THE INFLUENCE OF LAND USE ON PLANT SPECIES DIVERSITY IN THE BIOSPHERE AREA "SCHWÄBISCHE ALB", SOUTHWEST GERMANY

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Abstract

The aim of this study was to determine the relations between the intensity of land use and the characteristics of different habitat types within the grassland ecosystem in the Biosphere Area “Schwäbische Alb” in Germany. Data has been collected based on 50 examination plots (4×4 m) of the Biodiversity Exploratories project. These plots represented different land use types and levels of intensity which are 1) grazed, ungrazed 2) once, twice, three times mowed, 3) fertilised, unfertilised. All vascular plants, their ground cover and several environmental parameters (soil type, solum thickness, inclination and exposition) were recorded. Biomass was taken (g/0.2 m²) and was examined. Data analyses were taken from several bivariate and multivariate statistics. The results indicated that the land use parameters grazing, mowing and fertilisation were the most important determinants for species richness (species number/16 m²), evenness, (Shannon) diversity, composition and biomass production. Inclination was an important environmental factor. DCA showed an overlap between frequently mowed meadows and mowed pastures due to the similar species composition. Grazed pastures were clearly separated from all other samples due to a different species composition, high species richness and a rather low biomass production. Highest species richness and diversity and lowest biomass were found in semi-dry grasslands. Traditional used meadows with low mowing frequency and low or none fertilisation reached high species richness and diversity and low to intermediate biomass production compared to all other samples. Through raising the cutting frequency and the degree of fertilisation, biomass production was increasing respectively but species richness and diversity were shown to be reversibly related. Pastures with low livestock unit and long grazing duration showed a higher biomass production than other grazing schemes. Cattle and horse pastures obtained low species diversity and richness, compared to sheep grazed pastures, which mainly occurred in traditional transhumance shepherding. Since plant species' diversity and production was mainly affected by the intensity of the land use, the results may help to find appropriate land use management strategies in order to maintain and promote species diversity of the cultural ecosystem of the Biosphere Area "Schwäbische Alb".

Keywords:

Species richness, species evenness, species diversity, species composition, biomass production, grazing, mowing, fertilisation, Swabian Alb, Biodiversity Exploratories.

Dedication

This thesis is dedicated to my parents, who raised me with love and discipline, but always gave me the freedom to find my own way in life. Throughout my formative years they have always tried to support and encourage me whenever possible. They have a big influence in creating the person I am today.

Diese Thesis ist meinen Eltern gewidmet, die mich mit Liebe und Disziplin erzogen haben, mich aber immer meinen eigenen Weg finden ließen. Während meines Werdegangs haben sie mich allezeit ermutigt und unterstützt, wo auch immer sie konnten. Sie haben einen großen Anteil daran, wer ich heute bin.

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Declaration

I, Katrin M. Wuchter, declare hereby that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

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Signature………………………………. Date……………………………..

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Acronyms and abbreviations

AEG	Experimental grassland plot of the Swabian Alb Exploratory
a.s.l.	above sea level
BfN	“Bundesamt für Naturschutz” (Federal Office for Nature Protection)
CCA	Canonical correspondence analysis
DCA	Detrended Correspondence Analysis
EU	European Union
FFH	Fauna Flora Habitat of the Council of the European Communities (incl. protected European regions and species)
LGRB	“Landesamt für Geologie, Rohstoffe und Bergbau in Baden-Württemberg“ (State Office for Geology, Raw Materials and Mining)
LNatSchG	“Landesnaturschutzgesetz” (Federal Nature Conservation Law)
LUBW	“Landesanstalt für Umwelt, Messung und Naturschutz Baden-Württemberg“ (State Institution for Environment, Surveying and Nature Protection)
MLR	“Ministerium für Ernährung und Ländlichen Raum Baden-Württemberg“ (Ministry for Food and Rural Area Baden-Württemberg)
N	Nitrogen
RP	„Regierungspräsidium” (Regional council)
UNESCO	United Nations Educational, Scientific and Cultural Organization

1 Introduction

1.1 General introduction

Biodiversity describes “the variety of life, and refers collectively to variation at all levels of biological organization” (Gaston & Spicer, 2004). The term also includes diversity within species, between species and of ecosystems (Secretariat of the Convention on Biological Diversity, 2003). Due to the current impact of human activity, biodiversity is reducing at an alarming rate (Kim & Weaver, 1994; Blockstein, 1995; Zechmeister & Moser, 2001). Biodiversity is the essential resource of life and its destruction by humans has become a major issue worldwide (Soulé, 1991; Willems *et al*., 1993; Kim & Weaver, 1994; Forester & Machlis, 1996; Millennium Ecosystem Assessment, 2005). In 1992, at the Earth Summit in Rio de Janeiro, this concern was raised to global level (Kim & Weaver, 1994). The Convention of Biological Diversity states the need for “conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits” (Secretariat of the Convention on Biological Diversity, 2003).

More than 150 nations ratified the convention, including Germany (Gaston & Spicer, 2004).

Another older worldwide project that advances conservation of biodiversity is the establishment of biosphere reserves (BfN, 2007). The UNESCO is responsible for this World Network of Biosphere Reserves (UNESCO, 2008). Over 500 reserves have been established in 110 countries all over the world (Schulz 2006). There are three functions and levels of preservation for biosphere reserves. First, biosphere reserves include a protection (core) area in order to conserve landscapes, ecosystems, species, and genetic diversity. The second level monitors the development of the region (buffer zone) to promote sustainable development, both socio-culturally and ecologically. Finally, biosphere reserves provide logistic support (transition zone). The reserves promote demonstrations, environmental education, research, and environmental observation of local, regional, national, and international subjects and sustainable development (BfN, 2007).

Germany's 13 biosphere reserves cover a total area of 1.73 m ha (without the protected area of the North and Baltic Sea) (BfN, 2008; UNESCO, 2008). There are great efforts in creating a new reserve, which will then be the 14th biosphere reserve in the country (BfN, 2008). This reserve is located in the southwest of Germany and is called "Biosphärengebiet Schwäbische Alb", meaning "biosphere area". This neutral name was chosen to reduce inhabitants' anxiety of living in a protected area with many prohibited actions. "Biosphere area" emphasizes the cooperation of humans and nature (Lämmle, 2007; Schneider-Rapp & Steinberger, 2008). Since the beginning of 2008 it has already been proclaimed as "Biosphere Area" in the national law (RP Tübingen, 2008a).

1.2 Establishing a biosphere reserve

On 24th April 2007, the Cabinet of Baden-Württemberg finalised the border of the new Biosphere Area “Schwäbische Alb” (Start-Team Biosphärengebiet am RP Tübingen, 2007). The concept was finalised and signed on 11th March 2008 and was then handed in to be reviewed by UNESCO (MLR, 2008a). On 22nd March 2008 the new reserve was entered into force through the Federal Nature Conservation Law (§ 28 LNatSchG) (BfN, 2008; RP Tübingen, 2008a). Currently it is expecting some official resolutions from UNESCO.

1.3 Introduction of Biodiversity Exploratories

To advance biodiversity research in Germany a new project named “Biodiversity Exploratories” was launched in 2006. The exemplary large-scale and long-term research project emphasizes exploration as opposed to descriptive observations (Fischer *et al.*, 2006). It aims to establish and sustain “the scientific infrastructure and develop the intellectual framework needed to address critical questions about changes in biodiversity and to evaluate the impacts of those changes for ecosystem processes” (Pfeiffer, 2007b).

The Biodiversity Exploratories project established experimental and monitoring plots in grassland and forest areas, whilst the relationship between land use intensity, biodiversity change, and ecosystem functions is addressed (Pfeiffer, 2007b).

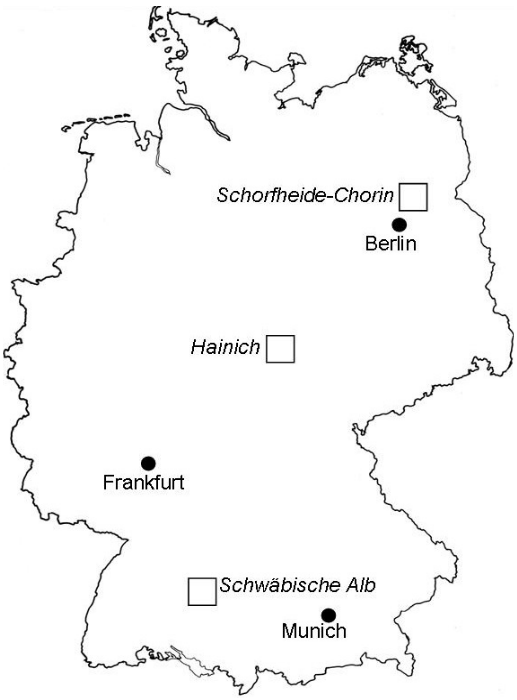


Figure 1: Locations in Germany, where biodiversity exploratories take place (Pfeiffer 2007b).

The project is taking place in three exploratories around Germany (Figure 1). The Biosphere Reserve Schorfheide-Chorin (State of Brandenburg), the National Park Hainich and its surroundings (State of Thuringia), and the designated Biosphere Area Schwäbische Alb (State of Baden-Württemberg) comprise the areas. In the three exploratories, 300 automated environmental sensing devices were installed to measure environmental parameters over extended spatial and temporal scales. After implementation it is assumed to be one of the largest scientific measurement systems in Central Europe (Pfeiffer, 2007b).

This thesis focuses on the biosphere exploratory "Schwäbische Alb" and does not address the other two areas.

1.4 Justification

Biodiversity, including plant diversity, supplies humanity with essential resources and ecosystem services (Schläpfer, 1999) like purifying air and water. As it serves like a buffer against pollution, recycles, removes toxins but also provides space for human recreation, it is seen as indispensable for humanity. To be able to protect

1 Introduction

Biodiversity its familiarisation needs to improve (Rescia, 1994). Research projects are important to address the effect of human domination on ecosystems and the benefits that ecosystems provide to society (Tilman, 1999b). There are still few empirical studies on how human actions affect biodiversity, although human impact on nature is immense (Forester & Machlis, 1996; Hengeveld, 1996). Thus it is important to point out the human's effect on ecosystems (Tilman, 1999b). A major determinant is agriculture causing detrimental environmental impacts on many ecosystems. Much agricultural interference happens on grasslands, which cover 5.5 m ha (19.6 %) of Germany (Fuchs & Schumacher, 2006). Particularly the intensity of land use is one key to conserve biodiversity (Willems *et al.*, 1993; Pfeiffer, 2007a). Extensive land use types promote species diversity, which makes them important to support (Bignal, & McCracken, 1996). Thus, it is necessary to increase the awareness about the different ecosystems and habitats. The impacts, especially on agricultural landscapes, can be minimized (Tilman, 1999a). This might not only be obtained through habitat protection but also by adjusting the management and finding appropriate strategies (Willems *et al.*, 1993; Rescia, 1994; Roberts & Gilliam, 1995; Zechmeister & Moser, 2001), which help in guiding towards sustainable land use. This is especially important for a densely populated country like Germany.

Maintenance and restoration of grasslands including mowing and grazing, are a central part of nature management policy in many European countries (Pykälä, 2003).

The Swabian Alb ("Schwäbische Alb") offers a highly structured cultural landscape, which serves as an ideal area to study biodiversity as can be seen in its mixture of different forests and grasslands maintaining different land use intensity and species richness (Fischer *et al.*, 2006) a typical feature of the European culturally shaped landscape. Thus the region is highly suitable for research in plant production and species diversity in conjunction with different land use types and their intensities.

1.5 The importance of the region for nature conservation

The study area (biodiversity exploratory, biosphere area) is located in the centre of the Swabian Alb. Its geomorphology is heterogeneous. The altitude is ranging from about 400 m a.s.l. to 850 m a.s.l. The area's characteristics are morphological fairly flat parts ("Mittleres Albvorland", "Mittlere Flächenalb") (Figure 3, p. 21) but also hilly parts and steep canyons. The region is an old area of settlement with an own developed land use system where agriculture treatments were adapted to. Nowadays the entire region is still been used relatively extensively and therefore conserving a high biodiversity. The markedly high diversity of the landscape, especially the complex mosaic of forests, grasslands, arable lands and settlements can not be found in any other biosphere reserves. Striking features are the canyon forests and different types of beech forests. Since the soil is fairly low productive grasslands are dominant compared to fields. Particularly valuable from a conservational perspective are the rocky habitats and dry meadows with many relicts of species (Bachmann *et al.*, 2007). Of high value are the juniper heats formed by transhumance shepherding ("Wanderschäferei") occurring on calcareous soils and giving rise to (semi-)dry grasslands. They maintain many rare and endangered plants like orchids, carline thistles and gentians. In Baden-Württemberg they have remarkably declined in the last decades due to the decrease of shepherding (Breunig, 2002).

The former military training area near Münsingen contributes to the stellar value of the Swabian Alb because it covers a large, non-fragmented area with many rare communities such as juniper heats, tall oatgrass meadow (“Glatthaferwiesen”); infertile pastures und woodland pastures (“Hutewälder”). The military training area with its open landscape, solitary trees and copses is considered today as the most continuous and most silent region of Baden-Württemberg (Figure 2). The landscape character of the area was formed by utilisation of the military and thus continual extensive agriculture (mainly transhumance shepherding). Also extensively used hay meadows are declining in favour of silage meadows. Once to twice and only moderately fertilised meadows maintain many plant species and describe a typical ecosystem of the Swabian Alb. In these small but unique ecosystems many rare and endangered plant and animal species can be found (see chapter 3.1.8). Many of these habitats and species are protected by the FFH-Guidelines of the European Union and

Figure 2: The picture gives and idea of the unfragmented grasslands of the old military training area. Forests, solitary trees and pasture grassland are scattered. On the left hand side an old military bunker is visible.

are listed in its Annex I, II and IV. Through the differentiated settlement structures and the development of the cultural landscape a biodiversity emerged, which turns the military training area and the whole biosphere area to a national and international valuable part of the European natural and cultural heritage. The development of the region's unique cultural ecosystem, which goes back over thousands of years, has created a very valuable and conservable region (Bachmann *et al*., 2007).

1.6 Objectives and research hypotheses

1.6.1 Overall objective

The overall aim of the study was to determine and assess the influence of land use systems and intensity levels on the cultural ecosystem in the Biosphere Area "Schwäbische Alb" in Southwest Germany.

1.6.2 Specific objectives

Therefore specific objectives were:

a) to describe the habitat types of grassland within different land use types and intensity levels in terms of species richness, evenness, diversity, species composition and biomass production

b) to compare different land use types and intensity levels

c) to determine the relation between species richness, diversity and biomass

d) to assess the influence of land use practices against the background of conservation strategies for the Biosphere Area ”Schwäbische Alb”

1.6.3 Research hypotheses

a) The grassland types differ in species richness, evenness, diversity, species composition and biomass production due to different land use types and intensity levels. It is expected that grasslands with similar land use types and intensity levels obtain similar species richness, evenness, diversity, species composition and biomass production and can be distinguished from grassland with other land use types and intensities.

b) It is expected that species composition alters with changing land use. Species richness, evenness and diversity are higher in areas with low agricultural use like no fertilisation, extensive mowing and extensive grazing. Biomass production is higher in areas with intensive land use due to agricultural treatments like the use of fertiliser, frequent mowing and grazing.

c) The relationship between species richness or diversity and biomass is influenced by different parameters. It is expected that both, species richness and biomass production, or diversity and biomass production are reversibly related to each other.

d) The practises of different land use are suitable in maintaining grasslands of the Biosphere Area ”Schwäbische Alb” in different ways. Only certain, in particular extensive, management strategies support the conservation of the cultural ecosystem.

2 Literature review

2.1 Plant species diversity and biomass production: an overview

2.1.1 Plant species diversity

Species richness and diversity are seen as being one of the most basic criteria of biodiversity (Zechmeister & Moser 2001). “Plant species diversity refers to the number of species (richness) and their relative abundance (evenness) within a defined area” (Sanderson *et al.*, 2004). Thus, diversity measures the amount and distribution of species within an area. This term should be seen as a constantly generated or readjusted measurement (Margalef, 1994). It influences the biomass production and stability of ecosystems whereas it is still unclear how important species diversity is (Tilman, 1999b).

Disturbance (especially in terms of agricultural use) of plant communities plays also an important role for species diversity. It has been hypothesized that species richness is highest at intermediate levels of disturbance, which is caused by the coexistence of colonizing species with competitive species that would out-compete the colonizer without disturbance (Grime, 1973a; Huston, 1979).

Studies have shown that the disturbance-diversity relationship can be either negative (Baur *et al.*, 2007) or positive depending on productivity (Proulx & Mazumder, 1998; Kondoh, 2001). Kondoh (2001) agrees that a positive disturbance-diversity relationship is observable only when productivity is high while a negative relationship is detected only when productivity is low and a unimodal pattern when productivity is moderate. According to Margalef (1994) productivity is highest if there is no disturbance. After disturbance experiments in low diverse, anthropogenic grasslands Gendron & Wilson (2007) concluded that the lowest species diversity is found in the undisturbed plots receiving the highest addition of N. Proulx & Mazumder (1998) showed that plant species richness increased with increasing grazing pressure in a nutrient-rich environment but it decreased in a nutrient-poor environment.

It does not necessarily mean that high species richness equals high value for biodiversity protection. The potential value of an area depends on what type of plant species occur in the area and not the amount. If an area contains few species and they can not be found elsewhere, it is valuable (Margules *et al.*, 1994).

2.1.2 Biomass production

"Biomass means […] organic material originating from plants, animals and micro-organisms" (United Nations Framework Convention on Climate Change [UNFCCC], 2005). In the context of thus study only plant biomass as the total mass of plant material in a specific area is addressed.

Biomass production differs among habitats due to biotic and abiotic factors. According to the hypothesis of Tilman (1999b) monocultures are the most productive systems and that communities with higher diversity should not be more productive. Other models promote niche complementarity (Loreau, 1998; Loreau & Hector, 2001; Hooper *et al.*, 2005). They expect that differences among species in resource or environmental requirements (e.g. space) would allow combinations of species to more completely capture and use resources (Naeem *et al.*, 1994; Hector, 1998;

Loreau, 1998). This phenomenon is called overyielding (Tilman, 1999b).

Different methods to measure biomass production have already been used. In grasslands, biomass is often clipped, oven dried and weighted (Ram *et al*., 1989; Willems *et al*., 1993; Ma *et al*., 2008). A further method is to use a disc pasture meter, which estimates the standing crop of herbaceous plant material in a grass sward (Bransby & Tainton, 1977). This is based on the fact that depending on the amount of grass the higher the height from the ground to where the disc settles (Bransby & Tainton, 1977). More recent methods are estimations of biomass through the usage of remote sensing and geographic information systems (GIS) modelling (Iverson *et al*., 1994; Ma, 2008). The biomass production can be calculated with the aid of different bands of satellite images and the colours vegetation reflects.

2.1.3 Plant species richness or diversity and its relation to biomass

One direction researchers are heading towards is the discussion about plant species diversity, composition, biomass, and the relation between them. Existing studies state that the productivity-diversity relationships can be positive (Abrams 1995; Lambers *et al*., 2004), negative (Rosenzweig 1971) or unimodal (Grime 1973b; Rosenzweig & Abramsky 1993; Tilman & Pacala 1993), as confirmed by empirical studies (Kondoh, 2001).

On the one hand data from an experiment confirmed that the species richness-productivity relationship and calculated measures for overyielding result in the positive relationship between species richness and biomass production (Balvanera *et al*., 2006; Cardinale *et al*., 2006; Roscher *et al*., 2007). On the other hand observations during experiments in grassland plots, showed loss of diversity led to significant decreases in productivity (Tilman, 1999b; Hector, 1999). Hector (1998) states that species-rich communities have a higher probability of containing highly productive species. Thus, it can be suggested that even the best monoculture does not reach many higher diversity communities (Hector, 1999). These finding are supported by Roscher *et al*. (2007), while they specify the increase of biomass from monocultures to mixed cultures. Their findings support the overyielding hypothesis as it has shown that their observed strong increase from monocultures to two-species mixtures was due to trait-independent complementarity effects. Overyielding was greater in mixtures but did not increase with species richness, which is consistent with the constant complementarity effect. Dominant species with broad niches and therefore similar requirements reach their potential for niche complementarity under conditions of low diversity due to reduced intra-specific competition (Roscher *et al.*, 2007). Manhoudt *et al.* (2005) state that a decrease in biomass clearly leads to an increase in plant species numbers. This trend has been confirmed by other scientists agreeing that over a wide range of moderate-to-high biomass values, biomass production is negatively related to species richness, driven by increasing competitive exclusion at higher productivity (Grime 1973a, 1979, 1990; Willems *et al*., 1993; Grace 1999; Thompson *et al*., 2005). Intraspecific competition occurs for nutrients, water, light and other for surviving essential factors (Van Der Wal *et al*., 2000). Decreasing species richness results in a decrease in biomass of certain trophic groups, leading to less complete depletion of resources used by that group (Cardinale *et al*., 2006).

Experiments have shown that the effect of species composition on biomass production is relatively high compared to the effects of species richness (e.g. Tilman *et al*., 1997; Hooper, 1998; Craine *et al*., 2003; Roscher *et al*., 2007). Contrarily, Hector *et al*. (1999) found a strong evidence of a simultaneous effect of species composition on biomass production like plant species diversity on productivity.

Biomass production also correlates positively with fertilisation (Stevens *et al*., 2004; Manhoudt *et al.*, 2005). Thus reducing nutrient input leads to an increase in species number (Manhoudt *et al.*, 2005, Schippers & Joenje, 2002). Furthermore studies found out that the species richness and productivity relationship also depends on soils. The general pattern of plant species richness in grasslands is described as poor in areas of very low soil productivity, rich in areas of low and intermediate productivity, and poor again in areas of high productivity (Huston, 1994; Margules *et al*., & Huston, 1994; Rescia, 1994).

2.1.4 Abiotic and biotic determinants

Plant species diversity and production depends on various abiotic and biotic factors. Vegetation depends on the ambient rainfall and actual moisture conditions may be among the most important ecological factors responsible for community composition (Rosen, 1988, 1995; Otsus & Zobel, 2002). Rainfall is, especially in calcareous grasslands, an important factor for species richness (Otsus & Zobel, 2004). Altitude, expressing mean annual temperature and the precipitation sum, is one of the major factors, which influences the variation in vegetation (Oglethorpe & Sanderson, 1998; Botta-Dukát, 2005; Hájek *et al*., 2008; Zelnik & Čarni, 2008). Species composition also depends on topography and soils (Marini, 2006), which are usually shallow in calcareous grasslands (Otsus & Zobel, 2004). Steepness and exposition can lead to high temperatures (up to 50 °C at semi-dry grasslands) (Döler & Haag, 1995). Abiotic factors like pH, plant-available P and silt content are also considered as important determinants for species richness and diversity (Zelnik & Čarni, 2008). Nutrients and site fertility are also essential. Schmid (2002) has shown that productivity correlates positively with site fertility. Furthermore exposition is important for diversity. Usually, northern exposed hill sides contain a lower diversity than south-exposed (Schmid, 2003).

An additional factor affecting plant diversity and community composition is grazing. Herbivores impact species richness either positive or negative depending on herbivore species, stocking rate and periodicity of grazing (Amiaud *et al*., 2007, as cited in Olff & Ritchie 1998; Menard *et al*., 2002). In general grazed meadows are characterized by annual species. Usually species richness is higher in grazed sites and plant community structure differs from ungrazed meadows (Amiaud *et al*., 2007). Experiments showed that after abandon grazing plant communities decrease in spatial heterogeneity, a few species dominate and species richness decreases (Adler & Lauenroth, 2001; Amiaud *et al*., 2007).

2.2 Land use practices: an overview

2.2.1 Land use practices and species diversity

Biodiversity is declining and even experiencing extinction, caused especially through the agricultural sector (Willems *et al*., 1993; Tilman, 1999b; Schmid, 2002). The changes in land use over the last 50 years have resulted in a less diversified and more fragmented landscape, which is particularly visible on a small scale (Rescia, 1994). Modern agriculture is characterized by the change in vegetation structure, its homogeneity (Rescia, 1994; Firbank, 2008) and the modification into monocultures (Tilman, 1999a).

However, some types of agriculture have increased the diversity of the landscapes (Ellenberg, 1988; Zechmeister & Moser, 2001). Unlike cultivation, grazing does not produce a decline in species richness (Díaz *et al*., 1994). Thus, appropriate grazing may be compatible with preserving diversity in some grassland types (Huston, 1994). Nevertheless, intensive grazing reduces diversity as plants can compensate the effects of grazing only to a certain point (Noy-Meir, 1993).

Frequent mowing has a distinct negative influence on plant species richness. Where intensive silage production happens plant species diversity is low (Zechmeister *et al*., 2003).

The intensity of fertiliser application also effects biomass production and plant diversity. Vascular plant species richness is highest at an intermediate nitrogen supply (Zechmeister *et al*., 2003).

2.2.2 Land use practices in Europe and Germany

European agriculture shows a long history. At about 4500 BC, many farmers settled in Germany (Ellenberg, 1988). In the area of the Swabian Alb the three-field rotation system was introduced in the 9th century (Fischer *et al*., 2006). It broke down in the 18th century and long-distance transhumance shepherding arose (Fischer *et al*., 2006).

Nowadays Germany’s landscape is characterised by its agriculture. Pristine landscapes are very rare and hardly exist (Koellner & Scholz, 2007). It can thus be described as a cultural landscape, rather than a natural landscape (Ellenberg, 1988). Through creating a cultural landscape, man has increased the diversity of the landscape in numerous areas (Ellenberg, 1988). Therefore, Europe's most highly valued biotopes occur on low-intensity farmlands (Bignal & McCracken, 1996), which also applies to Germany. At the present, traditional land use and management systems change dramatically (Rescia, 1994; Firbank, 2008). In many European regions with long periods of intensive land use, local extinction is widespread due to these changes in agriculture (Forester & Machlis, 1996; Schmid, 2002; Koellner & Scholz, 2007). This has led to strong fragmentation of the remaining grasslands (Kiehl & Pfadenhauer, 2007). Changes of agriculture can be seen on the one hand as the establishment of intensive land use types or on the other hand as giving up agricultural as a whole (Willems *et al*., 1993). Also species-rich calcareous grasslands as often found at the Swabian Alb, are a rarity in Europe due to land use intensification or abandonment (Gibson & Brown 1991; Willems 2001; Poschlod & Wallis DeVries 2002). They are even seen to be among the most threatened habitats in Central Europe (Fischer *et al*., 2006). To protect the calcareous grasslands and further ecosystems conservation of the biodiversity belong to the basic aims of German nature conservation and is fixed in the German Nature Conservation Law (§ 1 Abs. 1 Nr. 3 NatSchG) (Murmann-Kirsten *et al*., 2007).

2.2.3 Impact of land use on vegetation

Land use types strongly affect species composition, diversity (Díaz *et al*., 1994; Firbank, 2008) and biomass (Willems *et al*., 1993). Intensively used areas like grasslands, which are mowed several times a year to use for silage, do not maintain many different species (Schmid, 2002; Gendron & Wilson, 2007). This leads to changes in species composition where strong competitors are dominating the communities. Some pastures are mowed after grazing, which is done to reduce the expansion of certain species (*Rumex obtusifolius, Ranunculus acris*, and *Cirsium* spec.) (Schmid, 2003; Elsäßer, n.d.).

Has the depletion of a grassland happened, it is seen as a challenge or nearly impossible to turn it back as low-diversity grasslands caused by anthropogenic use are resistant towards change in species composition (Crawley *et al*., 1999; Gendron & Wilson, 2007).

Extensively used areas like meadows erratically grazed by sheep flocks exhibit relative high species richness and a diverse species composition of plant species (Schmid, 2002). Willems *et al*. (1993) state low fertility and episodic removal of foliage appear to be important for species diversity, which is promoted by grazing or mowing. However, mowing, grazing and fertilisation need to happen at an appropriate extent since they show a significant influence on productivity (Willems *et al*., 1993; Zechmeister *et al*., 2003; Královec & Malý, 2006).

2.2.4 Grassland management

Extensive grasslands are managed in various ways. Meanwhile the use of herbivores to maintain or even restore plant species diversity has become a crucial component (Gordon *et al*., 1990; Amiaud *et al*., 2007)**.** During their study Kiehl & Pfadenhauer (2007) recognised that in comparison to unmanaged plots management by mowing leads to higher species richness and a lower number of ruderals (Kiehl & Pfadenhauer, 2007). Oglethorpe & Sanderson (1998) described that especially four grass species (*Cynosurus cristatus*, *Festuca rubra*, *Dactylis glomerata* and *Holcus lanatus*) occurring in hay-meadow communities are associated with low but positive levels of organic and inorganic fertilizer application, moderate use of pesticides and low stocking rates. Besides they prefer locations facing southwards. It has shown that regular and moderate agricultural use by grazing livestock or regular mowing is probably the most important factor to maintain species richness in ancient calcareous grasslands (Willems 2001; Poschlod & WallisDeVries 2002; Kiehl & Pfadenhauer, 2007).

Fallows, where agricultural use has come to an end, show less species richness and also less biomass production (Ellenberg, 1988; Schmid, 2002). If ecosystems such as juniper heaths are not managed through removing above-ground biomass, species diversity will decline dramatically (Willems *et al*., 1993).

In order to maintain plant diversity agriculture treatments need to be changed in an appropriate way. Bignal & McCracken (1996) criticise that too much emphasis is placed on attempting to ameliorate damaging effects of agricultural management rather than supporting ecologically sustainable low-intensity farming practices. To promote extensive use of meadows and pastures many European countries have introduced economic incentives to farmers. Nevertheless, abandonment of grassland is still seen as a problem in Europe (Amiaud *et al*., 2007).

3 Materials and methods

3.1 Description of the study area

3.1.1 General description of the Swabian Alb

The Swabian Alb is formed as a hilly highland. The mountainous ridge is about 250 km long and 40 km wide with the highest point being over 1000 m a.s.l. It is one of the largest connected karst regions in Germany. Along the whole of the north-western boundary lays a 400 m high step in the terrain, named “Albtrauf” (steep escarpment). At its edge the escarpment gives way to the plateau of the Swabian Alb (Bachmann *et al.*, 2007). From the peak the area declines with a downward slope until it reaches the Danube (Figure 3). The river flows in average 40 km parallel to the “Albtrauf” and marks the south-eastern boundary of the highlands (Bachmann *et al.*, 2007). Erosion has caused the escarpment to be pushed back and created deep gulches and mountain peninsulas. The escarpment and the Swabian Alb itself are carved into steep valleys. The Swabian Alb is divided into two parts. The northern part following the escarpment is a hilly region called the “Kuppenalb”. It is followed by the “Flächenalb”, which is a flat plateau

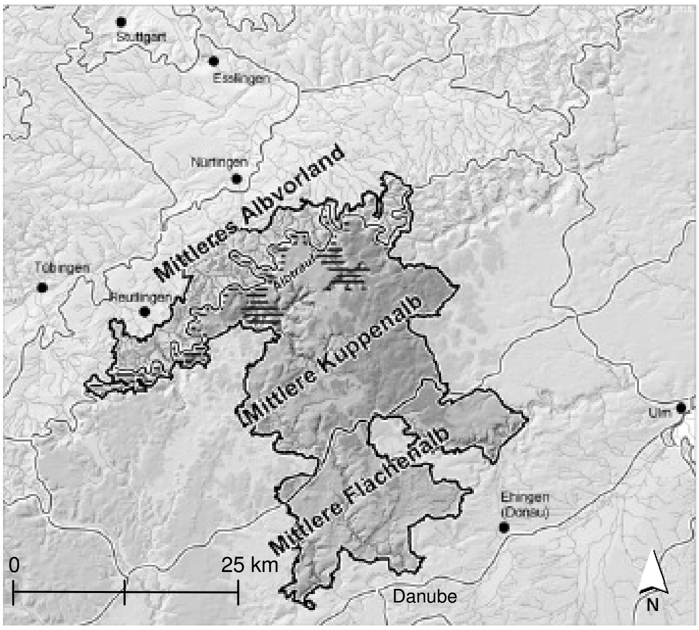


Figure 3: The region of the Biosphere Area “Schwäbische Alb” is divided into three parts. (Bachmann *et al.*, 2007)

without distinct mountain peaks (Figure 3, p. 21). The “Flächenalb” was created through the abrasion of the Miocene Molasse Sea (Geyer & Gwinner, 1991). The cliff line (“Burdigalkliff”) is located in the south of Münsingen. The foreland of the Swabian Alb, which is about 300-400 m deeper than the plateau, is characterised by settlements. At the end of the foreland along the step in the terrain a wide belt of orchard meadows can be found (Bachmann *et al*., 2007).

3.1.2 Location and extent of the biosphere area

The new biosphere area covers more than 84,525 ha (MLR, 2008a) and is located in the centre of the mountain range of the Swabian Alb. It includes the counties (“Landkreise”) Esslingen, Reutlingen, and Alb-Donau (Muschel, 2007). Mainly within the area of the biosphere reserve the investigation area of the biodiversity exploratory “Schwäbische Alb” is located (Figure 4, p. 23: red line).

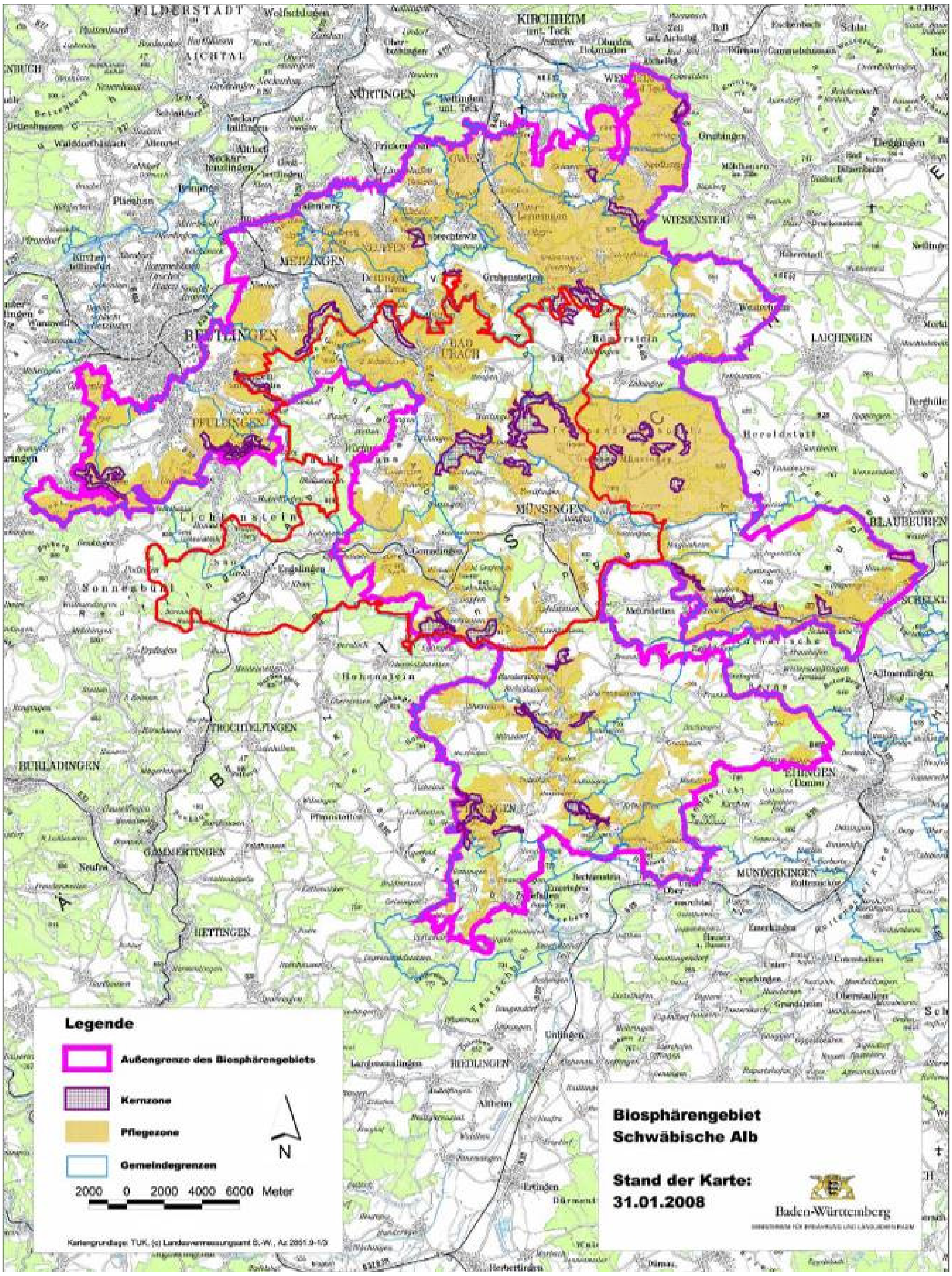


Figure 4: The map shows the designated area of Biosphere Area "Schwäbische Alb" (31.01.2008). The pink, bold line displays the border of the reserve, the purple squared area marks the area of protection (core area) and the brown, dense pattern indicates the development region (buffer zone). The area, which is neither purple nor brown but inside the pink line, receives logistic support. The thin, blue line marks the municipality borders (Regierungspräsidium Tübingen, 2008b). The red line indicates the area of the biodiversity-exploratory.

3.1.3 Historical background

The biosphere area is located around the town Münsingen. Heart of the reserve is an old military training area with a size of 6,700 ha (Fischer *et al.*, 2006). On the 21st of October 2005 the German armed forces closed this base (Streitkräfte, 2006). Since 1895 it was a military training area and therefore closed to the public, which means that there was hardly any agricultural or other economical use. This area was only affected by the military. Therefore, the nature in the area was somehow “protected” over a long period of time and was therefore able to develop a special ecosystem, which makes it of high interest for research and conservation. Following a long discussion, the Cabinet of Baden-Württemberg laid the foundations for the planned Biosphere Area “Schwäbische Alb”. As a result the concept was handed out to UNESCO to get that international status (Muschel, 2007).

3.1.4 Climate

The study area is characterised by a continental climate. Continentality is described as the difference between the average temperatures of the coldest and the warmest month. It reaches 17.1-17.5 K, which is already one of the higher values reachable in Baden-Württemberg (LUBW, 2006). Annual average temperature is about 6.5 °C (FH Rottenburg, 2002). The highest annually average is reached in July with 15.9 °C and the lowest in January with -1.5°C (LUBW, 2006). Annual total of precipitation averages 960 mm (in Münsingen-Apfelstetten). Precipitation maximum is reached in June with 124 mm (FH Rottenburg, 2002; LUBW, 2006). Lowest precipitation occurs in February with only 61-70 mm (LUBW, 2006). Since the area is located in a mountainous region vegetation period is short. Phenological beginning of spring, which is measured by the beginning of the apple blossom, is late on 16.-20. June. Autumn tints of birch, which starts on 8.-12. October marks the beginning of the autumn. Approximately 130 days per year are days of freezing (LUBW, 2006). There is even the possibility of frost days during summer. A closed or partial snow cover occurs around 85-90 days. In average there are 18-19 days with temperature beyond 25 °C (Hummel, 2006).

Mountains and traverse constellation of elevated land with regard to main wind direction, coming from the west, caused in special climate conditions (Krämer, 2000). Hence it is warmer than expected at this altitude also due to approximately 1700 sunshine hours at crests therefore the region is one of the sunniest areas in Germany (Hummel, 2006). As a result the region was settled and cultivated at a very early stage in time despite its high altitude (Krämer, 2000).

3.1.5 Morphology, geology and soils

The geology of the highlands was formed during the tertiary period, when the sediments of the Jurassic Sea rose because of tectonic movements in the upper Rhine Valley. During this process especially the southwest part of the Alb was elevated resulting in inclining geologic layers from northwest to southeast. The mountains contain calcareous bedrock and the landscape is representative for a wide range of similar calcareous mountain ranges. They extend from the Franconian Alb in the northeast of Baden-Württemberg to the Swiss and French Jura mountains (Geyer & Gwinner, 1991). Relief strongly influences the development of the soils, which results in mainly shallow soils (Pfeiffer, 2007b).

The geological underground is characterised by sediment rocks, which rose during the period where the Jurassic Sea covered the area, which was about 150 m years ago. Three main formations can be distinguished (Bachmann *et al.*, 2007). The clay containing black jura (lias) can be found at the foreland of the Swabian Alb occurring as a minority in the study area. Brown jura (dogger) builds up the middle jura-layer and is found at the base and steep escarpment ("Albtrauf") e.g. around Bad Urach, while the plateau of the Swabian Alb mainly consist of white jura (malm) (LGRB, 2003). Today the area is still subject to strong weathering processes due to chasms within the limestone, which allow water to flow through. The clays swell and slide and the limes glide to lower levels. Beginning at the escarpment the lime layer of the inclining plateau extents to the southeast (Geyer & Gwinner, 1991; Bachmann *et al.*, 2007). The remaining part contains of lime marl. Very young limestone soils contain mainly mineral substances (Bachmann *et al.*, 2007).

An extraordinary geological phenomenon can be found close to and in the surroundings of the town Bad Urach. (Bachmann *et al.*, 2007). It is the "Swabian volcano" ("Schwäbischer Vulkan"), possessing approximately 350 eruption craters (diatremes). They are distributed around Bad Urach within a radius of 25 km (LGRB, 2003). About 16 to 17 m years ago tectonic plate movement within the jura layers caused lave breakthroughs, which hardened into volcano vents as basalt tuff. But only 7 % of the vents were used by lava, whilst only gas eruptions developed in the others (Geyer & Gwinner, 1991). The former volcano vents are impermeable to water and created maars, peat bogs and small ponds called "Hülen" (Bachmann *et al.*, 2007).

Usually on top of limestone medium-heavy, clayey soils can be found containing water that is only partly available for plants ("Kalkverwitterungslehme") (Bachmann *et al.*, 2007). Soil types, which were mainly found in the area, are brown-earth-rendzinas and rendzinas with a high pH value (Bachmann *et al.*, 2007; Pfeiffer, 2007b). The height of the development of the soils is higher at deeper areas like in valleys. Due to high steepness shifting of soil material occur at sites with less vegetation cover. The results are colluvisols (Pfeiffer, 2007b).

3.1.6 Hydrology

The Swabian Alb shows a distinctive hydrology. The calcareous bedrock structure of the white jura leads to many caves, dolines and pores since it is soluble in water and rain seeps through cracks through forming subterranean rivers (Geyer & Gwinner, 1991; Bachmann *et al.*, 2007). At the plateau a small of amount of surface water can be found as water flows through a large system of caves until they emerge at boundary springs ("Schichtquellen") or karst springs e.g. near Seeburg (see map at appendix VIII) (Geyer & Gwinner, 1991; Bachmann *et al.*, 2007). The mattock geology has a low water storing capacity, causing water in "dry valleys" ("Trockentäler") to only be able to flow when snow is melting and the ground is frozen or after a strong thunderstorm. Normally, water trickles away immediately (Geyer & Gwinner, 1991; Krämer, 2000) and is unavailable for plants.

The European Watershed cuts from southwest to northeast through the study area, whereas the water from the southern parts drain to Danube and the northern parts to the Rhine (Geyer & Gwinner, 1991).

3.1.7 Fauna

The area provides habitats for many animal species, including protected species such as birds like Grey-headed woodpecker (*Picus canus*), Red-backed shrike (*Lanius collurio*), Boreal owl (*Aegolius funereus*), Red kite (*Milvus milvus*), Black woodpecker (*Dryocopus martius*), Peregrine falcon (*Falco peregrine*), Eurasian hobby (*Falco subbuteo*), Woodlark (*Lullula arborea*), Whinchat (*Saxicola rubetra*), Stonechat (*Saxicola torquata*), Quail (*Cortunix cortunix*) and Northern wheatear (*Oenanthe oenanthe*) (Fischer *et al.*, 2006). More than half of the grasshopper species in the region are endangered (Lenz *et al.*, 2005). At the orchard meadows near the escarpment one can find Bechstein's bat (*Myotis bechsteinii*), which is a highly endangered species (FFH Guidelines - Appendix II) (Bachmann *et al.*, 2007). Particularly meadows offer habitats for diverse insects including various species of butterflies and moths (Künkele, 2007b). Endangered butterflies such as Spotted Fritillary (*Melitaea didyma*), Baton Blue (*Pseudophilotes baton*), Purple-edged Copper (*Lycaena hippothoe*), Damon Blue (*Agrodiaetus damon*) occur in the study area (Bachmann *et al.*, 2007).

Additionally mammals like deer (*Capreolus capreolus*), hare (*Lepus europaeus*), fox (*Vulpes vulpes*) and wild boar (*Sus scrofa*) can be sighted. Although the habitats are not very humid, they support reptiles such as lizards and amphibians including frogs and newts (Künkele, 2007a).

3.1.8 Flora and land use types

The study area is characterised by a diverse pattern of land uses (Bachmann *et al*., 2007). In the area of the middle, flat part of the Swabian Alb mainly large-scale fields occur whereas on the middle, gently hilly part small units with a frequently change in land use of field; grassland, forest and villages are typical (Figure 5) (Bachmann *et al*., 2007).

Figure 5: The picture shows the highly structured cultural landscape (in view of Rietheim).

An exception in this pattern is the old military training area, which is dominated by grasslands and forests (Fischer *et al.*, 2006).

Different types of beech forests are the natural vegetation of most parts of the Swabian Alb (Fischer *et al*., 2006). Nowadays, the forests are composed of beech but also mixed beech woods. Tree species like beech (*Fagus sylvatica*), oak (*Quercus petraea*), ash (*Fraxinus excelsior*), sycamore maple (*Acer pseudoplatanus*), pine (*Pinus sylvestris*) and larch (*Larix decidua*) characterise the area with *Fagus sylvatica* being the most dominant species in the region (Ellenberg, 1988). Near-natural beech forests take up a big part of the core area of the reserve. They are not pristine but most similar to the potentially natural vegetation although they are used for timber production (Fischer *et al*., 2006). Beech forests are interrupted by several stands of spruce (*Picea abies*) monocultures (Fischer *et al*., 2006). They are planted as plantations to use for timber production. The steep surface of the escarpment is dominated by Canyon forests (“Hang- und Schluchtwälder”) with occasionally lime rocks sticking out (Bachmann *et al*., 2007). These forests are the natural vegetation of the humid and shady canyons and played a mayor part in qualifying as an UNESO site (Fischer *et al*., 2006). Many of them are part of small nature reserves and FFH areas.

Another characteristic land use type is the fostering of orchard meadows (“Streuobstwiesen”) (Bachmann *et al*., 2007). Usually these meadows are also extensively used since the trees are planted in rows not offering as much space as modern tractors would need. As a consequent mainly old and slow machines are used. Orchard meadows are also threatened due to the high investment in time but resulting in low profit (Seehofer & Wolf, 2008).

Root crop fields are scattered within forests and grasslands. Fields are hardly suitable for cultivation of cereals. Vegetation period is short and water availability is limited. In general, the area has been characterized by low-intensive agricultural use for many centuries (Pfeiffer, 2007a).

A relatively high part (ca. 20 %) of the biodiversity exploratories area is covered by grassland. This is mostly due to a many-century-long tradition of sheep herding (Pfeiffer, 2007a). Nowadays, grassland is mainly used as meadow, pasture or mowed pasture.

Mowed meadows occur in different intensity levels. At for agriculture favorable sites grasslands are mainly used as intensive grasslands, which are fertilised and mowed several times a year (Bachmann *et al*., 2007).

Figure 6: The picture shows a rotation pasture, which was grazed by cattle and horses (AEG 44). On the right side a part of a juniper heat is visible.

Further land use types are cattle or horse pastures. These pastures are usually intensively used as grazing duration is long and some are even fertilized. Different types occur at the Swabian Alb. Permanent pastures ("Dauerweiden") have long grazing periods and relatively short brakes in between. Usually growth is low limiting grazing selection of the animals. Grazing periods of rotation pastures („Umtriebsweiden") (Figure 6) are a few days and recovering periods three to six weeks. Grazing area is small and grazing pressure (less selection, high trampling) is high. Ration grazing ("Portionsweiden") are half-day or full-time pastures. Grazing area gets changed once or twice a day (Starz & Pfister, 2008). It is the most intensive way of grazing with the highest animal density and fertiliser input. Some of these pastures are mowed after grazing to remove residual plant material and suppress dispersal of so-called pasture weeds.

Many extensive used sheep pastures are located at the old military training area. At the moment 30,000 sheep (15,000 ewes) are grazing in that area (Bachmann *et al*., 2007).

In the study area protected semi-dry grasslands (juniper heats) with extensive sheep grazing occur (Figure 7, p. 33). These calcareous grassland communities developed in areas of clearing and forest-grazing and later became common pastures the so called “Allmende” (Fischer *et al*., 2006). With transhumance shepherding grazed semi-dry grasslands arose (Fischer *et al*., 2006). Especially at very shallow soils and rocky habitats some rare, arid grasslands are found (Bachmann *et al*., 2007).

At the Swabian Alb agriculture still happens on a small-scale basis and many producers are active. In total more than 50 farmers cultivate in the area (Biodiversity Exploratories, n.d.).

3.2 Field work

3.2.1 Selection of study sites and demarcation of the plots

As this thesis’ field work took place in the context of the Biodiversity Exploratories project the plots were chosen in order to fit to all the subjects and projects of the various working groups. As a first step 1000 grid points, including grasslands and forests, were laid on the area of the exploratory, which partly covers the Biosphere Area “Schwäbische Alb” (Figure 4, p. 23). At these grid points plant species number and abundance as well as land use types and intensity levels were recorded. Additionally, soil samples were taken and analysed. Next step required choosing grassland from the pool of grid points for more intensive studies, including the possibility to set up experiments. These plots represent a land use intensity gradient ranging from extensively to intensively used ecosystems (Pfeiffer, 2007b). Soil properties also played an important selection criterion as the two main soil types (rendzina and brown earth) should be included at approximately identical number. Besides, properties had to be found, where the owners allowed the establishment of the experimentation plots. Then 50 plots, which were stratified according to land use, from the total pool of possible plots were selected randomly.

After selection of the plots they were temporarily marked with rods (Figure 7) and permanently with a subterranean iron nail. Additionally GPS coordinates were given for each plot.

Figure 7: The rods mark plot AEG 26. The juniper heat is surrounded by mostly frequently mowed meadows.

3.2.2 Sampling units

The 50 grassland plots were located between the castle “Lichtenstein” near Groß-Engstingen (W), Böttingen (E), Bad Urach (N) and Buttenhausen (S). The north-south extension of the study area covered 13.25 km while eastern- and westernmost points were 22.5 km apart from each other (see appendix VIII).

The 50 grassland plots with a size of 4×4 m were aligned to the point of the compass. Usually the examination plot was situated in the interior of the land use unit to prevent edge effects.

The plots are called AEGs meaning “Alb Exploratory, Grassland” to be able to distinguish grasslands and forests of the plots of all three exploratories. Although the study was only undertaken at Alb grasslands the exploratories numbering was kept to be consistent.

3.2.3 Geographical output

To locate the examination plots, Geographical Information System (GIS) was used. The sampling units were marked in the digital map to provide the printed output with the location in the area and in relation to each other. The map can be found in appendix VIII.

3.2.4 Levels of intensity and combinations

The selected plots covered all main grassland land use types and levels of intensity occurring in the study area. The 50 examined plots contained three different treatments of agricultural land use as grazing, mowing and fertilisation. The treatments were undertaken in different intensity levels and combinations (12 combinations) as shown in Table 1.

Table 1: The land use treatments occur in different intensity levels. The plots were either mowed, grazed or both. Additionally, they were fertilised or unfertilised. Grazing took place through different animal species. It was not possible to find every combination in the field (e.g. meadow, 1x mowed, fertilised or meadow, 3 × mowed, unfertilised) since some combinations were not used by farmers. n shows the number of plots.

Land use treatment and intensity level	N
Pasture, sheep, unfertilised (semi-dry grasslands)	9
Pasture, sheep, unfertilised (pasture grassland)	1
Pasture, cattle, unfertilised	1
Pasture, cattle-horse, fertilised	3
Meadow, 1 × mowed, unfertilised	7
Meadow, 2 × mowed, unfertilised	2
Meadow, 2 × mowed, fertilised	2
Meadow, 3 × mowed, fertilised	13
Mowed pasture, sheep, unfertilised	6
Mowed pasture, cattle-horse, fertilised	4
Mowed pasture, cattle, fertilised	1
Mowed pasture, sheep, fertilised	1

This data set could be extended as in 2006 a questionnaire survey was undertaken in the context of the Biodiversity Exploratories project including all land owners of the experimentation plots. The survey contained questions on land use and its intensity.

In this context data was collected on the land use type, which could either be pasture, meadow or mowed pasture. The questionnaire included information on grazing. First question focused on whether a plot was grazed or not. Followed by measuring modality and intensity of grazing in terms of type of grazing animals (sheep, cattle, horse or no animals), livestock unit, which is usually defined as the grazing equivalent of one adult dairy cow (Mulder *et al*., 2005) and the number of grazing days. Further question involved investigating whether the plots were mowed or not. Mowing intensity was expressed in frequency of mowing, which could be, never, once, twice or three times a year. The last major variable taken from the questionnaire was fertilisation. Focusing in the first question on whether the plots were fertilised or not. For measuring intensity the amount of fertilisation usually used per year and the frequency of fertilisation within a year (never, once or twice) was recorded (see appendix III and IV).

All these data were used for statistical analysis whereas major parameters (grazing, mowing and fertilisation), which described whether that treatment occurred or not, were analysed first to give them the main evaluation in the analysis. Afterwards parameters with additional information about intensity levels (frequency, amount, etc.) were taken into account for delicate evaluation within the main parameters.

3.2.5 Environmental factors

To determine further factors that might have influenced biomass production and diversity, additional available data of the plots collected by other researchers of the

Biodiversity Exploratories project were reviewed. Data gathered by other groups included information on exposition (eight categories), soil type (rendzina or brown earth) and solum thickness. Additionally, whilst working in the field all plots were divided into inclination categories ranging from nearly flat (1), moderate steep (2) to steep (3). The data set is found in appendix I.

These factors were used as agents for abiotic variables, which could be applied for statistical analysis as independent variables.

3.2.6 Species diversity and composition

For plant nomenclature Wisskirchen and Häupler (1998) was used. To determine species diversity (number of species per plot and their evenness) and composition all vascular plants occurring at a 4×4 m square were identified and recorded for the inventory list (see appendix V and VI). Abundance was estimated as percentage cover of perpendicular projection of all aerial parts of the plant (Britz & Ward, 2007). All species with a high cover were recorded first. Cover of dominant and abundant species was estimated. The area was not entered before this process was finished to avoid trampling and therefore falsifying the records. To record and estimate cover of rare species the plot was entered and the ground searched for these plants. The estimation was undertaken for all vascular plants (adults or juveniles), shrubs and tree seedlings (there were no adult trees in the plots). Since grasslands usually consisted of different layers of plants the total cover estimation could exceed 100 percentages.

Some of the plots had already been mowed before they could be recorded. In this case mean height of vascular plants was not given to prevent biased data (see appendix II).

3.2.7 Biomass production

The records of the biomass were performed in a short period of time (09.06.2008-12.06.2008) to make sure that the plants were harvested promptly because biomass changes with onward vegetation period.

Figure 8: The picture shows biomass harvest through using a wooden frame at plot AEG 48.

To estimate the productivity of grasslands, above-ground biomass (g/m²) was recorded at each plot. Two samples of above-ground biomass were clipped at each grassland plot and packed into paper bags. Plant material was removed with hand scissors 2-3 cm above the soil surface, in order to prevent any lethal effects (Willems *et al.*, 1993). The constant size of the samples could be guarantied through using a wooden frame with fixed measurements (interior range: 20 x 50 cm) (Figure 8). To make sure to harvest all biomass produced since last winter the samples were taken in a part of the plot, which was fenced since the beginning of the vegetation period and therefore protected from mowing and grazing. Vegetation within that plot was not removed before July so all biomass could be harvested before. This strategy also allowed that the plot used for species recording could be utilised by agriculture as usual to keep the original land use treatments over years. That fenced plot was usually located 5 m in the north of the vegetation recording plot. In cases where this fenced part was not set up before biomass removal, samples were taken from the nearest and most similar point to the original plot.

After cutting the samples were put into an oven, where they were dried for 24 h at 80 °C (Ram *et al.*, 1989). To begin with some of the first samples were already weighted after 8 h to see whether the weights would change within another 16 h of drying. As no difference occurred it was guaranteed that the samples were tried to constant mass after staying in the oven for one day. Afterwards the two weight measurements of one plot were added and arithmetically averaged to get one mean biomass per examination plot.

3.3 Data manipulation and analysis

3.3.1 Environmental factors

The environmental variables of soil type, solum thickness, exposition and inclination were analysed in order to compare their importance in relation to the land use parameters. Data was investigated concerning normal distribution and equal variance. One Way ANOVA was used for environmental factors since they had low correlation with each other (Table 8, p.70). If the assumptions for a One Way

ANOVA was met it was run to investigate the means of the data sets and see whether an environmental parameter had significant influence on the dependent factors like species richness and diversity (see appendix VIII: One Way ANOVA). Two Way ANOVA was also used in combination with land use parameter to see whether they were additive.

3.3.2 Species diversity

Species richness was always referred to the number of species occurring in the 16 m² plot. Species diversity of grasslands was determined and expressed as Shannon-Index (H'= $-\sum_{i=1}^{S} p_i \ln p_i$, where S is the number of species in the community and p_i is the abundance of the $_i$th species in the sample). The records of the ground cover estimations were used as surrogates for abundance. The calculation of the index was done with a biometrics program that was able to compute diversity indices on basis of cover estimations in percentage. In the following species diversity was always referred to Shannon-diversity.

Evenness (Shannon's evenness) describes the level of equal distribution or the relative abundance of individuals among the species. The higher the index for species evenness the more even is the plant community.

To determine the importance of land use intensity for species richness, evenness and species diversity the data sets were tested for normality and equality of variances. If the assumption could be accepted, a multiple regression (ANCOVA) was carried out.

This was done separately for all three variables as species richness, evenness and diversity were not independent. It is one assumption of ANOVA or ANCOVA that the factors are independent from each other (Dytham, 2006). Multiple regressions were used to firstly find out the difference between mowed pastures and the other land use types to be able to have mowed pastures in a separate category because they were mowed and grazed (see appendix VII: Multiple regressions). Otherwise the mowed pastures would be allocated to meadows and pastures. Secondly mowing and grazing was analysed. Fertilisation was the third main parameter to be investigated. In the next step the more detailed intensity parameters were explored to see whether these factors make a difference in addition to the main parameters. Thus they were sorted and analysed according to their importance (amount of fertilisation, frequency of fertilisation, livestock unit, type of animal, duration of grazing and frequency of mowing) (see appendix VII). Mowing frequency was seen as less important since grasslands were first influenced first by fertilisation.

Two Way ANOVA indicated, whether interaction had taken place between two parameters concerning a dependent variable or not. If variance of the data was not equal a Scheirer-Ray-Hare Test was used (Dytham, 2006). All statistical analyses were done at a significance level of $p<0.05$.

3.3.3 Plant species composition

Species composition of grassland was analysed by describing the recorded species of all plots along a land use gradient as absence or presence. For running a DCA, which is a multivariate ordination, only species data were used (ter Braak, 1987). The gradients or axes of the indirect gradient analysis were unknown and were inferred from species composition data (ter Braak, 1987; Palmer, 2008). The axes were the explanatory variables of the environmental parameters (Leyer & Wesche, 2007). The unconstrained ordination axes correspond to the directions of the greatest variability within the data set (ter Braak, 1987). The DCA ordered the plots along that unknown environmental gradient (Digby & Kempton, 1987). The length of the axes could be seen as species turnover or beta diversity. Furthermore the length showed how different the plots were from each other and how far apart they were on the gradients of species composition (Palmer, 2008). Plots with similar acting and similar influencing variables were grouped together. The advantage was that correspondence analysis ran a search for the optimal gradient. On the basis of the clustering the environmental gradients could be interpreted (Leyer & Wesche, 2007). Thus Ellenberg's indicator values of plants helped to interpret the pattern (Ellenberg *et al.*, 1992).

The grouping of the samples in the output graph displayed the influence of both land use and environmental data on composition.

Additionally a cluster analysis was run to identify actual groups. A hierarchical clustering could be applied because the data set was still small. It determined similarity or distances between cases or in this case plots. To be able to visualise it a dendrogram was drawn. The lines indicated the distances of the plots displayed as ratio of the original distances. The smaller the distance, the higher was the similarity between the plots (Norušis, 2008). As date input species number data was used.

3.3.4 Biomass production

The biomass collected at each grassland plot and the means of parameters concerning land use intensity were statistically analysed with a multiple regression (ANCOVA) after the data were checked for normal distribution and for the same variation in each factor combination (Dytham, 2006). Multiple regression was used again to firstly determine the difference between mowed pastures and the other land use types. Then the three main land use treatments grazing, mowing and fertilisation were explored followed by the more detailed intensity parameters (amount of fertilisation, frequency of fertilisation, livestock unit, type of animal, duration of grazing and frequency of mowing).

Two Way ANOVA was used to signify, whether interaction had taken place between two parameters concerning biomass or not. All statistical analyses were done at a significance level of $p<0.05$.

3.3.5 Determinants of species composition

To find out whether environmental factors or land use factors had a stronger influence or which variable was the most important factor a direct gradient analysis was carried out. The environmental and land use factors were used for the ordination and served as explanatory variables for species composition. CCA was applied as it recognizes an environmental basis for community ordination (Britz & Ward, 2007).

It identified the patterns of variation in community composition, which could be explained through these environmental variables (Britz & Ward, 2007) and developed a theoretical gradient, which spread the plots in a maximal way (Leyer & Wesche, 2007). These gradients (ordination axes) displayed as much as possible of the variance and the linear combinations of the environmental parameters. In this way it was able to combine the relationship of environmental parameter and species. The length of the axes could be seen as species turnover or comparing species diversity along an environmental gradient (Palmer, 2008). The statistical calculations occurred on the basis of a multiple regression. The appropriateness of the axes was explained in eigenvalues. Eigenvalues describe the degree of the maximal dispersion, meaning the separation of the species value along the axis. They presented the degree of the participation of the variance measured at the total dispersion of the species composition. The bigger the eigenvalue the stronger was this axis, and thus the underlying gradient, in relation with the variation in species composition. The axes displaying the relationship between environmental variables and species composition were chosen by the programme slightly different than for the DCA. In the context of this study land use parameters could be seen as artificial environmental variables. The plots were scattered around the point of origin and along the axes. Arrows were indicating the environmental parameters. The longer an arrow the more important was that variable for changing species composition. The longer an arrow compared to an axis the closer was the relation of this environmental parameter to this axis and the axis variation. Plots lying at the same side of the coordinate system like an arrow had a higher weighting for this environmental variable. However, plots located very close to the origin did not have a relation to the axes or the environmental variables.

The direction of an arrow explained the direction of the variation of a variable and the length the power of the variation of that variable. The longer an arrow was concerning an axis the closer was the relation of the environmental variable and the species composition (Leyer & Wesche, 2007). Cumulative percentage variance of species-environment relation expressed the amount of inertia explained by the axes as a fraction of the total explainable inertia. It described the quality of the relationship of species and environmental variables (Palmer, 2008).

To check whether the correct environmental variables were used for the CCA, the DCA was applied. If the variables were correct the location of the plots of both ordinations are at the similar position within the graph. Additionally the eigenvalues of the axes should be the same (Leyer & Wesche, 2007).

3.3.6 Statistical variables

The data were tested for normality before using any other statistical analysis. After confirming homogeneous variances of the data by carrying out Levene’s Test of Equality of Error Variances the following tests to compare the means of the data were done with multiple regressions (ANCOVA) if not otherwise indicated.

4 Results

4.1 Data range of study area: an overview

In total 184 different plant species were found in the 50 grassland plots. The chosen plots and intensity levels covered a wide range of species poor to rich plots. The same was seen for species diversity. Also biomass production covered a wide range from nearly unproductive to high productive plots as displayed in Table 2.

Table 2: The table shows a short overview on the average and range of the results of the dependent variables, which were measured in the 50 plots of the study area.

Dependent variable	Average	Range
Species richness (n)	32.60	18.00 – 57.00
Species evenness (E)	0.708	0.534 – 0.848
Species diversity (H')	2.44	1.60 – 3.30
Biomass (g/m²)	613.00	30.00 – 1165.00

To receive more precise results the three main land use treatments (grazing, mowing and fertilisation) were investigated focusing on their different intensity levels.

4.2 Meadows, pastures and mowed pastures

Three main land use types occurred in the study area, meadows, pastures and mowed pastures. Out of 50 plots 20 were grazed, 22 plots were mowed and 8 plots were both grazed and mowed. These three land use types differed in abiotic factors. Meadows and mowed pastures occurred mainly on flat to intermediate steep plots. Pastures were usually situated at steep sites where solum thickness reached in average about 23 cm. Solum thickness of mowed pastures was also shallow with 25 cm in average. Meadows occurred on the thickest soils (mean: 30 cm). The habitat of meadows and mowed pastures was relatively moist while pastures were mainly situated on dry underground. Indicator plants showed low nitrogen content for pastures, higher for meadows but highest for mowed pastures.

Meadows in the study area contained a total of 81 different dicotyledons (herbs and tree seedlings); mowed pastures only 40 and pastures reached 129. The same order was found for monocotyledons (grasses). Meadows maintained 21, mowed pastures 12 and pastures 34 different species in total, which means that mowed pastures had the highest proportion of grasses (23.1 %) in the grass-herbs-ratio compared to meadows (20.6 %) and pastures (17.3 %).

Species like *Cerastium holosteoides*, *Taraxacum* spec. and *Trisetum flavescens* were very common and occurred in all investigated meadows. *Dactylis glomerata* ssp. *glomerata*, *Poa trivialis* ssp. *trivialis* and *Ranunculus acris* were found in 95 % of the meadows, *Trifolium repens*, *Veronica arvensis* and *Rumex acetosa* in 86 %, *Plantago lanceolata*, *Veronica chamaedrys, Galium mollugo* agg. and *Lolium perenne* in 82 %, and *Trifolium pratense* ssp. *pratense* and *Vicia sepium* in 77 % of the meadows. In 85 % of the pastures occurred *Plantago lanceolata*, in 80 % *Plantago media* and in 75 % *Taraxacum* spec. In all mowed pastures was *Taraxacum* spec., *Dactylis glomerata* ssp. *glomerata*, *Ranunculus acris*, *Poa trivialis* ssp. *trivialis* and *Rumex acetosa* found. *Cerastium holosteoides*, *Trisetum flavescens*, *Anthriscus sylvestris* ssp. *sylvestris*, *Alopecurus pratensis*, *Alchemilla* spec., and *Heracleum sphondylium* occurred in 88 % and *Veronica chamaedrys*, *Trifolium* *pratense* ssp. *pratense*, *Poa pratensis*, *Galium mollugo* agg. and *Arrhenatherum elatius* in 75 % of the mowed pastures.

Mean ground cover of vascular plants of pastures was rather low with 87.9 %. Mean cover of meadows was high with 93.7 % but the highest cover showed mowed pastures (95.9 %). The land use types also differed in mean vascular plant height. Average height of pastures was 20 cm while plants of meadows and mowed pastures were fairly high (50 cm, 60 cm).

Observations in the field have already shown that mowed pastures (Figure 9) had lower species numbers and diversity than pastures, while biomass was relatively high. Especially traditional grazed juniper heats (Figure 10) were low productive but high in species richness.

Figure 9: Mowed pasture used by cattle before grazing in spring 2008 (AEG 4).

Figure 10: Extensive grazed semi dry grassland before grazing in spring 2008 (AEG 27).

4.3 Grazing and mowing

Grazing and mowing were counterparts of each other and influenced species richness, evenness, diversity and biomass production in different ways. Usually grazed pastures were more diverse, species richer and less productive than mowed meadows or mowed pastures. Meadows were high productive and the most even land use type. Mowed pastures were poor in species richness and diversity and not as productive as meadows (Table 3).

Table 3: Mean and range of species number (n), evenness (E), diversity (H'), and biomass production (g/m²) were investigated on the three mean land use types occurring at the Swabian Alb.

Land use type	Mowed pasture	Meadow	Pasture
Species number (n)			
mean:	24.00	28.91	40.05
range:	21.00 – 30.00	18.00 – 42.00	20.00 – 57.00
Evenness (E)			
mean:	0.655	0.730	0.707
range:	0.534 – 0.764	0.594 – 0.829	0.542 – 0.848
Diversity (H')			
mean:	2.01	2.44	2.60
range:	1.60 – 2.60	2.00 – 2.90	1.70 - 3.30
Biomass (g/m²)			
mean:	713.13	776.36	392.50
range:	400.00 – 980.00	440.00 – 1165.00	30.00 – 1135.00

Grazing and mowing showed to be very important factors influencing species richness, and biomass but not diversity and evenness. However, species richness, evenness and diversity were negatively influenced when one plot got both mowed and grazed whereas this double utilisation had no significant influence on biomass production.

Mowed pastures had a significantly lower species richness (F=19.777, p<0.001), evenness (F=5.138, p=0.029), and diversity (F=16.879, p<0.001) compared to pastures and meadows (Figure 11, p. 50). For biomass production mowed pastures were not significantly different to the other land use types (F=2.527, p=0.120).

However, pastures and meadows themselves showed an important difference in influencing species richness (*F*=36.680, *p*<0.001) and biomass production (*F*=40.619, *p*<0.001). Species richness was higher at grazed plots and biomass production yielded higher at mowed plots. There was no significant difference between pastures and meadows for species evenness (*F*=1.018, *p*=0.319) and diversity (*F*=3.452, *p*=0.071).

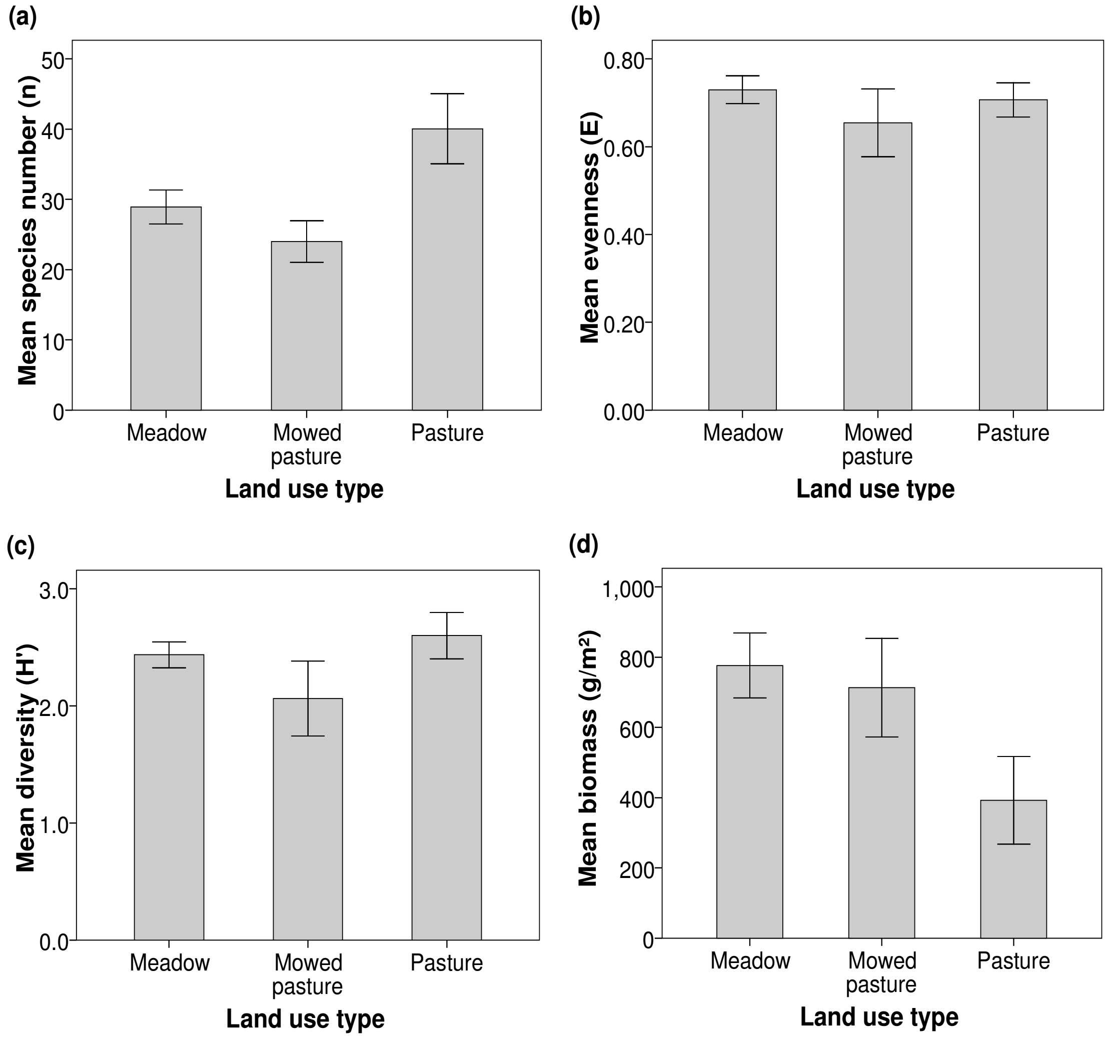


Figure 11: The three land use types of the 50 examination plots at the Swabian Alb differed in (a) species number, (b) evenness, (c) diversity, and (d) biomass. Given are mean values and 95 % confidence interval.

Species composition also differed. Mowed pastures mainly consisted of grasses like *Dactylis glomerata, Poa trivialis* and *Alopecurus pratensis* and herbs like *Alchemilla* spec. and *Rumex acetosa*. High productive meadows consisted of large perennial grasses such as *Poa trivialis* and *Trisetum flavescens*, while *Taraxacum* spec., *Trifolium repens* were the most common herbs. Low productive meadows contained often *Festuca* spp., *Phleum pratense*, *Trisetum flavescens*, and less *Poa trivialis* than intensive meadows. On only grazed pastures *Festuca* spec., *Helictotrichon pubescens* ssp. *pubescens* and hardly *Poa trivialis* were found. Juniper heats (semi-dry grasslands) maintained many herbaceous plants and relatively less grasses. Species like *Agrimonia eupatoria* ssp. *eupatoria, Asperula cynanchica, Carex* spp., *Carlina* spp., *Euphorbia cyparissias* and further rare species grew there.

4.4 Fertilisation

Fertilisation was essential for vegetation. In total 28 plots were fertilised and 22 plots were not fertilised artificially. Six plots were even fertilised twice a year. Farmers used nitrogen, phosphate, liquid and litter manure as fertiliser. Fertilisation mainly influenced species richness, diversity and biomass but not evenness (Table 4).

Table 4: The table shows mean species richness (n), evenness (E), diversity (H'), and biomass (g/m²) of the fertilised and unfertilised plots at the 50 plots at the Swabian Alb.

Dependent variable	Unfertilised grassland	Fertilised grassland
Mean species richness (n)	39.15	26.79
Means species evenness (E)	0.715	0.703
Mean species diversity (H')	2.64	2.30
Mean biomass (g/m²)	414.32	768.57

Multiple regressions demonstrated that fertilisation decreased the number of species (F=12.022, p=0.001), and diversity (F=6.197, p=0.017) (Figure 12). Evenness of fertilised and unfertilised grasslands was fairly similar (F=0.238, p=0.628). Fertilisation had a significantly positive effect on biomass production (F=4.919, p=0.032).

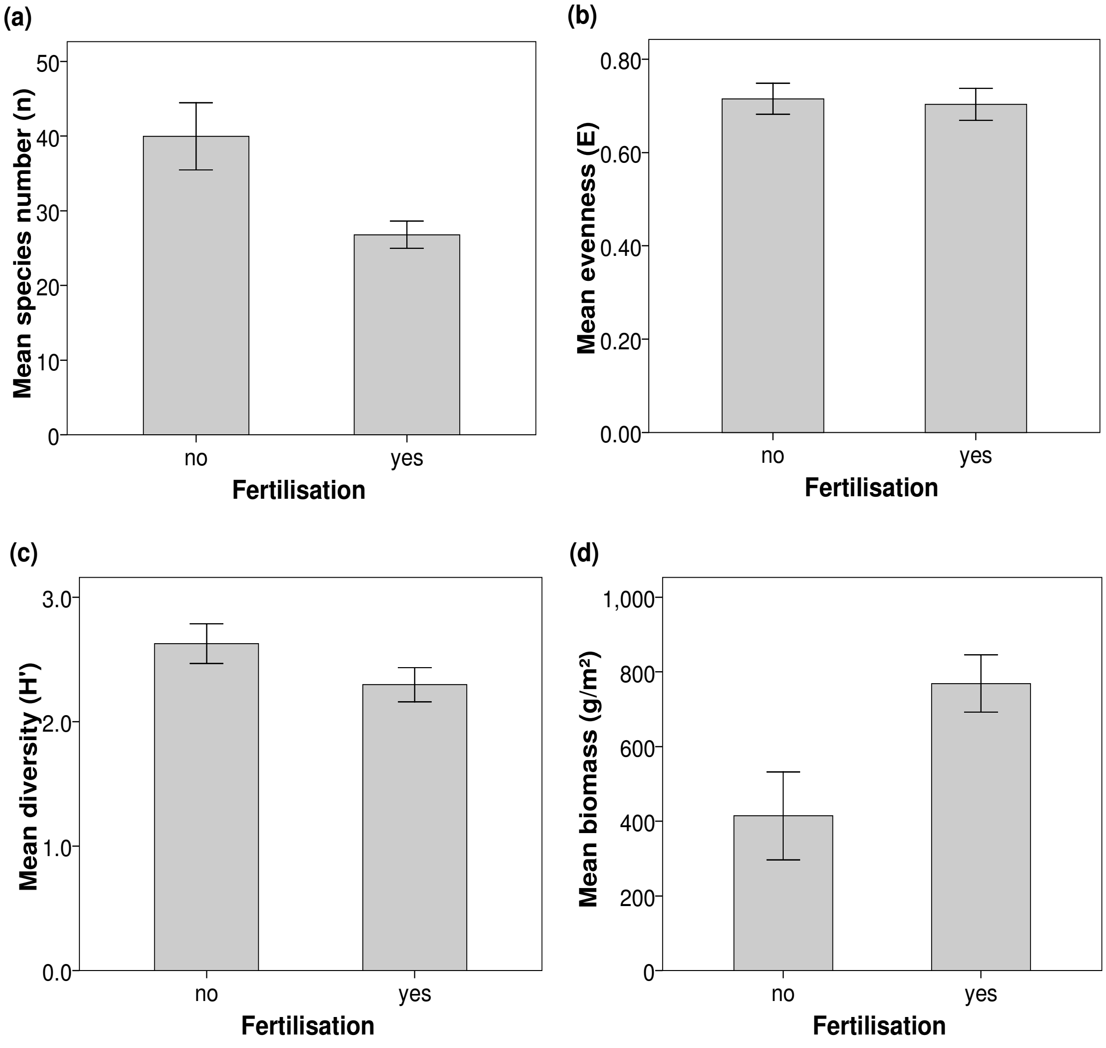


Figure 12: The charts show the effect of fertilisation on (a) species number, (b) evenness, (c) diversity, and (d) biomass in 50 grassland plots at the Swabian Alb. Given are mean values and 95 % confidence interval.

4.5 Fertilisation intensity

4.5.1 Amount of fertilisation

The amount of applied fertiliser at the 50 plots of the study area ranged between 10 kg and 130 kg N/ha/year. The most applied amount was around 50 N kg/ha/year and only four plots received more than 80 N kg/ha/year.

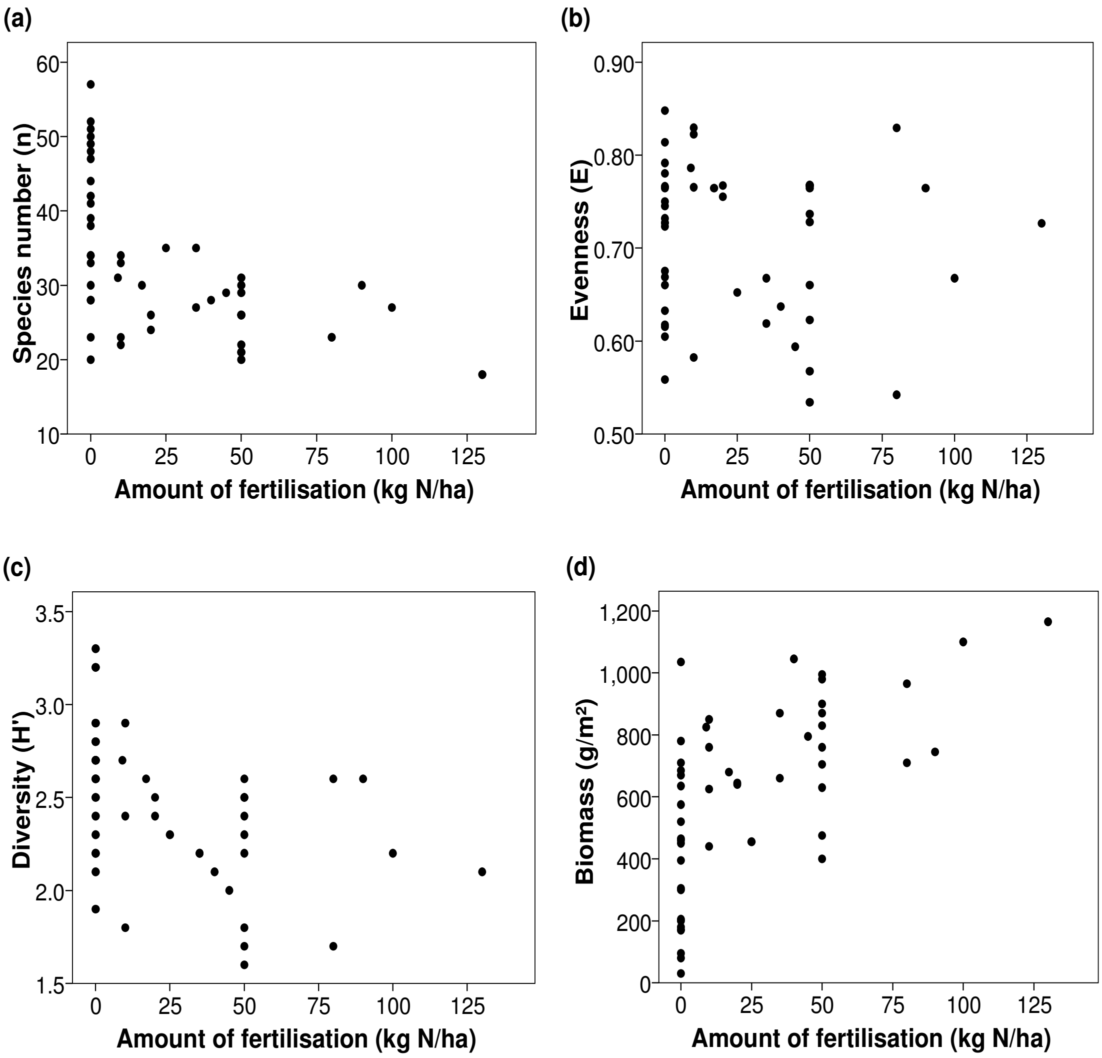


Figure 13: The charts display the effect of the yearly amount of fertilisation (kg N/ha) on (a) species number, (b) evenness, (c) diversity, and (d) biomass in 50 grassland plots at the Swabian Alb.

Increasing amount of fertilisation decreased species richness (F=4.995, p=0.031) and diversity (F=5.602, p=0.023) but not evenness (F=1.852, p=0.181) (Figure 13, p. 53). With decreasing fertilisation biomass production also decreased (F=8.416, p=0.006).

The difference in biomass production and species richness of highly fertilised plots (Figure 14) and unfertilised plots (Figure 15) was already visible in the field. Fertilised grasslands were high productive but low in species richness.

Figure 14: AEG 2 was fertilised twice a year with a total of 130 kg N/ha. The intensive meadow was mowed three times a year. It maintained 18 species and yielded 1165 biomass g/m² (see also Figure 32, p. 86).

Figure 15: This near natural meadow near Münsingen was not fertilised. AEG 22 was mowed once and late in the year. It reached 42 different plant species and 465 biomass g/m².

4.5.2 Frequency of fertilisation

Multiple regressions showed that after analysing the amount of fertilisation frequency (once or twice fertilised) was not important any more (see appendix VII: Multiple regressions). Nevertheless, biomass was higher at two of the fertilised plots compared to grasslands that were fertilised once per year (Table 5, p. 55). However, these differences amongst the plots were probably caused mainly through the amount of fertilisation as already illustrated.

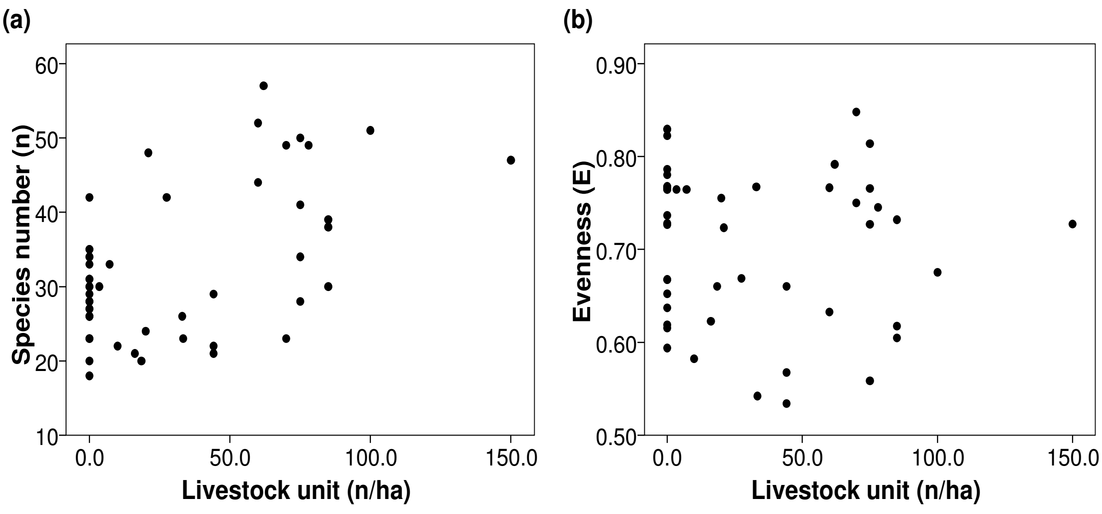
Table 5: The table shows mean species richness (n), evenness (E), diversity (H'), and biomass (g/m²) of once or twice per year fertilised grasslands of the study area at the Swabian Alb.

Dependent variable	1 × fertilised (per year)	2 × fertilised (per year)
Mean species richness (n)	27.24	25.83
Means species evenness (E)	0.703	0.703
Mean species diversity (H')	2.30	2.27
Mean biomass (g/m²)	711.67	969.69

4.6 Grazing type and intensity

4.6.1 Livestock unit

One considerable parameter of grazing was the density of animals or livestock unit. Livestock unit in the study area ranged from 0 to 150 animals per ha. However, different livestock units were not meaningful for species richness (F=3.450, p=0.071), evenness (F=0.145, p=0.706), diversity (F=0.255, p=0.616), and biomass production (F=3.535, p=0.067) (Figure 16).



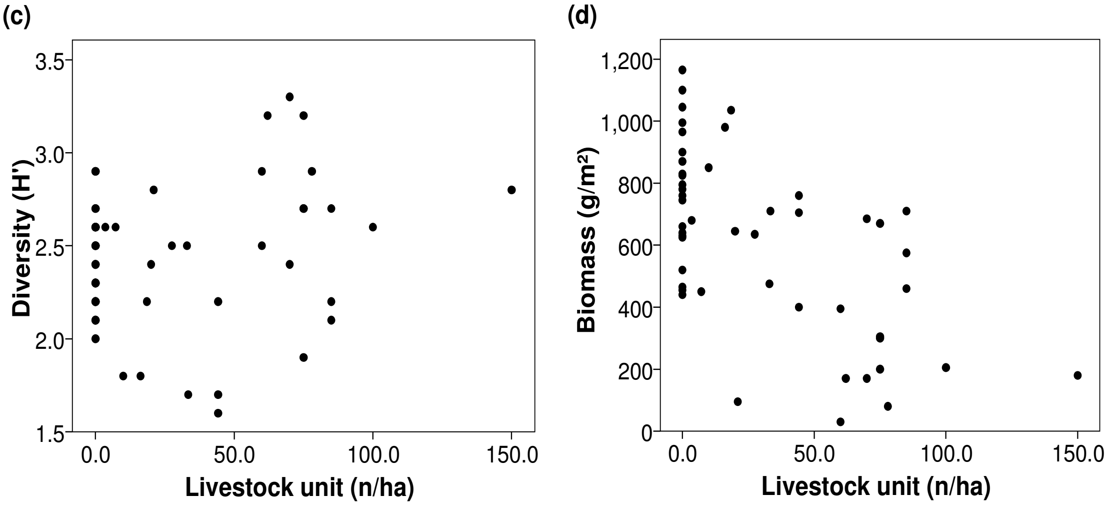


Figure 16: The charts display the effect of livestock unit (n/ha) on (a) species number, (b) evenness, (c) diversity, and (d) biomass in the 50 grassland plots at the Swabian Alb.

An approximate tendency was visible that pastures with a higher livestock unit (especially sheep pastures) had higher species richness, and diversity than plots with a low density. However, is density exceeding approximately 80 livestock units per ha then species richness, evenness and diversity seemed to decline again. Biomass production was increasing with decreasing animal density.

4.6.2 Type of animal

Out of 50 examination plots 22 were ungrazed, 19 were grazed by sheep, 5 by cattle

Figure 17: Cattle pastures were fairly productive (AEG 21). Only cattle-horse pastures were more productive.

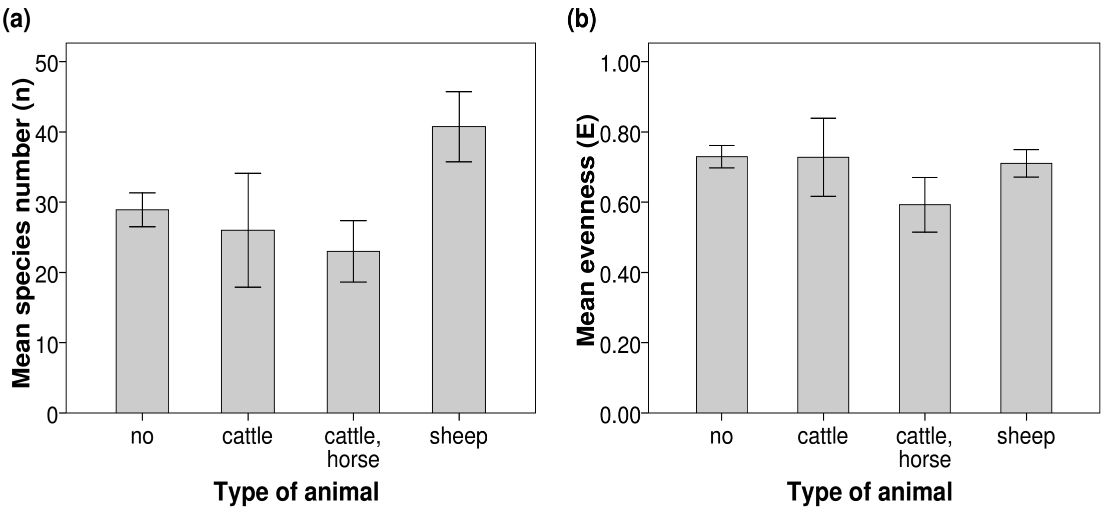
Figure 18: Sheep grazed pastures were less productive (AEG 8).

and horse and 4 by only cattle. Cattle (Figure 17, p.56) and cattle-horse plots had fairly similar dependent variables whereas sheep pastures (Figure 18, p. 56) differed (Table 6).

Table 6: The table shows mean species richness (n), evenness (E), diversity (H'), and biomass (g/m²) of cattle, cattle-hose and sheep grazed plots at the Swabian Alb.

Dependent variable	Cattle	Cattle-horse	Sheep
Mean species richness (n)	26.00	23.00	40.74
Means species evenness (E)	0.727	0.593	0.710
Mean species diversity (H')	2.33	1.88	2.63
Mean biomass (g/m²)	637.50	722.00	389.21

Type of animal was statistically important for evenness (*F*=6.796, *p*=0.013) (Figure 19 (b)). Cattle grazed and ungrazed plots (E=0.730) had the highest mean evenness. Cattle-horse pastures showed especially low evenness. Species richness (*F*=0.297, *p*=0.589) and biomass production (*F*=0.239, *p*=0.591) were not important but species diversity was nearly significant (*F*=4.018, *p*=0.052). Again sheep grazed and ungrazed plots were more diverse than plots grazed by cattle and horse.



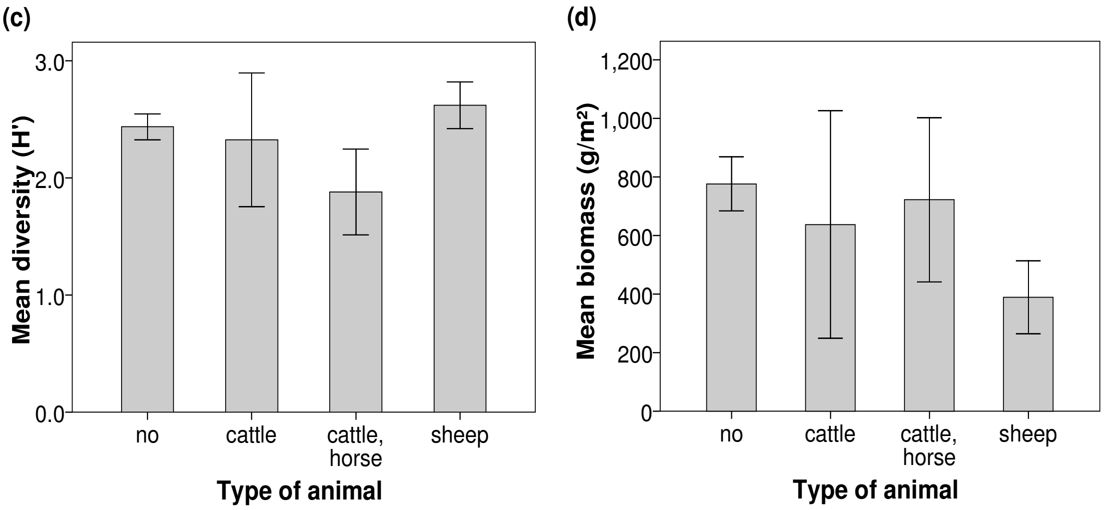


Figure 19: The effect of grazing animal species on (a) species number, (b) evenness, (c) diversity, and (d) biomass was less important at the Swabian Alb. Given are mean values and 95 % confidence interval.

4.6.3 Duration of grazing

The duration of grazing (0-240 days) was a very important parameter. It was still influencing all four dependent variables although it was the second last parameter that was entered into the multiple regressions analysis (see appendix VII: Multiple regressions). The duration of grazing was negatively related with species richness (F=19.894, p<0.001), evenness (F=5.111, p=0.029) and diversity (F=13.140, p=0.001) (Figure 20, p. 59). Two groups of grazing systems can be seen on the graphs. Grasslands with short grazing periods were used through traditional transhumance shepherding and long grazing periods took place at ration or permanent pastures. Biomass production increased with increasing grazing period (F=6.473, p=0.015). However, when grazing exceeded approximately 105 days biomass production was declining again. The unfertilised pasture grasslands of the military training area can be seen as a natural capable production. They produced 442 g/m² in average.

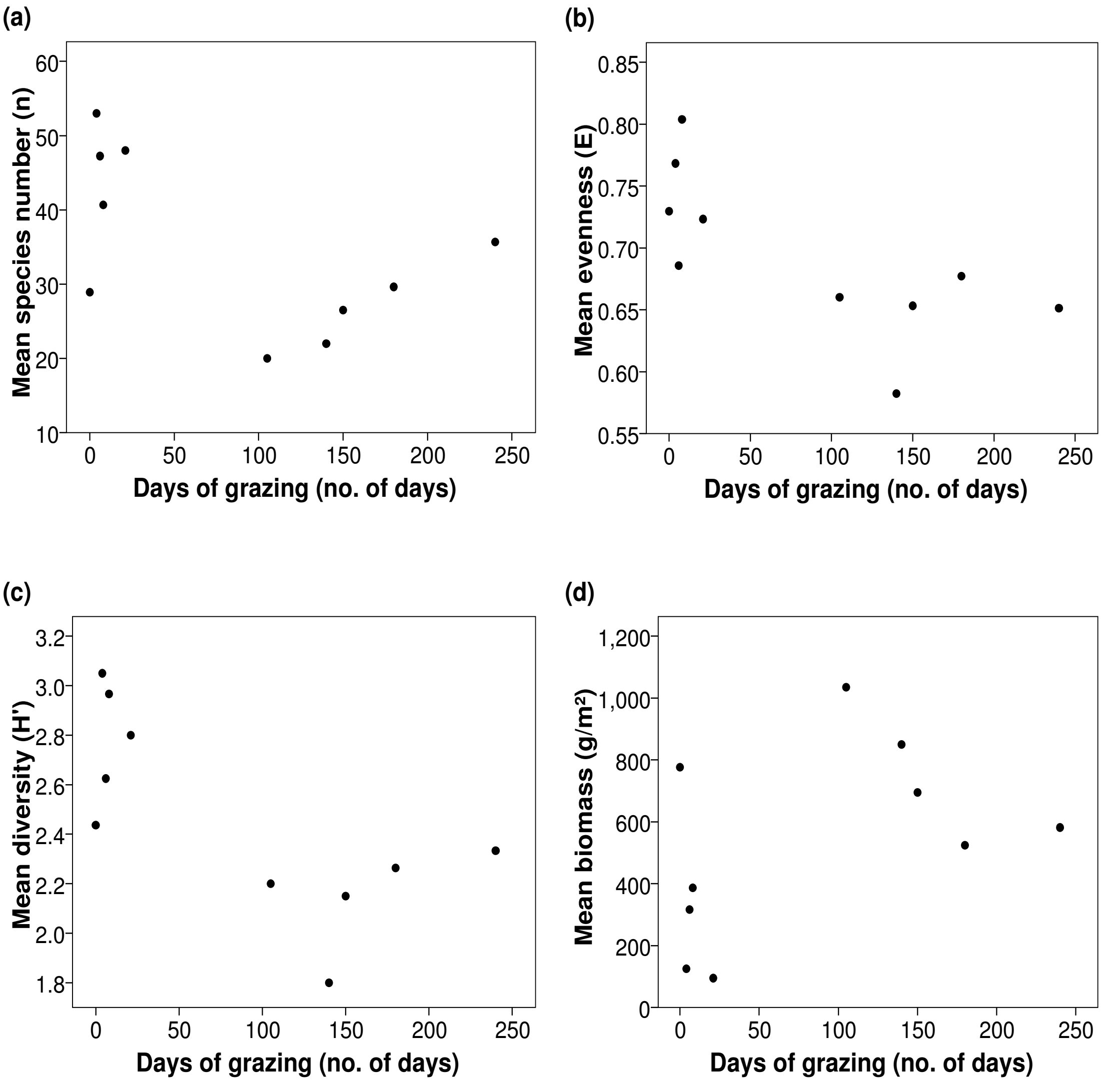


Figure 20: The graphs display the effect of grazing duration on (a) species number, (b) evenness, (c) diversity, and (d) biomass in the 50 grassland plots at the Swabian Alb. Given are mean values.

In order to analyse possible interaction within the dependent variables Two Way ANOVA was used, which showed significance in one combination only. The number of grazing days and vegetation cover of vascular plants showed interaction (F=3.622, p=0.011). The longer grasslands were grazed the thinner vascular plant vegetation cover was whereas semi dry grasslands were the most sensitive plots.

4.7 Mowing intensity

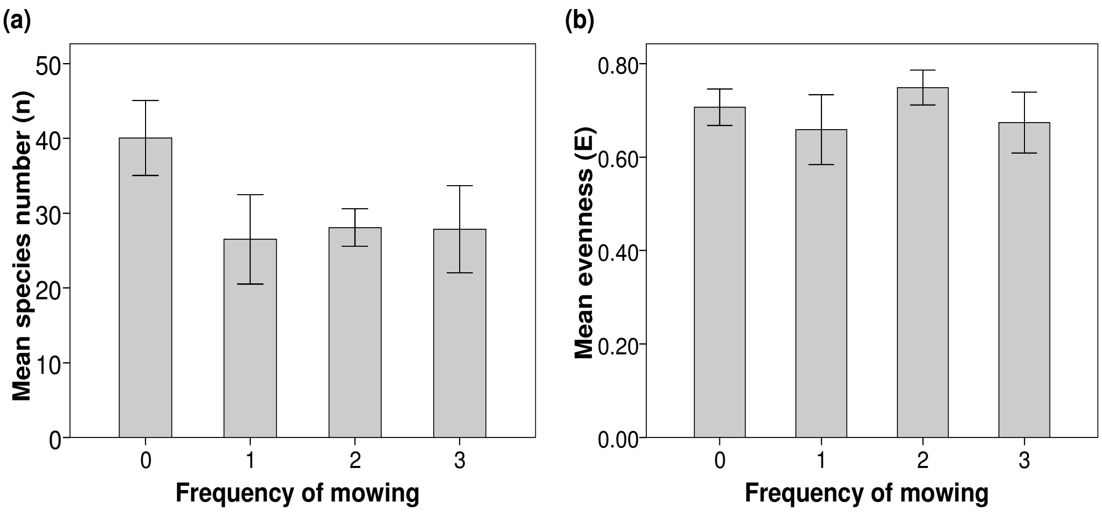
4.7.1 Frequency of mowing

Frequency of mowing was a closer description of mowing and its intensity. A tendency was visible showing increasing mowing frequency decreased species richness, but not evenness and diversity (Table 7). Biomass production increased with increasing frequency.

Table 7: The table displays mean species richness (n), evenness (E), diversity (H'), and biomass (g/m²) of once, twice and three times mowed grasslands at the Swabian Alb. Mowing frequency influenced the dependent variables only slightly although the values differed.

Dependent variable	1 × mowed	2 × mowed	3 × mowed
Mean species richness (n)	42.00	28.40	27.83
Means species evenness (E)	0.659	0.749	0.674
Mean species diversity (H')	2.30	2.49	2.22
Mean biomass (g/m²)	465.00	760.00	884.17

However, frequency of mowing was statistically insignificant for species richness (*F*=0.229, *p*=0.635), evenness (*F*=1.682, *p*=0.202), diversity (*F*=1.463, *p*=0.234), and biomass production (*F*=0.198, *p*=0.658) (Figure 21).



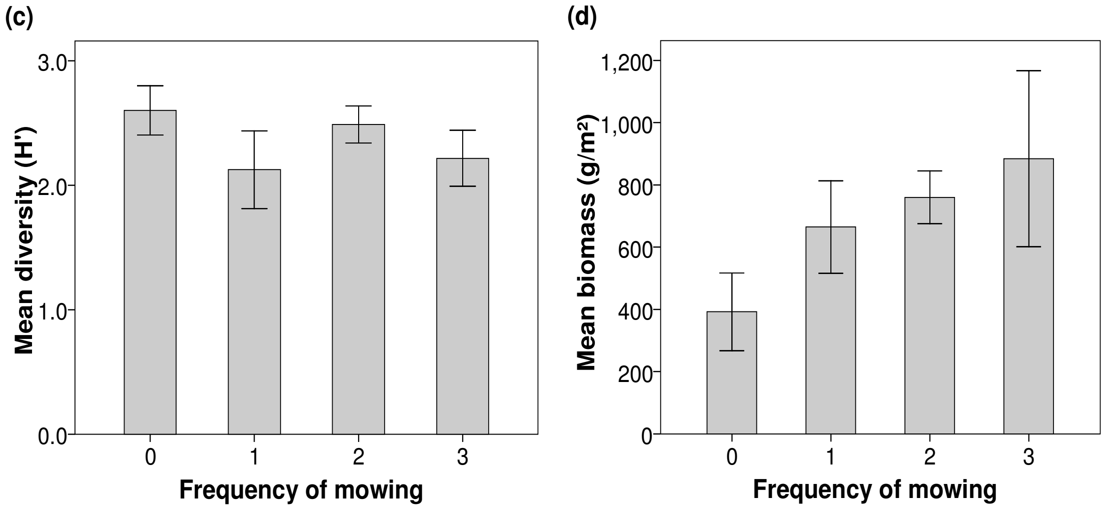


Figure 21: The graphs show the effect of mowing frequency on (a) species number, (b) evenness, (c) diversity, and (d) biomass in the 50 plots at the Swabian Alb. Given are mean values and 95 % confidence interval.

Observable was that the more frequent a meadow was mowed and the earlier in vegetation period the first cut happened (first mowing: around beginning of May) the lower was species richness and diversity. The extensively used once a year mowed meadow was not cut before the 15th of June after many plants had already flowered (Figure 15, p.54).

Interaction for biomass production was also found between the frequency of mowing and mean height of vascular plants (F=2.903, p=0.039). Vascular plant height pastures was in average 0.22 m high, 3 times mowed 0.37 m, 2 times mowed meadows 0.43 m and once a year mowed plots 0.54 m high.

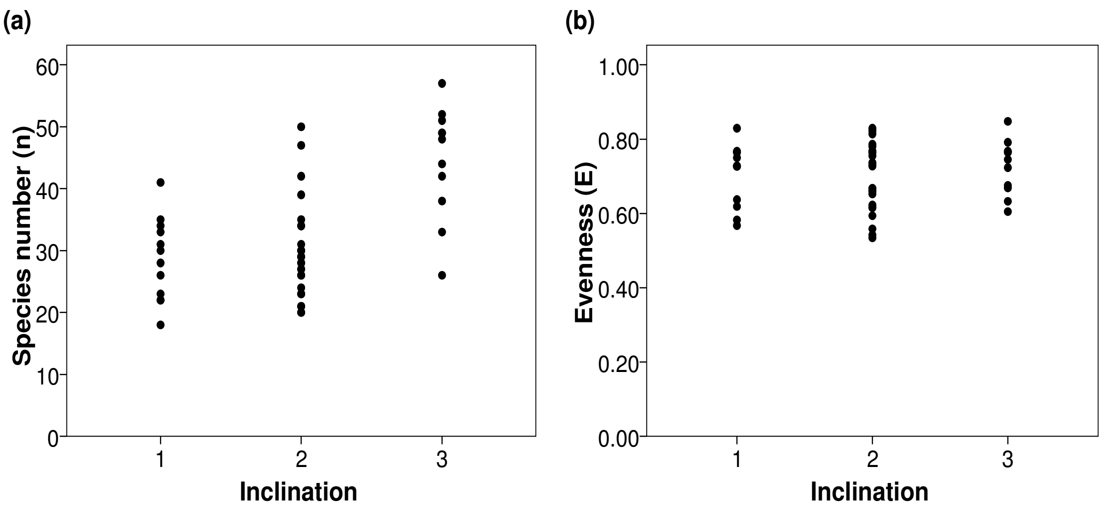
4.8 Environmental factors

Grasslands with brown earth as subsoil counted 16 and rendzina 34 plots and their solum thickness ranged from 0.11 m to 0.63 m. The plots were relatively evenly distributed concerning exposition whereas south exposed plots were the most (10). The study area contained 12 nearly flat plots, 11 were fairly steep and 27 plots were in between.

For One Way ANOVA neither soil type, nor exposition or solum thickness influenced species richness. Only inclination was significant (F=16.227, p<0.001) (Figure 22). None of the environmental parameters were significant for evenness.

The examined environmental variables were not essential for species diversity, however, inclination was significant (F=4.323, p=0.019). Flat plots reached a diversity of 2.35 H' followed by 2.37 H' for moderate steep plots. Steep plots, mainly in extensive agricultural use, had the highest diversity with even 2.73 H'.

The abiotic factors had no influence on biomass but again inclination was significant (F=12.634, p<0.001). Average biomass production of flat plots was 746.67 g/m² and moderate steep plots produced 681.30 g/m². Steep plots reached only 298.18 g/m² in.



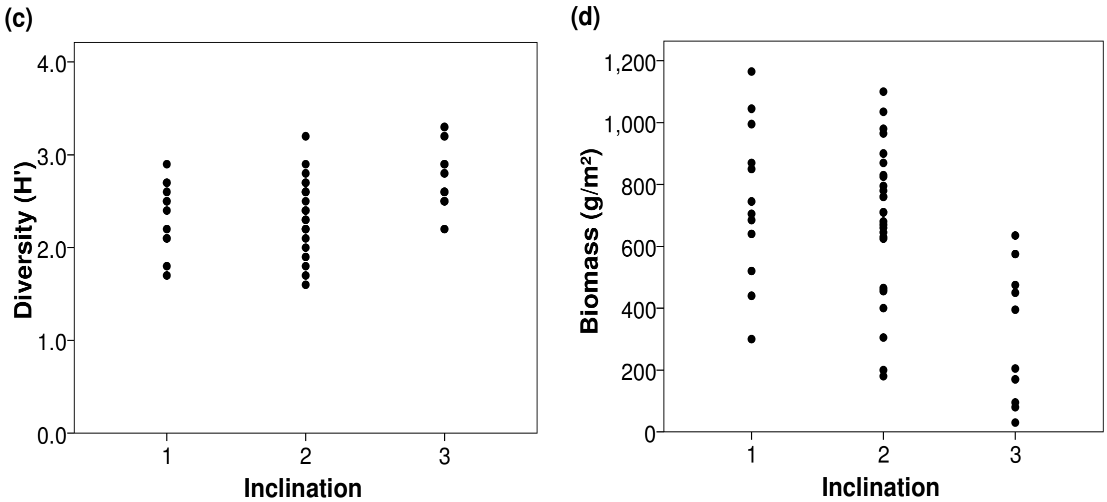


Figure 22: The graphs show the effect of inclination (1: nearly flat, 2: moderate steep, 3: steep) on (a) species number, (b) evenness, (c) diversity, and (d) biomass on the 50 plots at the Swabian Alb.

Two Way ANOVA showed that there was an interaction between soil type and exposition (F=2.486, p=0.41) in regards to biomass. Southern exposed plots had a higher biomass production than northern exposed plots. In the same way brown earths had a higher biomass production than rendzinas.

To analyse the interaction for species number in regards to soil type and fertilisation, which showed significance (Two Way ANOVA) but unequal variance, a nonparametric test had to be used (Schreier-Ray-Hare) since the variances were not the same. Nevertheless, after changing the test the result was not significant (p=0.419).

4.9 Species composition

The 50 plots contained different plant species compositions. Similar land use types caused similar plant species compositions. DCA was run to group similar plots together along synthetically axes indicating environmental variables. If their distance to each other was short the plots were similar. If they were far from each other the plots were dissimilar (Figure 23).

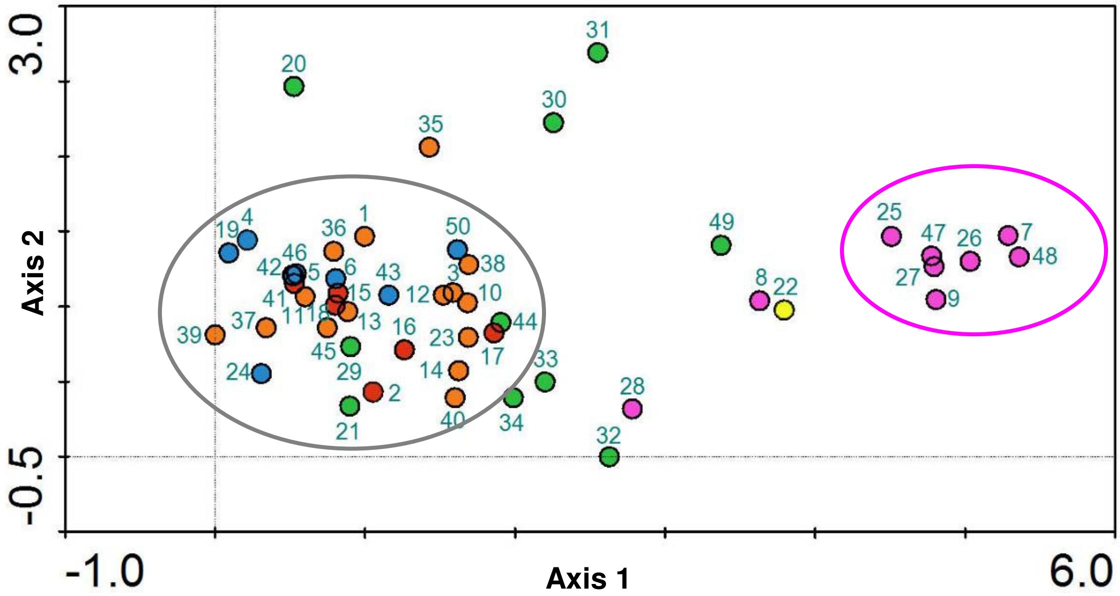


Figure 23: The DCA grouped plots of the Swabian Alb according to their similar plant species composition. Semi-dry grasslands (purple) were fairly different to all other plots. Mowed pastures (blue) twice (orange) and three times mowed meadows (red) were clustered together indicated by the grey ellipse. Pasture grasslands (green) were scattered in the middle of the chart. The once a year mowed meadow (yellow) was close to the semi-dry grasslands.

Clearly visible was the grouping of semi-dry grasslands (juniper heats). Just AEG 8 and 28 were divided from that group. Semi-dry grasslands were dominated by herbaceous plants. Graminoides covered only a small proportion of the ground cover. They contained more *Carex* species than other plots. Thorny plants like *Carlina vulgaris* and *Cirsium* spp. also occurred on the grazed semi-dry grasslands. A main decisive parameter was unfertilised and therefore rather nitrogen poor soils. Additionally, species richness was distinctively higher than on the other plots.

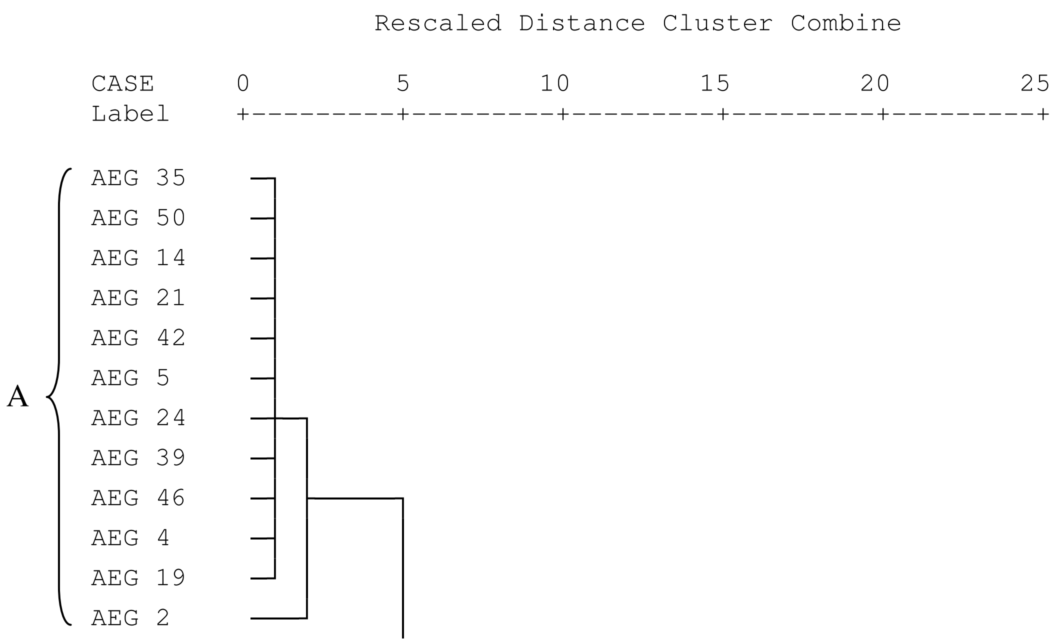
Mowed pastures, twice a year and three times a year mowed meadows were mainly assembled together near to the origins of the axis meaning the synthetically environmental gradients had only low influence on these plots. The plots had a higher amount of grasses and ruderals. Herbs were less dominant. Many of the plants (e.g. *Alopecurus pratensis*, *Heracleum sphondylium*, *Taraxacum* spec.) were indicators for nitrogen. The once a year mowed meadow (AEG 22) was located between meadows and mesoxeropytic pastures but closer to the latter. Species composition was similar to semi-dry grasslands but with more *Bromus erectus* and *Helictotrichon pubescens* ssp. *pubescens* were dominant. The species of these plots were also mostly decisive of nitrogen poor soils according to Ellenberg's indicator values.

The most scattered plots were the pastures although they were closer to the meadows and mowed pastures. More intensive used pastures were closer to intensive used grassland (AEG 21, 29, and 44). These pastures already had a high proportion of grasses (e.g. *Lolium perenne* and *Poa trivialis* ssp. *trivialis*) similar to frequently mowed meadows. Some pastures were similar to semi-dry grasslands (i.e. AEG 49). The part in herbaceous plants and *Carex* spp. was lower. *Briza media* and *Bromus* spp. were also less common then at semi-dry grasslands. They also contained grazing indicators like *Cirsium* spp. but no nitrogen indicators like *Alopecurus pratensis*.

The hierarchical cluster analysis using for species number displayed similar results (Figure 24, p. 67). The cluster sorted the 50 plots in two main groups. The first main group (A&B) was similar in species number since the distances between the vertical lines or linkages were close to the left side. Group A&B contained mostly two to three times mowed meadows and mowed pastures. Group A contained mainly (mowed) pastures and twice mowed meadows. Many different plots were found in group B. It included (mowed) pastures, twice mowed meadows and nearly all three times mowed meadows.

The second main group (C&D) was less similar in itself than group A&B since the linkage was further away from the origin (at around 7 compared to 5). That means that the variety in species number was bigger than in group A&B. Group C&D mainly contained semi-dry grasslands (AEG 8, 48, 7, 26, 47, 27, 28, 9, 25), some sheep grazed grasslands (AEG 30, 31, 49, 33) and the once a year mowed meadow (AEG 22). This group could be divided in mostly sheep grazed pastures (C) and semi-dry grasslands (D).

The cluster indicates that group A&B and group C&D are very dissimilar since their linkage was far away from the other linkages.



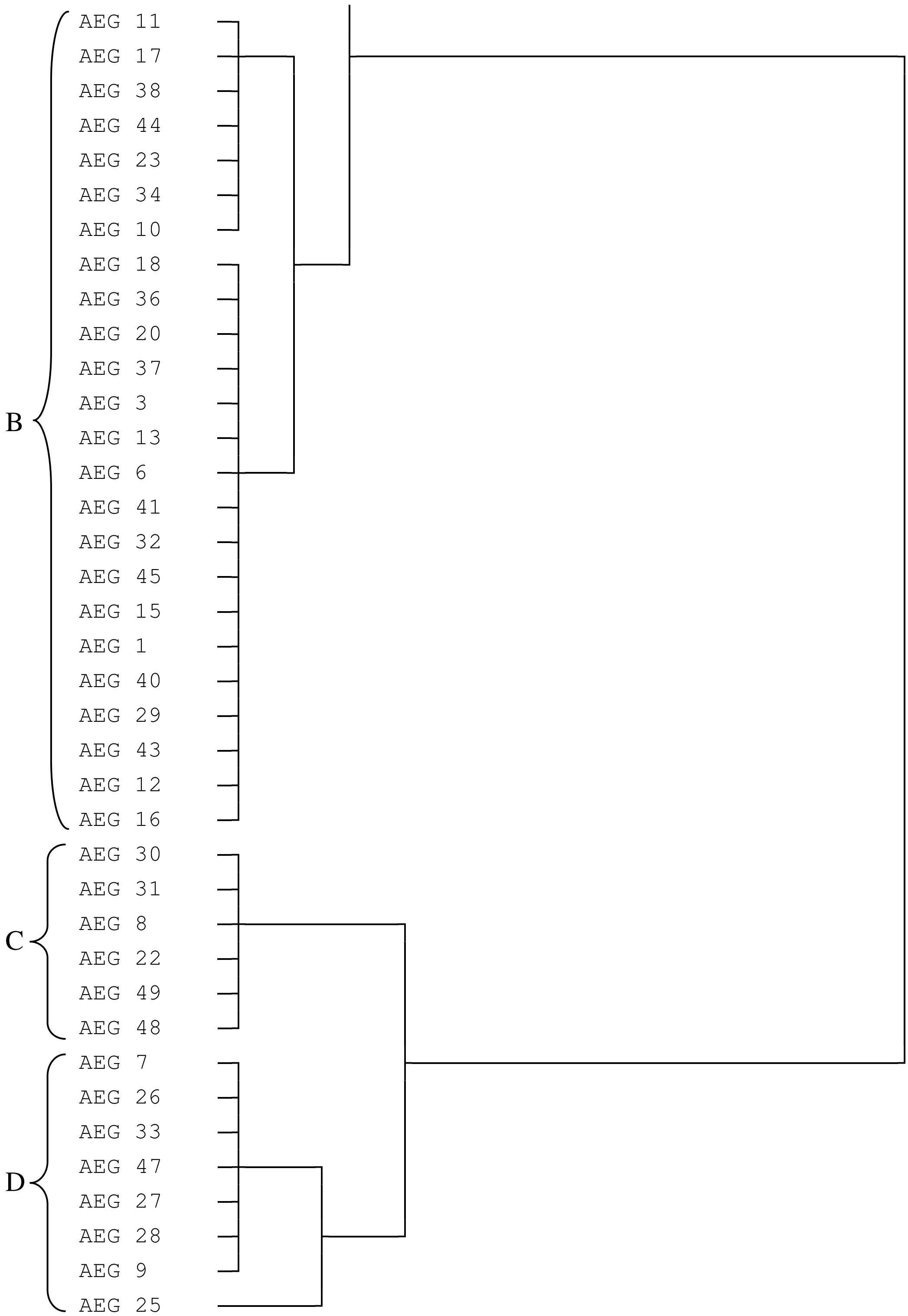


Figure 24: The hierarchical cluster analysis showed the influence of location parameter on the 50 plots at the Swabian Alb on species number. The dendrogram was using average linkage (between groups). Two main groups could be detected. The second group contained nearly all pastures grazed by sheep and the once a year mowed meadow. The first group contained all other meadows, mowed pastures and pastures grazed by cattle and horses.

4.9.1 Determinants of species composition

The CCA could explain which variables, or at least, which factors related to these variables, were controlling the plant species composition. In order to see whether land use or environmental variables were most important both were included.

The arrows of correlation variables were closer together as seen at the amount of fertilisation, frequency of fertilisation and frequency of mowing. Also soil type and exposition seemed to be fairly similar.

The arrows of the parameters could be seen as two main groups. Arrows pointing to the lower left corner illustrated mainly the frequency of mowing, frequency and amount of fertilisation. All three arrows were fairly long concerning the first axis but also the second, which showed that fertilisation and mowing, were closely related to these axes and its association to the variation in species composition. Fertilisation, for instant, influenced the first axis (soil properties) through changing soil fertility and the second axis through land use treatments. In the opposite corner pointed parameters concerning animals like livestock unit and type of animals. These parameters were less important for species composition since they were a bit shorter than fertilisation and mowing in comparison to the first axis. The parameter duration of grazing was relatively unrelated to the other parameters as the arrow was in a right angle towards them. However, it was the most important explanatory variable for the second axis followed by livestock unit and on the negative side frequency of mowing.

Abiotic factors were scattered a little bit more. Inclination was fairly strong and similar to the type of grazing animal. It was the most important variable for the first axis. Solum thickness was pointing in the opposite direction and was only a weak parameter; though, closely related to the second axis. Exposition and soil type were also relatively unimportant for vegetation composition but closer related to the second axis than solum thickness (Figure 25, p. 71).

Many plots, in particular meadows, were located close to the origin. These plots were influenced little by the parameters. However, all plots were influenced by several displayed factors. Plots located at one side of the axes where an arrow was indicating towards, were all influenced by this factor. At the lower left side mostly meadows and some mowed pastures were found. They were affected by mowing and fertilisation. Especially AEG 11 and AEG 38 were heavily manipulated by fertilisation although the amount was not very high. AEG 1 and AEG 37 were directed by mowing frequency. AEG 16 was also affected by mowing but also by further factors exhibited by the second axis. Duration of grazing, which was hardly correlated to the other variables, was important for AEG 29 and other pastures situated further apart from the duration arrow but at the same side of the coordinate system. AEG 4 and 5 were influenced through grazing duration but also from fertilisation. These plots were used as a fertilised and mowed cattle-horse pasture. In the upper left corner further pastures and mowed pastures were located. Only few meadows (twice mowed) were additionally found there. They were all affected by fertility and mowing or grazing. AEG 50 was a mowed sheep pasture situated between semi-dry and the other grasslands. Pasture grasslands were located in the upper middle of Figure 25 (p. 67). They were located at the other side of axis one than the juniper heats. Juniper heats were the scattered plots on the right hand site (AEG 26, 7, 9, 46, 47, 25). They were dominated by inclination, type of animal and livestock unit. Also soil type and exposition had some influence since juniper heats were steep and mainly on rendzinas.

Table 8: The statistical output of the CCA showed the mean, standard deviation and variance inflation factor (VIF) of the environmental and land use variables of the 50 plots at the Swabian Alb.

Name	(weighted) mean	stand. dev.	var. inflation factor
Environmental variables:			
Soil type			1.4583
Solum thickness	24.8841	13.4759	1.3944
Exposition			1.2011
Inclination			1.7732
Land use variables:			
Type of animal			5.5038
Livestock unit	28.6054	36.4981	3.8697
Days of grazing	67.8165	88.1948	2.0129
Frequency of mowing			8.2287
Frequency of fertilisation			7.4997
Amount of fertilisation	26.7979	30.1936	4.2414

Variables with a very low variation inflation factor (*VIF*) had very less correlation with other factors. Table 8 shows the variables soil type (*VIF*: 1.4583), and exposition (*VIF*: 1.2011) as such factors. Frequency of mowing (*VIF*: 8.2287) and frequency of fertilisation (*VIF*: 7.4997) correlated highly with each other and other factors, which is visible in Figure 25 (p. 71).

Table 9: The table displays a summary of axes and eigenvalues. The figures show how well the axes were able to explain total variation of the 50 plots at the Swabian Alb.

Axes	1	2	3	4	Total inertia
Eigenvalues:	0.650	0.189	0.146	0.118	5.428
Species-environment correlations:	0.899	0.714	0.749	0.767	
Cumulative percentage variance					
of species data:	12.0	15.4	18.1	20.3	
of species-environment relation:	43.4	56.0	65.8	73.7	
Sum of all eigenvalues					5.428
Sum of all canonical eigenvalues					1.496

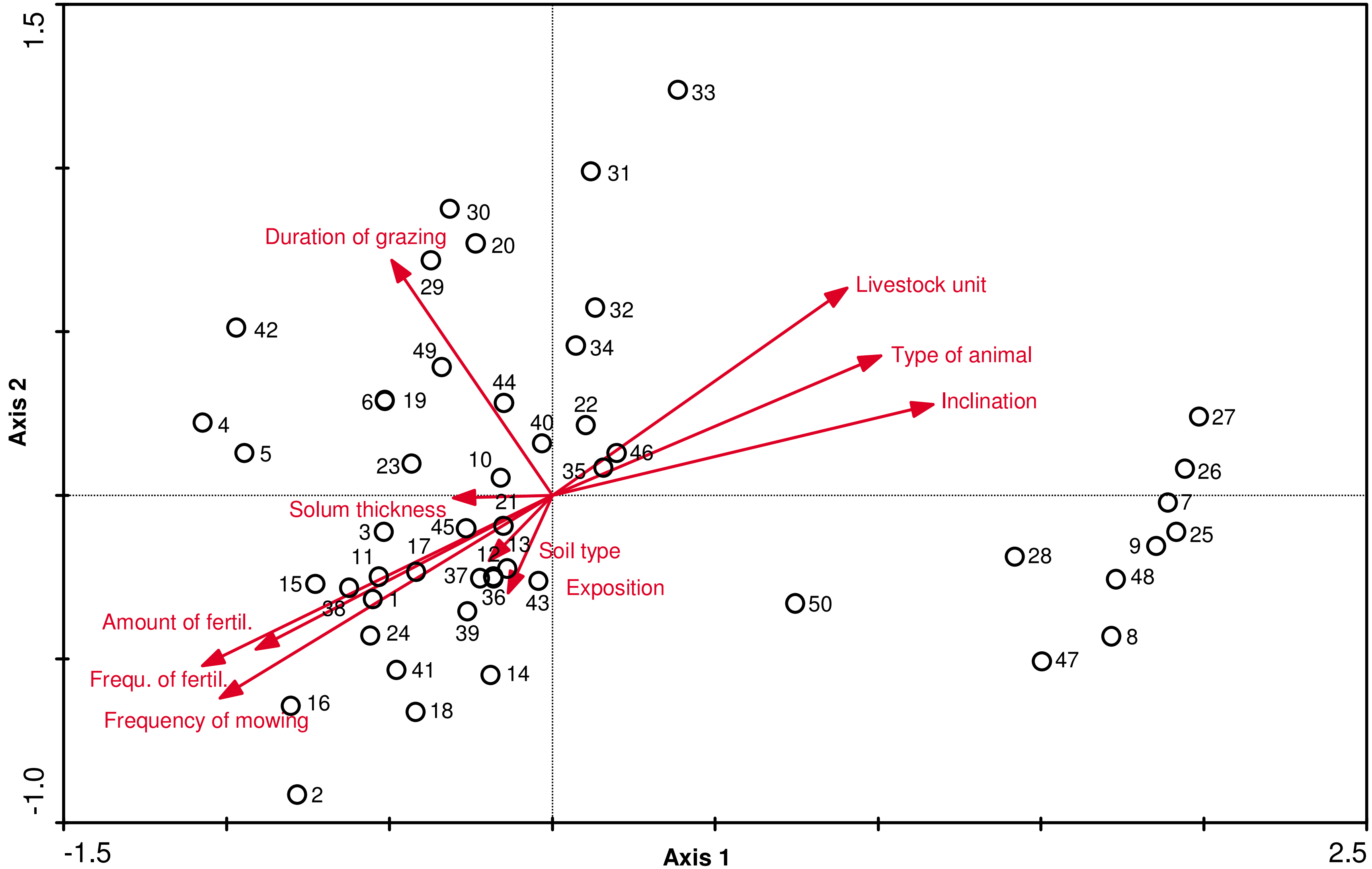


Figure 25: The CCA, a direct gradient analysis, shows parameters and their influence on plant species composition along a land use gradient at the Swabian Alb. Important factors for twice (AEG 1, 11, 37, 38) and three times mowed meadows (AEG 15, 16, 17, 41) were the amount and frequency of fertilisation and frequency of mowing since many plots were accumulated next to these factors. Livestock unit, type of animal and inclination were important for semi-dry grasslands (AEG 7, 8, 9, 25, 26, 27, 47, 48). Duration of grazing was influencing the plant species composition of mainly cattle and horse pastures (AEG 6, 19, 20, 44) and sheep pastures (AEG 31, 32, 33, 34). Exposition and soil were important parameters for twice (AEG 12, 13, 14, 36, 37, 39) and three times mowed meadows (AEG 2, 16, 18) and some pastures (AEG 24, 43). The once a year mowed meadow (AEG 22) was found at the grazing side.

The axes combined once again the relationship between environmental factors and species composition. Table 9 (p. 70) shows the eigenvalues of the four axes. The bigger the eigenvalue the closer the relationship of this axis to the variation in species composition was. The first eigenvalue was relatively high (0.650), meaning that the first axis represents a relatively strong gradient. The relationship of this axis to the variation in species composition was fairly close, which meant that species composition was well explained through this axis. The second axis was much weaker, and the third even weaker. Cumulative percentage variance of species data implied that the first axe explained 12.0 % of total variation. The second axe was weaker so the first and second axe explained together only 15.4 %.
For describing the quality of the relationship of species and environmental variables cumulative percentage variance was given. The first two axes taken together displayed more than half of the variation (56.0 %), which could be explained through the variables. This meant that more than half of the variation of species composition of the study area could be described from two variables (or variables combinations).

In general the CCA confirmed the selection of the parameters, which were analysed within this study. Especially the land use parameters were mainly affecting plant species composition of grasslands in the cultural characterised ecosystem.

4.10 Relationship of species richness, diversity and biomass production

The relationship of biomass production and species number was investigated through applying Univariate Analysis of Variance. The result of the test, using species number as depended variable and biomass production as covariate, was significant (F=65.624, p<0.001).

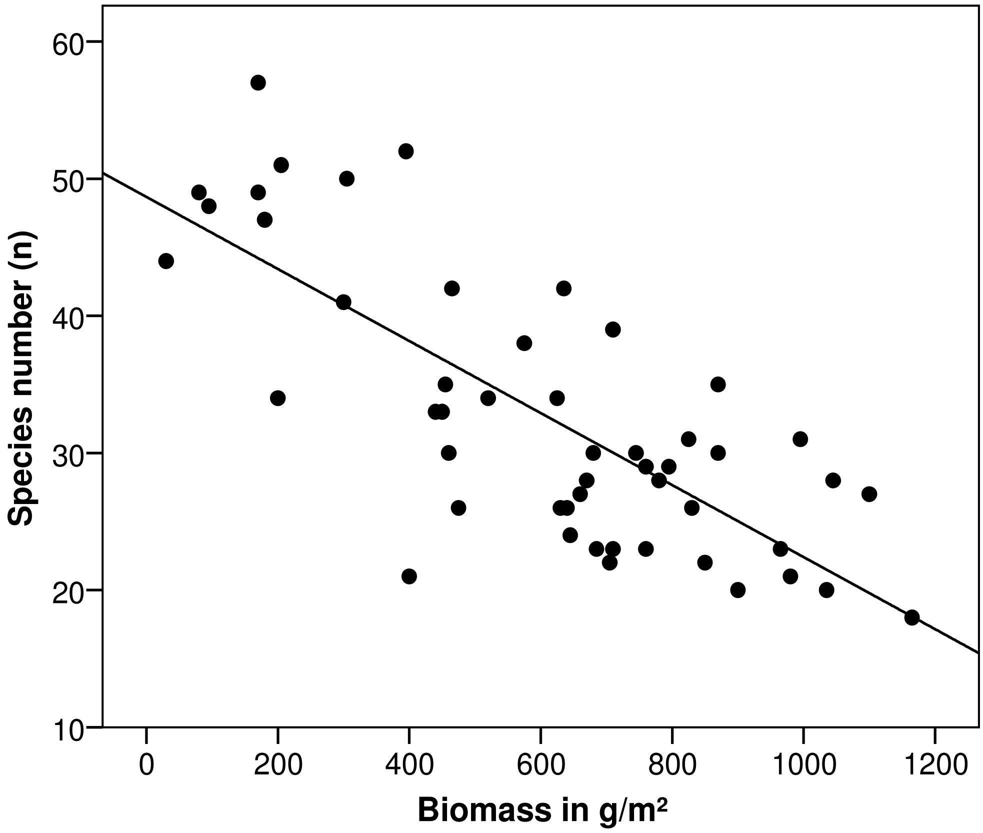


Figure 26: The relationship of species number and biomass (in g/m²) could be described with a linear function (y=-0.263*x+48.671) for the 50 plots at the Swabian Alb.

To be able to predict the relationship of biomass production and species number it was decided to perform a linear regression (R^2=0.578, p<0.001) (Figure 26). For the study area it was clearly visible that species number and biomass production were related linearly. Species number was declining while biomass was increasing.

One Way ANOVA showed that biomass and diversity (H') were significantly negatively correlated, too (F=2.680, p=0.009). The chart displayed the distribution of the plots according to their production and diversity. High diverse grasslands had a lower biomass production than low diverse grasslands. A trend was visible showing that biomass production increases with decreasing diversity. The graph could also indicate that at grasslands with very low biomass production diversity might start to decrease again (Figure 27).

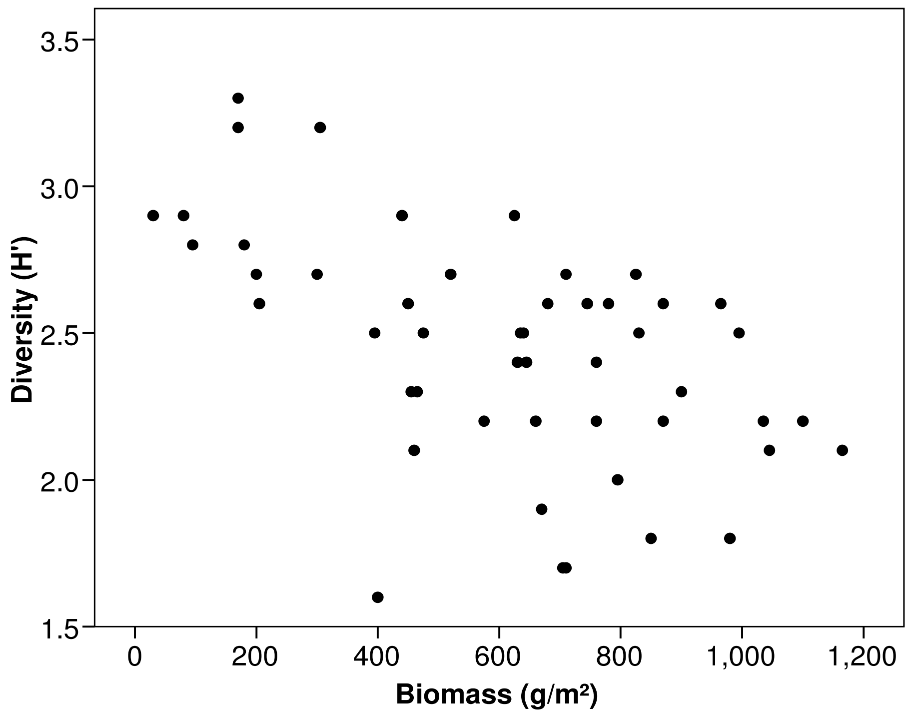


Figure 27: Biomass (g/m²) decreased with increasing diversity (H') in the 50 examination plots at the Swabian Alb. The outlier (400 g/m², 1.6 H') was a pasture (AEG 19), which might have been grazed before harvesting biomass.

5 Discussion

5.1 Data range of study area: an overview

The diverse land use types and intensity levels showed different effects on the independent factors species richness, diversity and biomass production.

Although the area was mainly used for agriculture mean species number was relatively high (approximately 33) compared to other regions in Germany (mean species number of Biodiversity Exploratory Hainich 22 and Biodiversity Exploratory Schorfheide-Chorin 16). Species diversity (2.44 H’) was also fairly high (Biodiversity Exploratory Hainich 2.03 H’ and Biodiversity Exploratory Schorfheide-Chorin 1.66 H’). High species richness and diversity was due to the variety of different habitats offered by the heterogeneous region of the cultural ecosystem Swabian Alb. Biomass production had a wide range due to the wide variety of plots. However, it was rather low compared to other regions in Germany or Europe (MLR, n.d.b). Extensive grasslands (e.g. the typical Swabian Alb semi-dry grasslands) located at mountain hillsides were unproductive. Intensive grasslands were often located in the limited valleys were more productive.

The precise results of the land use types and intensity levels are discussed in the following chapters.

5.2 Meadows, pastures and mowed pastures

Farmers of the Swabian Alb also distributed their land use types according to abiotic factors; therefore flat plots were mainly used as intensive meadows whereas steep and mostly shallow plots were used for extensive animal grazing (Döler & Haag, 1995; Briemle, 2007). More intensive utilisation of meadows and mowed pastures was also shown through higher nitrogen content of the soil as they got fertilised (Mayer *et al*., 2005).

Fewer herbs than grasses were found on mowed pastures compared to meadows since cutting was not selective and herbs, having a bigger leaf area, showed more sensitivity towards trampling than grasses (Briemle, 2007). Intensive grazing promoted plant growth and led to overcompensation of the losses. The greater the damage of grasses the greater the growth whereas herbs reacted more sensitively (Tidow, 2002). The lowest proportion of grasses compared to herbs was found at pastures (Döler & Haag, 1995) as many herbs were competitive under these conditions (no mowing, no or less fertiliser, grazing) (Schmid, 2003).

Mean ground cover of vascular plants was highest at mowed pastures, intermediate at meadows and lowest at pastures. Same results were found for average plant height, which also reflected that intensive land use (grazing or cutting) promoted plant growth, which led to high and ground-covering plants (Tidow, 2002). High growing plants also indicate a strong fertilisation (Mayer *et al*., 2005). Plants of pastures were more restricted in cover and height by abiotic factors like shallow soils and rocky parts of the ground (Thompson *et al*., 2005).

5.3 Grazing and mowing

Grazing or mowing or even the double utilisation was influencing strongly species richness. Species diversity and evenness showed differences at mowed pastures compared to meadows and pastures; however, there was no difference evident in diversity and evenness of meadows and pastures. This was caused through similar evenness due primarily to a similar proportional distribution of plants within the single land use types. Therefore diversity of grazed plots had a similar range as diversity of mowed plots (see Table 3, p.49).

Observable at the Swabian Alb was that species richness was higher at grazed pastures than at mowed meadows. On mowed plots (Figure 28) on average 11.14 fewer species occurred than on plots with grazing (Figure 29). This was, on the one

Figure 28: AEG 39 was a twice mowed pasture with relatively low species richness (20) due to few dominant species.

Figure 29: AEG 25 was a juniper heat grazed by sheep. It was very high in species richness (57). Especially many small plants occurred there.

hand, due mainly because of a more extensive way of utilisation of grazed plots compared to meadows (Sendžikaitė & Pakalnis, 2006). Especially semi-dry grasslands were grazed with a short duration, which kept the disturbance low or intermediate. In general grazing promotes species richness (Amiaud *et al*., 2007). Animal grazing was selective, caused trampling and leading to more different small scale habitats enabling more plant species to flower and reproduce (Bauschmann, 1994). The pastures of the military training area were still maintaining many different species although they were grazed more intensive than semi-dry grasslands.

On the other hand there was lower species richness at mowed plots due to additional stress for all plants (Willems, 1983). This pressure favoured some species, which were able to cope with these conditions, whilst less robust plants disappeared (Schmid, 2003). This was especially due for mowed pastures. The combination of mowing and grazing put additional pressure on the plants (Schmid, 2003) and therefore species richness and diversity was the lowest found in the study area. Often animal grazing started early in the vegetation period preventing many plants to reproduce. Surviving plants could deal with mostly irregular grazing and regular mowing. Grazing happens selectively and particular young plants get removed. Mowing removed all flowers at once and destroyed the structure (Schmid, 2003).

If land use would be more extensive and grazing would stop succession would take place and change species diversity and composition negatively (Döler & Haag, 1995; Briemle, 2007).

For biomass production statistical analysis did not make a difference whether grasslands were mowed pastures or used by the other land use types caused by the fact that mowed pastures and meadows were fairly similar in production. Mowed pastures and meadows can be described as very productive plots due to continuously removal of plant material and therefore promoting plant growth. Cutting stimulates plants to grow since they need new leaves for photosynthesis production (Nachtigall, 1986). Within mowed plots all plants were cut at the same time and also started to grow simultaneously encountering similar chances to develop (Briemle, 2007).

Nevertheless, too frequent cutting reduced biomass production and thus permanent pastures had a lower production than rotation pastures, which was also observed by Vinther (2004).

However, pastures and meadows were different in regards to each other in biomass production. Grazed plots produced remarkable lower biomass (only half) than mowed plots. One reason was that pastures were mainly located at hill sides with shallow soil (Thompson *et al*., 2005) and for agriculture unattractive places with low plant growth in general (Briemle, 2007).

5.4 Fertilisation

Fertilisation had an important effect on species richness and diversity. Fertilised plots maintained more than one third less species than unfertilised. On fertilised plots some species (e.g. *Taraxacum* spp., *Vicia sativa*, *Ranunculus repens*) were more supported than others (Figure 30) and could therefore prevent the establishment of less competitive (e.g. for light, Wilson & Tilman, 1993) species (*Asperula cynanchica*, *Campanula rotundifolia*, *Galium verum* ssp. *verum*, *Leontodon autumnalis*, etc.) resulting in a low number of species (Gendron &Wilson, 2007). Through the application of fertiliser plants can get the nutrients immediately (Schulze *et al*., 2006), which favours particularly some species (Gendron &Wilson, 2007) and therefore decreases

Figure 30: AEG 37 was a fertilised plot with a distinct *Taraxacum* spec. aspect.

diversity. Fertilisation had hardly any effect on evenness, which was due to an equal numerical distribution of plant species within unfertilised but also fertilised plots (King & Kemp, 2001). Fertilised plots had less different species but the occurring species were fairly uniformly distributed.

Fertilisation also had a major influence on biomass production. Fertilised grasslands were much more productive than unfertilised, which confirmed the results of Královec & Malý, (2006) and Willems *et al*. (1993). Plants (e.g. *Trifolium* spp.) grow faster because fertiliser (at the Swabian Alb is used: nitrogen, phosphorus, lime) supports plants to grow (Sendžikaitė & Pakalnis, 2006).

5.5 Fertilisation intensity

5.5.1 Amount of fertilisation

Not just fertilisation but also the amount of fertilisation strengthened the effect on species number and diversity. The higher the amount the lower was species richness and diversity. Species evenness was again unaffected. The more fertiliser was used the more grassland species (*Trifolium repens, Taraxacum* spec.) grew and hampered the establishment of low competitive or slow growing species (Gendron &Wilson, 2007). In particular *Poa trivialis* produced a thick felt preventing other species to grow (Elsäßer & Grund, 2003). Especially less competitive species (e.g. *Leucanthemum vulgare*, *Lotus corniculatus*, *Prunella vulgaris*, and *Rhinanthus* spp.) able to occur at meadows disappeared soon after high fertiliser application.

However, biomass was increasing with increasing amount of fertilisation (Stevens *et* *al*., 2004; Manhoudt *et al.*, 2005).

Some of the abundant species in fertilised grasslands (e.g. *Poa trivialis*) were even seen as undesirable for farmers due to their fodder quality and loss of power in the second and following cuts (Elsäßer & Grund, 2003; Elsäßer, 2004).

5.5.2 Frequency of fertilisation

Frequency of fertilisation was not important. There was no effect of frequency on the dependent variables as the amount of fertilisation was the crucial factor.

5.6 Grazing type and intensity

5.6.1 Livestock unit

The amount of animals grazing on the plots was very important in other European countries (Amiaud *et al*., 2007, as cited in Olff & Ritchie 1998; Menard *et al*., 2002) but not in the grazing system of the Swabian Alb. Probably even the heavy grazed plots had still less grazing animals compared to other regions. Nevertheless, animal density was only influencing species richness slightly. The trend showed that higher animal density led to higher plant species richness. Proulx and Mazumder (1998) discovered through comparing several reports that species richness increases with high grazing pressure in nutrient-rich ecosystems. Probably this also happened at the Swabian Alb since the soils are relatively nutrient-rich (UM Baden-Württemberg, n.d.). However, increasing species richness, whilst increasing livestock density, can only work to a particular stage. Plants can compensate the effects of grazing only up to a certain point (Noy-Meir, 1993). Furthermore, it had to be taken into consideration that livestock unit considers the number of animal per area but not per time. Plots with a high livestock density were always sheep pastures mainly used by long-distance transhumance shepherding, which meant that the grazing duration was only a few days at a stretch. Therefore, high density pressure was still low although livestock unit was high.

Diversity was not affected by livestock unit since the duration of grazing was much more important (see chapter 5.5.3). Livestock unit had also no influence on evenness. Livestock unit still had some influence on biomass production. High biomass production was found at plots with a low livestock density since the grassland was not overgrazed (Elsäßer, n.d). Additionally, it had to be taken into consideration that plots with the highest grazing density were semi-dry grasslands occurring at anyway fairly unproductive sites. However, the extensive plots at the old military training area had similar site conditions to the other pastures and they also produced less biomass under a high animal density. Probably too many grazing animals damaged plants' lasting and prevented high biomass production (Elsäßer, n.d).

5.6.2 Type of animal

The grazing animal species was less important compared to livestock unit and duration of grazing. Nevertheless, it was important for evenness. Where pressure was high (e.g. at cattle-horse pastures) species composition was shifted to few dominant species (low evenness) since they displaced other less competitive species (Grime, 1973a).

Although it was hardly significant any more there were some differences in grazing animal type for species diversity. Sheep pastures were more diverse than cattle-horse pastures although they were grazed by a higher number of animals since they were extensively grazed. Sheep are not as heavy as cattle or horse causing less trampling (Bauschmann, 1994) and they transport seeds from location to location (Fischer *et al.*, 1996). Lower diversity of cattle-horse used pastures could also be attributed to a greater grazing pressure (especially duration of grazing, trampling and deeper bite of horses, low selective bite of cattle) (Elsäßer, n.d).

Species richness was statistically unimportant since there was hardly any difference between cattle and cattle-horse pastures. Nevertheless, sheep grazed grasslands were species richer compared to cattle-horse and cattle pastures. Sheep are much more

Figure 31: The picture shows a cattle-horse pasture (AEG 19) after first grazing of horses at the beginning of May. The sward was damaged by trampling and deep grazing.

selective in grazing than cattle or horses. They favour some species whilst avoiding others (Bauschmann, 1994; Schmid, 2003). Cattle and horses are intensive grazers and therefore they put more pressure on the vegetation. However, cattle pastures showed higher species richness than horse-cattle used pastures. One reason for this could be that horses damage plants as they bite deeper than cattle (Schmid, 2003). Therefore they can still be used for pastures after cattle grazing. Horses cause a greater damage by trampling, also due to their shod hoofs and their strong urge to move (MLR, n.d.a) (Figure 31, p. 83).

Cattle-horse and cattle grazed plots produced more biomass than sheep pastures due to high promotion of plant growth (Tidow, 2002).

5.6.3 Duration of grazing

A short grazing duration had a positive influence on species richness, evenness and diversity since many different plant species could recover in between grazing periods. Pastures with lower livestock density were mostly horse and cattle pastures with a longer duration of grazing (permanent pastures). Permanent grazing leads to a shorter time to recover and a denser sward resulting in displacement of herbs in favour of grasses (LfL, 2008). Consequently valuable fodder grasses and herbs disappeared, species richness decreased and the plots got more uneven. The most species-rich, even and diverse plots were found at relatively short grazed semi-dry grasslands.

The frequency of grazing affects growth form, survival rate and reproductive output (Fisher *et al.*, 2004). Highest biomass was reached at a grazing duration of around

105 days. Permanent grazing resulted in even and short plant heights and therefore a higher light availability for seeds and small plants growing at the bottom. Probably plants were able to close the gaps in the sward causing higher biomass production. The plots were continuously fertilised by faeces and urine since animals stay on the same pastures. High grazing pressure (duration longer than 105 days) reduced biomass, which was confirmed by Vinther (2004) for Denmark. Plants were damaged (also from the season before) and not able to produce much biomass any more. Grasses storing nutrients in stubbles (*Lolium perenne, Festuca pratensis* and *Dactylis glomerata*) get damaged and start disappearing (Elsäßer, n.d.). Plots grazing less than 105 days were semi-dry grasslands. These plots would never produce a lot of biomass since they were restricted by abiotic factors like soil thickness (usually less than 0.2 m). When sheep were permanently moved, they defecate not at the same place where they have grazed and removed biomass. Usually they were fenced around a field or meadow next to the semi-dry grasslands (Beinlich, 2002).

The effect of vascular plant cover on species richness depended on the duration of grazing. Pastures, which were grazed over a short or long period, had less ground cover than intermediate plots around 105 grazing days. At intermediate grazed plots cover was dense as was explained earlier. Short grazed plots (semi-dry grasslands) often contained stones and dead wood covering the surface also leading to a low vegetation cover. Ground cover of long grazed plots was disturbed by trampling (Buchmann, 2008).

5.7 Mowing intensity

5.7.1 Frequency of mowing

Figure 32: AEG 2 was mowed for the first time at the beginning of May. It was the first cut meadow of the examination plots and had the lowest species number (18).

The frequency of mowing was not as important as fertilisation or mowing itself. However, pressure on plants increased with the frequency of mowing. The more frequent meadows were mowed, the poorer they were in species richness, which was also observed by Schmid (2002). If meadows were mowed once the moment of cutting was later than for twice or three times mowed meadows (Figure 32) and more species had the chance to flower and reproduce (Wieden, 2003).

Additionally, mowing several times over the course of a growing season increased the grass component, as already described.

Diversity was not continuously increasing with decreasing mowing frequency like species richness. That the once mowed meadow had lower species diversity than twice mowed meadows was due to its relatively low evenness. While *Bromus erectus* made up 55 % of the ground cover of the once mowed meadow, many other species were only represented by few individuals. In general, diversity decreases with highly increasing frequency (Gendron & Wilson, 2007) since some species, mainly annuals, were not able to survive frequent mowing and disappeared. Robust and often perennial species like *Poa trivialis,* which can deal with frequent cutting and much action of light, began to dominate with up to 60 % of total cover. They can outlast winter, proliferate vegetative and are light germinators (Elsäßer & Grund, 2003).

Biomass was increasing with increasing frequency (Tidow, 2002). Twice or three times mowed meadows, which were often used for silage, were high productive. Semi-dry grasslands and the once a year mowed meadow were similar in their low biomass production. On extensive grasslands high proportions of rosette plants occurred, growing just above the surface and covering a lot of the soil surface. This led to a low biomass production, since one usually low-growing rosette plant covered a higher proportion of the ground than one high-growing grass species. In addition rosette plants were not cut for sampling biomass when they were smaller than 2 cm. However, mowing frequency was a result of fertilisation and therefore increasing biomass production with increasing land use intensity could rather be attributed to fertilisation than to frequency of mowing.

The effect of mowing frequency on biomass depended on mean vascular plant height. The higher the plants were, the more frequent mowing was and the more biomass was produced. As already mentioned cutting promoted plant growth (Nachtigall, 1986) and high plants usually produce a lot of biomass.

5.8 Environmental factors

The investigated abiotic factors (exposition, soil type and solum thickness) did not influence species evenness, diversity and biomass. This could have been mainly due to the similar site conditions. However, inclination was important for species richness and biomass production. The steeper the plot, the higher was species richness and diversity, which could also be observed in other European regions (Baur *et al.*, 2007). Besides, steep plots offered more diverse habitats on small scales (open rocks, gravel, soil etc.). Higher habitat diversity leads to a higher species richness, which was also found by Zechmeister & Moser (2001). The steepest and highest diverse plots in the study region were the semi-dry grasslands. Flat plots could easily be used as intensive meadows and pastures resulting in low species richness and diversity (Briemle, 2007).

In contrary biomass production was decreasing with increasing steepness. Steep plots had shallow soils and nutrients were washed away (Berg & Rößing-Böckmann, 2003; Thompson *et al.*, 2005), which resulted in a low natural production. Slopes were difficult for mechanised agricultural utilisation and therefore not fertilised (Döler & Haag, 1995). Flat plots showed high production as soil was thick (Thompson *et al.*, 2005) and fertile due to erosion, which accumulates soil and nutrients in the valleys (Kuntze *et al.*, 1994).

There was interaction between soil type and exposition concerning biomass. The effect of soil type on biomass depended on exposition. On brown earth biomass production was also high at the unfavoured northern sites. The further developed soil type brown earth could probably compensate the disadvantages of sun adverted hill sides while plants on nutrient poor rendzinas were less supported by soil properties (Berg & Rößing-Böckmann, 2003).

5.9 Species composition

The DCA and the hierarchical cluster analysis showed similar sorting for plant species composition. The axes displayed synthetically environmental gradients. The first axis probably indicated parameters concerning nitrogen content or soil properties. AEG 39 was a well fertilised, intensive meadow located directly at the origin of the nitrogen axis. Nitrogen poor plots like the semi-dry grasslands were clustered war away from the origin. The second axis was less important as it was only half as long as the first axis (Leyer & Wesche, 2007). The second axis was much more difficult to interpret.

Semi-dry grasslands had a distinct species composition (Döler & Haag, 1995). Many herbaceous plants could survive at semi-dry grasslands because ground cover was gappy and competitive plants small. The plants were adapted to high temperatures and shallow soils (Döler & Haag, 1995). Plants with spikes (*Carlina vulgaris*, *Cirsium acaule* and *C. arvense*) were typical grazing indicators. Grazing animals avoid eating plants protected by spikes and thorns, whilst in mowed meadows thorns do not protect. They also avoid poison species like *Euphorbia cyparissias* and acrimoniously species such as *Gentianella* spec. and *Polygala amarella*. *Carex montana, Brachypodium pinnatum, Prunella grandiflora*, and *Bromus erectus* as they were indicators for dry and alkaline soils, which dominated the conditions of the juniper heats (Döler & Haag, 1995). Species like *Brachypodium pinnatum, Koeleria pyramidata* and *Festuca ovina* indicated grazing (Döler & Haag, 1995).

A main decisive parameter was nitrogen poor soils (Döler & Haag, 1995).

Intensive used grasslands like frequent mowed meadows contained a high cover of gramnoides and ruderals. Ruderals (e.g. *Plantago major*) were common in disturbed areas and condensed soils. Species such as *Anthriscus sylvestris* and *Heracleum sphondylium* indicated high nitrogen contents (Ellenberg *et al*., 1992). Mowed pastures maintained species like *Alchemilla* spec., *Dactylis glomerata*, *Poa trivialis, Alopecurus pratensis*, and *Rumex acetosa.* Many of them indicated again high nitrogen content (Ellenberg *et al*., 1992). *Poa trivialis* was prevalently on condensed soils with high fertiliser application. However, *P. trivialis* is an unpopular grass for farmers since its ability to store nutrients is low (Elsäßer, 2004).

If meadows were mowed once a year their species composition was similar to the composition of semi-dry grasslands. *Bromus erectus* dominating composition of that extensive meadow showed alkaline and nitrogen poor soils (Ellenberg *et al*., 1992).

Since very different insensitive uses of pastures occurred in the area, they were scattered in the DCA. Intensive used pastures played a high part in grasses. *Lolium perenne* is a typical grass able to deal with grazing since it is tolerable to trampling due to its runners (Starz & Pfister, 2008). *Poa trivialis* indicated again high nitrogen (Ellenberg *et al*., 1992) and was able to deal with frequent cutting also due to runners (Briemle *et al*., 2002). The moderate intensive used pastures at the old military training area showed similarity to semi-dry grasslands. However, typical plants of the semi-dry grasslands like *Bromus erectus* and *Brachypodium pinnatum* were missing. Very common were species such as *Cynosurus cristatus*, which is a typical indicator for grazing, especially sheep grazing (Döler & Haag, 1995). *Dactylis glomerata* ssp. *glomerata*, also found in these moderate intensive pastures, can be used as fodder grass (Aichele & Schwegler, 1998) but also occurred in two to three times mowed meadows.

5.9.1 Determinants of species composition

For CCA both land use and environmental variables were used, which permitted to see that land use parameters were definitely more important for the study area than environmental parameters. This was mainly due to a steeper gradient of land use factors.

Meadows parameter (frequency of mowing, amount and frequency of fertilisation) and pasture parameters (livestock unit, type of animal) had opposite effects on species composition. It can be explained with the fact that usually grassland were either mowed or grazed (but not mowed pastures) and therefore the effects were contrarily. Both groups were important, which showed the length of the arrow according to the axis of the CCA (Leyer & Wesche, 2007).

Fertilisation (amount and frequency) was important for twice and especially three times a year fertilised meadows (Pykälä, 2003). Nearly all plots at the fertilisation and mowing site were indeed fertilised and mowed. However, the plots were close to the origin meaning these variables were not strongly important for the plots (Leyer & Wesche, 2007) but their absence was essential for the plots on the right hand side far from the origin (semi-dry grasslands). Thus mowing and fertilisation was more important when they were absent.

Type of animal and livestock unit also was important in particular for the sheep grazed semi-dry grasslands and had the strongest influence on species composition of AEG 27 a juniper heat. This plot had the highest sheep density of all juniper heats. The other semi-dry grasslands were less dominated through grazing duration as grazing happened only a few days at a stretch. The juniper heats (except AEG 26, 27) seemed to also be influenced slightly by fertility, which could have originated from the soil, faeces or even from the air (Döler & Haag, 1995).

The pasture grasslands of the old military area were also influenced by livestock unit and type of animal. AEG 33 was the pasture grassland with the highest livestock unit and therefore located close to it and far from the origin. Additionally grazing duration was in particular important for pastures AEG 29 and 30. These two plots were the plots with the longest duration of the whole examination plots. AEG 50 was the pasture grassland with the lowest grazing duration and thus was located at the opposite site of the grazing duration arrow. Duration of grazing was unrelated to meadows and pasture parameters (right angle of the arrow and low variation inflation factor) (Leyer & Wesche, 2007). Grazing parameter determined species composition much more than mowing and fertilisation parameters since the plots were further apart from the origin (Leyer & Wesche, 2007).

All environmental variables were far less correlated and therefore not really influencing each other (Leyer & Wesche, 2007). The most important environmental variable was inclination. Especially the steep semi-dry grasslands were influenced by inclination. Strong inclination was also responsible for surface water run-off and temperature and therefore for dry and warm site conditions (Döler & Haag, 1995). Flat meadows and pastures were not really affected by inclination.

Solum thickness was a weak parameter but some plots seemed to be influenced by it. Their solum thickness was shallow (between 20 and 35 cm) and mainly rendzina (Marini *et al.*, 2006). However they were all very close to forests, which probably influenced composition too.

For many plots exposition and soil type were somehow affecting species composition (Marini *et al.*, 2006). Rendzina soils are usually poor and calcareous (alkaline) soils. Brown earths are loamy with weathered, ferrous minerals (Berg & Rößing-Böckmann, 2003). Exposition influenced the length of vegetation period and temperature (Pott, 2005) and therefore also composition (Marini *et al.*, 2006).

The axes demonstrated the relationship between environmental variables and species composition (Leyer & Wesche, 2007). Although solum thickness correlated highly with the first axis it could not be the only parameter influencing the first axis since the arrow was short. The first axis was rather expressed by soil properties (fertility and solum thickness). The variables of the first axis were explaining more than half of the variation of species composition. The second axis was much more difficult to interpret. It could to indicate something like pressure through land use treatments or even nature. Plots located at the negative side had to deal with higher pressure compared to plots on the positive side of the axis (Leyer & Wesche, 2007).

5.10 Relationship of species richness, diversity and biomass

As was observable in other regions (Grime 1979, 1990; Willems *et al.*, 1993) the findings showed that above-ground biomass was inversely related to plant species richness. Probably, an increase in biomass production resulted in an increasing rate of competitive exclusion and this finally led to a decrease in species richness (Grime 1979, 1990; Willems *et al.*, 1993; Stevens *et al.*, 2004; Thomson *et al.*, 2005). The competitive species were perennials (e.g. *Poa trivialis, Taraxacum* spec.) and biennials (e.g. *Carum carvi*), which probably exclude most species. However, if more harsh habitats (vegetation on rocks) would have been taken into consideration biomass would have declined further but also species richness would decrease.

As in further studies (Collins *et al*., 1998; Gendron & Wilson, 2007) the results showed that above-ground biomass was increasing with decreasing plant species diversity. This trend was caused by a change in plant species composition. High diverse plots like juniper heats showed a high proportion of herbaceous plants and a lower proportion of grasses (Döler & Haag, 1995) and low diverse plots contained a higher proportion of grasses. Herbaceous plants had an individual higher ground cover and were often smaller in height. In contrary, more individual grasses could cover the same area. Additionally, they were higher than herbaceous plants so they were able to produce more plant material. Some of the grasses were highly competitive and displaced other species resulting in a low diversity of high productive plots (Grime, 1973a).

Whilst the range of species diversity data was wider and the plots in the diversity-biomass graph (Figure 27, p. 74) were more scattered, the range of species number data (Figure 26, p. 73) was more narrow and the plots less scattered along the line of the linear function.

6 Conclusion

The region of the Biosphere Area “Schwäbische Alb” contained different land use treatments including mowing, grazing and fertilisation performed at different intensity levels. Environmental variables were also investigated and a few were seen of importance for the 50 examination plots. Analysis showed some main factors influencing species richness, diversity, composition and biomass production.

Different soil types, solum thicknesses and expositions had no significant influence on species richness, evenness, diversity and biomass production. Only sites with a strong inclination had higher species richness and diversity probably due to also steepness caused heterogeneous small scale habitats. An increase in inclination was negatively related to biomass. Many of the steep plots were juniper heats caused by a century old transhumance shepherding.

A very important land use treatment was grazing, mowing or both. The highest species richness was found on pastures; many of them were semi-dry grasslands, mostly juniper heats. Lowest species richness occurred on mowed pastures du to high land use pressure. Meadows could be ordered in between. Mowing and grazing heavily affected species composition.

Grazing or mowing was irrelevant for species diversity and evenness as both types maintained a wide range of intensity levels. However, diversity of mowed pastures was remarkable lower than diversity of meadows or pastures. Whilst mowed pastures and meadows had similar biomass, pastures reached about half of it.

Through increasing amount of fertilisation species richness and diversity were declining due to the increase of some plants species’ dominancy. To conserve species richness fertilisation needs to be accomplished very sensitive. Increasing fertilisation increased biomass production since nutrients were easily available and plant growth. There was no effect on evenness but fertilisation altered species composition. Frequency of fertilisation was not important for all dependent variables.

Livestock unit, as one indicator of grazing intensity, had its strongest importance for species composition of juniper heats and pasture grasslands of the old military training area. For other plots it was less meaningful since other parameters had a much stronger influence on them.

Which animal species were grazing on the plots was only important for species composition and a little for species diversity. The different animal types were different in selective grazing, trampling and depth of bite and thus pressure on vegetation. Sheep pastures were more species-rich and diverse than cattle or horse pastures. However, cattle-horse pastures had a higher biomass production than sheep pastures since grazing promotes plant growth. Plant composition was different and adapted to the grazers.

The duration of grazing was a very central parameter for species richness, diversity, composition and biomass. The longer pastures were grazed the lower species richness and diversity was and the longer plots were grazed the higher biomass was. At approximately 105 days of grazing, pressure was becoming too high and biomass was also declining again.

Frequency of mowing was not important since it was a consequence of fertilisation. The more a plot was fertilised the more biomass was produced and the more frequent cutting was possible. Thus, frequent cut meadows were low diverse and species poor but high in production. However, frequent cutting alters species composition, richness and diversity. Not all plants could withstand this high pressure and the survival of many herbaceous plants was hampered.

The relationship of biomass and species richness was inversely due to competitive exclusion. In the same manner biomass was increasing with decreasing plant species diversity. Once again it was visible that competitive grasses gained the upper hand over herbaceous plants.

The findings clearly showed that abiotic factors were less important for plant species diversity and biomass production than land use factors in the study area. Therefore one could conclude that the different land use treatment like mowing, grazing and fertilising and their intensity levels were major determinants for species richness, diversity, composition and biomass. This means that appropriate land use treatments are able to preserve high species richness and diversity whilst still reaching intermediate biomass production.

Furthermore the results indicate that the semi-dry grasslands are very different from all other plots in species composition, richness and diversity. Their species richness and diversity is extraordinary high and it serves for many rare and endangered species as retreat areas. Shepherding is one of the cultural important land use treatments for the Swabian Alb. These areas are highly valuable and need to be maintained and conserved. With their decline the region loses a typical character coining the region.

The pasture grasslands of the old military training area are not as diverse and species-rich as the juniper heats but they have never been used for intensive agriculture and are therefore still near-natural. They are stretched over a wide area and the grasslands are not fragmented. An unfragmented area similar to this can not be found in Baden-Württemberg any more. If this jewel gets destroyed, it can not be remediated again.

The region is less important for high agricultural production and therefore predestined for nature conservation. The uniqueness of the century old cultural landscape of the Swabian Alb, in particular the juniper heats and the pasture grassland of the military training area, makes the region highly valuable for biodiversity conservation. This also resulted in the dedication of a biosphere reserve. Thus, whatever is possible to conserve these habitats needs to be done!

7 Recommendations

To find an appropriate way to meet agriculture and nature conservation management models need to be developed, which consider the main factors and goals of both. For farmers a land use management system needs to be logistic and economic feasible. On the other hand it needs to be able to maintain high species diversity, richness, endangered species and habitat types to conserve biodiversity. Policies and support programmes (especially financially) of the EU, the Federal Republic of Germany and the Land Baden-Württemberg promote sustainable land use (MLR, 2008b).

The findings of the results and discussion should help in making suggestions on how to manage specific land use types to conserve and improve diversity of plants whilst the areas continue to be under agricultural utilisation. As agriculture created the landscape it is important to maintain land use. Many species and habitats, in particular calcareous grasslands, depend on grazing and mowing management and currently even more than in the past (Willems 2001; Poschlod & WallisDeVries 2002; Kiehl & Pfadenhauer, 2007; Pykälä, 2007).

7.1 Semi-dry grasslands

Since semi-dry grasslands or juniper heats should be grazed for a short duration (there should still be some remainder of flowers) by sheep herding, which was also the land use system, creating this vegetations type. Grazing of horse or cattle negatively influence juniper heats (Breunig, 2002). After a regeneration period of six to eight weeks the pasture in the study area is able to be grazed again by sheep

(MLR, n.d.a). Juniper heats should not be grazed by heavy grazers like cattle or horses since trampling, especially at steep sites, would destroy the grass sward, promote erosion and bite would be less selective (Bauschmann, 1994). Also goats could be used as they are grazers and browsers. They can avoid succession because they are able to eat tree seedlings (e.g. *Juniperus communis*). Apart from that it is often necessary to mow juniper heats. This should be enforced in late autumn or winter (Brys *et al*., 2004).

7.2 Pasture grasslands

There are different types of pastures occurring in the study area. Rotation pastures (especially sheep herding for hill sides) should be favoured before permanent pastures or ration grazing. The recovery period of rotation pastures is longer and therefore it is the pasture type with the highest species richness in the study area

There is no perfect point when grazing should start and it is suggested to have a mosaic of different beginnings. Pastures should be changed several times within a year to allow the vegetation to recover for approximately 4 weeks in spring and 6-8 weeks in autumn before grazing the grasslands again. Mean plant height should be more than 20 cm before reinforcing grazing and never shorter than 5 cm. Farmers have to reduce grazing density or shorten grazing duration, if biomass production is too low. With short grazing duration less fodder gets lost through trampling and grass pollution. Therefore intensive grazing reduces the quality of the pasture and the food for animals (Elsäßer, n.d.). Animal density for horses and cattle should not be too high and grazing periods should not be longer than two to three weeks with a two month brake in between (MLR, n.d.a). However, it is impossible to give an exact number of livestock units for pastures as it would be different for each pasture and year. Nevertheless, Fuchs & Schumacher state that only livestock units under 1.4 per ha enable a low increase of diversity. There could be one rule arguing for intensive used pastures, available biomass should be grazed to about 10 to 20 % remaining grass (Schmid, 2003). At steep sites nitrogen fertiliser should be drastically reduced otherwise sward looses and the pasture looses its trampling resistance (Elsäßer, n.d.).

7.3 Mowed pastures

From the conservation point of view pasture should be mowed once in autumn to avoid succession and dominance of some species. It is not necessary to mow the pasture after each grazing as the pressure on plants could be too high. The negative effects of mowing are combined with the negative effects of grazing. Selective removal of specific weeds can be achieved at some subareas (Schmid, 2003).

7.4 Mowed meadows

Frequent and early mowing changes species composition and hampers species richness but promotes *Poa trivialis*. Thus, the first cut should be later whilst the latest should be at the beginning of July (to keep species composition) but there can not be a fixed date (Briemle, 2000). However, Fuchs & Schumacher (2006) recommend that point and frequency of mowing should orientate at extensive grassland utilisation common practiced in the 1950s and 1960s. Important is, not to mow all meadows simultaneously and in the same sequence every year to give the plants a chance to reproduce. One should consider that plant height reaches at least 5 – 7 cm before mowing (Briemle *et al*., 2002).

High amount of fertilisation promotes strong competitors, which take space away from valuable meadow grasses. Fertilisation with liquid manure should not happen as ammonium (~ 60 % of N in liquid manure) as it is fast available and promotes grasses rather than herbs. Fertilisation, if necessary, should happen after the first cut (Briemle, 2007) and should not exceed 50 kg N/ha (Fuchs & Schumacher, 2006).

7.5 Incentives

Bignal & McCracken (1996) highlight that the continuation of low intensity farming, is the only feasible, socially acceptable, and sustainable management strategy for many European landscapes and biotopes of high nature conservation value. For extensive use of meadows and pastures different incentives need to be created and promoted. Thus, many European countries established especially economic incentives for farmers (Amiaud *et al*., 2007). Such financial incentives can be MEKA (Marktentlastungs- und Kulturlandschaftsausgleich), AZL (Ausgleichszulage Landwirtschaft), LPR (Landschaftspflegerichtlinie), PLENUM (Projekt des Landes zur Erhaltung und Entwicklung von Natur und Umwelt), LIFE+ (L'Instrument Financier pour l'Environnement - promouvoir l'union soutenable), direct farm bonus, and many more can be found at the ministries web site (MLR, 2008b).

The aim is to conserve landscapes and biodiversity as well as to promote sustainable use and development in agriculture.

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Appendices

Appendix I: Environmental variables

AEG ID	Soil type	Exposition	Solum thickness	Inclination
AEG 1	Rendzina	SW	16	1
AEG 2	Rendzina	SE	19	1
AEG 3	Rendzina	SW	23	1
AEG 4	Brown earth	S	24	2
AEG 5	Rendzina	SW	21	1
AEG 6	Rendzina	SE	15	2
AEG 7	Rendzina	SW	14	3
AEG 8	Rendzina	NW	11	3
AEG 9	Rendzina	S	27	3
AEG 10	Rendzina	NW	-	2
AEG 11	Rendzina	SW	30	1
AEG 12	Rendzina	W	11	2
AEG 13	Rendzina	S	21	2
AEG 14	Rendzina	W	40	2
AEG 15	Rendzina	SW	12	1
AEG 16	Rendzina	W	-	1
AEG 17	Brown earth	SE	35	2
AEG 18	Brown earth	N	28	2
AEG 19	Rendzina	SE	14	2
AEG 20	Rendzina	N	12	3
AEG 21	Rendzina	S	14	2
AEG 22	Rendzina	S	16	2
AEG 23	Rendzina	NE	36	1
AEG 24	Rendzina	NW	26	1
AEG 25	Rendzina	E	35	3
AEG 26	Rendzina	N	17	3
AEG 27	Rendzina	E	13	3
AEG 28	Rendzina	NW	20	2
AEG 29	Rendzina	NW	41	2
AEG 30	Rendzina	S	21	2
AEG 31	Rendzina	E	29	3
AEG 32	Rendzina	S	20	2
AEG 33	Rendzina	N	20	2
AEG 34	Rendzina	NW	27	2
AEG 35	Rendzina	E	60	2
AEG 36	Rendzina	NW	35	2
AEG 37	Brown earth	E	13	2
AEG 38	Brown earth	SSW	63	1
AEG 39	Brown earth	S	25	2
AEG 40	Rendzina	NE	28	2
AEG 41	Brown earth	W	60	2
AEG 42	Brown earth	NE	42	2
AEG 43	Brown earth	N	32	2
AEG 44	Brown earth	W	24	3
AEG 45	Brown earth	W	37	2
AEG 46	Brown earth	N	40	2
AEG 47	Brown earth	SW	21	3
AEG 48	Brown earth	S	22	3
AEG 49	Brown earth	E	35	1
AEG 50	Brown earth	S	-	1

Appendix II: Biomass, indices, cover

AEG ID	Biomass (g/m²)	Species No. (n)	Shannon Index (H')	Evenness (E)	Cover plants (%)	Mean height (m)
AEG 1	995.0	31	2.5	0.7280	95.00	0.60
AEG 2	1165.0	18	2.1	0.7266	85.00	-
AEG 3	640.0	26	2.5	0.7673	90.00	0.40
AEG 4	980.0	21	1.8	0.6228	100.00	0.60
AEG 5	705.0	22	1.7	0.5675	100.00	0.60
AEG 6	760.0	29	2.2	0.6602	98.00	1.00
AEG 7	80.0	49	2.9	0.7452	85.00	0.05
AEG 8	635.0	42	2.5	0.6689	60.00	-
AEG 9	395.0	52	2.5	0.6327	90.00	0.15
AEG 10	625.0	34	2.9	0.8224	96.00	0.40
AEG 11	870.0	35	2.2	0.6188	99.00	0.40
AEG 12	870.0	30	2.6	0.7644	95.00	0.35
AEG 13	830.0	26	2.5	0.7673	97.00	0.55
AEG 14	965.0	23	2.6	0.8292	96.00	-
AEG 15	1045.0	28	2.1	0.6372	98.00	-
AEG 16	745.0	30	2.6	0.7644	85.00	-
AEG 17	455.0	35	2.3	0.6522	98.00	0.60
AEG 18	1100.0	27	2.2	0.6675	95.00	0.55
AEG 19	400.0	21	1.6	0.5341	98.00	-
AEG 20	475.0	26	2.5	0.7673	97.00	0.35
AEG 21	710.0	23	1.7	0.5422	90.00	-
AEG 22	465.0	42	2.3	0.6154	85.00	0.30
AEG 23	520.0	34	2.7	0.7657	95.00	0.45
AEG 24	850.0	23	1.8	0.5823	84.00	-
AEG 25	170.0	57	3.2	0.7915	90.00	0.05
AEG 26	170.0	49	3.3	0.8479	85.00	0.10
AEG 27	205.0	51	2.6	0.6753	85.00	0.15
AEG 28	305.0	50	3.2	0.8139	96.00	0.20
AEG 29	460.0	30	2.1	0.6174	95.00	-
AEG 30	710.0	39	2.7	0.7319	85.00	0.50
AEG 31	575.0	38	2.2	0.6048	93.00	0.30
AEG 32	670.0	28	1.9	0.5586	80.00	0.30
AEG 33	180.0	47	2.8	0.7272	96.00	0.20
AEG 34	200.0	34	2.7	0.7657	98.00	0.20
AEG 35	760.0	23	2.4	0.7654	96.00	0.55
AEG 36	660.0	27	2.2	0.6675	97.00	0.45
AEG 37	630.0	26	2.4	0.7366	99.00	0.60
AEG 38	440.0	33	2.9	0.8294	90.00	0.40
AEG 39	900.0	20	2.3	0.7678	100.00	0.70
AEG 40	825.0	31	2.7	0.7863	85.00	-
AEG 41	795.0	29	2.0	0.5939	90.00	0.40
AEG 42	645.0	24	2.4	0.7552	94.00	0.50
AEG 43	680.0	30	2.6	0.7644	97.00	0.35
AEG 44	450.0	32	2.6	0.7644	97.00	0.50
AEG 45	780.0	28	2.6	0.7803	95.00	0.50
AEG 46	1035.0	20	2.2	0.6602	98.00	0.45
AEG 47	95.0	48	2.8	0.7233	75.00	0.20
AEG 48	30.0	44	2.9	0.7663	65.00	0.05
AEG 49	300.0	41	2.7	0.7271	98.00	0.20
AEG 50	685.0	23	2.4	0.75-	96.00	0.45

Appendix III: Land use (mowing, fertilisation)

AEG ID	Land use	No. of mowing	No. of fertilisation	Amount fertil. (kg N/ha)
AEG 1	Meadow_2xmowed_fertilised	2	1	50
AEG 2	Meadow_3xmowed_fertilised	3	2	130
AEG 3	Meadow_2xmowed_fertilised	2	1	20
AEG 4	Mowed pasture_cattle-horse_fertil.	1	1	50
AEG 5	Mowed pasture_cattle-horse_fertil.	1	1	50
AEG 6	Mowed pasture_cattle-horse_fertil.	1	1	50
AEG 7	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 8	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 9	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 10	Meadow_2xmowed_fertilised	2	1	10
AEG 11	Meadow_2xmowed_fertilised	2	1	35
AEG 12	Meadow_2xmowed_fertilised	2	1	50
AEG 13	Meadow_2xmowed_fertilised	2	1	50
AEG 14	Meadow_2xmowed_fertilised	2	2	80
AEG 15	Meadow_3xmowed_fertilised	3	2	40
AEG 16	Meadow_3xmowed_fertilised	3	2	90
AEG 17	Meadow_3xmowed_fertilised	3	1	25
AEG 18	Meadow_3xmowed_fertilised	3	2	100
AEG 19	Mowed pasture_cattle-horse_fertil.	1	1	50
AEG 20	Pasture_cattle-horse_fertilised	0	1	50
AEG 21	Pasture_cattle-horse_fertilised	0	1	80
AEG 22	Meadow_1xmowed_unfertilised	1	0	0
AEG 23	Meadow_2xmowed_unfertilised	2	0	0
AEG 24	Mowed pasture_Sheep_unfertilised	2	1	10
AEG 25	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 26	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 27	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 28	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 29	Pasture_Sheep_unfertilised (Pgrld)	0	0	0
AEG 30	Pasture_Sheep_unfertilised (Pgrld)	0	0	0
AEG 31	Pasture_Sheep_unfertilised (Pgrld)	0	0	0
AEG 32	Pasture_Sheep_unfertilised (Pgrld)	0	0	0
AEG 33	Pasture_Sheep_unfertilised (Pgrld)	0	0	0
AEG 34	Pasture_Sheep_unfertilised (Pgrld)	0	0	0
AEG 35	Meadow_2xmowed_fertilised	2	1	10
AEG 36	Meadow_2xmowed_fertilised	2	1	35
AEG 37	Meadow_2xmowed_fertilised	2	1	50
AEG 38	Meadow_2xmowed_fertilised	2	1	10
AEG 39	Meadow_2xmowed_fertilised	2	1	50
AEG 40	Meadow_2xmowed_fertilised	2	1	9
AEG 41	Meadow_3xmowed_fertilised	3	2	45
AEG 42	Mowed pasture_cattle_fertilised	1	1	20
AEG 43	Mowed pasture_Sheep_fertilised	1	1	17
AEG 44	Mowed pasture_cattle-horse_fertil.	0	0	0
AEG 45	Meadow_2xmowed_unfertilised	2	0	0
AEG 46	Mowed pasture_cattle_unfertilised	0	0	0
AEG 47	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 48	Pasture_Sheep_unfertilised (Sdg)	0	0	0
AEG 49	Pasture_Sheep_unfertilised (Pgrld)	0	0	0
AEG 50	Mowed pasture_sheep_unfertilised	1	0	0

Appendix IV: Land use (grazing)

AEG ID	Pasture type	Animals	No. Animals	Livestock unit	Grazing days
AEG 1	no	no	0	0	0
AEG 2	no	no	0	0	0
AEG 3	no	no	0	0	0
AEG 4	Rotation pasture	Cattle	27	16.2	180
AEG 5	Rotation pasture	Cattle; horse	57	44.2	180
AEG 6	Rotation pasture	Cattle; horse	57	44.2	180
AEG 7	Rotation pasture	Sheep	780	78	4
AEG 8	Rotation pasture	Sheep	350	27.5	6
AEG 9	Rotation pasture	Sheep	600	60	6
AEG 10	no	no	0	0	0
AEG 11	no	no	0	0	0
AEG 12	no	no	0	0	0
AEG 13	no	no	0	0	0
AEG 14	no	no	0	0	0
AEG 15	no	no	0	0	0
AEG 16	no	no	0	0	0
AEG 17	no	no	0	0	0
AEG 18	no	no	0	0	0
AEG 19	Rotation pasture	Cattle; horse	57	44.2	180
AEG 20	Rotation pasture	Cattle	55	33	180
AEG 21	Permanent pasture	Cattle; horse	50	33.4	150
AEG 22	no	no	0	0	0
AEG 23	no	no	0	0	0
AEG 24	Ration grazing	Sheep	100	10	140
AEG 25	Rotation pasture	Sheep	825	62	4
AEG 26	Rotation pasture	Sheep	950	70	8
AEG 27	Rotation pasture	Sheep	1000	100	6
AEG 28	Rotation pasture	Sheep	900	75	8
AEG 29	Rotation pasture	Sheep	1000	85	240
AEG 30	Rotation pasture	Sheep	1000	85	240
AEG 31	Rotation pasture	Sheep	1000	85	240
AEG 32	Rotation pasture	Sheep	900	75	180
AEG 33	Rotation pasture	Sheep	1800	150	180
AEG 34	Rotation pasture	Sheep	900	75	180
AEG 35	no	no	0	0	0
AEG 36	no	no	0	0	0
AEG 37	no	no	0	0	0
AEG 38	no	no	0	0	0
AEG 39	no	no	0	0	0
AEG 40	no	no	0	0	0
AEG 41	no	no	0	0	0
AEG 42	Rotation pasture	Cattle	25	20	180
AEG 43	Permanent pasture	Sheep	40	3.5	150
AEG 44	Rotation pasture	Cattle	12	7.2	180
AEG 45	no	no	0	0	0
AEG 46	Permanent pasture	Cattle; horse	25	18.5	105
AEG 47	Rotation pasture	Sheep	850	21	21
AEG 48	Rotation pasture	Sheep	600	60	6
AEG 49	Rotation pasture	Sheep	900	75	180
AEG 50	Rotation pasture	Sheep	700	70	8

Appendix V: Plants inventory list (AEG 1 – AEG 25)

AEG ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Achillea millefolium agg		1	0.5				0.5	1	0.5			7		0.5			0.5	2	0.5		2	0.5	1		0.5
Acinos arvensis																									
Aegopodium podagraria															5					25					
Agrimonia eupatoria ssp eupatoria								0.5	0.5													0.5			
Ajuga reptans										2	1														
Alchemilla spec				0.5		2					5				1		0.5		0.5					2	
Alchemilla monticola											1		1			5					1	0.5			
Alopecurus pratensis				20	30	15					35	5	10			0.5	0.5	5	60		0.5		5	1	
Antennaria dioica																									1
Anthoxanthum odoratum			0.5					2	2	5	8											3			0.5
Anthriscus sylvestris ssp sylvestris	20			1	0.5	5					0.5	15		0.5	1	0.5	0.5		1		0.5		0.5	0.5	
Anthyllis vulneraria							0.5																		
Arenaria serpyllifolia																									
Arrhenatherum elatius	30			0.5	5	0.5		1		15		2	3			0.5		3	5	20					
Asperula cynanchica							0.5		0.5																0.5
Bellis perennis	0.5	0.5	0.5							1				15		1	2				0.5		0.5		
Betonica officinalis																									
Bistorta officinalis				3											1										
Brachypodium pinnatum							25		30																
Briza media							4	0.5	3																1
Bromus erectus							5	35	35													55			0.5
Bromus hordeaceus ssp hordeaceus	0.5	0.5		1		3				0.5			15					0.5					0.5	1	
Campanula patula										0.5							0.5								
Campanula rapunculoides																		0.5							
Campanula rotundifolia							0.5	0.5	0.5								0.5					0.5			1
Capsella bursa-pastoris		0.5																			0.5			0.5	
Cardamine pratensis										0.5	1									0.5			4		
Carex caryophyllea							0.5		0.5																0.5

Carex ericetorum							0.5																		1
Carex flacca							4	0.5	0.5																4
Carex montana							0.5																		1
Carex spicata																									
Carlina acaulis ssp simplex							2		0.5																0.5
Carlina vulgaris							0.5																		0.5
Carum carvi	1	10				0.5						0.5					0.5						0.5	2	
Cerastium arvense ssp arvense								0.5																	
Cerastium holosteoides	1	3	0.5	0.5	0.5	0.5				0.5	0.5	3	0.5	3	0.5	0.5	0.5	2	0.5		0.5	0.5	1		0.5
Chaerophyllum aureum																									
Chamaespartium sagittale																									
Cirsium acaule							0.5		1																2
Cirsium arvense																									
Cirsium eriophorum																									
Cirsium palustre																									
Cirsium vulgare																									
Colchicum autumnale											3											0.5	5		
Convolvulus arvensis																									
Crepis biennis	0.5		0.5		0.5	1					0.5	0.5	0.5			0.5									
Cruciata laevipes																				3					
Cynosurus cristatus			0.5			0.5		1		4	2						5	8				2	2		0.5
Dactylis glomerata ssp glomerata	6	4	3	5	25	40		6		3	0.5	10	15	15	30	6	3		20	2	5	0.5	0.5	5	0.5
Daucus carota ssp carota									0.5													0.5			
Deschampsia cespitosa																							1		
Euphorbia cyparissias							4	0.5	3																0.5
Euphrasia officinalis ssp rostkoviana							0.5																		
Fallopia convolvulus																0.5									
Festuca guestfalica							15	1	1																5
Festuca nigrescens																						1			
Festuca pratensis ssp pratensis			4	10		5		2		6	5			5		4	0.5	1	0.5	5			10		
Festuca rubra ssp rubra								0.5		25	0.5		10		2	10				0.5		5	25		0.5
X Festulolium loliaceum			0.5	0.5						0.5	0.5												0.5		

Fraxinus excelsior											0.5									0.5					
Galium mollugo agg	6		10		10	8		0.5		10	0.5	8	4	0.5	2	7	5	5	1	6		3	4		
Galium pumilum							0.5		0.5													0.5			0.5
Galium verum ssp verum							1	0.5	0.5													0.5			0.5
Gentiana verna																									0.5
Geranium dissectum																									
Geranium pusillum																									
Geranium pratense											0.5		0.5												
Geranium pyrenaicum		0.5																							
Geranium sylvaticum			1								4		1		2							5			
Geum urbanum																								0.5	
Glechoma hederacea ssp hederacea		1			3										2					0.5					
Helianthemum nummularium ssp obscurum									3																
Helictotrichon pratense							5		0.5																0.5
Helictotrichon pubescens ssp pubescens	5		2					3	1	0.5	0.5	2					0.5	0.5				10			
Heracleum sphondylium	10		3	3	1	3					5	4	5	0.5		0.5	3	2	4		1		0.5	40	
Hieracium subg Pilosella																									
Hieracium pilosella							10	1	1																10
Hippocrepis comosa								0.5																	2
Holcus lanatus											1									0.5					0.5
Hypericum perforatum									0.5																
Hypochaeris radicata																									
Juniperus communis ssp communis (juv)																									1
Knautia arvensis																						0.5			
Koeleria macrantha ssp. macrantha							0.5		0.5																
Koeleria pyramidata ssp pyramidata							1		0.5																2
Lamium album ssp album					1	1							0.5						3						
Lathyrus pratensis																				1					
Lamium purpureum																		0.5							
Leontodon autumnalis																									0.5
Leontodon hispidus							0.5																		0.5
Leucanthemum vulgare agg																						0.5			0.5

Leucanthemum ircutianum	0.5											3					0.5						4		
Leucanthemum vulgare							0.5	0.5	0.5																
Linum catharticum							0.5		0.5																0.5
Lolium perenne	0.5	10	3	10	3	7				6	0.5	1	5	15	5	25	15	3			40		1	10	
Lotus corniculatus							1	0.5	0.5								0.5					2			0.5
Luzula campestris								0.5	0.5													5			0.5
Lysimachia nummularia																				1					
Medicago lupulina							0.5	0.5	0.5			0.5													0.5
Muscari neglectum																						0.5			
Myosotis arvensis	0.5			0.5	0.5	1				0.5	1	0.5	0.5		0.5	0.5			0.5						
Myosotis ramosissima										0.5															
Odontites spec																									
Ononis repens ssp procurrens							1																		
Orchis militaris																									
Origanum vulgare ssp vulgare								0.5														0.5			
Orobanche caryophyllum						0.5																			
Phleum bertolonii																									
Phleum pratense	1									3			0.5	2	1		20	0.5			0.5		0.5		
Phyteuma orbiculare																									
Pimpinella major																	0.5						0.5		
Pimpinella nigra							0.5																		
Pimpinella saxifraga							0.5	0.5	0.5													0.5			
Pinus sylvestris ssp sylvestris																									
Plantago lanceolata	0.5		15			0.5	1	1	1	1	3	2	6	15	3	1	10	1			0.5	5	0.5	3	3
Plantago major																					2				
Plantago media			20				1	0.5	1	1				15	0.5		5				0.5	0.5	0.5		2
Platanthera chlorantha																									
Poa angustifolia							0.5	1	0.5							3									0.5
Poa pratensis	0.5				0.5			0.5		5	0.5	2					1	1	0.5	0.5	0.5		15		
Poa trivialis ssp trivialis	15	20	40	60	50	15				20	65	8	55	25	60	15	10	60	50	20	50		15	60	
Polygala amarella							0.5		0.5																1
Polygala comosa									0.5																0.5

Polygala vulgaris							0.5																		0.5
Potentilla erecta																									0.5
Potentilla heptaphylla							1		0.5																1
Potentilla tabernaemontani							1		0.5																1
Primula veris ssp veris																									
Prunella grandiflora							20																		
Prunella vulgaris									12					0.5	0.5	0.5	1						0.5		2
Pseudolysimachion spicatum ssp spicatum							0.5															0.5			0.5
Pulsatilla vulgaris																									
Ranunculus acris	1		3	8	0.5	1				3	0.5	3	6	5	2	1	1	3	0.5	8	0.5	0.5	8	1	
Ranunculus bulbosus ssp bulbosus		0.5					1	0.5	1									0.5				0.5			1
Ranunculus ficaria																				0.5					
Ranunculus repens				30	0.5			0.5							5				15	25	0.5				
Rhinanthus alectorolophus																						0.5			
Rhinanthus glacialis									0.5																
Rhinanthus minor																						0.5			
Rumex acetosa	1		0.5	0.5	2	0.5				3	0.5	1	3	0.5		0.5		3	0.5	1	0.5	0.5	0.5	0.5	
Rumex crispus		0.5																							
Rumex obtusifolius		0.5		10																					
Rumex thyrsiflorus																									
Salvia pratensis																									
Sanguisorba minor							5	0.5	1													1			8
Scabiosa columbaria							0.5	0.5	0.5																0.5
Senecio jacobaea ssp. jacobaea																						0.5			0.5
Sesleria albicans ssp albicans																									0.5
Silene dioica	1																0.5								
Silene vulgaris																									
Stellaria graminea																					0.5				
Stellaria media																								0.5	
Taraxacum spec	15	30	1	1	1	0.5	0.5	1		8	0.5	7	8	18	6	6	2	5	1	0.5	2	0.5	0.5	10	
Teucrium montanum							0.5																		
Thlaspi arvense																0.5									

Thlaspi perfoliatum	0.5											0.5													
Thymus pulegioides ssp carniolicus							3	0.5	0.5																
Thymus pulegioides ssp pulegioides							1	0.5	0.5																20
Tilia spec																				0.5					
Tragopogon pratensis ssp. minor	0.5																								
Tragopogon pratensis ssp. orientalis												0.5													
Tragopogon pratensis ssp. pratensis	1					0.5				2							0.5					0.5			
Trifolium campestre									0.5																0.5
Trifolium dubium						1			0.5	0.5												0.5			
Trifolium montanum							0.5		0.5																1
Trifolium pratense ssp pratense	5		15	0.5		1		1	0.5	8		45	5	3	3		50	1			0.5		15	0.5	
Trifolium repens	0.5	10	2					3	1	5		15	1	25	12	1	10	1		4	20		3	3	0.5
Trisetum flavescens	20	20	15		30	30		1		6	12	30	30	5	10	6	25	15	2	3		0.5	1	1	
Urtica dioica ssp dioica															0.5					3					
Valerianella locusta												0.5				0.5									
Veronica arvensis	0.5	0.5	0.5		1	0.5				0.5	0.5	0.5		1		0.5	0.5	1	0.5				0.5	0.5	
Veronica chamaedrys	0.5		4		0.5	0.5		0.5		2	0.5		3	0.5	0.5	0.5	1	2		0.5		1		0.5	0.5
Veronica hederifolia																									
Veronica serpyllifolia										0.5	0.5			2	0.5								0.5		
Veronica teucrium								1														1			
Vicia angustifolia ssp angustifolia																									
Vicia sativa												0.5													
Vicia sepium	0.5		4		0.5	0.5					0.5	1	3		0.5	0.5	0.5	0.5	0.5	8		0.5			
Crataegus monogyna									1																
Fraxinus excelsior																0.5									
Juniperus communis ssp communis							0.5																		
Quercus robur									0.5															0.5	
Rosa rubiginosa agg									1																

Appendix VI: Plants inventory list (AEG 26 – AEG 50)

AEG ID	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Achillea millefolium agg		0.5	1			0.5		6	1						15			0.5		0.5		0.5		0.5	8
Acinos arvensis																							0.5		
Aegopodium podagraria																									
Agrimonia eupatoria ssp eupatoria	0.5	0.5	1				0.5	1	0.5													0.5		0.5	
Ajuga reptans					0.5								3												
Alchemilla spec							0.5		0.5								0.5	0.5	0.5		3				5
Alchemilla monticola			0.5	0.5		0.5					2		0.5							2					
Alopecurus pratensis					0.5	2				2	15	18	7	20		30	25	10	2		20				
Antennaria dioica	0.5	0.5																					0.5		
Anthoxanthum odoratum	0.5	1			1	0.5	5			5	2		1			1								5	
Anthriscus sylvestris ssp sylvestris				0.5	0.5	0.5	0.5			0.5	0.5	15		20	1	0.5	20	0.5	1	15	2				
Anthyllis vulneraria		3																							
Arenaria serpyllifolia											0.5														
Arrhenatherum elatius					30	15				50	7		3	3	1	0.5	1		5		2				20
Asperula cynanchica	0.5	0.5																				0.5	0.5		
Bellis perennis			5	0.5				0.5	0.5				0.5		8				0.5					0.5	8
Betonica officinalis	0.5																								
Bistorta officinalis																									
Brachypodium pinnatum	3	1	1																			6	12		
Briza media	12	15	2																			5	15	1	
Bromus erectus	8	40	6																			35	4		
Bromus hordeaceus ssp hordeaceus			0.5						5			0.5	0.5	0.5		0.5			0.5	0.5				0.5	
Campanula patula					0.5	0.5																			
Campanula rapunculoides																									
Campanula rotundifolia					0.5																	0.5	0.5		
Capsella bursa-pastoris																									
Cardamine pratensis																	0.5								
Carex caryophyllea	4	10																				1	1		

Carex ericetorum																									
Carex flacca		1																				3	12		
Carex montana	0.5																								
Carex spicata							0.5	0.5	5																
Carlina acaulis ssp simplex	0.5	1																				0.5	0.5	0.5	
Carlina vulgaris	0.5																					0.5	0.5	0.5	
Carum carvi				0.5				1	2			0.5			5	0.5			0.5	0.5					3
Cerastium arvense ssp arvense																									
Cerastium holosteoides			0.5	1	0.5	1		0.5	1	0.5	0.5	0.5	0.5	0.5	2	0.5	0.5	0.5	1	0.5	0.5			0.5	1
Chaerophyllum aureum				0.5						0.5															
Chamaespartium sagittale	2	10																							
Cirsium acaule	0.5	1																				4	0.5		
Cirsium arvense			4				0.5																		
Cirsium eriophorum															0.5										
Cirsium palustre							1																		
Cirsium vulgare									0.5																
Colchicum autumnale					0.5	0.5													4						
Convolvulus arvensis							0.5																		
Crepis biennis					4			0.5				2	2			0.5				2				0.5	2
Cruciata laevipes																									
Cynosurus cristatus	0.5		12	12	1	1		5	15		2		3											10	
Dactylis glomerata ssp glomerata			1	10	5	3	2	2	2	10	12	12	5	7	10	3	10	30	5	5	2			1	8
Daucus carota ssp carota			1					0.5	0.5													0.5	0.5	0.5	
Deschampsia cespitosa							10																		
Euphorbia cyparissias	3	1	0.5					1														2	0.5	2	
Euphrasia officinalis ssp rostkoviana																						0.5	0.5		
Fallopia convolvulus																									
Festuca guestfalica	5	7																				15	6		
Festuca nigrescens								0.5																	
Festuca pratensis ssp pratensis			5		0.5	0.5	1	2	0.5	8						2	5	5	5	10				1	
Festuca rubra ssp rubra			5		5	10	40	25	0.5		0.5		15						35		4			2	
X Festulolium loliaceum			1					1																	

Fraxinus excelsior		0.5			0.5						0.5														
Galium mollugo agg					7	10	1		2	2	7		5		0.5	0.5	2	5	15		2	0.5			4
Galium pumilum	1	1	0.5																						
Galium verum ssp verum	0.5		0.5				3															1	0.5	1	
Gentiana verna		1																					1		
Geranium dissectum																		0.5							
Geranium pusillum						0.5									0.5			0.5							
Geranium pratense												5		8	0.5										
Geranium pyrenaicum												0.5													
Geranium sylvaticum						0.5																			
Geum urbanum									0.5																
Glechoma hederacea ssp hederacea							2											0.5	8		1				
Helianthemum nummularium ssp obscurum																									
Helictotrichon pratense	3	0.5																					2		
Helictotrichon pubescens ssp pubescens			5		20	4	15	0.5			0.5		1			0.5			1					30	
Heracleum sphondylium				0.5								25		25	1	0.5	7	4	4	12					
Hieracium subg Pilosella																							0.5		
Hieracium pilosella	2	1	2					2														12	2	15	
Hippocrepis comosa	3	5																					0.5		
Holcus lanatus					0.5	0.5	0.5			8	7		0.5												
Hypericum perforatum		0.5	0.5																					0.5	
Hypochaeris radicata								1																0.5	
Juniperus communis ssp communis (juv)																									
Knautia arvensis		1	0.5		5																	1			
Koeleria macrantha ssp. macrantha	0.5																					0.5			
Koeleria pyramidata ssp pyramidata	1	2																				1	1		
Lamium album ssp album														20				0.5							
Lathyrus pratensis															0.5	0.5									
Lamium purpureum				0.5								0.5						0.5			1				
Leontodon autumnalis		0.5	0.5					0.5															0.5	0.5	
Leontodon hispidus	1	0.5						0.5														0.5	2		
Leucanthemum vulgare agg		1																							3

Leucanthemum ircutianum					0.5											0.5			1						
Leucanthemum vulgare	0.5																					0.5			
Linum catharticum	0.5	0.5																				0.5	0.5		
Lolium perenne			5	15				5	3			1	1	0.5	25			15		3				0.5	
Lotus corniculatus	1	1					0.5	0.5														2	0.5	0.5	
Luzula campestris	0.5	0.5	2				0.5	0.5																0.5	
Lysimachia nummularia																									
Medicago lupulina	2				0.5			0.5	0.5						0.5							0.5			
Muscari neglectum																									
Myosotis arvensis					1	0.5						0.5		0.5		1									0.5
Myosotis ramosissima						0.5							0.5												
Odontites spec		0.5	0.5					0.5																	
Ononis repens ssp procurrens			0.5																			0.5		2	
Orchis militaris																							0.5		
Origanum vulgare ssp vulgare			0.5																						
Orobanche caryophyllum																									
Phleum bertolonii			0.5				0.5																	0.5	
Phleum pratense				2				0.5	0.5	1					0.5		1	1	1						
Phyteuma orbiculare																							0.5		
Pimpinella major				0.5																					
Pimpinella nigra																			3				0.5		
Pimpinella saxifraga	0.5		0.5					0.5														0.5	0.5		
Pinus sylvestris ssp sylvestris		0.5																							
Plantago lanceolata	1	1	2	3	5	1	0.5	3	5	10	8		10		5	2	3	12	2			0.5		1	3
Plantago major				0.5													0.5								
Plantago media	1	2	15	0.5	1	0.5		4	3						6		0.5					1	5	0.5	2
Platanthera chlorantha																							0.5		
Poa angustifolia						60		5					5									0.5		15	
Poa pratensis			5		0.5	0.5		0.5	8	1	1	0.5	0.5		0.5	1	1	10	1		10				15
Poa trivialis ssp trivialis			1	60	1	0.5		0.5	15	15	60	30	12	30	2	60	25	2	10	30	60				5
Polygala amarella	0.5	0.5																				0.5	1		
Polygala comosa			0.5																			0.5			

Polygala vulgaris		0.5																							
Potentilla erecta																									
Potentilla heptaphylla	0.5	0.5																				0.5	0.5		
Potentilla tabernaemontani	1	1	0.5																			0.5	0.5		
Primula veris ssp veris		1																							
Prunella grandiflora	10	10																				4	13		
Prunella vulgaris		5	2	0.5				1							1									0.5	
Pseudolysimachion spicatum ssp spicatum	0.5																					0.5			
Pulsatilla vulgaris	0.5																								
Ranunculus acris				3	3	0.5	1	0.5	5	6	6	1	1	1	5	5	15	5	7	4	8			0.5	20
Ranunculus bulbosus ssp bulbosus	5	0.5	2			0.5		3	2			0.5				0.5						0.5	0.5	3	
Ranunculus ficaria																									
Ranunculus repens				3			0.5	10										2		1	3				
Rhinanthus alectorolophus					20	15																			
Rhinanthus glacialis	1																					0.5			
Rhinanthus minor		0.5											0.5												
Rumex acetosa					1	1				2	0.5	2	2	3	0.5	1	1	0.5	3	1	8				2
Rumex crispus																				0.5					
Rumex obtusifolius																				8					
Rumex thyrsiflorus																				1					
Salvia pratensis		0.5				0.5																3			
Sanguisorba minor	8	6	0.5																2			2	0.5		
Scabiosa columbaria	0.5	2																				0.5			
Senecio jacobaea ssp. jacobaea																									
Sesleria albicans ssp albicans																									
Silene dioica					0.5	0.5																			
Silene vulgaris						0.5																			
Stellaria graminea																									
Stellaria media																									
Taraxacum spec		0.5	0.5	4	3		0.5	0.5	2	1	2	10	2	5	20	3	12	8	4	6	5		0.5	0.5	8
Teucrium montanum	0.5																						1		
Thlaspi arvense				0.5																					

Thlaspi perfoliatum																									
Thymus pulegioides ssp carniolicus	1	1																				0.5	0.5		
Thymus pulegioides ssp pulegioides	0.5	2	2					1	0.5													2	0.5	8	
Tilia spec																									
Tragopogon pratensis ssp. minor																									
Tragopogon pratensis ssp. orientalis															0.5										
Tragopogon pratensis ssp. pratensis					0.5		0.5													0.5					
Trifolium campestre										10															
Trifolium dubium			0.5		0.5	0.5		0.5	1				0.5											1	0.5
Trifolium montanum	0.5																								
Trifolium pratense ssp pratense	2	10	2	1	15			0.5	2		0.5	1	2	1	0.5	10	3	0.5	30	1		3		1	10
Trifolium repens			20	6	1			25	40	3	0.5		1	1	12	3	3	5	10	20	2	1		10	8
Trisetum flavescens			10	0.5	1	2	5	20	12	20	15	30	2	20	10	5	1	25		12	2				6
Urtica dioica ssp dioica																		0.5		1					
Valerianella locusta												1													
Veronica arvensis			0.5	0.5	0.5	0.5		0.5		1	0.5	3	0.5	0.5	1	0.5			0.5	0.5					
Veronica chamaedrys			0.5	0.5	0.5	1	1	0.5	0.5	1	0.5	0.5	4		0.5	1	0.5	3	1	0.5	2			0.5	2
Veronica hederifolia				0.5																					
Veronica serpyllifolia			0.5	0.5				0.5	0.5		0.5		0.5		0.5			0.5	0.5	0.5				0.5	
Veronica teucrium																						0.5			
Vicia angustifolia ssp angustifolia			0.5			0.5		0.5																0.5	
Vicia sativa												0.5													
Vicia sepium				0.5	0.5	0.5	0.5	0.5		2	0.5	1	0.5	0.5		0.5	0.5	1	1	0.5	3				
Crataegus monogyna																									
Fraxinus excelsior																									
Juniperus communis ssp communis	0.5																						0.5		
Quercus robur																									
Rosa rubiginosa agg																									

Appendix VII: Multiple Regressions

Summary

Between-Subjects Factors

		N
OTHER LAND USE TYPE	0	42
MOWED PASTURE	1	8
MOWED PASTURE	0	8
MEADOW	1	22
PASTURE	2	20
NO FERTILISATION	0	22
FERTILISATION	1	28

Univariate Analysis of Variance – Species number

Tests of Between-Subjects Effects

Dependent Variable: Species number

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3468.166(a)	9	385.352	10.870	.000
Intercept	53072.820	1	53072.820	1497.102	.000
MOWED PASTURE	701.109	1	701.109	19.777	.000
PASTURE_MEADOW	1300.303	1	1300.303	36.680	.000
FERTILISATION	426.171	1	426.171	12.022	.001
AmountFertilisation	177.088	1	177.088	4.995	.031
FrequencyFertilisation	17.303	1	17.303	.488	.489
LivestockUnit	122.303	1	122.303	3.450	.071
TypeAnimal	10.526	1	10.526	.297	.589
DaysGrazing	705.235	1	705.235	19.894	.000
FrequencyMowing	8.127	1	8.127	.229	.635
Error	1418.014	40	35.450		
Total	57959.000	50			
Corrected Total	4886.180	49			

a R Squared = .710 (Adjusted R Squared = .644)

Univariate Analysis of Variance – Evenness

Tests of Between-Subjects Effects

Dependent Variable: Evenness

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.121(a)	9	.013	2.491	.023
Intercept	25.094	1	25.094	4664.333	.000
MOWEDPASTURE	.028	1	.028	5.138	.029
PASTURE_MEADOW	.006	1	.006	1.040	.314
FERTILISATION	.006	1	.006	1.036	.315
AmountFertilisation	.008	1	.008	1.571	.217
FrequencyFertilisation2006	4.81E-005	1	4.81E-005	.009	.925
LivestockUnit	.000	1	.000	.032	.858
TypeAnimal	.037	1	.037	6.796	.013
DaysGrazing	.027	1	.027	5.111	.029
FrequencyMowing	.009	1	.009	1.683	.202
Error	.215	40	.005		
Total	25.430	50			
Corrected Total	.336	49			

a R Squared = .359 (Adjusted R Squared = .215)

Univariate Analysis of Variance – Diversity

Tests of Between-Subjects Effects

Dependent Variable: Diversity (H')

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.151(a)	9	.461	5.676	.000
Intercept	298.168	1	298.168	3669.329	.000
MOWED PASTURE	1.372	1	1.372	16.879	.000
PASTURE_MEADOW	.281	1	.281	3.452	.071
FERTILISATION	.504	1	.504	6.197	.017
AmountFertilisation	.455	1	.455	5.602	.023
FrequencyFertilisation	.007	1	.007	.083	.775
LivestockUnit	.021	1	.021	.255	.616
TypeAnimal	.326	1	.326	4.018	.052
DaysGrazing	1.068	1	1.068	13.140	.001
FrequencyMowing	.119	1	.119	1.463	.234
Error	3.250	40	.081		
Total	305.570	50			
Corrected Total	7.402	49			

a R Squared = .561 (Adjusted R Squared = .462)

Univariate Analysis of Variance – Biomass

Tests of Between-Subjects Effects

Dependent Variable: Biomass

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2571306.272(a)	9	285700.697	7.518	.000
Intercept	18770064.500	1	18770064.500	493.899	.000
MOWED PASTURE	96049.339	1	96049.339	2.527	.120
PASTURE_MEADOW	1543680.195	1	1543680.195	40.619	.000
FERTILISATION	186955.831	1	186955.831	4.919	.032
AmountFertilisation	319839.950	1	319839.950	8.416	.006
FrequencyFertilisation	25792.401	1	25792.401	.679	.415
LivestockUnit	134327.256	1	134327.256	3.535	.067
TypeAnimal	11142.136	1	11142.136	.293	.591
DaysGrazing	245982.523	1	245982.523	6.473	.015
FrequencyMowing	7536.641	1	7536.641	.198	.658
Error	1520154.228	40	38003.856		
Total	22861525.000	50			
Corrected Total	4091460.500	49			

a R Squared = .628 (Adjusted R Squared = .54

Appendix VIII: One Way ANOVA

Summary

Between-Subjects Factors

		N
Exposition	S	9
	SW	8
	W	5
	NW	6
	N	6
	NE	3
	E	6
	SE	4
Inclination	1	10
	2	26
	3	11
SoilType	Rendzina	32
	Brown earth	15

		N
SolumThickness	11	2
	12	2
	13	2
	14	3
	15	1
	16	2
	17	1
	19	1
	20	3
	21	4
	22	1
	23	1
	24	2
	25	1
	26	1
	27	2
	28	2
	29	1
	30	1
	32	1
	35	4
	36	1
	37	1
	40	2
	41	1
	42	1
	60	2
	63	1

Univariate Analysis of Variance – Species number

Tests of Between-Subjects Effects

Dependent Variable: Species Number

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Exposition	611.306	7	87.329	.858	.547
Inclination	1995.795	2	997.898	16.227	.000
SoilType	141.812	1	141.812	1.435	.237
SolumThickness	2386.360	27	88.384	.701	.806

Univariate Analysis of Variance – Evenness

Tests of Between-Subjects Effects

Dependent Variable: Evenness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Exposition	.055	7	.008	1.185	.332
Inclination	.004	2	.002	.318	.729
SoilType	.005	1	.005	.683	.413
SolumThickness	.143	27	.005	.577	.907

Univariate Analysis of Variance – Diversity

Tests of Between-Subjects Effects

Dependent Variable: Diversity (H')

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Exposition	1.195	7	.171	1.155	.349
Inclination	1.150	2	.575	4.323	.019
SoilType	7.21E-005	1	7.21E-005	.000	.983
SolumThickness	3.107	27	.115	.540	.930

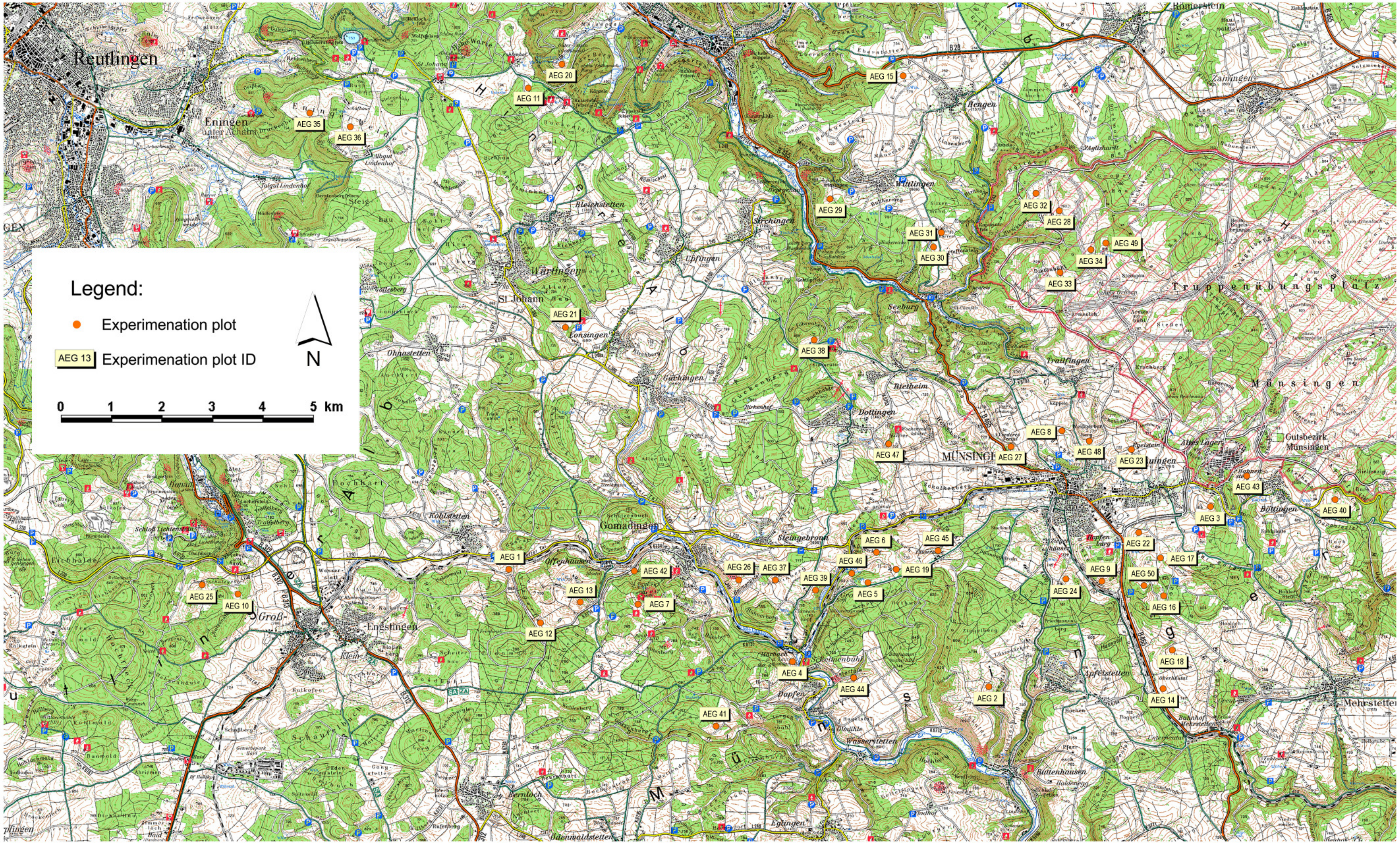
Univariate Analysis of Variance – Biomass

Tests of Between-Subjects Effects

Dependent Variable: Biomass

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Exposition	407837.286	7	58262.469	.664	.701
Inclination	1430550.567	2	715275.284	12.634	.000
SoilType	3559.765	1	3559.765	.042	.839
SolumThickness	2654679.743	27	98321.472	1.322	.267

Appendix IX: Locations of the experimentation plots at the Swabian Alb



Katrin Wuchter - October 11, 2008