University of West Hungary
Faculty of Forestry

Theses of doctoral (PhD) dissertation

Modelling the future distribution of beech at low-elevation xeric limits - comparison of empirical and stochastic models

Ervin Rasztovits

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Doctoral school:	Pál Kitaibel Doctoral School of Environmental Sciences
Leader:	Prof. Dr. Csaba Mátyás
Program:	Bioenvironmental Sciences
Leader:	Prof. Dr. Károly Németh
Supervisor:	Prof. Dr. Csaba Mátyás

Background and objectives

A significant drought event emerged between 2000 and 2003 in Southwest of Hungary which was unprecedented in duration and strength since the beginning of the 50's. After this drought event large volume of dead or already declining beech was logged.

Several studies suggest extensive beech dieback with worsening climatic conditions consequently modelling the vitality response of beech to predicted changes of climate is a critical issue.

For management and conservation issues species distribution models (SDMs) have been extensively used but it is not tested whether models that are successful in predicting current distributions are equally powerful in predicting distributions under different climates. Most of the SDMs do not differentiate between the "leading" and "trailing" edge, although the processes are fundamentally different. Furthermore the multidimensional climatic envelope created by SDMs is often described by long-term averages, but long-term climatic means do not express the importance of extreme weather events, which act as triggering effect on growth decline and pests or diseases attacking populations of weakened vitality.

Empirical models (EM) are considered superior for understanding the relationship between climate and the distribution of species. In an EM, the distribution of a species is defined by functions based on ecological response of that species, however ecological data limiting the distribution are not available for most species.

The aim of this study was to develop a consistent method to model potential future distribution of beech (*Fagus sylvatica* L.) near to the xeric limit with respect to the specific ecological and climatic problems of this region and to compare it with stochastic models.

The following scientific questions were addressed:

- Which SDM can best describe the present distribution of beech in Hungary?
- What is the relationship between weather conditions and vitality status of beech?
- What are the projections for the potential future distribution of beech using SDMs and vitality condition using an EM?

Materials and methods

First the performance of eight different SDMs (Support vector machine (*SVM*); BioClim; Domain; Generalized linear model (*GLM*); Maximum likelihood classification (*MLC*); Artificial neural network using back-propagation algorithm (*BP-ANN*); Maximum entropy (*Maxent*); Classification Tree (*CTree*)) were evaluated using the "ModEco" platform.

96 environmental (climate, soil and geomorphological) predictor were used as input with a spatial resolution of 0.0083^{0}. For current conditions, the WorldClim database, for future simulation the A1B scenario of the "ClimateLimited-areaModelling" (CLM) regional climate model was applied. Beech occurrence data were derived from the Hungarian Forest Inventory.

The factor importance analysis of the models was based on the Cohen's kappa values. Overall model performance was assessed using cross-validation, the Area Under the Receiver Operator Curve; Receiver Operating Characteristic, and maximum Kappa values. For presence-only models the true positive rate vs. the factional prediction area was used.

SDMs share two theoretical assumptions (equilibrium; range limits reflect climatic means) that may not hold during modelling the potential future distribution of beech near the xeric limit. Thus sanitary logging information as a proxy of vitality status was coupled with the modified Ellenberg's climate quotient in a selected study area to obtain the vitality response of beech in the EM. The future vitality status of beech to different terms of this century was simulated using the response function and the same regional climate model projection used by the SDMs.

For training the EM, 1372 beech subcompartments were used. The annual volume of beech sanitary logging was provided by the State Forest Companies (Szép Tibor - Szombathelyi Erdőgazdaság Zrt., Góber Zoltán - Zalaerdő Zrt) for each subcompartment of the study area for the period 2000-2008.

Theses of the dissertation

1. All evaluated models (*BioClim, Domain, One-Class SVM, Maximum Entropy, Maximum likelihood, Artificial Neural Networks with backpropagation algorithm, Classification Tree*) performed “fair” by describing the potential current distribution of beech in Hungary, but only the Artificial Neural Networks with backpropagation algorithm and Classification Trees was suitable for future predictions.
2. The range margins of beech in Hungary are formulated by short-term dry periods rather than by long-term climatic means.
3. Beech in Hungary at its trailing edge (xeric limit) is not in equilibrium with the climate, therefore the application of species distribution models, based on the equilibrium assumption is restricted.
4. Beech is distributed in Hungary mainly in relation to maximum temperatures during spring (maximum temperature of May) and secondly is related to precipitation.
5. Four consecutive extreme dry years with the average modified Ellenberg Quotient (*EQm*) value of 65 are enough for mass mortality in beech stands situated near to the xeric limit.
6. Although the artificial neural networks with backpropagation algorithm and the empirical model showed temporal and spatial differences, both methods identified the same vulnerable areas:
   - Zselic (Nyugat-Zselic, Kelet Zselic)
   - Outer Somogy (Külső-Somogy)
   - Heves-Borsod Hills (Heves-Borsodi-dombság)
   - Göcsej Hills (Göcseji-dombság)
   - East-Zala loess region (Kelet-Zalai-löszvidék)

Application of the results

Forest management and conservation strategies will have to be modified in the light of rapid climate change. The analysis has clearly indicated the vulnerable beech regions in Hungary which could be utilized by nature conservation for selection and maintenance of beech conservation areas.

Wildlife response to spatial and temporal changes in forest habitat is under intense research. The future vitality condition maps were used to assess the impact of climate change on the optimal food selection rule of red deer in Hungary.

Within the project "Beech dieback and climate change in the West-Pannonic region" a decision supporting system (DSS) is currently under construction which is fundamentally based on the results of this work. This is web-based assessment and reporting tool that connects current climate change knowledge and forest planning information. The system aims to support mainly forest stakeholders and forest managers by identifying the most vulnerable forests (on subcompartment level) and by utilizing a database of climate change forecasts (the A1B scenario of the CLM regional climate model) and direct ecosystem impacts (future potential growth and damage ratio).

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