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Are landscape complexity and farm specialisation related to land-use intensity of annual crop fields?

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Abstract

Little is known about the predictive value of landscape complexity and farm specialisation for land-use intensity, although this is critical for regional agri–environmental schemes and conservation of biodiversity. Here, we analysed land-use intensity of annual crop fields of 30 farms in northern Germany that were located in 15 landscapes differing in structural complexity ranging from <15% to >65% non-crop habitats. The proportion of arable land per landscape was used as simple predictor of landscape complexity due to its close correlation with habitat-type diversity, and the proportion of arable land per farm acted as an indicator for farm specialisation due to its negative correlation with stock farming. Land-use intensity was quantified using questionnaires. Landscape complexity and farm specialisation were related to several but not all indicators of land-use intensity. Structurally simple landscapes were related to more nitrogen input and higher crop yields, and farms specialised on annual crops had reduced crop-species diversity, larger fields, higher crop yields and more pathogen species. In contrast to general expectations, pesticide use in annual crop fields was exceptionally high and not a function of landscape complexity or farm specialisation. Our results show that generalisations such as "farms specialised on annual crops and structurally simple landscapes show increased land-use intensity" may be misleading.
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1. Introduction

Since the beginnings of agriculture, land-use practices were steadily improved resulting in a food supply that (theoretically) has been able to feed the increasing world population. For example, in the last 40 years the global cereal production has doubled (FAO, 2001), which can mainly be ascribed to increasing yields resulting from new technologies of the "Green Revolution" such as greater inputs of fertilisers and pesticides. However, modern agriculture as well as agricultural landscapes are multifunctional, as they do not only provide food, water and other marketable goods, but also environmental goods (Marggraf and Streb, 1997). Intensification of agricultural practices caused ecological problems such as environmental pollution and biodiversity losses (Matson et al., 1997; Krebs et al., 1999; Tilman et al., 2001, 2002). Land consolidation caused a change from formerly complex landscapes with well-balanced proportions of arable land, grassland, forests, fallows, hedgerows and other natural and semi-natural habitats to simple landscapes with high proportions of arable land.

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The trade-off among ecological and economical goods is one of the greatest scientific challenges facing humankind (Tilman et al., 2002). Agri–environmental schemes in the form of management agreements on fields do not necessarily protect species richness of several groups (plants, birds) effectively (Kleijn et al., 2001). On the one hand, such analyses of effectiveness of these schemes at the "field scale" may be a prerequisite to improve current schemes. On the other hand, effects of land-use intensity on local biodiversity and ecological functioning depend on spatial scales much larger than a single field. This demands the use of a landscape perspective, i.e. the "landscape scale", considering area and spatial arrangement of the surrounding land-use types (Kareiva, 1990; Turner and Gardner, 1991; Kareiva and Wennergren, 1995; Pickett and Cadenasso, 1995; Polis et al., 1997; Roland and Taylor, 1997; Gonzalez et al., 1998; Menalled et al., 1999; Thies and Tscharntke, 1999; Wiegand et al., 1999; Cadenasso and Pickett, 2000; Tischendorf and Fahrig, 2000; Ricketts, 2001; Thies et al., 2003). Only few studies investigated the relationship between farm characteristics and landscape structure. Thenail (2002) showed that production, economic levels, productivity and technical means of dairy farms increased as hedgerow density in a "bocage" landscape decreased. Thenail and Baudry (2004) analysed the relationship between farm spatial land-use pattern and hedgerow structure in the same region. They found different degrees of land-use allocation in farms depending on the hedgerow density, which in turn influenced the landscape structure. Whether land-use intensity of annual fields also changes with changing landscape context is not well known yet; intensity may also be related to farm specialisation on annual cropping.

In this paper, we analysed the relative impact of landscape complexity and farm specialisation on local land-use intensity of annual crop fields in southern Lower Saxony (northern Germany). Farm sizes, proportions of different land-use types, and livestock of 30 farms were analysed to quantify and characterise their degree of specialisation towards annual cropping. Data on crop species, yields, the use of nitrogen fertilisers and pesticides, and field sizes of a set of fields cultivated by these farms were collected to quantify land-use intensity. The analysed sets of fields were located in 15 landscapes (i.e. fields of two farmers per landscape) differing in structural complexity ranging from structurally simple landscapes with a high proportion of annual crop fields to structurally complex landscapes with large areas of non-crop habitats such as fallows, field margins, hedges, grasslands, and forests. We expected (1) that crop species diversity increases, and the field sizes, yields as well as the use of nitrogen fertilisers and pesticides decrease in structurally complex landscapes, and (2) that crop species diversity decreases, and the field sizes, yields as well as the use of nitrogen fertilisers and pesticides increase in farms specialised on annual crops (Haber and Salzwedel, 1992; Mander et al., 1999).

2. Material and methods

2.1. Study area

The study was conducted in agricultural landscapes of Southern Lower Saxony (North Germany). This area is characterised by cropland–grassland mosaics, which are dominated by agricultural land-use covering on average about 75% of the region, and patchily distributed fragments of semi-natural habitats such as grasslands, fallows, hedges, and forests. We selected 15 non-overlapping circular landscape sectors with a diameter of 5000 m. These landscape sectors represent a gradient in landscape complexity ranging from extremely simple and structurally poor landscapes with a high proportion of annual crop fields (>85%) to structurally complex landscapes with large areas of non-crop habitats such as fallows, field margins, grasslands, hedges, and forests (>65% non-crop area). The distribution of landscape complexity did not show any north-south or east-west gradient to prevent potential problems such as correlations between landscape complexity and abiotic factors (e.g. soil fertility; see Steffan-Dewenter et al., 2002). In general, the soil in the 15 landscapes was dominated by leptosols (35.7%), followed by luvisols (27.7%), cambisols (23.7%), fluvisols (5.9%), anthrosols (3.9%), and chernozems (3.1%) (according to official data of the Niedersächsisches Landesamt für Bodenforschung, 1997; for classification, see FAO-UNESCO, 1990).

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