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Article *in* Animal science papers and reports · January 2010

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Animal Science Papers and Reports vol 28. (2010) no. 4, 315-334
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Grazing as a tool to maintain biodiversity of grassland – a review

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(Received October 2, 2009; accepted September 20, 2010)

The intensification of agriculture has a great influence on grassland, resulting in the disappearance of many plant and animal species and changing open landscape. Sustainable farming practices, which use farm animal grazing, are seen as a potential solution to continued biodiversity loss resulting from over- or undergrazing. In the article the influence of grazing animals on grassland biocenoses and their use in active biodiversity protection are reviewed based on over 100 references. It is concluded that animal grazing can be a tool to maintain or restore biodiversity of open landscape and contribute to the aesthetic and leisure importance of grassland. The successful use of grazing for environment protection and biodiversity enhancement requires careful planning and should be adapted to local conditions. A deep understanding of the relationship between herbivores, plant, and small animal communities and the abiotic environment is essential. Therefore, there is a need for comprehensive research programmes in the area of extensive grazing, combining expertise from ecology, botany, agronomy, animal production and rural economics. The research should include both field experiments and development of appropriate models, allowing for the design of agro-environmental schemes aimed at the protection of grassland biocecenoses.

KEY WORDS: biodiversity / grassland / grazing / herbivores / landscape protection

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Introduction

Grassland is an important agroecosystem, constituting more than 30% of agricultural land in Central Europe [Zimkova *et al*. 2007] and 20-22% of the total area used in agriculture in Poland [Sawicki 2006, European Commision 2009]. Grassland plays an important role in European animal production, particularly in production of milk [Smit *et al*. 2008]. As well as their contribution to food and feed production, pastures and meadows form specific landscape and are a habitat for many species of plants and animals, resulting in a high biodiversity referring to all living organisms existing and interacting within an ecosystem [Vandermeer and Perfecto 1995, van Wieren and Bakker 2008].

In agroecosystems, biodiversity performs a variety of ecological services beyond the production of food and feed, including the recycling of nutrients, regulation of microclimate and local hydrological processes, suppression of undesirable organisms and detoxication of noxious chemicals [Altieri 1999]. There is growing evidence that the level of internal regulation of functions in agroecosystems is largely dependent on the level of plant and animal biodiversity present. Thus, biodiversity of grassland is important not only as a tool to protect plant and animal communities, but also in sustaining their agricultural productivity.

The intensification of agriculture, largely driven by economic factors, has a major influence on grassland. In general, extensive meadows and pastures are less productive and give crop with a lower net energy content compared to those managed intensively. Thus, farmers expect to achieve quicker and better results with intensive practices, such as frequent fertilization. Agricultural activities such as tillage, drainage, intercropping, rotation, grazing and extensive use of pesticides and fertilizers have significant implications for wild species of flora and fauna [McLaughlin and Mineau 1995]. In consequence, the overly-intensive use of grasslands is the main reason for the disappearance of many plant species [Bohner 2007]. Gough and Grace [1998] and Marty [2006] also highlight, that an increase in grassland productivity results in a decline in number of plant species in many habitats. Consequently, a remarkable decrease in the range and abundance of many species associated with farmland has been reported across Europe. Sustainable farming systems such as extensive or organic farming, with the use of farm animal grazing, are seen as a potential solution to continued biodiversity loss. It has been shown that organic and low-input production systems support greater genetic and biotic diversity of agricultural ecosystems [Duelli 1997, Bartoszuk *et al*. 2001, Hansen *et al*. 2001, Bohner 2007]. In regions with rich soils, the number of species on organic fields has been found to be up to 10 times higher compared to conventional fields [Heineken 1990].

Extensively managed pastures and meadows are of crucial importance for grassland biodiversity across Europe. Unfortunately, biodiversity of such biocenoses is currently threatened either by intensive use or by abandonment [Bartoszuk *et al*. 2001, Dolek and Geyer 2002, Poschlod and Wallis de Vries 2002]. In many areas of Europe, low grazing pressure leads to the creation of unexploited areas that are progressively covered with shrubs [Bailey *et al*. 1998]. Soussana and Duru [2007] state that within 20 years, permanent grassland and pastures in Western Europe have declined by 12%. This phenomenon has also been observed in Poland, where, as a result of the decreasing numbers of cattle and horses, fewer of them are being grazed on grasslands [Jankowska-Huflejt 2007]. This is particularly the case in areas with unfavourable agricultural conditions. The result is a succession of undesirable plant communities leading to a biodiversity decline.

Extensive farming which uses animal grazing, can be a tool to maintain or restore open landscapes, and also has a beneficial effect on adjacent wild ecosystems [Bartoszuk *et al*. 2001, van Braeckel and Bokdam 2002a, Dumont *et al*. 2007, Isselstein *et al*. 2007, Jankowska-Huflejt 2007, Scimone *et al*. 2007, Wallis De Vries *et al*. 2007]. Conversion of intensively managed farms to organic methods of management is also beneficial to nature conservation [Haggar and Padel 1996]. A mixed farming system with a high proportion of grassland habitats is likely to maintain a number of important farmland bird populations in many countries including Poland [Sanderson *et al*. 2009]. The importance of extensive grassland use for biodiversity and landscape conservation is the main reason for the substantial support of these practices in the form of subsidy payments, through EU and national government legislation [Hole 2005].

The effect of grazing animals on grassland biocenoses

Grazing animals can affect an ecosystem through defoliation, treading and leaving excreta [Warda and Rogalski 2004, Duncan 2005, Wasilewski 2006]. The transport of seeds is another significant way in which grazers can influence plant diversity [Olff and Ritchie 1998]. Natural fertilization and transport of nutrients in animals' excreta is also important for grassland and adjacent biocenoses which may be used by herbivores for feeding and resting. It may be assumed that wild plants are adapted to herbivores since they have evolved together. However, the intensity of defoliation, treading and natural fertilization in farming landscapes may exceed the levels occurring in natural systems, thus adverserly affecting grassland biocenoses.

Defoliation is the main way in which herbivores affect plant communities. Periodic defoliation is vital for controlling succession of plants [Rook *et al*. 2004]. Intensive defoliation, on the other hand, inhibits the development of trees and shrub seedlings and supports mass growth of grasses [van Braeckel and Bokdam 2002a]. Unselective defoliation on a massive scale stimulates the growth of short plants, thus creating and maintaining open landscapes such as pastures and meadows. However, herbivores usually defoliate selectively. Selective defoliation encourages the growth of unpalatable tall plants and supports the creation of a mosaic landscape structure [Warda and Rogalski 2004]. Rook *et al*. [2004] concluded that the main mechanism through which grazing animals influence pastures is their dietary selection, which in consequence creates and maintains the structural heterogeneity of pasture swards.

Treading can have both a positive and negative effect on pasture soil. Treading or trampling creates gaps in the sward and has a positive effect on the establishment of annual and bi-annual species. [Van Braeckel and Bokdam 2002]. Treading of the soil surface creates gaps thus allowing seeds to sprout, which in effect speeds up the growth of grasses, and eventually prevents soil erosion [Warda and Rogalski 2004]. The extent of that impact depends largely on the size of grazing animals and the number of individuals per surface area. For example, Bartoszuk *et al*. [2001] suggest that size is an advantage of using cattle for pasture conservation, as heavy animals prevent the growth of weeds by trampling and disturbing the soil with their hoofs. According to Vavra [2005], grazing animals can protect specific plant seeds by churning the soil and creating mulches which cover them. On the other hand, trampling may reduce stream bank stability and increase soil erosion [Kauffman *et al*. 1983, Vavra 2005]. The risk of erosion increases when a soil is wet, when animals cut the canopy very short (less than 20 mm) or when stocking rate is too high [Russell *et al*. 2001].

Trampling is potentially dangerous for groundnesting birds' nests and animal burrows. However, the ornithological studies in the Biebrzanski National Park in Poland have indicated that extensive grazing of cattle contributed to the improvement of nesting conditions. The positive effect of grazing was a result of the creation of a habitat structure optimum for birds. Moreover, the presence of grazing cattle reduced the pressure of small predators on nests and nestlings. The positive effects far exceeded nest losses caused by the cattle themselves [Mazurek 2002, 2003].

Animal manure plays an important role in creating and preserving biological diversity. The excreta produced by herbivores during grazing act as a natural fertilizer and influence seed distribution. Manure is a rich source of nutritive substances essential for green biomass growth. The dispersal of faeces results in species and structural diversity of flora [Guziak and Lubaczewska 2001, Peco *et al*. 2006]. However, intensive grazing can also cause over-fertilization of pastures, disturbing organic matter and the nutrient circulation balance, thus negatively influencing the biodiversity of a whole ecosystem. For example, a decrease in wader populations on mown and grazed peat grassland is observed when the farmland is drained and heavily manured [Dyrcz *et al*. 1985, Kleijn *et al*. 2001].

Factors modifying the influence of grazing on the environment

As already mentioned, the way in which herbivores utilize plants differs between species. This is demonstrated by the different browsing strategies and preferential grazing of different plant species. Van Braeckel and Bokdam [2002] divide large herbivores into three functional groups. The first group, the grazers, includes cattle, horses and other social herbivores capable of digesting the plant cell wall fibre efficiently. The second group is browsers, which include elk and roe deer. They are very selective, solitary herbivores, which mainly digest the cell content of plants. The third group consists of the intermediate feeders (*e.g*. red deer and European bison).

They are social herbivores that can switch between the grazing and browsing strategy [Hofmann 1989]. We will focus on the role of grazers, as the majority of grazing farm animals belong to this category.

Animal species differ in their preference for taking various plants, im the order of selection of species taken and in height of the cut made [Abaye *et al*. 1994, Bailey 1999]. Due to the diverse feeding behaviour and feed preferences, the impact on the area grazed differs between species. For example, Bartoszuk *et al*. [2001] pointed out that cattle prefer taller grasses and other plants, whereas horses (Polish Konik) select the shorter sward. Cattle prefer the reproductive parts of plants whereas sheep show preference for vegetative parts. Compared to cattle, horses are more inclined to take fibrous grasses. Furthermore, they can bite closer to the ground because of their teeth structure [Dumont *et al*. 2007]. Cattle often utilize grassland selectively by grazing some areas more intensively than the other, resulting in local overgrazing [Coughenour 1991]. Goats are less selective than other farm ruminants in the species of plant eaten [Bartoszuk *et al*. 2001]. Sheep and goats generally need more energy in relation to their gut capacity than cattle, and they have, therefore, to select plant parts with higher nutritive value (flowers, pods, shoots) - Rook *et al*. [2004]. The degree of selectivity of animals to the plants eaten depends also on sward composition and quality [Rook *et al*. 2004, Dumont *et al*. 2007]. When the sward is rich in diverse species of flora, animals tend to choose plants which meet best their nutritional requirements. When the sward diversity is smaller, animals start to graze less selectively.

Interactions between herbivores and ecosystems are especially complex in the case of free-ranging animals, as abiotic zones and successive stages of biocenoses are of different attractiveness for foraging *vs*. resting animals. For example, floodplains with short grass swards are preferred foraging habitats by grazers, whereas woodland on nutrient-poor fens and bogs are nonattractive. Short vegetation in minerotrophic, base-rich fens occupies an intermediate position. Woodlands on uplands are a second-choice foraging habitat but they may be preferred for resting. This differential use of habitats generates nutrient transport between ecosystems [Van Braeckel and Bokdam 2002]. The ability of herbivores to move between different ecosystems is especially important when they are used in order to protect or conserve natural landscapes.

Rogalski *et al*. [2001] quote several examples of the way in which species of grazed animals affect the botanical composition of pasture swards. Due to selective biting, valuable grass species such as perennial ryegrass (*Lolium perenne*) were found to disappear from pastures grazed by cattle. This grass species also decreased in abundance on pastures grazed by sheep. *L. perenne* and smooth meadow grass (*Poa pratensis)* decreased in abundance on horse grazed pastures. The declining grass species were replaced mainly by orchard grass (*Dactylis glomerata)*. When goats were grazed, meadow fescue (*Festuca pratensis*) gradually declined and was replaced by *D. glomerata* and *L. perenne*, which became dominant in the sward. Sheep, and especially horse grazing, reduced the abundance of white clover (*Trifolium repens*) the abundance of which was positively affected by goat grazing. Generally, grazing animals increased the abundance of herb species in the sward.

Grant *et al*. [1985] compared grazing sheep and cattle and found that the two species differed significantly in all major aspects of their diet. Sheep diets contained more forbs and less grass flower stems than those of cattle. The differences between sheep and cattle diets were explained by a difference in the height at which the animals bit the sward, related to the distribution of plant species within the sward canopy. Other important differences included the greater ability of sheep to select from fine-scale mixtures; and the greater readiness of cattle to graze on tall, more fibrous components.

Grazing can be useful in controlling valueless grasses, as Dumont *et al*. [2007] showed in the case of nard (*Nardus sp*.). Cattle grazing reduced the area covered by this grass by 30% in five years. During the same period, grazing by sheep decreased its area by 80%. It was also shown that the share of same grass was more greatly reduced after six years of grazing by horses then in the same period of grazing by cattle. Moreover, horses keep grassy areas short, at a height of less than 4 cm, because they can bite closer to the ground, due to their teeth structure [Dumont *et al*. 2007]. Cattle prefer taller grasses, at a height between 9 and 16 cm. The above comparison indicates that horses can be used to reduce tall grass vegetation successfully. This has in fact been shown in practice, both in France and in the Netherlands [Dumont *et al*. 2007].

It is not only animal species, but also breed that affects the way in which a sward is grazed. Rook *et al*. [2004] suggested that the differences in question are primarily a result of differences in body size and gave many examples of such variations. For example, French dual-purpose steers (Meuse-Rhine-Yssel) were more selective than Hereford steers, and Salers heifers were less selective than Limousine heifers. The quoted authors found also that Aberdeen Angus steers with the "small" genotype were more selective that those with "large" genotype, which confirms that size of animals is important in determining grazing preferences.

Studying commercial and traditional livestock breeds, Dumont *et al*. [2007] found some differences in their grazing strategy. North Devon steers expressed a greater preference for tall grass-forbs than Charolais × Holstein crossbreds, but generally traditional breeds appeared to be less selective than commercial ones. The age and physiological status of the animal also alters its feeding preferences. Young animals and pregnant or lactating females prefer forages with higher nutritive value and so are more selective when grazing [Rook *et al*. 2004].

The effect of grazing on the environment depends on regional variation in major habitat characteristics, such as soil fertility and availability of water. There is evidence that differences occur between herbivore species in their preference for pasture soil type. For example, horses (Polish Konik) prefer plants typical of dry soils [Bartoszuk *et al*. 2001], whereas cattle will readily graze on plants from both dry and humid soils [Wasilewski 2006]. Consequently, free-ranging animals move between biocenoses, depending on time of day or season, seeking for preferred food or convenient resting place. Large herbivores will use the nutrient-rich floodplain (and peat zone) as summer foraging habitats and the uplands as winter habitats. In the absence of floodplains, their function may be substituted by fertilized upland sites or by supplements. Winter feed supplementation or shelter may substitute a lacking upland site. In complete successional mosaics, animals shift daily and seasonally between grassland and woodland for foraging and resting, respectively.

Peco *et al*. [2006] stressed that moderate grazing increases fertility of very poor soils and promotes species richness at the local scale as well as vegetation cover, which contributes to protecting the soil from erosion. It also improves the soil's ability to retain water, which is important for seed germination and seedling establishment in environments where the main limiting factor for these processes is water. On the other hand, animals grazed on sensitive soils can cause serious environmental damage. For example, the exposure and maintenance of bare soil in the UK by grazing animals, especially sheep, initiates erosion of sensitive soil, particularly in the uplands. When initiated, erosion processes can be very difficult to stop, even when animals are excluded from the area by fencing [Evans 1997]. This indicates that both the type of grazed animals and the grazing intensity have to be carefully adjusted to local conditions in order to achieve beneficial results of grazing for biodiversity. Providing that this is done, the influence of grazing animals together with the spatial diversity of soil and water conditions, supports development of rich, mosaic landscapes. The mosaic landscape offers habitats for foraging and breeding for waders, waterfowl and marsh birds [Haggar and Padel 1996]. Diversification of swards also ensures a variety of niches for invertebrates, which are part of the birds' diet. Moreover, birds such as plovers and lapwings prefer clustered plants for egg laying and raising nestlings [Guziak and Lubaczewska 2001].

The effect of grazing on the ecosystem depends on its intensity, and particularly on livestock density. According to Scimone *et al*. [2007], grazing intensity generally had profound effects on vegetation diversity, but the effect depended on site-specific vegetation characteristics.

Extensive or semi-intensive grazing has a positive effect on 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 [Isselstein *et al*. 2005, Tallowin *et al*. 2005]. Verhulst *et al*. [2004] found the most bird species in extensive grassland, whereas intensively grazed fields had lower species numbers, and lower density and diversity. Based on these findings, the authors suggest that conservation efforts aimed at farmland birds should be focused on maintaining extensive farming systems. Light grazing can increase species richness and the abundance of wild animals, especially butterflies, grasshoppers and ground-dwelling arthropods [Wallis De Vries *et al*. 2007]. Moderate grazing can be a useful tool to limit expansion of shrubs, as shown by Casasus *et al*. [2007] in the mountain pastures of the Pyrenees, resulting in the enhancemetnt of the environmental and recreational value of the area.

In the case of intensive grazing practices, the opposite effect can be expected. Overgrazing affects soil properties resulting in reduced water infiltration, less soil moisture and fertility. It changes microbiological activity and increases soil erosion [Czeglédi and Radácsi 2005, Thurow 2005]. High grazing pressure decreases plant diversity, changes the botanical composition of the sward and can lead to the invasion of undesirable plant species. For example, when grazing is intensive, bunch grasses tend to be eliminated. Intensive grazing leads to an increase of short grasses and annuals, which do not stimulate soil maintaining because of their poor root system.

There are many examples of the negative effect of intensive grazing on ecosystems [Evans 1997, Lennon 1999, Czeglédi and Radácsi 2005]. The Project "Transhumans for Biodiversity Conservation" revealed that overgrazing significantly decreases the number of endemic plant species [GEF 1999, Debayle 2004]. Lapointea *et al*. [2000] presented another example, where an excessive number of grazing cattle was a major factor responsible for the decline of duck populations throughout islands in South Quebec (North America). Lennon [1999] describes damages done to fragile alpine ecosystems in Australia by cattle and sheep grazing over the last century.

Undergrazing can be equally harmful for biodiversity as overgrazing. Undergrazing leads to less stimulation and gradual loss of grazing-dependent endemic grasses and legumes. It was found that long-term grazing abandonment can result in the loss of more than 60% of grassland species [Peco *et al*. 2006].

One way of benefiting from the different feeding preferences of animal species is to graze them together – a practice called mixed grazing. Mixed grazing could be beneficial both for quality of forage and performance of grazing animals as shown by Abaye *et al*. [1994] in simultaneous grazing of sheep and cattle. Extensive, mixed grazing has been practiced for many centuries and has had profound effects on landscape and biodiversity [Collins 1989].

Loucougaray *et al*. [2004] examined the effect of mixed grazing of horses and cattle on the diversity of coastal grasslands in western France. These areas contained diverse plant communities, ranging from hygrophilus through seasonally flooded, meso-hygrophilus on slopes where the soil remains saline to mesophilus on higher altitudes. Mixed grazing enhanced the development of rosette, sub-halophyte and halophyte species in saline areas, and limited the strongly competitive couch grass (*Elymus repens*) and creeping bent (*Agrostis stolonifera*). They concluded that mixed grazing supports the creation of the most species-rich and structurally diversed swards. The results indicate that mixed grazing can be used to manage plant diversity and preserve endangered communities at the scale of grassland ecosystem.

Certain authors have stated that sheep and goats can graze together effectively, and that goats may be used to improve pastures for sheep production [Del Pozo *et al*. 1998, Animut *et al*. 2005, Celaya *et al*. 2007]. The advantages of co-grazing of sheep and goats are derived primarily from differences in their preferences for particular plant species and parts, their ability or willingness to consume forages that are not highly preferred and would have adverse effects on the other species, and physical capabilities to gain access to specific types of vegetation. Co-grazing of sheep and goats illustrates the importance of browsers in many grazing systems and shows how management practices can be employed to maintain or increase their prevalence and vegetation diversity [Animut and Goetsch 2008].

Little research has been carried out into the co-grazing of cattle and pigs. However, Stoegaard *et al*. [2000] and Sehested *et al*. [2004] have shown that the diversity of plants on pasture is highest when grazing heifers alone, followed by mixed grazing of heifers and sows. The lowest diversity was found when grazing sows alone.

Generally, mixed grazing can be used effectively in order to enhance plant diversity and animal performance, but overly high density of animals or a bad selection of species can be harmful to diversity of the habitat [Animut and Goetsch 2008].

Use of grazing animals for active biodiversity protection

Due to its influence on the environment, animal grazing is used as a tool for protection and restoration of biocenoses of high biological and cultural value. Grazing is considered to be an important practice for the survival of many threatened plant and animal species in Europe [Bignal *et al*. 1994, Poschlod and Wallis de Vries 2002, Dolek and Geyer 2002]. The main role of animals grazed on threatened grasslands is to control plant species richness. This is a critical issue in the conservation and management of grassland biodiversity. In order to achieve the expected results, the species of grazing animal and method of pasture management must be chosen carefully whilst taking into account the local natural conditions and the conservation goals of that particular area.

Numerous field experiments on grassland plant communities have shown that herbivores often, although not always, increase plant diversity. In most cases, grazing was introduced as a prevention measure against the proliferation of shrubs. Van Braeckel and Bokdam [2002b] studied Biebrzanski National Park (Poland) in order to evaluate the effectiveness of cattle and horse grazing as a tool to prevent the succession of undesirable plants. Their results show that grazing animals prevented and limited the invasion of reeds, but did not restore desirable agglomerations of sedges and mosses. This indicates that a major role of extensive grazing is to preserve, not to restore desirable sward composition. They concluded that grazing of cattle, horses and geese should be integrated with mowing once or twice a year in order to be effective in maintaining and preserving the unique landscape and biological richness of the Biebrza Valley basin.

Hoffmann [2002] described the successful use of cattle, horses and sheep in Flanders to halt the expansion and succession of shrub species. Warda and Rogalski [2004] have also confirmed the positive effect of grazing on open biocenoses. Cattle and horse grazing on saline meadows in the Swina valley (Poland) contributed to the protection of 21 plant species growing there as well as the protection of rare bird habitats.

Many authors have described the use of sheep grazing for nature conservation, both in the uplands and in the mountains [Nowakowski *et al*. 1999, 2000] as well as in the lowlands [Groberek 2005]. Sheep grazing inhibited the succession of undesirable plants and had a positive effect on the enrichment and diversity of floristic communities [Gordon 1990, Harnett 1995, Gutman *et al*. 1997, Niznikowski 2003]. Sheep were also successfully used for grassland conservation in France [Debayle 2004]. Harris [2002] reported that use of sheep was successful in the conservation of habitats for endemic plants, such as the Scottish primrose (*Primula scotica*) on the Orkney Islands.

As already mentioned, grazing can slow down the expansion of shrubs on meadows and pastures, but is not enough to prevent it completely or to reverse succession. In order to maintain open landscapes, grazing must be combined with other practices. Bartoszuk *et al*. [2001] note that there is no meadow management without grazing and no pasture management without mowing, as these two practices must compliment each other. In order to maintain and preserve biodiversity of open landscapes, a combination of practices including grazing, mowing, and reed and wood cutting were suggested by van Braeckel and Bokdam [2002b].

Some authors emphasize the usefulness of local, indigenous breeds for the protection of valuable landscapes through extensive or semi-intensive grazing [Bartoszuk *et al*. 2001, Wasilewski 2002, 2006]. The advantages of using these breeds for the above mentioned purpose include their resistance to difficult climatic and environmental conditions and ability to utilize low quality feed. Moreover, they have a calm temperament, with good health and resistance to diseases and parasites, including insects, and show good reproductive performance. When horses are used for such a purpose, then light breeds, such as the Konik Polski, which are well adapted to harsh conditions, should be preferred over heavier working horses [Bartoszuk *et al*. 2001]. Groberek [2005] reported that sheep of the native Polish breed Wrzosowka (Hether Sheep) were successfully used to prevent undesirable plant succession in lowland areas.

Opinions about the use of mixed grazing for environmental protection are not consistent. Some authors claim that mixed grazing can lead to restoration of plants diversity, while others believe that it reduces the biodiversity of a sward.

Generally, many published results suggest that the introduction of large herbivores into natural grasslands may help to maintain and enhance its botanical diversity. However, in the examples published, grazing was not always the correct method for vegetation management, as demonstrated by Kohyani *et al*. [2008] in coastal dune habitats. Thus, the existing scientific evidence indicates that scale and environmental site conditions are both to be considered when grazing animals are introduced.

The successful use of grazing for environmental protection and biodiversity enhancement requires careful planning. In all cases, the choice of breed, animal density and pasture management should be suited to local conditions and conservation goals in order to achieve the desired results. There is no universal solution, and grazing programmes should be tailored to local conditions. Usually, such programmes are developed by using examples of similar work carried out in practice, and then accommodated through trial and error. A prerequisite for the development of viable programmes is a deep understanding of the relationship between herbivores, plant and animal communities and the abiotic environment. Moreover, predicting the effects of grazing on ecosystems requires modelling [Van Oene *et al*. 1999]. The models used should include the spatio-temporal distribution of herbivores and plant species, across-zone influences, successional stages and subsequent responses. Simulation models should be developed to calculate the effects of grazing and other management on vegetation succession and related ecosystem properties. The models can facilitate the comparison of different management practices only if they are reliable. This is a key issue for environment conservation experts. The development and testing of such models is of crucial importance and requires much research.

Socio-economic aspects of extensive grazing

Grassland is vital for health and welfare of farm ruminants and for horses, as well as for milk production [Smit *et al*. [2008]]. Plant species diversity influences both the performance of livestock grazing on pastures, and the quality of the raw animal products. On the other hand, grazing animals impacts pasture biodiversity in the whole meaning of the term (*i.e*. of plants, animals and insects).

The positive influence of sward diversity on the performance of grazing animals was confirmed by Soder *et al*. [2007] and Edouard *et al*. [2007]. The presence of herbs and specific plant species in the sward positively influences the fatty acid composition of milk and meat, with a particular influence on health promoting substances, such as polyunsaturated fatty acids. The greatest advantage of pasture-based milk and meat production is obtaining a product with higher content of unsaturated fatty acids and vitamins, known to be beneficial for human health [Jahreis *et al*. 1997, Enser *et al*. 1998, Bugaud *et al*. 2001, Martin *et al*. 2004, Couvreur *et al*. 2006, Strzałkowska *et al*. 2009abc]. Pastushenko *et al*. [2000] have shown that pasture feeding in organic beef and veal production improved the quantity and composition of polyunsaturated fatty acids of meat. Wood *et al*. [2003] reviewed the information about fatty acid composition of pork, beef and lamb and concluded that feeding grass elevates the content of polyunsaturated fatty acids and vitamin E. Raziminowicz *et al*. [2006] has shown that beef from pastured cattle is rich in n-3 fatty acids and has a better ratio of n-6/n-3 fatty acids than beef from other origins. Adnoy *et al*. [2005] confirmed that meat from lambs raised in extensive systems on unimproved mountain pastures had significantly better chemical content and sensory quality compared to meat from lambs grazing on cultivated lowland pastures. Fraser *et al*. [2009] reported that pasture type had a greater effect than breed on fatty acid composition, meat colour, stability and vitamin E content. Lourenco *et al*. [2005] showed that feeding of forages from semi-natural meadows resulted in better composition of milk fatty acids, compared to forage from intensively managed grasslands.

It can be concluded that the type of sward grazed has a greater influence on animal performance and meat and milk quality than breed. Species-rich, diverse grasslands allow for the production of high quality, health promoting animal products.

The examples cited above indicate that in most cases, extensive grazing is a useful tool to maintain valuable grassland biocenoses and to preserve open landscapes. In order to encourage farmers to continue these practices, extensive grazing must also be technically and economically sustainable. In this context, the findings of Isselstein *et al*. [2007] who examined the effects of grazing intensity on animal production and diverse conservation aspects are particularly promising. They concluded that biodiversity-targeted extensive grazing systems have the potential to be integrated into modern livestock production systems, as individual livestock performance was comparable to that in a system using moderate grazing intensity.

Dillon *et al*. [2005] studied the feasibility of pasture-based milk production systems in temperate regions. They indicated that such systems were characterized by lower unit production costs, through lower feed and labour expenses, as well as reduced capital investment. The systems utilizing grazed pasture are useful in regions where the potential production of pasture is high, variation in seasonal pasture supply and quality is low, and where large areas of land are available at relatively low cost. Pasture-based systems allow for greater sustainability, increase product quality, improve animal welfare and increase labour efficiency. The production of green forage from permanent grassland consumes less energy than crop cultivation, with relatively high energy and protein yields. As a result, low-input pasture provides cheap green forage [Soder *et al*. 2007]. Kasperczyk [2008] emphasizes, that economical rationalization of pro-ecological use of meadows and pastures is possible only under sustained management and should be supported by further, reliable scientific investigations.

It seems that extensive grazing can be a competitive agricultural practice in areas less suitable for intensive agriculture. Frelich *et al*. [2008] surveyed the impact of grazing on milk performance and health of dairy cows in sub-mountain areas and found that health status of animals kept seasonally on pasture was significantly better as compared to that of cows fed with total mixed ration. They concluded that seasonal pasture is beneficial for milk production and ensures better welfare of grazed cattle. Bugaud *et al*. [2001] and Collomb *et al*. [2002] also found dairy cattle pasturing in unfavourable areas to be profitable for milk production. They concluded that careful planning and implementation of pasture systems allows for the reconciliation of economic effectiveness with environmental goals, as was also shown by Lapointea *et al*. [2000]. The latter authors presented an example from islands in south Quebec (North America), where the introduction of rotational grazing allowed for the simultaneous growth of duck populations and an increase of beef production, while soil erosion was reduced.

Despite the possible economical advantages of extensive grazing systems, some financial support appears to be needed in order to support this kind of agricultural land use. According to Mills *et al*. [2007], economic analysis has indicated that financial support for farmers is essential to reconcile sustainable grazing systems with high biodiversity. Isselstein *et al*. [2005] also raise the issue of compensation payments for farmers to support grass production on high-biodiversity swards. Moreover, Nilsson [2009] concludes that biodiversity restoration and conservation costs differ between geographical areas. Therefore, financial support must be suited to local conditions. In any case, the beneficial economic effects of low-input grazing systems would be a strong argument in persuading farmers to maintain or restore this kind of activity.

The socio-economic aspect of animal use for biodiversity protection has been investigated by several authors [Gandini and Villa 2003, Rook *et al*. 2004]. Duncan [2005] also reviewed some papers dealing with the co-influence of farm animals and biodiversity. They concluded that agri-environmental schemes including the use of grazing animals could be beneficial for farmers, nature conservation and communities. By re-establishing common property regimes, and providing carefully designed economic and institutional incentives for a revival of transhumance, over-grazing and under-grazing would be avoided on the local scale, and habitats would be preserved for endemic flora and fauna. Warda and Rogalski [2004] suggest another important benefit of low-input, pasture-based animal production systems. They stress the aesthetic and leisure importance of pastures, as well as of the animals grazing on them. They also mention the social role of pasture management in maintaining cultural heritage and restituting local animal breeds.

Many authors encourage the use of local breeds of cattle, horses, sheep and even geese for low-input pasture management [Bartoszuk *et al*. 2001, Warda and Rogalski 2004, Groberek 2005]. The use of these breeds for landscape protection would create a niche for threatened breeds and would support animal biodiversity. Another aspect of the use of native breeds, besides the preservation or restoration of animal genetic resources, is the production of region-specific products, labelled as Protected Designation of Origin – PDO. The higher price of these goods would encourage farmers to maintain a production system which is beneficial for biodiversity and environmental protection. In this context, Warda and Rogalski [2004] mention that farmers specialized in animal production based on grassland are also seen as active ecologists, protecting the environment and the natural landscape.

Conclusions

Animal grazing is essential for the growth of green biomass and composition of plant communities on grasslands. Grazing creates favourable conditions for the formation of habitat structure preferred by many endangered birds, small mammals and invertebrates. As a result, grazing animals have a positive impact on biodiversity of grasslands. As well as the beneficial impact on biodiversity, extensive grazing contributes to the aesthetic and leisure importance of pastures.

Inappropriate use of pasture – both overgrazing and undergrazing – poses a threat for its biodiversity. Thus, both abandonment and overly intensive management of pastured grassland are harmful for biodiversity and should be avoided. Light grazing can be a tool to maintain or enhance biodiversity of grazed areas. The practice can also contribute to the production of healthy food of high quality.

Animal grazing can be used as a tool to limit the expansion of weeds and shrubs in open landscapes, but in most cases cannot stop or reverse natural succession. Thus, for purposes of biodiversity conservation, grazing should be combined with other practices, such as mowing, cutting or burning. The question of which method or combination of methods is most suitable and most feasible in a particular area, depends on local biological and socio-economic factors.

The conservation and protection of pastures and meadows requires the careful selection of grazing management and appropriate number of grazing animals. Grazing species differ in their preference of habitat and plant species, which can enable the effective use of mixed grazing systems with different animal species.

The continuation of extensive pasture practices by farmers requires financial aid and greater social and political support, especially where large areas are concerned. Research findings suggest that existing agro-environment schemes based only on blanket stocking rates are too crude to increase plant diversity and that site conditions must also be taken into consideration. Moreover, the method of financial support must be suited to local conditions. Local authorities and farmers should co-operate to obtain funds for appropriate agro-environment schemes. Government policies in this area need to be continuously reviewed with respect to biological, environmental and economic impacts. The design, implementation, monitoring and effects of agricultural policies must be constantly evaluated and improved.

Strategic research is required into methods of achieving compliance with environmental protection and sustainable agriculture legislation in grassland areas. Therefore, there is a need for comprehensive research programmes combining ecology, botany, agronomy, animal production and economics. The fields of interest include not only interactions between grazing animals and biotic and abiotic elements of grazed area, but also interrelationships with adjacent wild and agricultural biocenoses. This touches on the subject of close cooperation between agricultural and conservation experts. The research should include both field experiments and development of appropriate models, allowing for design of agro-environmental schemes aimed at the protection of grassland biocecenoses.

REFERENCES

1. ABAYE A.O., ALLEN V.G., FONTENOT J.P., 1994 – Influence of grazing cattle and sheep together and separately on animal performance and forage quality. ***Journal of Animal Science*** 72, 1013-1022.
2. ADNOY T., HAUG A., SORHEIM O., THOMASSEN M.S., VARSZEGI Z., EIK L.O., 2005 – Grazing on mountain pastures – does it affect meat quality in lambs? ***Livestock Production Science*** 94, 25-31.
3. ALTIERI M.A., 1999 – The ecological role of biodiversity in agroecosystems. ***Agriculture, Ecosystems and Environment*** 74, 19-31.

4. ANIMUT G., GOETSCH A.L., 2008 – Co-grazing of sheep and goats: Benefits and constraints. ***Small Ruminant Research*** 77(2-3), 127-145.
5. ANIMUT G., GOETSCH A.L., AIKEN G.E., PUCHALA R., DETWEILER G, KREHBIEL C.R, MERKEL R.C., SAHLU T., DAWSOND L.J., JOHNSON Z.B., GIPSON T.A., 2005 – Performance and forage selectivity of sheep and goats co-grazing grass/forb pastures at three stocking rates. ***Small Ruminant Research*** 59, pp: 203–215.
6. BAILEY D.W., 1999 – Influence of species, breed and type of animal on habitat selection. In: Grazing Behaviour of Livestock and Wildlife Symposium. (K. Launchbaugh**,** K. Sanders, and J. Mosley**,** Eds.**).** Moscow, ID, USA, 101-108.
7. BAILEY D.W., DUMONT B., WALLIS DE VRIES M.F., 1998 – Utilization of heterogeneous grasslands by domestic herbivores: theory to management. ***Annales de Zootechnie*** 47, 321-333.
8. BARTOSZUK H., DEMBEK W., JEZIERSKI T., KAMIŃSKI J., KUPIS J., LIRO A., NAWROCKI P., SIDOR T., WASILEWSKI Z., 2001 – Spasanie podmokłych łąk w dolinach Narwi i Biebrzy jako metoda ochrony ich walorów przyrodniczych. In Polish. Biblioteczka Wiadomości IMUZ, no. 98 (PL).
9. BIGNAL E.M., MCCRACKEN D.I., CURTIS D.J., 1994 – Nature conservation and pastoralism in Europe. Proceedings of the Third European Forum on Nature Conservation and Pastoralism. 21-24 July 1992, University of Pau, France. Joint Nature Conservation Committee, Peterborough, UK.
10. BOHNER A., 2007 – Phytodiversity in the intensive and extensive used valley meadows. Biodiversitat in Osterreich, 28 Juni 2007, 29-36, Hohere Bundeslehr- und Forschugsanstalt fur Landwirtschaft Raumberg-Gumpenstein, A-8952 Irdning.
11. BUGAUD CH., BUCHIN S., COULON J.-B., HAUWUY A., DUPONT D., 2001– Influence of the nature of alpine pastures on plasmin activity, fatty acid and volatile compound composition of milk. ***Lait*** 81, 401-414.
12. CASASUS I., BERNUES A., SANZ A., VILLALBA D., RIEDEL J.L., REVILLA R., 2007 – Vegetation dynamics in Mediterranean forest pastures as affected by beef cattle grazing. ***Agriculture, Ecosystems and Environment*** 121, 365-370.
13. CELAYA R., OLIVÁN M., FERREIRA L.M.M., MARTÍNEZ A., GARCÍA U., OSORO K., 2007 – Comparison of grazing behaviour, dietary overlap and performance in non-lactating domestic ruminants grazing on marginal heathland areas. ***Livestock Science*** 106, 271-281.
14. COLLINS W.B., 1989 – Single and mixed grazing of cattle, sheep and goats. PhD Thesis. University of Lincoln, New Zealand, 195 pp.
15. COLLOMB M., BUTIKOFER U., SIEBER R., JEANGROS B., BOSSET J.-O., 2002 – Correlation between fatty acids in cows' milk produced in the Lowlands, Mountains and Highlands of Switzerland and botanical composition of the fodder. ***International Dairy Journal*** 12, 661-666.
16. COUGHENOUR M.B., 1991 – Spatial components of plant-herbivore interactions in pastoral, ranching and native ungulate ecosystems. ***Journal of Range Management*** 44, 530-542.
17. COUVREUR S., HURTAUD C., LOPEZ C., DELABY L., PEYRAUD J.L., 2006 – The linear relationship between the proportion of fresh grass in the cow diet, milk fatty acid composition, and butter properties. ***Journal of Dairy Science*** 89, 1956-1969.
18. CZEGLÉDI L., RADÁCSI A., 2005 – Overutilization of pastures by livestock. ***Grassland Studies*** 2005/3, 29-35.
19. DEBAYLE J., 2004 – A pastoral sheep farm in Provence expected to manage biodiversity. ***Fourrages*** 179, 447-449.
20. DEL POZO M., OSORO K., CELAYA R., 1998 – Effects of complementary grazing by goats on sward composition and on sheep performance managed during lactation in perennial ryegrass and white clover pastures. ***Small Ruminant Research*** 29, 173-184.

21. DILLON P., ROCHE J.R., SHALLOO L., HORAN B., 2005 – Optimising Financial Return from Grazing in Temperate Pastures. In: Utilisation of grazed grass in temperate animal systems (J.J. Murphy, Ed.) Proceedings of a satellite workshop of the XX[th] International Grassland Congress, Cork, Ireland.
22. DOLEK M., GEYER A., 2002 – Conserving biodiversity on calcareous grasslands in the Franconian Jura by grazing: a comprehensive approach. ***Biological Conservation*** 104(3), pp: 351-360.
23. DUELLI P., 1997 – Biodiversity evaluation in agricultural landscapes: An approach at two different scales. ***Agriculture, Ecosystems and Environment*** 62, 81-91.
24. DUMONT B., ROOK A.J., CORAN CH., RÖVER K.-U., 2007 – Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 2. Diet selection. ***Grass and Forage Science*** 62(2), 159-171.
25. DUNCAN A., 2005 – Farm Animals and Biodiversity. ***Animal Science*** **81**, 187-188.
26. DYRCZ A., OKULEWICZ J., WITKOWSKI J., 1985 – Bird communities on natural eutrophic fen mires in the Biebrza River Valley, N.E.Poland. ***Die Vogelwarte*** 33, 26-52.
27. EDOUARD N., FLEURANCE G., DUNCAN P., DUPONT B., BAUMONT R., 2007 – How does sward accessibility affect intake and feeding choices in horses? In: 58th Annual Meeting of the European Association for Animal Production, Dublin, Ireland, 26-29 August 2007.
28. ENSER M., HALLETT K.G., HEWETT B., FURSEY G.A.J., WOOD O.J.D., HARRINGTON G., 1998 – Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. ***Meat Science*** 49(3), 325-341.
29. EUROPEAN COMMISSION, 2009 – Key figures on Europe, 2009 edition. Eurostat Poket books. ISSN 1830-7892.
30. EVANS R., 1997 – Soil erosion in the UK initiated by grazing animals. A need for a national survey. ***Applied Geography*** 17(2), 127-141.
31. FRASER M.D., DAVIES D.A., VALE J.E., NUTE G.R., HALLETT K.G., RICHARDSON R.J., WRIGHT I.A., 2009 – Performance and meat quality of native and continental cross steers grazing improved upland pasture or semi-natural rough grazing. ***Livestock Science*** 123(1), 70-82.
32. FRELICH J., SLACHTA M., STARY J., 2008 – Milk performance and health response of dairy cows to seasonal pasture in sub-mountain areas. Animal husbandry section. Proceedings of 43[rd] Croatian and 3[rd] International Symposium of Agriculture. Opatija, Croatia, 838-841.
33. GANDINI G.C., VILLA E., 2003 – Analysis of the cultural value of local livestock breeds: a methodology. ***Journal of Animal Breeding and Genetics*** 120(1), 1-11.
34. GEF, 1999-Transhumans for Biodiversity Conservation in the Southern High Atlas Marocco Project, GEF http://www.gefonline.org/projectDetails.cfm?projID=1
35. GORDON I., DUNCAN P., GRILLES P., LECOMPTE T., 1990 – The use of domestic herbivores in the conservation of the biological richness of European wetlands. ***Bulletin of Ecology*** 21, 49-60.
36. GOUGH L., GRACE J.B., 1998 – Herbivore effects on plant species density at varying productivity levels. ***Ecology*** 79(5), 1586-1594.
37. GRANT S.A., SUCKLING D.E., SMITH H.K., TORVELL L., FORBES T.D. A., HODGSON J., 1985 – Comparative studies of diet selection by sheep and cattle: The Hill Grasslands. ***Journal of Ecology*** 73(3), 987-1004.
38. GROBEREK J.J., 2005 – Evaluation of nutritive value of forage from fallow land extensively grazed by polish wrzosowka sheep. Ocena wartości pokarmowej roślinności na gruntach odłogowanych ekstensywnie wypasanej przez owce rasy wrzosówka polska. PhD Thesis, Warsaw Agricultural University. In Polish.
39. GUTMAN M., KAPLAN D., GUTMAN R., 1997 – Restoration and conservation of flora and fauna in the re-flooded Hula Wetland in the Northern Israel, LIFE Third Countries Project no: TCY/97/1L/038, Final Report 1997-2000, www.migal-life.co.il

40. GUZIAK R., LUBACZEWSKA S., 2001 – Ochrona przyrody w praktyce. Podmokłe łąki i pastwiska. Polskie Towarzystwo Przyjaciół Przyrody „proNatura”. Wrocław. In Polish.
41. HAGGAR R., PADEL S., 1996 – Conversion to organic milk production. ***IGER*** (Institute of Grassland and Environmental Research at Aberystwyth) ***Technical Review,*** 4.
42. HANSEN B., ALRŘE H.F., KRISTENSEN E.S., 2001 – Approaches to assess the environmental impact of organic farming with particular regard to Denmark Agriculture. A Review. ***Ecosystems and Environment*** 83, 11-26.
43. HARNETT D.C., 1995 – Role of grazing and fire management in the grassland diversity and production. 50 years of range research revisited, USA, 72-76.
44. HARRIS R.A., 2002 – Sustainability of grazing and mowing as management tools in Western Europe. Experiences in Scotland and the United Kingdom. In: Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April 2002 in Goniadz, Poland.
45. HEINEKEN T., 1990 – Die Ackerwildkraut-Vegetation auf biologisch und konventionell bewirtschafteten Ackerflächen bei Gut Adolphshof (Ldkrs. Hannover). ***Beiträge zur Naturkunde Niedersachsens***, Pp: 38-45.
46. HOFFMANN M., 2002 – Experience with grazing in Flemish nature reserves (Northern Belgium). In: Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April 2002 in Goniadz, Poland.
47. HOFMANN R.R., 1989 – Evolutionary steps of ecophysiological adaptations and diversification of ruminants: a comparative view of their digestive system. ***Oecologia*** 78, 443-457.
48. HOLE D.G., PERKINS A.J., WILSON J.D., ALEXANDER I.H., GRICE P.V., EVANS A.D., 2005 – Does organic farming benefit biodiversity? ***Biological Conservation*** 122, 113–130.
49. ISSELSTEIN J., GRIFFITH B.A., PRADEL P., VENERUS S., 2007 – Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 1. Nutritive value of herbage and livestock performance. ***Grass and Forage Science*** 62(2), 145-158.
50. ISSELSTEIN J., JEANGROS B., PAVLU V., 2005 – Agronomic aspects of biodiversity targeted management of temperate grasslands in Europe: A review. ***Agronomy Research*** 3(2), 139-151.
51. JAHREIS G., FRITSCHE J., STEINHART H., 1997 – Conjugated linoleic acid in milk fat: high variation depending on production system. ***Nutrition Research*** 17(9), 1479-1484.
52. JANKOWSKA-HUFLEJT H., 2007 – Rolno-środowiskowe znaczenie trwałych użytków zielonych. Agro-environmental significance of grasslands. ***Problemy Inżynierii Rolniczej***, 1/2007, 23-34. In Polish.
53. KASPERCZYK M., 2008 – Environmental friendly economy on permanent grassland. ***Prace i Materiały Zootechniczne*** 65, 27-33.
54. KAUFFMAN J.B., KRUEGER W.C., VAVRA M., 1983 – Impacts of cattle grazing streambanks in northeastern Oregon. ***Journal of Range Management*** 36, 683-685.
55. KLEIJN D., BRENDSE F., SMIT R., GILISSEN N., 2001 – Agri-environment schemes do not effectively protect biodiversity in Dutch agricultural landscapes. ***Nature*** 413, 723-725.
56. KOHYANI P.T., BOSSUYT B., BONTE D., HOFFMANN M., 2008- Importance of grazing and soil acidity for plant community composition and trait characterisation in coastal dune grasslands. ***Applied Vegetation Science*** 11(2), 179–186.
57. LAPOINTEA S., GIROUX J.-F., BÉLANGER L., FILION B., 2000 – Benefits of rotational grazing and dense nesting cover for island-nesting waterfowl in southern Quebec. ***Agriculture, Ecosystems and Environment*** 78, 261-272.
58. LENNON J., 1999 – The International Significance of the Cultural Values of the Australian Alps National Parks. Jane Lennon & Associates, Melbourne.

59. LOUCOUGARAY G., BONIS A., BOUZILLÉ J.-B., 2004 – Effects of grazing by horses and/or cattle on the diversity of coastal grasslands in western France. ***Biological Conservation*** 116(1), 59-71.
60. LOURENCO M., VLAEMINCK B., BRUINENBERG M., DEMEYER D., FIEVEZ V., 2005 – Milk fatty acid composition and associated rumen lipolysis and fatty acid hydrogenation when feeding forages from intensively managed or semi-natural grasslands. ***Animal Research*** 54, 471-484.
61. MARTIN B., FEDELE V., FERLAY A., GROLIER P., ROCK E., GRUFFAT D., CHILLIARD Y., 2004 – Effects of grass-based diets on the content of micronutrients and fatty acids in bovine and caprine dairy products (A. Lúscher, B. Jeangros, W. Kessler, O. Huguenin, M. Lobsiger, N. Millar, D. Suter, Eds.) In: Land Use Systems in Grassland Dominated Regions. Proceedings of the 20th General Meeting of the European Grassland Federation, Luzern, Switzerland. ***Grassland Science in Europe*** 9, 876-886.
62. MARTY J., 2006 – Grazing effects on biodiversity and ecosystem function in California vernal pool grasslands. CAL-PAC society for range management symposium-grazing for biological conservation. Conference materials.
63. MAZUREK Ł., 2002 – Wpływ wypasu bydła oraz presji drapieżników na liczebność i sukces lęgowy ptaków wodnobłotnych gniazdujących na powierzchni „Brzostowo" w 2002 r. WWF, Białystok.
64. MAZUREK Ł., 2003 - Wpływ wypasu bydła oraz presji drapieżników na liczebność i sukces lęgowy ptaków wodnobłotnych gniazdujących na powierzchni „Brzostowo" w 2003 r. WWF, Białystok.
65. MC LAUGHLIN A., MINEAU P., 1995 - The impact of agricultural practices on biodiversity. ***Agriculture, Ecosystems & Environment*** 55 (3), 201-212.
66. MILLS J., ROOK A.J., DUMONT B., ISSELSTEIN J., SCIMONE M., WALLIS DE VRIES M.F., 2007 – Effects of livestock breed and grazing intensity on grazing systems: 5. Management and policy implications. ***Grass and Forage Science*** 62(2), 429-436.
67. NILSSON F.O.L., 2009 – Biodiversity on Swedish pastures: Estimating biodiversity production costs. ***Journal of Environmental Management*** 90, 131-143.
68. NIŻNIKOWSKI R., 2003 – Schafhaltung in den Mittel- and Osteuropäischen Ländern, Bundesanstalt für alpenländischen Landwirtschaft in Gumpentstein, Austria, BAL-Bericht I, 3-6.
69. NOWAKOWSKI P., ĆWIKŁA A., GAWECKI J., ŁUCZAK W., PIASECKI M., 1999 – Year-round grazing of the four herbivore species on degenerated shrubby pasture in Sudetes, Livestock Farming Systems, Proceedings of the 5th International Symposium of EEAP, Posieux, Switzerland, 191-193.
70. NOWAKOWSKI P., DOBICKI A., ANIOŁOWSKI K., POPIEL J., MORDAK R., TWARDOŃ J., 2000 – Pobranie składników pokarmowych przez krowy matki i cielęta z naturalnego pastwiska górskiego. In Polish, summary in English. ***Zeszyty Naukowe Akademii Rolniczej we Wrocławiu***, Konferencje XXIV, No 375, 179-185.
71. OLFF H., RITCHIE M.E., 1998 – Effects of herbivores on grassland plant diversity. ***Trends in Ecology & Evolution*** 13(7), 261-265.
72. PASTUSHENKO V., MATTHES H.-D., HEIN T., HOLZER Z., 2000 – Impact of cattle grazing on meat fatty acid composition in relation to human nutrition. Proceedings of the 13th International IFOAM Scientific Conference, 293-296.
73. PECO B., SANCHEZ A.M., AZCARATE F.A., 2006 – Abandonment in grazing systems: Consequences for vegetation and soil. ***Agriculture, Ecosystems and Environment*** 113, 284-294.
74. POSCHLOD P., WALLIS DE VRIES M.F., 2002 – The historical and socioeconomic perspective of calcareous grasslands-lessons from the distant and recent past. ***Biological Conservation*** 104(3), 361-376.

75. RAZIMINOWICZ R.H., KREUZER M., SCHEEDER M.R.L., 2006 – Quality of retail beef from two grass-based production systems in comparison with conventional beef. ***Meat Science*** 73, 351-361.
76. ROGALSKI M., WIECZOREK A., KARDYNSKA S., PLATEK K., 2001 – Effect of grazing animals on floristic biodiversity of the sward. In Polish, summary in English***. Zeszyty Problemowe Postępów Nauk Rolniczych*** 478, 65-70.
77. ROOK A. J., DUMONT B., ISSELSTEIN J., OSORO K., WALLIS DE VRIES M.F., PARENTE G., MILLS J., 2004 – Matching type of livestock to desired biodiversity outcomes in pastures: a review. ***Biological Conservation*** 119, 137-150.
78. RUSSELL J.R., BETTERIDGE K., COSTAL D.A., MACKAY A.D., 2001 – Cattle treading effects on sediment loos and water infiltration. ***Journal of Range Management*** 54, 184-190.
79. SANDERSON F.J., KLOCH A., SACHANOWICZ K., DONALD P.F., 2009 – Predicting the effects of agricultural change on farmland bird populations in Poland. ***Agriculture, Ecosystems and Environment*** 129, 37-42.
80. SAWICKI B., 2006 – The role of fodder, landscape and tourist constant grasslands at the Kozłowiecki Landscape Park. ***Annales of the University of Maria Curie Sklodowska***, Sec. E, 61, 361-367.
81. SCIMONE M., ROOK A.J., GAREL J.P., SAHIN N., 2007 – Effects of livestock breed and grazing intensity on grazing systems: 3. Effects on diversity of vegetation. ***Grass and Forage Science*** 62(2), 172-184.
82. SEHESTED J., STOEGAARD K., DANIELSEN V., ROEPSTORFF A., MONRAD J., 2004 – Grazing with heifers and sows alone or mixed: herbage quality, sward structure and animal weight gain. ***Livestock Production Science*** 88(3), 223-238.
83. SMIT H.J., METZGER M.J., EWERT F., 2008 – Spatial distribution of grassland productivity and land use in Europe. ***Agricultural Systems*** 98, 208-219.
84. SODER K.J., ROOK A.J., SANDERSON M.A., GOSLEE S.C., 2007 – Interaction of plant species diversity on grazing behaviour and performance of livestock grazing temperate region pastures. Congrčs Beyond the Plant: Biodiversity Impacts on the Grazing Animal. CSSA Symposium (11/2005) 47(1), 416-425.
85. SOEGAARD K., SEHESTED J., DANIELSEN V., 2000 – Mixed grazing with heifers and pregnant sows. ***Grassland Science in Europe*** 5, 359-361.
86. SOUSSANA J.-F., DURU M., 2007-Grassland science in Europe facing new challenges: biodiversity and global environmental change. ***Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*** 2(2), 1-11.
87. STRZAŁKOWSKA N., JÓŹWIK A., BAGNICKA E., KRZYŻEWSKI J., HORBAŃCZUK J.O., 2009a – Studies upon genetic and environmental factors affecting the cholesterol content of cow milk. I. Relationship between the polymorphic form of beta-lactoglobulin, somatic cell count, cow age and stage of lactation and cholesterol content of milk. ***Animal Science Papers and Reports*** 27 (2), 95-103.
88. STRZAŁKOWSKA N., JÓŹWIK A., BAGNICKA E., KRZYŻEWSKI J., HORBAŃCZUK J.O., 2009b – Studies upon genetic and environmental factors affecting the cholesterol content of cow milk. II. Effect of silage type offered. ***Animal Science Papers and Reports*** 27 (3), 199-206.
89. STRZAŁKOWSKA N., JÓŹWIK A., BAGNICKA E., KRZYŻEWSKI J., HORBAŃCZUK K., PYZEL B., HORBAŃCZUK J.O., 2009c – Chemical composition, physical traits and fatty acid profile of goat milk as related to the stage of lactation. ***Animal Science and Reports*** 27 (4), 263-272**.**
90. TALLOWIN J.R.B., ROOK A.J., RUTTER S.M., 2005 – Impact of grazing management on biodiversity of grasslands. ***Animal Science*** 81, 193-198.

91. THUROW T.L., 2005 – Biodiversity: Grazing practices, soil management. Encyclopaedia of Animal Science. Wilson G. Pond, Allan W. Bell, p. 499.
92. VAN BRAECKEL A., BOKDAM J., 2002a – Grazing as a conservation management tool in peatland. In: Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April in Goniadz, Poland.
93. VAN BRAECKEL A., BOKDAM J., 2002b – Habitat selection of cattle and horses in the Lower Basin of the Biebrza National Park. In: Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April in Goniadz, Poland.
94. VAN OENE H., VAN DEURSEN E.J.M., BERENDSE F., 1999 – Plant-herbivore interactions and its consequence for succession in wetland ecosystems: a modelling approach. ***Ecosystems* 2**, 122-138.
95. VAN WIEREN S.E., BAKKER J.P., 2008 – The impact of browsing and grazing herbivores on biodiversity. In: The Ecology of Browsing and Grazing, Springer Berlin Heidelberg, 263-292.
96. VANDERMEER J., PERFECTO I., 1995 – Breakfast of Biodiversity: the truth about rainforest destruction. A Food First Book, Oakland, p. 185.
97. VAVRA M., 2005 – Biodiversity: Grazing management. Encyclopaedia of Animal Science. Wilson G. Pond, Allan W. Bell, p. 127.
98. VERHULST J., BÁLDI A., KLEIJN D., 2004 – Relationship between land-use intensity and species richness and abundance of birds in Hungary. ***Agriculture, Ecosystems and Environment*** 104, 465-473.
99. WALLIS DE VRIES M.F., PARKINSON A.E., DULPHY J.P., SAYER M., DIANA E., 2007 – Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 4. Effects on animal diversity. ***Grass and Forage Science*** 62(2), 185-197.
100. WARDA M., ROGALSKI M., 2004 – Grazing animals as an element of natural landscape. ***Annales of Univeristy of Maria Curie Sklodowska***, Sec. E, 59(4), 1985-1991.
101. WASILEWSKI Z., 2002 – Typological characteristics of grassland and way of use the priority plant communities to preserve their natural assets. In: Current problems of wetland conservation. Natural values of wetlands and their agricultural use. ***Water-Environment-Rural Areas. Dissertations and monographs*** 4, 62-81. In Polish.
102. WASILEWSKI Z., 2006 – An evaluation of sward quality in grazed grasslands of various habitats. ***Water-Environment-Rural Areas*** 6(1) (16), 413-421. In Polish.
100. WOOD J.D., RICHARDSON R.I., NUTE G.R., FISHER A. V., CAMPO M.M., KASAPIDOU E., SHEARD P.R., ENSER M., 2003 – Effects of fatty acids on meat quality: a review. ***Meat Science*** 66, 21-32.
101. ZIMKOVA M., KIRILOV A., ROTAR I., STYPIŃSKI P., 2007 – Production and quality of seminatural grassland in South-eastern and Central Europe. ***Grassland Science in Europe*** 12, 15-26.