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Climate-related analyses along the Austrian Railway Network, part III:
Vegetation database and climate envelope models of railway relevant woody species in Austria

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Abstract

Under the assumption of ecosystem services, in general, and protective functions, specifically, being provided by resilient vegetation communities, the prediction of potential natural site conditions can be among others a tool for modelling climate change scenarios concerning future protective functions of railway relevant vegetation. Within the "clim_ect" project, the results of 43 climate envelope models show which tree species can contribute protective functions for different hazardous events under climate change aspects. In combination with the vegetation database considering hazard specific and protection related attributes and the syntheses of predicted hazard development corridors (short paper II) it can be used as a planning tool for future species composition on protection forest stands on a regional scale.

Keywords: climate change, protective forest, climate envelope model (cem), ecosystem services, railway relevant vegetation.

1 Introduction

Railway corridors offer a wide range of ecosystem services that represent an added value or benefit for an infrastructure operator [1] and can provide multiple ecosystem services that are not linked to the operational performance of rail traffic [2]. In the

“clim_ect” project, the protective functions of vegetation for reducing the damage potential of natural events were assessed under different climate change scenarios. The protective and regulating services unfold when vital, resilient stands and stand structures develop on the railway accompanying areas. The effects of climate change lead to changes in native forests, which also has consequences for the fulfilment of the protective functions and ecosystem service provision of vegetation. Climate change aspects in the protection forest can be divided into "impacts on the forest" and "impact on the protective performance of the forest" [3], with the former being attributed to changed site conditions and resulting changes in tree species composition.
Due to the heterogeneous landscape, there are very different site conditions for vegetation on the railway associated areas in Austria and the species spectrum of the woody vegetation is accordingly diverse. In order to gather the variety of current and potential vegetation, an extensive vegetation database was created in the “clim_ect” project. In this database, a classification of different characteristics and traits of the species has been made, which can be helpful in designing future protection measures. So-called climate envelope models were calculated as a further component for the selection of future railway relevant vegetation. The climate envelope models can be used to quantify potential natural vegetation sites and their changes in the course of climate change on a regional level. Based on the presented approach, a selection of species adapted to climate change shall be supported and thus a contribution shall be made to the design of measures that support the protective functions of vegetation and secure protection forests also in the future.

2 Methods

Within this part of “clim_ect” the resilience of railway relevant forests under aspects of their protective function against natural hazards was observed and modelled. The methodology is based on the assumption, that vegetation can provide secured ecosystem services in case of adequate locational conditions. It compares the natural site conditions along the Austrian railway network with current climate variables and changing future conditions. Three different but interacting methodical parts build a basis for the definition of climate change mitigation measures, which is not focused on in this paper:

- **Railway related vegetation database:**
  For 92 woody species relevant attributes were summarized and categorized by a review of selected literature ([4]-[11]) and supplemented by expert judgement within the research group Soil and Water Bioengineering, University of Natural Resources and Life Sciences, Vienna. The selection of species was based on prevailing species in Austrian railway relevant forests and supplemented by species linked to ecosystem services. Characteristics concerning site conditions, morphology, sprouting capacity, climatic resistance, protective function regarding natural hazards, susceptibility to browsing by game, bee pasture and forest fires. Through the categorization standardized queries were enabled.

- **Climate envelope models:**
  Natural distribution areas, extracted form [12], of each species are assigned ranges of annual precipitation and average annual temperature based on the reference period 1961-2020. The distribution area was corrected by species-specific limitations of distribution in altitude. Climatic scopes representing potential natural site conditions were defined.
  In a second step, the observation areas along the Austrian railway network were analyzed regarding their current and future climatic conditions. Therefore, four socioeconomic pathways were considered and two different periods were analyzed. Via a synthesis of the species climatic demands and the current and future climate situations along the railway network a forecast predicting the presence of potential natural site conditions on species level was created and plotted in climate envelopes.

- **Quantification of changes in potential natural site conditions:**
  Based on the climate envelope models, the development of potential natural site conditions was analyzed along the Austrian railway network for two observation periods. Variations in frequency of potential natural conditions between the reference period 1961-2020 and the observation periods 2036-2065 and 2071-2100 were quantified. Further on, a classification was carried out by three categories: (I) decrease of potential natural site conditions of -100 to -5%, (II) minor changes in natural site conditions of -5 to +5%, (III) increase of potential natural site conditions +5 to + 100%.

3 Results

The analysis concerning climate resilience of railway relevant species in Austria result in models predicting future potential natural habitat site conditions for two observation periods, four socioeconomic pathways, 26 areas of observation, representing the whole Austrian railway network, and 43 species, including deciduous and conifers. The results are plotted as climate envelopes and summarized in tabular format. As an example, Figure 1 shows the climate envelope model for *Picea abies* calculated for a railway section in eastern Austria.
Changes in the potential natural site conditions as an average over 43 species state major reductions over both observation periods. Regarding 2036-2065 (e.g. Fig. 2) only one area of observation, surrounding Innsbruck, shows increases of potential natural site conditions. All other reaches are confronted with small to large scale decreases. Predicting the period 2071-2100 the whole railway network shows negative tendencies.
Referring to species level, several species (e.g. Pinus sylvestris, Picea abies, Larix decidua) show clear decreases along the observed railway stretches. Trends of other species are strongly connected to regional aspects (e.g. Caprinus betulus, Populus alba, Sorbus torminalis, Ulmus minor). Mainly increases in the amount of potential natural site conditions over the whole railway network are accounted for Castanea sativa.

In general, the results show trends of deciduous species generally performing better in the forecasts than conifers. Furthermore, the models show strong changes in the federal state of Upper Austria.

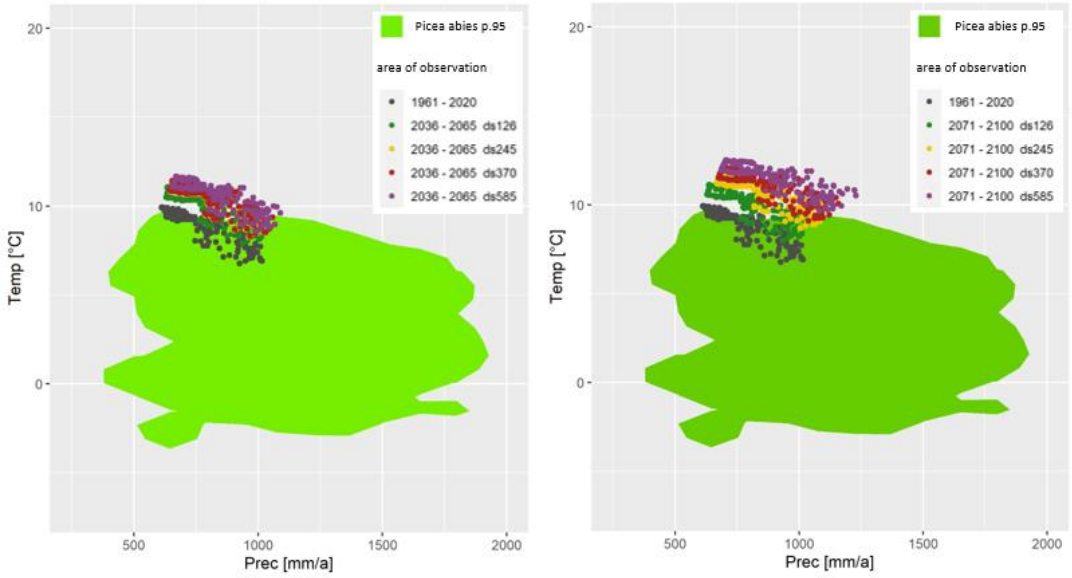

Figure 1: Climate envelope model Picea abies: the area of observation is a section of the railway corridor in eastern Austria; two observation periods and four socioeconomic pathways are plotted: The green area represents the potential natural sites of Picea abies referring to annual precipitation and average annual temperature. Point data represents the area of observation. An overlay of polygon and point data defines the presence of natural site conditions on the point of observation.

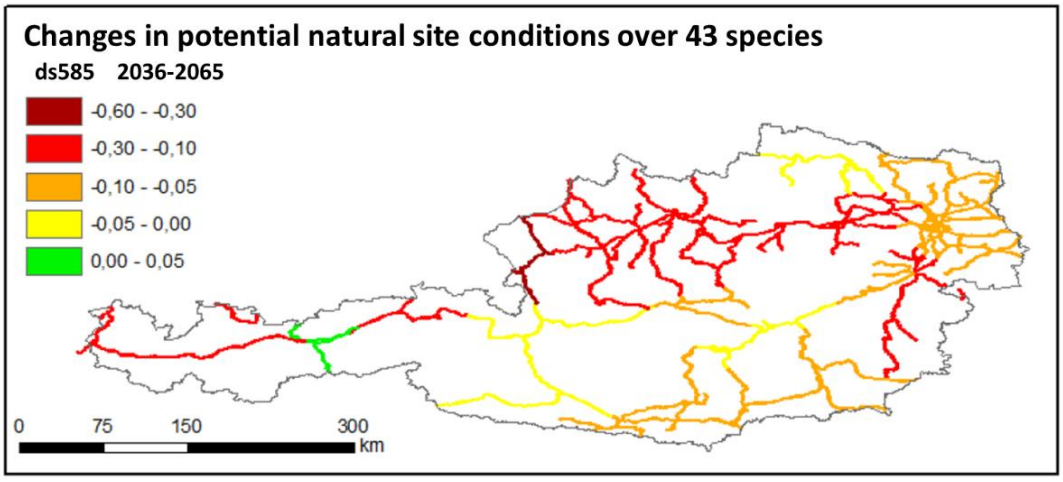

Fig. 2: Example of predicted changes in potential natural site conditions along the Austrian railway network based on an average over all 43 observed species for the socioeconomic pathway ds585 and the observation period 2036-2065

4 Conclusions and Contributions

A combination of the information from the vegetation database and the prediction of future development at the species level can support the selection of species adapted to climate change.
Under the assumption of ecosystem services, in general, and protective functions, specifically, being provided by resilient vegetation communities, the prediction of potential natural site conditions can be among others a tool for modelling climate change scenarios concerning future protective functions of railway relevant vegetation.
Within the "clim_ect" project, the results of the climate envelope models show which tree species can contribute protective functions for different hazardous events under climate change aspects. In combination with the vegetation database as well as its hazard specific and protection related attributes and the syntheses of predicted hazard development corridors (short paper II) it can be used as a planning tool for future species composition on protection forest stands on a regional scale.
It should be noted that the climate envelope models are based on average annual temperature and precipitation and do not take into account other site-specific characteristics such as soil or exposure. For this reason, the results can support the selection of vegetation types on regional scale, but an adaptation to the specific local conditions is indispensable.
Although there are large regional differences, very clear trends can be identified for various tree species. Furthermore, the study shows that the potential vegetation differs greatly between the climate change scenarios, which makes the formulation of concrete measures considerably more difficult. Even if the probability of occurrence of the extreme scenarios considered in this study is lower, the possible impacts should also be taken into account in a risk assessment.

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