HUMBOLDT-UNIVERSITÄT ZU BERLIN

HU | MatNat, Geographisches Institut | 10099 Berlin

Polish Academy of Sciences

Prof. Dr. Elzbieta Wilk-Wozniak

Adama Mickiewicza 33
31120 Krakow
Poland

Mathematisch-Naturwissenschaftliche Fakultät

Geographisches Institut

Prof. Dr. Tobias Kuemmerle
Conservation Biogeography

17 June 2024

Evaluation of the Doctoral Thesis of Mrs. Monika Teresa Hoffmann

Postanschrift:
Humboldt-Universität zu Berlin
Unter den Linden 6
10099 Berlin
Telefon +49 [30] 2093 6972
Telefax +49 [30] 2093 6848

tobias.kuemmerle@geo.hu-berlin.de

Sitz:
Geographisches Institut
Rudower Chaussee 16
12489 Berlin

Relevance

Habitat change, and its often negative impact on species, is a major driver of the biodiversity crises. Roads are particularly relevant in this context, as they are associated with many negative edge effects, fragment habitat areas into often isolated patches, and open up inaccessible areas to a range of human activities that translate into threats to biodiversity. Understanding the impacts of roads on the environment and where areas without such impacts remain are therefore important topics for conservation science and practice. Using broad-scale geospatial analyses, Mrs. Hoffmann's thesis addresses this challenge by studying the global geography of roads. The thesis defines and maps roadless areas, asks how roads impact on ecological functioning and thus how roadless areas benefit conservation, and evaluates the quality of global road data available for describing road geography. In doing so, the thesis clearly addresses an interesting research issue, expands the state-of-the-art on spatial road ecology, and contributes to the field of conservation science by generating new knowledge and data on roadless areas.

Structure of the thesis

Mrs. Hoffmann's dissertation is written in English and includes an English and Polish summary. The thesis starts with an introductory chapter (18 pages), followed by three individual research papers and a short conclusions section (2 pages). The first chapter provides background on the importance of roads in a conservation context, specifically on the negative effects that roads often have on ecosystems and biodiversity, and uses this to make a case for the conservation value of roadless areas. The first part of the thesis also provides six research questions and summarizes the objectives and general approach taken in each of the research papers. This is followed by the three papers themselves, all of which are already published. Paper I was published in *Science,* one of the most distinguished journals that exists for research in ecology and conservation. Paper II was published as a book chapter in the *Encyclopedia of the World's Biomes*. While this book (series) is published by a recognized publisher (Elsevier) it was

somewhat unclear whether the book chapter had been peer-reviewed. Paper III was published in the open-access journal *Scientific Reports*.

Based on the author's contribution statements at the end of the thesis, Mrs. Hoffmann made major contributions to all these papers. She is the second-author of paper I, highlighting the key contribution she made to this high-impact paper, and the first author of the other two research papers. In addition, a total of 12 coauthors contributed to the work with various levels of contributions. The thesis is overall formatted well, with a clean layout and well-designed figures and tables. The papers are provided in the format of the respective journals, which by default means formatting varies a lot across the thesis. The thesis is quite well-written but had some typos and minor grammatical issues.

Evaluation of the thesis

General remarks

The thesis tackles an important and arguably understudied research issue – the geography of roads and how it matters for conservation science and practice. It does so through innovative empirical work that provides novel insights and datasets, not the least a conceptual definition of roadless areas, a literature review of documented road effects, and the first map of roadless areas (all in paper I), and the first validation of this map for two large and contrasting regions (paper II). These results are considerable and relevant. The thesis also discusses both the conservation value of roadless areas and argues that roadless areas are useful conservation targets (all papers, but especially paper 2), and the dissertation ends with a summary of overall conclusions.

In evaluating the thesis, I had the following general, cross-cutting remarks. None of these comments is meant as a major critique of the thesis. Rather, they mark areas where deeper engagement with the topic could have enriched the thesis further.

- While the introduction sets the scene very well for the thesis in terms of providing background, it could have clearly carved out more clearly the 'unknowns', the knowledge gaps that exist this thesis addresses (e.g., missing concepts for roadless areas, unclear geography of roads at broad scales, the unclear value of roadless areas for biodiversity, etc.). Research questions are provided and they are well-formulated, but how they derive from the state of the art could have been made more clear.
- The introduction chapter highlights the adverse impacts of roads on ecosystems and biodiversity. However, that is not necessarily true for all species. In Europe, for instance, many grassland-dependent species do well along roads which now often are the last low-intensity, late-mown (or never-cut) grasslands in the landscape. Similarly, some species benefit from edge-habitat in forests. A discussion about possible 'winners' of roads and fragmentation would have enriched the introduction and the individual papers.
- The thesis as a whole does not discuss very much *why* roads are built, in other words, what the benefits of roads are for society. This seems relevant because as paper II, highlights there are sometimes major trade-offs between keeping areas free of roads for biodiversity on the one hand, and building roads to improve well-being and achieve development goals. This brings the question of what the societal and well-being implications of promoting roadless areas are. There seem to be clear ethical dilemmas here: would it be justified to not develop roads if that increases access of local communities to healthcare? There is a contextual element as the social trade-offs of keeping roadless areas might be different in developing and highly developed countries. All of this might have deserved a deeper discussion in the thesis.
- The thesis makes a convincing case for the conservation value of roadless areas, not the least through the comprehensive literature review on road effects in paper I. This is used to call for protecting roadless areas, as a proactive conservation strategy. At the same time, there is increasing awareness of a prevailing 'high-and-far' bias of protected areas (which would be amplified if more roadless areas were protected) and that many of these protected areas might not need protection because they are so remote. Given limited conservation funding, how do increasing calls to focus on protected area effectiveness and creating 'additionality' align with ideas to protect roadless areas? This potential trade-off could have been addressed and discussed more deeply in the dissertation (e.g. in the conclusions section).

- Mapping roadless areas seems to be closely related to efforts to map wild and remote areas (e.g., wildlands, wilderness areas, last of the wild, etc.) – as discussed in paper II. The thesis could have linked head-on (in the introduction section, in paper I) to such efforts to make a case for what blind spots of prior work were and why an effort focused on roadless areas is needed.
- Wilderness mapping efforts and maps have often been criticized for furthering a nature/people dichotomy that is often perceived as Western and colonial, and that has been suggested to be unhelpful for conservation in the Global South. Is there a risk that roadless area maps could be furthering such a (surely unintended) image?
- Throughout the thesis, two types of road impacts seem to be sometimes mixed up: (a) the local impact of roads away from them, in other words, an edge effect, and (b) the landscape-scale impact of roads on the fragmentation of habitat. Since both are different in their impact on ecological functions, species' populations, and biodiversity, it could have been useful to more clearly distinguish edge effects of roads from fragmentation effects. It might have furthermore been interesting to link to the recent 'fragmentation 'per se' debate in conservation science (see recent papers by Fahrig et al and responses to them), where it seems this dissertation would have something to contribute.
- The conclusions section was short and could have carved out more clearly how the results achieved in the individual chapters combine to provide more than the individual pieces. For example, paper III very clearly shows that the analyses carried out in paper I must underestimate roadless areas quite substantially, but this was not discussed as a cross-cutting finding. Similarly, paper II argues that roadless areas should not be defined using a single buffer, which appears to be what was done in paper I and III. Discussing these issues more across the paper could have enriched the synthesis and conclusions section.

Paper 1: A global map of roadless areas and their conservation status

This paper used a large, citizen-science-based road dataset to define and map roadless areas, as well as to evaluate the protection status and ecological integrity of roadless areas. The paper is novel in providing the first, comprehensive assessment and maps of roadless areas, and the literature review of road effects on ecological parameters is valuable by itself. The paper was prominently published in *Science*, which is outstanding for a dissertation chapter. Judging from the authors' contribution statements, Mrs. Hoffmann carried out the bulk of the analytical part, especially the geospatial analyses (i.e., the core contribution of this paper). To what extent she contributed to the conceptual parts of the paper was less clear. The insights and datasets generated in this paper are scientifically new and of potentially great value for conservation planning. Clearly, this is a landmark publication for road ecology and wilderness conservation efforts! Specific comments to this chapter are:

- Given that there are two large global road datasets (plus comprehensive regional ones) and given that their main weakness is an underreporting of roads, why were the different datasets not combined (i.e., a union of the various sources)?
- The sensitivity of some of the results to the buffer size chosen to define roadless areas (1 km) was not clear. The Supporting information shows a map of roadless areas for a 5-km buffer definition. This suggests somewhat of a polarization (high vs low road impact for the 5km buffer vs. more nuanced impact for the 1-km buffer). How the study's results depend on the roadless area definition could have deserved more discussion.
- Several issues surrounding the EVIRA analyses were unclear to me. First, the index was conceptually a bit unclear, especially in how the datasets chosen link to aspects of functionality (self-organization, regulation, and exergy – highlighted as the conceptual framework for the index). Second, a key input to the index is the size of roadless patches, suggesting a risk of circularity when comparing back to the roadless area maps. Third, the ecosystem functionality index, one of the key inputs to the EVIRA, is itself an index composed of many inputs (e.g., global plant species richness, carbon storage). It was unclear how the data was evaluated in terms of uncertainty and possible error propagation. Fourth, the EFI and thus EVIRA index is compared to roadless areas defined with a 1-km buffer, but it was unclear whether the EFI actually supports such a high spatial precision. Finally, the decisions behind weighting the three main inputs to the EVIRA could have been explained more.

- The sensitivity analyses for the EVIRA provided in the Supporting Information of paper I is highly commendable. It shows rather high sensitivity, and one wonders what that would mean for this part of the analyses and the results from them.
- It was somewhat unclear how the scoring of road impact per SDG indicator was carried out (i.e., by whom, how many, how were potentially contradictory scores unified, etc.).

Paper 2: Roadless areas as key approach to conservation of functional forest ecosystems

This paper, a book chapter, mainly summarizes and extends the key findings from the more empirical paper 1. It does so very nicely, carving out the main messages of both the review of road effects, as well as of the mapping of roadless areas. The paper goes a step further than chapter II in translating these empirical results into recommendations for conservation policymaking and planning, starting from the assumption that roadless areas are important to maintain. Specific comments on this chapter are:

- Commendably, this chapter also addresses the 'social' impacts of roads and roadless areas on local communities, showing that the impacts of roads and road expansion/improvement can be substantial. Thus, there are trade-offs between keeping roadless areas free of roads and social-ecological and development – as also shown in the analyses of roadless areas and SDGs. It comes as a surprise that the next section then argues that 'the key message to policymakers is clear': roadless areas should be given priority. A more nuanced message might be more appropriate.
- In the introductory chapter, paper II is framed as exploring the conservation benefits of roadless areas. The paper itself, however, does not provide much evidence for such benefits. Instead, it was framed normatively (Roadless areas are good), contrasting the question posed in the introduction (Are roadless areas good?).
- The introductory chapter states (p15) that the opportunity costs of maintaining roadless areas are often lower than the costs of fragmentation. This is a strong statement and I was looking forward to seeing this backed up, but could not find much evidence in paper II on this. Perhaps a clearer definition of opportunity costs (which costs, for whom) and how they were estimated would have been desirable.

Paper 3: Mapping roadless areas in regions of contrasting human footprint

This paper is an empirical evaluation of the roadless area definition and roadless areas mapping for two contrasting regions, Central Europe as a densely-populated area and boreal Canada as a very sparsely populated region. To me, this was the empirically most interesting paper of the thesis, using a robust sampling design, then screen-checking a large number of sampling plots against very-high-resolution imagery, and then using this to systematically validate the roadless area maps and the completeness of the OSM road layer. The results are interesting, highlighting first and foremost a major underestimation of roads in the OSM data, and as a result an overestimation of about 30% in terms of the roadless areas identified. The paper uses this to discuss ways of closing these data gaps to improve the mapping of roadless areas. Specific comments on this chapter are:

- The selection of the two study areas is explained, but one still wonders why a more global assessment was not carried out. Would this not have enabled an even more direct evaluation and validation of the roadless area map from paper 1?
- The validation plots were sampled following a random design and used a large number of plots. Still, it is unclear whether sampling bias could exist in the assessment (e.g., areas with high or low road density systematically over- or undersampled). A random stratified approach would have potentially allowed for a better-distributed validation dataset and corrected for potential sampling bias.

Summary

Mrs. Hoffmann's thesis tackles a relevant research issue, focusing on the impact of roads on biodiversity and where areas without such impacts are found. The thesis uses generally appropriate methodology, generates substantial and novel insights and datasets, is well-written and appropriately formatted. Some room for improvement exists in terms of working out the research gaps and synthesizing cross-cutting research findings and conclusions. Furthermore, some of the underlying assumptions and conclusions could have deserved a more detailed discussion. These are all minor points of criticism.

In conclusion, I declare that the doctoral dissertation submitted for review, whose author is Mrs. Monika Teresa Hoffmann, meets the criteria for doctoral dissertations pursuant to art. 187 of Act of 20 July 2018, Law on Higher Education and Science (Journal of Laws of 2018, item 1668, as amended) and I put forward a motion to the Scientific Council of the Institute of Nature Conservation of the Polish Academy of Sciences in Krakow to admit M.Sc. Monika Teresa Hoffmann to further stages of the doctoral dissertation.

Sincerely,

Prof. Dr. Tobias Kümmerle