Productivity, Biodiversity and Nitrate in Groundwater of Multifunctional Grasslands

H. KOREVAAR and R.H.E.M. GEERTS
Plant Research International, P.O. Box 16, 6700 AA Wageningen, the Netherlands

ABSTRACT
Multifunctional land use is an option to increase economic and environmental sustainability and to make a region more attractive for local inhabitants and visitors. Between 2002 and 2004 we studied 76 grasslands on different farms. This paper presents results on production, flora and fauna (butterflies and grasshoppers) and nitrate concentration in upper groundwater from six different grassland types. We conclude that a combination of agronomic, ecological and environmental goals is possible and that it is possible to combine a high biodiversity with a rather high production level. In most cases this multifunctionality is not profitable for the individual farmer. However, for the region as a whole it provides good opportunities to create extra income. The most important potential for extra income is an increase in recreation and tourism.

INTRODUCTION
Grasslands are complex ecosystems and play an important role in our daily life:

- Grassland is a continuous crop; management and utilisation have an impact on the growth rate of the grass and its regrowth potential.
- Grassland is a part of the soil-sward-animal cycle. Grass production and quality influences animal production. Dung, urine and poaching have an impact on soil fertility and sward quality.
- Species composition of grasslands is dependent on many factors, such as climate, soil structure, moisture, fertility and management conditions. Grass species can grow under varied conditions and many insects (e.g. butterflies), mammals, (e.g. hare) and ground nesting birds (like lapwing) are dependent on grassland.
- Grassland is not only a part of our dairy and sheep farms, it is a major component of our urban environment (and is indispensable for soccer fields and golf courses and for the lawns in our gardens and public areas).
- Grassland is even more an important component of our countryside. Green grasslands dominated many highly valued landscapes.

However, the countryside in many countries is changing rapidly. The number of employees working in agriculture has decreased strongly after the Second World War. In a country like the Netherlands nowadays only 2.5% of the labour force is involved in food production. Services on the other hand create much more jobs. The countryside is not so important anymore for employment; it is becoming more and more important for residence and recreation. These new functions demand maintenance of landscape structures, nature conservation, water management and protection of the environment. Multifunctional land use is an option to integrate these changing requirements to make the countryside more attractive for local inhabitants and tourism and to enlarge the socio-economic viability of rural areas. In this paper we integrate these different agronomic, ecological and environmental aspects.

Korevaar, H. & R.H.E.M. Geerts. 2007. Flora, fauna and nitrate in groundwater of multifunctional grasslands. In: High Value Grassland. Providing biodiversity, a clean environment and premium products. Occasional Symposium 38 British Grassland Society, Cirencester, UK: 64-69.

MATERIALS AND METHODS

Between 2002 and 2004 we studied a group of 14 farms in the Winterswijk region of the Netherlands (eastern part of province Gelderland, next to the German border), a small scaled landscape of sandy soils with high natural values and a variety of grasslands, arable fields, hedgerows and woodlots. The study sites consisted of 5 dairy farms, 2 beef, 1 young stock rearing, 1 pig, 2 arable and 1 mixed farm and 2 small estates. Four of these farms were organic farms. The farms also differed in their level of function combinations (Korevaar *et al.*, 2006). We studied the impact of multifunctional land use at field level, farm level and rural community level. The region is 20,000 ha in size and was recently designated as a national landscape. With 30,000 inhabitants, its population density is about half the average density of the Netherlands.

On these farms grasslands and arable fields were selected and monitored. In this paper we present only data obtained from grasslands: dry matter production, grass quality, composition of the vegetation, butterflies and grasshoppers, nitrate concentration in upper groundwater and amenity of the landscape (scenic beauty). 76 sets of data were collected, but not all parameters were available for each field and every year. We measured grass production and grass quality by cutting the grass under four grass cages per field every time a field was grazed or cut for hay or silage.

Each farmer recorded data at farm level, on fertilization, grazing management, harvesting and labour and machinery costs. Margin over feed and fertilizers was calculated yearly for all fields based on production and quality of the grass minus the costs of fertilizers and machinery. Two to three times a year all the farmers met, to be informed about progress and results of the project and to exchange their experiences and to discuss further adaptations. They also visited each others farms.

At local community level we interviewed local inhabitants and tourists about their opinion on the value of a multifunctional landscape; what did they appreciate and what they did not. We also studied the economic perspective of a possible further increase of multifunctional land use for income of individual farmers and for the whole region.

RESULTS

Most of our research was focussed on field level, but we will also present some data drawn from farm and local community level.

Field level

The fields were grouped into six grassland types: ranging from fertilized ryegrass and grass-clover swards, to unfertilized species-rich grasslands (Table 1). N-fertilization (inorganic fertiliser N and directly available component (Nmin) of N in slurry) on grass-clover swards was less than half the amount of fertilized ryegrass swards (which were regarded as a kind of control for the ordinary farming system in that region), but the average dry matter production, number of plant species, N-uptake and nitrate concentration on grass-clover swards were similar. Although the fertilization level on the fertilized grass mixtures (of native grasses) and species-rich grasslands (grassland with wild flowers) was low, the DM production on these low fertilized types was fairly high and species numbers were similar to the unfertilized types.

The relationship between N-gift, including N fixation by legumes, and DM production showed a broad range (Figure 1A), and some low fertilised grass mixtures and species-rich grassland produced more than 10 T DM/ha/year. The contribution of N fixation by legumes is based on an estimated contribution of legumes of 50 kg N per T DM from legumes (Van der Meer and Baan Hofman, 1989).

Also the number of plant species varied between the fields, with lowest numbers in fertilized ryegrass and clover swards and higher numbers in species-rich grasslands, but even in the so-called species-rich grasslands the number varied between 15 and 35 per 100 m^2 (Figure 1B). The N-concentration under most ryegrass and grass-clover swards exceeded the EU-limit of 50 mg NO_3/l and under almost all grass mixtures and species-rich grasslands the nitrate concentration was far below that limit (Figure 1C).

Table 1 Agronomic, economic, ecological and environmental data for different grassland types; average data for the years 2002 till 2004 (Korevaar *et al.*, 2006)

Grassland type	Ryegrass fertilized	Grass-clover fertilized	Grass mixtures		Species-rich	
			fertilized	unfertilized	fertilized	unfertilized
Number of fields	11	10	8	8	16	23
N-fertilization Kg/ha	179	107	59	0	50	0
N-uptake by the grass kg/ha	349	336	244	143	181	90
DM production T/ha	11.5	11.3	9.2	7.5	8.8	5.5
Net energy MJ/kg DM	6.3	6.5	5.9	5.6	5.4	5.1
Plant species on 100 m^2	11	8	17	16	29	24
Plant species on 0.5 ha	21	19	29	37	44	39
Margin €/ha	528	710	518	263	125	-16
Butterfly index[1)]	0.4	0.1	0.6		2.4	
Grasshopper index[2)]	2.6	2.0	3.7		4.9	
Amenity index[3)]	54	30	245	313	536	533
NO_3 in ground-water mg/l	92	91	18	18	25	4
% of fields with $NO_3 < 50$ mg/l	33	43	80	100	75	100

1) Butterfly index: number of butterflies per ha x number of species divided by number of visits x 100.
2) Grasshopper index: the logarithm of the number of grasshoppers per ha x number of species divided by number of visits.
3) Amenity index: attractiveness (flowers, color) of plant species x their proportion in the vegetation.

NOTE: The Butterfly and Grasshopper indices provided for Grass mixtures and Species-rich grasslands are the mean of both fertilized and unfertilized situations

Plant species composition is influenced by changing management, but also some insect groups respond quickly to changing management. Butterflies and grasshoppers were recorded in 2003 on a limited number of grasslands. Butterflies react in particular to changes in the abundance of flowering species, grasshopper to changes in the structure of the vegetation. The numbers of butterflies and grasshoppers varied also with grassland utilisation and management; just after grazing or cutting the recorded numbers were low.

Figure 1. Relations between: **A.** N-fertilization and N-fixation by legumes (kg/ha; see text) and DM production (T/ha); **B.** DM production (T/ha) and number of plant species per 100 m^2; **C**. N-fertilization, including N-fixation (kg/ha) and nitrate concentration in upper groundwater (mg NO_3/l); ■ Ryegrass, □ Grass-clover, ▲ Grass mixtures fertilized, Δ Grass mixtures unfertilized, ♦ Species-rich fertilized, ◊ Species-rich unfertilized.

Figure 1A

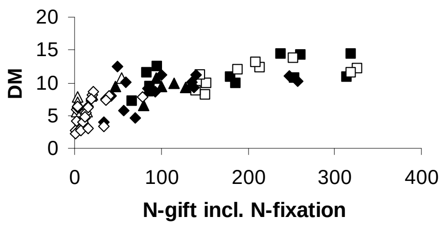


Figure 1B

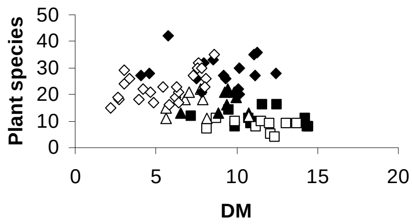


Figure 1C

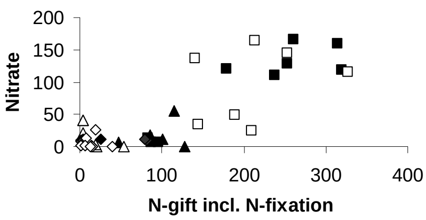


Figure 2. Relations between: **A.** Butterfly index and number of plant species per 100 m^2; **B**. Grasshopper index and number of plant species per 100 m^2. For legend see Figure 1.

Figure 2A

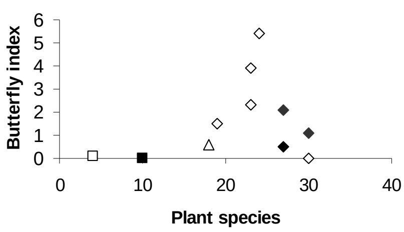
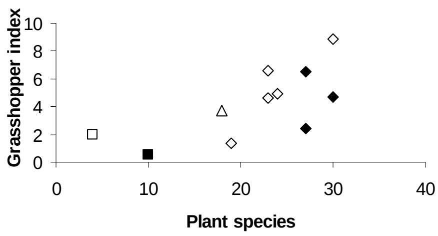


Figure 2B



One of the problems in restoration ecology of grasslands is the lack of seeds of grassland plants in the seed bank and in the neighbourhood, especially after a long period of intensive grassland utilisation. Grasslands with good conditions to develop species-rich grasslands (low soil fertility and extensive management) often stay relatively low in species numbers due to a lack of seeds. To overcome this lack we re-introduced seeds collected from existing species-rich grasslands with the same habitat as our fields. The basis for the seed mixtures were eight grass species. In these mixtures we restricted the amount of perennial ryegrass seed to 5-10 kg/ha to prevent too much competition from this species. We added also some legumes to the seed mixture to improve production and feeding value of the grass. The averaged number of plant species after re-introduction was higher on both fertilized and unfertilized fields when compared to situations without reintroduction (Table 2). These results are in accordance to earlier experimental work on reintroduction of grassland species (Korevaar *et al*., 2004). The percentage of legumes in the biomass was higher after reintroduction and also the DM production. A limited N-fertilization of 50 kg /ha seems, at least in the first years, to not harm species richness and also results in a slightly higher percentage of legumes in the sward.

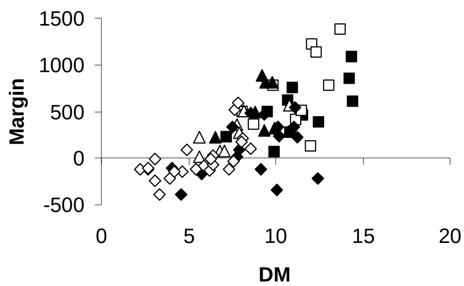
Table 2. Average number of plant species on 100 m^2, proportion of legumes in total grass production and DM production with and without re-introduction of grass species. Averaged species numbers in years 2-4 after re-introduction.

			Number of plant species	Legumes in biomass (%)	DM (T/ha)
Species-rich	&	without re-introduction	26	6	8.3
fertilized:		after re-introduction	30	14	9.1
Species-rich	&	without re-introduction	21	4	5.1
unfertilized:		after re-introduction	28	10	6.3

Farm level

The margin over feed and fertilizers was calculated based on grass production and the feeding value of the grass minus the costs of fertilizers and machinery costs to care and harvest the grass. The profitability of grass-clover swards is higher than the profitability of fertilized ryegrass (Table 1 and Figure 3) and fertilized grass mixtures. Species-rich grasslands have the lowest profitability due to lower production and grass quality in combination with high costs for harvesting the grass for silage or hay.

Figure 3. Margin over feed and fertilizers (€/ha) related to DM production (T/ha). For legend see Figure 1.



Local community level

To study the economic potential of a further increase of multifunctional land use for farmers and for the region, we carried out an economical analysis (Bos, 2006) in which we assumed that in 2020 50% of the farms would apply some kind of multifunctional land use activities on 50% of there acreage (so 25% of the whole area became multifunctional grassland and crops). For farmers the profit of most types of multifunctional grassland (except grass-clover) was predicted to be lower than for conventional grassland (= fertilized ryegrass) (Figure 3). However for the whole region it was predicted to be profitable. The most important potential for extra income is the increase in recreation and tourism. The increase in spending by visitors was predicted to be about 75 M € for the period 2006-2020. The income by farmers is in the same period reduced due to the adaptations in land use by 4 M € (Bos, 2006). So there must be ample space to make agreements between the farmer community and the tourist sector to get a more balanced division of costs and revenues.

DISCUSSION

Multifunctional grassland is considered as an option to enlarge economic and environmental sustainability and to make the area more attractive for local people and visitors. Therefore an integration of agronomic, economic, ecological and environmental goals is necessary, but how to weigh the importance of different parameters? The impact depends on the relative weight given by stakeholders (whether individual or collective). For a farmer for instance DM production and farm economics are important, for a nature organization the number of plant species and for water authorities the nitrate concentration in groundwater. Next to this, policy goals and subsidies may influence the original weight of the parameters.

From this study we can conclude that combination of agronomic, ecological and environmental goals is possible. But in most cases this multifunctionality is not profitable for the farmer. For the region as a whole it offers good opportunities to create extra income. We need a mechanism to reallocate this extra income, therefore a system of “green-blue services” (Anonymous, 2006) is under construction in the Netherlands and negotiations are going on with Brussels to ensure that this system meets the requirements for integrated EU regulations.

ACKNOWLEDGEMENTS

Financial support from Ministry of Agriculture, Nature and Food Quality, Province Gelderland, Farmers organisation LTO Noord, Rabobank and EU.

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