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Effects of changes in agricultural land-use on landscape structure and arable weed vegetation over the last 50 years

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Abstract

Agricultural dynamics and associated changes in the structure of habitat patches affect species composition and distribution in the landscape. Land-use, landscape changes and vegetation changes of weeds were analysed in a 4 km^2 area in Central Germany (Saxony-Anhalt) from 1953 to 2000. This period includes the collectivisation (1952–1968), the agricultural industrialisation (1969–1989) and the privatisation of agricultural land following the political changes in East Germany in 1990. For the analyses, historic and current aerial photographs and vegetation data were used. Landscape indices and the average amount of mineral fertilizers were used as indicators for landscape structure and land-use intensity. Intensification of agriculture and the collectivisation in East Germany in the fifties and sixties led to a decline of the spatial heterogeneity of the landscape matrix (arable fields). The average number and cover of weed species, especially archaeophytes, decreased significantly since 1957. However, the total number of weed species increased. There was a remarkably high number of species with an average cover below 0.05%, called ''chance'' species in 2000. Out of 17 tested landscape indices only mean patch size and mean patch fractal dimension were significantly correlated with the average number of weed species. The average amount of the mineral fertilizer potash used as land-use intensity indicator was significantly negatively correlated with the total number of weed species. However, there was an increase in the number of farms after 1990 without changes in landscape structure and arable weed vegetation. The results suggest that structural variability of the landscape and habitat quality are the principal correlates of plant species diversity.
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Keywords: Agricultural policies; Landscape change; Landscape indices; Land-use history; Vegetation change; Weeds

1. Introduction

Agricultural land-use is dynamic and is related to changes in the structure of habitat patches, e.g. their spatial pattern, size or connectivity (Arx von et al., 2002; LaGro, 2001; Wagner et al., 2000). Agricultural intensification implies changes such as an increase in plot size of arable fields and the removal of linear elements. The resulting habitat isolation affects plant population dynamics and its basic processes at the landscape level, e.g. migration or colonisation. This is likely to play an increasingly important role for biodiversity patterns at the landscape level because many plant populations become isolated in otherwise unsuitable landscapes. This is why biodiversity studies need to be conducted also at the landscape level (Wiens et al., 1993).

More than half of the territory of the E.U. is managed by farmers today (Vidalis and Lucas, 1999). The highest level of plant species diversity was reached in the 19th century, including many archaeophytes, known to be typical 'weeds' adapted to agricultural land-use (Jäger, 1977). However, increasing agricultural intensification led to changes in landscape structure and thus in the composition and diversity of weed communities after 1950 (e.g. Medley et al., 1995).

In East Germany, four periods of agricultural policies after the Second World War can be distinguished. During the first period from 1945 to 1952 a land reform was carried out (Eckart and Wollkopf, 1994). A state pool of the whole ground was created and small- and medium-sized farming

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units were developed during this time. During the second period (1952–1968) called ''collectivisation'', which was connected with the creation of the socialist state and of socialist public property, small farms were pooled to form large agricultural producers' cooperatives (''LPG''). Only few companies with many employees handled a large area of arable fields and a high number of animals. In the third period (1968–1989) of ''industrial agriculture'' agricultural intensification increased, with progressive enlargement of farms associated with a separation of the farms for plant and animal production. However, 1990 marked another major turning point in agricultural policy, when the fourth period started with the privatisation of agricultural land following the political changes in East Germany. All agricultural producers' cooperatives had been shut down by the end of 1991 (Eckart and Wollkopf, 1994) and since 1990, all German agricultural policies are subject to E.U. norms and regulations.

So far numerous reports have dealt with the changes in the weed communities in Germany (e.g. Hilbig and Bachthaler, 1992; Otte, 1984). Only a few (e.g. Voigtländer et al., 2001) however have included the period after the political change and thus the modified agricultural situation in East Germany since 1990.

The objective of this study was to explore the influence of changing agricultural land-use and landscape structure on weed species richness in the last 50 years. We used data sets from the periods 1952–1968, 1969–1989 and after 1990 and focused on the following questions:

- What were the effects of changing agricultural land-use on the landscape structure, especially the arable fields?
- How did plant species numbers and species composition of agricultural habitats change?
- What are the main factors controlling species richness and composition in arable fields?

2. Material and methods

2.1. Study area

The study area is located in the dry region of Central Germany near the village of Friedeburg (10°34′E, 45°12′N) and covers about 4 km^2. It has subcontinental climatic conditions with a mean annual air temperature of about 9 °C (Veit et al., 1987) and an average annual precipitation below 500 mm.

A plateau with nutrient rich loess deposits borders the steep slopes of the river Saale valley that forms the east border of the study area. The rivers Saale and Schlenze formed a wide floodplain with alluvial soil to the south of the study area. The geodiversity in the study area is coupled with high habitat and land-use diversity. The slopes are covered with woodland, meadows and pastures, and the areas of the floodplain and the plateau are under intense arable use.

2.2. Floristic data

Floristic inventories of weed species of arable fields in the study area were available for the three periods from surveys performed in 1957 (Schubert and Mahn, 1959, 120 relevés), 1979 (Westhus, 1980, 115 relevés) and 2000 (220 relevés). The current floristic composition of arable fields was documented by vegetation relevés that were made from May to September 2000, just before harvesting of the different crop types. The relevés (100 m^2) were randomly placed in the total arable area. The sample plots were located at least 20 m from the field margins, because the agricultural conditions and thus the vegetation of this area often differ from the rest of the field (Elsen van, 1989). As in past inventories, the phytosociological method was followed according to Braun-Blanquet (1951) and Wilmanns (1989). Nomenclature of plant species follows Rothmaler (1994).

2.3. Land-use intensity and landscape structure

As general indicators of land-use intensity the average amount of mineral fertilizers applied and farm size structure was used. Data for the three periods were taken for 1957, 1979 and 2000 from statistical yearbooks of the former German Democratic Republic (GDR) and the states of East Germany (Staatliche Zentralverwaltung für Statistik, 1960, 1980, 1987; Statistisches Landesamt Sachsen-Anhalt, 2000, 2001).

Landscape structure was quantified by a set of landscape indices derived from land-use data. Data used for the three periods were extracted from aerial photos (black and white orthophotos) recorded in 1953 (1:22,000), 1969 (1:12,300) and 1997 (1:14,500). For the third period, we had to use the aerial photo recorded in 1969 because no aerial photo closer to 1979 was available. However, from the end of the 1960s until the beginning of the 1980s landscape structure did not change a lot (Schubert, 2001, personal communication). Minor changes of landscape structure between 1997 and 2000 were updated and ground truthing was performed by field mapping in 2000. To minimise possible interpretation errors the interpretation of all aerial photos was carried out by the same person. The land-use classification system included only seven types: woodland (including all woody habitats), meadows, dry and semi-dry grassland, arable fields, built-up areas, the river Saale and ''others'' (unclassified areas, total proportion <3%, Table 1). Based on the landscape elements (Forman, 1995; McGarigal and Marks, 1994) of the seven selected land-use types landscape indices were determined for each period. The landscape indices were calculated using FRAGSTATS, version 3.3 (McGarigal and Marks, 1994). In addition to the indices available in FRAGSTATS the index number of shape characterising points (NSCP) was used as a measure of shape and boundary complexity (Moser et al., 2002). The calculation of this index was carried out with an ArcView script developed by Moser et al. (2002).

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