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Predicting plant species richness and vegetation patterns in cultural landscapes using disturbance parameters

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Abstract

A new methodological framework for plant diversity assessment at the landscape scale is presented that exhibits the following strengths: (1) potential for easily standardizable sampling procedure; (2) characterization of disturbance regime; (3) use of selected disturbance descriptors as explanatory variables which probably allow for better transferability than site specific land use types—for example, to evaluate the emerging use of energy plants that pose novel management challenges without historic precedence to many landscapes; (4) analysis of quantitative and qualitative aspects of plant species diversity (alpha and beta diversity). For data analysis, a powerful regression method (PLS-R) was applied. On this basis, after further validation and transferability tests, a practical tool for the development and validation of effective agri-environmental programmes may be developed.

Keywords: Agri-environmental programmes; Alpha diversity; Beta diversity; Fichtelgebirge; Land use; Disturbance; Pattern analysis

1. Introduction

The EU Sustainable Development Strategy, launched by EU leaders in Gothenburg in 2001, assigns priority to halting the loss of biodiversity in the EU by 2010. Accordingly, a variety of agri-environmental programmes was set up to reach this goal. Via these programmes, which support specifically designed farming practices going beyond the baseline level of ‘‘good farming practices’’ (GFP), farmers shall be remunerated for specific efforts made for sustaining ecosystem services, e.g. for management methods supporting species diversity and ecosystem sustainability. Since a new EU law was introduced in 2005 (CAP Reform 2003), which decouples agricultural payments from production or mode of land use, the financial attractiveness of agri-environmental programmes might rise. Now, farmers are paid per ha of arable land or grassland managed, and are no longer subsidized according to the quantity of certain goods produced or land use activity maintained.

However, those programmes are often assumed to have positive influence on biodiversity but this has rarely been proven (Kleijn and Sutherland, 2003). In some cases, programmes even turn out to be ineffective and miss the target (Kleijn et al., 2001). Single programmes in limited areas were successfully set up and evaluated (e.g. Knop et al., 2006) but, especially over large areas, neither the effect of the programmes can be assessed nor does their validation seem feasible (Moser et al., 2002). Most statistical models for predicting species diversity at the landscape level are not transferable to other large areas, as they incorporate extremely detailed information on either abiotic conditions or land use practices. In addition, data collection is often too time-consuming and cost intensive to be used as a standardized tool. Accordingly, an applicable, transferable and standardized method for quantifying biodiversity at the landscape scale is needed to serve three purposes: first, to

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develop guidelines for the design of effective agri-environmental programmes; second, to evaluate their effectiveness for the maintenance of biodiversity; and third, to predict the development of plant species diversity under various land use scenarios.

Thus, the first challenge consists of developing a standardized method for quantifying and indicating biodiversity at these two different levels of observation: within and between plots or patches. The sampling design is based on a systematic grid approach developed for biodiversity assessment in cultural landscapes (Retzer, 1999; Simmering et al., 2006). The second challenge consists of developing a method for assessing the underlying factors that determine plant diversity at these two levels (alpha and beta diversity). For predictions of biodiversity, the variability and heterogeneity of various factors has been tested (e.g. geomorphologic forms by Muller et al. (2004) or land use types combined with soil data by Haberl et al. (2004) or Wamelink et al. (2003)). At the landscape scale, Duelli (1997) points towards variability and heterogeneity of a landscape for explaining species richness, where "habitat variability" describes the difference between land use types or distinct land use patches, and "habitat heterogeneity" indicates the number of such different patches within a given area. Those models that employ land use as a predictor are very precise in their forecasting ability (Waldhardt and Otte, 2003; Waldhardt et al., 2003). However, the number of variables needed is usually too large and sampling often too time consuming to develop an applicable, standardized method from the existing models (Moser et al., 2002). Variables on land use type are easy to collect; however, they are very explicit, may be unique to a certain agricultural region and do not account for novel uses, so that transferability is limited. Thus, the introduction of new crops or altered management practices, as may occur in future or in other regions, cannot be included in the models without additional training data.

We assume that our approach has the power to overcome this problem of transferability by using disturbance parameters, such as disturbance frequency, size and selectivity, in order to characterize the anthropogenic disturbance regime. These parameters allow a more precise and abstract description of dynamic factors in a landscape than the commonly used surrogate variables of land use type. A surrogate variable provides an indirect measurement effect in situations where direct measurement of effects is not feasible or practical. Disturbance is defined as any relatively discrete event in time, which disrupts community structure, changes resources or the physical environment (Pickett and White, 1985; White and Jentsch, 2001). A disturbance regime is the sum of all disturbances in a given landscape, including interacting disturbances. In order to find suitable factors for the prediction of plant diversity in cultural landscapes, plant species alpha and beta diversity values are correlated with both the land use type and the underlying descriptors of disturbance regime. During the optimization process of the regression models the use of the surrogate variable land-use and the very case specific variable of disturbance type were avoided to demonstrate the predictive potential of disturbance data. The focus is on vascular plants as they are easily monitored and their richness is a good indicator for the richness of many other taxa (Duelli and Obrist, 1998).

Biodiversity implies much more than counting species. It is the sum total of genes, species and ecosystems in a region or the world (quantitative biodiversity), their heterogeneity, turnover or contrast (qualitative biodiversity) and functional biodiversity, including variability of function or ecosystem complexity (CBD, 2001–2005; Beierkuhnlein and Jentsch, 2005). This study incorporates alpha and beta diversity of higher plants as quantitative and qualitative measures of vegetation diversity.

Our central hypothesis was that the variability of disturbance explains plant species richness. Instead of using the common land use types as predictors, it was proposed that the heterogeneity of the disturbance regime is a powerful explanation for plant species richness in cultural landscapes in Central Europe. In order to provide a first test for this hypothesis, an easily standardizable sampling procedure and a mathematical method of data analysis was executed exemplarily in a mid-elevation, rural area in north-eastern Bavaria, Germany.

2. Materials and methods

The study area was located at about 600 m a.s.l. within the Fichtelgebirge in north-eastern Bavaria, Germany. The highest elevation in the Fichtelgebirge is 1053 m a.s.l., geology consists of granite bedrock, precipitation ranges from 600 to 1200 mm/a. Mean annual temperature at the highest elevation is 6 °C, the growing season comprises 4 months. Agriculture, hay and silage production, and forestry are the main forms of land use.

A regular grid of 100 plots was established in a mixed cultural landscape. It spread over an area of 1600 ha (4 km × 4 km). The plots were quadratic and covered 1 ha (100 m × 100 m) each. The grid was positioned randomly inside a part of the investigated region, which was found characteristic for the mountain range of the Fichtelgebirge. The grid was oriented towards North to facilitate plot identification in the field. In each of the plots, areas of different land use/disturbance regime were differentiated and specified as separate patches if their size exceeded 10 m^2 (including footpaths and transition patches of >1 m in width). For each patch, plant species composition, land use and disturbance descriptors were recorded. A classification scheme to characterize the land use and disturbance regime is given in Tables 1 and 2. Important structures, such as riparian zones, paths, hedgerows and transition zones were characterized in the same way as, for example, agricultural areas, forests, meadows or wetlands.