Farm-level phytodiversity of dairy farms is related to within-farm diversity of grassland management types

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Abstract

We analysed 163 vegetation relevés from grassland plots of 24 conventional dairy farms in Lower Saxony, NW Germany. The sample covered farms with a different magnitude of the contribution of pasture to the roughage ration of the dairy cows: zero-grazing, grazing for <6 h d^{-1}, or >14 h d^{-1}. At each farm, the sward botanical composition of two plots per existing grassland management type was determined in one quadrat of 25 m^2 per plot. Average plot-level species numbers was distinct among types of plot management (P<0.001) and ranged from 10.6 in intensively managed meadows to 15.0 in plots managed according to agri-environmental schemes. The species number of dairy cattle pastures did not differ significantly among farms implementing different daily grazing periods. The total species number at the whole farm-level ranged from 10 to 39 and increased significantly (P=0.001) with the number of grassland management types implemented on the farms. Our results emphasize the importance of farm-level organizational structures for regional phytodiversity.

Keywords: farm scale, γ diversity, management intensity, pasture, species number, sward botanical composition

Introduction

The majority of experimental and observational studies on sward phytodiversity–management relationships in permanent grassland have focussed on the plot level and linked phytodiversity to management and site conditions prevalent immediately on the studied plot. In contrast, few studies have so far examined the scale level of the whole farm to investigate phytodiversity–management relationships.

In Central and North-Western Europe, the total productive area of grassland-based dairy farms is usually divided into parcels (fields or paddocks) which are subjected to various management types like (a) meadows for silage or cut-grass production, (b) dairy cow pastures, eventually mown, (c) pastures for young stock, bulls or non-lactating cow, or (d) meadows or pastures managed extensively according to agri-environmental schemes. The respective plots feature swards of distinct phytodiversity: species richness is generally higher in pastures than in intensively managed meadows. Implementation (present/absent) and relevance (area share of the total grassland area of a farm and proportion in total roughage production) of each of these management types depend on the overall farm-level organisation and the production targets of the farmer.

The aim of the present study was to quantify the phytodiversity of conventional, intensive dairy farms in NW-Germany at several scale levels and to determine interrelations between farm organisation structures and phytodiversity. We considered α diversity in terms of the plant species number at the plot level and γ diversity in terms of the respective farm-level plant species number. We examined the relationship between phytodiversity and the farm-level structure of grassland management. The sample of farms for this study was designed to cover a range of models of farm organization with a varying importance of pasture for the roughage ration of the dairy cows. We hypothesised (I) that plot-level phytodiversity of dairy cattle pastures would be lower in farms with a larger contribution of pasture to the roughage ration,

on the basis that the composition of the sward would be managed more intensively in favour of high-value species in settings where pasture forage holds a more important share of the ration, and (II) that farms implementing a higher number of grassland management types would feature a higher γ diversity, on the basis that they would comprise a higher number of plots bearing a comparatively high α diversity.

Materials and methods

This study is based on a total of 163 botanical relevés from 24 conventional dairy farms in Lower Saxony, NW Germany. The farms were selected to represent three groups differing with regard to the contribution of grazing to the roughage ration of the dairy cows: zero-grazing (n=5), farms with a minor contribution of pasture (grazing for <6 h d^{-1}; n=7), and farms with a large contribution of pasture to the roughage ration of the dairy cows (grazing for >14 h d^{-1}; n=12). This classification was chosen in order to represent a wide range of models of farm organization. At each farm, the total number and the identity of grassland management types implemented – e.g. dairy cow pasture, meadow (cutting only), young stock pasture, mown pasture – was obtained by asking the farmers, and the sward botanical composition was determined on two parcels per existing grassland management type by recording the yield proportions of the individual species in one quadrat of 25 m^2 per parcel.

We used linear models to analyse (a) the effects of grassland management type and farm organisation structure on α diversity (plot-level species number) and (b) the effect of the number of grassland management types per farm on γ diversity (farm-level species number).

Results and discussion

As expected, the plots of different grassland management types featured a significantly (P<0.001) distinct α diversity. Altogether, α diversity was comparatively low. The average species number ranged from 10.6 in intensively managed meadows to 15.0 in parcels managed according to agri-environmental schemes (Figure 1). The latter, as well as young-stock pastures, featured a higher number of both common grassland species and species indicative of extensive management. The α diversity values of dairy cow pastures and of intensively managed meadows were close to equal. Alpha diversity of dairy cow pastures was not affected by the implemented daily grazing period; this finding therefore fails to support our hypothesis (I).

The three groups of dairy farms which had been defined with regard to the contribution of pasture to the roughage ration of the dairy cows differed significantly, both regarding the number of implemented grassland management types (P<0.001) and regarding γ diversity (P=0.001) (Figure 2). The total farm-level species number increased significantly with the number of grassland management types present

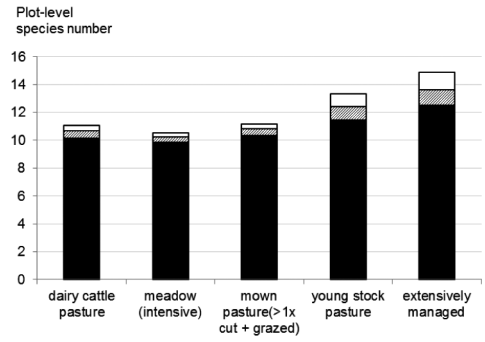

Figure 1. Species number (α diversity, plot-level) of grassland swards in parcels of different management type. Colour of bar sections: black: species common to farmed grassland in general; shaded: grassland weeds (unpalatable species or indicators of excess N supply); white: species indicative of extensive management or target species listed for result-oriented agri-environment schemes.

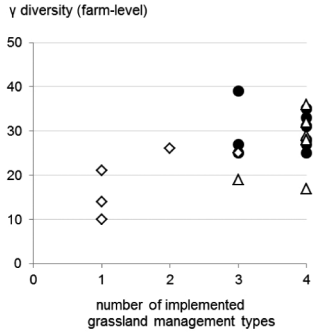

Figure 2. Relationship between γ diversity (farm-level species number) and the number of grassland management types implemented on the farm. Symbols represent farms differing with regard to the contribution of pasture to the dairy cow roughage ration: diamonds – zero-grazing; triangles – grazing <6 h d^{-1}; dots – grazing >14 h d^{-1}.

on the farm, which is supportive of our hypothesis (II). Zero-grazing dairy farms in most cases merely implemented one grassland management type – intensive cutting – which yields the lowest α diversity. Additional implementation of pasture for non-lactating cows or young stock enhanced farm-level phytodiversity due to the higher α diversity of these plots. The farms which included pasture in the roughage ration of the dairy cows in general implemented a higher number of grassland management types, and therefore also featured a higher γ diversity. This interrelation appears to be independent of the magnitude of the contribution of pasture to the roughage ration of dairy cows (Figure 2).

Our study follows the approach of relating phytodiversity of grassland-based farms with farm-level organisation structures, which is innovative in the way that farm-level structures have, so far, seldom been taken into account in studies on grassland biodiversity. We recommend that consideration should be given to the factor 'intensity of grassland management' at a larger number of scale levels for understanding regional phytodiversity; in addition to the plot-scale (the immediate site management), the farm-scale appears to be of major importance. This includes the production targets and decisions of the farmer and the resulting within-farm diversity of grassland management types. An approach of this kind may be crucial to analysing the effects of the ongoing shift in dairy farm organisation (Van den Pol-van Dasselaar *et al.*, 2008) on ecosystem services. Yet, we acknowledge that further research is required to strengthen the robustness of our findings. In particular, this encompasses the mining of data from a larger number of farms, the inclusion of plot size into the analysis of phytodiversity in order to take account of species-area relationships, and the consideration of socio-economic factors governing the implementation (presence/absence and intensity level) of individual grassland management types.

Conclusions

Our study highlights the relationship between within-farm organisation structures and farm-level phytodiversity. We deem that our results emphasize the importance of considering farm-level processes in the analysis of ecosystem services at the regional scale.

References

Van den Pol-van Dasselaar A., Vellinga T.V., Johansen A. and Kennedy E. (2008) To graze or not to graze, that's the question. *Grassland Science in Europe* 13, 706-716.