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Review

Agronomic aspects of biodiversity targeted management of temperate grasslands in Europe – A review

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Abstract. Maintaining and enhancing the biodiversity of the agriculturally utilised area has a high priority in environmental policy worldwide. Temperate grasslands in Europe make an important contribution to the biodiversity of agricultural landscapes. The species and community diversity of grasslands is a result of a traditional extensive grassland management interacting with a broad range of site conditions. Until the early decades of the last century, grassland sites were hardly ameliorated and the agronomic potential was generally low, depending on the fertility of the soils. Later on the production from grassland was markedly improved by regular fertilisation, by liming and by artificial drainage of wet sites. Correspondingly, the stocking rates and the cutting frequency increased. Thus, biodiversity strongly decreased, and unimproved species-rich swards only persisted on a low percentage of the total grassland area. The preservation of the remaining species-rich grassland is a primary goal of nature conservation. The continuation of traditional ways of grassland management that would best preserve biodiversity is often not compatible with the requirements of intensive livestock production. Therefore, this grassland is at risk of being abandoned from agricultural use. There is a need to identify and develop improved management measures that better integrate biodiversity and agronomy targets of species-rich grassland farming. In addition, compensation payments for farmers are required to support grass production on species-rich swards. Apart from the unimproved species-rich grassland, there is an increasing area of now de-intensified species-poor grassland which can be managed to increase biodiversity. Grazing at a low stocking rate seems to have the potential to facilitate the restoration of diverse swards and to support reasonable individual performances of the grazing animals.

Key words: grassland management, biodiversity, species-rich grassland, agronomic potential, grazing

INTRODUCTION

Maintaining and enhancing the biodiversity of European grasslands has been given a high priority in national and supranational policy and research initiatives. In the European Union an increasing amount of money is allocated to support the non-production function of agriculture among which biodiversity is a main target (STOA Publication). Grassland plays an important role in the land use of Europe. It is a main part of agricultural production systems and it strongly supports the livelihood of farmers. In the EU (EU25) more than 30% of the agriculturally utilised area is covered by grassland (EUROSTAT). There is a large variation between countries from less than 5% of grassland in Finland to more than 75% in Ireland. Site conditions, grassland vegetation, management, and production potential are highly variable. European grasslands make an important contribution to the total biodiversity of the rural landscapes (Nösberger & Rodriguez, 1996). A considerable percentage of plants and animal species mainly occur in open grasslands and are rarely found in other vegetation types. In addition, diverse grasslands are highly valued by society due to their potential for recreation and their attraction for tourism (Schüpbach et al., 2004). Therefore, grasslands have become of primary interest for society, politics and research. About 60% of the farms in Europe that keep cattle are located in disadvantaged regions (Dabbert & Krimly, 2004); this emphasizes the importance of grassland managed for biodiversity and nature conservation as less favoured areas usually have a higher diversity compared to productive areas.

If biodiversity targets are to be integrated into grassland systems, the effect of biodiversity on agronomic performance and profitability of grassland has to be explored. Usually, farmers perceive the biodiversity targeted management of grassland as a limitation to the potential livestock production. The maintenance and enhancement of biodiversity commonly require a reduction of inputs and result in a loss of herbage yield and quality compared to intensively managed grassland. On the other hand, ecologists claim that preserving and restoring grassland diversity may be beneficial to maintain desirable levels of several ecosystem processes, and may therefore have applications in land management and agriculture (Minns et al., 2001). Whether biodiversity could promote the production function of grassland is however largely unexplored and a matter of debate (Isselstein, 2005).

The aim of this paper is to investigate the agronomic consequences of nature conservation and biodiversity targeted grassland management. First, the recent situation of grassland farming in Europe is briefly outlined. The historical development of species-rich grassland and the following loss of diversity as a result of intensification of grassland management are described. Secondly, the management of unimproved swards with a high nature conservation value and of mesic now de-intensified formerly improved swards is investigated.

Grassland farming in Europe today – general options for integrating agronomy and biodiversity targets

The utilisation of grassland in Europe has seen considerable changes during the last two decades. Whereas the overall agriculturally used area in Europe (EU25) has not show a consistent trend of change, the grassland area has decreased slightly in most countries (EUROSTAT). A much stronger decrease occurred in the livestock numbers. Cattle numbers, including dairy and beef, were reduced by 10% from 1992 to 2002 in the European Union (EU25, EUROSTAT, ZMP) with a much stronger decline in the new member states (32% in EU10) compared to the older member states (6% in EU15). A similar situation is found for sheep numbers. The reduction of cattle numbers led to a decrease in beef production of 6% for the whole EU, and of 26% for the new member states. The number of dairy cattle showed a stronger decrease with more than 20% for the whole EU (15% and 38% for EU15 and EU10 respectively). Although the number of dairy cows decreased markedly, dairy production in the whole EU countries hardly changed during this period. Again, a difference between old and new member states occurred with a slight increase in dairy production in EU15 and a decrease of 15% in EU10. A similar amount of milk had been produced with fewer dairy cows; the milk yield per cow increased by some 30%, from about 4400 kg per cow and year in 1992 to about 5500 in 2001 (ZMP).

These changes in land use and production figures are related to changes in grassland farming. The eastern and central European countries, formerly belonging the COMECON, changed their agricultural land use when they switched from a state to a market economy. Since 1989 livestock numbers have generally decreased by more than 50% up to 70%. The management intensity of improved grassland used by intensive livestock husbandry was reduced, particularly in less favoured regions. Some of the grasslands were even completely abandoned from agricultural use and are now exposed to successional change. In many central and western European countries, such as in Germany, The Netherlands, Denmark and Sweden, the dairy performance was increased by introducing high digestible forages from arable land (e.g. maize) and concentrates into the rations, mainly at the expense of herbage from grassland. Thus, with a fixed milk quota, the percentage of milk being produced from grass is decreasing and grassland is less and less used for dairy production. If technology of production and animal performances continue to progress at current rates, the grassland area needed for dairy farming and intensive grazing will further decrease in the future, unless the demand for dairy and beef products increases significantly (Feehan et al., 2005).

As dairy production is the most profitable way of grassland utilisation, this development will have a strong impact on the maintenance of grassland in the future. Grassland that was no more used for dairy production during the last years has then, to some extent, been de-intensified and further grazed by suckler and beef cattle. However, the market for beef and consequently the potential of grassland based beef cattle farming is limited in Europe. The situation in eastern European countries has demonstrated that some formerly intensively utilised grasslands may be converted into fallow land directly, when dairy and beef production decrease.

With regard to the maintenance and enhancement of grassland biodiversity, the above outlined situation presumably has the following consequences: For grassland that is no longer needed for intensive dairy cow or beef cattle husbandry, intensive management is unlikely to be continued, for economic reasons. Heavy fertilisation and regular sward renovation will be ceased and stocking rates will be low. This management seems to be in accordance with management measures that are generally recommended to enhance biodiversity. However, unimproved species-rich grassland will be increasingly at risk of being abandoned from any agricultural use. Indeed, in the first place, extensive grazing systems will rely on de-intensified grassland which has a history of agricultural improvement and which is therefore superior to unimproved grassland in terms of herbage yield and quality.

For the farmed land as a whole and for grassland in particular, there is an increasing social awareness of the multifunctional character of farming (Jeangros & Thomet, 2004; Lehmann & Hediger, 2004). Grassland provides multiple benefits to farmers and society and among these benefits, biodiversity receives special attention. Agri-environment schemes have been established to accomplish non-market performances of grassland farming. It is estimated that at least 20% of the agriculturally used area in the EU is managed under an agri-environment scheme (Rounsevell et al., 2005); in Switzerland, ca. 100.000 ha (ca. 13% of the total Swiss grassland area, alpine pastures excluded) of meadows and pastures are managed according to ecological compensation area schemes (Walter et al., 2004). Presumably, the importance of agri-environment schemes for the continuation of farming on de-intensified and on unimproved species-rich grasslands will increase in the future (Rounsevell et al., 2005) and will therefore be essential to maintain and enhance biodiversity.

Historical background of grassland management and grassland biodiversity

The origin of grassland, its vegetation and plant species composition are closely related to human activities and farming practices that have developed since the Neolithic Age. In the temperate regions of Europe, the distribution of natural grassland was limited to sites where natural forests fail to grow, such as sites above the timberline in mountainous regions, very wet or dry sites in the lowlands, or marshlands close to the sea (Ellenberg, 1996). New studies on the history of grasslands suggest that, apart from these sites, grassland could also develop on fertile sites as a result of megaherbivore grazing (Vera, 2000). Grassland dominated open landscapes could have been created in fluvial plains before man controlled the vegetation through deforestation and introduction of crop and animal husbandry. There is evidence that many of the species-rich grassland communities date back to the bronze and iron ages, when regular pasture management and grazing started to establish (Prins, 1998). Since the Middle Ages, when the human population increased, forests on less fertile sites had also been cleared and replaced by grassland and arable land (Korneck et al., 1998). The large diversity of plant species and communities that is found on semi-natural, unimproved grasslands today, has its origin in the Middle Ages and in the early Modern Era (Speier, 1996; Prins, 1998). It is the result of a broad range of site conditions and traditional extensive management systems (Nösberger & Rodriguez, 1996). Soils were not improved until the first half of the 20th century, the agronomic potential was rather low and grass production was dependent on the natural fertility of sites. Traditional grassland utilisation systems were characterised by a generally low level of nutrient return to the swards and, on grazed grassland, by little adaptation of the stocking rates to the actually available herbage. Communal grazing was a common practice. Swards were underutilised in times of herbage surplus and overgrazed when grass growth was limited. In addition, in the traditionally man-made landscape, sheep, cattle and other livestock were important vectors for plant propagules (Poschlod et al., 1998).

At the beginning of the 20th century, diverse, unimproved semi-natural grasslands covered a large percentage of the agriculturally utilised area throughout Europe. Starting from this time, grasslands were agriculturally improved and the management intensified. On acid soils with a low fertility, the pH values of the soils and the soil nutrient contents were raised by liming and regular fertilisation. On wet soils, artificial drainage was introduced to remove surplus water. This process was accompanied and followed by an increased use of fertiliser nitrogen and higher stocking rates and defoliation frequency. Thus, grasslands with a high species and community diversity were replaced by productive pastures and meadows. The result was a dramatic decrease in biodiversity as the swards of improved grasslands were dominated by few productive forage species with a high competitive strength and less productive species were eliminated. Traditionally managed grasslands lost their function as a feed resource for livestock (Willems, 2001) and were reduced to a low percentage of the agriculturally utilised area (Fuller, 1987; Green, 1990; Poschlod, Schumacher, 1998). The remaining semi-natural grasslands are now highly valued by nature conservationists and, in many countries, their maintenance has received priority in nature conservation activities and in agri-environment schemes (Söderstrom et al., 2001; Kumm, 2003; Dipner, & Madel-Kubik, 2004; Jeangros & Thomet, 2004).

Maintaining species-rich grasslands by agricultural management

The maintenance of unimproved semi-natural grasslands requires that grassland management is not intensified (Schellberg et al., 1999), i.e. soils are not ameliorated, no or little fertilisation is applied, and stocking rates are low. However, a regular defoliation of the swards is necessary. It has been frequently suggested that the best way of maintaining semi-natural grasslands would be the maintenance of traditional management measures (Bakker, 1994; Spatz, 1994; Poschlod & Schumacher, 1998; Prins, 1998; Fischer & Wipf, 2002; Muller, 2002). Consequently, management prescriptions laid down in many agri-environment schemes are based on historical ways of agricultural management, such as late cutting, low stocking rates, or reduced fertiliser use. This demonstrates the general problem of integrating semi-natural grasslands into production systems of modern grassland farming. Traditional grassland management systems had been given up during the last century because they no longer met the requirements of the improved livestock production systems in terms of herbage yield and quality and thus were no longer profitable. Therefore, farmers who continue to manage their grasslands in a traditional extensive way act, in many situations, against economic interests unless they receive subsidies to compensate production losses. The amount of payments necessary to maintain a traditional grassland management depends on the gross margin that can be obtained from agricultural products. The more efficiently a semi-natural grassland is integrated into the production process of the grassland farm, the higher is the economic return by the sale of agricultural products. Thus, the need for subsidies to maintain the nature conservation value of these grasslands would be lower and a larger area could be reached with agri-environment schemes within the limitation of public budgets.

Abandonment of semi-natural grasslands from agricultural use is a major risk for grassland diversity. Many investigations have shown that almost independently of the vegetation type, cessation of grassland management leads to successional change and to a loss of plant species diversity. At a local scale, vegetation succession facilitates the invasion of shrubs, the dominance of tall growing species from later successional stages and the competitive exclusion of species typical for managed grasslands (Krahulec et al., 2001; Moog et al., 2002; Tasser & Tappeiner, 2002; Pykala, 2003; Gaisler et al., 2004; Hejcman et al., 2004; Kahmen & Poschlod, 2004). At the regional scale, succession increases the similarity of different grassland communities and thereby reduces the total species diversity (Dullinger et al., 2003).

Major constraints for a continued agricultural management of semi-natural grasslands are the low herbage yield and quality. In a review on the agronomic potential of semi-natural lowland hay-meadows, Tallowin and Jefferson (1999) showed that the herbage growth rate and harvestable yield of species-rich grasslands were at least 50% lower compared to intensively managed meadows. Similar results were obtained from upland and mountainous grasslands (Peeters & Janssens, 1998; Schmid & Jeangros, 1990). The herbage yield of meadows is an important aspect of profitability. As herbage conservation through silage or hay-making is expensive, a minimum herbage yield per cut should be attained; Spatz (1994) suggested 3 tonnes dry matter per ha. This level is frequently missed by marginal grasslands on acid sandy soils or limestone. The herbage quality is even more important for the potential use of herbage from species-rich grasslands. When the primary growth of a species-rich hay-meadow and that of an agriculturally improved grassland are cut at the same time, the digestibility may be the same (Schellberg et al., 1999) or slightly lower on species-rich swards (Tallowin & Jefferson, 1999), obviously depending on the botanical composition. Such comparison is, however, hardly relevant for the farming practice as unimproved swards are less frequently defoliated. Hence, if the late cut primary growth of diverse swards is compared with early cut herbage from improved swards, a large difference between systems is found. This is particularly relevant for many agri-environment schemes where a late first cut is prescribed. Late cut hay from species-rich swards rarely exceeds an organic matter digestibility of 60% (Daccord, 1990; Stoll et al., 2001). Hay or silage of such a low quality cannot be used in intensive livestock systems, i.e. for dairy cows or fattening bulls. It may, however, be fed to dry suckler cows or growing heifers (Spatz, 1994; Stoll et al., 2001).

Grazing is an interesting alternative to cutting in order to maintain species-rich grasslands. Grazing is cheap compared to cutting and forage conservation, it requires less labour input, and the individual performance of the animals is usually higher with grazing compared to barn feeding of conserved late cut herbage. Although some of the traditionally diverse grasslands have developed through long-term hay-cutting and diversity could be best maintained through the continuation of cutting (Spatz, 1994; Fischer & Wipf, 2002; Stammel et al., 2003), there is some evidence that plant species diversity can also be maintained by extensive grazing (Schlapfer et al., 1998; Stammel et al., 2003; Troxler & Chassot, 2004). Plant communities of formerly species-rich grasslands that have been abandoned from agricultural use can be restored by extensive grazing (Hellström et al., 2003; Pykala, 2003). Such grazing creates a mosaic of short and tall grass patches (Bakker et al., 1983; Isselstein et al., 2003). It was shown that in tall grass patches plant species typical for hay-meadows were able to flower and to set seed which is necessary for the persistence of the species in the sward (Correll et al., 2003). In addition, grazing can maintain and increase community diversity at the landscape or regional level (Dullinger et al., 2003). The re-introduction of communal grazing and the establishment of payment schemes that would allow support of the joint utilisation of nature conservation grassland by a group of farmers could be a promising tool for the future management of species-rich grasslands.

Various investigations with grazing sheep and cattle on species-rich, low productive grasslands have shown that the animal performance per unit area is generally low, depending on the fertility of the sites (Jans & Troxler, 1990). However, it also appeared that the individual animal performance is not necessarily lower as compared to intensive grassland, even if the average herbage quality is lower (Troxler & Chassot, 2004). Obviously, grazers can maintain a good individual performance through selective grazing when the herbage on offer exceeds the demand (Pavlu et al., 2001). This is characteristic for extensive grazing.

Management of de-intensified grassland to enhance biodiversity

Since the early nineties of the last century, an increasing percentage of grassland has been abandoned from intensive agricultural use. Management has either been changed to support less intensive livestock production such as suckler cow or sheep farming or the grasslands have no longer been utilised at all. This is particularly obvious in less favoured areas in central and eastern Europe. Due to a history of agricultural improvement, the biodiversity and therewith the nature conservation value of these grasslands are relatively low. However, many investigations have been performed to study the possibilities to increase biodiversity through extensive management. With regard to the profitability of farming on de-intensified grassland the production costs have to be low. Measures to improve the productivity of the swards like fertilisation, herbicide application, or reseeding etc. are usually not employed and area rents are generally low. Therefore, grazing rather than cutting and forage conservation seems to be the appropriate option for grassland utilisation due to its low costs. In addition, the individual performance of the livestock gains in importance as compared to the performance per unit area. Thus, the management becomes similar to the situation before the agricultural improvement of the sites during the last century. The conditions for a restoration of species diversity are promising in this respect. This was the starting point for various attempts to develop management systems that meet both agronomic and biodiversity targets. A new challenge in the changing agri-environment is therefore to develop management systems that meet both agronomic and biodiversity targets and that are based on the idea that relatively large grassland areas are to be managed with relatively little stock (Rook et al., 2004b).

Various experiments during the last decade have shown that de-intensification of grassland management does not immediately reverse the process of species loss that occurred during the agricultural improvement of the sites. Species number increases if at all slowly (Jeangros & Bertola, 1997; Bakker & Berendse, 1999; Dyckmans et al., 1999; Jeangros & Thomet, 2004; Marriott et al., 2004). Major constraints to the restoration of plant diversity are a high residual fertility of the soils and a continuing high nutrient availability. On mineral soils, phosphorus availability is obviously a key factor (Janssens et al., 1998; Bakker & Berendse, 1999; Koch & Masé, 2001). Herbage production remains on a relatively high level and the dominating forage species prevent the invasion of lost species and the re-establishment of a diverse vegetation. An important prerequisite for the restoration of diverse swards is the decrease in herbage production (Oomes, 1990; Berendse et al., 1992). Unless drastic techniques of nutrient depletion, such as deturfing of the swards, are employed, the reduction of available phosphorus in the soils and the decrease of herbage production is not readily achieved. Therefore, it has been suggested that new techniques should be explored which support the enhancement of species diversity despite a moderate or high nutrient availability (Critchley et al., 2002).

Similarly important is the availability of propagules of plant species that are not present in the current vegetation (Bakker & Berendse, 1999; van Diggelen & Marrs, 2003). Experiments during recent years have shown that the restoration of diverse grasslands was often not successful even if the productivity of the existing swards had decreased. This was due to a lack of appropriate propagules, either from the soil seed bank or from neighbouring vegetation (Bakker et al., 1996; Bekker et al., 1997; Muller et al., 1998; Coulson et al., 2001). In order to overcome this limitation, the addition of propagules had been suggested (Bakker & Berendse, 1999) and investigated in field experiments (e.g. Hopkins et al., 1999; Jones & Hayes, 1999; Kowarsch et al., 2001; Hofmann & Isselstein, 2004). Propagule additions proved to be successful as long as regeneration niches (Grubb, 1977) were sufficiently provided in the sward (Walker et al., 2004). This is primarily dependent on the botanical composition and the sward structure which in turn are controlled by grassland management. Appropriate grazing systems and cutting dates have to be implemented to provide microsite conditions that facilitate germination and establishment of introduced seeds (Smith et al., 2000; Marriott et al., 2004). Recent research on seedling recruitment in lowland grassland suggests that seedling emergence and seedling survival have different requirements on the microsite conditions. Germination and emergence were enhanced in leniently defoliated swards with a low tiller density or where the sward was partly disturbed by mechanical treatment. Obviously, this provided space for germination and emergence. In contrast to emergence of seeds, their survival was improved by frequent defoliation following emergence. This was due to a reduced competition by the existing vegetation (Hofmann & Isselstein, 2004). A great temporal and spatial heterogeneity of the sward structure with patches of short and tall grasses generally occurs with extensive grazing when the herbage on offer exceeds the demand of the grazing livestock (Correll et al., 2003; Kohler et al., 2004). This is a result of selective grazing due to dietary choices of the grazing animals, of treading, and of the heterogeneous return of nutrients to the swards (Rook et al., 2004a). In addition, grazing has a particular advantage over cutting with regard to biodiversity management: the dispersal of plant species propagules is favoured by grazing livestock (Poschlod et al., 1998). To investigate the potential benefits of extensive grazing for the enhancement of biodiversity, an experiment has been set up in five countries throughout Europe. Biodiversity targeted grassland management with low stocking rates is compared with livestock-production orientated management with moderate stocking rates (Rook et al., 2004b). Preliminary results confirmed other findings that the plant species number does not change rapidly in relation to the grazing treatment (Scimone et al., 2004). However, abundance and diversity of butterflies responded more clearly with higher numbers at the low stocking compared to the higher stocking. The reason is obviously the differences in average sward heights (WallisdeVries et al., 2005).

In agronomic terms, grazing seems to have a clear advantage over cutting in many situations. Late cut hay or silage from de-intensified grassland have frequently been demonstrated to have a poor quality and not to be a suitable forage for livestock with increased energy requirements (e.g. Dyckmans et al., 1999; Isselstein et al., 2001). On extensive pasture, the livestock may achieve an individual performance that is close to intensive systems. However, various authors have shown that the performance per unit area of extensive grazing may decrease to 50 to 70% compared to a moderate or intensive grazing (Hofmann et al., 2001; Fothergill et al., 2001; Pavlu et al., 2001;

Barthram et al., 2002; Isselstein et al., 2004). This is an important result for the prospects of integrating extensive grazing into economically viable livestock systems. Assuming the area costs are low, it can be concluded that the individual performance of the livestock is becoming more important and that by this the economic position of extensive grazing compared to intensive grazing is strengthened.

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