Nordia
Geographical Publications

Volume 40:1

Habitat suitability modeling of boreal biodiversity: predicting plant species richness and rarity

Miia Parviainen

ACADEMIC DISSERTATION

to be presented with the assent of Faculty of Science, University of Oulu, for public discussion in the lecture hall GO101, on 3rd of June, 2011, at 12 noon.

Nordia
Geographical Publications

Volume 40:1

Habitat suitability modeling of boreal biodiversity: predicting plant species richness and rarity

Miia Parviainen

Nordia Geographical Publications

Publications of
The Geographical Society of Northern Finland
and
The Department of Geography, University of Oulu

Address: Department of Geography
P.O. Box 3000
FIN-90014 University of Oulu
FINLAND
juho.luukkonen@oulu.fi

Editor: Teijo Klemettilä

Nordia Geographical Publications
ISBN 978-951-42-9452-5
ISSN 1238-2086

Multiprint Oy,
Oulu 2011

Habitat suitability modeling of boreal biodiversity: predicting plant species richness and rarity

Contents

Abstract vii

List of Original publications x

Responsibilities of the authors xi

Acknowledgements xii

1. Introduction 1
    1.1. Aims of the thesis 2

2. General background 5
    2.1. Habitat suitability modeling 5
    2.2. Environmental gradients driving diversity patterns 6
    2.3. The issues of data in habitat suitability modeling 8
    2.4. The choice of modeling technique and model selection criteria 10

3. Study areas 13

4. Material and methods 17
    4.1. Species data 17
    4.2. Environmental predictors 21
    4.3. Modeling techniques 24
    4.4. Model calibration and evaluation 27
    4.5. Spatial prediction maps 28

5. Results and discussion 31
    5.1. Environmental conditions explaining threatened plant species distribution 31
        5.1.1. The responses between threatened plant species and environmental gradients 32
    5.2. Visualization of threatspots 34
    5.3. Potentiality of productivity estimates in plant species richness modeling 36
        5.3.1. The responses between species richness and productivity 37
        5.3.2. The importance of productivity levels in neighborhood 39
        5.3.3. Advantages and limitations 40

5.4. Methodological aspects – realistic or biased models? 40
5.4.1. Does good modeling performance guarantee ecologically reliable predictions? 41
5.4.2. Model selection criteria 42
5.4.3. Advantages of summation and ensemble methods 43
5.5. The nature of data – opportunities and limitations 44
5.5.1. Sources of uncertainty 46

6. Themes for future research 49

7. Conclusions 51

References 53

Errata 67

Original publications

Abstract

Habitat suitability modeling of boreal biodiversity: predicting plant species richness and rarity

Parviainen, Miia, Department of Geography, University of Oulu, 2011

Keywords: biogeography, biodiversity, GIS, remote sensing, productivity, modeling, species distribution, species richness

Understanding both the spatial patterns of species distributions and richness and predicting the occurrences of high biological diversity are central themes in biogeography and environmental conservation. Much of the data on species occurrences gathered in different surveys and for different purposes can be compiled into spatially-explicit databases and used for research purposes beyond the scope of the original individual studies. Predictive habitat suitability models of species geographical distributions and species richness are increasingly used as an alternative for incomplete or spatially biased survey data as a basis for conservation planning. In cases in which reliable models for occurrences and richness of species can be produced, they can play a significant role in land-use planning and help managers to meet different conservation challenges.

The work described in this thesis aimed to determine the main environmental variables which predict the variation in plant diversity patterns in boreal landscapes (NE Finland) using existing and readily available environmental data sources and different habitat suitability modeling methods. Species distribution models were built using occurrence records of 28 threatened vascular plant species and 17 ecologically relevant environmental variables based primarily on generalized additive modeling (GAM). Species richness models constructed for 28 plant families and a total of six remote sensing-based productivity measures were used to investigate and predict richness patterns. All the analyses were performed at the same, 25 ha resolution. The performances of the models were evaluated and their predictions extrapolated to the whole study areas.

The results showed that the meso-scale distribution patterns of rare boreal vascular plants are strongly associated with favorable thermal and moisture conditions as well as with stressful, low temperatures. Growing degree days, water balance and temperature of the coldest month were found to be important predictors of threatened plant species distributions. Certain land cover (e.g. mire) and geology variables (e.g. calcareous soils) appeared also as important predictors for several threatened plant species at the 25 ha resolution. The predicted threatspots of rare species were concentrated in certain areas where important habitat composition variables, such as relatively high elevation with rather continental and dry climate, sun-drenched cliffs, and a cover of calcareous rich sandy soils were abundant. Productivity and its variability, as estimated by using remotely sensed NDVI values, provided a useful predictor of plant species richness in high-latitude landscapes. Furthermore, incorporating neighbourhood information into the local productivity-models produced ecologically more reliable predictions of species richness.

In methodological terms, the results showed that there may be great deal of variability in predictions from alternative models and it was thus not possible to single out a 'best' technique or way for predicting suitable habitats. The use of flexible modeling technique such as GAM was found to be useful, as it allowed the calculation of response curves that more closely fit the data. Another way to reduce the uncertainty stemming from the differing projections of single species models is to use several models in the analysis, and combine their projections. Ensemble methods applied in this thesis, i.e. summation of the predictions from different models and consensus methods provided some clear advantages over the single modeling techniques. The results showed, that although choice of modeling technique is one of the 'core' issues in habitat suitability modeling, it should be remembered that the technique is only one part of the modeling process; other methodic topics, including the nature of the biological data, selection of environmental variables and examining the shapes of the responses are also key elements in the modeling process which may affect model results and may be varied regardless of the modeling technique used.

Habitat suitability models can lead to important advances in our understanding of the factors underlying for the distribution of species, and provide valuable tools for the conservation planning. In conclusion, habitat suitability models can help in determining which aspects of the environment of a given species have a critical impact on its distribution, and thus advance our understanding of the ecological requirements of species and provide valuable information concerning where species are likely to be found in insufficiently surveyed landscapes. Given this, such models have great potential as tools for conservation, but it is crucial that their predictions and the underlying assumptions in the models are evaluated thoroughly.

Supervisors

Prof. Miska Luoto
Department of Geosciences and Geography
University of Helsinki
Finland

Dr. Risto K. Heikkinen
Finnish Environment Institute
Helsinki
Finland

Prof. Jarmo Rusanen
Department of Geography
University of Oulu
Finland

Pre-examiners

Dr. Tuuli Toivonen
Department of Geosciences and Geography
University of Helsinki
Finland

Prof. Heikki Hänninen
Department of Biosciences
University of Helsinki
Finland

Official opponent

Dr. Tuuli Toivonen
Department of Geosciences and Geography
University of Helsinki
Finland

List of Original publications

This thesis is a summary of the following articles, which are referred to in the text by their Roman numerals:

I. Parviainen, M., Luoto M, Ryttäri T & R.K. Heikkinen (2008). Modelling the occurrence of threatened plant species in taiga landscapes: methodological and ecological perspectives. Journal of Biogeography, 35, 1888-1905.

II. Parviainen, M., Marmion, M., Luoto, M., Thuiller, W. & R.K. Heikkinen (2009). Using summed individual species models and state-of-the-art modelling techniques to identify threatened plant species hotspots. Biological Conservation, 142, 2501-2509.

III. Marmion, M., Parviainen, M., Luoto, M., Heikkinen, R. K. & W. Thuiller (2009). Evaluation of consensus methods in predictive species distribution modelling. Diversity and Distributions, 15, 59-69.

IV. Parviainen, M., Luoto, M., & R.K. Heikkinen (2010). NDVI-based productivity and heterogeneity as indicators of species richness in boreal landscapes. Boreal Environment Research, 15, 301-318.

V. Parviainen, M., Luoto, M & R.K. Heikkinen (2009). The role of local and landscape level productivity in modelling of boreal plant species richness. Ecological Modelling, 220, 2690-2701.