Czech University of Life Sciences Prague

Faculty of Environmental Sciences

Master Thesis

Seasonal dynamic of herbage biomass under long term intensive and extensive grazing management

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DIPLOMA THESIS ASSIGNMENT

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Seasonal dynamic of herbage biomass under the long term intensive and extensive grazing management

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Objectives of thesis

The aim of the thesis is to analyze a long-term data (2002-2015) concerning growing dynamic of herbage biomass during vegetation season under extensive and intensive grazing.

Methodology

There will be used long-term data from the grazing experiment in Oldřichov in Hájích (2002-2015). Treatments: intensive and extensive grazing performed in two blocks (four paddocks). There were used four exclosure cages of the size of 1 m x 1 m in each paddock. The herbage biomass was collected under the cages by electric scissors every 3 weeks during the vegetation season. After collection, the biomass was dried and weighed. Statistical analyzes will be performed by univariate method (ANOVA).

The proposed extent of the thesis

50 pages

Keywords

grassland, biomass yield, heifers grazing, exclosure cages

Recommended information sources

Frame J. (1992): Improved Grassland Management. Farming Press. UK, 351 pp.
Hodgson J., Illius A.W. /Eds/ (1996): The Ecology and Management of Grazing Systems. CABI International. UK, 466 pp.
Valentine J.F. (2001): Grazing Management. Academic Press. US, 659 pp.

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Prague on 19. 04. 2016

Declaration

I hereby declare that I am the sole author of this master thesis entitled: “Seasonal dynamics of herbage biomass under long-term intensive and extensive grazing management”.

I certify all the works presented in this thesis are original and all the used literatures and sources are enclosed in the attached list of references.

Prague, 19th April, 2016

Teowdroes Kassahun

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Abstract

Grasslands main role is to provide sufficient feed for livestock, and there has been huge interest to understand and quantify available biomass from different management strategies that can meet livestock demand and landscape management. A fourteen year (2002–2015) study was conducted on upland grassland maintained under long-term experiment in the Jizerské hory (Oldrichov v Hájích village), Czech Republic. The study analyzed the effect of intensive (IG) and extensive (EG) grazing on the dynamic of biomass production in the course of the grazing season. The sward height was maintained under 5 and 10 cm for IG and EG treatments respectively. Total biomass production in the grazing season was found to be higher under IG than EG and varied between (2.4 to 5 t DM ha^{-1} year^{-1}) under IG and (2.3 to 4.7 t DM ha^{-1} year^{-1}) under EG. Double peak (spring and summer) curves of biomass growth during the growing season was found nine times in the fourteen year experiment which makes it very unique form what is commonly found us a single peak curve in the spring in Czech uplands. Sward height was found to be a significant predictor of herbage biomass with strong relationship between sward height and herbage biomass under IG (R^2 =0.933) and (R^2= 0.748) in EG. Considering the number of herbivores in Czech Republic it is clear that EG is a better landscape management that can fulfill the livestock needs and mitigate temporary or permanent abandonment of grasslands.

Keywords: Grasslands, Biomass yield, Heifers grazing, Ex-closure cages

Abstrakt

Hlavní účel travních porostů je poskytnout dostatek píce pro dobytek a proto je velkým zájmem porozumět a kvantifikovat dostupnou biomasu z různých managementových strategií, které by měly uspokojit potřeby zvířat a obhospodařování krajiny. Studie, která trvala 14 let (2002-2015) byly prováděna na podhorském travním porostu na dlouhodobém experimentu v Jizerských horách (obec Oldřichov v Hájích), Česká republika. Tato studie analyzovala vliv intenzivní a extenzivní pastvy na dynamiku produkce biomasy v průběhu pastevní sezóny. Výška travního prostu byla udržována pod 5 cm u IG varianty a nad 10 cm u EG varianty. Celková produkce biomasy v průběhu pastevní sezóny byla větší na IG variantě (2,4 to 5,0 t sušiny ha^{-1} rok^{-1}) než na EG variantě (2,3 to 4,7 t sušiny ha^{-1} rok^{-1}). Dvouvrcholová křivka pro nárůst biomasy (jaro, léto) bylo v průběhu pastevní sezóny zjištěno devět krát ze čtrnáctileté řady experimentu, což ukazuje, že typická jedno vrcholová křivka růstu je méně častá v podhorské oblasti České republiky. Výška travního porostu byla významným prediktorem biomasy travního porostu, s významnou korelací mezi výškou a biomasou pro IG variantu (R2 =0,933) a pro EG variantu (R2= 0,748). Výsledky ukazují, že extenzivní pastva je vhodný krajinný management, který může uspokojit potřeby zvířat a může zmírnit dočasné, nebo trvalé opuštění obhospodařování na travních porostech.

Keywords: Travní porost, Výnos biomasy, Pastva jalovic, Pastevní klece, Výška porostu

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Chapter 1

1.1 Introduction

Grasslands are one of the main parts of the European cultural landscape. When it comes to a place that support species rich grassland communities Central Europe comes in front. But lack of appropriate management has lead these semi-natural, nutrient deficient grasslands to degradation and gradually encroached by shrubs or wooded communities (Klimeš et al. 2013). Since the mid of the 20th century these semi natural grasslands have faced significant reduction due to fertilization, conversion into arable land or sometimes even abandonment (Isselstein et al. 2005). These intensification plans has replaced several permanent grassland species with more productive species. Czech Republic is one of those countries that were not immune from these changes. Grasslands are important feature in Czech landscapes, and in 1970s out of 724,000 ha of grasslands, more than forty eight thousand hectors of meadows and pastures were ploughed and reseeded and more than thirty three thousand hectares were drained (Pavlů et al. 2003). At the same time livestock population have been declining steadily, this has a serious consequence were more than 30% of grasslands in Czech landscape are unmanaged meadows and pastures, where grazing is necessary (Pavlů et al. 2006a).

Following a change in political regimes in the 1990s, many post-communist countries have applied various grassland management strategies. Some of the measures taken have led to decline in livestock numbers, which is the case in Czech Republic and increase in grassland areas by reseeding previous arable lands (Pavlů et al. 2006a). But the pressure form consumers and attention for nature conservation from decision makers have pushed for a change that led to more extensive management. Hence shift from intensification to extensive management has been regarded as better alternative for the problem of increasing grassland area and declining livestock population. But the need for more information especially on biomass production under the different management strategies has been growing. As grasslands main role is supplying feed for herbivorous, their are huge interest in understanding and quantifying the amount of biomass produced from grasslands. These helps to know the amount of forage available for animals, number of livestock we can feed and also measure the effects of grassland management. Hence critical decisions regarding which management to accept are made based on vegetation measurements (Mannetje and Jones 2012).

Reseeding, cutting frequency and application of fertilizer have been widely accepted and regarded as the main indicator for intensive grassland management in central and Western Europe (Pavlů et al. 2006a). Mowing, grazing and very limited application of fertilizer have been described as extensive management indicators, which are also the way grasslands have been historically managed. So far their have been few studies which focused on the effect of change or shift in management systems such as shift from intensive to extensive grazing management. These shifts have brought significant changes in sward structure, plant species diversity and most importantly change in productivity of the grasslands. Therefore it is important to see the variability on these indicators both within the different months and also across the growing season. Until now their have been limited information available on long-term effect and seasonal dynamics of biomass under intensive and extensive grazing management. In climate change era were weather becomes more unpredictable with unbalanced precipitation and temperature, management decisions are becoming difficult. Therefore, to successfully secure the role of grasslands, we need to evaluate their productivity and also assess the appropriate management practices that can help us meet different targets in terms of herbage yield and the sustainability of grasslands.

Chapter 2

2.2 Aim of the study

The aim of the thesis is to analyze a long-term data (2002-2015) concerning growing dynamic of herbage biomass during vegetation season under extensive and intensive grazing management. The purpose of the study is:

- Measure the effect of the different managements on dry matter biomass production
- Asses factors that influence production of biomass
- Test the potential of sward height as herbage biomass predictor.

Chapter 3

3.1 Literature review

3.2 Temperate Grassland

Grasslands give different meaning to different authors. It can refer to as a plant community which is opposite to forest, or to an ecosystem consisting of soil, domestic/wild animals, vegetation and management. Others also define it as plant community in which grasses are dominant and shrubs are rare and trees are not available at all. However, in global scale, they are areas which are covered by grasses, which are used for livestock production or as game reserves, usually consisting of woody species. UNESCO-UNEP-FAO, (1979), defines grasslands as “a plant community in which woody species do not exceed 40% of the total cover”.

We can also distinguish grasslands between rangelands and improved/sown grasslands. Rangelands are grasslands were management is limited to grazing; burning and elimination of woody species prevail and comprise species that are native or naturalized. On the other hand improved grasslands are mainly sown and management mostly includes fertilization, irrigation and drainage (Mannetje and Jones 2012).

After tropical forest, grasslands form the greatest terrestrial biome, in terms of biomass. They can be natural or manipulated (by human). In terms of ecology, grasslands are considered as pure or areas free of wooded vegetation types controlled by several factors such as soil, climate, biotic factors and topography. Natural grasslands are in general more common in areas were climatic conditions are either too cold or too dry for forests to occur. They are also quite common in areas that are burnt or in heavy textured soils. Man-made or manipulated grasslands are common in humid and sub-humid climates, because these areas do not have the necessary climatic conditions needed for grasslands to prevail naturally (Mannetje and Jones 2012).

Grasslands are one of the most important parts of the European cultural landscape, regardless of the amount of agricultural exploitation that is going on for generations. It represents the only crop that has well developed homeostatic mechanism and stable even without any additional input of energy. They are by far the best source of solar energy for the proteins required by livestock, with minimal disturbance to the landscape and soil (Rychnovska 1993). In central European condition, most of the grasslands we find do not represent climax communities as they were largely created after large scale deforestation and maintained by agriculture activities. In general Grazing and mowing have been the most widely used management strategy for centuries or even in some areas possibly up to Neolithic or Bronze Age. These grasslands posse not only natural values, but also have huge cultural-historical value, as they have been under the influence of human for several generations (Jongepierová et al. 2012).

We find temperate grasslands in regions were the climatic conditions (mid-altitude) are favorable for dominant perennial grasses. The Eurasia, steppes covers 250 million ha of the plain extending from Hungary to Northeast China. These grasslands are important buffer zones between forest and deserts and can act as a frontier for expansion between the forest and desert depending on the dominant climatic conditions (Shinoda et al. 2011). In the context of European grasslands, they have rich flora and can develop a very high small scale species density compared to other community types. For example, the largest vascular plant species numbers are found at the smallest scale of a few square centimeters to one square meter in temperate grasslands. European grasslands are also famous for their richness in terms of genetic variability within plant species. They possess several threatened species and show diverse landscape patterns (Pärtel et al. 2005). In central Europe, the importance of grasslands is even bigger. In the past they played significant role especially in the mountain region were they are used as a source of fodder for ruminant animals, mostly for sheep’s.

A review by Hejcman (2013) divides grasslands in central Europe, in to three broad categories based on their origin:

(1) Natural grasslands: differentiated by the climatic condition like shortage of moisture which is common for a steppe region on the eastern border of Central Europe and low temperature with shorter growing season for higher mountains above the upper tree limit;

(2) Semi-natural grasslands: These grasslands are mostly linked to human interaction starting from the beginning of agriculture during the Mesolithic-Neolithic transition.

They have also a wide range of species richness of vascular plants ranging from 1 to 67 species and herbage production from 1 to 10 ton dry matter. Semi-natural grasslands can also be further divided based on the management system they are in as pastures, meadows, and grazed meadows. Livestock grazing is the key management for pastures, regular cutting for meadows and cutting in spring and grazing in summer/autumn for grazed meadows.

(3) Intensive grasslands: are the result of intensive agriculture, which includes sowing of highly productive forage grasses and legumes.

Temperate grasslands usually exist because of moderate disturbances such as grazing, mowing or fire incidences. Most of them are sub climax communities, hence they require periodic defoliation to avoid succession that could lead to being converted into scrubs and woodlands (Rook et al. 2004). During the last millennia temperate European grasslands have been largely managed by grazing of domestic animals or by hay making activities. This is one of the main reasons why this ecosystem is mostly described as semi-natural. It just implies the importance of grazing be it wild or domestic animals. In general they are dependent on some kind of disturbance that inhibits dominance of woody plants (Pärtel et al. 2005).

Within the last 100 years we have seen significant decline of grassland areas across Europe. Humans have played tremendous role in these changes. They have changed various land use and grasslands have been one of the major expansion area. Highly productive grasslands were converted to artificial pastures, arable land and mixed farming. Although conversion of grasslands came more prominent in temperate grasslands before 1950s, the conservation efforts dedicated for this biome compared to other biome is relatively small (Dixon et al. 2014). Currently, there are huge efforts across Europe to conserving and restoring grasslands. But the destruction and fragmentation that has occurred for several decades in many regions have been so severe, long-term sustainability of biodiversity has become an issue. In the long run restoration may help to alleviate extinction and reduce the effect of fragmentations. But we should always remember that time is a limiting factor in restoration activities. Natural species immigration is a long-term process. It has been suggested that we may need more than

100 years to properly restore grassland vegetation that has been converted to arable land (Pärtel et al. 2005).

3.2.1 Grassland vegetation

Even though grasses are expected to be the most dominant in grasslands, the term grasslands has a broader meaning when we consider defining it in a comprehensive ecological vegetation types such as grasslands versus forests, desert, tundra or wetlands. Still in this concept they are dominated by grasses or grass like plants (graminoids) and lack of trees, narrow leaved herbs and forbs (Dixon et al. 2014). Evolutionary processes are responsible for creating a set of plant species that can sustain life in grasslands species spool. The present climatic conditions and land use history are mainly the reason for the formation of complex landscapes, where various vegetation types exist and form a mosaic (Pärtel et al. 2005).

During the 1960s to 1980s, many species rich grasslands in Czech Republic have been reseeded and ploughed with highly productive forage grasses and also fertilized. This process has led to the dominance of certain tall species such as *Alopecurus pratensis, Dactylis glomerata, Festuca arundinacea, Festuca pratensis and Phleum pretense.* Furthermore, huge parts of the arable lands were grassed down by tall grasses in less favorable places such as mountain regions. These tall grass swards are by far the dominant grassland type in Czech Republic. In areas where they are unmanaged, *Urtica dioica* is dominant, especially on soil that has good nutrient supply and water (Hejcman et al. 2012). In the study area near the town of Liberec in Oldrichov at Hájích village, the dominant species were different from what we have today. Before the area was used for experiment in the 1980s the dominant species were *Elytriga repens*, *Agrostis capillaris, Lolium perenne, Trifolium repens and Taraxacum spp*. On the later stages the area was ploughed and reseeded with more productive grasses such as *Dactylis glomerata*, *Festuca pratensis*, *Lolium perenne* and *Phleum pretense* (Pavlů et al. 2003).

Table 1 Functional groups of the study area

Tall grasses	Short Grasses	Prostate herbs	Annuals
Alopecurus pratensis	*Agrostis capillaris*	*Bellis perennis*	*Capsella bursa-pastoris*
Dactylis glomerata	*Lolium perenne*	*Hypochoeris radicata*	*Cirsium vulgate*
Elytrigia repens	*Poa pratensis*	*Leontodon autumnalis*	*Poa annua*
Festuca pratensis		*Leontodon hispidus*	*Veronica arvensis*
Holcus mollis		*Plantago major*	
Poa trivialis		*Taraxacum spp.*	
		Trifolium repens	

Source: "Effect of rotational and continuous grazing on vegetation of an upland grassland in the Jizerské hory Mts., Czech Republic" by Pavlů,. et al., 2003. *Folia Geobotanica*.

Description and Characteristics of dominant plant species in the study area based on Grime et al. (1998):

Agrostis capillaris (A.c.): It is a perennial grass which is present almost in all major types of habitats. It is largely abundant in permanent pastures, on heaths and waste places, urban to coastal wetlands. Other common habitats are grassy paths, road sides, railways ballast, rock outcrops and open or grazed areas in plantations, scrubs and woodlands. Defoliation experiments show *A.c* is a resilient species especially in fertile conditions. It also survives burning which is also factor in grasslands. In general it can regenerate by rhizomes or stolon's which enable it to form extensive patches, and at upland pastures and other areas it is usually the dominant species due to its ability to spread laterally. It is also able to grow by seed, germinating in autumn, or in spring.

Festuca pratensis (F.p.): It is found in both unmanaged and managed (meadows, pastures) moist grasslands and also common in marshy habitats and reaches its peak in areas were water retention is high in clay and alluvial soils. It can grow in wide range of altitudes. The species has huge agricultural importance, mainly in meadows. It is short lived grassland species which is also palatable to livestock's. The regeneration strategies of the species are by seed in autumn and it does not form persistent seed bank.

Alopecurus pratensis (A.p.): It is a moderately productive species common at meadows and pastures. It can grow also on road sides and hedgerows. One can see this species easily in other grassy habitats but not on wetlands or arable lands. It is more abundant at altitudes above 400 m, which makes it more common in permanent pastures and hay meadows in upland regions. It grows early in the spring and it is the earliest flowering species of all common perennial grasses. It has important dimension of niche that helps it to grow under moderate shade. When it comes to ecological distribution, it is restricted to moist soil, well drained soils and rarely grows in water logged soils during the summer.

Trifolium repen (T.r.): A species that is either native or naturalized across most part of the temperate region. It is a perennial and insect pollinated species; it can also spread vegetatively by stolon. We can find the species in meadows, pastures as well as in arable lands mainly as seedling. *T.r,* is shade in-tolerant species and rapidly suppressed in tall vegetation. It is a nitrogen fixing species, which creates conditions sufficient for invasion and temporary dominance by other grasses. This in turn affects *T.r.* by suppression from other growing species, ultimately decreasing the available Nitrogen. *T.r.* potential growth comes in the summer rather than spring and autumn peaks like other species. Additionally the species can survive intensive grading, trampling and frequent cutting.

Festuca rubra (F.r.): It is a wide spread species throughout the northern hemisphere tolerating many habitats and climates. *F.r.* is mostly common on base rich grasslands and absent in most acidic soils. It is common in areas were competition is less or moderate due to intensities by disturbance. In areas where *F.r.* is the dominant species, the vegetation is usually species rich.

Aegopodium podagraria (A.p.): It is an herbaceous perennial species that can grow and be considered as tall. It reproduces vegetatively via stolon and has the potential to spread aggressively if its root zones have no restriction. *A.p.* is native species to Europe and can grow in shady places. Once established *A.p.* is highly competitive, even in conditions were the environment is mostly shaded.

Taraxacum: It is one of the species that is very challenging to taxonomically group. It is very common in meadows and pastures, waysides and wastelands. Basically one can find *Taraxacum* in all habitats except in aquatic habitats. In some areas it is considered as garden weed. It is widely distributed and can grow up to an altitude of 1220 m. Majority of *Taraxacum* species are seed dispersed and can colonize disturbed soil.

Gallium album (G.a.): It is one of the species that is widespread over much of Europe. It is common on meadows and pastures, grassy banks and disturbed habitats etc. It can grow on various altitudes ranging from lowland to uplands and foothills. The species has erect stem and reaches up to 150 cm with ascending branches.

3.2.2 Grassland management

Grasslands of various types account over 3.000 million ha or about a quarter of the earth's land area. They are one of the largest terrestrial ecosystems, were grazing is the main land use. Within the past 100 years considerable changes in utilization of grasslands have occurred, leading to decline in diversity and overall biological diversity which became a major conservation challenge (Pavlů et al. 2011a). Considering nature conservation objectives, the years between 1950s and 1980s was devastating. Dramatic decline in flora and fauna species richness of grasslands occurred due to change from their traditional land use. These changes are mostly characterized by either intensification and ploughing or abandonment of the lands and sometimes totally converted and used for reforestation (Gibon 2005). Due to this and increasing public demand for an attractive landscape, conservation of plant and animal wildlife, and desire for food from environmentally friendly farming, new approaches to grassland management emerged (Frame 1992). Various conservation biologists try to divide grassland management aims into three broad categories: (1) preserving the biological diversity of grasslands, (2) Preserving the open landscape and (3) protection of aesthetic values (Hansson and Fogelfors 2000).

Despite understanding the importance of grasslands, 20th century, brought severe reduction in many parts of the world. Not surprisingly the biggest changes have occurred within the last fifty years. After the end of World War II, the main objective in agricultural development was replacement of permanent grasslands with more productive forage crops. Furthermore the ploughing up of permanent grasslands in lowlands and hills has been the most significant changes in many parts of Europe. The greatest impact has been in lands that were traditionally used for rearing herbivores in the plains. The amount of land needed for grazing declined dramatically as much of the plains were replaced with high yielding forage crops. The areas that did not face these changes are either areas that are located in harsh environments such as mountainous and wetland areas and those in lowlands with an oceanic climate (western Europe) that have specialized in dairy or meat production (Gibon 2005).

Economy has played an important role in influencing the management aspects. Under economic pressure, intensive grazing has been promoted and on other hand abandonment of livestock grazing supported (Hopkins and Holz 2006). These rapid changes were more visible in eastern and central European countries that were undergoing economic transformation and building a market economy. For instance in Czech Republic, livestock's are important especially in the uplands and mountainous areas. And due to economic transformation the management scheme for grassland needed to be adjusted. Following this the livestock population declined from 3.36 million in 1990 to 1,127 million in 2003. In the same period, permanent grassland area increased from 833,000 to 961,000 ha, as more arable land was reseeded with grasses in less favorable areas (Pavlů, et al. 2006a).

The management system we apply will have significant effect on the taxonomic as well as on the functional plant composition through resource availability and disturbances. Although several factors can be mentioned the most influential are defoliation and change of nutrient availability through fertilization. In some cases site specific traditional management regimes can also have effect (Muller et al. 2015). The management strategies that have been followed for several years also brought several environmental problems, whether it is intensive or extensive management. For instance, in low lands areas intensive application of organic and mineral fertilizer was promoted to increase livestock production, but soil and water pollution was also linked to this intensification (Atkinson and Watson 1996). In areas were abandonment succeeded due to harsh conditions, encroachment by shrubs and trees succeeded, which intern increased the risk of fire and decline in biodiversity (MacDonald et al. 2000). In general the intensification programs have led to increasing structural and biological homogenization or in extreme cases loss of grasslands. In these intensively managed grasslands, few productive species out-compete other plant species and functional groups such as tall herbs and legumes, which will affect the ecosystem structure and function (Muller et al. 2015). Since the last twenty years, we are seeing serious shift from decision makers in terms of encouraging large areas of grassland that were previously intensified to be de-intensified for ecological reasons. Off course restoration of these eutrophic grasslands and re-establishment of native communities is not easy, it requires suable technical knowledge. Several studies show depletion of the excess nutrient could be one way in restoring eutrophic grasslands. Furthermore, the interaction of elements such as Nitrogen and Phosphorus must also be considered if nutrient depletion is chosen as a means for restoration of species-rich grasslands (Pavlů et al. 2011a).

When we are referring to management of temperate grasslands, we should not forget the roles played by grazing animals. In sward management we can divide grazing methods in two broad categories: continuous and rotational grazing. The main difference between them is capital cost, labor needed to operate, easiness of operation, degree of control of the stock and interaction between stock and sward. Under continuous grazing we let the animals to graze the area for the whole grazing season. But in rotational grazing the area is divided in to paddocks that will be grazed in sequences, giving each paddock a rest period. In Czech Republic, the main pasture management before 1989 was rotational grazing. But in 1980s, due to the decline in capital cost continuous stocking was introduced (Pavlů et al. 2003). Grazing or defoliation is very important in temperate grasslands especially to control succession to scrubs or woodlands. We can still have these defoliations in places that are not conducive for livestock such as steep slopes or uneven grounds, using mechanical harvesting equipment’s. This has been clearly demonstrated in hay meadows that have evolved to such management.

Defoliation using grazing animals is vital to maintain and enhance structural heterogeneity of the sward canopy, which can also influence floral and faunal diversity (Rook and Tallowin 2003). The selective defoliation which is mainly due to dietary choice is the main mechanism in which grazing animals create sward heterogeneity. Firstly, it changes the competitive advantage between species plant species due to direct removal of plant biomass, secondly it opens up spaces which will be colonized by gap colonizing species and thirdly, the nutrient cycling which occurs through dung and urine (Rook et al. 2004). It is well documented that grasslands communities in Europe depend on several kinds of physical disturbances that inhibit shrub and tree. Evidences show grassland management by livestock grazing at moderate level can help to maintain species diversity by suppressing the abundance of competitive species. The disturbance in the soil and the sward structure is also important as it enables species establishment through niches (Klimek et al. 2007).

Several factors affect grazed grasslands in contrast to cut grasslands. Trampling, nutrient addition through urine and feces, selective defoliation by herbivores and seed dispersal are few of them. Hence grazing management that we apply will have different effects on sward, and the specific effect of grazing on sward depends on the type of grazing animal, grazing pressure and intensity, timing and duration of stocking. Heterogeneous sward structure with mosaic height is created as the grazing animals graze selectively on specific species and at certain plant parts (Ludvíková et al. 2015).

3.2.2.1 Intensive management

Since the second half of 20th century cutting frequency, reseeding, drainage and increase use of fertilizers have been accepted as the main indicator of grassland intensification in Central and Western Europe. Historically, grasslands have been managed and utilized extensively using mowing and grazing and very rarely received any kind of artificial fertilizers (Klimek et al. 2007). But despite their relative importance, grassland areas experienced tremendous decline during the last 50 years all over Europe. As part of the intensification plan, replacement of permanent grasslands with more productive forages crops and indiscriminate plough of grasslands (hills) occurred rapidly. For instance, the European community (EC) reported 4 million hectares of permanent grassland lost between 1975 and 1995 in 9 countries (Gibon 2005). The land that is needed for grazing significantly declined as they were replaced by high-yielding fodder crops. For example, in Czech Republic, huge areas of land were incorporated into arable land. The so called low yield meadows and pastures were ploughed and reseeded with more productive species and cultivars. In general, In 1970 out of 724,000 ha of grassland, around Forty-eight thousand hectares of meadows and pastures were ploughed and reseeded (Pavlů et al. 2003). At the same time, the rising demand for livestock products brought huge demand for animal feed which is mostly grown as crops and pastures leading to intensification of livestock production. This brought the proportion of pasture based feed significantly lower compared to crop based feeds (Hasha 2002). Hence to fulfill these growing demands of forage requirements for ruminant livestock's, the semi natural grasslands that are highly appreciated for their species diversity were intensively fertilized by both organic and inorganic fertilizers over the last decades (Chang et al. 2015). What is more interesting is the grasslands that were managed intensively still show residual effect of these NPK fertilizers many years after application has been stopped. For instance, Hrevušová et.al (2009) reported significant residual effect of NPK fertilizers 16 years after termination of long-term fertilizer application.

Although the intention of grassland intensification is clear, it has also brought unintended consequences leading to decline in conservation value of meadows or pastures and resulted in the disappearance of endangered plant species from the landscape. This has been indicated in most of the experiments that have been ongoing throughout Europe. For instance, the longest experiment in Southern England shows high species richness on plots that did not face fertilization, whereas on plots that are fertilized had the soils acidified and also got lowest species richness. Similarly experiment from Rengen Grassland Research Station in Germany also show lowest species richness in plots that are fertilized with Ca, N,P and K (Hejcman et al. 2007a).

Intensification of grasslands is not only about application of NPK fertilizers, activities such as high grazing intensity and mowing can also be considered as part of intensive management. With high intensity grazing, grasslands structural heterogeneity and tall grasses are mostly absent, which seriously affects spider abundance by reducing the structure needed to build webs, farmland birds, and many invertebrates that require tall heterogeneous sward structure (Eschen et al. 2012). Often the invertebrate species are much higher on diverse grasslands due to increased number of plant species number or higher structural heterogeneity (Kruess and Tscharntke 2002). At the same time several birds also get good foraging habitat in a structurally diverse swards, which is not possible in intensive grazing management. For instance, we can see the impact of grazing on invertebrate diversity in two ways, as short-term and long-term effects. The short term effect can be (1) destruction of specific niches, thereby affecting specific insect species that are dependent on such structures, and (2) Emergence of plant tissues due to regrowth after grazing, hence fresh and nutrient rich plant is available. The long-term effect is change in species composition and thus in vegetation structure (Kruess and Tscharntke 2002).

In temperate grasslands grazing intensity and animal preference have influence on the floristic composition and heterogeneity of vegetation resulting in patchy structure of swards. Because of differences in quality of biomass, Cattle's graze shorter patches compared to taller patches that are mostly left un-grazed. This trend of selective grazing gets stronger over the course of the grazing season (Ludvíková et al. 2015). Under this system the amount of neglected patches are dominant due to excess supply of forage availability than herbivores demand. Grazing animals also affect the nutrient content of the soil. By grazing and removing vegetation from the grasslands, they remove nutrients. At the same time high amount of nutrient is returned via dung and urine deposition. Similarly, grazing animals also create soil compaction through trampling which could increase moisture runoff and erosion. Under intensive grazing trampling is so high creating higher compaction. Likewise, Ludvíková et al. (2014) found higher compaction of soil under intensive grazing treatment and lower compaction under extensive grazing treatment.

At times, governments also played a major role in incentivizing certain schemes such as, reseeding of grasslands with high productive species, and intensive application of fertilizers. This has been the case in the UK between 1940 and 1980, were intensification of upland grasslands was encouraged with a clear objective of achieving national food security and increasing rural prosperity. This has led to increase in output from sheep system at the expense of nature conservation objectives (Fothergill et al. 2001).

In mountainous areas, were mountain meadows are important source of feed for livestock's, as hay harvested for winter period, soil fertility is a problem. It has been found as a major limiting factor for forage production as nitrogen being the limiting nutrient. In temperate regions, highland grasslands fix there nitrogen biologically (reduction of atmospheric nitrogen to ammonia) as the main source of nitrogen. If we consider farm animal production that is dependent on intensive grassland management, biological nitrogen fixation is not sufficient enough for pasture and animal demand. For this reason intensification of grasslands with application of nitrogen fertilizers were used to increase productivity (Brum et al. 2009).

Mountain meadows also faced intensification for several decades. Species rich alpine grasslands of *Nardus stricta* habitat that were once wide spread throughout high mountain ranges of Europe, are now rare due to land use changes that comes from livestock management intensification and pasture management schemes in the best areas and shrub encroachment in less favorable areas. These habitats were mainly dependent on traditional management such as summer livestock grazing. But due to intensive management grazing with large herbivores is not possible, hence maintaining the species rich *Nardus* grassland is difficult and became rare and even recognized as threatened habitats within the European Union (Bedia and Busqué 2013).

Several studies reported various responses of grasslands due to various intensive management schemes. Hejcman et al. (2012) reported the response of sown cut grassland in Czech Republic after application of NPK fertilizers. It was found a dramatic change in species composition, biomass production and its chemical properties. Tall forage grasses were severely affected by high application of Nitrogen which also supported spread of weeds. Similarly, increase application of NPK supply in long-term fertilizer experiments in many countries showed a change in grassland swards leading to (1) low species richness. (ii) low proportion of species adapted to low soil fertility and (iii) high dry matter yield (Hejcman et al. 2007a).

3.2.2.2 Extensive management

Decline in grassland diversity and overall biological diversity has been ongoing for the last hundred years. Among several reasons, changes on agricultural management such as intensive milk husbandry in cowsheds is top of the list leading only few portions of grassland to be used and the vast amount of them to be abandoned. The situation is much more serious in less accessible areas such as mountainous areas that have low productivity, were semi-natural grassland is common. Extensification in terms of avoiding or minimizing intensive application of fertilizers as well as change in the frequency and timing of defoliation can be beneficial. But in reality it can be challenging as it can bring various risks due to temporary or total abandonment of the grasslands (Pavlů et al 2006b). The absence of grassland defoliation leads to decline in plant species diversity and abundance of tall species as more litter on the ground promotes nutrient availability and restricting seedling emergence (Pavlů et al. 2011a). It is also concluded that introduction of grazing in previously abandoned species grassland, increases density of sward components, especially grass tillers (Pavlů et al. 2006b). As more intensification of livestock production with larger and more specialized farm units continue to develop, the more the role of grasslands in livestock production diminishes (Kristensen et al. 2005). This trend probably will continue as intensification of cattle production with highly digestible forages from arable lands and concentrates is applied (Isselstein et al. 2005 ; Pavlu et al. 2007).

During the intensification era, several grasslands in Europe, especially in the uplands and marginal areas that are less suitable for crop production were sown with permanent pastures and faced intensive application of inorganic fertilizers. Off course such system of grassland management lead to self sufficiency of livestock products but with sever consequence on nature conservation values (Barthram et al. 2002). To avert this problems variety of Agri-Environment subside programs focusing on compensation payments for farmers to go against intensification management have been introduced in European countries to preserve and enhance biological diversity (Klimek et al. 2007). Extensive grazing with cattle or sheep normally require little input such as labor and capital, which makes this option more suitable and a solution that can save agricultural grasslands that are on the verge of being abandoned (Correll et al. 2003). In Europe several measures have been taken to support this management shifts. Gibon 2005, describes the main design and implementation of Agri-Environment schemes that deeply modified the grassland system development in the EU countries, i.e.:

(1) The regulation and incentives to limit grassland fertilizer application and modify manure management, in order to minimize nutrient loss, mitigate soil and water pollution, and

(2) The delineation of sensitive areas, with incentives for the maintenance of biodiversity and landscape (increase grassland area, enhancement of species/rich grasslands and control of encroachment).

In general the European Agri-Environment schemes aims at restoring grassland biodiversity, especially species rich, extensively managed hay meadows that are understood to be of high value ecosystem. These ecosystems have normally fungal web food webs, which is very important for reducing nitrogen leaching in to the soil and increase nitrogen retention in the ecosystem. Grasslands that are intensively managed support bacterial based food webs, which could contribute to pollution and affect the effort of sustainable food production due to Nitrogen leaching (de Vries et al. 2012).

Societal views or perception and advanced research on livestock production also put more emphasis for better grassland management. As more and more surplus agricultural products are engulfing European markets, the EU started to promote extensification and decrease stocking rate on grasslands. In addition, the increased consumer concern for natural animal production systems and animal welfare has pushed for alternative livestock system than intensive production, such as organic production, which favors biodiversity conservation (Gibon 2005). Further extensification of grasslands is likely due to EU quotas for ruminants and conversion of arable land to grasslands (Pavlů et al. 2006a).

Overall extensive grazing management is described by creation of a significant difference in sward height and species composition. The way grazing livestock helps to maintain biodiversity in pastures is by the creation and maintenance of sward structure heterogeneity. Off course these provides patches on the grasslands which is attractive for nature conservation. This is one of the reasons behind many recommend extensive grazing as the best option to manage semi-natural hay meadows (Pavlu et al. 2007).

Several reasons lie behind the support for reducing fertilizer application, as it contributes for reduction of pollution, minimizing unwanted surplus and above all increasing the biodiversity. Although many studies show the benefits of extensification in terms of reduction or to some extent elimination of mineral fertilizer application as well as change in timing and frequency of defoliation, it can also have negative consequence due to risk in temporary or permanent abandonment of marginal areas. Several studies confirmed that when management is stopped for long periods of time, change in the structure of vegetation occurs (Pavlů et al. 2011a). When the grasslands abandonment occurs or when livestock's are removed from grassland system we see impact on biodiversity, on ecosystem function and on the delivery of goods and services from ecosystems, unless livestock removal is replaced by increased grazing by wild herbivores especially on marginal areas (Pakeman and Marriott 2010). This is very important consideration for countries such as Czech Republic, were around 30% of grasslands are unmanaged meadows and pastures (Pavlů et al. 2005). In other cases change in socioeconomic conditions and technological improvements in the agriculture sector has also brought large arable land abandonment, were keeping these fields are considered as non-profitable. Off course several conservationist consider this scenario as suitable especially for grassland conservation, as grassland restoration on ex-arable land, which is becoming a common practice in Europe (Knappová et al. 2012).

Change in management intensity can also affect sward structure, species diversity, as well as nutritive value of the forage. Extensive grazing management promotes selective patch grazing which can increase heterogeneity and spatial diversity in species distribution (Rook et al. 2004). It is also characterized by strong variable sward height and species composition. Under extensive grazing management, patches that are neglected by herbivores are quite a lot, as the amount of forage available for the herbivores is higher than their demand, hence these non-grazed patches can increase total species diversity (Pavlů et al. 2006b). Grazing animals maintain high biodiversity through creation and maintenance of sward structure heterogeneity (Pavlu et al. 2007).

Selective grazing also leads to uneven distribution of grazing pressure both within and between plant communities. In Czech Republic that is facing continuous decline in livestock number and an area with more than 30% is unmanaged meadows and a pasture, grazing is very important. Hence, to mitigate the increasing amount of grassland abandonment and declining livestock population, extensification could offer a better solution (Pavlů et al. 2006a).

The intensive application of nitrogen has been increasing for decades to increase productivity of grasslands. This has led to serious environmental consequences such as emission of gaseous nitrogen to the atmosphere. The increased gaseous nitrogen loss occurring due to denitrification is one of the main contributors to climate change as nitrous oxide, which is stronger greenhouse gas than carbon dioxide. Additionally, eutrophication is also another problem that arises through excessive leaching of nitrogen. Hence the shift to extensive management not only addresses the demand for preserving nature but also decrease the nitrogen leaching losses that are contributing to climate change (de Vries et al. 2012).

Although the shift from intensive management to extensive management has been favored and confirmed by several studies as a better solution, the long-term effect of fertilizer application can still be visible even though fertilizer application has stopped for many years. For instance a grassland experiment established in Alps, found clear effect of fertilizer effect on plants species composition, soil pH and concentration of P and N in leaves of selected plant species. Similarly a study in the Giant mountains (Krkonose, Karkonosze), were the effect of all fertilized treatments (ca, N and P) was very much visible on sward structure 37 years after the last fertilizer application (Hejcman et al. 2007). Hrevušová et. al (2009) also reported significant fertilizer residual on the concentration of nutrient in the plant biomass 16 years after the last fertilizer application, indicating after effect of fertilizer treatments on grasslands.

Currently various efforts are ongoing across Europe to restore species rich grasslands with high conservation value that are today under intensive management. Many studies show species richness in semi natural grasslands as negatively correlated with available soil nutrient and thus with high biomass production as well (Hejcman et al. 2007b).

The reason behind is the shift in competition from below ground competition for nutrients to above ground competition for light, hence fast growing species taking advantage and reaching greatest plant height, consequently outcompeting other species. Significant decline in biomass production after cessation of fertilizer application can be achieved by introducing cutting management with biomass and nutrient removal. Cutting management without fertilization is more effective than grazing as it decreases biomass production and induces a decline in available nitrogen, phosphorous and potassium. During grazing 60-90% of the nutrient is returned into the pasture in the form of excreta (Hejcman et al. 2010).

3.3 Grassland productivity

During the last two decades, decision makers have followed the path of de-intensification of grasslands, for ecological reasoning which lead to large areas of grasslands across Europe being freed from intensive management (Isselstein et al. 2005). It is expected that Nature conservation will shoulder important role in the future, as its benefit becomes widely recognized and more lands are converted from agricultural production to extensively managed grasslands (Frame 1992). Hence, understanding of the ecosystem response to this land use change is vital, in particular those which are used for grazing (Hopkins and Holz 2006).

3.3.1 Factors affecting grassland productivity

In spite of their relative importance, grassland area have experienced a decline and they were considered as a limiting factor for efficient livestock production systems (Gibon 2005). During the same period, increased use of fertilizer, drainage, reseeding and cutting frequencies were considered as the best way for grassland intensification in Central and Western Europe (Pavlů et al. 2011b). Majority of them were converted in to arable lands with few exceptions on areas located in harsh natural environments (mainly mountains and wetlands) that hindered ploughing (Gibon 2005). Czech Republic is one example where the so called low–yield meadows and pastures were ploughed and reseeded with more productive species and cultivars. Furthermore wet meadows were also drained and reseeded (Pavlů et al. 2003).

In general several measures to enhance productivity were taken in many parts of Europe. Majority of the local species that were considered as low productive were ploughed and replaced with highly productive species. In addition, intensive application of NPK fertilizers was utilized to increase the nutrient content of the soil and productivity of the grasses at the expense of species richness. when application of fertilizers are ceased or reduced form this eutrophic pasture lands, one can see significant reduction of dry matter yield (Pavlů et al. 2011b). Regarding nutrients, nitrogen is the most important one that can influence the production of grass, for this reason many framers increased the use of nitrogen fertilizer in the past. It is well documented that continuous long term application of Phosphorous, Nitrogen and Potassium fertilizer improve stand productivity and nutrient content in the soil but decrease the species richness (Pavlů et al. 2012).

According to Frame (1992), 27 to 30 t/ha of herbage dry matter can be produced and is considered as potential production of grass. Such results have been tested and confirmed in experimental plots were water and nutrients are not limiting. In experimental plots of $5m^2$ and upwards, 18 to 21 t/ha of dry matter is commonly produced with intensive application of nitrogen fertilizer and frequent cutting. And in a situation were more frequent defoliation is applied to simulate grazing, the maximum dry matter production has been between 12 to 15 t/ha. If we consider farm level experience the result is quite different (10 to 13 t/ha dry matter) as there are a number of limitations. Many studies repeatedly confirmed a high productivity of temperate grasslands by intensive application of Nitrogen fertilizer. The input helps plant growth which leads to a higher forage yield (i.e. increased productivity) or achieving rapid level of production. The time it takes to produce a biomass of 2 t of organic matter per hectare is shortened by 14 days just by applying 50 kilogram of Nitrogen per hectare, compared to a grassland managed without any application of fertilizer (Peyraud and Astigarraga 1998). But the current economic and environmental concerns are pushing for more control on Nitrogen fertilizer application in intensive grassland managements and reduce possible environmental pollution due to Nitrogen losses. Reduced application of Nitrogen fertilizer reduces herbage growth rate, tiller density and height, ultimately leading to decline in herbage mass for a given age of growth (Delagarde et al. 1997).

Change in management system or intensity have been also discussed in several studies as one potential factor that can affect species diversity as well as productivity. Majority of the time the changes are either extensification from its current use or total abandonment which is even more dangerous for biodiversity and limiting the ecosystem function leading to loss of goods and services from the ecosystem (Pakeman and Marriott 2010). When there is a shift from intensive grazing to extensive grazing, a lower quality of forage that is expressed in nutritional value for grazers is obtained. Equally, forage yield is also affected when grazing intensity is decreased (Marriott et al. 2010 ; Pavlů et al. 2006a). The amount of available nitrogen in the soil will also be affected by minimizing the grazing intensity, which limits the cycling of nitrogen rich excreta (Frame 1992). The outcomes from these shifts are sometimes site specific, for instance the biodiversity gains form shifting the management to extensification was very moderate compared with the conventional treatment sites, implying the productivity to be maximized with intensive management, that contradicts the current demand of restoring species rich grasslands (Marriott et al. 2010).

Grassland productivity is not only affected by management, but also responds to rising atmospheric CO_2 concentration and climate change (Soussana and Lüscher 2007). Future climates are predicted to have frequent droughts, heat waves, and high-intensity rainfalls (Knapp et al. 2008). According to IPCC (2007) climate change will most probably cause rise in temperature, change in rainfall pattern and increase the occurrence and severity of extreme climatic events such as droughts. Under these conditions temperate grasslands will struggle to provide the growing demands for forage and other ecosystem services (Deleglise et al. 2015).

Many researchers also suggested parameters such as rainfall and its variability to have severe impact on ecosystem functioning, especially temperate grasslands systems which seems to respond to rainfall variability (Walter et al. 2012). Variability in rainfall expressed in terms of extreme regimes affects the above ground net primary productivity (Barrett et al. 2002). Similarly drought and heat waves also affect grasslands by lowering its productivity (Craine et al. 2012). Drought can reduce available water which is important for photosynthesis (Knapp 1985), and heat waves can lower productivity by lowering soil moisture (De Boeck et al. 2011). Hence, it is possible to see drought and heat waves share a common mechanism in reducing productivity, which was proven by records from a quarter of a century from climate, soil moisture and grass productivity data (Craine et al. 2012). Climate change and grazing have also been recognized as factors that control plant biomass production, as an experiment testing the effect of warming reported a reduction in biomass production (Carlyle et al. 2014).

3.3.2 Direct measurement

In ecological forestry and agricultural studies, above ground biomass is one of the main characteristic of the ecosystem which is measured, but there are no universal method that can help to estimate the biomass across all plant communities and landscapes (Redjadj et al. 2012). The methods which are now being used to measure herbage production are comparatively recent. Due to huge interest on grasslands, rapid advances were made in the development of techniques for measuring herbage production on cut and grazed swards. Consistent with the development of methods, several equipment's were also produced (such as mechanized cutting), that has increased the effectiveness of researchers in the field, but also gave opportunity for rapid sampling of herbage mass from several treatments, whether from small plot cutting trails or from large scale grazing plots. Thus measurement of herbage mass by cutting is a direct sampling technique as well as defoliation treatment. The direct measurement methods are normally considered as accurate, but they are time consuming and also destructive (Redjadj et al. 2012).

Animals are being used as defoliators parallel with the cutting methods of measurement in order to improve simulation of grazing effects under cutting treatments. The development of direct sampling techniques based on cutting procedure and indirect methods based on several appraisal methods raised due to the need of having herbage mass to characterize sward, before and after grazing.

Direct methods to determine biomass typically involve sampling procedures using a sample unit with defined boundaries, so that biomass can be expressed relative to a known area. In this way, the biomass values obtained from a small area are subsequently converted to a more conventional scale, such as kilograms/hectare or pounds/acre.

Direct Method: Whole–Plot Sampling

Herbage production is mostly assessed using a small plot cutting trail technique. As long as the treatment provided are randomized and replicated properly according to the standard statistical principles and procedures, one can get a very precise and reliable result with this method. In small plot experiments the estimates of herbage mass with good precision can consistently be obtained from rectangular plots of 5 to 10 m^2. Additionally sampling height is also important factor to consider. It is usually defined as height of defoliation of a sward from ground level as opposed to sward height before defoliation. The sampling height usually reflects the sward management it attempts to simulate and predetermined in advance.

Direct Method: Plot Sub-Sampling

Method of estimating herbage that minimizes serious interference with the sward is required more in grazing studies. For this reason it is good to sub sample the treatments plots in a trail. In order to estimate either the amount of herbage removed at a grazing or the amount accumulated between grazing, one sample before grazing and another sample after grazing is taken. Most of the procedures and equipment's that are used in whole plot sampling are very much useful here also.

In various studies enclosure cages have been also used to exclude grazing animals from sward areas reserved for sampling herbage mass. The cages vary substantially in form and construction; they might be roofed or roofless, portable or fixed and some are electrified. It might have also its limitations, but mostly the measurement with cages be useful to assess the effects of weather on the seasonal pattern of net herbage accumulation or to compare sites, seeds mixture or herbage varieties.

3.3.3 Indirect measurement

According to Frame (1992), the decision for selecting which methods to use for measuring herbage mass push us to make compromise between precision and accuracy of estimation on one side and limitations set by the management requirements of the sward and available resources of equipment and labor on the other side. When we consider using indirect methods we are relaying on indirect indices which are assumed to relate to biomass. This includes plate or disk meters, point contact and point quadrat. This methods are quite different from direct methods as they are non-destructive, but they are not necessarily cheap and not always quick (Redjadj et al. 2012). These methods that are used for measuring above ground biomass are mostly for quantifying temporal and spatial changes which are controlled by biotic and abiotic factors. Since the 1930s, huge interest from scientific community both researchers as well as users are the major driver for continued development and evaluation of quicker, reliable and non-destructive biomass estimation methods (Radloff and Mucina 2007).

In evaluating production, cutting is used to obtain direct estimate of herbage mass and other indirect estimates using several appraisal techniques such as (Frame 1992):

- ***Measurement of sward height:*** the height and density as the two characters that influence the herbage mass and its visual assessment. Both have been used together or separately in various techniques for estimation of the mass. Sward height observation is advantageous because of the speed and simplicity for taking several measurements on non-uniform grazed swards. But this method is most accurate in short swards and uniform density because overestimation of herbage mass is likely to occur with increasing height due to high proportion of herbage concentrated in the lower layer of the sward. Several procedures exist for measurement. Few of them are rulers, sward stick and weighted disc methods.
- ***Electronic capacitance:*** The change in the systems capacitance is caused by measuring probe which is placed in the sward. Then the change is measured and converted to an estimate of herbage mass from a prediction equation based on paired estimates from cut samples and probe meter readings, The capacitance change is caused due to air being replaced by herbage, where herbage having high, and air low, dielectric constant. Unfortunately several factors such as sward type, season growth, herbage moisture affect the functioning of the probe, hence proper relationship must be obtained for specific sward at specific time.

- ***Visual estimates:*** Introductory training is very important to estimate herbage mass by eye evaluation. The method is not objective; it is open to bias by the operator. Even though this method helps to make several estimates per treatment for analysis, it cannot be taken us precise. Seasonal variation in sward height, density and moisture contents are the major reason for its low precision.
- ***Point quadrants:*** Herbage mass and total point biomass can be measured using point quadrats and a regression of biomass on the number of quadrat contacts.

There are several reasons behind for developing indirect methods for estimating herbage mass that could minimize physical removal of herbage;

a) To reduce labor, equipment, time or resources needed which can also decrease the cost of measurement.
b) To make measurements on big fields or plots, especially those that are under grazing management or in remote areas where it is not possible to use cutting techniques to sample swards.
c) To use small scale grazing trails where sampling by cutting could affect a relatively large proportion of the treatment area.
d) To rank treatments in trials with large comparative differences.
e) To provide a guide to estimation of herbage mass in animal production systems where an absolute measure may not be necessary.

Chapter 4

4.1 Materials and methods

4.2 Study area

The experiment is undertaken in the Jizera Mountains in the northern part of the Czech Republic, 10 km north from the township of Liberec (50°50' N, 15°06' E) in Oldrichov v Hájích village. The first record about the village was in 1651 when identification for agricultural areas was conducted. Then four years later another record shows a census on livestock population that was used as a reference to establish tax payment system. In 1651 the total agricultural area was roughly 150 ha, but continued to increase and became more than 400 ha during the 18th and first half of 20th century (Hejcman et al. 2013).

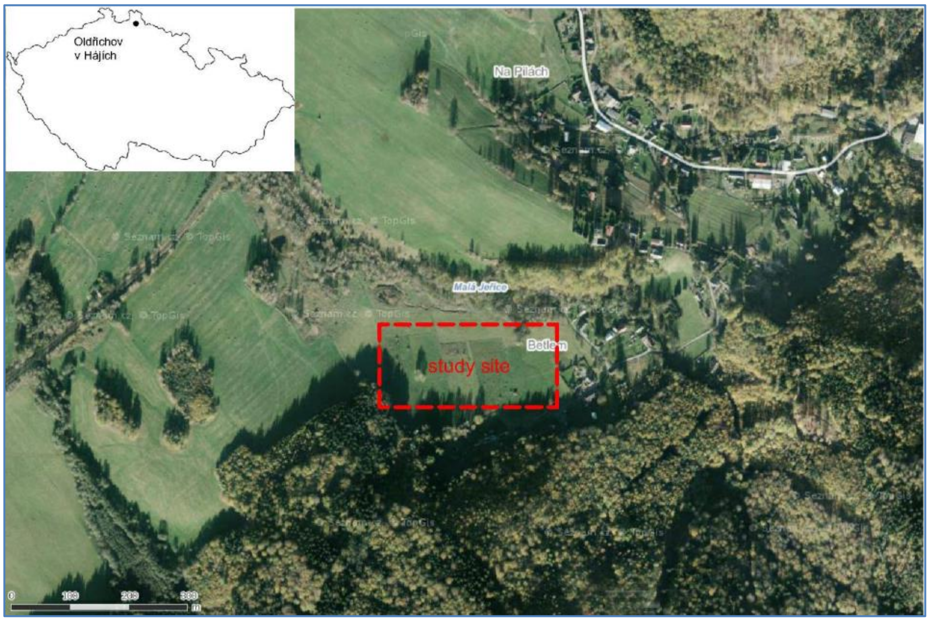

Figure 1 Map of experiment site

Currently there is a site with ongoing long-term grazing experiment by the Grassland Research Station Liberec (Pavlů and Velich 2001). The site is underlain by granite bedrock and medium deep brown soil (cambisol) with the following attributes: pH/KCl = 5.1, available P content = 64 mg.kg^{-1}, available K content = 95 mg.kg^{-1} and available Mg content = 92 mg.kg^{-1}. The altitude is 420 m a.s.l., the average annual precipitation is 803 mm and the mean annual temperature is 7.2 °C (Liberec meteorological station).

Highly productive grass/clover was reseeded after the experiment site was drained and ploughed in the 1980s, followed by intensive management using cutting and grazing. At the beginning of the 1990s mulching was applied around august and then the grassland was abandoned once again. Until 1998, there was no agricultural management in this experiment site. Before the start of the experiment the site was classified as upland hay meadows. The dominant species of the unmanaged sward were *Agrostis capillaris, Alopecurus pratensis, Festuca rubra agg., Aegopodium podagraria* and *Galium album*. No fertilizer had been applied since the 1980s.

4.3 Experimental design

The experimental site was established in 1998 on formerly abandoned grassland (Pavlu et al. 2007). Since 1998, the experimental pasture has been continuously stocked with young heifers each year from May to November. Two treatments are applied: (1) extensive grazing (EG), where the stocking rate was adjusted to achieve a mean target sward surface height greater than 10 cm, and (2) intensive grazing (IG), in which the stocking rate was adjusted to achieve a mean target sward surface height of less than 5 cm (Ludvíková et al. 2015). The sward height in IG (3 -5 cm) is maintained by five heifers and for EG (above 10 cm) by two heifers. To make sure the heifers are not mixing and influence the grazing management each paddock is protected with fence. Grazing was applied from early may till end of November during the whole experiment period. The experiment was arranged in two completely randomized blocks: intensive and extensive grazing applied (Fig 1 and Fig 2). The experiment is replicated one more time to avoid the influence from factors such as topography, water table gradient, soil moisture and available nutrients.

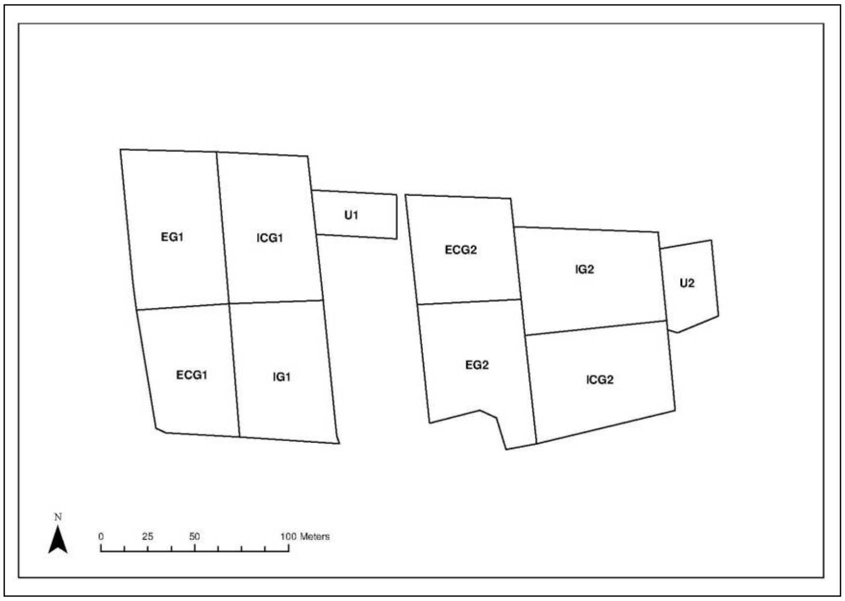

Figure 2 Schematic of the study site; EG= Extensive Grazing, IG= Intensive Grazing

Each treatment has paddocks and in each paddock four movable ex-closure cages of the size 1m x 1m is installed in order to exclude grazing animals and reduce the heterogeneity of swards which is also influenced by nutrients, soil moisture and feces. From each ex-closure fresh herbage was cut using electric scissor. After taking the herbage the ex-closures are relocated randomly within the designated paddock to a different location than the previously harvested or cut. During the relocation sites were also checked carefully for cattle dung before the ex-closures are installed back until the next cutting period which is every three week. The same procedure is applied in both treatments with the exception of the cutting procedure. For the intensive treatment cutting was deep and less than 5 cm and for extensive it was 10 cm. The 3 week period for sampling is maintained since the beginning of the grazing season which continued till autumn. All treatments were grazed continuously in each grazing season. Grazing was applied from early may till end of November.

Figure 3 Ariel Photograph of the study site; EG= Extensive Grazing, IG= Intensive Grazing

4.4 Measurement

4.4.1 Herbage mass

Fresh herbage cut from the study plots both from intensive (IG) and extensive (EG) that are growing under a movable ex-closures cage (1m x 1m) at a specified height (5 cm for IG and 10 cm for EG) was taken every three week throughout the growing season for the last 14 years. After cutting the fresh herbage it was packed and taken for weighing. During the measurement consideration was given for the weight of the bag itself. Once weighing is finalized, the sample in each bag was thoroughly mixed on separate paper until uniformly disperses on the paper. Finally all samples from both treatments were oven dried at appropriate temperature and re-weighted to determine the dry matter content to calculate the dry matter yield of each plot for a specific date. Drying fresh herbage is absolutely necessary as the amount of moisture in herbage depends upon stage of growth, plant species or variety, fertilizer nitrogen use and amount of external water as rain (Mannetje 2012). Hence fresh matter, is not the correct expression of herbage mass, so dry matter is the conventional basis.

4.2.2 Sward height measurement

Sward height is usually defined as height of defoliation of a sward from ground level. The sward height in the study site is adjusted to reflect the sward management it implies to simulate which is determined in advance. Sward height was measured using the rising plate meter (Correll et al. 2003) every three week before cutting for fresh herbage was conducted. The rising plate meter consists of a light metal plate which slides along the graduated measurement scale. The height of the above ground biomass was measured when the plate stops due to the resistance from the vegetation. Four points at each corner and one in the middle within the ex-closures were selected, and the rising plate height at each point was recorded. The measurement was taken in all ex-closures at both treatments. Stable height was about 5 and 10 cm in IG and EG treatments, respectively. Finally suitable place within the treatment block is selected and ex-closures are re-installed until the next measurement period.

4.5 Data Analysis

Before the data's collected form the plots were analyzed careful recalculation was done suing excel for dry matter biomass and height measurement. Following this univariate analyses were performed using STATISTICA 13 (StatSoft, 2015) software. Repeated measures of ANOVA were applied to identify the effects of grazing treatments, months and the interaction between them for individual years. To identify the relationship between sward height and biomass production linear regression analysis was performed.

Metrological data for the year 2002-2015 was also carefully summarized and analyzed to produce Walter climate diagram (Walter and Lieh 1960). The diagrams are produced to display monthly averages of temperature and precipitation for a specific year. Each number across the horizontal are arranged to indicate months. All diagrams start with January and ends with the last month of the year December.

Chapter 5

5.1 Results

5.2 Effect of treatment, month and their interaction on biomass production

The result from a repeated measure of ANOVA is presented in Table 2. The effect of month was found to be significant for all years whereas the effect of treatment was significant only eight times (2003, 2004, 2005, 2006, 2009, 2010, 2012, and 2013) of the fourteen analyzed years.

	Tested variables	**Degrees of Freedom**	***F*-ratio**	***P*-value**
2002	Treatment	1	2.95	<0.090
	Month	4	15.95	**<0.001***
	Treatment x Month	4	4.92	**<0.001***
2003	Treatment	1	4.43	**<0.038***
	Month	5	44.02	**<0.001***
	Treatment x Month	5	2.61	**<0.030***
2004	Treatment	1	4.87	**<0.030***
	Month	6	85.95	**<0.001***
	Treatment x Month	6	0.7	<0.654
2005	Treatment	1	8.85	**<0.004***
	Month	5	62.17	**<0.001***
	Treatment x Month	5	3.86	**<0.003***
2006	Treatment	1	28.86	**<0.001***
	Month	6	76.25	**<0.001***
	Treatment x Month	6	3.95	**<0.001***
2007	Treatment	1	2.45	<0.121
	Month	5	86.65	**<0.001***
	Treatment x Month	5	1.42	<0.226
2008	Treatment	1	0.1	<0.972
	Month	5	70.55	**<0.001***
	Treatment x Month	5	5.73	**<0.001***
2009	Treatment	1	12.94	**<0.001***
	Month	5	45.97	**<0.001***
	Treatment x Month	5	5.72	**<0.001***
2010	Treatment	1	9.6	**<0.003***
	Month	5	50.23	**<0.001***
	Treatment x Month	5	6.35	**<0.001***
2011	Treatment	1	0.72	<0.399
	Month	6	35.81	**<0.001***
	Treatment x Month	6	3.49	**<0.004***
2012	Treatment	1	43.5	**<0.001***
	Month	6	39.43	**<0.001***
	Treatment x Month	6	3.03	**<0.009***
2013	Treatment	1	19.66	**<0.001***
	Month	5	83.62	**<0.001***
	Treatment x Month	5	4.59	**<0.001***
2014	Treatment	1	1.62	<0.207
	Month	5	81.6	**<0.001***
	Treatment x Month	5	0.87	<0.503
2015	Treatment	1	2.32	<0.131
	Month	6	57.77	**<0.001***
	Treatment x Month	6	4.12	**<0.001***

Table 2 Result of repeated measures of ANOVA analyses-effect of IG & EG treatments, months and interaction between them on biomass production for 14 years. Significant results are marked with * and highlighted bold

The analysis result showed a significant interaction between month and treatment affecting the biomass production in all years except in the year 2004, 2007 and 2014. In 2007 and 2014 the effect of treatments was also not found significant. The significant interaction between month and treatment indicate a non- parallel biomass growth with in a season under both intensive and extensive treatments.

5.3 seasonal pattern of biomass growth

The grazing season in the study site normally lasted from end of April till end of October, and the data collected for biomass growth under intensive and extensive grazing treatment followed similar pattern, though with slightly higher biomass growth under intensive grazing. The analysis of total biomass produced in each month for each treatment for all years combined from 2002 up to 2015 clearly indicates a higher biomass production under intensive grazing compared to extensive grazing (Fig 4).

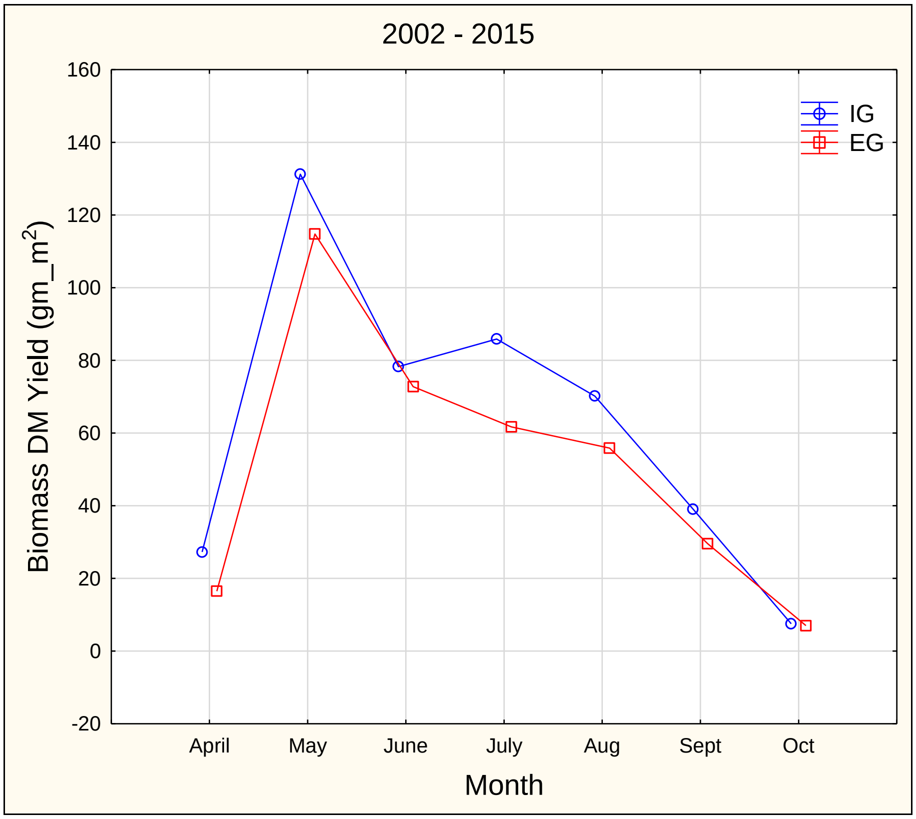

Figure 4 Total biomass yield in Intensive and Extensive grazing across growing season from 2002-2015

The biomass production reaches its peak time in spring (May) and starts to decline until it reaches its second peak in the summer (July/August). This was consistent in both treatments. Additionally, the highest biomass production occurred in May in both treatments with intensive grazing producing higher biomass. Biomass growth in both treatments continued to decline sharply as the growing season proceeds and reaches its minimum growth around October.

5.4 Biomass growth under different treatment for specific years

The 14 year data analysis on dry matter (DM) biomass production result a significant difference across the particular year. In each year spring (May) biomass production has been consistently recorded as the peak production time except for the years 2011 and 2012 were biomass growth was by far higher in the summer under intensive grazing. May was also the peak DM biomass production time under extensive grazing except for the years 2008, 2009 and 2012 were the summer peak was again higher than the spring (Fig 5 and Fig 6).

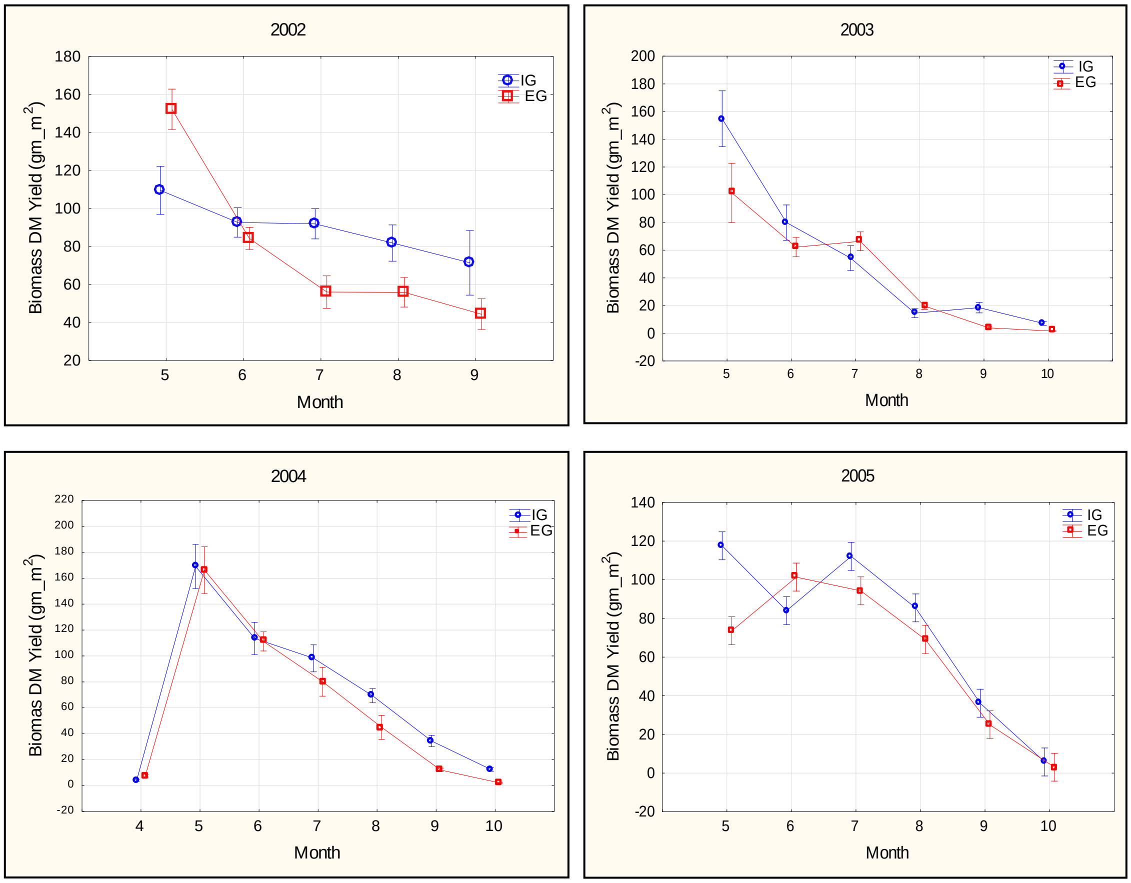

Figure 5 Seasonal pattern of biomass production under Intensive and Extensive grazing for the year 2002 - 2005. Error bars represent standard errors of the mean

Comparing the fourteen years data, two peak periods (months) were biomass production in spring and summer reaches its maximum were recorded nine times (2002, 2005, 2006, 2008, 2009, 2010, 2011, 2012, and 2013) under both intensive and extensive grazing (Fig 5, Fig 6& Fig 7).

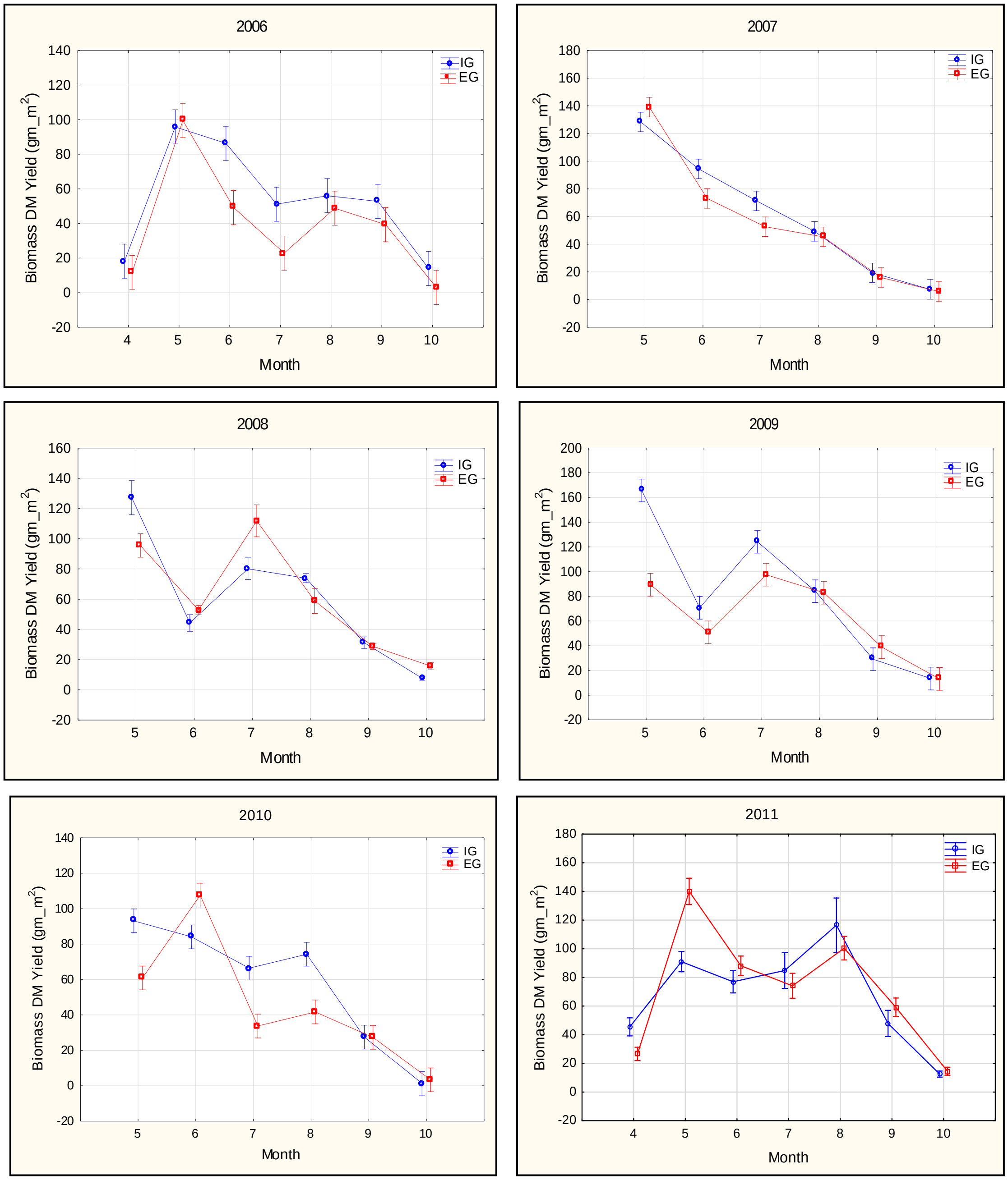

Figure 6 Seasonal pattern of biomass production under Intesnive and Extensive grazing for the year 2006-20011. Error bars represent standard errors of the mean

In all recorded years the analysis clearly shows rapid decline in biomass growth at the end of the summer as the growing season progresses. In years such as 2003, 2007, 2014 and 2015 the summer biomass growth peak was not recorded and the decline in biomass production after the spring growth was very sharp. The decrease in biomass in these years is also consistent for both treatments. Furthermore high year to year variability in terms of biomass production was also recorded.

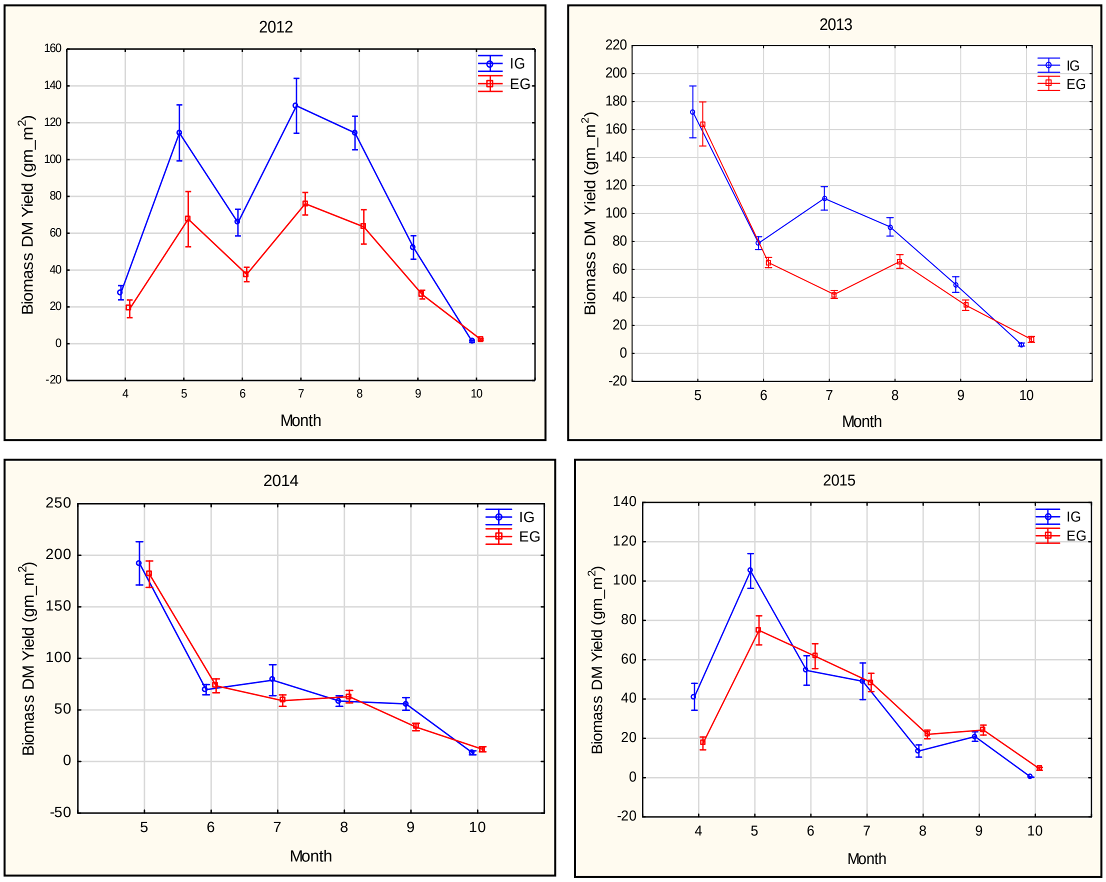

Figure 7 Seasonal pattern of biomass production under Intensive and Extensive grazing for the year2012- 015. Error bars represent standard errors of the mean.

5.5 Total Biomass yield under intensive and extensive treatment

During the fourteen year of experiment the above ground biomass has been significantly fluctuating from year to year (Fig 8). For both intensive and extensive treatment the biomass fluctuation occurred in consistent pattern. Except for the year 2011 were the biomass was slightly higher under extensive treatment, intensive grazing seems to offer a higher biomass monthly (fig 4) across the growing season as well as on yearly basis (Fig 8).

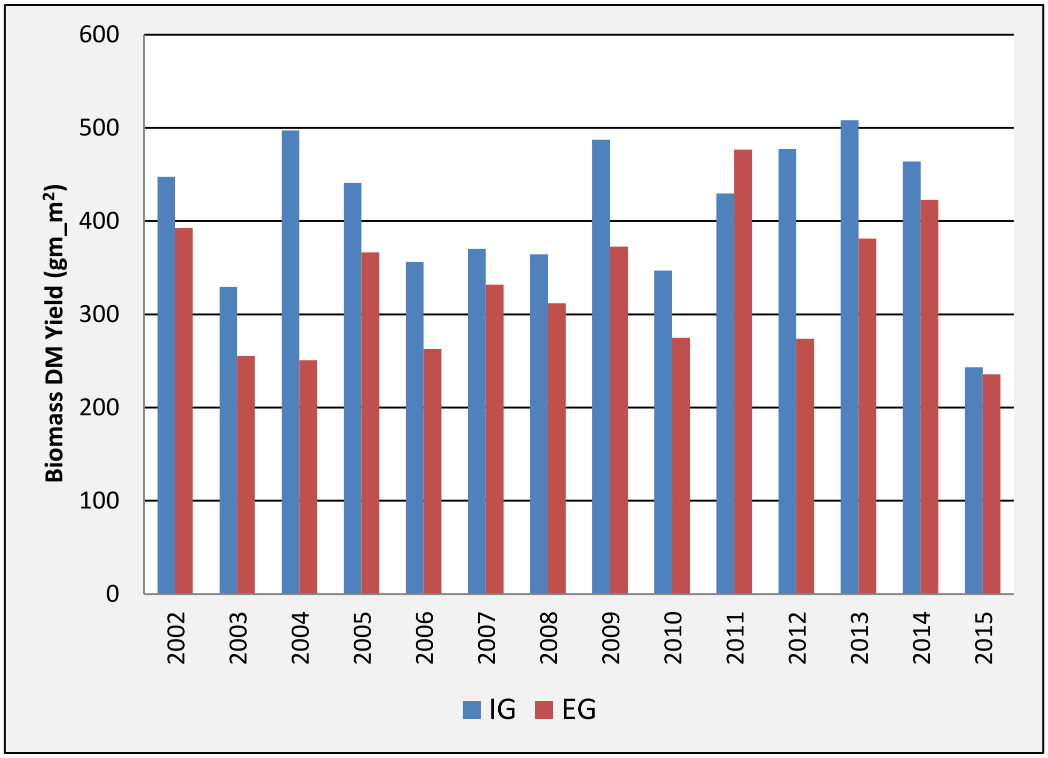

Figure 8 Total Biomass yield in Extensive and Intensive treatment from 2002 - 2015

In general the total biomass production in the study site ranged between 2.4 to 5 t DM ha^{-1} year^{-1} under intensive grazing and 2.3 to 4.7 t DM ha^{-1} year^{-1} under extensive grazing. In comparison to other years, the above ground biomass produced in 2015 is by far small in both grazing treatments. This could be attributed to sever shortage of precipitation that has happened in this specific year for most part of Czech Republic.

5.6 Relationship between sward height and herbage biomass

The linear regression analysis for sward height and dry matter biomass under both IG and EG were significant ($P < 0.001$) and showed a strong relationship ($R^2 = 0.933$ under IG and $R^2 = 0.748$ under EG treatments) but the relation was explained more under IG (Fig 8).

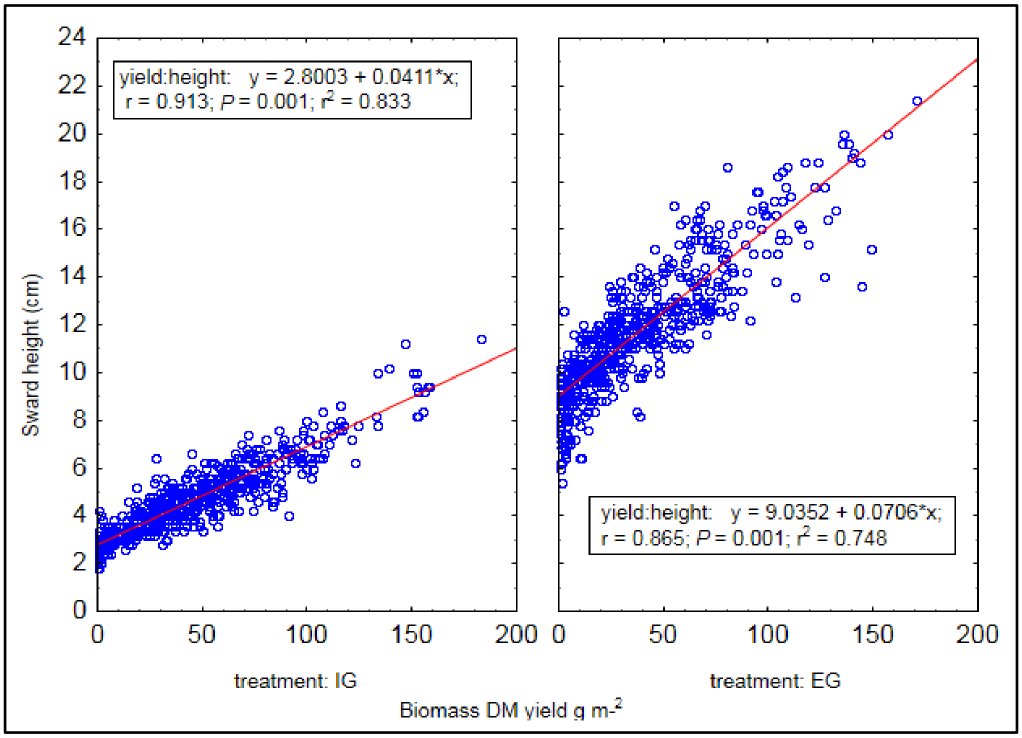

Figure 9 Sward height and herbage mass relationship

The relation between sward height and herbage biomass clearly shows a linear relationship. At the initial stage of the growing season sward height accurately predicts herbage mass and gets slightly off as the sward height increases especially under extensive treatment. To the contrary the strong linear relationship is maintained under intensive treatment. Even though the relationship between sward height and dry matter biomass is strongly expressed in both treatments it was less expressed under extensive grazing ($R^2 = 0.748$). This could be attributed to sward components being grazed less frequently or sometimes not grazed at all which is typically the case under extensive grazing.

Chapter 6

6.1 Discussion

In temperate grasslands there is strong relationship between sward height and biomass production. In this study a strong relationship under intensive grazing was identified in comparison to extensive grazing. This finding is consistent with Pavlů et al. (2006b) who found a higher variability of actual sward height under extensive grazing which is attributed to selective grazing. Similarly, a study conducted by Braga et al. (2009) on Marandu palisadegrass, Brazil, found a high mean determination coefficient (R^2) for the regression model, implying a sward height as a reliable predictor of herbage mass in grazed pastures for low growing leafy swards, which is typical of vegetative temperate grasses. This indirect and non-destructive method of estimating the herbage mass especially in grazing management helps growers or managers to estimate herbage mass precisely and quickly.

The study site is considered as a typical upland grassland area in Czech Republic. In this regard it is not expected to have a higher biomass production. The experiment result in terms of total biomass produce showed a considerable variation in annual biomass yield ranging between 2.4 to 5 t DM ha^{-1} year^{-1} under intensive grazing and 2.3 to 4.7 t DM ha^{-1} year^{-1} under extensive grazing. Contrary to this finding Muller et al. (2013) found significant decline in herbage mass under intensive grazing in a study conducted on the steppe of inner Mongolia, implying negative effect of intensive grazing on grassland productivity and the lack for herbage mass that will occur during years were shortage of perception occurs. In different regions grasslands will produce different amount of herbage biomass due to differences in temperature and precipitation.

The overall biomass production in both treatments has been consistently fluctuating from year to year and these fluctuations on biomass could be attributed to fluctuations on climatic parameters such as temperature and precipitation. According to Craine et al. (2012) and Barrett et al. (2002) biomass production and productivity is affected by variability in precipitation and temperature. Herben et al. (1995) also suggested direct correlation between biomass production and amount of precipitation. Furthermore, he describes a significant effect of weather conditions from the current year as well as from the previous year on biomass production. This fourteen year experiment that showed significant variability in annual biomass production is very much consistent with other long-term studies conducted in central Europe, reporting variability in biomass production due to difference in distribution of precipitation during the growing season and unsteady temperature (Hejcman et al. 2010; Maskova et al. 2009; Hrevušová et al. 2009).

Productivity of grasslands (pastures) in the study area is mostly limited from end of April through end of November. Hence supporting production of quality forage production during the grazing season and preparation for winter storage is vital for dairy or farm productivity. In this experiment, the biomass growth under both intensive and extensive grazing reached peak production in spring time (May). This has been consistent throughout the experiment period. Additionally, second peak production occurred in nine of the experiment years around July or August which is also connected to a higher temperature during these months complemented with higher precipitation. Comparing the two treatments, the summer peak is mostly outstanding under intensive grazing. In both treatments the above ground biomass production declines in the summer, most probably following unbalanced distribution of precipitation during the grazing season. The double peak that was found nine times is consistent with Pavlů et al. (2006b) who also found double peak curves three times in a four year experiment. Following our result we should consider a curve with double peak is more typical than with a single peak curve that is traditionally shown by seaside (Orr et al. 1988) and by Czech authors (Velich 1991). A low yield of herbage was produced in the experiment site and according to Velich (1991) classification the study site fits as low productive grassland under Czech condition.

Chapter 7

7.1 Conclusion

The fourteen year intensive and extensive grazing management experiment delivered clear messages. The first one is that we have a significant relationship between sward height and herbage mass production, which confirm sward height as a good predictor of herbage mass. This result is very relevant for management of pastures were critical information is needed quickly and accurately. Second message is that the biomass production in both intensive and extensive grazing is severely affected by weather variability. Furthermore, biomass growth with double peak occurring in spring (May) and summer (July/August) has been found nine times within the last 14 year. These results are not new but concretely prove a curve with a double peak as more typical for upland grassland area in Czech Republic. Thirdly, intensive grazing treatment produced a higher biomass (2.4 to 5 t DM ha^{-1} $year^{-1}$) than extensive grazing (2.3 to 4.7 t DM ha^{-1} $year^{-1}$).

Finally, the total yield of herbage in the experiment is comparatively low with intensive grazing treatment performing slightly better. But in a country like Czech Republic with livestock population in decline and an increase in total area of permanent grasslands, finding alternative landscape management is critical. Hence to avoid increased abandonment of grassland areas, extensive grazing management could be a better management that can still provide sufficient feed for livestock and also protect the landscape.

Chapter 8

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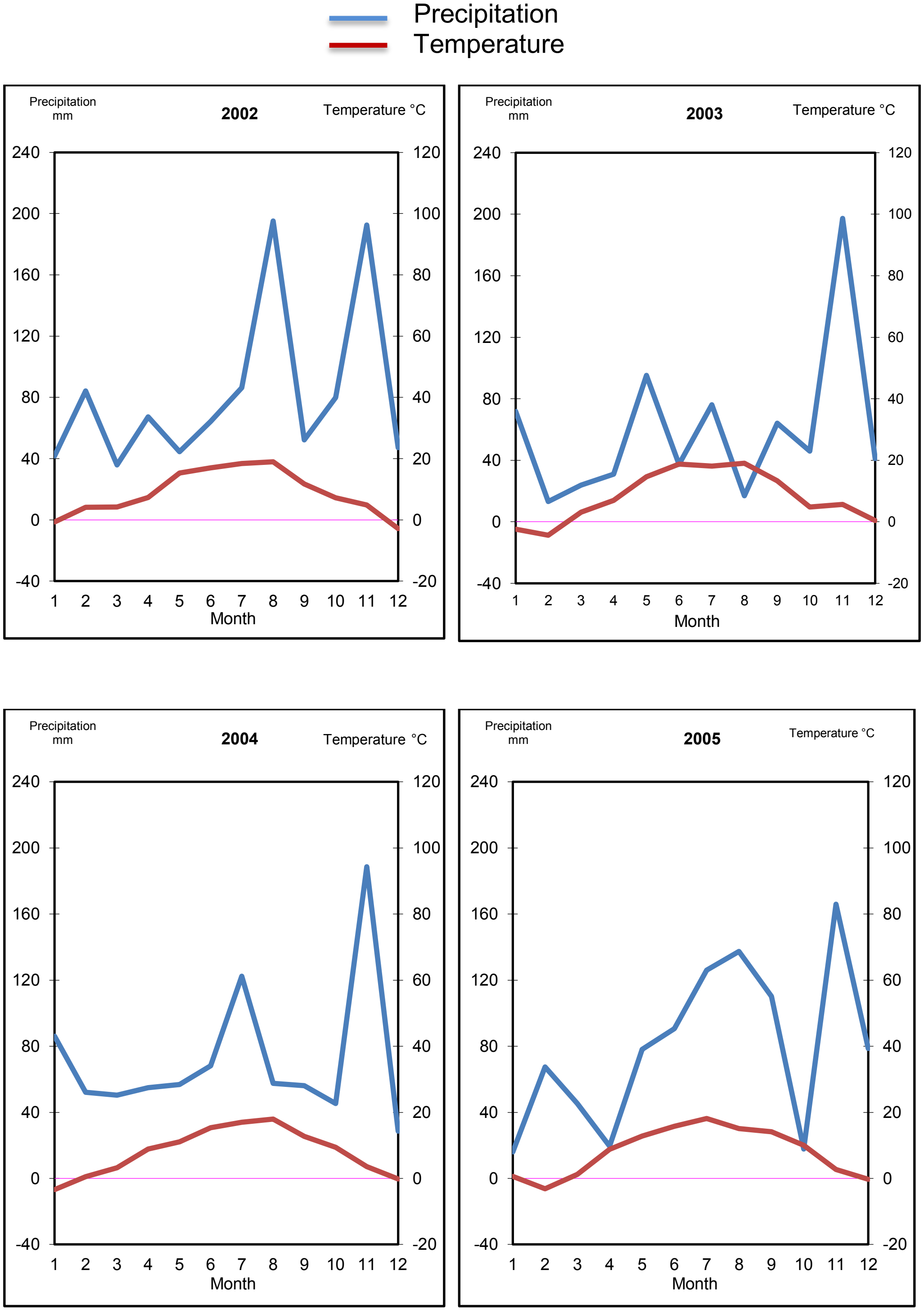
8.2 List of Figures

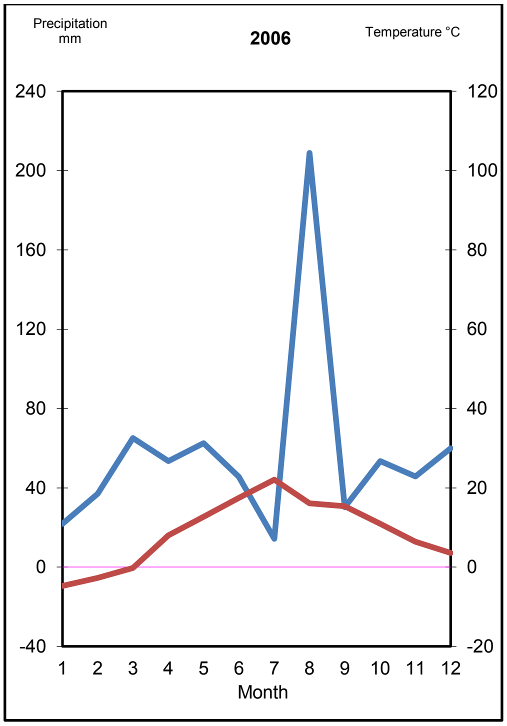
8.3 List of Tables

Chapter 9

List of Appendices

Walter climate diagram for the year 2002 - 2015

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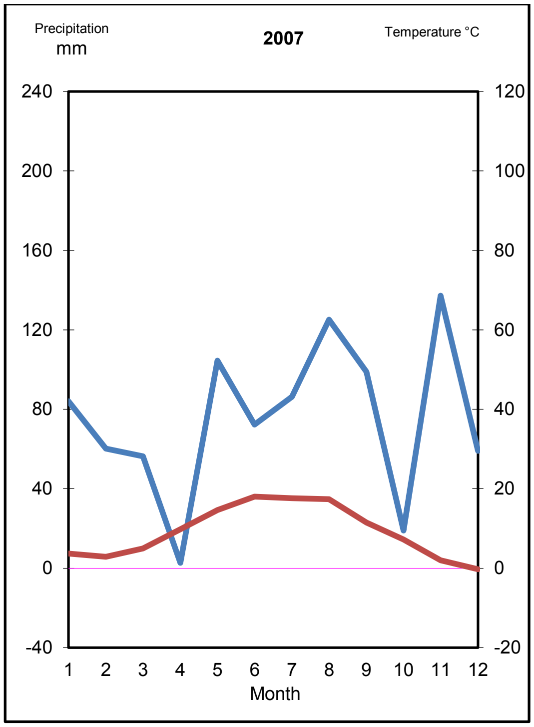
240
200
160
120
80
40
0
-40
120
100
80
60
40
20
0
-20
1 2 3 4 5 6 7 8 9 10 11 12
Month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Temperature °C
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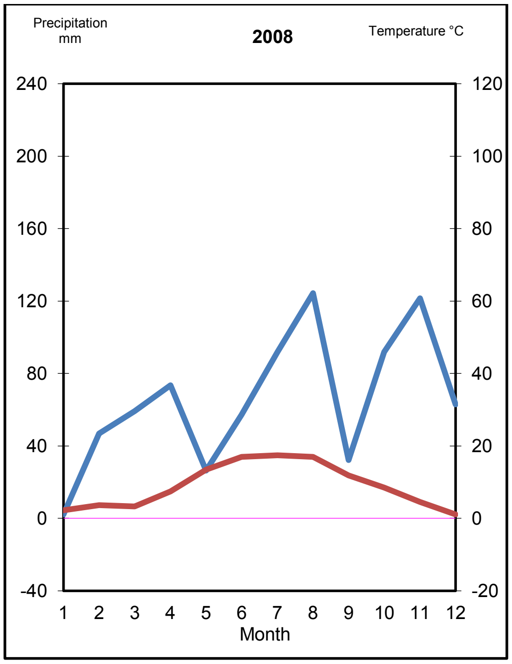
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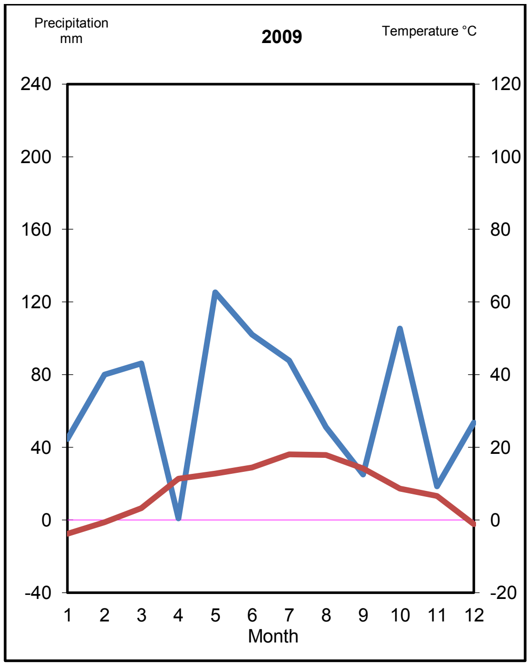
1 2 3 4 5 6 7 8 9 10 11 12
Month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Temperature °C
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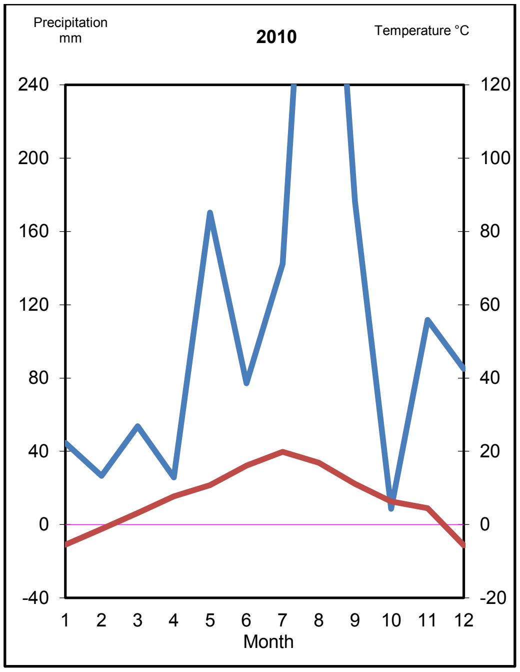
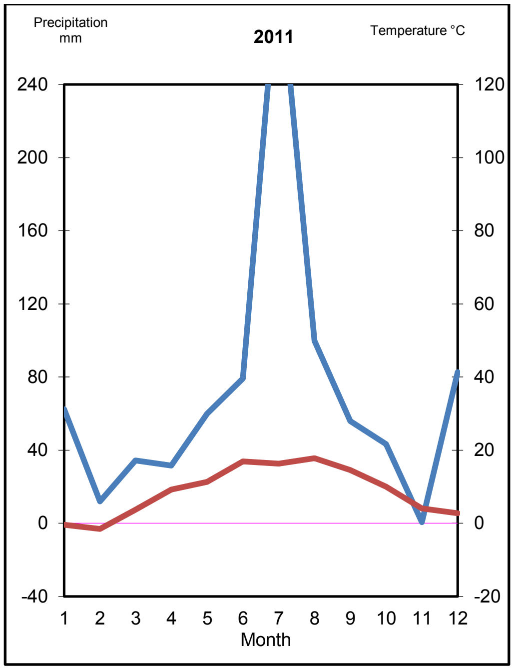
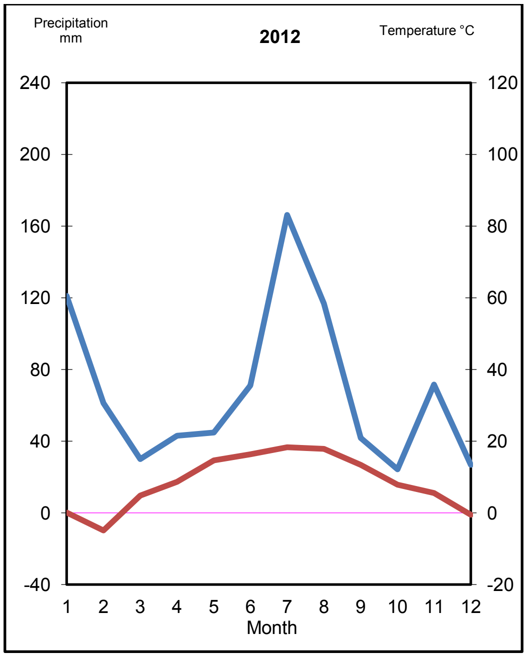
Month

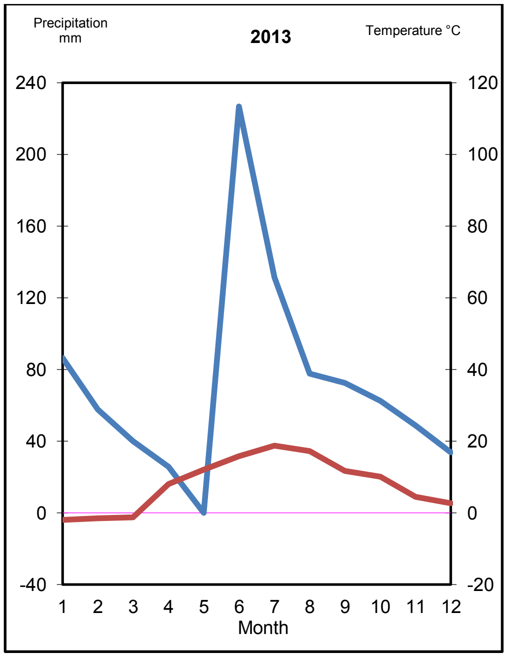


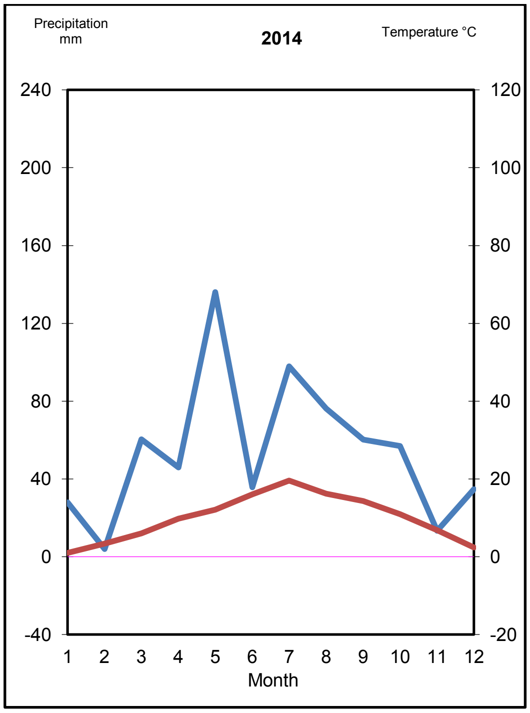
2010 (Precipitation at 8 = 458.5 mm)



2011 (Precipitation at 7 = 308.3 mm)



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mm
2014
Temperature °C
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200
160
120
80
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4
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6
7
8
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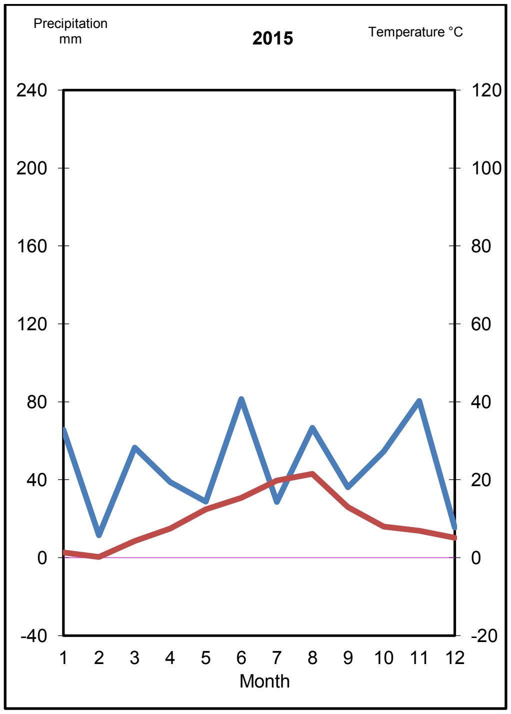
10
11
12
Month


Precipitation
mm
2015
Temperature °C
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160
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80
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-20
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11
12
Month