be bridged?

Gap analysis

Previous authors have discussed gaps in biodiversity assessment in EIA in Europe (Gontier et al. 2006, Karlson et al. 2014), India (Khera & Kumar 2010) and southern Africa (Brownlie et al. 2006, Hallatt et al. 2015), finding weaknesses in assessment practices beyond the local habitat level. Similarly in North America, Gagné et al. (2015) found that knowledge from landscape ecology was seldom used in land use decision-making, and that the abundance of literature on ecological guidelines had made little change in terms of informing decisions.

Building on this work, we analyzed the content of EIAs of projects proposed in the province of Ontario, Canada, for their use of landscape ecology concepts and landscape analysis methods. We focused specifically on the extent to which landscape ecology was expressed in EA in Ontario, how landscape ecology concepts were represented, and identified gaps between the science of landscape ecology and the practice of EIA.

Responsibility for EIA in Canada is shared among levels of government, with provinces having authority to manage and make decisions regarding their natural resources. The nature of a project dictates which level of government will be responsible for EIA review and decision making, although it is not mutually exclusive. For example, EIA for mines larger than a specified threshold fall under federal jurisdiction as well as provincial authority, major highways and electricity transmission lines are subject to provincial EIA and occasionally a federal process, while EIA for municipal development falls primarily under municipal authority with occasional provincial or federal involvement. Requirements are slightly different for each jurisdiction, although the aims are essentially the same.

We examined a total of 28 EIAs spread among each of these regulatory jurisdictions over a ten-year period from 2007-2016. These EIAs covered four different project sectors: mining, transportation, electricity transmission and municipal development. These represent project sectors with potential to impact terrestrial land uses and effect land use change on biodiversity. They also encompass a range of land use alterations including both areal and linear disturbances.

We started by developing an indicator framework of themes and key concepts in landscape ecology with known relationships to biodiversity, in order to look for the expression of these concepts in the selected EIAs. We defined a total of 19 key concepts under four broad themes: habitat amount, composition, context, and configuration. We then evaluated the expression of those key concepts in the EIA reports (Rehbein et al. 2017).

Each of the four broad themes had some degree of representation within the EIA reports; however, our findings overall aligned with those of previous authors that described weaknesses in addressing landscape and broader-scale impacts on biodiversity. Among our results were two important gaps where opportunities to enhance EIA using landscape analysis could add to the accuracy and effectiveness of EIA predictions. We will focus on these two gaps for the purposes of this short paper, illustrating how bridging these gaps might be tested using a simulation experiment.

One important gap was that 24 of the 28 EIA reports did not relate the predicted changes in habitat as a result of the proposed project to any habitat targets or thresholds for the watershed, landscape or region. Without reference to this kind of an ecological cornerstone, predictions for habitat change can be relatively meaningless. Habitat amount in a broad landscape context is a critical variable in biodiversity conservation (Fahrig 2003).

A second notable gap discounted the importance of the landscape matrix, or the dominant land use or land cover type in a landscape, in contributing to the overall permeability of the landscape to species dispersal between preferred habitats (e.g., Ewers & Didham 2006). Landscape permeability focuses on the ability of the landscape as a whole – including all land use types – to facilitate or impede flows and ecological processes (Figure 1). These flows include dispersal and movement of plants and animals, which are critical processes that maintain biodiversity.

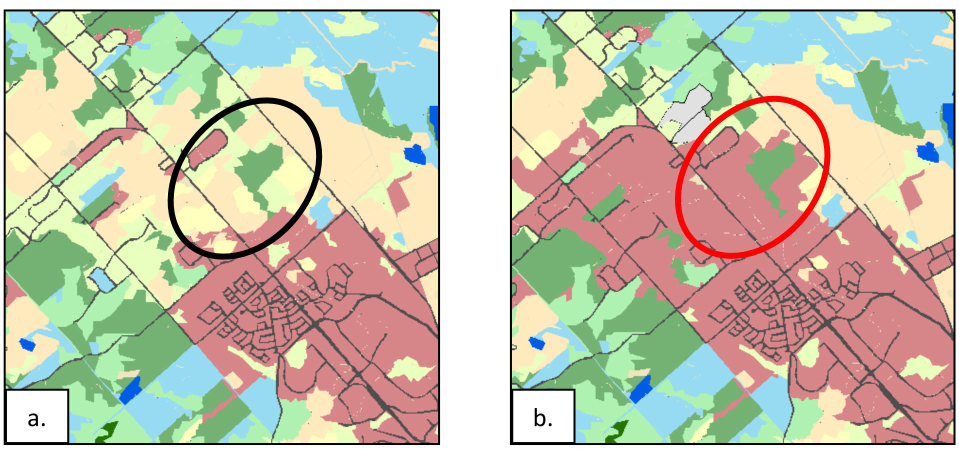

Figure 1. A forest patch in a rapidly urbanizing area of eastern Ontario, surrounded by (a) agricultural fields, and (b) urban land. While the size and shape of the forest patch is unchanged, biodiversity is affected by the changes in the broader landscape and its permeability.

Simulating landscape-based decision making to address these gaps

Of these two gaps in biodiversity assessment, the first is a simpler one to address from an operational perspective. In Ontario, we have a resource document produced by federal government scientists at Environment Canada: *How Much Habitat Is Enough* contains habitat amount guidelines related to forests, grasslands, wetlands, and riparian areas in Ontario ecoregions (EC 2013). While there are limitations to this document, such as the generality of the guidance across regions and species, it is still a useful tool in providing science-based information and guidelines related to these habitats and their biodiversity.

Addressing the second gap is a more complex matter. First, landscape permeability depends on the species or process in question – a land use change that enhances permeability for one species may do so at the detriment of another. Thus, multiple measures would be required in order to gauge the impacts of a single land use change on multiple focal species or species guilds. Additionally, tools for supporting this kind of landscape analysis are relatively complex in theory and practice. Theories of connectivity form the basis for modelling tools commonly used to analyze permeability across landscapes and regions. Examples include Conefor (graph theory; Saura & Torné 2009) and Circuitscape (circuit theory; McRae et al. 2008). Expert opinion is often required to define the resistance of the landscape matrix and to identify habitat suitability for focal species in these models (Correa Ayram et al. 2016).

Because of the simpler nature of addressing the first gap, we consider it more likely to gain initial traction among EIA practitioners. It is also possible that by addressing habitat amount in the broader landscape we can also influence landscape permeability, because of the inherent correlation between landscape composition and configuration (Fahrig 2003, Duflot et al. 2017). We therefore chose to investigate how this first gap might be addressed, and the impact this may have on biodiversity and on other identified gaps such as landscape permeability.

To do so, we designed a scenario-based approach that simulates decision-making regarding land use change in a region, where decisions are informed by feedback regarding proposed changes similar to in EIA. Our experimental approach uses an agent-based modelling platform and an existing dataset from an agricultural region at the urban interface in eastern Ontario, Canada. The platform, *Envision*, is an open-source, spatially-explicit GIS-based tool housed at Oregon State University. *Envision* allows for representation of decision-makers who make management decisions in parallel with landscape change models using a variety of decision models and landscape feedbacks (Bolte n.d.). Decision models can be customized and associated with different alternative scenarios.

In our study, outcomes of individual decisions effect land use change in the region by allowing or prohibiting simulated 'projects' to go forward. Projects are represented by local land use changes specified by land conversion rules: for example, a land area underlain by a particular deposit may become an aggregate mine, if allowed by the decision-making agents. As a scenario is run over many years, land use changes iteratively according to the scenario's decision rules regarding proposed projects. This results in a simulated future landscape at the end of a 30-year period, a product of cumulative effects of multiple decisions over time. The resulting landscapes for each scenario can then be compared according to indicators of biodiversity.

We propose two scenarios: (1) a base case, which incorporates status quo decision-making based on criteria currently considered in the EIAs we studied, and (2) a habitat amount-based scenario, in which any proposed land use changes are compared with habitat amounts in the broader landscape according to Environment Canada guidelines. Land conversion rules that simulate project proposals will be common to both scenarios.

Choosing indicators with which to evaluate the resulting landscapes under each scenario is not a straightforward task, as biodiversity is itself a complex concept. Primary types of indicators include species richness measures based on habitat association, habitat suitability assessments for focal species, and landscape metrics that correlate with biodiversity (e.g., White et al. 1997, Botequilha Leitão & Ahern 2002, Walz & Syrbe 2013). Using different types of indicators in our evaluation will help to more accurately gauge biodiversity potential. Here we propose to assess how well the simple habitat amount-based strategy indirectly addressed more complex gaps in landscape-based biodiversity assessment, such as changes in landscape permeability. Our evaluation will therefore include a permeability analysis of the resulting landscapes under each scenario for a set of focal species. Should results show that a simple habitat amount-based strategy can positively impact landscape permeability over the long term, this could save on the need for complex and potentially costly analysis done on a project-by-project basis.

Conclusion

Incorporating measures of broad-scale landscape change into EIA is important to effectively assess impacts of a project on biodiversity. This is an area of EIA with opportunities for improvement in Canada; important gaps include linking changes in local habitat amount to ecologically relevant measures at a landscape to regional scale, and considering the impact of land use changes on the overall permeability of the landscape to species flows. A well-structured, simple landscape analysis may be able to address these gaps in biodiversity dimensions of EIA. We propose an experimental simulation to measure the cumulative impact of incorporating landscape analysis in project decision-making over time on regional biodiversity, testing whether a simple analysis based on habitat targets and thresholds is able to cover off more complex gaps related to biodiversity in current EIA. We see potential in this research to improve biodiversity conservation through decision-making that is better informed by incorporating landscape ecology into project assessment practices. We will be publishing this work in the upcoming months as research progresses; in the meantime, interested readers are welcome to contact the corresponding author for updates.

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