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The temporal dynamics of a regional flora—The effects of global and local impacts

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ABSTRACT

The main trends in changes in the global vascular plant biodiversity are generally considered to be a decrease in rare indigenous species and a spread of invasive plants. In the present paper, the impact of these changes on the flora of the state of Baden-Württemberg (Southwest-Germany) is examined. The data come from a regional floristic mapping project, which consists of two consecutive surveys, dating from 1970 to 1998 and from 2005 to present. In contrast to many other studies, not only a part of the flora or of an ecosystem was studied but the entire vascular plant flora of a region. As the recent survey is not yet completed, samples of 46 out of 1100 grid cells are analysed as a preliminary study on the trends in entire Baden-Württemberg. In the present paper we address the issues (1) whether changes in biodiversity observed in other studies, e.g. decrease of rare native species and increase of invasives, affect the flora of Baden-Württemberg, (2) which abiotic factors, i.e. climatic or soil conditions, cause these changes of species diversity.

The analysis of the two consecutive surveys revealed a continuing decrease of rare native species and a constant increase of neophytes, thus reflecting the global trends. Many extinction events happened before 1970, some already in the 19th century. Changes in land use and urbanisation of former rural regions are two important factors for these changes. A statistic analysis using Ellenberg indicator values revealed the nitrogen input from agriculture and the effects of global warming as further potential causes for these trends.

1. Introduction

The main causes for contemporary changes in global vascular plant diversity are human activities leading to the extinction of species or the biological invasion of many communities (Vellend et al., 2013; Wardle et al., 2011). Land use (e.g. Hautier et al., 2009) and the loss of suitable habitats (e.g. Krauss et al., 2010) are two major factors for biodiversity loss, apart from climatic factors, especially temperature (Tamis et al., 2005) and precipitation parameters, as well as eutrophication (Ellenberg, 1993; Bobbink et al., 1998; Stoate et al., 2001; Diekmann and Falkengren-Grerup, 2002; Suding et al., 2005; van Calster et al., 2008). Although many nature conservation programmes were implemented, the change and loss of biodiversity was in no way reduced or even stopped (Brooks et al., 2002; Hooper et al., 2012; Jackson and Sax, 2010; Dornelas et al., 2014).

As global changes may be indicated by the changes on regional or local level, a comparison of a given region's historic flora with the current species composition provides valuable insights in the temporal alteration of the plant species composition. Still, the availability of data documenting the changes of biodiversity especially on the regional level is scarce, and many studies were based on specific parts of ecosystems, monitoring programs of agricultural land, or certain organism groups.

The study presented here is based on samples of all taxa of vascular plants on the regional scale in Central Europe and allows an analysis of the species compositions across a large diversity of habitats. The data rely on a floristic mapping project of the state of Baden-Württemberg in SW-Germany. Contrary to most analysis of floristic mappings which treat correlation of the flora with geographical, i.e. spatial factors, for example soil, climate, altitude, etc. (Haeupler, 1974; Wohlgemuth, 1998; Hoechstetter et al., 2005; Bechtel and Schmidt, 2012), we present the results of two consecutive mappings of Baden-Württemberg, with two periods of data collection, one from 1970 to 1998 and the second from 2005 to present. This provides the rare opportunity for a temporal analysis of a whole flora. The only similar studies with a complete com-

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parison of a previous and a recent floristic mapping of a entire region in similar size were presented by Walz and Müller (2009) for the "Saxon Switzerland" and by Korsch and Westhus (2004) for Thuringia.

The intensively fluctuating human impact makes this region an especially interesting area for the study of changes in time rather than in space. The long tradition in floristics and the sound documentation of ferns and flowering plants even allows a partly reconstruction of the flora of the 19th and early 20th century.

The reasons for the shifts in the flora of Baden-Württemberg are still not examined. Therefore, two main questions will be addressed to:

- Do the changes in biodiversity observed in other studies, e.g. decrease of rare native species and increase of invasives, affect the flora of Baden-Württemberg as a whole and on a regional scale?
- Which abiotic factors produce changes of species diversity? Do climatic or soil factors have a larger impact? To what extend does increased nutrient availability affect the entire flora?

In this paper, some well-surveyed grid cells were selected for a first study on the shifts in species composition over an interval of several decades. Their temporal changes were compared by means of the status of the floristic records (i.e. whether they are indigenous or introduced, see Perring and Walters, 1962) and the ecological data by using a statistic analysis of the indicator values of the species (Ellenberg et al., 1991).

2. Methods

2.1. The area of investigation

Baden-Württemberg covers about 35,752 km^2 and is a densely populated part of Central Europe consisting mostly of hills and low mountain ranges with limestone, sandstone, and crystalline rocks. The climate is temperate (nemoral) with relatively high precipitation ranging from more than 1912 (Feldberg, Black Forest) to about 669 mm/year (Mannheim) and with temperature means from 10.3 °C p.a. to 3.3 °C p.a. (all climate data from www.klimadiagramme.de/Bawue/bawue.html, 27.8.2015). The land management by agriculture and forestry has been extremely intensified in the recent decades with the use of fertilizers and herbicides. Since World War II a radical change in the landscape in many parts of the region occurred due to construction activities (roads, industrial estates, urban settlements, etc.) as a consequence of economic prosperity. New residential areas grew around former rural villages, often resulting in a displacement of farms and the disappearance of the rural character of villages. The percentage of residential and traffic area of the total land surface is about 14%, of agricultural land 46%, of forests 38% and of other uses 2% (http://www.statistik.baden-wuerttemberg.de/veroeffentl/Statistik_AKTUELL/803413010.pdf, 22.9.2015). Natural and near-natural flora and vegetation is rare in this area and largely restricted to nature conservation areas, which require a management with traditional methods.

2.2. Floristic mapping

The mapping of the flora began in Europe in the 1940s and 1950s resulting in the Atlas of the flora of Northwest Europe (Hultén, 1950), which was the first complete distribution atlas of a region. In the following decades, many similar works were published, e.g. Atlases of the British Isles (Perring and Walters, 1962; Preston et al., 2002), The Netherlands (Mennema et al., 1980–1989), Belgium and Luxembourg (van Rompaey and Delvosalle, 1972–1978), Switzerland (Welten and Sutter, 1982) and the large volumes of Northern Europe (Hultén and Fries, 1986). In Germany, most provincial subunits/states of the country ("Bundesländer") have their own floristic mapping projects, which were compiled in separate atlases for former West-Germany (Haeupler and Schönfelder, 1988) and East-Germany (Benkert et al., 1996), now united in a new and revised combined volume (Netzwerk Phytodiversität Deutschland e.V. and Bundesamt für Naturschutz, 2013) comprising Germany as a whole.

For Baden-Württemberg, which is in the southwestern part of Germany, the systematic floristic mapping of ferns and flowering plants began in the 1970s, when a first survey of the region as a whole was launched and implemented with the help of about 250 volunteers. It was completed and published in the 1990s (Sebald et al., 1990–1992; Sebald et al., 1996–1998). Since 2008, a second floristic mapping programme is under way with a new period beginning with the date 1.1.2005, aiming at the updating and renewal of the data. It is based on the same geographical grid, thus providing an opportunity to compare the former mapping with the recent results. Preliminary distribution maps are presented as interactive maps in Wörz et al. (2015). Before 1970, scattered data are available from literature, herbaria, and plant lists as well as historic archives. They are not the result of a systematic and standardized mapping; nevertheless they are valuable sources to reconstruct the former flora back to the 19th century.

Therefore, three time intervals are relevant for the present paper:

1.) before 1970 (oldest data), scattered,
2.) 1970–2004 (former survey),
3.) from 2005 (recent survey).

The floristic mapping is based on the official 1:25,000 scale maps, which correspond to the Ordnance Survey maps in Great Britain. The basal mapping grid cell is ¼ of a map sheet, i.e. a quadrant which in Central Europe corresponds to a rectangular grid cell of about 6 km × 5.5 km. The mapping grid of Baden- Württemberg comprises about 1100 grid cells. The date line of 1.1.2015 between the former and the beginning of the recent mapping was set on the year of the first presentation of our distribution maps in the web. The sporadic data collected between 1998 and 2004 were therefore included in the former mapping.

As the recent survey is far from being completed, an overall analysis is not possible at the moment. Instead, for this study 46 grid cells were selected that have a good degree of exploration and with a similar number of recorded taxa in the former and recent mapping suggesting a similar degree of floristic exploration ("recording effort" cf. Rich and Woodruff, 1996). It is assumed, that the probability of finding and re-finding (recording probability, species detectability) of a certain taxon in the grid cells is approximately equal in both the former and the recent survey. This selection by similar numbers of species, however, does not allow a quantitative comparison of species numbers of the former and the recent survey.

Any statement on the accuracy of floristic mapping depends on the degree of floristic exploration. Errors due to insufficient mapping must in any case be considered. To assess the degree of exploration of the selected grid cells, the % presence of the 100 most common species in Baden-Württemberg from the former survey was calculated. A second indicator was the percentage of shared species of the former and the recent mapping which gives some idea of the state of the investigation of the grid cell during the recent mapping. For a grid cell considered well-surveyed enough for an analysis, more than 90% of the 100 most common species must be present and 55–60% or more of the species shared in the former and