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Assessing the impact of grassland management extensification in temperate areas on multiple ecosystem services and biodiversity

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ABSTRACT

In order to halt further biodiversity loss in the agricultural landscape, measures for grassland management extensification have been proposed and implemented. Apart from biodiversity conservation and enhancement, these measures are expected to affect a range of ecosystem services delivered by these grasslands. It is well-known that grasslands have the potential to contribute to the delivery of multiple ecosystem services, but there generally is a trade-off between provisioning services and regulating services, which is strongly linked to grassland management. This study investigated the effect of the extensification of grassland management on multiple ecosystem service and biodiversity indicators. To do so, two sets of grasslands in Flanders with varying management types were monitored: a regular, intensive management, a meadow bird management and a botanical management. For every monitored grassland, a land use intensity index was calculated and linked to the ecosystem service and biodiversity indicators. The results showed that biomass yield, forage quality, soil mineral N content and number of plant species differed among the various management types and that increasing land use intensity resulted in higher biomass yields, forage quality and soil mineral N content and in a lower number of plant species. However, it was observed that other factors such as the timing of the first cut affected these variables as well. A literature review was subsequently performed to quantify the link between land use intensity of other temperate grasslands and the same response variables. Results of the literature review confirmed the trends that were found in the monitoring data, but an additional effect of manure and slurry application on soil carbon stock was noted. Taken together, the results suggest that the impact of grassland management in terms of fertilization, mowing and grazing on the selected ecosystem service delivery and biodiversity indicators can be predicted, but that other management components should be considered as well.

1. Introduction

Semi-natural grasslands are among the most diverse ecosystems in Europe. They can host up to 80 plant species per square meter, many bird species depend on grasslands for feeding, nesting and wintering, and almost 50% of all European butterfly species are typically found in grasslands (Habel et al., 2013; Vickery et al., 2001; WallisdeVries and Van Swaay, 2009). Semi-natural grasslands are maintained by human management, especially mowing and grazing (European Environment Agency, 2015). In north western Europe, almost all grassland management is intensified in order to increase productivity, for example through grassland renewal, the application of fertilizers and pesticides, intensive mowing and grazing and drainage. This has resulted in a significant drop in grassland biodiversity (Batáry et al., 2015; Habel et al., 2013; Plantureux et al., 2005). Measures have been proposed to put an end to biodiversity loss, for example via agri-environment schemes or the Natura 2000 network (EU Birds and Habitats Directive). In Flanders, 30% of the agricultural area is in grassland management (FOD Economie, 2016). Seventy percent of these grasslands are intensively managed and highly productive. The remaining grasslands are more extensively managed because they are less suitable for agricultural production or because they are subject to biodiversity conservation targets (Meiresonne and Turkelboom, 2012). In this case, their management is restricted in terms of fertilization intensity and/or timing and intensity of mowing and grazing.

Apart from hosting biodiversity, all grasslands have the potential to contribute to the delivery of multiple ecosystem services (ES), such as climate regulation, water quality regulation and soil quality regulation

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(Maes et al., 2011). However, there seems to be a trade-off: negative relationships have been described between high forage yield (a provisioning ES) on the one hand and many other regulating ES, biodiversity conservation and landscape quality on the other hand (Maes et al., 2011; Pilgrim et al., 2010). Thus, in almost all cases, the extensification of grassland management in order to increase biodiversity is expected to have a negative effect on provisioning ES and a positive effect on several regulating ES.

Grassland management consists of many aspects (fertilization amount, fertilization type, number of cuts, livestock management etc.) which could all affect provisioning and regulating ES and biodiversity. Despite of a growing interest in the effect of grassland management on multiple ES delivery, quantification of the expected effects of varying management is still missing. Several studies have compared presence and absence of a management practice, for example grazed versus ungrazed grasslands (Cichota et al., 2016; Grandchamp et al., 2005) or mown versus unmown grasslands (Callaham et al., 2003; Eriksen-Hamel and Whalen, 2006), but these studies do not capture the impact of varying management intensity (Blüthgen et al., 2012). The effect of fertilization intensity on several ES has been described (Malhi et al., 2005; Müller et al., 2011), but there are few studies that have investigated the association between the intensity of fertilization or more broadly the intensity of grassland management and a broad set of ES and biodiversity simultaneously. Consequently the trade-offs and interactions between these different components remain insufficiently understood (Batáry et al., 2015; Pilgrim et al., 2010).

The objective of our study was to evaluate the impact of management type (regular, meadow bird or botanical management) on a set of provisioning and regulating ES and on biodiversity components, based on an on-field assessment on two sets of grasslands in Flanders. We also quantify the relationship between management intensity and the same set of response variables. The definition of management intensity was based on a fertilization, mowing and grazing component (Blüthgen et al., 2012). A second objective is to examine whether the observed trends were in line with the results from other studies on temperate grasslands. Thereto, a systematic literature review was performed and relationships between management intensity and provisioning and regulating ES and biodiversity components were quantified. Finally, we explored whether there are trade-offs in grassland management with respect to ES delivery and biodiversity.

2. Materials and methods

2.1. Study area

In 2014, twelve grassland parcels, which could be categorized into three different management types, were monitored (Table 1). These grasslands were located in Turnhouts Vennengebied (TVG), in the Campine region in the north of Flanders (51°21′48.2″N 4°54′50.6″E) (Appendix E). Soils are Gleyic Podzols and the texture is sandy (IUSS Working Group WRB, 2006). Four grasslands were not subject to specific management restrictions or prescriptions apart from general Flemish legislation. They were in conventional agricultural use and will be referred to as CON grasslands. Four grasslands were owned by the Flemish Agency for Nature and Forest (ANB), who granted concessions to farmers for management under specific conditions. Management focuses on the promotion of meadow bird populations. Meadow birds typically thrive under a postponed first cut or grazing activity in order to reduce egg and chick mortality. The soil should have a sufficiently high organic carbon content, enhancing availability of invertebrates which make up an important part of the diet of meadow birds (Breeuwer et al., 2009). These grasslands were therefore fertilized with farmyard manure with a total application restricted to 120 kg N/ha, dung deposition by the grazing cattle was not considered. Grazing was permitted after June 15th and mowing after July 15th. Application of pesticides was not allowed. Based on the fertilization type that was applied, these grasslands are referred to as FYM grasslands. Finally, four grasslands were owned by Natuurpunt, the largest nature conservation organisation in Belgium. Similar to the FYM grasslands, Natuurpunt granted concessions to farmers for the exploitation of the grasslands. They were managed to increase botanical diversity by means of nutrient depletion. No fertilizers or pesticides were applied on these grasslands. Both grazing and mowing were only allowed after July 15th. These grasslands are referred to as zero input (ZER) grasslands.

In 2015, six grasslands, corresponding with two management types, were monitored (Table 1). Grasslands were situated in Bos van Aa (BVA), located centrally in Flanders (50°59′20.2″N 4°23′59.6″E) (Appendix E). Soils are Gleyic Lumisols and the texture is sandy loamy (IUSS Working Group WRB, 2006). Three grasslands were not subject to specific management restrictions or prescriptions, apart from general Flemish legislation. They were in conventional agricultural use and will also be referred to as CON grasslands. Three grasslands were managed by Natuurpunt. They were mown after June 15th and no fertilizers or pesticides were applied on these grasslands (ZER grasslands).

Within both study sites, all selected grasslands were in close vicinity in order to reduce heterogeneity in terms of surrounding landscape, soil conditions, etc. Before the implementation of meadow bird or botanical management, all grasslands were intensively managed. Grasslands were only selected for monitoring if they had received the same management for at least three years.

2.2. Experimental data collection

We measured dry biomass yield and forage quality as provisioning ES, climate regulation and maintenance of chemical water quality as regulating ES and number of carabid and plant species as biodiversity components on two sets of grassland parcels in Flanders with varying management. Selection of the regulating ES was based on relevance for the regional context and parcel-level impact.

For every ES and for biodiversity, parcel-level indicators were selected and monitored. Total grass yield (ton ha^{-1}), crude protein concentration (%) and yield (ton ha^{-1}) were the indicators for forage productivity and quality. To enhance interpretation of the crude protein data, organic matter digestibility (OMD) (%) was additionally measured. Soil organic carbon (SOC) stock (ton ha^{-1}) was an indicator for climate regulation because a higher soil carbon stock implies that more CO_2 has been captured (Smith et al., 2000). Soil mineral nitrogen (N) content (kg ha^{-1}) was selected as an indicator for chemical water quality, because soils with more N entail a higher risk for N leaching (Dhondt et al., 2002) and thus a negative effect on the maintenance of chemical water quality. Biodiversity was expressed in terms of the number of carabid and plant species (alpha diversity) and in terms of the difference among carabid and plant species compositions under different management types (beta diversity).

On every grassland parcel (Table 1), three plots were selected for ES and biodiversity indicator monitoring. When the grasslands were grazed, plots were fenced. Fencing excludes the direct impact of cattle, but because the grasslands were under the same management for at least three years, we expected to measure the potential impact of the cattle of previous years. Grazing of the grasslands was rotational. In order to measure forage yield, the grass was mown with a cutter bar mower (1.4 m wide) over a length of 8 m. Mowing of the plots was done just before the farmer mowed the rest of the parcel. When the parcel was grazed, the plots were mown every month or every two months, depending on grass (re-)growth. In TVG, CON1 and CON2 plots were mown six times, CON3, CON4 and all FYM grassland plots were mown four times and all ZER grassland plots were mown twice. On FYM2, yield could not be measured because the fences were destroyed early in summer, most probably by the cattle. In BVA, CON grassland plots were mown four times and ZER grassland plots were mown twice. Fresh herbage yield was recorded in the field. Herbage samples of about 300 g were taken per plot and oven-dried at 65 °C to calculate dry biomass