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The effect of land use on taxonomical and functional diversity of lichens in an agricultural landscape

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ABSTRACT

The objective of this work was to determine the effect of land use on lichen richness and their functional groups in agricultural land. A significant overall effect of land use on the number of species was found. In general, there was a marked dissimilarity with regard to species richness of forest versus non-forest sites. An analysis of some ecological requirements of lichens showed the most apparent differences concerning tolerance to nutrients and acidity value of particular species. Richness of species capable of producing soredia, isidia and reproducing via fragmentation was higher in coniferous forest compared to non-forest habitats (including wooded patches). Functional traits were a more sensitive and more informative index of lichen response to land use intensity compared to species richness.

1. Introduction

Lichenized fungi exist in many ecosystems, influence biodiversity, and are thus important for its conservation (e.g., Ellis and Coppins, 2006; McCune and Geiser, 2009). Lichens are commonly considered as bioindicators due to their sensitivity to anthropogenic pressure, even when the intensity of anthropogenic disturbances is low (Pinho et al., 2012). Even though lichens have a wider distribution range in comparison with, for example, plants, the lichen biota differs between biogeographic regions of Europe (Bergamini et al., 2005). Lichens exhibit sensitivity to different kinds of habitat disturbances, both of natural and human origin, e.g. land use. Landscape structure (Motiejûnaitë and Fałtynowicz, 2005), habitat parameters, e.g. size and degree of patch isolation, soil pH and depth, the cover of vascular plants, microtopography (Löbel et al., 2006), substrata and habitat diversity (Löbel et al., 2006; Wolseley et al., 2006) and the type of management regime (Ardelean et al., 2015; Boch et al., 2016) can all affect diversity and richness of lichen species and their separate groups.

In general, land use changes usually cause lichen diversity loss (e.g., Stofer et al., 2006; Boch et al., 2016). Many studies have revealed a higher number of lichen species in less intensively managed habitats and their decline under intensive land use (e.g., Ruoss, 1999; Wolseley et al., 2006; Giordani et al., 2010; Boch et al., 2016). As early as the 1980s, Gilbert (1980) pointed to land use as the chief determinant of terricolous lichen abundance in the limestone plateau of Derbyshire, England. In Switzerland, the number of lichen species was found to decrease from mountains to agricultural areas (Ruoss, 1999). The response of lichen diversity to, among others, land use was intensively studied in W Sardinia, Italy (Giordani et al., 2010). The strongest differences were detected for the forested sites vs. managed agroforestry lands; a high within-group diversity (esp. for epilithic species), and a high homogeneity of species composition were observed in managed agroforestry lands (Giordani et al., 2010). An investigation in six different biogeographic regions in Europe showed a significant overall effect of land use on lichen species richness and significant differences in means were detected between natural forests and farmland (Bergamini et al., 2005). Even though the studied areas ranged from northern Europe to the Mediterranean, differences in lichen composition caused by land use were similar (Bergamini et al.,

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2005).

Recently, much attention has been focused on the diversity of functional groups, which helps to understand mechanisms leading to biodiversity impoverishment better than any analyses based on species richness alone. Functional groups consist of species exerting a comparable effect upon a particular process or responding in a similar manner to changes in their external constraints (Lévêque and Mounolou, 2003 in: Giordani and Brunialti, 2015). According to Pinho et al. (2008), the advantages of use of functional groups to detect environmental changes result from the fact that this approach provides a balance between the very robust indicators including all species (e.g. total number of species) and a more detailed analysis, based on individual species. Species traits could be indicative of lichen community adaptation to environmental conditions (Diaz and Cabido, 2001 in: Giordani et al., 2012), therefore providing relevant ecological information (Giordani et al., 2012). Trait patterns along environmental gradients have been interpreted as indicators of mechanisms behind lichen adaptation to the environment (Nelson et al., 2015). The recognition of how management affects environment based on lichen diversity can be a cost-effective and important source of information for environmental planning and biodiversity policies (Bergamini et al., 2005; Pinho et al., 2012). Such analyses also enable a better understanding of environmental conditions, their changes and the importance of agriculture landscape for lichen conservation (e.g., Boch et al., 2016).

Some studies on lichens in the agricultural landscape in Europe that involved a classification of species according to their tolerance to eutrophication gave similar results. Lichen communities in open agricultural landscape are mainly characterized by a high contribution of nitrophiles accompanied by low richness and abundance or even absence of oligotrophic species, compared to sites with less intensive land use (Wolseley et al., 2006; Pinho et al., 2008; Giordani et al., 2010; Munzi et al., 2014). Munzi et al. (2014) found positive relationships between nitrophilous, xerophilous and photophilous groups and agricultural areas, while sensitive functional groups (oligotrophic, hygrophilous and mesophilous) were associated with more forested sites. Land use also seems to affect reproductive traits and morphological forms. Growth form, reproductive strategy and photobiont type were among tested functional traits and their response to environmental factors related to climate, human disturbances and stand structure was investigated (Giordani et al., 2012). Studies on species richness of lichen functional groups across land use gradients in Europe showed that fertile species preferred open and intensively managed landscapes, while sterile species, as well as the substratum generalists, were found mainly in forests (Stofer et al., 2006). Other findings include increase of the importance of species with the principal photobiont *Trebouxia* s.l. and decrease of species with *Trentepohlia* with intensification of land use (Stofer et al., 2006). Despite the advantages of using functional groups, they were rarely used and functional response of lichens to land-use intensification has been poorly studied (Stofer et al., 2006; Pinho et al., 2008; Giordani et al., 2012; Ardelean et al., 2015; Matos et al., 2015; Spickerman, 2015).

To detect human impact in agricultural landscapes, it is necessary to conduct monitoring of organisms with high indicative value. Effect of land use on lichens in rural areas, also considering functional traits, remains still poorly understood in central Europe. Some authors (Boch et al., 2016) already pointed out a need for regional replication of studies that would facilitate our understanding of the degree to which land use decreases biodiversity, with regard to variation in abiotic conditions between the regions, to find general patterns ruling the process.

The objective of this work was to determine the effect of land use on lichen richness and their functional groups in agricultural land. Based on the literature data presented above, we expected some differences in lichen species diversity and a shift in the lichen functional groups across land use spectrum, from forest communities (deciduous forest, coniferous forest) to rural areas under diverse intensity of human activities (wooded patches, grasslands, turf, ruderal, segetal and mixed). We studied the differences and shifts with the use of a possible indicator value of lichen diversity variables (i.e. total species richness and richness of functional groups of species classified according to their light, temperature, moisture, continentality, acidity and nutrient requirements, morphological forms and reproductive strategy) for measurement and monitoring of land use effect on lichens.

2. Materials and methods

2.1. Study area

The study area is situated on the Równina Nowotomyska plain, a part of Wielkopolska province (Kondracki, 2009) in western Poland. According to the geobotanical division of the country, this area belongs to the western part of Kraina Wielkopolsko-Kujawska range (Szafer, 1972). The altitude ranges from 60 to 100 m a.s.l. The climate is transitional, marked by interlacement of oceanic and continental impacts, with average yearly precipitation of ca 550 mm and average yearly temperature of ca 8 °C (Graf, 2001; Kaniecki and Kostecki, 2001; Wrzesiński, 2001; Kozacki et al., 2006a,b). Agricultural landscape covers most of the investigated area. The persistence of scattered housing combined with a dense, quite regular network of wooded patches that separate fragments of fields, meadows and pastures is a typical spatial layout in the central part of the study region and is the remnant of an Olęder ('Dutch') settlement. The process of 'Dutch' settlement in Poland took place between the 16th and the 19th century (Chodyła, 2006). The colonists, first the Dutch and later principally Germans and Poles, created independent communities and their settlements were organized under a particular type of law. Conifer forests (mainly *Leucobryo-Pinetum*) growing on the dominant sandy soils, make up most of the forest communities.

2.2. Sampling design

Ninety six sample plots (20 × 50 m, N-S oriented) were located within a 45 × 12 km rectangle of the study area, considering physical-geographic conditions of the region (Kondracki, 2009), with the application of systematic sampling design (for example see Wohlgemuth et al., 2008). The distance between most plots amounted to ca 2.5 km. Some plots did not match the regular distribution grid for practical reasons (difficult access, presence of a highway). In such cases the sample plots were located in alternative, accessible sites with the same land-use category as the primary location. The sample plots represented eight land-use categories, which were distinguished based on vegetational features. They included a variety of habitats both from forest communities (deciduous forest, coniferous forest), and rural areas under diverse impact of human activities (wooded patches, grasslands, turf, ruderal, segetal and mixed). All lichenized fungi, except parasites, were considered. Species were recorded taking into account the type of substrate (especially wood, bark of living tree, and soil). Stumps, snags, fallen pieces of barks and branches were included in the 'wood' category. When species could not be determined in the field, specimens were collected for further identifications in the laboratory (with the use of microscope and thin-layer chromatography). Species nomenclature follows Diederich et al. (2016). We compiled data on ecological indicator