University of South Bohemia in České Budějovice
Faculty of Science
Department of Ecosystems Biology

Jihočeská univerzita v Českých Budějovicích
Přírodovědecká fakulta
Katedra biologie ekosystémů

Zuzana Mašková

Functioning of Mountain Meadows under Different Management Impacts

Funkce horských luk při různých způsobech jejich obhospodařování

Ph.D. Thesis
Doktorská disertační práce

Supervisor: RNDr. Jan Květ, CSc.
Faculty of Science, University of South Bohemia, České Budějovice
Institute of Systems Biology and Ecology, Academy of Sciences
of the Czech Republic, Třeboň

České Budějovice 2008

Mašková, Z., 2008. Functioning of Mountain Meadows under Different Management Impacts. Ph.D. Thesis, in English. - 175 pp., Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic.

Annotation:
Influence of different management practices on the mountain meadows communities and possibilities of their maintenance in the National Park, Protected Landscape Area and Biosphere Reserve of Šumava are discussed. The aim of the study was to compare the effect of mulching of grassland vegetation with those of traditional mowing or leaving a grassland fallow. The results of a ten-year field experiment are presented - the changes of plant biomass, plant community structure and physical properties of the soil A horizon. Acceptable possibilities of mulching as an alternative technique for the maintenance of secondary grassland in the Bohemian Forest are proposed on the basis of data obtained during the experiment.

Financial support:
The study was accomplished within the project no. VaV/620/5/97 "The Effect of Changes in Cultivation Practices and Atmospheric Deposition on Biosphere Quality in Mountain and Submontane Areas of the Bohemian Forest", supported by the Ministry of Environment of the Czech Republic, and the Project no. 206/99/1410 of the Grant Agency of the Czech Republic "Functioning of Mountain Meadows under Different Management Impacts".

I declare hereby that I worked out this thesis on my own only with the use of the cited literature and other cited sources.

Prohlašuji, že v souladu s § 47b zákona č. 111/1998 Sb. v platném znění souhlasím se zveřejněním své disertační práce, a to v nezkrácené podobě elektronickou cestou ve veřejně přístupné části databáze STAG provozované Jihočeskou univerzitou v Českých Budějovicích na jejích internetových stránkách.

Datum:

Zuzana Mašková

Poděkování:
Ráda bych poděkovala všem kolegům a spolupracovníkům, ze kterých se za léta společné práce stali skvělí přátelé. Za všechny bych pak ráda jmenovala svého školitele Jana Květa, který mi byl po celá léta po odborné a zejména lidské stránce nedocenitelnou oporou.

CONTENTS

Summary:

Possibilities of the mountain meadow maintenance in the National Park, Protected Landscape Area and Biosphere Reserve of Šumava are discussed in the present Ph.D. Thesis.

Secondary grasslands in the Bohemian Forest contribute substantially to the characteristic landscape pattern and biodiversity of these mountains. The stability and species diversity of these communities fully depend on human management. Proposals for the secondary grassland management should primarily come out from a detailed acquaintance with the actual stage of its vegetation. A large pilot project of the non-forest vegetation mapping was accomplished in the former military area of Dobrá Voda in 1996. The main types of the montane and submontane grassland vegetation were defined according to the presence of dominant plant species; each classification unit was located on the moisture nutrient gradient and in the appropriate successional sere.

Mountain meadow production cannot be as high as that in lowland areas. For that reason harvesting of such meadows is less favourable economically. Thereby large areas of mountain meadows are in an unsatisfactory condition in the Bohemian Forest. As a rule, they are mown only occasionally; when they are, relatively large quantities of organic matter and mineral nutrients are exported with the hay while their recycled proportions are small (this is due to difficult availability of remote forest-free areas for application of the complementary fertilizer). Nevertheless, the importance of mountain meadows and pastures is not only economic. They primarily have landscape-forming functions. The long-term strategy of mountain secondary grassland management should aim at soil conservation, biodiversity maintenance and protection of water resources, especially in large protected areas.

Alternative management forms are needed for the conservation of the secondary grassland areas as landscape-forming elements, and also of the maintenance of their biodiversity. These forms of management should be acceptable both economically and ecologically. Mulching has been expected to become one of the prospective practices applicable to the management of mountain grassland. However, only little qualified information is available on the effects of mulching on mountain grassland.

A large pilot-scale field experiment has been carried out in the Šumava National Park since 1997. The aim of this experiment has been to compare the effects of mulching of grassland vegetation with those of traditional mowing or leaving meadows fallow. Before initiation of the research project the data on the history and development of the study area were extracted from available literature and, especially, from museum archives. These data summarize the area's history

from the first colonization during 14th century to the present exploitation. A reconstruction of the post World War II changes in land cover/land use within the study site (an enclave amidst forests) has been made. The evaluation of the last fifty years' development has been based on a quantification of changes identified by visual interpretation of a time series of aerial photographs, and by field surveys.

At the beginning of the experiment, the main vegetation units all over the forest-free area of the study site were mapped and an inventory of vascular plants was carried out.

Throughout the ten-year duration of the experiment, the selected ecosystem components and processes were monitored: plant biomass, plant community structure, decomposition of plant biomass and cycling of essential biogenic elements, physical properties of the soil A horizon and microclimatic processes in the grass cover. A specialized partial study has been made to test the possibility of using the Normalized Difference Vegetation Index (NDVI) for distinguishing between differently managed mountain grassland sites. In the process of the data evaluation, the climatic characteristics of the study area and potential relationships between the monitored components were taken into account.

According to the results, the meadow management strongly influenced the aboveground biomass, its yearly harvest by mowing reduced it significantly. A decrease of the species richness was observed in the fallow plot. The mulched plot exhibited slightly higher values of Shannon diversity and evenness compared to both the mown and fallow plots. In this experiment, the main effects of the treatments on plant species diversity seem to be the shifts of dominance among certain species.

During the vegetation season, there were significant differences between higher soil temperatures in the mown plot and lower temperatures in the fallow plot. In the mulched plot, the soil temperature varied between those of the other two plots, being closer to that in the fallow plot. The type of management influenced the soil A horizon moisture content only when the effect of precipitation was not strong. In this case, the soil moisture content was highest in the fallow plot and lowest in the mown one. Soil moisture in the mulched plot varied between those in the other two plots, being closer to that in the mown plot.

The fundamental conclusions of this study may be summarized as follows:

- The production of mountain meadow plant biomass is low on the whole, regular mowing without complementary fertilization further gradually diminishes the production of aboveground biomass. Mulching moderates the decline of aboveground biomass production.

- The mulched plant material persists on the plot for more than one vegetation season, but its decomposition is faster than the decomposition of standing dead material and litter in the fallow plot.
- The different management was reflected, at first, in different cover degrees of the dominant species. The long-term holding fallow of the meadow resulted in a gradually decreasing species richness of the meadow plant community.
- For distinguishing between differently managed mountain meadows, it is possible to use, on a local scale, the Normalized Difference Vegetation Index, which exhibits a linear relationship with green aboveground biomass during the period before the application of the respective treatments.

It has to be recognized that data obtained during the ten-year experiment are not fully sufficient for reliable estimation of the possible influence of different treatments on mountain meadow communities. The experimental site is situated at a relatively high altitude with a short growing season, relatively low temperatures and a nutrient-poor acidic soil. The responses of the plant community to the different types of management applied are slow and seem to be largely controlled by the weather conditions during the current or preceding vegetation seasons. More precise information of this kind can result from long-term experiments, involving more than ten years of experimental management application

Acceptable conditions for the application of mulching as an alternative technique for the maintenance of secondary grassland in the Bohemian Forest were proposed on the basis of data obtained during the experiment:

Annual harvesting of oligotrophic meadows without a simultaneous nutrient supplement can cause a decline of plant species diversity. The nutrients released from the mulched biomass and left on the spot (at least at intervals of a few years) can retard the oligotrophication of regularly mown meadows, simultaneously preventing the potential impoverishment of the species diversity of these meadows.

If regular mowing of mountain meadows is not feasible for economic or technical reasons, mulching can represent an economically advantageous alternative. It will temporarily check the successional changes that sooner or later occur in the meadows left fallow. Mulching can also be used as a simple treatment retarding the decrease of species diversity and productivity in regularly mown, but unfertilised, mountain meadows.

1. Introduction

The largest part of the Bohemian Forest (the Šumava Mts.) was covered with primary forests before human colonisation. Thanks to a long-lasting landscape management during the gradual colonisation of the mountain region, a sensitive equilibrium has established itself between humans and nature. The present mosaic pattern of forests, meadows, pastures, and small groves has resulted from a combination of various human activities. Important for the formation and a sustainable existence of the species rich mountain grasslands has especially been the low-impact agriculture practised by small farmers who managed the grasslands as hay meadows or pastures, or a combination of both. These newly formed and harmonious communities encompass not only such plant species that are characteristic of original forest stands, spring-heads, wetlands and river valleys, but also species introduced by humans (Kučera, 1995).

The stability and species diversity of the mountain meadow communities thus fully depend on human management. Breaking off from the traditional mountain farming practices threatens the mountain meadows - scattered shrubs and trees gradually develop into forest, which was cleared in the past in order to give way to grassland. This development endangers the existence of those plant and animal species, populations, and communities, which can survive only in open biotopes.

The risk of disturbing the established balance between humans and nature increased mainly after World War II. Traditional low impact agriculture was forcibly discontinued when the borderland territory became almost depopulated. Many villages and hamlets were abandoned and large areas both of grassland and arable land were left fallow. Former meadows and pastures markedly started to be grown over by tree seeding. Subsequently, in the 1950's, the forested area of the Bohemian Forest markedly increased (Kučera and Guth, 1998). The remaining farmers gradually adopted a new wave of large-scale farming, heavily subsidised by the state. Many small groves, borderlines of grassland with shrubs separating individual plots, and heaps of stones were removed from the cultivated plots and disappeared from the countryside. Most of the plant communities of the still managed or restored meadows were thus degraded by excessive doses of manure and fertilisers, and by superfluous drainage of the mountain grassland.

The beginning of the 1990's brought fundamental changes to the agriculture in Czech mountain regions. The heavy state subsidies were reduced, in consequence only a few people remained interested in farming. Though the interest in mountain meadows and pastures maintenance has again increased (Zemek and Heřman, 1999), degradation of the forest-free areas due to the absence or unsuitability of agricultural management still has not been stopped. Therefore new alternative practices of a non-profit management of mountain meadows and pastures are needed.

Goals of the Thesis:

This thesis intends to:

- **Characterize the past use and present state of the study area.**
- **Compare the development of normally managed (mown), mulched and fallow plots.**
- **Establish potential negative effect of meadow mulching or leaving them fallow on the meadow environment.**
- **Propose acceptable use of mulching as an alternative technique of secondary grassland maintenance in the Bohemian Forest.**

2. Maintenance of the secondary grassland areas in the Šumava National Park, Protected Landscape Area and Biosphere Reserve

Mountain meadow production cannot be as high as that in lowland areas. Nevertheless the importance of mountain meadows and pastures is not only economic. They should primarily have landscape-forming functions. The long-term strategy of mountain secondary grassland management should aim at soil conservation, biodiversity maintenance and protection of water resources, especially in large protected areas. Alternative management forms are needed in the interest of conservation of the grassland areas as landscape-forming elements, and also of the maintenance of their biodiversity. These forms of management should be acceptable both economically and ecologically.

2.1. Mapping of the flora and vegetation

Proposals of secondary grassland management should primarily come out from a detailed acquaintance with the actual state of its vegetation. Some specialized studies dealt with the mapping of forest-free areas in the National Park and Protected Landscape Area of Šumava (e.g., Eiblová, 1993; Fošumová, 1995; Hakr, 1995; Havlíková, 1995; Randáková, 2003). Needed are not only the understanding of the plant community composition (phytocenological classification) but also the knowledge of the basic characteristics of the surrounding environment. The main types of the montane and submontane vegetation of the Bohemian Forest were defined according to the presence of dominant plant species, each classification unit was located on the moisture and nutrient gradient (possibly also ruderalization) and successional stage (Bufka *et al.*, 2000).

A large pilot project of the grassland vegetation mapping, based on the above-mentioned classification, was accomplished in the National Park, Landscape Protected Area and Biosphere Reserve of Šumava in 1996. The most important forest-free areas were mapped in the former military area of Dobrá Voda during this study. At present, most of the grassland areas are described, continuous updating is in progress.

Prach, K., Bufková, I., Zemek, F., Heřman, M., Mašková, Z., (2000).
Grassland vegetation in the former military area Dobrá Voda, the Šumava National Park. Silva Gabreta 5, 103-113.

Secondary grasslands in the Bohemian Forest contribute substantially to a characteristic landscape pattern and biodiversity of the mountains. Vegetation units in 17 grassland areas have been mapped around former settlements in the former military training zone. The vegetation units (31) have been defined mostly according to dominant species and they were related to moisture and nutrient gradients and successional state. For particular units an optimum management has been suggested, reflecting interests of both nature conservancy and agricultural use.

This paper is being submitted as parts of this Ph.D. Thesis.

2.2. Proposals for a suitable agricultural management

The most suitable management for individual vegetation types is recommended on the basis of executed vegetation maps and with regard to the occurrence of important plant species. Improvement, or at least maintenance, of the plant community quality is the basic criterion of the management suitability, whereby the support to the important and endangered plant species is desirable. Subsequently examined are the modifications taking into account other facts - the presence of important animal species (namely avifauna and insects), water conservation, etc.

Such an "ideal type of management" primarily resolves the nature conservation demands. These proposals do not take account of real possibilities of management at a given locality. The main reason of such an order of preferences is the fact that the local farmers` requirements can change markedly within a few years (e.g., in the context of state subsidies). A hardly practicable management can be readily implemented in the future under different economic conditions. Moreover, the management proposals are continuously updated according to the results of research studies, which investigate the influence of the management techniques on selected components of the mountain meadow ecosystems (e.g., Boudová, 1995; Hakrová, 2003; Marková, 2002; Montagová, Z., 2005; Pojerová, 2002; Procházka, 1996; Schusserová, A., 2003; Šraitová, 2000).

2.3. Accomplishment of the proposed agricultural management

Close cooperation with local farmers is established after proposing an "ideal type of management". Those farmers who manage the chosen land or neighbouring plots obtain financial compensation. The "optimal type of management" is proposed following the evaluation of the farming limits; available state subsidies are taken into account. Demands for the terms of cutting, terms and

intensity of pasture, making of paddocks, etc., are, if possible, accommodated. The primary aim during the whole process is the improvement of anthropogenic grassland communities. If conditions warranting the improvement cannot be fulfilled, any violation of nature conservation requirements, leading to deterioration or damage is prohibited. In this way, the management is a compromise respecting the farmers` possibilities on the one hand and nature conservation requirements on the other.

2.4. Mulching as an alternative method of meadows maintenance

At present, most mountain meadows of the Czech Republic are in an unsatisfactory condition. As a rule, they are mown only occasionally; when they are, relatively large quantities of organic matter and mineral nutrients are exported with the hay while their recycled proportions are small. This is due to the small numbers of livestock grazing on the mountain grassland and to a difficult availability of remote forest-free areas for application of the complementary fertilizer. The ecosystem is enriched only with the nutrients from the disintegrating bedrock (namely from soil skeleton) and by substantial amounts of nitrogen contained in rain, fog and snow water (Eliáš, Tesař and Buchtele, 1993; Tesař, Eliáš and Šír, 1995). Acid rain leaches cations out of the soil and makes it base-poor and acidic (Ripl *et al.*, 1994).

A possible partial remediation can be the recycling of a large proportion of nutrients and organic matter contained in the plants. This is achieved by mulching, i.e., leaving finely cut mown green plant parts on the site to decompose and release a large proportion of their mineral nutrient contents (Kitou and Yoshida, 1994). The process of oligotrophication (nutrient deprivation) of the mountain meadows can thus be retarded or stopped, which is desirable for the maintenance of the meadows` fertility and species diversity.

2.4.1. What is the “mulch”?

Mulch is any material spread on the soil surface with a view to reduce evaporative water loss, suppress weeds and reduce temperature fluctuations. (Jack, 1955, in Struzina, 1990). The mulched material influences the physical, chemical and biological soil properties, soil fertility and also properties of the layer of atmosphere adjacent to soil (Turke, 1976, in Struzina, 1990). In former times, mulching was an important method used predominantly in gardening and plantations. Baumeister (1963) excerpts from Gourleye and Howletta (1949), who mention mulching with grass in a plantation during 2nd half of 19th century in the

USA. Mulching with grass includes multiple cuts with leaving the cut and chopped sward on the spot, whereby the mulched material markedly suppresses underlying vegetation.

Presently regular directed mulching of grassland is still constrained to permanent crops such as orchards, tree plantations and vineyards. Published studies mention mainly the influence of mulch on these stands, possible improvement of the hydrothermic conditions, limitation of erosion processes and weed control (Blasse, 1990; Hoffmann, Korper and Werner, 1995; Merwin, Stiles and Vanes, 1994). Mulching is also used for the maintenance of road verges (Kromer and Reloe, 1991).

2.4.2. Mulching impact

Mulching with organic material constitutes a new "microzone" with an autonomous water, air and temperature régime. Decomposition processes in the mulch evoke losses of mulch weight, changes in optical mulch properties and changes in mulch absorptivity and water retention capacity.

The active surface extent of the mulch depends on the nature and structure of the material used and its distribution on the soil surface, and on the eventual incorporation of the mulch into the upper soil layer.

The intensity of mulch influence depends not only on the kind of the mulching material but also on climatic and soil conditions (Struzina, 1990). The rate of mulch decomposition depends mainly on the soil temperature and moisture. The decomposition of the mulch can take only a few weeks in regions where moisture and temperature conditions are suitable for soil microbial activity (Moog *et al*., 2002). In colder and drier areas the mulch can persist on the soil surface for more than one vegetation season (Mašková *et al*., 2008).

Mulch supports the **soil structure** by its protection from adverse influence of intense rain. The organic layer on the soil surface slows down the surface drainage and moderates erosion processes. Mulch supports the maintenance of the soil porosity and positively affects water infiltration into the soil by keeping off deterioration of the soil aggregates (Dharmasena, 1994; Jung, Koh and Um, 1989; Vogel, Nyagumbo and Olsen, 1994).

Mulch markedly interacts with evaporation and thereby also with **water availability** in the soil. Heat from absorbed sun radiation is predominantly used for evaporation from the humid mulch layer; consequently, evaporation from the soil is expressively reduced. The intensity of this effect depends on the climatic conditions and the time and way of the mulch application (Lascano *et al.*, 1994; Lascano and Baumhardt, 1996; Yunusa, Sedgley and Siddique, 1994).

Mulching limits **soil temperature** fluctuations (Achraya and Sharma, 1994; Gajri, Arora and Chauddhary, 1994; Struzina, 1990; Wicks *et al.*, 1994). Soil temperature is affected mainly by the colour of the mulch. Lighter organic materials have a greater albedo, i.e., a higher reflectance of sunshine. Soil temperature measurably decreases under the organic mulch mainly in the subsurface soil layer in dependence on the climate, vegetation period and kind and quantity of the mulched material (Kvítek *et al.*, 2000; Merwin, Stiles and Vanes, 1994). The soil temperature decreases also because the sunshine heat is primarily utilized for evaporation from the mulched material, not for warming of the mulch or soil (Struzina, 1990).

The presence of mulch significantly affects the **nutrient balance** of the soil. Long-term mulching results in a higher humus content (Blasse, 1990). Kitou and Yoshida (1994) describe the positive impact of mulching on nitrogen fixation and its changes in the soil. In addition, the mulched plant material contains the nutrients required by plants (N, K, P, Ca, S, etc.). Some of these nutrients are releasable by simple processes (e.g., potassium is directly leached out by rain or snow water, while some nutrients are released during the mulch decomposition (N, P). An extensive root system often developing under the mulched layer can also improve the plant nutrient utilization (Garji, Arora and Chauddhary, 1994; Yibrin, Johnson and Eckert, 1993).

2.4.3. Mulching as an alternative method of secondary grassland maintenance

Mulching can facilitate nutrient cycling in grassland stands. On the contrary, this maintenance method can have an undesirable influence on the plant community composition (Zelený *et al*., 2001; Kornaś and Dubiel, 1991). Physical soil properties (temperature, moisture content, water-holding capacity, bulk density, porosity, aeration) as well as chemical ones (nutrient content, rate and dynamics, pH) can be markedly affected (Kvítek, Duffková and Peterková, 2001; Kvítek, Peterková and Duffková, 2001a,b). It is expected that changes of soil characteristics induce changes in the soil microbial community structure and function (Šimek *et al.*, 2001). The influence of mulching on partial components of the natural environment as well as the possible use of mulching as an alternative method of secondary grassland maintenance ought to be increasingly investigated.

3. Research of the meadow ecosystems

The selection of a suitable mountain meadow and pasture management ought to result not only from the respective communities' classification and descriptive characteristics, but also from a detailed knowledge of the grassland ecosystem functioning. A substantial number of studies has dealt with a global view on the secondary grassland ecosystems and the investigation of their components and processes.

In the course of an evaluation of mountain meadow processes, it is mostly possible to consider the results of research studies also from other altitudes. Complex research of grassland ecosystems was accomplished, e.g., by Breymeyer and van Dyne (1980, description of plant and animal biomass in relation to production, consumption and decomposition), Gáborčík (1989, ecology of grassland ecosystems), Moravec (1965, classification of the grassland plant communities of the Bohemian Forest), Regal (1967, ecological indication values of selected plant species), Lavorel and Garnier (2002, functional groups in meadow communities).

Some authors monitored grassland vegetation in selected areas. Klečka (1936) studied the Nardetum communities in the Bohemian Forest. One of the most detailed studies was published by Rychnovská *et al.* (1985, 1993). They investigated the structure and functioning of seminatural meadows in the Bohemian-Moravian Uplands. Krahulec *et al.* (1990) followed up the dynamics of mountain meadows in the Krkonoše mountains, Bufková, Prach and Bastl (2005) scanned alluvial meadows in the Bohemian Forest.

In view of the great number of influencing factors, which cannot be considered objectively or separated in an experiment, complex research of grassland is very sophisticated and complicated. Long-term monitoring is also necessary. Most studies therefore concentrated on the observation of partial characteristics or influence of single factors on grassland communities.

Herben *et al.* (1993a,b), Klimeš *et al.* (2001), Krahulec (1990, 1995), Smulders *et al.* (2000) and Stampfli (1992, 1995) monitored changes of species diversity in plant communities. Plant biomass production was studied, e.g., by Hitz *et al.* (2001) and Titlyanova *et al.* (1999), the relationship between plant biomass production and species diversity was described by Troumbis *et al.* 2000. Nutrient availability and influence of fertilization on meadow vegetation were evaluated, e.g., by Best and Jacobs (2001), Myklestad (2004), Olff and Bakker, (1991), Oomes (1991), Oomes and Kemmers (1995), Oomes *et al.* (1996), Roscher *et al.* (2004). Nitrogen cycling in grassland communities was monitored, e.g., by Grootjans *et al.* (1985, 1986), Makarov *et al.* (2003) and Meyers *et al.* (1982). Processes of the plant biomass decomposition were described, e.g., by Lexa and Krahulec (2000), Shaw and Harte (2001) and Tesařová (1976).

Grassland ecosystems along the moisture gradients in inundated areas were studied by, e.g., Balátová-Tuláčková (1957), Jakrlová (1975), Jeník and Květ (1983) and Rybníček and Rybníčková (1974). Čermák *et al.* (2001), Voženílková and Květ (2001) and Voženílková *et al.* (2008) reported on a potential relationship between plant species diversity and phytopathogen expansion. Monitoring of successional changes on abandoned sites was accomplished, e.g., by Lepš and Štursa (1989), Van der Putten *et al.* (2000) and Wilsey and Potvin (2000).

3.1. Influence of agricultural management on the species diversity of secondary grassland

The changes in plant species composition and diversity under different management seem to be among the most frequently observed processes. It is the type of management that largely determines the prevailing vegetation type (Andrieu *et al.*, 2007; Marini *et al.*, 2007; Warren *et al.*, 2002). Most of these studies indicate that regular mowing enhances plant species richness and diversity (e.g., Bobbink and Willems, 1993; Kahmen *et al.*, 2002; Moog *et al.*, 2002; Rosén, 1995; Sykes *et al.*, 1994). Mowing frequency is considerably significant (Fiala, 1993; Ryser, Langenauer and Gigon, 1995), the term of cutting can also change the plant community composition by disturbing the plants at different developmental stages (Smith and Jones, 1991). A frequently confirmed fact is that leaving a meadow fallow often leads to a decrease of species diversity. In this respect, the results of various studies often differ, whether the abandonment of the meadows leads to a decrease of their species richness (Taser and Tappeiner, 2002; Willems, 1983), or whether the total number of plant species does not differ significantly (Ryser, Langenauer and Gigon, 1995; Schusserová, 2003; Zelený *et al.*, 2001).

Relatively scarce information is available on the mulching impact on species diversity in meadow communities. Some authors distinguish between the responses of particular meadow species to mulching (e.g., Bakker, 1989; Kornaś and Dubiel, 1991; Kvítek et. al, 1998; Lexa and Krahulec, 2000). Other studies suppose comparable impacts of mulching and cutting on the structure of the respective plant communities; their authors nevertheless recognize that the similarity of these types of management could be given by the coincidence of the term and frequency of both treatments (Kahmen *et al.*, 2002; Moog *et al.*, 2001).

3.2. Influence of agricultural management on the meadow productivity

Mowing of meadows without additional fertilizing reduces their productivity (e.g., Dickinson and Polwart, 1982; Chen *et al*. 1998; Willems 1983). Fertilizing can assist in the achievement of a markedly higher production (e.g., Wilson and Tilman, 1993). Mulched meadows can also have a higher production of aboveground biomass than unfertilised and mown ones (Oomes *et al.*, 1996). Only a few studies deal with the belowground biomass production. These data altogether show a decrease of belowground biomass production in the course of regular mowing (Fiala, 2000; Pecháčková and Krahulec, 1995). On the contrary, Mašková *et al.* (submited to press) show that in a long-term run the mowing of the meadows can result in a higher belowground biomass than that in abandoned or mulched mountain grassland.

Biomass production largely depends on the character of the vegetation season (its duration, amount of precipitation, temperature stratification, etc.). Monitoring of the different management impacts on the plant production therefore requires long-term observation. Stampfli (1995) observed the dependence of plant production on the sunshine duration, precipitation amount and relative air humidity. Nevertheless a transparent relationship between plant production and climatic factors can hardly be demonstrated (Silvertown *et al.* 1994) by reason that the biomass production often seems to be controlled by the weather of the preceding rather than current year (Krahulec, 1995; Herben *et al.*, 1995).

4. Aims of the research project
- Functioning of mountain meadows under differentiated management impact

The impact of mulching on secondary grassland is only sporadically included in available published studies. In addition, it is necessary to keep in mind that plant species are mostly site specific, affected by the type of community, character of environment as well as climate (Louault *et al.*, 2005).

A large pilot-scale field experiment was set up in the Šumava National Park in 1997. The aim of this study was to compare the effect of mulching of grassland ecosystems with those of traditional mowing or leaving the meadows fallow.

Monitored ecosystem components and processes:

- plant biomass,
- plant community structure,
- decomposition of plant biomass and cycling of essential biogenic elements,
- physical properties of soil A horizon,
- microclimatic processes in grass cover.

The setup of the pilot-scale experiment was derived from the basic requirement that the experimental treatments ought to correspond with the practical agricultural management in the surrounding area. The treatments are practiced with standard mechanization and during a corresponding period of the vegetation season. It was also necessary to provide sufficient fetch for microclimatic and heat- balance measurements (Šmahel *et al*., 2001). Therefore three permanent plots of 50 × 100 m each, subjected to different treatments, were established on the experimental site. The biomass samples and phytocenological relevés were taken with an appropriate number of replicates in each plot (four replicates for the biomass, five for the phytocenological relevés).

At the start of our experiment in 1997, the vegetation cover of the whole experimental area was homogeneous (Tab. 1) (Zelený *et al.,* 2001). The pre-treatment species richness, diversity, evenness and biomass of 1997 (Tab. 2), both above- and belowground as well as the amount of litter, were much the same over the whole area. In our opinion, these circumstances compensate for the impossibility to ensure the replication of differently treated plots in our experiment and, at the same time, justify statistical comparison between the treatments applied.

a)

Species	Average cover (Braun-Blanquet scale) mown	fallow	mulched
Acetosa pratensis	r	r	r
Acetosella vulgaris	r	+	r
Agrostis capillaris	1	2	2
Anthoxanthum odoratum	r	0	r
Campanula rotundifolia	r	r	r
Cardaminopsis halleri	r	r	r
Dactylis glomerata	0	r	0
Deschampsia cespitosa	3	2	3
Festuca rubra	3	3	3
Hypericum maculatum	2	2	2
Lilium bulbiferum	r	r	r
Luzula luzuloides	1	1	1
Luzula multiflora	r	0	r
Poa pratensis	+	+	+
Potentilla erecta	r	0	0
Silene dioica	+	1	1
Stellaria graminea	0	r	r
Taraxacum officinale	0	0	r
Veronica serpyllifolia	r	0	r

b)

Treatment	Number of present species	Average cover (%)
mown + fallow + mulched	12	85.634
only in mown+fallow	0	0.000
only in mown+mulched	3	0.078
only in fallow+mulched	1	0.013
only in mown	1	0.035
only in fallow	1	0.002
only in mulched	1	0.024

Table 1 a,b
Presence of the individual plant species in each treatment at the start of our experiment in 1997, in five $1m^2$ plots for each treatment.

This table (Tabs. 1a,b) lists, for each treatment, only those species that occurred within the phytocenological relevés taken. They may have occurred, however, elsewhere in the respective treatments. The low cover of the species that were not recorded in all three treatments had a negligible influence of the initial homogeneity of the vegetation on the Zhůří study site (see Tab. 2).

	Kruskal-Wallis ANOVA by rank test, *p* values
aboveground biomass	0.7351
belowground biomass	0.7788
litter	0.2575
species richness	0.5281
species diversity	0.2101
species evenness	0.2491

Table 2
Significances of the differences between pre-treatment biomass, species richness**,** diversity and evenness in the mulched, mown and fallow treatments at the start of our experiment in 1997.

General hypotheses:

1. **The plant dry matter production** will increase in the following order: fallow < mown < mulched stands. This implies the highest release and re-use of nutrients in the mulched stand in comparison with the mown and fallow ones.

2. **The species variety and diversity** will decline in the mulched and fallow stands (with a probable decline of the number of protected and/or endangered plant species) while in the mown stand it will remain more or less unchanged or will slightly increase.

3. **The soil temperature** and its fluctuations will decrease during the vegetation season in the following order of stands: mown > mulched > fallow. This implies the effect of thickness of the accumulated mulched material, plant litter or standing dead plant material.

4. **The moisture content in the soil** will change in response to the management régime. The susceptibility of the soil environment to desiccation during occasional dry conditions will increase in the following order: fallow < mulched < mown stands.

5. **The amount of plant matter decomposed** will increase in the following order: mown < fallow < mulched stands. This implies the lowest accumulation of humus in the mown stand in comparison with the fallow and mulched ones.

6. **The microclimatic conditions and water and temperature relations between the soil and plant cover** will become markedly differentiated during the second half of the vegetation season (following the application of the experimental management) in response to the management régime. The maximum temperature will increase in the following order: fallow < mulched < mown stands. On the contrary, the relative air humidity will increase in the near-ground air layer in the reverse order (mown < fallow < mulched stands).

Partial studies were published in the following papers:

Mašková, Z., Květ, J., Zemek, F., Heřman, M., 2001.
Functioning of mountain meadows under different management impact - research project. Silva Gabreta 7, 5-14.

Mašková, Z., Zemek, F., Heřman, M., Květ, J., 2001.
Post World War II development and present state of non-forested area at Zhůří - Huťská hora Mt. Silva Gabreta 7, 15-30.

Smejkal, Z., Pojerová, J., Mašková, Z., Zemek, F., Heřman, M., 2001.
Flora and vegetation of the study area at Zhůří (Huťská hora Mt.). Silva Gabreta 7, 31-44.

Kvítek, T., Duffková, R., Peterková, J., Mašková, Z., 2000.
Soil temperature and moisture in differently used grassland in the Bohemian Forest. Silva Gabreta 5, 51-62 (in Czech with English summary).

Zelený, D., Šraitová, D., Mašková, Z., Květ, J., 2001.
Management effects on a mountain meadow plant community. Silva Gabreta 7, 45-54.

Zemek, F., Heřman, M., Mašková, Z., Květ, J., 2005.
Multifunctional land use - a chance of resettling abandoned landscapes? (A case study of the Zhůří territory, Czech Republic). Ekológia 24, suppl. 1/2005, 96-108.

Mašková, Z., Zemek, F., Květ, J., 2008.
Normalized Difference Vegetation Index (NDVI) in the management of mountain meadows. Boreal Env. Res. 13, xx-xx.

Mašková, Z., Doležal, J., Květ, J., Zemek, F., submitted to Agriculture, Ecosystems and Environment.
Long-term functioning of a species-rich mountain meadow under different management regimes.

These papers are being submitted as parts of this Ph.D. Thesis.

Prach, K., Bufková, I., Zemek, F., Heřman, M., Mašková, Z., 2000. Grassland vegetation in the former military area Dobrá Voda, the Šumava national Park. Silva Gabreta 5: 103-113, Vimperk.

Secondary grasslands in the Bohemian Forest contribute substantially to a characteristic landscape pattern and biodiversity of the mountains. However, in the past decades they have degraded in the great extent and the degradation is still in progress. We mapped vegetation units in 17 grassland areas (the total area of 27 km2) around former settlements in the former military training zone. The vegetation units (31) were defined mostly according to dominant species and they were related to moisture and nutrient gradients and successional age. The vegetation data were elaborated by GIS methods. For particular units an optimum management was suggested, reflecting both interests of nature conservancy and agricultural use.

Mašková, Z., Květ, J., Zemek, F., Heřman, M., 2001. Functioning of mountain meadows under different management impact - research project. Silva Gabreta 7: 5-14, Vimperk.

Small interest in agriculture under less favourable natural conditions is one of the phenomena related to political changes in Central Europe at the end of the 20th century. As a result, extensive areas of meadows and pastures have been abandoned and lay fallow. The existence and quality of secondary grassland depend, however, fully on human management. New alternative practices of non-profit grassland management are necessary to preserve the natural values and characteristic appearance of secondary grassland in a seminatural mountain landscape. Mulching has been expected to become one of the prospective practices applicable to the management of mountain grassland. However, it can also bring about some unwanted changes to the grassland ecosystem. So far, only little qualified information has been available on the effects of mulching on mountain grassland. A long-term field experiment has been therefore set up in the Šumava National Park, with the aim to compare the impact of mulching on the grassland ecosystem and its components with the impacts of traditional grassland management by mowing and cattle or sheep grazing. Leaving the grassland fallow is a treatment with which the other treatments of the mountain grassland have been compared. This paper presents some of the problems related to the management of mountain grassland and describes the establishment of the long-term field experiment. It informs briefly about the main results of the experiment and other related investigations.

Mašková, Z., Zemek, F., Heřman, M., Květ, J., 2001. Post World War II development and present state of non-forested area at Zhůří - Huťská hora Mt. Silva Gabreta 7: 15-30, Vimperk.

A reconstruction has been made of the post World War II changes in land cover/land use within the Zhůří – Huťská hora Mt. enclave, an area of secondary grassland on the Kvilda Plains in central Bohemian Forest, with respect to the history of its management. The evaluation of the last fifty years development is based on a quantification of changes identified by visual interpretation of a time series of aerial photographs, and by field surveys. Among seven monitored categories of land cover/land use, significant expansion occurred of the forest-covered area, from 21.5% of total area in 1949 to 35.9% in 2000. Within the same period, the secondary grassland area shrank from 54.6% to 43.5%. These changes resulted from natural regeneration processes, which started as a consequence of either complete abandonment of agricultural land, or reduced intensity of management of the remaining grassland plots. The rate of these changes was enhanced by the neighborhood of Norway spruce (*Picea abies*) forests, and also by the climatic conditions favoring the growth of seedlings of this tree in mountain habitats.

Smejkal, Z., Pojerová, J., Mašková, Z., Zemek, F., Heřman, M., 2001. Flora and vegetation of the study area at Zhůří (Huťská hora Mt.). Silva Gabreta 7: 31-44, Vimperk.

An inventory of vascular plants was carried out at Zhůří (Huťská hora Mt.) – an area of secondary grassland and successional woody vegetation. We paid special attention to important and protected species. Further, we mapped the main vegetation units, and suitable agricultural management was proposed on the basis of the mapping. Meadow communities of Zhůří are represented by the phytosociological alliances *Violion caninae*, *Polygono-Trisetion*, *Calthion*, *Caricion fuscae* a *Caricion rostratae*. The meadow in the SW part is overgrown by successional peaty birchwoods of the alliance *Betulion pubescentis*. The investigation confirmed 204 species of vascular plants, 18 of them enjoying legal protection.

Kvítek, T., Duffková, R., Peterková, J., Mašková, Z., 2000. Soil temperature and moisture in differently used grassland in the Bohemian Forest. Silva Gabreta 5: 51-62, Vimperk (in Czech with English summary).

Soil temperature and soil moisture were measured at three types of grassland use (one cut, no cut, mulching) on experimental locality "Zhůří" (Huťská hora Mt.). Results from two-years measurements of soil temperature show, that there were no significant differences among three types of grassland use in out-of-vegetation season. Significant differences were always found out between one cut and no cut types of grassland use in vegetation season. In the second experimental year, significant differences between one cut and mulching type of grassland use were not confirmed. Evaluation of differences of soil moisture values, measured in the first sampling depth of each grassland use type, before and after the cut, in the relation to the data of precipitation taken during each experimental season from the nearest meteorological stations show, that influence type of grassland use to the soil moisture is significant only in case when influence of precipitation is not so strong. In cases of low precipitation, types of grassland use declare different values of soil moisture. In the opposite case when precipitation is high, influence of grassland use to the soil moisture was not found out. Hydrothermal regime of mulching type of grassland use was found as a gradation between one cut and no cut variation of grassland use (soil temperature measured on mulching variation is closer to no cut type of grassland use, soil moisture measured in 0.05-0.25 m sampling depth is closer to one cut type of grassland use).

Zelený, D., Šraitová, D., Mašková, Z., Květ, J., 2001. Management effects on a mountain meadow plant community. Silva Gabreta 7: 45-54, Vimperk.

The response of an oligotrophic mountain meadow plant community to mowing and mulching was studied in a manipulative experiment for four years (1997–2000) in the Bohemian Forest, Czech Republic. We established the changes of diversity and equitability of grassland vegetation as well as seasonal and year-to-year patterns of its species composition. Our results indicate that mowing and mulching have positive effect on the species diversity in comparison with no management; the main reason is increased equitability and suppression of dominant graminoids in the managed plots. Seasonal variation does not indicate considerable differences in the constituent species' response to management type. The four-year experiment seems to have been too short to enable unambiguous conclusions to be made on the advantages or disadvantages of mulching in comparison with the other management techniques tested, and with leaving the meadow fallow, with no management at all.

Zemek, F., Heřman, M., Mašková, Z., Květ, J., 2005. Multifunctional land use - a chance of resettling abandoned landscapes? (A case study of the Zhůří territory, Czech Republic).
Ekológia 24, suppl. 1/2005: 96 - 108, Bratislava.
Small interest in agriculture under unfavourable natural conditions is one of the phenomena related to political changes in Central Europe at the end of the 20th century (in last decade). As a result, extensive areas of secondary grasslands have been abandoned and are now lying fallow. The existence and quality of secondary grassland depend, however, fully on human management, especially on further low impact agricultural practises.
This paper presents some of the problems related to the management and development of secondary mountain grassland situated in protected area. A reconstruction has been made of the post World War II changes in land cover/land use with respect to the history of its management to understand better recent status. The evaluation of the last fifty years' development is based on a quantification of changes identified by visual interpretation of a time series of aerial photographs, and by field surveys.
Special interest is paid to potential impact on local biotopes and ecosystem of planned resettlement of the territory and multifunctional land use. Main objections to lay-out master plan from administration of nature conservation are discussed here. In this case, no simple solution about the secondary grassland enclave's development exists from an impartial point of view. Site specifics, historical context and societal preferences with long-live perspective should be taken into the consideration in decision-making process.

Mašková, Z., Zemek, F., Květ, J., 2008 (in press). Vegetation indices in the management of mountain meadows. Boreal Env. Res. 13, xx-xx.

The aim of the study was to test the possibility of using the Normalized Difference Vegetation Index (NDVI) for distinguishing between differently managed mountain grassland sites surrounded by boreal forests. The NDVI was assessed under field conditions in three differently managed meadows (mown, mulched, unmanaged), at an altitude of 1150 to 1170 m in the Bohemian Forest Mts. The mowing and mulching were applied to the respective plots in mid-July and three successive NDVI/aboveground biomass assessments were made before and two after the application of the treatments. The presence of litter, expressed by the green ratio index (GR), strongly affected the reflectance of the grassland canopy. The linear relationships between green biomass and NDVI were statistically significant for all treatments only during the period before the application of the treatments. It was only in the unmanaged plot that a statistically significant linear relationship between NDVI and GR was recorded.

Mašková, Z., Doležal, J., Květ, J., Zemek, F., submitted to Agriculture, Ecosystems and Environment. Long-term functioning of a species-rich mountain meadow under different management regimes.

The aim of this study is to assess the effect of different management practices on mountain meadow plant biomass, species richness and diversity. The experiment was carried out in the Bohemian Forest Mts. at the altitude of 1150 to 1170 m for 10 years. We applied three treatments (mowing, mulching, abandonment - fallow) to a mountain meadow with dominant *Deschampsia cespitosa, Agrostis capillaris, Festuca rubra* and *Hypericum maculatum.* The aboveground biomass was significantly highest in the fallow treatment and lowest in the mown one, the belowground biomass was the lowest in the fallow treatment and the highest in the mown one. The litter accumulation was higher in the fallow treatment than in the mulched one, where, nonetheless, the mulched material persisted for more than one growing season.

The treatments significantly affected the plant species diversity and shifts of dominance among certain species were observed. Decrease of the species richness was observed in the fallow plot, while slightly lowered Shannon diversity and evenness were observed in the mown plot.

5. Recapitulation

Verification of the general hypotheses:

1. **Plant biomass - unconfirmed hypothesis**
   In our experiment, the meadow management strongly influenced the aboveground biomass, yearly harvest reduced it significantly. The aboveground biomass was highest in the fallow plot and lowest in the mown plot. On the contrary, belowground biomass was highest in the mown plot and lowest in the fallow one, but with statistically significant differences only between individual years within the same treatments.

2. **Species richness and diversity - partly confirmed hypothesis**
   The decrease of the species richness was observed in the fallow plot, but the differences between the treatments were not statistically significant - it seems that a significant differentiation between the treatments requires more than ten years. The mulched plot exhibited slightly higher values of Shannon diversity and evenness compared to both the mown and fallow plots. In our experiment the main effects of the treatments on plant species diversity seem to be the shifts of dominance among certain species.

3. **Soil A horizon temperature - partly confirmed hypothesis**
   During the vegetation season there were significant differences between higher temperatures in the mown plot and lower temperatures in the fallow plot. In the mulched plot, the soil temperature varied between those of the other two plots, being closer to that in the fallow plot. The reduction of soil temperature fluctuations under the mulched or litter layer was not statistically significant, its expression (in terms of intensity and time delay of temperature change) was affected by the temperature and moisture character of the given vegetation season.

4. **Soil A horizon moisture - unconfirmed hypothesis**
   The type of management influenced the soil A horizon moisture content only when the influence of precipitation was not strong. In this case, the soil moisture content was highest in the fallow plot and lowest in the mown one. Soil moisture in the mulched plot varied between those in the other two plots, being closer to that in the mown plot. Higher sums of precipitation reduced the differences between all three treatments.

5. **Nutrient turnover rates in the vegetation and rates of plant matter decomposition - still evaluated hypothesis**
   By this time, the nutrient turnover rate and rates of plant matter decomposition have not yet been evaluated. Nevertheless, the data about the contents of essential nutrients (C, N, P, K, Ca, Mg) in the plant biomass during four vegetation seasons are available as well as the data about plant litter and mulched material decomposition.

6. **Microclimatic conditions - unconfirmed hypothesis**
   By this time, the major part has not yet been evaluated of our measurements of the microclimatic conditions and water and temperature relations between the soil and plant cover. Nevertheless, the data about air temperature and humidity within the vegetation during two vegetation seasons are available.
   Note: The heat balance measurements, performed by Šmahel et al. (2001), showed a decrease of the daily average Bowen ratio (i.e., increase in the amount of heat dissipated through evapotranspiration) in the following order of differently managed stands: fallow > mown > mulched plot.

The ratio between the confirmed and unconfirmed hypotheses documents the formerly published data deficiency. These data are not sufficient for reliable estimation of the possible influence of mulching on mountain meadow communities. Required specifications should be given during long-term experiments, involving more than ten years of experimental management application.

Completion of the goals:

- **Summarization of the history and present state of the study area**
  Data about the history and development of the study area were selected from available literature and, especially, from museum archives. These data summarize the area`s history from the first colonization during 14th century to the present exploitation (Mašková et al., 2001).

- **Comparison of the differently managed experimental plots**
  The selected characteristics of the vegetation, soil A horizon and microclimate in the mown, mulched and fallow plots were observed and compared during the ten-year pilot-scale experiment (Kvítek *et al.,* 2000; Mašková *et al.,* 2008; Mašková *et al.*, submitted to press; Zelený *et al.,* 2001).

- **Estimation of the potential effects of mulching on the meadow community**
  The results of fundamental vegetation and soil A horizon characteristics were analysed and statistically evaluated. In the process of data interpretation the climatic characteristics of the study area and potential relationships between the monitored components were taken into account. A part of the data obtained, which needs to be analysed in more detail, is available in unpublished form with the author of this dissertation.

- **Proposals for acceptable application of the mulching**
  Acceptable possibilities of mulching as an alternative technique for the maintenance of secondary grassland in the Bohemian Forest were proposed on the basis of data obtained during the experiment (Mašková *et al.*, 2008; Mašková *et al.*, submitted to press, Smejkal *et al*., 2001).

Conclusions:

The experimental site is situated at a relatively high altitude with a short growing season, relatively low temperatures and a nutrient-poor acidic soil. The responses of the plant community to the different types of management applied are slow and seem to be largely controlled by the weather conditions during current or preceding vegetation seasons.

The influence of the different agricultural management on the species diversity and productivity of the mountain grassland vegetation may be summarized as follows:

- The production of plant biomass is low on the whole, regular mowing without complementary fertilization further gradually diminishes the production of aboveground biomass. Mulching moderates the decline of aboveground biomass production.
- The mulched plant material persists on the plot for more than one vegetation season, but its decomposition is faster than the decomposition of standing dead material and litter in the fallow plot.
- The different management was reflected, at first, in different cover degrees of the dominant species. The long-term holding fallow of the meadow resulted in a gradually decreasing species richness of the meadow plant community.
- For distinguishing between differently managed mountain meadows it is possible to use, on a local scale, the Normalized Difference Vegetation Index, which exhibits a linear relationship with green aboveground biomass during the period before the application of the treatments (=management techniques).

Recommendations:

Annual harvesting of oligotrophic meadows without a simultaneous nutrient supplement can cause a decline of plant species diversity. The nutrients released from the mulched biomass and left on the spot (at least at intervals of a few years) can retard the oligotrophication of regularly mown meadows, simultaneously avoiding the potential impoverishment of the species diversity of these meadows.

If regular mowing of mountain meadows is not feasible for economic or technical reasons, mulching can represent an economically advantageous alternative. It will temporarily check the successional changes that sooner or later occur in meadows left fallow. Mulching can also be used as a simple treatment retarding the decrease of species diversity and productivity in regularly mown, but unfertilised, mountain meadows.

For the expression of unambiguous or generally available conclusions about the effects of regular mulching on meadow productivity and species diversity, it is necessary to undertake and evaluate more long-term experiments.

6. References:

Achraya, C.L., Sharma, P.D., 1994. Tillage and mulch effects on soil physical environment, root growth, nutrient uptake and yield of maize and wheat on an Alfisol in north-west India. Soil Till. Res. 32, 291-302.

Andrieu, N., Josien, E., Duru, M., 2007. Relationships between diversity of grassland vegetation, field characteristics and land use management practices assessed at the farm level. Agric. Ecosyst. Environ. 120, 359-369.

Bakker, J.P., 1989. Nature Management by Grazing and Cutting. Kluwer Acad. Publ., Dordrecht, 400 pp.

Balátová-Tuláčková, E., 1957. Meadow plant communities in relation to the humidity of the soil. A study from meadows in the vicinity of Brno. Sb. ČAZV, Rostlinná výroba 3, 529-557 (in Czech with English, German and Russian summary).

Baumeister, J., 1963. Die Anfangsentwicklung von gemulchten Raseneinsaaten und ihre Beeinflussung durch Obstbestand und Pflegemassnahme. Die Gartenbauwissenschaft 28, 375-410.

Best, E.P.H., Jacobs, F.H.H., 2001. Production, nutrient availability, and elemental balances of two meadows affected by different fertilization and water table regimes in The Netherlands. Plant Ecol. 155, 61-73.

Blasse, W., 1990. Förderung der Bodenfruchtbarkeit durch Kurzgrasmulch und Deckfruchtanbau. Obst und Garten 109, 511-513.

Bobbink, R., Willems, J.H., 1993. Restoration management of abandoned chalk grassland in The Netherlands. Biodiv. Conserv. 2, 616-626.

Boudová, V., 1995. Zhodnocení negativních důsledků zemědělské výroby na společenstva rašelinišť v oblasti Borových Lad a Nového Světa. [Evaluation of the negative effects of agriculture on the plant communities of mires in the area of Borová Lada and Nový Svět]. B.Sc. Thesis, BF JU, České Budějovice (in Czech).

Breymeyer, A.I., Van Dyne, G.M. (Eds), 1980. Grasslands, Systems Analysis and Man. Cambridge University Press, 950 pp.

Bufka, L., Bufková, I., Kovařík, K., Mánek, J., Martanová, J., Mašková, Z., Silovský, V., Skolek, M., Valenta, M., Zatloukal, V., Zelenková, E., 2000. Plán péče Národního parku Šumava [Management plan of the Šumava National Park]. Ms., Šumava NP Administration, Vimperk, 140 pp. (in Czech).

Bufková, I., Prach, K., Bastl, M., 2005. Relationships between vegetation and environment within the montane floodplain of Upper Vltava River (Šumava National Park, Czech Republic). Silva Gabreta, Supplementum 2, 76 pp.

Čermák, B., Voženílková, B., Kadlec, J., 2001. Fungal diseases of selected grasses under various methods of their managements. 23. Mykotoxin Workshop. Veterinärmedizinische Universität Wien, Institut für Ernährung. Wien, Austria, 45.

Dharmasena, P.B., 1994. Conservation farming practices for small reservoir watersheds: A case study from Sri Lanka. Agroforest Syst. 28, 203-212.

Dickinson, N.M., Polwart, A., 1982. The effect of mowing regime on an amenity grassland ecosystem: above- and below- ground components. J. Appl. Ecol. 19, 569-577.

Eiblová, V., 1993. Travní porosty suchých stanovišť v oblasti Kvildských Plání [Grassland vegetation of dry stands in the Kvilda Plain area]. M.Sc. Thesis, ZF JU, České Budějovice, 85 pp. (in Czech).

Eliáš, V., Tesař, M., Buchtele, J., 1993. Occult precipitation: sampling, chemical analysis and process modelling in the Šumava Mts. (Czech Republic) and in the Taunus Mts. (Germany). J. Hydrol. 166, 409-420.

Fiala, K., 1993. Underground biomass in meadow stands. In: Rychnovská, M. (Ed.), Structure and Functioning of Seminatural Meadows. Academia, Praha, 135-153.

Fiala, K., 2000: Proportion of living biomass in the total dry mass of belowground organs of various plant communities. Preslia 72, 73-85.

Fošumová, P., 1995. Kategorizace a návrh managementu antropogenního bezlesí centrální Šumavy na modelovém území Bučina [Categorization and management proposals for the anthropogenic forest-free areas in the central Bohemian Forest – demonstration area of Bučina]. M.Sc. Thesis, ZF JU, České Budějovice, 91 pp. (in Czech).

Gáborčík, N. (ed.), 1989. Ekológia trávneho porastu III [Ecology of Grassland Vegetation III]. Dom Techniky ČSVTS, Banská Bystrica (in Slovak).

Gajri, P.R., Arora, V.K., Chauddhary, M.R., 1994. Maize growth responses to deep tillage, straw mulching and farmyard manure in coarse textured soils of N.W.India. Soil Use Management 10, 15-20.

Grootjans, A.P., Schipper, P.C., Van der Windt, H.J., 1985. Influence of drainage on N-mineralization and vegetation response in wet meadows. I. Calthion palustris stands. Acta Oecologica, Oecol. Plant. 6, 403-417.

Grootjans, A.P., Schipper, P.C., Van der Windt, H.J., 1986. Influence of drainage on N-mineralization and vegetation response in wet meadows. II. Cirsio-Molinietum stands. Acta Oecologica, Oecol. Plant. 7, 3-14.

Hakr, P., 1995. Kategorizace a návrh managementu antropogenního bezlesí centrální Šumavy na modelovém území Knížecí Pláně [Categorization and management proposals for the anthropogenic forest-free areas in the central Bohemian Forest – demonstration area of Knížecí Pláně]. M.Sc. Thesis, ZF JU, České Budějovice, 92 pp. (in Czech).

Hakrová, P., 2003. Studium podmínek pro podporu druhové diverzity travních porostů [The research of conditions of the support of the specific diversity grasslands]. Ph.D. Thesis, ZF JU, České Budějovice, 132 pp. (in Czech, with English summary).

Havlíková, Š., 1995. Kategorizace a návrh managementu vybraných lučních porostů v oblasti Prášily [Categorization and management proposals for the anthropogenic forest-free areas in the central Bohemian Forest – demonstration area of Prášily]. M.Sc. Thesis, ZF JU, České Budějovice, 72 pp. (in Czech).

Herben, T., Krahulec, F., Hadincová, V., Kovářová, M., 1993a. Small-scale spatial dynamics of plant species in a grassland community over six years. J. Veget. Sci. 4, 171-178.

Herben, T., Krahulec, F., Hadincová, V., Skálová, H., 1993b. Small-scale variability as a mechanism for large-scale stability in mountain grassland. J. Veget. Sci. 4, 163-170.

Hitz, Ch., Egli, M., Fitze, P., 2001. Below-ground and above-ground production of vegetational organic matter along a climosequence in alpine grasslands. J. Plant Nutr. Soil Sci. 164, 389-397.

Hoffmann, U., Korper, P., Werner, G.A., 1995. Ökologischer Weinbau. Ulmer Fachbuch "Ökologie und Landwirtschaft" Verlag E. Ulmer, Stuttgart, 260 pp.

Chen, R., Corlett, R.T., Hill, R.D., 1998. The biological sustainability of biomass harvesting. Agric. Ecosyst. Environ. 69, 159-170.

Jakrlová, J., 1975. Primary production and plant chemical composition in floodplain meadows. Acta Sci. Nat. Brno 9, 1-52.

Jeník, J., Květ, J. (eds.), 1983. Studie zaplavovaných ekosystémů u Třeboně. (Ecological study of inundated ecosystems near Třeboň, S. Bohemia, Czechoslovakia.). Studie ČSAV, 4/83, 1-156 (in Czech with Engl. summary).

Jung P.K., Koh M.H., Um K.T., 1989: Evaluation of soil erosion management practices on sloping farm land. The Research Reports of the Rural Development Administration Soil and Fertilizer (Korea R.) 31: 16-22.

Kahmen, S., Poschlod, P., Schreiber, K.-F., 2002. Conservation management of calcareous grasslands. Changes in plant species composition and response of functional traits during 25 years. Biological Conservation 104, 319-328.

Kitou, M., Yoshida, S., 1994. Mulching effect of plant residues on soybean growth and soil chemical properties. Soil Sci. Plant Nutr. 40, 211-220.

Klečka A.,1932. Studie o smilkových porostech na pastvinách šumavských (Étude relative aux peuplements du nard des près dans les pâturages de la Šumava). Rozpravy České Akademie Zemědělské, 101-138 (in Czech with French summary).

Klimeš, F., Střeleček, F., Čermák, B., Hrabě, F., Tetter, M., 2001. Methodological aspects in the study of species richness and diversity in species of grasslands. Collection of Scientific Papers, Faculty of Agriculture in České Budějovice, Series for Crop Sciences, 18, No 2, 91-98.

Kornaś, J., Dubiel, E., 1991. Land use and vegetation change in the hay meadows of Ojców National Park during the last thirty years. Veröff. Geobot. Inst. Eidg. Tech. Hochsch. Stift. Rübel Zür. 106, 208-231.

Krahulec, F., 1990. Nardo-Agrostion communities in Krkonoše and West Carpathians Mts. Folia Geobot. et Phytotax. 25, 337-347.

Krahulec, F., Agnew, A.D.Q, Agnew, S., Willems, J., 1990 (eds.): Spatial processes in plants communities. SPB Publishers (The Hague) & Academia (Prague), 259 pp.

Krahulec, F., 1995. Species coexistence in temperate grasslands. Folia Geobot. 30, 113-116.

Krahulec, F., Skálová, H., Herben, T., Hadincová, V., Wildová, R., Pecháčková, S., 2001. Vegetation changes following sheep grazing in abandoned mountain meadows. Appl. Veget. Sci. 4, 97-102.

Kromer, K.H., Reloe, H., 1991. Verfahren des mechanischen Offenhaltens. Technik der Landschaftspflege, 9-22.

Kučera, S., 1995. Geobotanické posouzení centrální části Národního parku Šumava pro účely zonace a management [Geobotanical assessment of the central Šumava National Park for its zoning and management]. In: Pecharová E., Rada P. (eds.): Šumavské studie. BÚ AV ČR, Třeboň, 112 pp. (in Czech).

Kučera, T., Guth, J., 1998. Stabilization of the natural landscape in the Bohemian Forest frontier area (Czech Republic/Germany) abandoned for 40 years. In: Kovář, P., Pušová, R., Kulíšek, P. (eds.): Present and historical Nature-culture interactions in landscapes (Experience for the 3rd millenium) - International conference program and abstract book. Univerzita Karlova, Praha, 183-190.

Kvítek, T., Duffková, R., Peterková, J., 2001. Spatial and seasonal variability of some soil characteristics of A horizon in Zhůří enclave. Silva Gabreta 7, 97-108.

Kvítek, T., Duffková, R., Peterková, J., Mašková, Z., 2000. Teplota a vlhkost půdy rozdílně využívaných porostů lučního stanoviště na Šumavě (Soil temperature and moisture in differently used grassland in the Bohemian Forest). Silva Gabreta 5, 5-62 (in Czech with English summary).

Kvítek, T., Klímová, P., Šonka, J., 1998. Vliv mulčování na botanické složení a pokryvnost lučního porostu, evapotranspiraci a vlhkost půdy (The effect of mulching on botanical composition and species representation in grassland, evapotranspiration and soil moisture content). Rostlinná výroba 44, 553-560 (in Czech, with English summary).

Kvítek, T., Peterková, J., Duffková, R., 2001a. Agrochemical properties of soil in Zhůří enclave. Silva Gabreta 7, 109-118.

Kvítek, T., Peterková, J., Duffková, R., 2001b. Seasonal dynamics of infiltration in soil horizon A in Zhůří enclave. Silva Gabreta 7, 119-130.

Lavorel, S., Garnier, E., 2002. Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. Functional Ecol. 16, 545-556.

Lascano, R.J., Baumhardt, R.L., 1996. Effects of crop residues on soil and plant water evaporation in a dryland cotton system. Theoretical and Applied Climatology 54, 69-84.

Lascano, R.J., Baumhardt, R.L., Hicks, S.K., Heilmann, J.L., 1994. Soil and plant water evaporation from strip-tilled cotton: Measurement and simulation. Agron. J. 86, 987-994.

Lepš, J., Štursa, J., 1989. Species - area relationships, life history strategies and succession - a field test of relationships. Vegetatio 83, 249-257.

Lexa, M., Krahulec, F., 2000. Vliv mulčování na rozkladné procesy a druhové složení horských luk v Krkonoších (Influence of mulching on the process of decomposition and on the species composition of the mountain grasslands in the Krkonoše mountains). Opera Corcontica 37, 571-577 (in Czech with English summary).

Louault, F., Pillar, V.D., Aufrère, J., Garnier, E., Soussana, J.-F., 2005. Plant traits and functional types in response to reduced disturbance in a semi-natural grassland. J. Veget. Sci. 16, 151-160.

Makarov, M.I., Glaser, B., Zech, W., Malysheva, T.I., Bulatnikova, I.V., Volkov, A.V., 2003. Nitrogen dynamics in alpine ecosystems of the northern Caucasus. Plant and Soil 256, 389-402.

Marini, L., Scotton, M., Klimek, S., Isselstein, J., Pecile, A., 2007. Effects of local factors on plant species richness and composition of Alpine meadows. Agric. Ecosyst. Environ. 119, 281-288.

Marková., E, 2002. Mapování škod způsobených zemědělskou činností [Mapping of the damage caused by agriculture]. M.Sc. Thesis, PřF UK, Praha (in Czech).

Mašková, Z., Zemek, F., Heřman, M., Květ, J., 2001. Post World War II development and present state of non-forested area at Zhůří - Huťská hora Mt. Silva Gabreta 7, 15-30.

Mašková, Z., Zemek, F., Květ, J., 2008 (in press). Normalized Difference Vegetation Index (NDVI) in the management of mountain meadows. Boreal Env. Res. 13, xx-xx.

Mašková, Z., Doležal, J., Květ, J., Zemek, F., submitted to Agriculture, Ecosystems and Environment: Long-term functioning of a species-rich mountain meadow under different management regimes.

Merwin, I.A., Stiles, W.C., Vanes, H.M., 1994. Orchard groundcover management impacts on soil physical properties. J. Amer. Soc. Hort. Sci. 119, 216-222.

Meyers, R.J.K., Campbell, C.A., Weier, K.L., 1982. Quantitative relationship between net nitrogen mineralization and moisture content of soil. Canad. J. Soil. Sci., 62, 111-124.

Montagová, Z., 2005. Rozdíly v biometrii a fenologickém stavu vybraných lučních druhů na několika lokalitách v Přírodním parku Vyšebrodsko - Jihočeský kraj, jižní Šumava (Differences in biometric and phenological characteristics of several grassland species on several sites in Vyšebrodsko Nature park - South Bohemia, Czech Republic). B.Sc. Thesis, BF JU, České Budějovice, 45 pp. (in Czech with English annotation).

Moog, D., Poschlod, P., Kahmen, S., 2001. Application of plant functional groups for the evaluation of different grassland management. Verh. Ges. Ökol. 31, 66.

Moog, D., Poschlod, P., Kahmen, S., Schreiber, K.-F., 2002. Comparison of species composition between different grassland management treatments after 25 years. Appl. Veg. Sci. 5, 99-106.

Moravec, J., 1965. Wiesen im mittleren Teil des Boehmerwaldes (Šumava). Vegetace ČSSR A1, 179-385. Academia, Praha.

Myklestad, Å., 2004. Soil, site and management components of variation in species composition of agricultural grasslands in western Norway. Grass and Forage Science 59, 136-143.

Olff, H., Bakker, J.P., 1991. Long term dynamics of standing crop and species composition after the cessation of fertilizer application to mown grassland. J. Appl. Ecol. 28, 1040-1052.

Oomes, M.J.M., 1991. Effects of groundwater level and the removal of nutrients on the yield of non-fertilized grassland. Acta Ecol. 12, 461-469.

Oomes, M.J.M., Kemmers, R.H., 1995. Effects of raising the groundwater level on availability and uptake of nutrients by grassland. Wageningen University and Researchcenter Publications, NNA-Berichte 8, 13-16.

Oomes, M.J.M., Olff, H., Altena, H.J., 1996. Effects of vegetation management and raising the water table on nutrient dynamics and vegetation change in a wet grassland. J. Appl. Ecol. 33, 576-588.

Pecháčková, S., Krahulec, F., 1995. Efficient nitrogen economy: Key to the success of *Polygonum bistorta* in an abandoned mountain meadow. Folia Geobot. 30, 211-222.

Pojerová, J., 2002: Ekologie ohroženého rostlinného druhu *Lilium bulbiferum* L. na stanovištích sekundárního bezlesí v NP a CHKO/ BR Šumava. [Ecology of the endangered plant species *Lilium bulbiferum* L. in the habitats of secondary grassland in the Šumava National Park, Protected Landscape Area/ Biosphere Reserve]. B.Sc. Thesis, BF JU, České Budějovice, 20 pp. (in Czech).

Prach, K., Bufková, I., Zemek, F., Heřman, M., Mašková, Z., 2000. Grassland vegetation in the former military area Dobrá Voda, the Šumava National Park. Silva Gabreta 5, 103-113.

Procházka, J., 1996. Srovnání přirozených a kulturních lokalit mrazového bezlesí [Comparison between the natural and managed frost-exposed forest-free localities]. M.Sc. Thesis, ZF JU, České Budějovice, 76 pp. (in Czech).

Randáková, L., 2003. Vegetace druhotného bezlesí okolí Zadova, Churáňova a Popelné [Vegetation of the forest-free areas surrounding Zadov, Churáňov and Popelná]. M.Sc. Thesis, PřF UK, Praha, 97 pp. (in Czech).

Regal, V., 1967. Ekologické indikační hodnoty nejrozšířenějších lučních rostlin ČSSR. (Ecological indication values of the most common meadow plants of Czechoslovakia.) Rostl. výroba 13, 87-95 (in Czech with English summary).

Ripl, W., Pokorný, J., Eiseltová, M., Ridgill, S., 1994. A holistic approach to the structure and function of wetlands, and their degradation. In: Eiseltová M. (ed.): Restoration of Lake Ecosystems - a Holistic Approach, pp. 36-43. IWRB Publication no. 32, Slimbridge, U.K.

Rosén, E., 1995. Periodic droughts and long-term dynamics of Alvar grassland vegetation on Öland, Sweden. Folia Geobot. 30, 131-140.

Roscher, R., Schumacher, J., Baade, J., Wilcke, W., Gleixner, G., Weisser, W.W., Schmid, B., Schulze E-D., 2004. The role of biodiversity for element cycling and trophic interactions: an experimental approach in a grassland community. Basic and Appl. Ecol. 5, 107-121.

Rybníček, K., Rybníčková, E., 1974. The origin and development of waterlogged meadows in the central part of the Šumava foothills. Folia Geobot. Phytotax. Praha, 9, 45-70.

Rychnovská, M. (ed.), 1985. Ekologie lučních porostů. (Ecology of Meadows.) Academia, Praha, 386 pp. (in Czech with English summary).

Rychnovská, M. (ed.), 1993. Structure and Function of Seminatural Meadows. Academia, Praha, 386 pp.

Ryser, P., Langenauer, R., Gigon, O., 1995. Species richness and vegetation structure in a limestone grassland after 15 years' management with six biomass removal regimes. Folia Geobot. 30, 157-167.

Schusserová, A., 2003. Sekundární travní porosty v západní části Přírodního parku Vyšebrodsko -současný stav, vliv vybraných abiotických faktorů, hospodaření a možné scénáře vývoje budoucnosti. (Secondary grasslands in western part of the Vyšebrodsko Nature Park - present state, influence of selected abiotic factors, management and possible future development). M.Sc. Thesis, BF JU, České Budějovice, 68 pp. (in Czech with English annotation).

Shaw, R., Harte, J., 2001. Control of litter decomposition in a subalpine meadow-sagebrush steppe ecotone under climate change. Ecological Applications 11, 1206-1223.

Smejkal, Z., Pojerová, J., Mašková, Z., Zemek, F., Heřman, M., 2001. Flora and vegetation of the study area at Zhůří (Huťská hora Mt.). Silva Gabreta 7, 31-44.

Smith, R.S., Jones, L., 1991. The phenology of mesotrophic grassland in Pennine Dales, northern England: historic hay cutting dates, vegetation variation and plant species phenologies. J. App. Ecol. 28, 42-59.

Smulders, M.J.M., van der Schoot, J., Geerts, R.H.E.M., Antonisse-de Jong, A.G., Korevaar, H., van der Werf, A., Vosman, B., 2000. Genetic diversity and the reintroduction of meadow species. Plant Biol. 2, 447-454.

Stampfli, A., 1992. Year-to-year changes in unfertilized meadows of great species richness detected by point quadrat. Vegetatio 103, 125-132.

Stampfli, A., 1995. Species composition and standing crop variation in an unfertilized meadow and its relationship to climatic variability during six years. Folia Geobot. 30, 117-130.

Struzina, A., 1990. Der Einfluss von Mulch auf bodenphysikalische Wachstumsfaktoren. Dissertation. Forschungsbericht Agrartechnik des Arbeitskreises Forschung und Lehre der Max-Eyth-Gesellschaft (MEG), Bonn, 148 pp.

Sykes, M.T., van der Maarel, E., Peet, R.K., Willems, J.H., 1994. High species mobility in species-rich plant communities: An intercontinental comparison. Folia Geobot. 29, 439-448.

Šimek, M., Šantrůčková, H., Uhlířová H., Záhora J., Picek T., Brychtová L., Šetlík, J., 2001. The effect of management practice of montane meadows in the Bohemian Forest on selected soil biological and chemical properties. Silva Gabreta 7, 69-78.

Šmahel, L., Schusserová, A., Květ, J., 2001. Comparison of plant species composition and heat balance in three mountain grassland communities. Silva Gabreta 7, 55-68.

Šraitová, D., 2000. Vliv způsobu obhospodařování na druhové složení horských luk v NP Šumava [The effect of management practices on mountain meadows species composition in the Šumava National Park]. M.Sc. Thesis, FŽP, Univerzita J.E. Purkyně, Ústí nad Labem, 61 pp. (in Czech).

Štursová, H., 1974. Příspěvek k ekologii porostů smilky tuhé (*Nardus stricta* L.) v Krkonoších [Contribution to the ecology of *Nardus stricta* L. vegetation in the Krkonoše mountains]. Opera Corcontica, Praha, 11, 79-129 (in Czech).

Tasser, E., Tappeiner, U., 2002. Impact of land use changes on mountain vegetation. Appl. Veg. Sci. 5, 173-184.

Tesař, M., Eliáš, V., Šír, M., 1995. Preliminary results of characterization of cloud and fog water in the mountains of southern and northern Bohemia. J. Hydrol. Hydromech. 43, 412-426.

Tesařová, M., 1976. Litter production and disappearance in some alluvial meadows. (Preliminary results.) Folia Geobot. Phytotax. Praha 11, 63-74.

Troumbis, A.Y., Dimitrakopoulos, P.G., Siamantziouras, A.S.D., Memtsas, D., 2000. Hidden diversity and productivity patterns in mixed Mediterranean grasslands. Oikos 90, 549-559.

Titlyanova, A.A., Romanova, I.P., Kosykh, N.P., Mironycheva-Tokarev, N.P., 1999. Pattern and processes in above-ground and below-ground components of grassland ecosystems. J. Veget. Sci. 10, 307-320.

Van der Putten, W.H., Mortimer, S.R., Hedlund, K., Van Dijk, C., Brown, V.K., Lepš, J., Rodriguez-Barrueco, C., Roy, J., Diaz Len, T.A., Gormsen, D., Korthals, G.W., Lavorel, S., Santa Regina, I., Šmilauer, P., 2000. Plant species diversity as a driver of early succession in abandoned fields: a multi-site approach. Oecologia 124, 91-99.

Vogel, H., Nyagumbo, I., Olsen, K., 1994. Effect of tied riding and mulch ripping on water conservation in maize production on sandveld soils. Tropenlandwirt 95, 33-44.

Voženílková, B., Květ, J., 2001. Fytopatologické aspekty fytocenologické dynamiky a možnosti harmonizace produkčních a mimoprodukčních funkcí travních porostů (Phytopathological aspects of phytocenological dynamics and possibilities of harmonization of grasslands production and non-production functions). Collection of Scientific Papers, Faculty of Agriculture in České Budějovice, Series for Crop Sciences 18, 99-102 (in Czech).

Voženílková , B., Marková, J., Klimeš, F., Květ, J., Mašková, Z., 2008 (in press). The influence of mountain meadow management on the occurrence of *Puccinia perplexans* Plow. J. Plant Dis. Protect. 115, xxx-xxx.

Warren, J., Christal, A., Wilson, F., 2002. Effects of sowing and management on vegetation succession during grassland habitat restoration. Agric. Ecosyst. Environ. 93, 393-402.

Wicks, G.A., Crutchfield, D.A., Burnside, O.C., 1994. Influence of wheat (*Triticum aestivum*) straw mulch and metolachlor on corn (*Zea mays*) growth and yield. Weed Sci. 42, 141-147.

Willems, J.H., 1983. Species composition and above ground phytomass in chalk grassland with different management. Vegetatio 52, 171-180.

Wilsey, B.J., Potvin, P., 2000. Biodiversity and ecosystem functioning: Importance of species evenness in an old field**.** Ecology 81, 887-892.

Wilson, S.D., Tilman, D., 1993. Plant competition and resource availability in response to disturbance and fertilization. Ecology 74, 599-611.

Yibrin, H., Johnson, J.W., Eckert, D.J., 1993. No-till corn production as affected by mulch, potassium placement, and soil exchangeable potassium. Agron. J. 85, 639-644.

Yunusa, I.A.M., Sedgley, R.H., Siddique, K.M.H., 1994. Influence of mulching on the pattern of growth and water use by spring wheat and moisture storage on a fine textured soil. Plant and Soil 160, 119-130.

Zelený, D., Šraitová, D., Mašková, Z., Květ, J., 2001. Management effects on a mountain meadow plant community. Silva Gabreta 7, 45-54.

Zemek, F., Heřman, M., 1999. Natural and socio-economic potential in land use strategic planning. Acta Universitatis Carolinae, Environmentalica 13: 119-124.

Curriculum vitae

Zuzana Mašková née Krátilová,
born 26th January 1969 in Klatovy, Czech Republic

EDUCATION:

1983-1987 Grammar school (Gymnasium), Klatovy, Czech Republic, Specialization mathematics and physics

1987-1992 M.Sc., Department of Plant Anatomy and Physiology, Faculty of Natural Sciences, Charles University, Prague, Czech Republic
Specialization: influence of stress factors on the growth and development of plants
Topic of M.Sc. Thesis: Vliv nedostatku kyslíku na růst a vývoj kukuřice *Zea mays* L. (Effect of oxygen deficiency on the growth and development of maize *Zea mays* L.). In Czech.
(Supervisor: Doc. RNDr. Olga Votrubová, CSc.)

1996-2008 Ph.D. student, Department of Ecosystems Biology, Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic
Topic of Ph.D. Thesis: Functioning of Mountain Meadows under Different Management Impacts (Funkce horských luk při různých způsobech jejich obhospodařování)
(Supervisor: RNDr. Jan Květ, CSc.)

PROFESSIONAL EXPERIENCE:

since 1992 Administration of the Šumava National Park and Protected Landscape Area (botany, coordination of external research activities, coordination of the programme NATURA 2000)

PROJECTS:

Principal investigator of the project no. VaV/620/5/97 "The Effect of Changes in Cultivation Practices and Atmospheric Deposition on Biosphere Quality in Mountain and Submontane Area of the Šumava Mts." (supported by the Ministry of Environment of the C.R.).

Joint investigator of the project no. 206/99/1410 "Functioning of Mountain Meadows under Different Management Impacts" (supported by the Grant Agency of the C.R.).

List of publications

a) Publications in journals with a scientific impact

Zemek, F., Heřman, M., **Mašková, Z**., Květ, J., 2005. Multifunctional land use - a chance of resettling abandoned landscapes? (A case study of the Zhůří territory, Czech Republic). Ekológia 24, suppl. 1/2005, 96-108.

Mašková Z., Zemek F., Květ J., 2008. Normalized Difference Vegetation Index (NDVI) in the management of mountain meadows. Boreal Env. Res. 13, xx-xx.

Voženílková, B., Marková, J., Klimeš, F., Květ, J., **Mašková, Z**., 2008. The influence of mountain meadow management on the occurrence of *Puccinia perplexans* Plow. J. Plant Dis. Protect. 115, xx-xx.

Mašková, Z., Doležal, J., Květ, J., Zemek, F., submitted to Agriculture, Ecosystems and Environment. Long-term functioning of a species-rich mountain meadow under different management regimes.

b) Other scientific publications

Mašková, Z., 1996. Alternativní metody údržby trvalých travních porostů v horské a podhorské oblasti Šumavy [Alternative methods of perennial grassland vegetation maintenance in the mountain and submontane area of the Šumava Mts.]. Šumava, Léto: 25 (in Czech).

Prach, K., Bufková, I., Zemek, F., Heřman, M., **Mašková, Z**., 2000. Grassland vegetation in the former military area Dobrá Voda, the Šumava national Park. Silva Gabreta 5, 103-113.

Kvítek, T., Duffková, R., Peterková, J., **Mašková, Z**., 2000. Teplota a vlhkost půdy rozdílně využívaných porostů lučního stanoviště na Šumavě (Soil temperature and moisture in differently used grassland in the Bohemian Forest). Silva Gabreta 5, 51-62 (in Czech with English summary).

Mašková, Z., Květ, J., Zemek, F., Heřman, M., 2001. Functioning of mountain meadows under different management impact - research project. Silva Gabreta 7, 5-14.

Mašková, Z., Zemek, F., Heřman, M., Květ, J., 2001. Post World War II development and present state of non-forested area at Zhůří - Huťská hora Mt. Silva Gabreta 7, 15-30.

Smejkal, Z., Pojerová, J., **Mašková, Z**., Zemek, F., Heřman, M., 2001. Flora and vegetation of the study area at Zhůří (Huťská hora Mt.). Silva Gabreta 7, 31-44.

Zelený, D., Šraitová, D., **Mašková, Z**., Květ, J., 2001. Management effects on a mountain meadow plant community. Silva Gabreta 7, 45-54.

Albrecht, J., et al., 2003. Českobudějovicko. In: Mackovčin, P. a Sedláček, M. (eds.): Chráněná území ČR, svazek VIII. Agentura ochrany přírody a krajiny ČR & EkoCentrum Brno, Praha, 808 pp.

Mašková, Z., Květ, J., Zelený, D., 2004. Produktivita horských luk při různých způsobech hospodaření (Productivity of different managed mountain meadows). In: Mánek, J. (ed.): Aktuality šumavského výzkumu II, Srní 4.- 7. října 2004, 243-250, Vimperk (in Czech with English summary).

c) Presentations at conferences, symposia, etc., and their abstracts

Mašková, Z., et al., 1999. Functioning of differently managed mountain meadows. The 4th Central and East European Regional Meeting of the International Long-Term Ecological Research "Towards the 21st Century", Prague, Czech Republic, April 8-11, 2001. (PowerPoint Presentation).

Květ, J., **Mašková, Z.,** Šraitová, D., Pojerová, J., 2000. Produkce a kvalita rostlinné biomasy (Production and quality of plant biomass). (poster)

Kvítek, T., Duffková, R., Peterková, J., **Mašková, Z.,** 2000. Teplota a vlhkost půdy rozdílně využívaných porostů lučního stanoviště na Šumavě (Soil temperature and moisture in differently used grassland in the Šumava). (poster)

Šimek, M., Šantrůčková, H., Uhlířová, E., Picek, T., **Mašková, Z.,** 2000. Mikrobiální charakteristiky půd a emise plynných metabolitů (Soil microbial properties and emissions of gaseous metabolites). (poster)

Šraitová, D., **Mašková, Z.,** 2000. Druhové složení lučního porostu (Species composition of grassland community). (poster)

All four posters were parts of complex poster presentations at the following three conferences:

In: Květ, J., et al., 2000. Funkce horských luk při různých způsobech jejich obhospodařování (Functioning of mountain meadows under different management impacts). III.mezinárodní konference "Agroregion" 2000, 30.8.-1.9. 2000, ZF JU České Budějovice.

In: Květ, J., et al., 2000. Funkce horských luk při různých způsobech jejich obhospodařování (Functioning of mountain meadows under different management impacts). 4th International Conference "Ecophysiology of Plant Production Processes in Stress Conditions", Račkova dolina, September 12-14, 2000.

In: Květ, J., et al., 2000. Funkce horských luk při různých způsobech jejich obhospodařování (Functioning of mountain meadows under different management impacts). Konference "Aktuality šumavského výzkumu", Správa NP a CHKO Šumava, Srní 2.-4. dubna 2001.

Abstracts

Květ, J., **Mašková, Z**., Šimek, M., Voženílková, B., Kvítek, T., Pižl, V., 2001. Vliv rozdílného způsobu hospodaření na horské louky [The effect of changes in cultural practices on mountain meadows]. In: Mánek, J. (ed.): Aktuality šumavského výzkumu, Srní 2.-4. dubna 2001, p. 26, Vimperk (in Czech).

Šimek, M., **Mašková, Z**., Šantrůčková, H., Uhlířová, E., 2001. Carbon cycling in mountain meadows: the effect of management practices on CO_2 emissions from and microbial carbon accumulation in soil. In: Interaction in the microbial world. 9th International Symposium on Microbial Ecology, Amsterdam, 26-31 August 2001. Final programme and abstracts, P.20.058, p. 340.

Voženílková, B., Klimeš, F., Květ, J., **Mašková, Z**., Čermák, B., Suchý, K., 2005. The influence of management on health status of *Festuca rubra* in mountain meadows. In: Milne, J.A. (ed.): Pastoral systems in marginal environments. Proceedings of a satellite workshop of the XXth International Grassland Congress, July 2005, Glasgow, Scotland. Wageningen Academic Publishers, Netherlands, p. 144.

d) Participation in research projects

Principal investigator of the project no. VaV/620/5/97 ”The Effect of Changes in Cultivation Practices and Atmospheric Deposition on Biosphere Quality in Mountain and Submontane Area of the Šumava Mts.” (supported by the Ministry of Environment of the CR).

Joint investigator of the project no. 206/99/1410 ”Functioning of Mountain Meadows under Different Management Impacts” (supported by the Grant Agency of the CR).

e) Unpublished materials

Bufka, L., Bufková, I., Kovařík, K., Mánek, J., Martanová, J., **Mašková, Z.,** Silovský, V., Skolek, M., Valenta, M., Zatloukal, V., Zelenková, E., 2000. Plán péče Národního parku Šumava [Management plan of the Šumava National Park]. Ms. Šumava Nat. Park Admministration, Vimperk, 140 pp. (in Czech).

Mašková, Z., 2003. Radkov (P0112A). Závěrečná zpráva k mapování biotopů soustavy Natura 2000 a Smaragd [Biotope mapping final report - Natura 2000 and Smaragd]. Ms., depon. in AOPK ČR Praha, Správa NP a CHKO Šumava Sušice (in Czech).

Mašková, Z., 2004. Churáňov - Nové Hutě (P0135A). Závěrečná zpráva k mapování biotopů soustavy Natura 2000 a Smaragd [Biotope mapping final report - Natura 2000 and Smaragd]. Ms., depon. in AOPK ČR Praha, Správa NP a CHKO Šumava Sušice (in Czech).

Mašková, Z., 2005. Vymezení a charakteristika přírodních komplexů soustavy Natura 2000 v CHKO Šumava [Delimitation and characterization of Natura 2000 biotopes in the LPA of Šumava]. Ms., depon. in AOPK ČR Praha, Správa NP a CHKO Šumava Sušice (in Czech).

Mašková, Z., 2005. Vymezení a charakteristika Evropsky významné lokality Šumava v soustavě Natura 2000 [Delimitation and characteristics of The Site of Community Importace of Šumava in Natura 2000]. Ms., depon. in AOPK ČR Praha, Správa NP a CHKO Šumava Sušice (in Czech).

Mašková, Z., 2005. Závěrečná zpráva k rektifikaci mapování biotopů v CHKO Šumava [Final report on the biotope mapping rectification in the LPA of Šumava]. Ms., depon. in AOPK ČR Praha, Správa NP a CHKO Šumava Sušice (in Czech).

Mašková, Z., 2006. Zdíkovsko. Závěrečná zpráva k aktualizaci mapování biotopů v CHKO Šumava [Final report on the updated biotope mapping in the LPA of Šumava]. Ms., depon. in AOPK ČR Praha, Správa NP a CHKO Šumava Sušice (in Czech).

Mašková, Z., 2007. Javorensko. Závěrečná zpráva k aktualizaci mapování biotopů v CHKO Šumava [Final report on updated biotope mapping in the LPA of Šumava]. Ms., depon. in AOPK ČR Praha, Správa NP a CHKO Šumava Sušice (in Czech).

Mašková, Z., 2007. Železnorudsko. Závěrečná zpráva k aktualizaci mapování biotopů v CHKO Šumava [Final report on updated biotope mapping in the LPA of Šumava]. Ms., depon. in AOPK ČR Praha, Správa NP a CHKO Šumava Sušice (in Czech).