**Comparing spatial prioritization methods for biodiversity conservation and ecosystem service supply in Europe**

**Joona Lehtomäki**1\* and **Peter verburg**1

1Environemntal Geography Group, Department of Earth Sciences, De Boelelaan 1105, 1081 HV Amsterdam, Vrije Universiteit Amsterdam, the Netherlands.

\* Corresponding author

**Contact:** j.lehtomaki@vu.nl, tel. +31-20-59-87294  
ORCID: 0000-0002-7891-0843

peter.verburg@vu.nl, tel. +31-20-59-83594

**Type of paper:** Environmental modelling and software, Research article

**Running title:** Spatial prioritization comparison

**Manuscript version:** 0.1 (see also associated NEWS.md)

**Manuscript statistics:** 236 words (abstract)  
178 words (main text)  
694 words (everything)  
7 references  
XX figures  
XX tables

**Abstract:**

Identifying priority areas that simultaneously target safeguarding the supply of ecosystem services as well as biodiversity underlying the supply of ecosystem services is essential for well-informed decision-making on land use and conservation planning. Multiple methods for the spatial prioritization of locations supplying individual or multiple ecosystem services, and for the balanced or optimal allocation of biodiversity conservation actions exist, but the benefits and disadvantages of using these methods are seldom explored. Furthermore, the technical complexity, data requirements and the transparency of the method parameterization further make a great difference in the usability of each method in practical work. Here, we compare a simple scoring method, heuristic prioritization software Zonation, and an exact spatial optimization method in prioritizing locations important for multiple ecosystem services and biodiversity at the European scale. Each method is used within a realistic, but hypothetical decision-making context. We show that for very simple analysis types, the scoring-type of approach performs very similarly to Zonation and the exact optimization method. However, more complex - and arguably more policy-relevant - analysis types can only be accommodated by the more complex methods. We demonstrate the practical implications of using each approach in operationalizing the concept ecosystem services and biodiversity conservation planning into more widespread practical use. We argue that the road forward in using planning methods is a combination of technical credibility, decision-making relevance, and effort in opening up the planning process to the stakeholders involved.

**Keywords:** spatial prioritization; ecosystem services; biodiversity conservation; Zonation; optimization; environmental decision-making

**Software and/or data availability:**

# 1. Introduction

Ecosystem services, activities or functions of ecosystems that provide benefit (or occasionally disbenefit) to humans (Mace et al., 2012), is today one of the most popular concepts guiding decisions on environmental management. Ecosystems are thought to provide a broad spectrum of different services that directly or indirectly contribute to the human well-being on multiple spatiotemporal scales (REFS). Given the strong emphasis placed on ecosystem services especially in the national and international policy arenas (REFS), the operationalization of the concept of ecosystem services is still well underway. Part of this operationalization process is the development of methods and tools for spatial planning that integrates multiple objectives simultaneously in a transparent and cost-effective manner. Spatial planning and spatial support systems are widely studied and used in environmental context in land use, natural resource, urban and conservation planning (REFS). For practical relevance, spatial planning needs to be able to include ecological, economic and social factors relevant for whatever decision-making problem is at hand. Integrating spatial planning with decision-analytical methods has been done under the rubrics such as multi-criteria decision making (REFS), XXX (REFS) and XXX (REFS).

In the field of conservation science, systematic conservation planning (Margules and Pressey, 2000) has been a particularly influential framework combining aspects of spatial planning to implementation of biodiversity conservation (Kukkala and Moilanen, 2012). Within this broader decision-analytical framework, the more technical biogeographic-economic assessment of which areas are the most important for biodiversity and when and how particular actions should be implemented to achieving conservation goals, is called spatial conservation prioritization (Ferrier and Wintle, 2009; Kukkala and Moilanen, 2012; Wilson et al., 2007). In addition to ecological effectiveness, socio-economic efficiency is a key aspect of spatial conservation prioritization: how should limited resources be invested to maximize expected outcomes (the persistence of biodiversity)(Evans et al., 2015). While spatial conservation prioritization has its origins in designing more effective protected area networks, the underlying principles and methods developed on top of them in are, in fact, suitable for prioritizing between a suite of different actions (REFS). For example, spatial conservation prioritization has been applied in context of natural resource extraction (Kareksela et al., 2013), habitat restoration (Thomson et al., 2009) and also ecosystem services (Casalegno et al., 2014; Nin et al., 2016; Schröter et al., 2014). As so long as the underlying assumptions in spatial conservation prioritization methods are met, they are suitable for general spatial prioritization of actions addressing multiple goals other than biodiversity conservation.

The extent to which spatial prioritization methods and tools are applicable also to the prioritization of areas important for the supply of ecosystem services depends on multiple factors.

# 2. Material and methods

# 3. Results

# 4. Discussion

# 5. Conclusions

# 6. Acknowledgements

# 7. References

Casalegno, S., Bennie, J.J., Inger, R., Gaston, K.J., 2014. Regional scale prioritisation for key ecosystem services, renewable energy production and urban development. PLoS One 9. doi:10.1371/journal.pone.0107822

Evans, M.C., Tulloch, A.I.T., Law, E.A., Raiter, K.G., Possingham, H.P., Wilson, K.A., 2015. Clear consideration of costs, condition and conservation benefits yields better planning outcomes. Biol. Conserv. 191, 716–727. doi:10.1016/j.biocon.2015.08.023

Ferrier, S., Wintle, B.A., 2009. Quantitative approaches to spatial conservation prioritization: matching the solution to the need, in: Moilanen, A., Wilson, K.A., Possingham, H.P. (Eds.), Spatial Conservation Prioritization: Quantitative Methods & Computational Tools. Oxford University Press, Oxford, p. 304.

Kareksela, S., Moilanen, A., Tuominen, S., Kotiaho, J.S., 2013. Use of Inverse Spatial Conservation Prioritization to Avoid Biological Diversity Loss Outside Protected Areas. Conserv. Biol. 27, 1294–1303. doi:10.1111/cobi.12146

Kukkala, A.S., Moilanen, A., 2012. Core concepts of spatial prioritisation in systematic conservation planning. Biol. Rev. 88, 443–464. doi:10.1111/brv.12008

Mace, G.M., Norris, K., Fitter, A.H., 2012. Biodiversity and ecosystem services: A multilayered relationship. Trends Ecol. Evol. 27, 19–25. doi:10.1016/j.tree.2011.08.006

Margules, C.R., Pressey, R.L., 2000. Systematic Conservation Planning. Nature 405, 243–253. doi:10.1038/35012251

Nin, M., Soutullo, A., Rodríguez-Gallego, L., Di Minin, E., 2016. Ecosystem services-based land planning for environmental impact avoidance. Ecosyst. Serv. 17, 172–184. doi:doi:10.1016/j.ecoser.2015.12.009

Schröter, M., Rusch, G.M., Barton, D.N., Blumentrath, S., Nordén, B., 2014. Ecosystem services and opportunity costs shift spatial priorities for conserving forest biodiversity. PLoS One 9. doi:10.1371/journal.pone.0112557

Thomson, J., Moilanen, A., Vesk, P.A., Bennett, A., Nally, R. Mac, MacNally, R.M., 2009. Where and when to revegetate: a quantitative method for scheduling landscape reconstruction. Ecol. Appl. 19, 817–828. doi:10.1890/08-0915.1

Wilson, K.A., Underwood, E.C., Morrison, S.A., Klausmeyer, K.R., Murdoch, W.W., Reyers, B., Wardell-Johnson, G., Marquet, P.A., Rundel, P.W., McBride, M.F., Pressey, R.L., Bode, M., Hoekstra, J.M., Andelman, S.J., Looker, M., Rondinini, C., Kareiva, P.M., Shaw, M.R., Possingham, H.P., 2007. Conserving biodiversity efficiently: what to do, where, and when. PLoS Biol. 5, 12. doi:10.1371/journal.pbio.0050223