Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Natural Resources and
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Comparison of plant species communities in meadows of the nature reserve "Bodenmöser" from 1987 to 2014

Katharina Viebranz

Department of Aquatic Sciences and Assessment
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Katharina Viebranz

Supervisor: Ulf Grandin, SLU,
Department of Aquatic Sciences and Assessment
Assistant Supervisor: Anders Glimskär, SLU,
Department of Ecology
Klaus Schmieder, University of Hohenheim, Institute for Landscape Ecology and Vegetation Science

Examiner: David Angeler, SLU,
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Popular science summary

Wetlands are disappearing more and more on a global scale. Mostly the transition into agricultural land is the driving process behind the wetland area decrease. Also in Germany this trend is visible. To preserve the remaining wetland areas legally, they are mostly protected as nature reserves.

Nature reserves are created to protect, develop or restore endangered habitats, biotopes or cohabitations of specific plant and animal species. Loss of endangered species together with shifts in species composition is therefore inconsistent with the initial aims of a nature reserve. But this is what is happening in a nature reserve in southern Germany. Through this master thesis it was proven that some endangered species which used to be present in the study area have disappeared. At the same time the comparison of plant species inventories from three different times over the last 27 years showed the valuable plant species composition has shifted to more common and generalistic species. This is of course against the initial purpose of the nature reserve and indicates flaws in the ongoing management of the area. When comparing the variation of species over the years a constant decrease was discovered. In the earlier years species with more “extreme” characteristics considering the explanatory variables have been more common. In 2014 many species have rather generalistic characteristics.

The nature reserve in question is called “Bodenmöser” and is located in the South of Germany. It was legally protected because it is one of the few left areas in this part of the country where all natural mire states from the high peat bogs to the peripheral low bogs and fens are still present and closely interlinked. This implies a large number of species – plants and animals - and a high variety of different wetland biotopes. For my master thesis a study area in the peripheral wet grasslands has been examined more closely. What is special about those meadows is their history. For a time span of about 800 years they were used as water meadows. This is a historic form of meadow use which was well known all over Europe. The principle was easy: water from a nearby stream was lead into an extended system of ditches, which covers the area like a spider web. Over this system the water was lead into the meadows. It brought dissolved nutrients to the meadows and regulated the soil temperature to support grass growth. In the middle of the last century this practice was stopped as it wasn’t profitable anymore. But because of its many endangered species the area was included in the nature reserve which was enacted in 1987. The loss of endangered species of course contradicts the goal to protect them. To stop this negative development and take countermeasures the most probable reasons had to be detected.

During my master thesis I have shown that soil moisture is the most important factor influencing the species composition in the wet meadows of the study area, followed by plant available nutrients. Therefore observed temporal changes in the

plant species composition are most likely being caused by changes in those factors. For future management these are the adjusting screws that need to be handled to stop the negative developments and to restore the site conditions. For example the ditches, initially designed for leading water into the meadows are now working as drainage. Here action needs to be taken to stop the drainage.

Another important result is a trend to a more homogeneous plant species composition. In the past species variation between the biotopes was relatively large. In 2014 there was a large number of species which were found in nearly every polygon. More variation in the management of the meadows could be beneficial for the ecological value of the area for plant and animal species.

Abstract

This master thesis compares plant species communities which were conducted within the same area at thre different times. The study area of this thesis is located in the southeast of the German federal state of Baden-Württemberg close to the town Isny im Allgäu. For a period of over 700 years the meadows in this region were traditionally used as water meadows. Water meadows are a traditional agricultural practice where meadows are irrigated in early spring every year to unfreeze the soil, start the vegetation growth earlier and to fertilize them. This practice was stopped in the middle of the last century.

In 1990 large parts of the study area, together with surrounding mires and other types of wetlands, were declared a nature reserve. It is one of the last large contiguous areas in Baden-Württemberg where different stages of mire development and wetland habitats exist next to each other. Of special interest for this thesis are the different types of meadows in the eastern parts of the nature reserve "Bodenmöser".

It is suspected that the plant species diversity of the meadows has decreased and the plants species composition has markedly changed since 1989. Since the declaration as a nature reserve in 1990 until today several experts in ecology increasingly suspected that the plant species diversity in the former water meadows had been reduced. It was observed that some plant species seem to have become dominant and to have superseded others. This of course would counteract the aim of the nature reserve, which is the conservation of nature.

The focus of this master thesis will be to investigate whether this is the case and if so, what could possible reasons for those changes be. Therefore two data sets from previous plant species inventories (1987 and 1997) are compared with a new data form spring/summer 2014. The field mapping of this data set was part of this master thesis. The analyses of the three data sets show temporal trends in the plant species composition. Changes in local conditions were assessed using Ellenberg's indicator values and available data on management. The results show that soil moisture and nutrient content of the soil has the biggest influence on the distribution of plant species in the study area. Both were proven to be big explanatory factors for the plant species composition.

Also it was confirmed that the species composition has changed over the years. Especially the loss of several endangered species was alarming. It was concluded that the current management measures need to be evaluated, revised and adjusted. The partial restoration of the water meadow system could help to restore wetter soil conditions to support the adapted plant species composition. At the same time the nutrient input on some biotopes should be reduced to lower productivity and raise biodiversity.

Keywords: plant ecology, nature conservation, wet meadows, Ellenberg indicator values, Detrended correspondence analysis

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1. Introduction

The meadows of the nature reserve ”Bodenmöser” in Isny im Allgäu are protected, because of their high number of endangered species and their species richness in general. Today they are suspected that their plant species diversity has decreased. A small number of plant species seem to have become dominant and superseded competitively weaker species. The goals of the nature reserve are therefore jeopardized by this development (Dechert 2000).

This master thesis examines the development of the species composition to find out whether those subjective impressions can be confirmed, through analysing the available data on the area. Also possible correlation to local conditions and management are tested. The available data was collected for making a management plan for the nature reserve. In the course of the enactment of the nature reserve in 1990 and the establishment of its first management plan all biotopes of the area were mapped and recorded. In 1997-2000 this inventory was repeated to monitor the development of the biotopes and to adapt and further develop management procedures and measures (Bezirksstelle für Naturschutz und Landschaftspflege Tübingen 1990; Dechert 2000). The expression “biotope” and “biotope type” in English scientific terminology is used when referring to an area that is defined by a specific floristic or faunistic inventory that distinguishes itself from its surroundings, e.g. grassland or forest. However the mapping method of Dechert (2000), which was used for the mappings, explicitly uses this term because its differentiation of biotopes is not only based on vegetation types, but also on morphological attributes. Therefore the expressions “biotope” and “biotope type” are used in this thesis instead of e.g. vegetation type.

The study area of this thesis is a historic water meadow area. Water meadows are a historic form of land management. In Germany the practice was first introduced in the late middle age (Leibundgut 2009). The purpose was to increase the agricultural productivity of meadows. Therefore water was led under controlled conditions onto grassland parcels to support grass growth.

There were many and – from an agricultural point of view – positive effects awarded to water meadow systems:

- Soil humidification/moistening
- Fertilization
- Sedimentation and soil genesis
- Pest control (moles, mice, locusts, cockchafer-grubs)
- Frost protection
- Organization of farmers
- Soil decontamination of humus acids, salt, soda
- Decreasing soil temperature for flax cultivation
- Support of bleaching processes of linen
- Support of hard grasses growth to lay the linen onto for bleaching
- Support buffering function of acidic soils through water diluted minerals
- Changes of vegetation from sedges to sweet grasses

(Leibundgut 2009; Herbst 1988; Pusey 1849; Konold 1991; Bettey 1977; Bettey 2003; Cook et al. 2003)

In contrast to irrigation systems in the southern parts of Europe, moistening of the soil was not the main purpose of the water meadow systems in central and northern Europe. The humid climate normally guarantees a sufficient water supply of the plants. Although in occasionally dry periods of hot summers the systems were also used to prevent drought damages. But still soil moistening was not the main objection of water meadows. The main purpose was instead fertilization (Leibundgut, Kohn 2014b). Suspended solids, dissolved minerals and nutrients in the water made it a valuable fertilizer for the plants of the meadows. Therefor especially waste water from settlement areas was treasured (Lauter 1851). Together with fertilizing effects the suspended particles sedimented and supported the soil genesis (Cook et al. 2004). Another effect was pest control. In years with significant high populations of pests like moles, mice, locusts or cockchafer grubs the water was used to kill them (Fachschaft für Ornithologie Südlicher Oberrhein 2009). Another purpose, especially in the colder regions of the submountain and mountain range, was frost protection. During frost periods water was used to keep soil temperature above 5°C (Cook et al. 2003). This brought advantages for the plant germination and growth of the meadows, as frost damage on the plants was avoided. In spring, snow covering the meadows was melted away by the water and soil temperature increased, so it was favourable for an earlier start of the vegetation period. In autumn, an extension of the vegetation period was possible (Cook, Williamson 1999).

Establishing a water meadow system acquired a large amount of knowledge and work for construction and maintenance. As the water resources were limited in volume, regulations for distributing the water among the meadow parcels had to be set up and controlled (Smith 1806; Seidenspinner 2014). Therefore so called water meadow societies were founded including all water meadow owners or users. But also other parties were dependent on a constant water supply like mills and handcrafts like tanners or dyers. To avoid conflicts between the water users a far-reaching set of rules was set up to regulate minimum water levels in the water bodies, abstraction volumes and specific times for the use of the water (Konold 1994).

The water meadow principle was known nearly all over Central Europe. Water meadow systems have been used in for example Great Britain, Netherlands, France, Switzerland, Austria, Italy, Sweden and Germany (Leibundgut, Kohn 2014a; Cook et al. 2003; Davidsson, Leonardsen 1998). Historically, two peaks in the development and spread of water meadow systems can be identified. First one started in the late Middle Ages and second between the end of the 18th and the middle of the 20th century (Leibundgut, Kohn 2014a). The methods varied, depending on the water source and particularly on the terrain. Stagnant water is counterproductive for plant growth as the roots need oxygen, which is rapidly depleted in stagnant water. Therefor the water has to constantly flow with the help of slopes and gradients of the terrain (Cutting et al. 2003). In alpine and subalpine areas, the natural contour lines were used whereas in the lowland the slopes mostly had to be created artificially.

There are several reasons the water meadow system in most areas of Central Europe are abandoned today. One is that during and after World War II many systems were neglected, no longer maintained and repaired, so they partly lost their function. Because of fundamental changes in agricultural processing the restoration was often not profitable. The many channels and ditches cutting through water meadows are making the parcels small and wet and therefore unsuitable for big and heavy machinery used in modern agriculture. This made the use inefficient and economical unsustainable for farmers. Another major reason for the abandonment was the introduction of artificial fertilizers, which replaced the fertilizing effects from the (waste) water led onto the meadows. To create larger parcels, channels and ditches at former water meadows were filled.

The typical vegetation of water meadows was very similar to mesotrophic wet meadows or more rarely litter meadows (Cutting, Cummings 1999; Galatowitsch et al. 2000; Fream 1888). Litter meadows are a type of wet grassland that cannot be used as hay for feeding livestock but as litter for the stables of the livestock. It mainly consists of hard sedges and other grasses, which the animals don’t like to eat. The litter is put into the stables to take up the dung and in spring this is brought mainly to the fields as manure. This means that nutrients from the litter meadows are extracted and there is no fertilization in form of manure. The meadows are only cut once a year in late summer or autumn. So litter meadows are characterized by wet and nutrient poor conditions together with being cut only once in late summer or autumn. They have become widely spread in the 19th century together with the increasing practice of keeping the livestock in the stables all year-round.

After the abandonment of the watering system meadows were degraded and going under succession becoming tall forbs communities, shrubs or forests. Also some areas were simply overbuilt with the extension of settlements.

History and development of the water meadow area in Isny im Allgäu are well documented (Konold 1991; Konold 1994; Herbst 1988). The water meadow system here can be accounted as the subalpine type. The treatment was able to improve the productivity of meadows significantly. The precipitation rate of the area is relatively high so irrigation because of dryness can be ruled out. Fertilization and frost protection were the main benefits expected for the watering.

In case of the water meadows of Isny several water sources where used. The main source was the small river Isnyer Ach, but also smaller streams like Schweinebach, Dreifingerbach, Riedbach, Kehlbach und Stadtbach were used (Konold 1991).

The water in these streams was rich in nutrients. It first passed through the settlement area of Isny im Allgäu. There it was used and enriched in nutrients by butchers, tanners, animal waste, human waste and kitchen waste. After flowing out of the settlement area it was spread over an ingenious system of channels, ditches and even aqueducts throughout the area shown in *Figure 1* (Konold 1991).

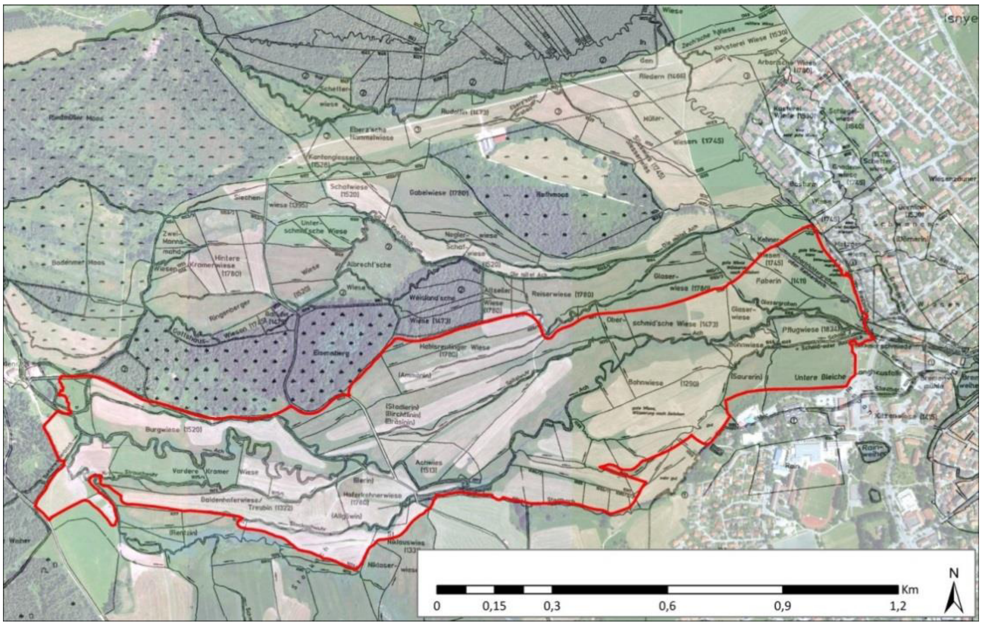

Figure 1. Overview on the historic water meadow area of Isny im Allgäu based on Konold (1991). The map was scanned and geo-referenced. In the background are the latest aerial pictures (Landesamt für Geoinformation und Landentwicklung 2013). The arrows along the streams and ditches indicate the flow direction.

In Isny im Allgäu the exact water amounts and times for watering were written down in a watering book and a water meadow master was employed by the water meadow society. He was responsible for the construction and maintenance work and regulated the water distribution and amounts for the meadows (Konold 1994).

For meadows on the same level as the river the supply of water was relatively easy. A wooden board in the water would create enough backwaters to lead water into outgoing channels to use for irrigation. For meadows that were located on higher elevation the water had to be taken from the water sources at an even higher elevation upstream. The water was transported over long distances ditches oriented along the contour lines of the terrain with a very slight gradient. Sometimes other subjacent water bodies had to be crossed so aqueducts were constructed. Remains of them are still visible today. When the water reached its target meadow the channels were dammed. The water would flow laterally out of the conduit and down the slope over the meadow. A lower parallel ditch would catch the water again. Finally, the water directly or indirectly over further ditches and meadows returned to the water source. The establishment of such a water meadow system required advanced knowledge and resources.

The first documentation of the use of a water meadow system at Isny im Allgäu dates back to 1290 (Konold 1991). After that the system expanded further and the technique became well established. Continuous maintenance measures and extensive regulations are documented (Konold 1994). For the already described reasons in the middle of the last century the water meadow system of Isny was abandoned completely.

The narrow system of ditches and the general unfavourable wet conditions made the cultivation unattractive for intensive farming.

The species-richness and close proximity to the settlement area on the other hand made the area attractive to conservationists and citizens of Isny. It is an important local and regional recreation area.

Big parts of these former water meadows are now preserved as part of the nature reserve "Bodenmöser". They are used extensively with mostly one or two mowing dates a year. The management measures are specified in management plans and contracts with local farmers.

The meadows in the study area are prone to succession processes if it wasn't for frequent management. Wet meadows and Litter meadows can only be preserved by regular mowing. Otherwise degradation and succession with shrubs and trees will consequently grow and come to dominance (Buttler 1992).

Grime (2001) describes this process a "hump-backed model". It basically states that plant species diversity is unevenly distributed along a productivity gradient (like a hump back). Under adverse conditions species diversity is also low but is increasing with also increasing nutrient availability and production. At a medium productivity level the maximum species diversity level is reached. More nutrients and productivity leads to steep decline in species diversity. This pattern is also confirmed by Havlová et al. (2004) by stating that wet meadows have a higher diversity than mesic meadows. The hump-backed model is caused by the higher growing plants coming to dominance as they shade smaller plants and displacing them (Lepš 1999).

This could also account for the study area. Fallow areas with different states of succession follow well known patterns. The first stadium is characterized by tall forbs communities. It leads to loss of species diversity (Jensen 1997). Few species become dominant. Filipedula ulmaria is one of those generalist tall growing species that typically comes to dominance in abandoned fen meadows. Species adapted to low nutrient levels disappear (Pauli et al. 2002). In the long run shrubs and later forests are following with ongoing succession (Jensen 1997). Many biotopes in the study area seem to be in an early stadium of succession.

Olde Venterink et al. (2001) describe the limitation of soil nutrients along a productivity gradient in wet meadows. It is pointed out that soil fertility in meadows is often reduced to promote biodiversity. This is a typical and often also successful procedure in nature conservation of meadows (Wittig et al. 2007), but there are clear indications that nutrient limitation is not a static characteristic. It varies in combination with other environmental factors such as soil moisture. Potassium is also proven to be a important limiting factor for moist organic soils (Olde Venterink et al. 2001).

Defining drivers for changes in species composition in fens can be trophy as well as pH-gradient (Hajek et al. 2006). Kapfer (2001) defines moisture levels as the most important driver, but also mentions trophy and soil acidity as additional abiotic factors. The most important abiotic limiting factors for species diversity are moisture, nutrient availability (trophy) and soil acidity/availability of bases (Zerbe 2009).

In relation to nutrient availability it is important to mention that this factor is easily influence by human actions (fertilization), but there is also diffuse unintended nutrients input. Diekmann (2003) evaluated changes in plant species composition in calcareous meadows in relation to atmospheric nitrogen deposition over a 70 year period. He found N-deposition was not a main driver in species decline, rather than soil water content. In contrast to this, the same question on acidic grassland showed notable correlations of atmospheric nitrogen deposition and species composition. Duprè et al. (2010) confirms the connection between increasing N-deposition and loss of species in nutrient-poor meadows.

1.1 Hypotheses and research questions

The master thesis is embedded in the NABU nature conservation project “Moore mit Stern” (Mires with a star), which is carried out by the Institute for Landscape and Environment (ILU) of the University of Nürtingen-Geislingen. The topic of this thesis is the comparison of three data sets recorded at the same study area in three different years. The study area is legally protected as a nature reserve by different national and European protection categories for its diversity of wetland and mire biotopes and its function as refugee for endangered species.

Long before the declaration as a nature reserve the area of the “Bodenmöser” have been of interest for scientific research. Raab (1982) did a plant sociological study for different meadow types in the area of today’s nature reserve Bodenmöser and another reserve in close proximity.

At the same time Ruppaner (1982) examined the N-cycle of differently used wetlands at the same area. Before the implementation of the nature reserve in 1990 several reports enforced the legal protection of the area with a specific focus on the meadows.

Already Bauer (1973) pointed out the importance of the mire and wetland complex for nature conservation purposes and made an application for the area being legally protected.

Groß (1980a; 1980b) underlined the importance to include the meadows into the nature reserve. She emphasizes their function as habitats for endangered meadow breeding bird species and their function as essential link between the raised bogs areas of the reserve.

The meadows are also valued by the Bezirksstelle für Naturschutz und Landschaftspflege Tübingen (1990). All those studies built the scientific foundation for the implementation of the area as a nature reserve as well as part of the Natura 2000 network.

Now since the declaration as a nature reserve in 1990 until today several local experts and from the responsible Regional Council Tübingen increasingly suspected that the plant species diversity in the former water meadows has decreased. Some plant species seem to have become dominant and superseded others. This of course would contradict the goals of the nature reserve (Dechert 2000).

Also local farmers are complaining about mosses spreading on the meadows, which make them lose their value for grass production. This in turn makes the use of the meadows for farmers unprofitable. Even though the farmers are paid for mowing the meadows through management contracts they have with the Regional Council Tübingen, this doesn't seem to be enough of an incentive. It is hypothesized by local authorities that the changes in plant composition are caused by changes in the environmental conditions as a result from the abandonment of the water meadows. Considering the main purposes of watering was fertilization, it seems reasonable to assume decreasing nutrient availability. Also dropping soil moisture can be considered as a reason. The discontinued watering practice also stopped the input of bases to the meadows. Therefore increasing soil acidity can be hypothesized.

Most recently several parties wished for the practice to be re-established at least in parts of the area. They are hoping this would stop the ongoing changes and hopefully correct the degrading processes.

Now to closer examine the hypotheses on ongoing processes in the study area and enable insight on possible changes of the environmental conditions the method of indicator values was chosen. Indicator values describe the ecological behaviour of plant species. This means the behaviour of plant species under the influence of competing species. Ellenberg et al. (2001) established a systematic scheme classifying plant species based on their ecological behaviour on the environmental factors Light, Continentality, Temperature, Moisture, Reaction and Nutrients. He derived those factors from the geographic distribution of species and from studies on the physiological and sociological behaviour of a vast majority of the European plant species. The method is well established in plant ecology. It has been used and evaluated in many scientific studies. Comparisons of the Ellenberg values with field measurement confirmed their general validity (Schaffers, Sýkora 2000); especially for comparisons of similar vegetation types (Wamelink et al. 2002).

In this thesis only Moisture, Reaction and Nutrients are considered. They were also identified as the most important abiotic factors for biotope changes in wet meadows by Kapfer (2001).

Moisture represents the range of soil moisture from very dry shallow soil (e.g. rocky precipices) to wet swamp soil and even flooded soils. Expressed in numbers, the range goes from 1 = very dry soil conditions to 9 = wet soil conditions. Only in the Moisture range three more levels are added to represent 10 = periodically flooded to 12 = permanently flooded conditions.

Reaction represents the range of soil acidity or alkalinity. It ranges from 1 = very acidic conditions to 9 = base-rich/calcareous conditions.

Nutrients represent the accessibility to mineral nitrogen during the vegetation period. It ranges from 1 = nitrogen-poor conditions to 9 = overly nitrogen-rich conditions.

Ellenberg indictor values for Light, Continentality, Temperature and Salinity values have been included in the analysis at first, but the results added no relevant information to the species and biotope distribution or the changes in environmental condition. Therefore they were excluded from the analysis.

Calculating mean values from the indicator values bears some problems, because the levels of each indicator values are not cardinal. This means they are not a series of numbers that result from summing the values up. The levels are not divided in equal intervals. Therefore the calculation of means is actually not allowed. Zelený, Schaffers (2012) points out that this can cause biased results and cause misinterpretations. Despite of this it is recommended in many studies for practical use (Kowarik, Seidling 1989; Diekmann 2003; Durwen 1982). It also has to be kept in mind that the intervals, especially for the indicator values Moisture, Reaction and Nutrients, are overlapping (Ellenberg et al. 1992; Böcker et al. 1983). Ewald (2003) proved that also incomplete datasets can offer satisfying mean indicator values for biotopes.

Research questions

With regards to the stated hypotheses the following research questions for this thesis have been formulated:

Has the plant species composition of the study area changed from 1987 to 2014?

- Have species disappeared or new occurred?
- Do those species indicate changes of the local conditions based on Ellenberg's indicator values?
- Have endangered species disappeared?
- Has biodiversity decreased?
- Are there plant species associated with specific years?
- Have the biodiversity hotspots changed?

Has the spatial distribution of biotopes changed from 1987 to 2014?

- Have biotope types disappeared or new occurred?
- Have the areas of the biotope types changed?

Can changes in the plant species compositions be explained by the local conditions (Ellenberg's indicator values) or the management of the area?

- Are there correlations between species composition, indicator values and management variables?
- Which variables can explain the plant species composition?
- Which drivers are responsible for the distribution of plant species and biotopes?
- Which implications on the management measures can be derived from the results?
- How did the indicator values vary over the years?

2. Materials and Methods

2.1 Description of the study area

2.1.1 Geographical position and protection status

The study area of this master thesis is about 2.1 km long and about 0.4 km wide (*Figure 2*). The area is 79.8 ha. It is located in southern Germany in the south east of the federal state of Baden-Württemberg (*Figure 2*). It verges on the town Isny im Allgäu which is part of the administrative district of Ravensburg. All analyses and comparisons for this thesis are focused on this study area.

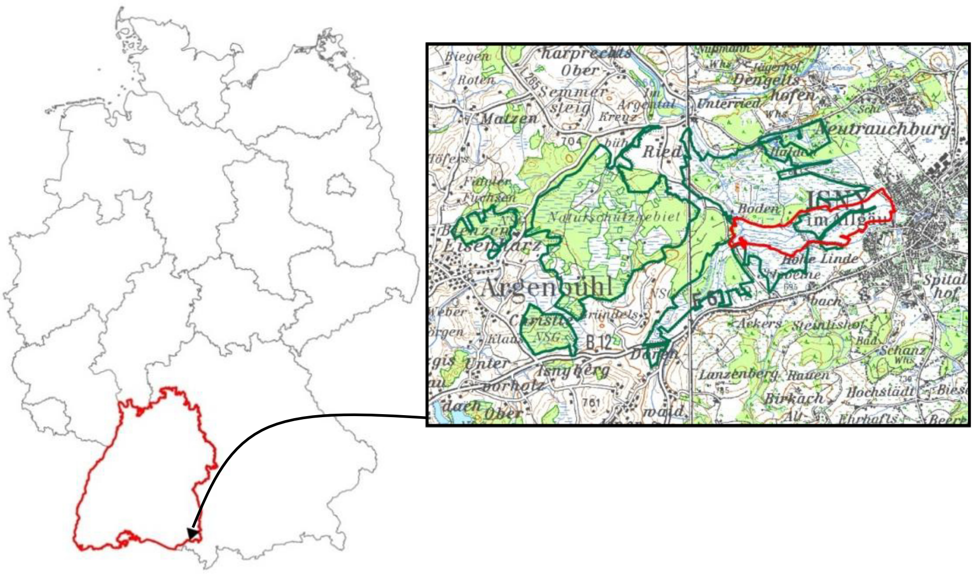

Figure 2. Federal republic of Germany with federal states (left side). The red outline marks the federal state of Baden-Württemberg, where the study area is located. On the right side the town Isny im Allgäu. The red outline marks the study area and the green one the nature reserve "Bodenmöser".

The study area is by a large extent covered by the nature reserve “Bodenmöser” (*Figure 2*) and its serving landscape protection area “Bodenmöser” which works as a buffer for the 606.6 ha wide nature reserve. It is also within the extent of the Special Protected Area (SPA) “Bodenmöser” and the Flora-Fauna-Habitat Area (FFH) “Bodenmöser und Hengelesweiher” and therefore part of the European Natura 2000 program (*Figure 3*).

The need for protection and the importance of the area for nature conservation and biodiversity interests is underlined by the different protection categories overlapping each other (*Figure 3*).

The western part of the nature reserve is defined by raised bogs and surrounding forests whereas in the east, where the study area is situated, wet meadows, litter meadows, tall forbs communities, reeds and sedge fens are prominent.

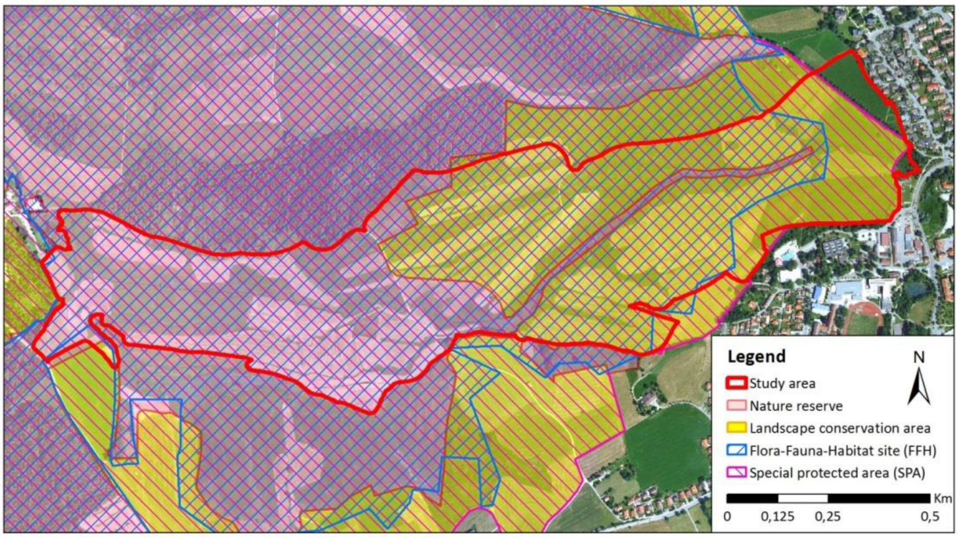

Figure 3. Study area (79.8 ha) with different categories of protection.

The nature reserve stands out with its extensive mosaic of different types of wetlands. Several raised bogs are part of the reserve including their surrounding fens and marshes which are often merging into one another. The site is exemplary of its natural sequence of mire development, which is very rare at this extent and in this part of the country. A large variety of biotopes developed under the conditions of those different types of wetlands. The close linkage and spatial proximity of those biotopes are what makes the area special and worthy of protection (Bezirksstelle für Naturschutz und Landschaftspflege Tübingen 1990).

Most important for this study are the grassland biotopes of the marshes, like litter meadows, wet meadows and small sedge fens. They bear a large variety of endangered species of flora and fauna. To define states of endangerment of plants their status in the red list of Baden-Württemberg is used (RL BW) (Breunig, Demuth 1999).

Examples for endangered plant species in the study area are Iris sibirica (RL BW 2), Gentiana verna (RL BW 2), Pedicularis palustris (RL BW 2). Also the large abundances of Trollius altissimus (RL BW 3) and Dactylorhiza majalis (RL BW 3) make the site stand out. A complete list of species found in the nature reserve and their status of endangerment based on Breunig, Demuth (1999) can be found in 8.1 Appendix 1.

The area is feeding and breeding habitat to many animal species. Within the class of aves the highly endangered Corn crake (Crex crex) is worth mentioning. There are 25-30 breeding couples left in Baden-Württemberg (Hölzinger, Boschert 2001). The study area is one of the very few sites where it is detected regularly. Also large abundances of the Eurasian skylark (Alauda arvensis) and several whinchats (Saxicola rubetra) use the meadows for breeding. There are several nests of the white stork at the town edge of Isny. This specie uses the meadows as feeding habitat (Bezirksstelle für Naturschutz und Landschaftspflege Tübingen 1990).

Also many butterflies can be found in the meadows and the tall forbs communities. Examples are the moorland clouded yellow (Colias palaeno), lesser marbled fritillary (Brenthis ino) and large copper (Lycaena dispar). Especially the moorland clouded yellow is dependent on raised bogs and wet meadows in close proximity to each other as it needs the one for breeding and the other for feeding (Bezirksstelle für Naturschutz und Landschaftspflege Tübingen 1990).

It is not only the animal and plant species that are endangered. The different wetland biotope types themselves are also at threat. Intensification of agricultural use is the main reasons for the decline of this biotope type on an international scale. Especially drainage and high fertilizer rates are able to change the site conditions so they become more suited for agricultural production. Litter meadows, small sedge communities and wet meadows are more and more replaced by fields and intensively used grassland all over Europe (Verhoeven 2014; Joyce 2014). This trend is also observable in the area around Isny. The grasslands surrounding the nature reserve are mostly under intensive use. Only in protected areas - such as the nature reserve “Bodenmöser” - those extensively used biotope types can be protected and maintained.

2.1.2 Geology and Hydrology

The morphology of the region is characterized by moraine hills and glacier basins formed through glacial periods. This landscape is typical for the nature unit of the northern alpine upland. Isny and the study area are situated in a basin (Isny basin) that was carved out by glaciers. Eventually it was filled up with fluvial sediments like clay, sand and gravel. The clay sealed the basin and a temporary lake filled with melting water from the glaciers was formed. From the lake mires formed. Also the hydrogeological conditions supported the development of mires. Artesian confined groundwater is pressing to the surface through the gravel layers beyond. It emerges from the ground as springs or extensively. One example is the spring of the Isnyer Ach, a small river which is flowing through the study area from east to west.

The elevation in the study area is around 680 m above sea level. The soil is characterized by the upmost peat layer that is varying in thickness and level of decomposition. The thickness ranges from a few centimetres to several meters. The Moorland cadastre Baden-Württemberg defines the mire type as fen (Göttlich 1975).

At some locations topsoil from other locations and building rubble was used to transform the natural surface morphology with slight inclines and dams in order to establish a water meadow system. Related to this also ditches for irrigation and drainage were dug which are still observable. Most of seem still to be functional. Therefore they are relevant factors influencing the hydrological conditions in the area.

2.1.3 Climate

The closest climate observing station is located in Leutkirch and Leutkirch-Herlazhofen about 14 km from the study area.

The mean temperature in the period from 1981-2010 was 7.7 °C within a range of -1.4 in January and 17.2 in July (Table *1*). Precipitation in the period 1981-2010 was 1278.0 mm/y with its peak in June with 149.0 mm and 100.6 mm in October (Climate Data Centers (CDC) 2014) (Table *2*).

The basin situation together with the mountain chain in the east (Schwarzer Grad, Allgäuer Alpen) probably contributes to even higher precipitation rates in Isny compared to Leutkirch. The climate conditions supported the development of mires in the area where the nature reserve is situated today.

Table 1: Average temperature 1996-2014, at Leutkirch-Herlazhofen meteorological station (id 7403), Germany (Climate Data Centers (CDC) 2014).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year
-1,4	-0,6	2,7	7,2	12,1	15,1	17,2	16,5	12,6	8,4	2,7	-0,3	7,7

Table 2: Average precipitation 1996-2014, at Leutkirch meteorological station (id 2967), Germany (Climate Data Centers (CDC) 2014).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year
82,0	77,0	94,0	89,0	120,0	134,0	149,0	134,0	108,0	89,0	94,0	108,0	1278,0

The study area was selected based on information on the location and extent of the former water meadow system as it was described by Konold (1991). There are plans to re-establish the old watering technique at least in some parts of the area, so access to water from the Isnyer Ach and conditions of the old ditches were also factors taken into account for the differentiation of the study area. The selected study area has the greatest potential for the restoration plans.

2.2 Description of field methods

The mapping of the study area - meaning the process of differentiating the different biotope polygons in the field - took place from the 14th of May to the 2nd of July 2014. As there was a relatively mild winter 2013/14 and a relatively early and warm spring the vegetation period was about 2 weeks further in progress compared to the annual average. The biotope mapping was concentrated on a ca. 400 m wide and 2 km long band from the area of the “Bodenmühle” (a saw mill) in the West to the very edge of the peat deposition which at the same time is the edge of the settlement area of Isny im Allgäu in the east (*Figure 3*). The border in the South was a gravel path.

The classification of the biotope type was done according to the method described in Breunig et al. (2009). This method of Breunig et al. (2009) is commonly used in Baden-Württemberg to identify, describe and evaluate species, biotopes and landscapes. It was created to unify terms and parameters raised and is used for all projects of public authorities concerning nature conservation. It was first introduced in 1997. In 2009 the fourth and most recent edition was released. The method includes both biotope types located in the countryside as well as in settled areas. All biotope types are listed hierarchically and coded. The code is four-digit. The first two numbers name the biotope group. The last two numbers specify the type and subtype.

Example: The biotope type code 33.22 consists of the biotope group number 33.00, which is “Meadows and Pastures” (orig. “Wiesen und Weiden”). The second part of the code stands for the biotope type 33.20, which is “Wet meadows” (orig. “Nasswiesen”). The last number specifies the subtype of the biotope type 33.22, which is “Wet meadows of base-rich conditions of mountainous regions” (orig. “Nasswiesen basenreicher Standorte der montanen Lagen”). The mapping for this thesis did not include the subtypes. It stayed on the level of biotope types e.g. 33.20.

The biotopes were differentiated in the field using colour aerial pictures from 2013 with official land parcel lines at 1:2.000 scale. For every biotope a polygon was differentiated and a prepared data sheet was filled out in German language. The requested data fields were date, processor, plot number, working title, photo number, description, plant species with abundance, shrub cover and moss cover. For the plant species identification several different identification books were used (Schmeil, Fitschen 2011; Oberdorfer 2001; Jäger, Rothmaler 2013; Eggenberg, Möhl 2009; Rothmaler, Jäger 2011; Lüder 2013).The final nomenclature in this thesis follows (Kubát, Bělohlávková 2002). A list of original species names used in the data sheets and their corresponding names according to Kubát, Bělohlávková (2002) can be found 8.3 Appendix 3. Moss species were not identified. The abundance of the plant species was noted based on a four-stage scale (Table *3*).

Table 3. Plant species abundance abbreviations in German and English and their corresponding number.

Abbreviation	German	English	Numeric expression
W	wenige	few	1
M	mehrere	several	2
Z	zahlreich	numerous	3
D	dominant	dominant	4

German names of the biotope types have been translated. A list can be found in 8.5 Appendix 5.

After the field work the paper maps with the 135 differentiated biotopes were digitized as polygons and attributed with their biotope type using ArcGIS 10.2 (ESRI 2011).

Also two historic data sets were used for analysis. The oldest data set was mapped in 1987 for the designation as a nature reserve in 1990. The 1987 dataset is a part of the background report for the acknowledgment of the area as a nature reserve (Bezirksstelle für Naturschutz und Landschaftspflege Tübingen 1990).

Report, maps and copies of the original data sheets for the polygons were available in paper form. The paper maps have been scanned, geo-referenced, digitized and attributed using ArcGIS 10.2 (ESRI 2011). The program was also used for geo-referencing ("Geo-referencing" toolbar) and clipping ("Analysis" toolbox-> "Extract" toolset-> "Clip" tool) the inventory from 1987 to the extent of the study area.

The method of the biotope inventory 1987 was established by Schwertle (1987). The data sheets had header data (processor, date, plot number on map, field number, area and slope) and open data fields (description/stock and management measures). Additionally the biotope type with its corresponding state and successional stage and the target biotope type with its corresponding state and successional stage were noted in code. Also the maintenance measures, maintenance effort, maintenance cycle, maintenance time, maintenance design, maintenance mode and their priority were put in code (8.2 Appendix 2). An exemplary data sheet and species list is provided in 8.3 Appendix 3. It was not recorded a complete species list with all species growing at the polygon but rather it is a selection of species determining the biotope type and its state.

37 polygons with according data sheets were located within the study area in 1987. Three sheets could not be included as they couldn't be read because the writing had faded. Also biotope datasheets existed only for biotopes within the extent of the nature reserve "Bodenmöser". Biotopes exceeding the nature reserve border, but which were still within the landscape conservation area, were also recorded by the processor. For those biotopes only information on the biotope type and the maintenance measures were available, but no data sheets with species information were created.

The second data set is from 1997. The processor in this year was not the same as in 1987. The whole area of the nature reserve was mapped in spring 1997 together with large parts of the surrounding landscape protection area for updating the maintenance and development plan from 1989. This plan consisted of a report, maps and data sheets for all biotopes (Dechert 2000). The report and data sheets with corresponding species list were available in PDF form. The maps were in ArcGIS format. They were clipped to the extent of the 2014 inventory just like the one from 1987. Geo-referencing was not necessary.

The method for the plant inventories of 1997 was based on a preliminary edition of the first edition of the biotope mapping key designed by Breunig, Demuth (1999), which later version was also used for the mapping in 2014 (Breunig et al. 2009). There were slight changes made by the author. Those changes included a sometimes more specific definition of biotope types including additional subtypes, which are not included in the method. This had no influence on the analysis process of this thesis as subtypes where not taken into account. All analysing procedures where based on the biotope type level.

The mapped area of 1997 covers about 80% of the 2014 study area. For 1987 about 60% of the 2014 study area is covered. This can be explained by the fact that 1987 species information was only collected for biotopes within the extent of the nature reserve. 1997 also the species for the biotopes within the extent of the landscape protection area were mapped. 2014 all biotopes within the extent of the peat layer were mapped which extended the landscape protection area in the eastern study area.

All information on the biotopes and the according species lists were entered and summarized in a table using the software VEGEDAZ (Küchler 2014). For every year of observation an excel table was created.

For all species the corresponding indicator values were found using the software JUICE 7.0 (Tichý 2002). The values of the software are based on Ellenberg et al. (2001).

For this thesis Ellenberg's indicator values Light, Continentality, Temperature, Moisture, Reaction and Nutrients were used. Only the indicator values "Moisture", "Reaction" and "Nutrients" are used in the following Analysis and Results part. "Light", "Temperature", "Continentality" and "Salinity" are not relevant and showed to have no significant impact on the species composition in various test runs. Therefore results on those indicator values are not presented or discussed in this thesis.

Based on the indicator values of the individual species of a biotope, mean values for every single biotope were calculated. To avoid mean values that are based on a very small number of species values, because many species were classified as indifferent, a rule was established. If less than 5 species of a biotope had a value for one indicator or less than 20% of the sum of species had a value for one indicator, the biotope was left without a value for this specific indicator. The fact that there are much less species building the mean for the 1987 biotopes has to be kept in mind, even though Ewald (2003) proved that also incomplete datasets can offer satisfying mean indicator values for biotopes.

Additionally from the maintenance measures noted on the data sheets some explanatory variables were derived. Two maintenance variables could be derived from the data for comparison of all three years:

- Mowing frequency (1= mown every 2 years, 2= mown once a year, 3= mown once to twice a year, 4= mown twice a year)
- Mowing month (6 = June, 7 = July, 8 = August, 9 = September)

The measures noted for each biotope of one historical dataset were implemented for the following time period. Therefor the measures mentioned for a biotope in 1987 had influence on the species composition of the following species inventory in 1997; and likewise the 1997 on the 2014.

2.3 Description of GIS methods

The differentiation of polygons aimed to show their real spatial position and extent at the specific time. But this also means that they differ in spatial position and extent over the years. To be able to look at the development of the polygons over time a method needed to be established to find spatially matching polygons from all years. Therefore the area of all polygon polygons from 1987, 1997 ad 2014 were calculated in ArcGIS (ESRI 2011). As the extent of 1987's mapping are the earliest data and was the smallest in extent, both later mappings were clipped to this extent. Then the area of the polygons included in the 1987 clip was calculated again. The polygons from 1997 were intersected with those of 1987 using the "Intersect" tool from the "Overlay" toolset of "Analysis" toolbox. The same was done for the 2014 and the 1987 polygons. In the attributes table of the new intersectionshapes a field was added to calculate the new area of the individual polygons. The dbf-table file of the shape was then loaded with Microsoft Excel and sorted after the polygon numbers of the 1987 polygons. Then the percentage of the 1987 polygon matching a 1997 polygon was calculated. If more than 50% of the 1987 polygon was covered by a polygon from 1997 the polygons were marked as matching. Additionally it was also calculated the percentage of which a 1997 polygon is contained in a 1987 polygon. If more than 50% of the 1997 polygon was included in the extent of the 1987 polygon and it made up more than 50% of the 1987 polygon it was also a match. Or if they combined with other polygons, from which more than 50% are included in the 1987 polygon, made up more than 50% of the area of the 1987 polygon, they were also marked as a match.

The same criteria were used to find matching polygons for the comparison of 1997 and 2014.

For 17 of the 37 polygons of the initial year 1987 matching polygons from 1997 and 2014 were found. For the comparison of 1997 and 2014 42 matching polygons were found out of 97 polygons from 1997.

2.4 Description of statistical methods

The statistic software R (R Development Core Team 2008) first was used to create boxplots of the mean indicator values on Moisture, Reaction and Nutrients for all years. The whisker interval represents the 95% concentration interval based on the standard deviation. Also the mean Shannon index was calculated for every year and presented in boxplots. The Shannon index describes the variety of the data, taking into account both the number of different categories of data (e.g. number of species) and abundance (number of individuals per species).

The Detrended correspondence analysis (DCA) was used on the polygons matching all three years (Hill, Gauch 1980). Polygons from the same year were enveloped to visualize the differences in plant species composition between the years.

The mean indicator values from the different years then were tested for being significantly different from each other. This was done using the Statistics menu "Univariate" in PAST. A one-way ANOVA (analysis of variance) tested for equal means. A p-value lower than 0.05 indicates no significant difference.

PAST was also used to calculate the means of the Shannon diversity index as well as the species diversity on each polygon of every year using the diversity menu. Then for every year means on the Shannon diversity index were built and presented as boxplots together with means on the species diversity on every year.

To see which indicator values had the most influence on the species variation first a direct method was chosen. A Canonical Correspondence Analysis (CCA) was performed with R based on the method of Legendre, Legendre (2012). It is a multivariate constrained ordination method used to extracts relevant gradients among a number of combinations of explanatory variables in a dataset (Legendre, Legendre 2012). In case of this thesis the explanatory variable are indicator values by Ellenberg et al. (2001) and variables derived from the management measures. The indicator values used are Moisture (soil moisture), Reaction (soil acidity) and Nutrients (Nitrogen availability). The management variables are mowing month (6= June, 7=July, 8=August and 9=September) and mowing frequency (1= mown every second year, 2= mown once a year, 3= mown once to twice a year and 4= mown twice a year). The CCA showed that several explanatory variables have very little explanatory value for the species and biotope distribution. Therefore an indirect method was chosen to analyse the data again. This time the Detrended correspondence analysis (DCA) was used. It only displays explanatory variables with significant values (p= 0.05). For every year a DCA was done with the available indicator values and managment variables. The “envfit” function of the “vegan” package (Oksanen et al. 2015) was used to find the indicator values and explanatory variables that correlated to the species and biotopes in the DCA. The p-value level in the analysis was set to p= 0.05.

The software R 3.2.1 (R Development Core Team 2008) and R packages "labdsv" (Roberts 2013), "vegan" (Oksanen et al. 2015), „permute“ (Simpson 2015) and "lattice" (Deepayan Sarkar 2015) were used to determine how well each species could be used as an indicator for a biotope or year and to display them, following the method developed by Hill, Gauch (1980).

The “adonis” function from the “vegan” package (Oksanen et al. 2015) was used to test if the species compositions of the different years differ significantly from each other with a distance matrice.

The “indval” function from the package "labdsv" (Roberts 2013) was used to calculate indicator values (relative abundance and fidelity) of species and to show whether there are species correlated with speciefic years.

DCA was also used to determine whether the species composition has changed over time and whether there are species significantly correlated with specific years.

Basing on the 1987 extent for all years the total percentage of biotope types was calculated to show changes in the areas of biotope types. Also the most frequent species, the biotopes with the most species and the species that only occurred in one year were identified.

3. Results

The results are separated into the descriptive comparisons that have been made, based on the data of all three years. At first the data is descriptively analysed. Then statistical analysis methods are used to compare the datasets on all three years followed by the comparison on the more extensive data of 1997 and 2014.

3.1 Descriptive Characteristics

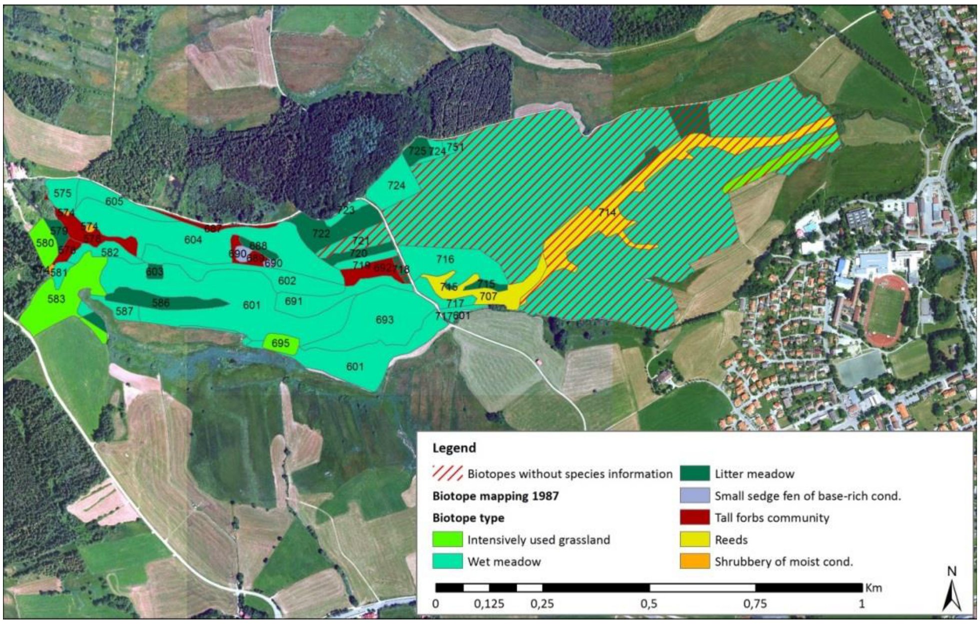

Figure 4. Map of biotopes from 1987 mapping clipped to the extent of the study area. Only the numbered polygons are part of the nature reserve. The hatched areas are not included in the nature reserve and have therefore no species information or the datasheets were in unreadable condition.

In the 1987's mapping there are 44 polygons but only 37 are part of the nature reserve and therefore have data sheets with species information (*Figure 4*). Three of them weren't readable.

Wet meadows are the most present biotope type in the '87's mapping. They make up around 75% of the whole area. It is followed with a great distance by reeds (ca. 7%). They are concentrated at the eastern part of the study area along both banks of the Isnyer Ach. Litter meadows often have small areas (ca. 6%) and intensively used grassland (ca. 5%) are spread all over the study area. Tall forbs communities are small sedge fens of base-rich conditions and shrubs of moist condition account only a small portion (combined about 3%) of the study area. In those biotopes 117 different vascular plant species were found.

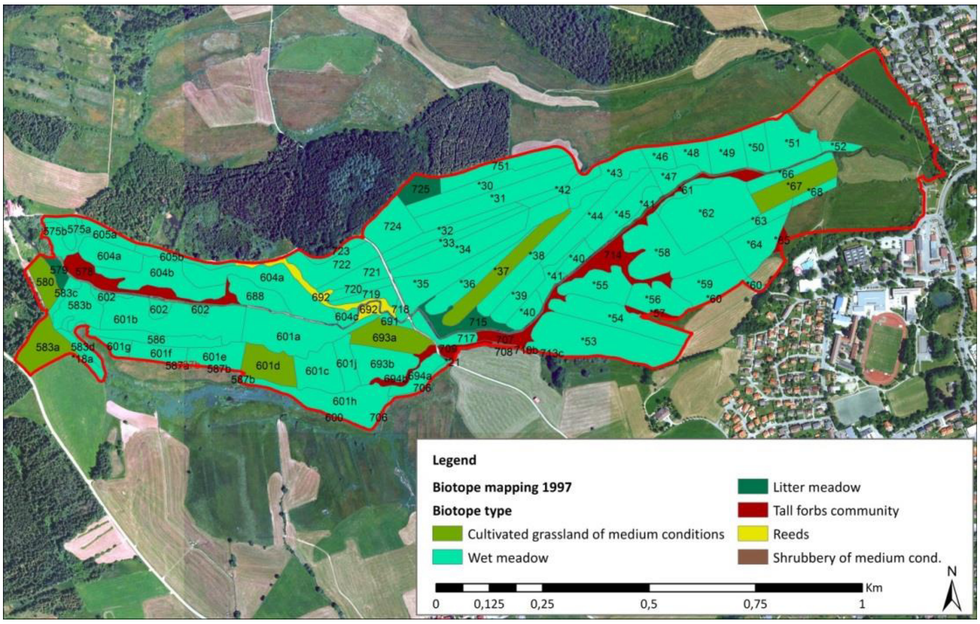

Figure 5. Map of biotopes from 1997 mapping. The biotopes that have numbers with an asterisk in front are not part of the nature reserve but of the landscape protection area.

In 1997 104 polygons were recorded in the study area (*Figure 5*). The number codes of the 1997 biotopes are superimposed on the mapping of 1987 (*Figure 4*). Often areas which were differentiated as one biotope in 1987 have been further divided, e.g. biotope number 605 in 1987 was divided into 605a and 605b in 1997. In the eastern part of the map most numbers have an asterisk in front. This marks polygons located outside the nature reserve but which are still part of the landscape protection area. A total of 214 plant species were found in the 1997 mapping.

The meadows are dominated by wet meadows (about 70%). Cultivated grassland of medium conditions can be found distributed over the study area. Tall forbs concentrate along the small river and its inflows as well as its outflows. Reeds are found along a big outflow of the Isnyer Ach. This outflow was formerly used for leading water into the meadows. The biotope type “shrubs of medium conditions” can only be found in the very south of the middle part of the study area.

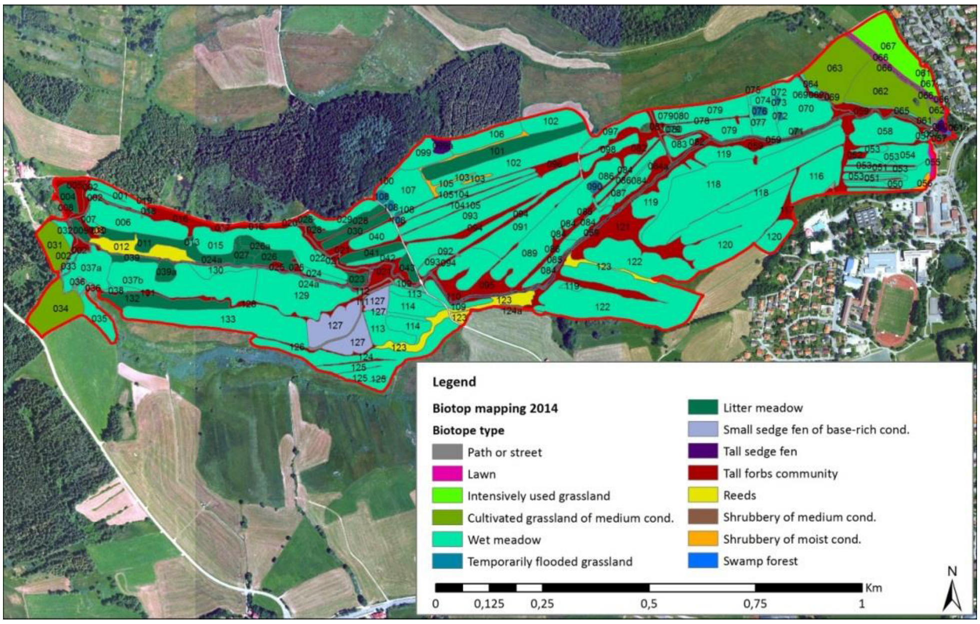

Figure 6. Map of biotopes from 2014 mapping.

When looking at the spatial distribution of the different vegetation types in 2014 it becomes obvious that wet meadows are the most dominant. About 70% of the area is covered with this vegetation type (*Figure 6*). The water bodies Isnyer Ach and the many channels and ditches are mostly accompanied by tall forbs communities and reeds. In the east bordering at the settlement area the meadows are used more intensively illustrated by the intensively used grassland. The western part bears the majority of litter meadows and all small sedge fens. The shrubs of moist conditions are mostly build up by Salix species growing along the water bodies as single shrubs or grouped together in the north of the middle part. Shrubs of medium conditions can only be found in the very south of the middle part of the study area. The relatively low percentage of shrub biotopes does not represent the spread of shrubs in the area. Often they are interspersed in other biotope types, especially in tall forbs communities. Temporarily flooded grassland occurred on relatively small areas often at the ends of ditches where the open ditch leads into a pipe and water is occasionally accumulated. Tall forbs communities have only been found at one location in the very north of the middle part.

When comparing *Figure 4*, *Figure 5* and *Figure 6* it becomes clear that mapping acuity got higher with every time step. It has to be kept in mind that the mappings were done by different people with 2014’s mapping is far more detailed and more biotope types have been differentiated. Especially the 2014 mapping is more divers looking at the number of different biotope types. This is partly due to the larger mapping area which also included biotopes at the edge of the settlement area. Those are swamp forest and lawn. Also paths and streets were not included in the former mappings.

When looking at the share of tall forbs communities in 2014 compared with the former years they have spread along the ditches.

1987 the species number is markedly lower than 1997 and 2014. This can be traced back to the diverging mapping method. Species number comparing 1997 and 2014 are about the same (214 and 211).

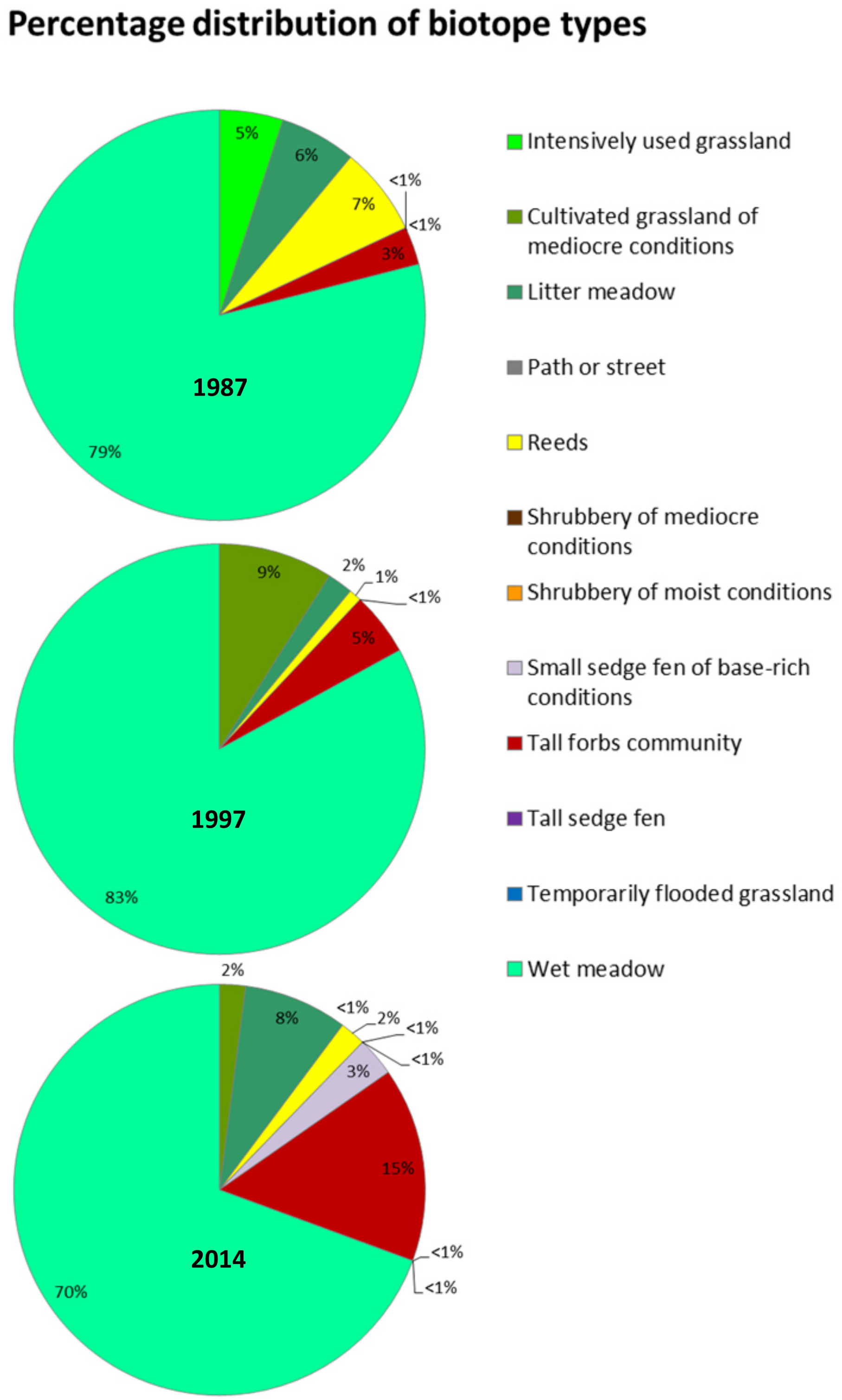

Figure 7. Percentage distribution of biotope types in 1987 (top), 1997 (middle) and 2014 (bottom).

Looking at the development of the percentage distribution of biotopes shows that wet meadows are in all three years the most common biotope type (*Figure 7*). They are characterizing of the study area. Tall forbs communities are constantly increasing. The development of the other biotope types is not continuous, which can be explained by different mapping methods 1987 and the different levels of detail as well as the different processors.

Table 4. *Species that occurred most frequently over the years: Species which also occur in the top 5 most frequent species in the later years are marked in grey. The second column gives the number of biotopes the species were found in and the total number of biotopes.*

1987		1997		2014	
Anthoxanthum odoratum	25/35	Caltha palustris	80/96	Filipendula ulmaria	111/135
Ranunculus acris	22/35	Filipendula ulmaria	80/96	Holcus lanatus	98/135
Filipendula ulmaria	21/35	Anthoxanthum odoratum	72/96	Ranunculus acris	97/135
Caltha palustris	19/35	Ranunculus acris	65/96	Bistorta maior	93/135
Carex disticha	17/35	Cirsium rivulare	64/96	Caltha palustris	92/135

There are three analogies within the top five most frequently occurring species of all years (Table *4*). These are *Ranunculus acris, Filipendula ulmaria, Caltha palustris*. *Anthoxanthum ododratum* appears in two years.

Table 5. *Biotopes with most present species for all years. Given are the number of the biotope and the number of species of it. Same colours mark matching biotopes.*

1987		1997		2014	
Biotope nr.	Species nr.	Biotope nr.	Species nr.	Biotope nr.	Species nr.
579	39	725	55	119+130	63
603+722	37	715+714	52	41	61
586	36	*66	50	131	59
575+720	30	720	47	132	58
725	28	586	46	039a+095	55

There are two polygons which have continuous high numbers on plant species on all three years (Table *5*). These are polygons 586, 586 and 132 ('87, '97, '14) and 720, 720 and 41 ('87, '97, '14). Both polygones are identified as litter meadows in all three years. They are marked green and cyan. Further matching biotopes on only two years are marked yellow, red and pink. Those are 603 and 039 ('87 and '14, litter meadows), 725 and 725 ('87 and '97, litter meadows) and 715 and 095 ('97 and '14, tall forbs communities).

Table 6. *Species that occurred only in one year. Empty cells have no values in Ellenberg (2001). An x stands for indifferent behaviour. M = Moisture, R= Reaction (soil acidity) and N = Nutrients.*

1987	M	R	N	1997	M	R	N	2014	M	R	N
Bromus racemosus	8	5	5	Elytrigia repens	x	x	7	Achillea millefolium			

Tofieldia calyculata	8	8	2	Blysmus compressus	8	8	3	Alliaria petiolata	5	7	9
				Calystegia sepium	6	7	9	Aquilegia vulgaris	4	7	4
				Campanula rotundifolia	x	x	2	Artemisia vulgaris	6	x	8
				Capsella bursa-pastoris	5	x	6	Carex diandra	9	6	3
				Leucanthemum vulgare				Carex muricata	4	x	6
				Dactylorhiza maculata	8	x	2	Convolvulus arvensis	4	7	x
				Eriophorum angustifolium	9	4	2	Epilobium ciliatum			
				Euonymus europaea	5	8	5	Epilobium montanum	5	6	6
				Hypericum perforatum	4	6	4	Equisetum arvense	x	x	3
				Juncus acutiflorus	8	5	3	Eupatorium cannabinum	7	7	8
				Nasturtium officinale	10	7	7	Geranium palustre	7	8	7
				Orchis morio	4	7	3	Geum urbanum	5	x	7
				Primula elatior				Hypericum maculatum	6	3	2
				Ficaria verna				Hypericum tetrapterum	8	7	5
				Rhamnus catharticus	4	8	4	Hypochaeris glabra	3	3	1
				Trifolium dubium	4	6	4	Juncus articulatus	9	x	2
				Typha latifolia	10	7	8	Juncus compressus	8	7	5
				Veronica anagallis-aquatica	9	x	6	Juncus tenuis	6	5	5
				Veronica arvensis	x	6	x	Lamium album	5	x	9
				Viburnum lantana	4	8	4	Medicago polymorpha	3	7	5
								Nardus stricta	x	2	2
								Paris quadrifolia	6	7	7
								Persicaria maculosa	5	7	7
								Petasites albus	6	x	5
								Plantago major			
								Poa annua	6	x	8
								Polygonum aviculare	4	x	6
								Potentilla anserina	6	x	7
								Primula veris	4	8	3
								Pteridium aquilinum	5	3	3
								Rhinanthus alec-	4	7	3

torolophus			
Scrophularia umbrosa	9	8	7
Scutellaria galericulata	9	7	6
Senecio jacobaea	4	7	5
Stellaria alsine	8	4	4
Veronica beccabunga	10	7	6
Veronica serpyllifolia	5	5	5

There are some species that have only been detected in one specific year (Table *6*).

For 1987 there are only two species which have been found in that year but in none of the following mappings. Those species are *Bromus racemosus* (RL BW 3) and *Tofieldia calyculat* (BW RL 3) and both are considered as endangered. They also represent rather moist condition based on their indicator values.

When looking at the indicator values of plant species that were only found in 1997 they show two separated trends. There are several species ranging between indicator values of 10 to 8, which represent moist to very wet conditions. On the other hand there are also several with a value of 4 or 5 which means moderately dry to fresh conditions. The Reaction values mostly range between 4 and 6 giving moderately to rather low acidity levels of the soil. The majority of indicator values for Nutrients range in the 2 to 4 section representing low to moderate nutrient levels, but also some species with rather high values on Nutrients.

The species that have only been found in 2014 show no obvious trends on the Moisture values. There is no clear trend to wetter or drier conditions visible as values for vary a large range between 4 and 9 (rather dry to wet). The plants values on Reaction (soil acidity) have a clear majority of the value 7 (low acidity).

Table 7. *Species which have disappeared from the study area. They have been found in 1987 and 1997 but haven't been confirmed in 2014.*

	Ellenberg value			
	Moisture	Reaction	Nutrients	Red list Baden-Württemberg
Carex hostiana	9	6	2	2
Carex pulicaris	9	4	2	2
Juncus alpino-articulatus	9	8	2	V
Pimpinella major				
Pinguicula vulgaris	8	7	2	3
Platanthera bifolia	5	7	x	V
Polygala amara	4	8	2	
Primula farinosa	8	9	2	2
Thymus pulegioides				

Nine species, which have been found in former mappings haven't been found again in 2014 (Table 7). For *Pimpinella major* and *Thymus pulegioides* there are no indicator values. The nutrients show most of the disappeared species indicate a nutrient value of 2 (nutrient-poor to low nutrient levels). Six of the nine disappeared plant species are listed as 2 = highly endangered, 3 = endangered or V = early warning list. For *Pimpinella major, Polygala amara* and *Thymus pulegioides* there are only RL BW listings on the subspecies level.

3.2 Statistical Characteristics

The following comparisons are divided into a comparison on 15 polygons on all three years and a separated comparison on 42 biotopes only of 1997 and 2014.

3.2.1 Comparisons 1987/1997/2014

15 polygons of 1987 are being compared during the following analyses with spatially matching polygons from 1997 and 2014 (*Figure 4*, *Figure 5* and *Figure 6*).

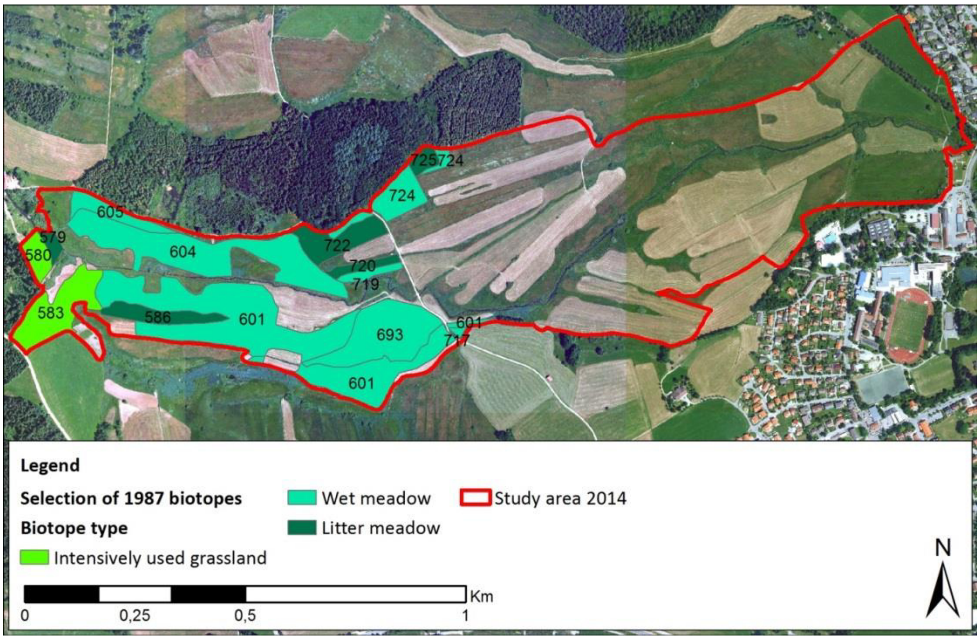

Figure 8. Biotopes of 1987 with matching biotopes from the 1997 and 2014 biotope mapping.

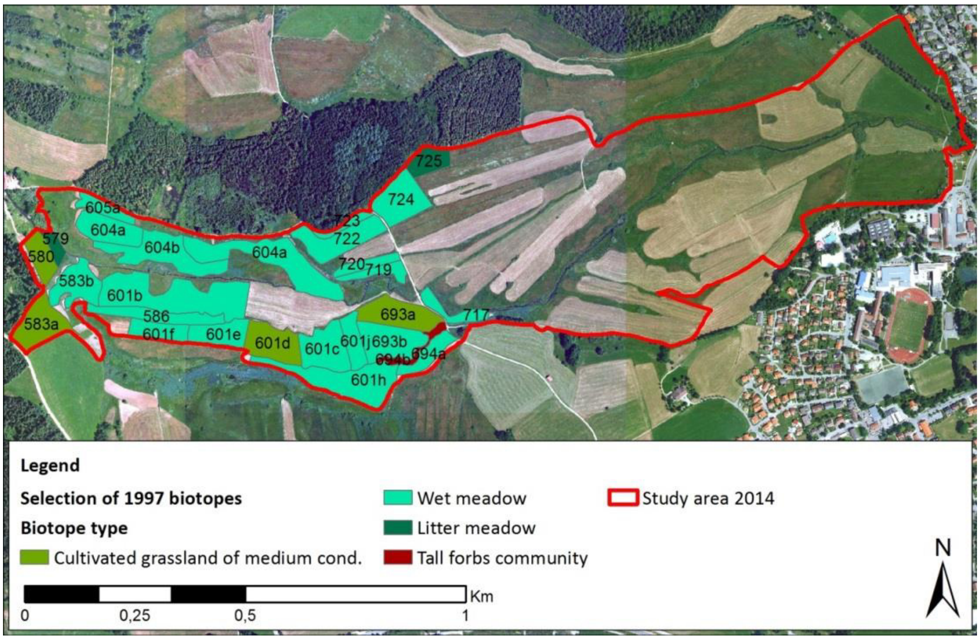

Figure 9. Biotopes of 1997 with matching biotopes from the 1987 and 2014 biotope mapping.

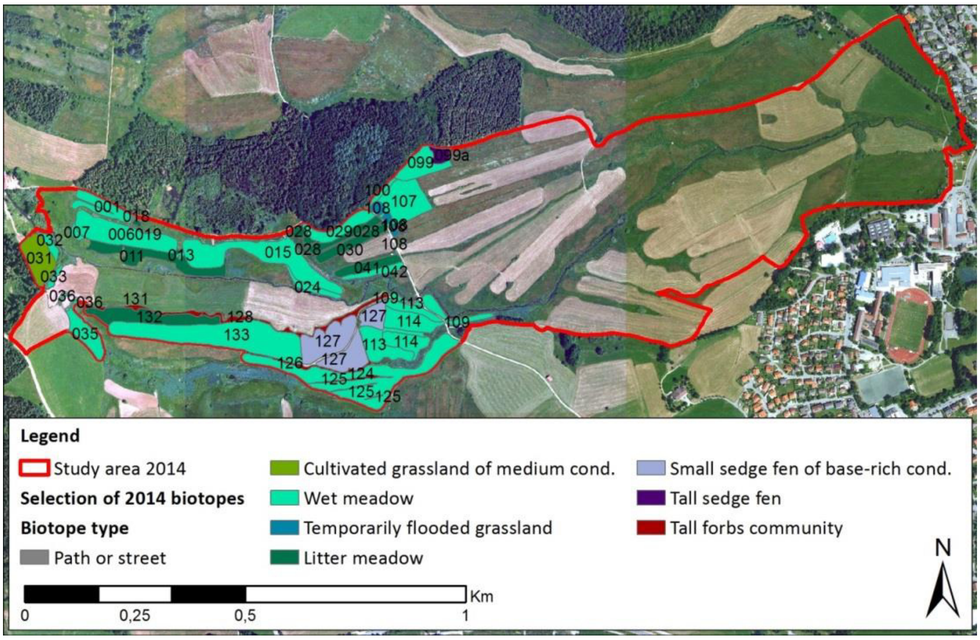

Figure 10. Biotopes of 2014 with matching biotopes from the 1987 and 1987 biotope mapping.

The mean Ellenberg value for Moisture did not differ among the three inventories (ANOVA, $p = 0.4$). The same is true for Nutrients (ANOVA, $p = 0.4$, *Figure 11*). When testing for equal means of Reaction (ANOVA, $p = 0.03$) the difference was significant. The Tukey pairwise comparison revealed the years 1987 and 2014 were significantly different ($p = 0.03$). Other comparisons showed no significance.

The box plot diagrams visualize the development of the Indicator values Moisture, Reaction and Nutrients over all time periods (*Figure 11*). The Moisture means of all years are assigned to a value of 6 (fresh to moist). There is no observable change over the years. Whereas the soil reaction mean shows a continuous decrease from 6 (slightly to moderately acidic) to 5 (moderately acidic). This indicates a trend to more acidic soil conditions. The Nutrient values development is not continuous. In '87 the nutrients mean is 6 (moderately to rich in nitrogen) and then drops to 5 (moderately rich in nitrogen) in '97. Between '97 and '14 there is a slight increase again, but the mean is still 5 (moderately rich in nitrogen). When looking at the exact numbers the differences become even smaller. For Reaction the values are ranging from 6.2 in '87 over 6.0 in '97 to 5.6 in 2014. So the difference is only 0.6 over all years. For Nutrients the maximum range is from 5.8 in '87 to 4.5 in '97 with a 1.3 difference, but only a 0.1 difference between '97 and 2014. The Moisture means are only varying in a range of 0.2 over all years. The differences are therefore mostly very small.

But it also has to be emphazised that the scales of the indicator values of Ellenberg are no cardinal scales that are built on summation of values and the scale intervals are partly overlapping. Therefore the use of decimals is strictly speaking not allowed. Nevertheless it is a commonly used method in plant ecology and it shows that the overall differences between the years are rather small.

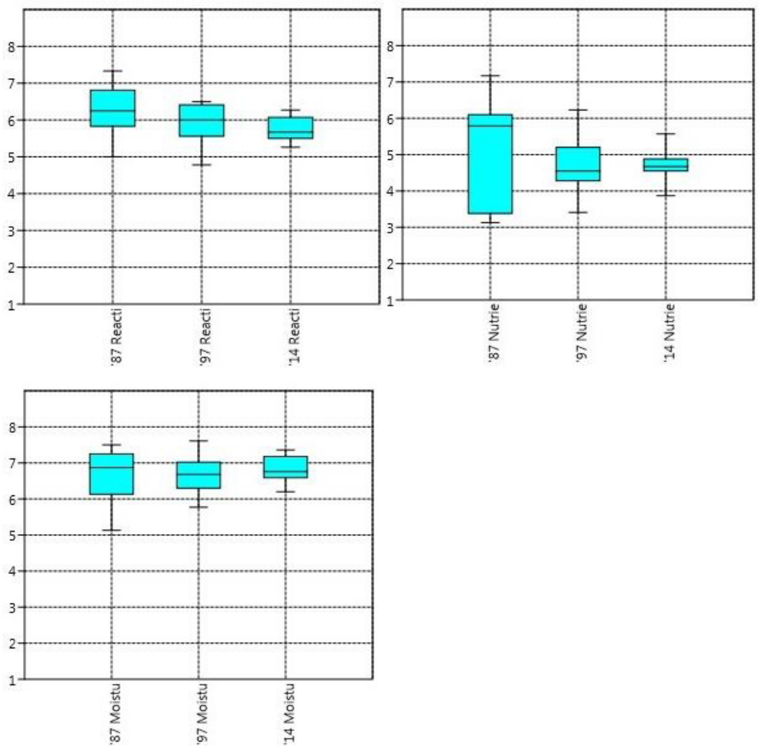

Figure 11. Mean values of the indicator value Moisture; Reaction and Nutrients from 1987, 1997 and 2014.

The Shannon diversity index (*Figure 12*) shows a clear increasing trend to higher levels of diversity with every time step from ’87 to ’97 to’14. The small numbers in ’87 are explained by the smaller species numbers in the mapping due to the differing method, which only considered biotope defining species. The trend on the species numbers is corresponding (*Figure 13*). The increase of the Shannon diversity index values from ’97 to 2014 can partly be explained by the summarization of species from the matching polygons. Most of the time several polygons and their corresponding species inventories have been combined to match the former polygon extent. This caused higher species numbers in 2014 and therefore a higher value in the Shannon diversity index.

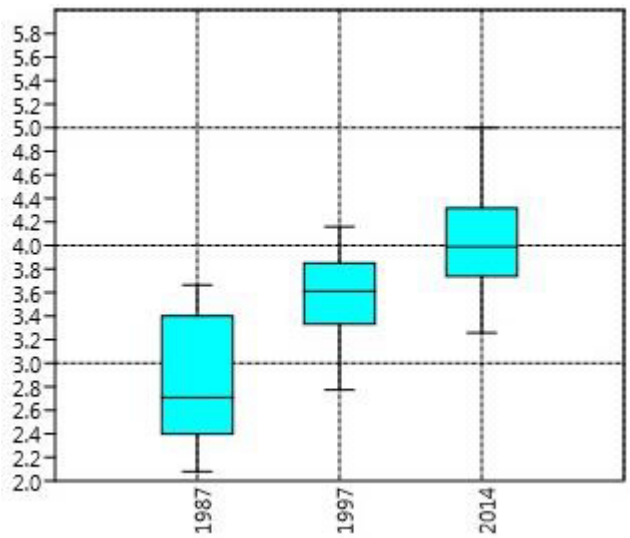

Figure 12. Mean values of the Shannon index values from 1987, 1997 and 2014.

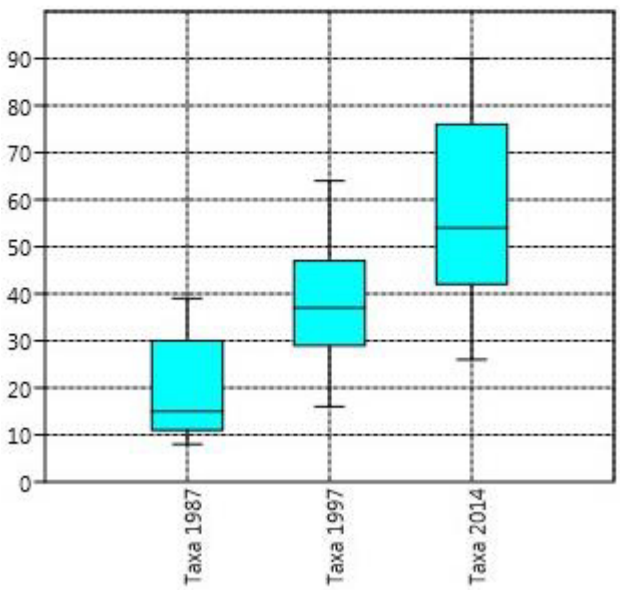

Figure 13. Mean values of the number of different species from 1987, 1997 and 2014.

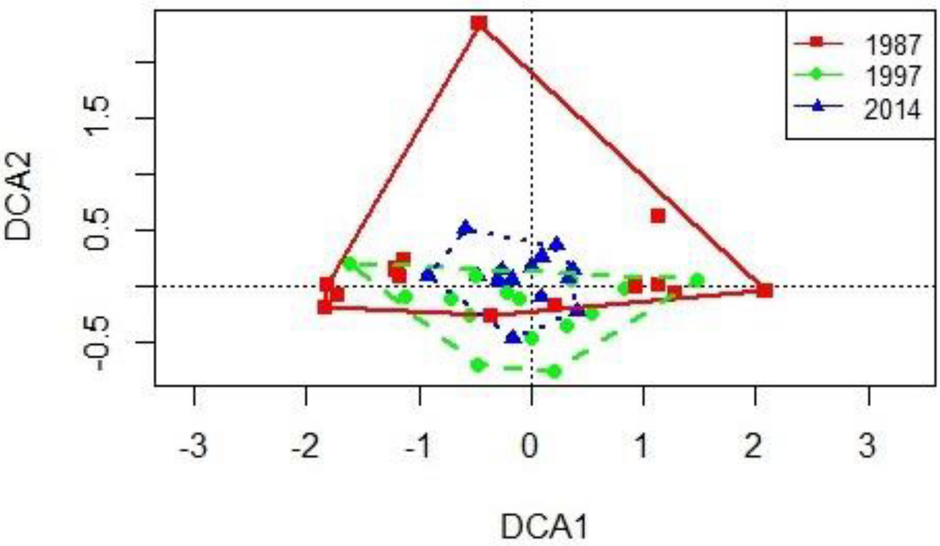

Figure 14. Detrended correspondence analysis on the biotopes matching all three years. Each point represents a biotope. Biotopes from the same year are enveloped.

The DCA (Detrended correspondence analysis) shows that the species compositions of the biotopes recorded in 1987 was relatively different from each other (*Figure 14*). In relation to the later mappings in 1997 and 2014 there is a clear trend observable. The differences of the biotopes with regard to their species composition are constantly decreasing from 1987 over 1997 to 2014. This means the species composition of the different biotopes of 2014 are relatively similar. A type of multivariate analysis of variance (adonis, R-package vegan) confirmed that the three years differed significantly in species composition (adonis, $F = 5.8$, $df = 1,44$, $p = 0.001$, 999 permutations).

The results on the Indval analysis shows that there is a number of species significantly ($pval < 0.05$) related to one year (Table *8*). The majority of species have a significant relation to the 2014 mapping. This implicates that these species have been recorded in most of the polygons in 2014.

Table 8. *Significant associations of species with one of the three years, as indicated by the IndVal method (Roberts 2013). Run only on species present in all three years.*

Species	year	p	IndVal
Carex vesicaria	2014	0.044	0.28
Agrostis stolonifera	2014	0.008	0.33
Carex brizoides	2014	0.003	0.33
Hypericum maculatum	2014	0.008	0.33
Salix aurita	2014	0.003	0.33
Lythrum salicaria	2014	0.012	0.34
Crepis biennis	2014	0.015	0.36

Vicia cracca	2014	0.039	0.37
Luzula multiflora	2014	0.013	0.39
Ranunculus aconitifolius	2014	0.01	0.39
Myosotis palustris	2014	0.032	0.40
Primula veris	2014	0.003	0.40
Carex acuta	2014	0.002	0.41
Agrostis canina	2014	0.005	0.42
Phalaris arundinacea	2014	0.008	0.42
Ranunculus flammula	2014	0.008	0.42
Plantago lanceolata	2014	0.017	0.43
Caltha palustris	2014	0.015	0.44
Carex nigra	2014	0.011	0.44
Scirpus sylvaticus	2014	0.002	0.44
Galium uliginosum	2014	0.003	0.45
Galium mollugo	2014	0.013	0.46
Holcus lanatus	2014	0.007	0.47
Juncus filiformis	2014	0.001	0.47
Carex acutiformis	2014	0.003	0.48
Cirsium rivulare	2014	0.005	0.48
Equisetum fluviatile	2014	0.001	0.49
Lotus uliginosus	2014	0.001	0.49
Festuca rubra	2014	0.003	0.50
Poa pratensis	2014	0.002	0.51
Lathyrus pratensis	2014	0.001	0.54
Geum rivale	2014	0.001	0.57
Cirsium oleraceum	1997	0.039	0.3
Primula elatior	1997	0.007	0.33
Deschampsia caespitosa	1997	0.021	0.42
Carex hostiana	1987	0.028	0.28

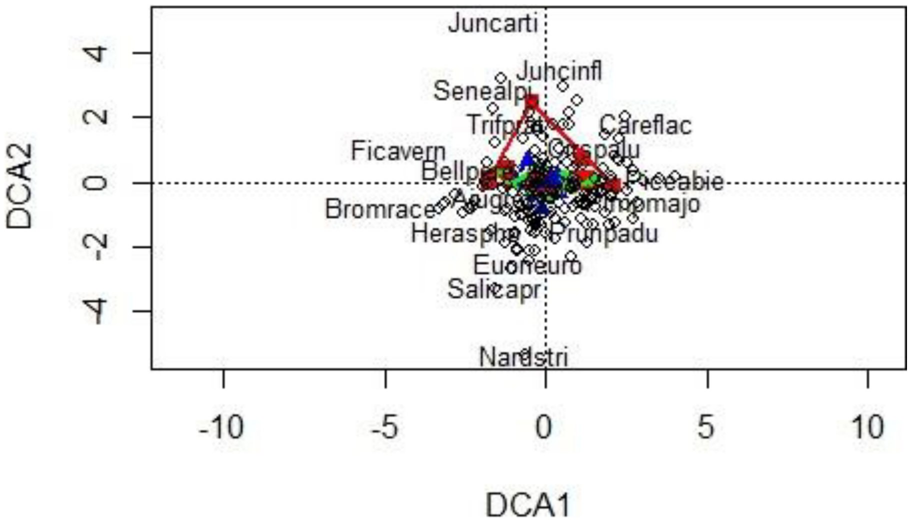

Figure 15.Detrended correspondence analysis. Circles represent species. Speciesnames are shortened.

When including the species in the DCA graph (*Figure 15*). The peripheral species are the rare species where as a zoom to the centre makes the common species of the comparison visible (*Figure 16*). Rare species are fare from the graph centre and therefore occurred rather seldom in the mappings of the different years. The common species are those in the centre of the graph and they have been found in many polygons of the comparison.

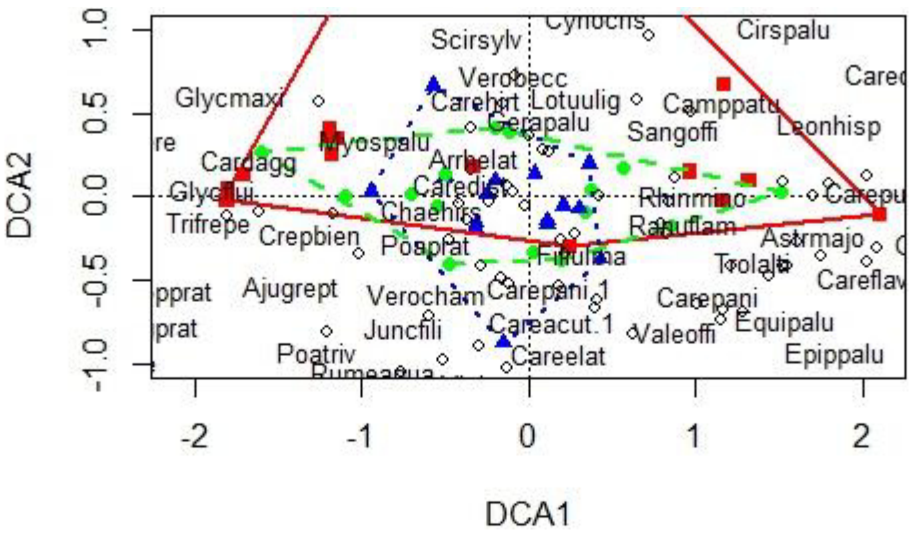

Figure 16. Zoom to the centre of Detrended correspondence analysis.Cirles represent species. Species names are shortend.

In the following the data on the matching polygons of the three different years are analysed. This is followed by the comparison on the ’97 and ’14 data.

Detrendend correspondence analysis with 1987’s data

The first axis of the DCA on the 1987’s data is the most important one for explaining the species composition (74%). Also axis 2 explains a relevant amount of the species composition (27%). Axis 3 is not considered (21%).

In the 1987 mapping Nutrients is closely correlated with axis 1 and has major influence on the distribution of species and biotopes (*Figure 17*). Moisture is also influencing the distribution. It is correlated with axis 2. Although the influence of Moisture is a little less than Nutrients, those two variables are negatively correlated. The graph indicates species and biotopes with high Nutrient values consequently have low Moisture values and the other way round.

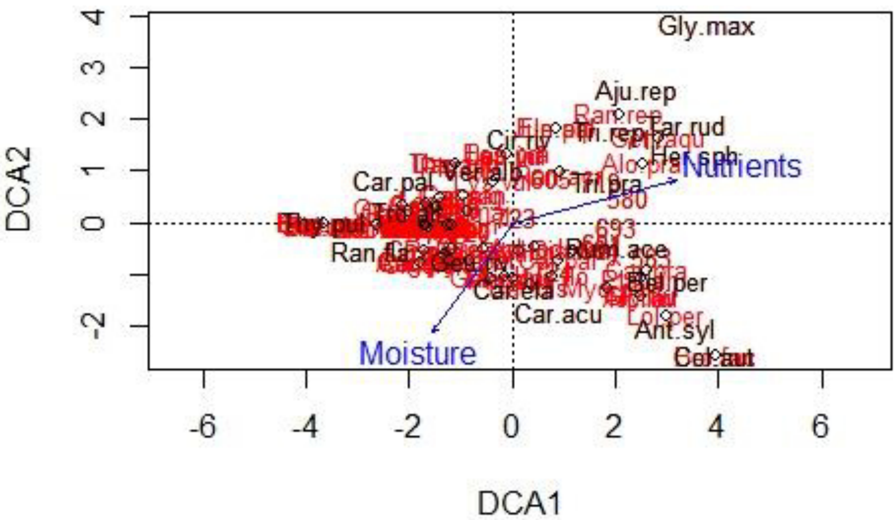

Figure 17.1987 Triplot of a Detrendend Correspondence Analysis with variables Moisture and Nutrients. Red crosses mark the species; black circles the biotopes.Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

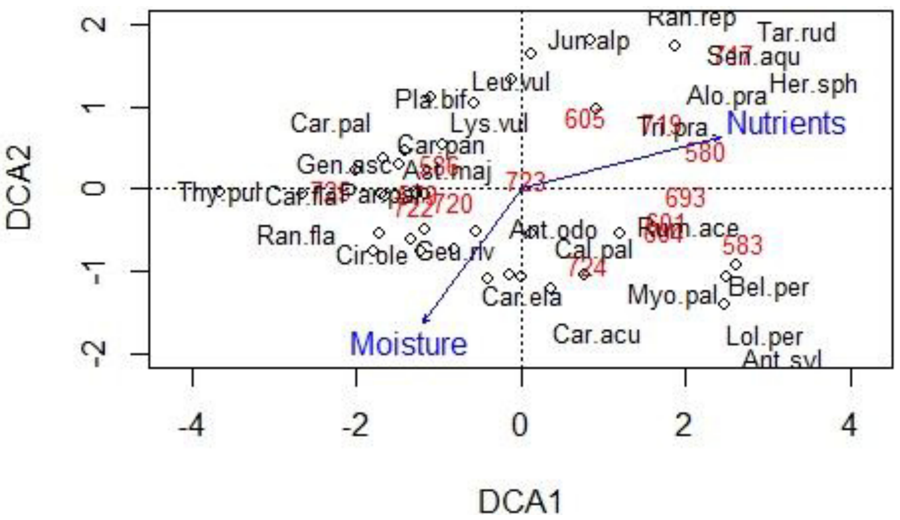

Figure 18. Zoom to the centre of the 1987 Triplot of a Detrendend Correspondence Analysis with variables Moisture and Nutrients. Red crosses mark the species; black circles the biotopes. Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

Detrendend correspondence analysis with 1997's data

For the DCA on the data of 1997 indicator values as well as management variables were taken into account. Axis 1 (41%) and axis 2 (19%) explain most of the variation (*Figure 19*). The other axes have only low explanatory value (14%, 13%).

Nutrients has big influence on the variation of species and biotopes as it is closely correlated with axis 1. Moisture is influencing the distribution of species as well, but its influence is a little less important than nutrients. Again those two variables are negatively correlated with the before mentioned implications. The distribution of the explanatory variable Mowing frequency shows close correlation of the twice mown polygons (Mowing frequency = 4) and the only once mown polygons (Mowing frequency = 2) with Nutrients (*Figure 20*). Therefore biotopes and species with high nutrient levels have most certainly also high mowing frequencies and the other way round. Mowing month June (6), July (7) and September (9) are correlated with Nutrients. Earlier mowing months are correlated with higher Nutrients levels and later dates with rather low Nutrients levels. The correlation of Mowing frequency and Moisture shows a correlation of rather high moisture levels with lower mowing frequency (2) and higher Mowing frequency (4) with lower Moisture levels. It is derived: Species and biotopes with high Moisture levels are not mown often. Also biotopes and species with a low Nutrients level are mown at a later month.

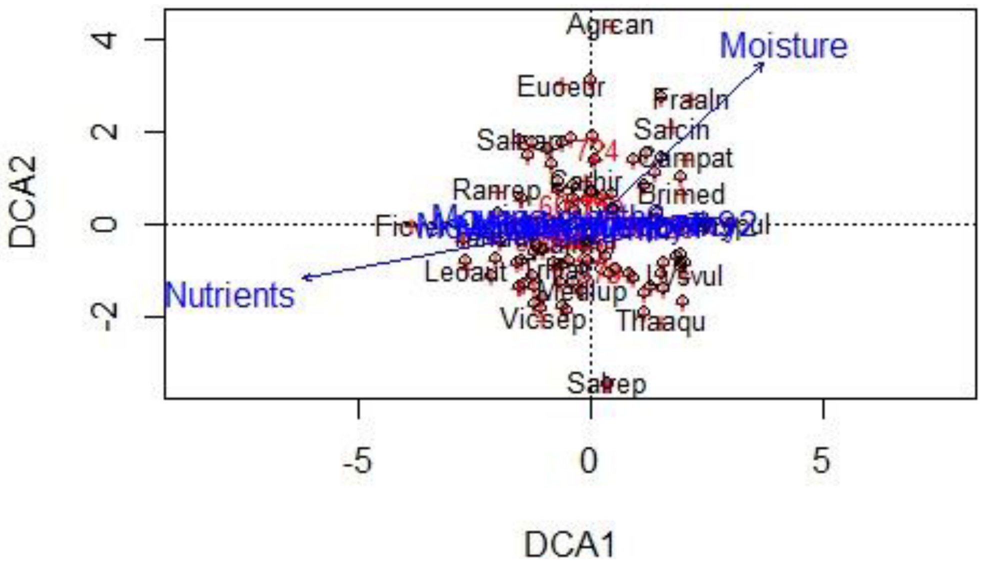

Figure 19. 1997 Triplot of a Detrendend Correspondence Analysis with variables Moisture and Nutrients. Red crosses mark the species; black circles the biotopes.Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

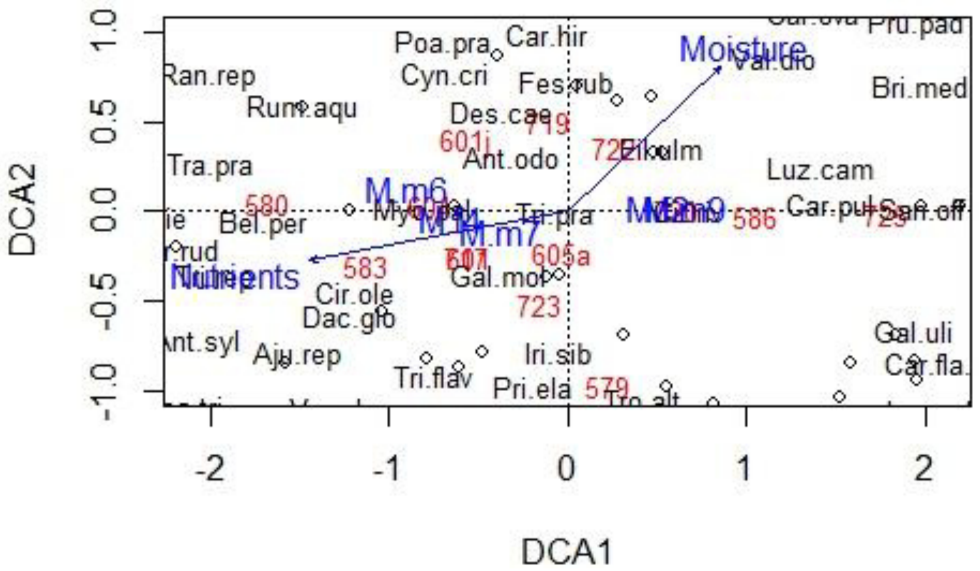

Figure 20. Zoom to the centre of the 1997 Triplot of a Detrendend Correspondence Analysis with variables Moisture and Nutrients. Red crosses mark the species; black circles the biotopes. M.m. is Mowing month and M.f. is Mowing frequency. Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

Detrendend correspondence analysis with 2014's data

When taking indicator values as well as management variables into account, axis 1 (18%) and axis 2 (15%) have relevant influence on the variation. All further axes are not considered.

Moisture has big influence on the variation of species and biotopes (*Figure 21*) and is closely correlated with axis 1. Nutrients are influencing the distribution of species as well, but its influence is a little less important than Moisture. Mowing month and frequency are also notable explanatory variables (*Figure 22Figure 22*).

In this DCA Nutrients and Moisture are strongly negatively correlated. Species and biotopes of the dataset with high Nutrient levels tend to have low Moisture levels and the other way round.

The distribution of the Mowing frequency levels shows that polygons that are mown twice (Mowing frequency = 4) tend to have higher Nutrient levels and lower Mowing frequencies (2 and 3) indicate rather low Nutrient levels. So the fertile meadows are mown more often whereas the meagre ones are mown less.

In correlation with Moisture the distribution of Mowing frequencies indicate that polygons that are mown more often are drier and those that are mown less are often moister.

The distribution of Mowing months also shows a clear trend. Early mowing months are correlated with higher Nutrient levels and with later mowing months also the Nutrient level is decreasing. The opposite is true for the correlation of Mowing month and Moisture. Late Mowing months tend to have higher Moisture levels and early mowing dates have accordingly lower Moisture levels.

Therefore fertile Meadows are mown earlier and are drier and meagre meadows are mown later and are moister.

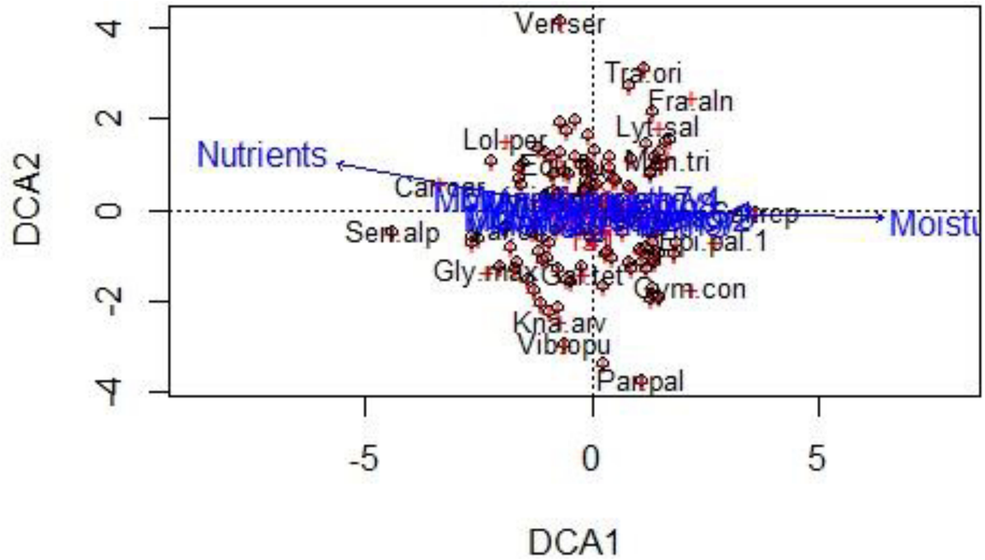

Figure 21. 2014 Triplot of a Detrendend Correspondence Analysis with variables Moisture and Nutrients. Red crosses mark the biotopes; black circles the species.Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

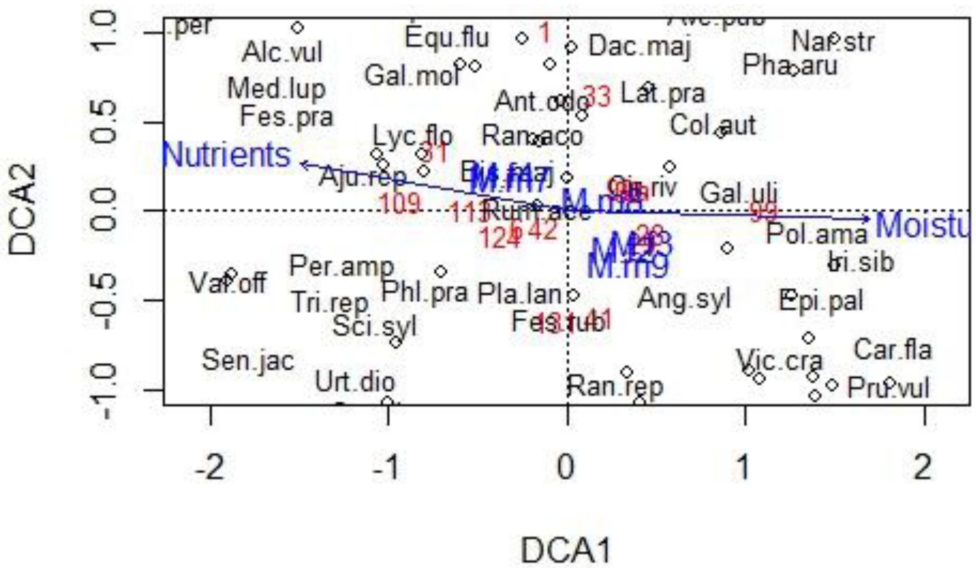

Figure 22. Zoom to the centre of the 2014 Triplot of a Detrendend Correspondence Analysis with variables Moisture and Nutrients. Red crosses mark the species; black circles the biotopes. M.m. is Mowing month and M.f. is Mowing frequency Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

3.2.2 Comparison 1997/2014

The comparison of the species inventories of the years 1997 and 2014 is more valid than the comparison on all three years with only 15 matching polygons. Also the method for the biotope mapping was similar. There are 42 plots from 1997 that have a matching plot from 2014 (*Figure 23* and *Figure 24*).

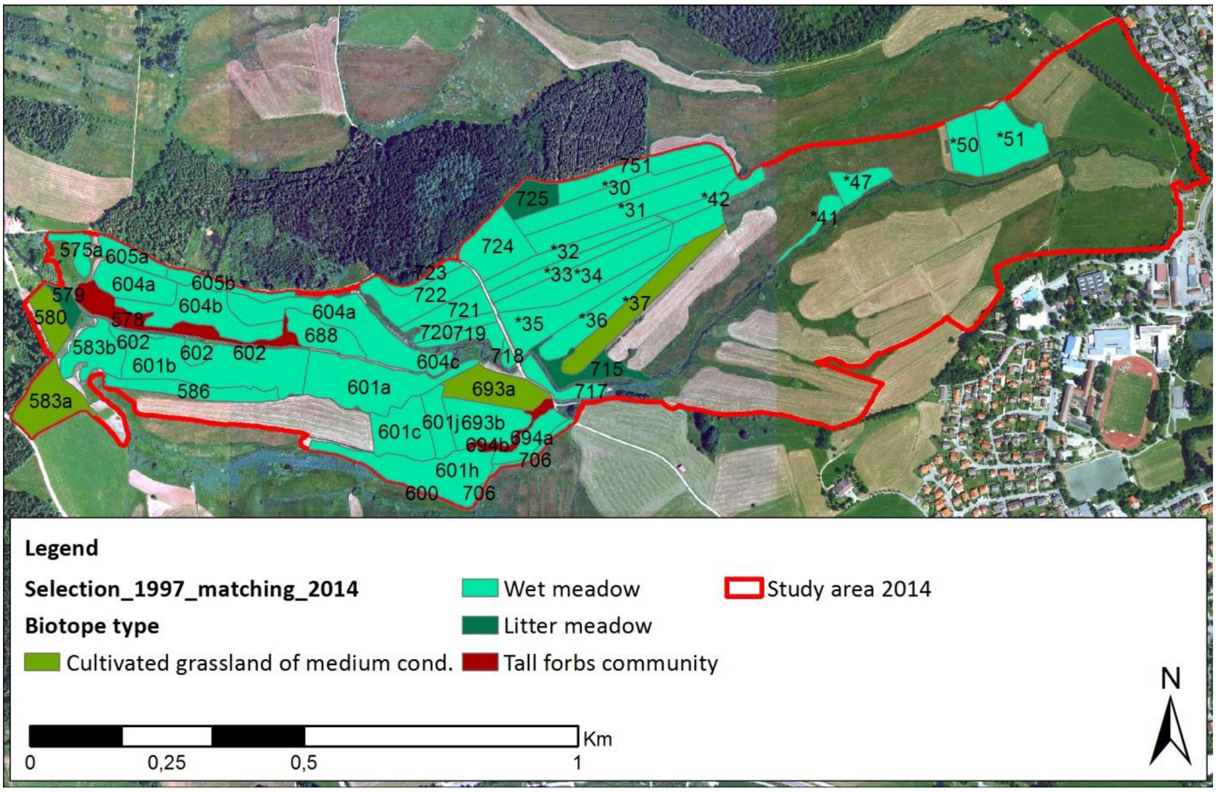

Figure 23. Biotopes of 1997 with matching biotopes from the 2014 biotope mapping.

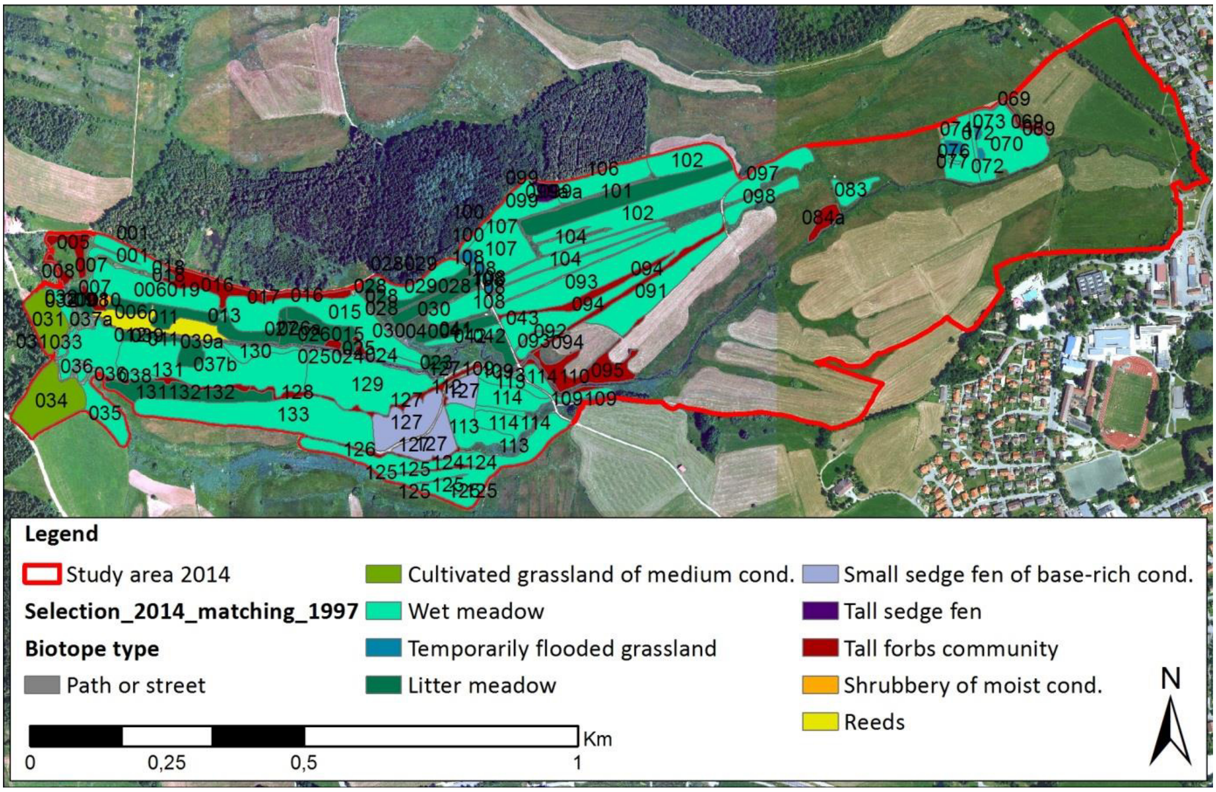

Figure 24. Biotopes of 2014 with matching biotopes from the 1997 biotope mapping.

The test for equal means for the indicator value moisture showed no significant difference (ANOVA, p = 0.9). For reaction the difference was significant (ANOVA, p = 0.02) and likewise for nutrients (ANOVA, p = 0.04)
The Moisture mean values for both years are levelled at 6.8 (fresh to moist) (*Figure 25*). Looking at the Reaction mean values a slight decreasing trend is observable. '97 it was exactly 6.0 (slightly to moderately acidic). 2014 it slightly decreased to 5.8 (moderately acidic). The mean values of the indicator value Nutrients also show change. The values drop from 5.0 (moderately rich in nitrogen) in '97 to 4.7 (moderately rich in nitrogen to low in nitrogen) in 2014.

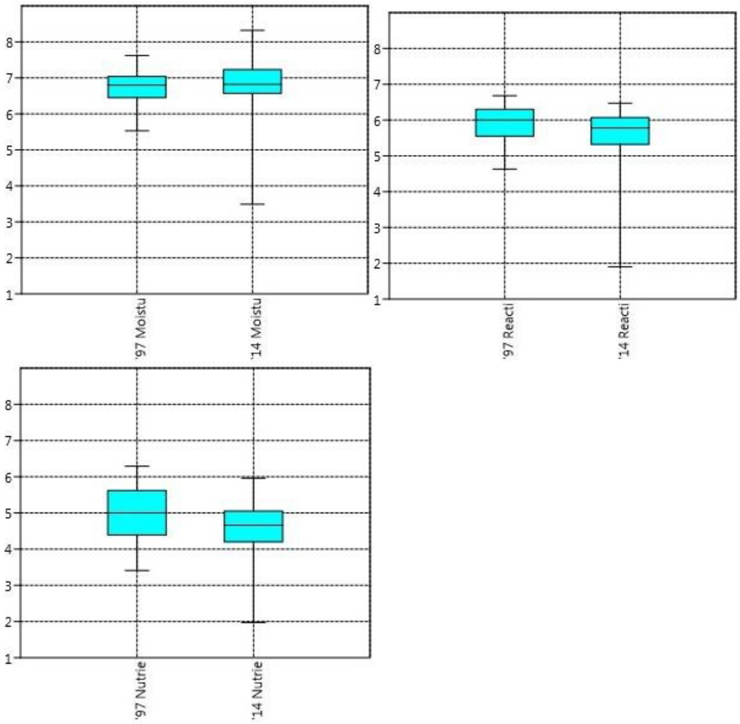

Figure 25. Mean values of the indicator value soil moisture, soil reaction and nutrients from 1997 and 2014. Whiskers type: Standard deviation.

Detrendend correspondence analysis with 1997's data

The DCA on 1997 data shows the first axis is the most important one for explaining the species composition (39%). Also axis 2 explains a relevant amount of the species composition (21%). Axis 3 is not considered (13%).
Moisture and Nutrients have the most influence on the distribution of species biotopes (*Figure 25*). Nutrients is closely correlated with axis 1. Reaction has also influence on the species and biotope distribution but in comparison the least. Also it is not correlating with the other variables, but with axis 2. Overall there is only little correlation between the three variables.

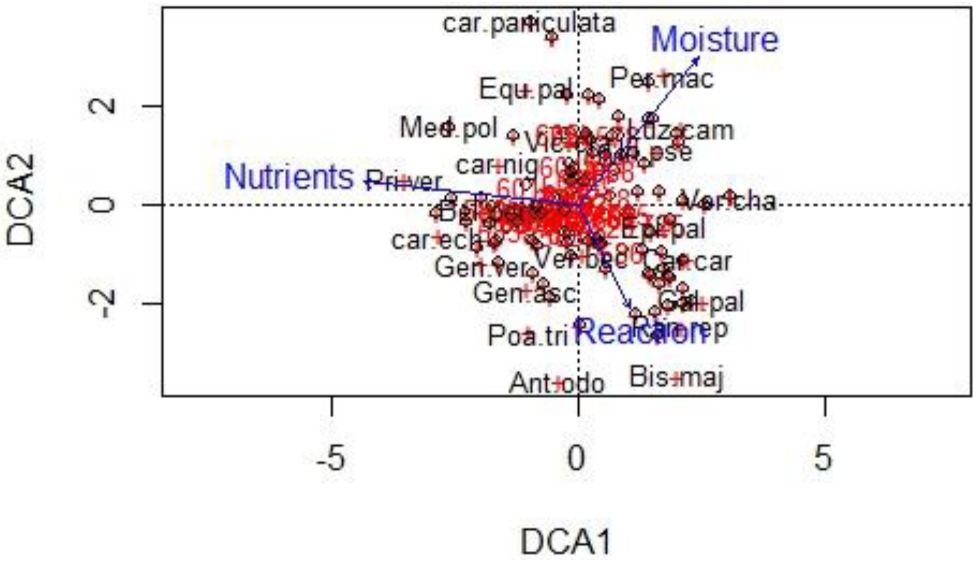

Figure 26. 1997 Triplot of a Detrendend Corresponcence Analysis with variables Moisture, Reaction and Nutrients. Red crosses mark the species; black circles the biotopes.Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

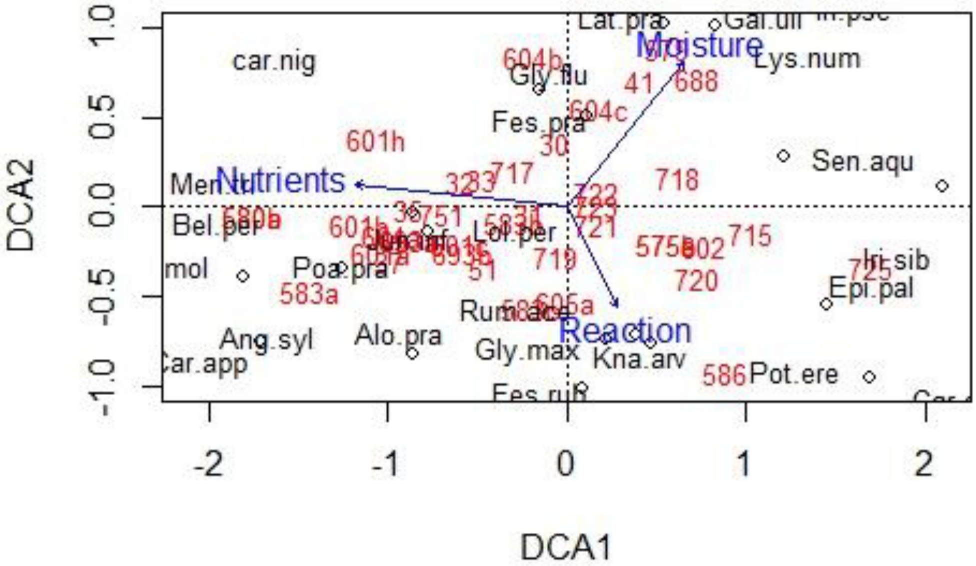

Figure 27. 1997Triplot of a Detrendend Correspondence Analysis with variables Moisture, Reaction and Nutrients. Red crosses mark the species; black circles the biotopes.Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

Detrendend correspondence analysis with 2014's data

The DCA on indicator values and management variables of 2014 shows axis 1 (21%) and axis 2 (15%) have relevant influence on the variation. All further axes are not considered.

Again Nutrients has big influence on the variation of species and biotopes (*Figure 28*) and is closely correlated with axis 1. Moisture on the other hand is correlated with axis 2 and negatively correlated with Nutrients. The species and biotopes correlated with high Moisture levels also tend to have rather low Nutrient levels and the other way round.
An early Mowing month in June (6) tends to have low Moisture levels. And later dates higher Moisture levels, although they only differ little between July, August and September (7,8 and 9).
Also the Mowing frequencies don't seem to have clear tendencies to Moisture. They differ very little (*Figure 29*).
The distribution of the Mowing month indicates that earlier dates (6 and 7) tend to have higher Nutrient levels and the later dates (8 and 9) lower levels accordingly. Also the Mowing frequency is following this trend. More frequently mown (4 and 3) also indicate higher Nutrient levels with a decreasing tendency to lower Nutrient levels when mown only once a year or only every other year (1 and 2). Species and biotopes with high Nutrient levels seem to be mown early and less moist.

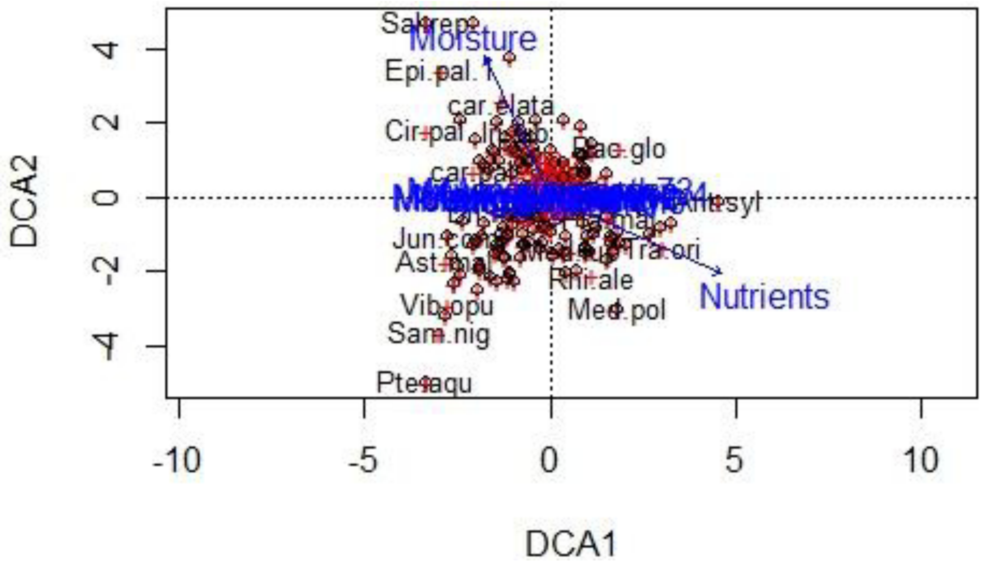

Figure 28. 2014 Triplot of a Detrendend Corresponcence Analysis with variables Moisture, Reaction and Nutrients. Red crosses mark the species; black circles the biotopes.Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

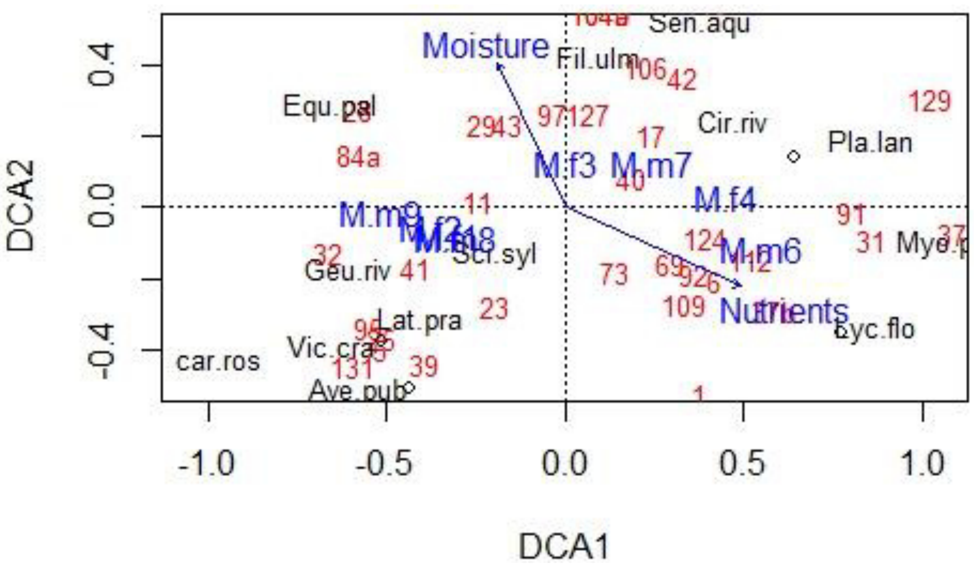

Figure 29. Zoom to the centre of the 2014 Triplot of a Detrendend Correspondence Analysis with variables Moisture, Reaction and Nutrients. Red crosses mark the species; black circles the biotopes. M.m. is Mowing month and M.f. is Mowing frequency.Only explanatory variables with significant results (p<0.05) from the envfit testing are displayed.

4. Discussion

Has the plant species composition of the study area changed from 1987 to 2014?
Nine species from the mappings of 1987 and 1997 were not found again in 2014 (Table *7*). When looking at the indicator values of those species the nutrient values are meaningful. The values indicate soil conditions with low nutrient availability. Therefore their absence suggests an increase of nutrients in those biotopes the species have been detected in. Also their indicator values on moisture indicate quite moist to wet conditions. So this can be interpreted as a sign for a development towards drier conditions in the biotopes where those plants have been formerly found.

It also is interesting that the majority of these disappeared species are classified as highly endangered, endangered or at least are part of the early warning list (Breunig, Demuth 1999). This loss indicates that the ongoing management has flaws as it has not been able to sustain the necessary conditions for the endangered species. Although these results cannot be transferred to the whole area, they give first hints, that there is a need for adjustment in the ongoing management of the area.

There are also some species that have only been detected in one specific year (Table *6*). For 1987 there are only two species which have been found in that year but in none of the following mappings. Those species are *Bromus racemosus* (RL BW 3) and *Tofieldia calyculata* (BW RL 3) and both are considered as endangered. They also represent rather moist condition based on their indicator values, so a reason for them not being found, could be less moist soil conditions.

When looking at the indicator values of plant species that were only found in 1997, they show two separate trends. Several species indicate the biotopes, those species have been found in, have become wetter; others that they have become drier. The majority of indicator values for Nutrients represent low to moderate nutrient levels, but also some species with rather high values on Nutrients. This would on the one hand indicate a trend for biotopes becoming richer in nutrients and others lowering their nutrient levels.

The species that have only been found in 2014 show no obvious trends when looking at the Moisture values. There is no clear tendency to wetter or drier conditions visible as values vary at a large range between rather dry to wet. Again this could mean that the biotopes those species have been found in have become wetter or drier, but the results are weak. The plants values on Reaction (soil acidity) have a clear majority of values indicating low soil acidity. This could indicate that the soil acidity has levelled at this value allowing new plant species to establish themselves in the conditions. At the same time the establishment of new species can cause the supersession of other species (Ellenberg et al. 1992). For Nutrients - like for Moisture before - there is no clear trend observable. The Nutrient values are varying too much.

The results on all years can give hints to ongoing trends. There are some hint for changes in the nutrient and the water regime in the study area. So far no consistent trend was observable. Results on disappeared and newly occurred species cannot be generalized as there is no information on the abundances of the species in the former years. To confirm or withdraw the assumed trends additional tests and comparisons of the individual biotopes would have to be done.

Another interesting result is the relative stability in species-richness among the polygons with the highest species numbers (Table *5*). Many of these polygons still have kept their high species numbers, partly even over all three time periods. At least for those polygons a relatively good stability on the environmental conditions can be assumed. It also is interesting that most of the polygons with high species numbers are identified as litter meadows. This biotope type naturally has high species numbers. Together with calcareous grassland it is accounted as one of the most species –rich vegetation type in central Europe (Kapfer 2001; Zerbe 2009).

The most frequent species can be used to get an overall impression on the plant composition of the study area (Table *4*). *Filipendula ulmaria* is the plant species which was noted most frequently in all years. It is a generalist and typically found along ditches and streams. It needs relatively high nutrient levels and moist soil conditions, but is excluded from nutrient poor conditions. *Filipendula ulmaria* underlines the need for constant maintenance measures to keep the meadows open (Pauli et al. 2002). Otherwise tall forbs communities and later shrubs and forests would take over the area (McGovern et al. 2011; Briemle, Ellenberg 1994).

Caltha palustris occured second most often. *Caltha palustris* is a characteristic species of wet meadows, which are typical for the study area (Oberdorfer 2001). It emphasizes the most characteristic biotope type: wet meadows (Oberdorfer 1993). *Ranunculus acris,* as third most often occurring species, is a rather unspecified generalist with indifferent behaviour (Oberdorfer 1993). Basing on this no profound derivations can be made.

The DCA indicates that many species have high associations with specific years (Table 8, *Figure 14*). Most of the species which are significantly ($p < 0.05$) associated with the year 2014. This means that there is a set of species that occurred in almost every biotope during the 2014 mapping. Those species can be found in the centre of the graph (*Figure 16*). In former years the variation of species between the biotopes was higher. Possible reasons for this development could be a higher diversity in the management regime in former times. Bringing the maintenance measures in line supports a specific plant species composition. These results are supported by personal impressions in the field. At the end of the mapping period the first mowing date for the meadows had arrived. Within two days every meadow in the study area which had their mowing date in July was mown. There was no variation in the mowing regime. Zerbe (2009) made similar observations for wet meadows all over Germany. He claims that more variation in the mowing regime would support a larger variation of ecological niches. As a consequence a larger variation of species could establish in those niches (Verhoeven 2014). More diverse species composition and possible higher species diversity could be reached.

Has the spatial distribution of biotopes changed from 1987 to 2014?

When comparing the spatial distribution of biotopes and biotope types it becomes clear that - especially in 2014 - biotopes have been recorded, that haven't been recorded in former mappings. Those are path or street, swamp forest, tall sedge fen, lawn and temporarily flooded grassland. Paths and streets simply weren't differentiated in the former years. The swamp forest as well as lawn are biotope types that occurred at the edge of the settlement area which wasn't included in the former mappings. The tall sedge fen is probably a result of maintenance efforts of the former management plans and developed from the litter meadow that was recorded at the area before.

The maps also show that biotopes identified as Tall forbs communities in one year are identified as reeds in another year. The reasons for this are overlaps in the found species which define the biotope type (Breunig 2009). The biotopes contained both species, which define the biotope type tall forbs communities, as well as species defining reeds. The main distinctive species for the biotope type reeds are of course reeds, in case of this thesis mostly *Phragmites australis*. Therefore biotopes which appearance was clearly characterized by *Phragmites australis* were recorded as reeds. When *Filipendula ulmaria* ultimately come to the fore instead of *Phragmites* it was recorded as Tall forbs community. As *Phragmites* is rather incompatible with mowing, it disappears from areas which are mown on a regular basis and invades rather fallow areas (Ellenberg 1952). This means maintenance measures have big influence on its spread. Also Tall forbs communities grow on fallow meadows suppressing small forbs and grasses by shading them and therefore decreasing the species numbers (Lepš, Wan 2014). Only few tall growing plant species like *Filipendula ulmaria* reach dominance (Scharff 2009; Pauli et al. 2002). The Tall forbs communities as well as the Reeds have spread along the ditches of the former water meadow system and accompany the small river Isnyer Ach.

Remembering the boxplots which indicated increasing Nutrient values over the years the spread of Tall forbs communities and Reeds are offering an alternative interpretation. The tall and dominant species defining those two biotope types often have intermediate or high Nutrient values whereas the smaller and weaker species that are superseded tend to have lower Nutrient values. Therefore the increasing spread of typical species of Tall forbs communities and Reeds are causing an overall increase in mean Nutrient values over the years.

This development also indicate a degrading process as upcoming Tall forbs meadows or Reeds are a sign for no or irregular use (Prach 1993). It is also a strong indication for eutrophication along the ditches (Pauli et al. 2002).

On the other hand this development is at least partly striven for by the maintenance plan of the nature reserve. The plan gives measures for certain biotopes in which is stated that parts of the meadow should be left out at the first mowing, if they are mown twice or every other year if they are mown once a year. These measures are supposed to support the upcoming of reeds and tall forbs like Filipedula ulmaria in order to improve the conditions for breeding bird, like the Saxicola rubetra (Dechert 2000; Bezirksstelle für Naturschutz und Landschaftspflege Tübingen 1990). So this biotope changes are - at least the transfer from wet meadows to all forbs communities - deliberated changes. But despite this intended transfer of wet meadow area, the spread of tall forbs and communities and reeds especially on the account of litter meadows can be seen as a degrading and damaging process. Here the transfer is not intended. Litter meadows bear the most species and also the most endangered ones in this study. Nevertheless also on those biotopes tall forbs communities and reeds are spreading.

The spread of tall forbs communities and reeds according to the progressive secondary succession process described by Zerbe (2009) is followed by the upcoming of shrubs. This can be detected in parts of the study area. Shrubs are spreading along the ditches slowly replacing the tall forbs communities and reeds. They are mainly made up of *Salix aurita* and other *Salix* species. This process has to be prevented as the biotopes may shift to another biotope type, if they are not managed properly. The upcoming of shrubs is indicated by the biotope type shrubs of moist conditions in the 2014 mapping. This succession process has to be kept under control as this development runs contrary to the management goals of the nature reserve for the meadows. Regular mowing and removal of shrubs is required to stop the process (Buttler 1992; Prach 1993).

Comparing the overall species numbers of the last two mapping years there are 214 species found in 1997 and 211 found in 2014 (*Figure 6*). So in total it can be said that the biodiversity did not substantially decrease, but there was rather a shift in species composition. The results on disappeared and newly occurred species supports this conclusion. Also the DCA shows that in 2014 several species are very common in most polygons. This is a common development in landscape ecology and has been observed many times before (Scharff 2009; Zerbe 2009). Shifts in species composition indicate changes in the environmental conditions (Wittig et al. 2007).

The Shannon diversity index (*Figure 12*) on the other hand shows a clear trend to higher levels of diversity with every time step. This is explained by the smaller species numbers in the '87 mapping due to the differing method, which only considered biotope defining species. The increase of diversity from '97 to 2014 can partly be explained by the summarization of species from the matching polygons (*Figure 13*). Most of the time several polygons and their corresponding species inventories have been combined to match the former polygon extent. Even though there is a visible increasing trend in the Shannon diversity index and the total number of species from the early inventories to the newest this trend is at least partly explainable by the data structure. Nevertheless the suspected overall decrease in plant species diversity cannot be proven.

Can changes in the plant species compositions be explained by the local conditions (Ellenberg's indicator values) or the management of the area?

Even though there are trends observable in the comparison over the years, they should not be over interpreted. All mean indicator values are located in a very small range and it should be kept in mind that the intervals are overlapping (Ellenberg et al. 1992; Böcker et al. 1983). Even though there are no big differences between the indicator values over the years, they can give hints on the development. But it has to be kept in mind that those are not to be over interpreted as there are only 15 matching biotopes on all years and only 42 on 97/14 to be compared. Also we have to remember that the three mappings were done by different people with partly different methods. This naturally jeopardizes the overall comparability.

Also it has to be considered that the development of indicator values over the years represents a comparison of only a relatively small number of biotopes in the study area and the comparison is predominated by wet meadows and litter meadows (*Figure 8*, *Figure 9*, *Figure 10*, *Figure 23* and *Figure 24*). The importance of the spread of tall forbs communities and reeds for indications on development and changes in environmental conditions is not proportionally represented in the comparison (*Figure 7*).

It is important to point out these flaws in the method, because the results from the comparison of mean indicator values are also contradicting some of the indications which have been derived from the species, that have disappeared and species that have only been found in one year (Table *6* and Table *7*). This mustn't mean that one result must be wrong. It rather paints a more diverse picture on the ongoing processes in the study area.

The moisture levels seem to be in balance over the years, but moisture is also the most important factor explaining the plant composition based on species and biotope distribution. It is very likely that, even though the overall levels have not changed in the different polygons, changes are weightier than it was uncovered by the methods used in this thesis. Even in one polygon the soil moisture conditions can differ severely depending e. g. on their proximity to the next ditch. The same is true for the nutrients levels. Even though the overall change over the years is not large, in some polygons the nutrient level has probably increased causing species loss because of higher productivity levels like it is described by Grime (2001).

On the one hand the spread of tall forbs communities and reeds along the ditches indicate rather eutrophic and wet conditions that are favourable for their spread (Oberdorfer 2001). Also the results on disappeared species indicate increase of nutrient availability.

On the other hand the results from the comparison of mean indicator values indicate decreasing nutrient availability and increasing soil acidity (*Figure 11*), but almost exclusively for wet meadows and litter meadows.

Nutrients are more or less easily influenced. Increasing the nutrient content of soils can be achieved by simply adding fertilizer. Reducing nutrients is not that simple, but can also be achieved in the long-run. Fertilization needs to be diminished or stopped entirely. Also the meadows need to be mown frequently and the mowing material has to be removed (Zerbe 2009). This would also reduce tall forb communities and reeds. But it is very important to be clear on the biotope type that should be achieved in the end.

The impact of nutrient availability in litter meadows is very different from wet meadows. Their distinction can mainly be traced back to significant differences in nutrient availability (Kapfer 2001). Litter meadows are naturally low in nutrients, which makes them vulnerable to high fertilization rates. Studies have shown that even atmospheric nitrogen input has damaging influence on the species composition of acidic grassland types (Duprè et al. 2010). All practices which could increase the nutrient levels of this biotope type should be avoided. This includes the water meadow practice.

It was hypothesized that moisture has probably decreased as watering has stopped. When thinking about the area being a historic water meadow area, those developments are comprehensible. When the watering stopped the logical consequence would be drier meadows. This was in fact a problem with some water meadows in other regions (Landesnaturschutzverband Baden-Württemberg 1995), but there the meadows had very different soil types and soil conditions. For the study area this argument would be short-sighted. The main purpose of watering the meadows was fertilization not irrigation (Leibundgut, Kohn 2014a). The meadows in Isny are naturally wet because they are growing on a fen peat layer (Göttlich 1975).

Nevertheless the ditches of the water meadow system have remained and this is a key factor for the area. Some of the ditches are derelict but many are still functional. Now that the watering is no longer practiced, they no longer function for watering but as drainages. However, a decreasing moisture content of the soil could not be proven based on the statistical analyses, but the former water meadow system with its numerous ditches still has a big influence on the water regime in the area. Ditches are filling up which causes water to accumulate in some parcels. On the other hand the ditches, which are no longer filled with water, have draining influence on the parcels. But despite those observations, no changes have been revealed based on the mean indicator values. The lost species paint a different picture supporting the assumption of decreasing soil moisture in several polygons. This is also supported by observations in the field. At some location very dry and open soil was visible during a long dry and sunny period in June. Occasional dry seasons do not change the overall situation of naturally wet soil conditions.

Results on the DCA of all three years on the indicator values Moisture and Nutrients show clear patterns. Those patterns are supported by the results of the DCA on 1997 and 2014. For Reaction the results are weak in both comparisons.

Both DCAs identify the indicator value Nutrients and Moisture as the overall main drivers on species and biotope distribution. They offer high explanatory value on the species distribution and the biotope distribution. They are the most important factors explaining the variation and therefore also most likely the reason for changes in the plant species composition. All DCA results on the different years support this.

The DCAs also identify Moisture and Nutrients as being strongly negatively correlated. This result is easily comprehensible as the study area is defined by typical wetland biotope types.

Nutrients and Moisture being negatively correlated seems to make sense thinking about nutrients availability in moist soils. Moister sites have less species indicating lots of nutrients and vice versa. This is supported by Olde Venterink et al. (2001). It is also important o think of the use of the meadows. Wet meadows in comparison to Litter meadows are drier and can therefore be cultivated more easily. They are more productive and therefore used more often; mostly twice a year. Also low fertilization rates are allowed and practiced. This explains their higher Nutrient values. Litter meadows on the other hand are very moist meadows which are difficult to cultivate with heavy machinery. They are only mown once a year when the soil of the meadows is passable. Fertilization of litter meadows is not allowed in the nature reserve, so their Nutrient levels are rather low. The productivity is in comparison lower as productive species that increase the fodder value do not tolerate very wet soil conditions.

Mowing frequency and Mowing month have partly been closely correlated with Nutrients and with Moisture. High mowing frequencies (like twice a year) on a meadow biotope in the study area means at the same time that the biotope is most certainly fertilized. For those more productive meadows moderate fertilization rates are allowed through the management plan to hold the productivity on level. Low mowing frequency (like every other year) are typical for nutrient low meadows, like litter meadows. For those meadows no fertilization is allowed. They are rather losing nutrients with every cut.

Also high mowing frequencies are more likely on biotopes with lower moisture values. The drier soil condition makes them more accessible for farmers. Very wet meadows are often flooded and the vegetation is still very small in early months. The heavy machinery of the farmers is not suited to those wet soil conditions. They are mown in August or September when the summer heat has dried the soil. Less wet and rather nutrient-rich meadows are easier to cultivate so they are used more frequently and earlier in the season so they can be mown again later in the season (Kapfer 2001).

5. Conclusions and Implications

The results of this study bring support to the general believes that species loss, shifts in species composition and succession are the main problems the meadows of the nature reserve Bodenmöser in Isny im Allgäu are facing. Those problems are well known in nature conservation and have already been subject to extensive scientific research (Zerbe 2009; Duprè et al. 2010; Diekmann et al. 2014).

Especially the loss of endangered and characteristic plant species is a clear sign that the existing management of the study area has flaws. A revision of maintenance measures is recommended. For example the mowing dates could be made more flexible because a strict mowing date hinders the establishment of ecological niches (Verhoeven 2014).

Further investigation should be considered to confirm the management recommendations of this thesis. Especially in regard of the plans to re-establish the water meadow practice. It should be weight whether the investment is really expended. The conditions today are very different from the past. The water of the small stream Isnyer Ach is no longer nutrient-rich as the waste water is going to the sewage system. Fertilizing effects are therefore not expected. A very positive effect could the watering have on those parts of the study area which suffer from dry soil conditions in the summer. Also to counteract the draining effects of the ditches it should be considered to dam the water in the ditches and slow down the water outflow from the meadows. Real watering of the meadows like it was done in the past is not explicitly necessary, but rather keeping the water level high in the ditches for example through wooden dam constructions which can regulate the water level. During the mowing times the water level could be lowered so machines can drive without problems on the meadows.

The results indicate nutrient accumulation at least in parts of the study area. This leads to negative changes in species composition. Therefore influences causing eutrophication should be minimized (Pauli et al. 2002).

The key biotopes are wet meadows and litter meadows. They characterize the area and bear many endangered species. Also the tall forbs and reeds areas are playing a key role in the development of the area. They typically do not have the plant diversity like wet meadows or litter meadows, but they are important for the fauna especially birds and butterflies. Both biotope complexes, the meadows and the tall forbs plus reeds, are closely related. Only the management decides over their future development. The management of the area needs to weigh which management goals should be reached for every biotope. It is clear that the open landscape character, with meadows as the main biotope complexes, has to be maintained by regular mowing. Allowing the tall forbs communities and reeds to further invade the meadows would contradict the conservation goals.

The maintenance measures for the nature reserve like mowing of the meadows are performed by local farmers. They have maintenance contracts with the administration of the nature reserve and receive money for their efforts. In their contacts it is specified when they have to mow, how often and whether or not they are allowed to use manure or other fertilizer at a parcel. Those specifications originate from the maintenance plan of the reserve. Now based on the results found during this thesis this plan needs to be revised. A more divers maintenance regime could be beneficial for the future development of ecological niches and the desired plant species composition.

If the water meadows should be reactivated the stage of degradation of the peat soil has to be consider as open peat soil is more vulnerable to decomposition and therefor release of greenhouse gases (Joyce 2014).

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7. References

Bettey, J. H. (1977)*:* The development of Water Meadows in Dorset during the seventeenth Century. In *Agricultural History Review* (25), pp. 37–43.

Bettey, Joseph (2003)*:* The Development of Water Meadows on the Salisbury Avon, 1665-1690. In *Agricultural History Review* 51 (2), pp. 163–172&is_mobile=0.

Bezirksstelle für Naturschutz und Landschaftspflege Tübingen (Ed.) (1990)*:* Naturschutzgebiet und dienendes Landschaftsschutzgebiet "Bodenmöser". Gemeinde Argenbühl, Stadt Isny im Allgäu. Mitteilungen der Bezirksstelle für Naturschutz und Landschaftspflege (19). Tübingen.

Böcker, Reinhard; Kowarik, Ingo; Bornkamm, Reinhard (1983)*:* Untersuchungen zur Anwendung der Zeigerwerte nach Ellenberg. In *:* Verhandlungen der Gesellschaft für Ökologie. Festschrift für Heinz Ellenberg, XI. XI. Göttingen, pp. 35–56.

Breunig, Thomas; Demuth, Siegfried (1999)*:* Rote Liste der Farn- und Samenpflanzen Baden-Württemberg. 3., neu bearb. Fassung, Stand 15.4.1999. Karlsruhe: Landesanstalt für Umweltschutz Baden-Württemberg (Naturschutz-Praxis Artenschutz, 2).

Breunig, Thomas; Demuth, Siegfried; Höll, Norbert (2009)*:* Arten, Biotope, Landschaft : Schlüssel zum Erfassen, Beschreiben, Bewerten. 4.th ed. Karlsruhe.

Briemle, G.; Ellenberg, Heinz (1994)*:* Zur Mahdverträglichkeit von Grünlandpflanzen. Möglichkeiten der praktischen Anwendung von Zeigerwerten. In *Natur und Landschaft* 69 (4), pp. 139–147.

Buttler, A. (1992)*:* Permanent plot research in wet meadows and cutting experiment. In *Vegetatio* 103 (2), pp. 113-124. DOI: 10.1007/BF00047697.

Climate Data Centers (CDC) (2014)*:* Wetter und Klima - Deutscher Wetterdienst - Klimadaten. 1996-2014. Edited by DWD - Deutscher Wetterdienst. Bundesministerium für Verkehr und digitale Infrastruktur. Available online at http://www.dwd.de/bvbw/appmanager/bvbw/dwdwwwDesktop?_nfpb=true&_pag

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bel=_dwdwww_klima_umwelt_klimadaten_deutschland&T82002gsbDocumentPath=Navigation%2FOeffentlichkeit%2FKlima__Umwelt%2FKlimadaten%2Fkldaten__kostenfrei%2Fabrufsysteme__ftp__home__node.html%3F__nnn%3Dtrue, checked on 12/12/2014.

Cook, Hadrian F.; Cutting, Roger L.; Buhler, Willie; Cummings, Ian P.F. (2004)*:* Productivity and soil nutrient relations of bedwork watermeadows in southern England. In *Agriculture, Ecosystems & Environment* 102 (1), pp. 61–79. DOI: 10.1016/S0167-8809(03)00227-5.

Cook, Hadrian F.; Stearne, Kathy; Williamson, Tom (2003)*:* The origins of water meadows in England. In *Agricultural History Review* 51 (3), pp. 155–162.

Cook, Hadrian F.; Williamson, Tom (Eds.) (1999)*:* Water management in the English landscape. Field, marsh and meadow. Edinburgh: Edinburgh University Press.

Cutting, Roger L.; Cook, Hadrian F.; Cummings, Ian P. F. (2003)*:* Hydraulic conditions, oxygenation, temperatures and sediment relationships of bedwork watermeadows. In *Hydrol. Process.* 17 (9), pp. 1823–1843. DOI: 10.1002/hyp.1215.

Cutting, Roger L.; Cummings, Ian P.F. (1999)*:* Water meadows: Their form, operation and plant ecology. In Hadrian F. Cook, Tom Williamson (Eds.)*:* Water management in the English landscape. Field, marsh and meadow. Edinburgh: Edinburgh University Press.

Davidsson, Torbjörn Emil; Leonardsen, Lars (1998)*:* Seasonal dynamics of denitrification activity in two water meadows - Springer. In *Hydrobiologia* 364, pp. 189–198. Available online at http://link.springer.com/article/10.1023/A:1003103222351#page-1, checked on 8/11/2014.

Dechert, G.*:* Pflegekonzeption Natur- und Landschaftsschutzgebiet N-163 Bodenmöser (2000). Erläuterungsbericht. Edited by Bezirksstelle für Naturschutz und Landschaftspflege Tübingen. Tübingen.

Deepayan Sarkar (2015)*:* Package ‘lattice’. Lattice Graphics. Version 0.20-30.

Diekmann, Martin; Jandt, Ute; Alard, Didier; Bleeker, Albert; Corcket, Emmanuel; Gowing, David J.G. et al. (2014)*:* Long-term changes in calcareous grassland vegetation in North-western Germany – No decline in species richness, but a shift in species composition. In *Biological Conservation* 172, pp. 170–179. DOI: 10.1016/j.biocon.2014.02.038.

Duprè, C.; Stevens, C. J.; Ranke, T.; Bleeker, A.; Peppler-Lisbach, C.; Gownig, D. J. G. et al. (2010)*:* Changes in species richness and composition in European acidic grasslands over the past 70 years: the contribution of cumulative atmospheric nitrogen deposition. In *Global Change Biology* 16 (1), pp. 344–357. DOI: 10.1111/j.1365-2486.2009.01982.x.

Eggenberg, Stefan; Möhl, Adrian (2009)*:* Flora vegetativa. Ein Bestimmungsbuch für Pflanzen der Schweiz im blütenlosen Zustand. 2., vollst. überarb. Aufl. Bern, Stuttgart, Wien: Haupt.

Ellenberg, H.; Weber, H. E.; Düll, R.; Wirth, V.; Werner, W. (2001)*:* Zeigerwerte von Pflanzen in Mitteleuropa. 3. ed.: Scripta Geobotanica (18).

Ellenberg, Heinz (1952)*:* Wiesen und Weiden und ihre standörtliche Bewertung. Landwirtschaftliche Pflanzensoziologie. With assistance of A. Stählin. 3 volumes. Stuttgart, Ludwigsburg: Eugen Ulmer (18).

Ellenberg, Heinz; Weber, Heinrich E.; Düll, Ruprecht; Wirth, Volkmar; Werner, Willy; Pauliß, Dirk (1992)*:* Zeigerwerte von Pflanzen in Mitteleuropa. 2nd ed. Göttingen: Verlag Erich Goltze KG (Scripta geobotanica, 18).

ESRI (2011)*:* ArcGIS. Version 10.2. Redlands, California: ESRI Inc.

Ewald, Jörg (2003)*:* The sensitivity of Ellenberg indicator values to the completeness of vegetation relevés. In *Basic and Applied Ecology* 4 (6), pp. 507–513. DOI: 10.1078/1439-1791-00155.

Fachschaft für Ornithologie Südlicher Oberrhein (Ed.) (2009)*:* Das Natur- und Landschaftsschutzgebiet "Elzwiesen". Herausragendes Naturpotential einer alten Kulturlandschaft. With assistance of Karl Westermann. Freiamt: Repro-Service & pk-Verlag Peter Klüber (Naturschutz am südlichen Oberrhein, 5).

Fream, W. (1888)*:* On the Flora of Water-Meadows, with Notes on Species. In *The Journal of The Linnean Society* (XXIV), pp. 454–464.

Galatowitsch, Susan M.; Whited, Diane C.; Lehtinen, Richard; Husveth, Jason; Schik, Karen (2000)*:* The vegetation of wet meadows in relation to their land-use. In *Environmental Monitoring and Assessment* 60 (2), pp. 121–144. DOI: 10.1023/A:1006159028274.

Göttlich, K.-H. (1975)*:* MOORKARTE VON BADEN-WÜRTTEMBERG; 1:50 000. Stuttgart: Landesvermessungsamt Baden-Württemberg.

Grime, J. P. (2001)*:* Plant strategies, vegetation processes and ecosystem properties. Chichester: Wiley.

Hajek, M.; Horsak, M.; Hajkova, P.; Dite, D. (2006)*:* Habitat diversity of central European fens in relation to environmental gradients and an effort to standardise fen terminology in ecological studies. In *Perspectives in Plant Ecology, Evolution and Systematics* 8 (2), pp. 97–114. DOI: 10.1016/j.ppees.2006.08.002.

Havlová, Marcela; Chytrý, Milan; Tichý, Lubomír (2004)*:* Diversity of hay meadows in the Czech Republic: major types and environmental gradients. In *Phytocoenologia* 34 (4), pp. 551–567. DOI: 10.1127/0340-269X/2004/0034-0551.

Herbst, Lutz Dietrich (1988)*:* Brühle, Missen und Doggen - Zur Wässerungslandwirtschaft in Oberschwaben. In *Schwäbische Heimat: Zeitschrift für Regionalgeschichte, württembergische Landeskultur, Naturschutz und Denkmalpflege* 39 (3), pp. 204–212.

Hill, M.; Gauch, H. (1980)*:* Detrended correspondance analysis, an improved ordination technique. In *Vegetatio* (42), pp. 47–58.

Hölzinger, J.; Boschert, M. (Eds.) (2001): Die Vögel Baden-Württembergs. Nicht-Singvögel 2. Stuttgart: Verlag Eugen Ulmer GmbH & Co (2.2).

Jäger, Eckehart Johannes; Rothmaler, Werner (2013): Exkursionsflora von Deutschland. Gefäßpflanzen: Atlasband. 12., neu bearb. und erw. Aufl. Berlin: Springer Spektrum (Exkursionsflora von Deutschland, [Bd. 3, Ed. 12]).

Jensen, K. (1997): Vegetationsökologische Untersuchungen auf nährstoffreichen Feuchtgrünland-Brachen Sukzessionsverlauf und dynamisches Verhalten von Einzelarten. In *Feddes Repert.* 108 (7-8), pp. 603–625. DOI: 10.1002/fedr.19971080714.

Joyce, Chris B. (2014): Ecological consequences and restoration potential of abandoned wet grasslands. In *Ecological Engineering* 66, pp. 91–102. DOI: 10.1016/j.ecoleng.2013.05.008.

Kapfer, A. (2001): Streuwiesen und Nasswiesen. Biotope in Baden-Württemberg. 2,. Karlsruhe (5).

Konold, Werner (1991): Wasser, Wiesen und Wiesenwässerung in Isny im Allgäu. Ein Beitrag zur Agrar- und Stadtgeschichte, pp. 161–213.

Konold, Werner; Deutscher Verband für Wasserwirtschaft und Kulturbau e.V. (Eds.) (1994): Historische Wasserwirtschaft im Alpenraum und an der Donau. Wasserbewirtschaftung und wassernutzung in Isny im Allgäu. Stuttgart: Konrad Wittwer.

Kubát, Karel; Bělohlávková, Radmila (2002): Klíč ke květeně České republiky. Praha: Academia.

Küchler, Meinrad (2014): VEGEDAZ. Version March 2014. 64-bit version. Birmensdorf: Forschungseinheit Biodiversität und Naturschutzbiologie, Eidg. Forschungsanstalt WSL. Available online at http://www.wsl.ch/dienstleistungen/produkte/software/vegedaz/index_DE, checked on 8/28/2014.

Landesamt für Geoinformation und Landentwicklung (2013): Digitale Orthophotos (DOP) Baden-Württemberg. Karlsruhe.

Landesnaturschutzverband Baden-Württemberg (Ed.) (1995): Wässerwiesen. Geschichte, Technik und Ökologie der bewässerten Wiesen, Bäche und Gräben in Kraichgau, Hardt und Bruhrain : ein Gemeinschaftsprojekt des Landesnaturschutzverbandes Baden-Württemberg … With assistance of Dieter Hassler. Ubstadt-Weiher: Verl. Regionalkultur (Veröffentlichungen für Naturschutz und Landschaftspflege in Baden-Württemberg : Beiheft, 87).

Lauter, W. (1851): Anleitung zur behandlung der wässerwiesen nach jahroszeiten, monaten und witterungsverhältnissen … Karlsruhe: Verlag der Herder'schen buchhandlung. Available online at http://books.google.de/books?id=1q81AAAAMAAJ.

Legendre, Pierre; Legendre, Louis (2012): Numerical ecology. 3rd English ed. Amsterdam, Boston: Elsevier (Developments in environmental modelling, 24).

Leibundgut, Christian (2009)*:* Grundzüge der Wiesenwässerung in der Oberrheinebene - historisch und gegenwärtig. In Fachschaft für Ornithologie Südlicher Oberrhein (Ed.)*:* Das Natur- und Landschaftsschutzgebiet "Elzwiesen". Herausragendes Naturpotential einer alten Kulturlandschaft. With assistance of Karl Westermann. Freiamt: Repro-Service & pk-Verlag Peter Klüber (Naturschutz am südlichen Oberrhein, 5), pp. 39–50.

Leibundgut, Christian; Kohn, Irene (2014a)*:* EUROPEAN TRADITIONAL IRRIGATION IN TRANSITION PART I: IRRIGATION IN TIMES PAST-A HISTORIC LAND USE PRACTICE ACROSS EUROPE. In *Irrig. and Drain. DOI:* 10.1002/ird.1826.

Leibundgut, Christian; Kohn, Irene (2014b)*:* EUROPEAN TRADITIONAL IRRIGATION IN TRANSITION PART II: TRADITIONAL IRRIGATION IN OUR TIME-DECLINE, REDISCOVERY AND RESTORATION PERSPECTIVES. In *Irrig. and Drain.* 63 (3), pp. 294–314. DOI: 10.1002/ird.1825.

Lepš, Jan (1999)*:* Nutrient status, disturbance and competition: an experimental test of relationships in a wet meadow. In *Journal of Vegetation Science* 10 (2), pp. 219–230. DOI: 10.2307/3237143.

Lepš, Jan; Wan, Shiqiang (2014)*:* Scale- and time-dependent effects of fertilization, mowing and dominant removal on a grassland community during a 15-year experiment. In *J Appl Ecol* 51 (4), pp. 978–987. DOI: 10.1111/1365-2664.12255.

Lüder, Rita (2013)*:* Grundkurs Pflanzenbestimmung. Eine Praxisanleitung für Anfänger und Fortgeschrittene. 6., korr. und aktualisierte Aufl. Wiebelsheim: Quelle & Meyer (Quelle-&-Meyer-Bestimmungsbücher).

McGovern, Stephanie; Evans, Chris D.; Dennis, Peter; Walmsley, Clive; McDonald, Morag A. (2011)*:* Identifying drivers of species compositional change in a semi-natural upland grassland over a 40-year period. In *Journal of Vegetation Science* 22 (2), pp. 346–356. DOI: 10.1111/j.1654-1103.2011.01256.x.

Oberdorfer, Erich (1993)*:* Süddeutsche Pflanzengesellschaften. 3 Aufl. Jena: Gustav Fischer.

Oberdorfer, Erich (2001)*:* Pflanzensoziologische Exkursionsflora für Deutschland und angrenzende Gebiete. 8., stark überarb. und erg. Aufl. Stuttgart (Hohenheim): Ulmer.

Oksanen, J.; Blanchet, G.; Kindt, R.; Legendre, P.; Minchin, P. R.; O'Hara, R. B. et al. (2015)*:* Community Ecology Package. Package 'vegan' for R. Version 2.2. Available online at http://cran.r-project.org, https://github.com/vegandevs/vegan.

Olde Venterink, H.; van der Vliet, R.E.; Wassen, M. J. (2001)*:* Nutrient limitation along a productivity gradient in wet meadows. In *Plant and Soil* 234 (2), pp. 171–179. DOI: 10.1023/A:1017922715903.

Pauli, Daniela; Peintinger, Markus; Schmid, Bernhard (2002)*:* Nutrient enrichment in calcareous fens: effects on plant species and community structure. In *Basic and Applied Ecology* 3 (3), pp. 255–266. DOI: 10.1078/1439-1791-00096.

Prach, K. (1993)*:* Vegetational changes in a wet meadow complex, South Bohemia, Czech Republic. In *Folia geobot. phytotax.* 28 (1), pp. 1-13. DOI: 10.1007/BF02853197.

Pusey, Philip (1849)*:* On the theory and practice of water-meadows. Available online at http://books.google.de/books?id=NBkAAAAAQAAJ.

R Development Core Team (2008)*:* R: A language and environment for. Version 3.1.2. Vienna: The R foundation for Statistical Computing.

Roberts, D. W. (2013)*:* Ordination and Multivariate Analysis for Ecology. Package 'labdsv' for R. Version 1.6. Available online at http://ecology.msu.montana.edu/labdsv/R.

Rothmaler, Werner; Jäger, Eckehart Johannes (2011)*:* Exkursionsflora von Deutschland. Gefäßpflanzen : Grundband. 20., neu bearb. und erw. Aufl. Heidelberg: Spektrum Akademischer Verlag.

Scharff, Gottfried (2009)*:* Vergrasung und Verstaudung von Wiesen bei später Mahd - eine Entwertung des Grünlands. In Fachschaft für Ornithologie Südlicher Oberrhein (Ed.)*:* Das Natur- und Landschaftsschutzgebiet "Elzwiesen". Herausragendes Naturpotential einer alten Kulturlandschaft. With assistance of Karl Westermann. Freiamt: Repro-Service & pk-Verlag Peter Klüber (Naturschutz am südlichen Oberrhein, 5), pp. 61–62.

Schmeil, Otto; Fitschen, Jost (2011)*:* Die Flora Deutschlands und der angrenzenden Länder. Ein Buch zum Bestimmen aller wildwachsenden und häufig kultivierten Gefäßpflanzen. 95., vollst. überarb. und erw. Aufl. Edited by Siegmund Seybold. Wiebelsheim: Quelle und Meyer (Quelle-&-Meyer-Bestimmungsbücher).

Schwertle, M.*:* Kartierung von Lebensraumeinheiten im Naturschutzgebiet Bodenmöser, Isny im Allgäu (1987). Bezirksstell für Naturschutz und Landschaftspflege.

Seidenspinner, Wolfgang (2014)*:* Historische Wiesenwässerung im Teinachtal. Relikte der Agrar- und Technikgeschichte zwischen Funktionsverlust und Zeugniswert. In *Denkmalpflege in Baden-Württemberg–Nachrichtenblatt der Landesdenkmalpflege* 20 (3), pp. 136–144. Available online at http://journals.ub.uni-heidelberg.de/index.php/nbdpfbw/article/viewFile/13577/7413, checked on 8/10/2014.

Simpson, G. L. (2015)*:* Package 'permute'. Functions for generating restricted permutations of data. Version 0.8-3.

Smith, William (1806)*:* Observations on the Utility, Form and Management of Water Meadows, and Draining and Irrigating of Peat Bogs: With an Account of Prisley Bog and Other Extraordinary Improvements, Conducted for His Grace the Duke of Bedford, Thomas William Coke … and Others. London: John Harding. Available online at http://books.google.de/books?id=KT5FAAAAYAAJ.

Tichý, Lubomír (2002)*:* JUICE, software for vegetation classification. version 7.0. In *Journal of Vegetation Science* 13 (3), pp. 451–453. DOI: 10.1111/j.1654-1103.2002.tb02069.x.

Verhoeven, Jos T.A. (2014)*:* Wetlands in Europe: Perspectives for restoration of a lost paradise. In *Ecological Engineering* 66, pp. 6–9. DOI: 10.1016/j.ecoleng.2013.03.006.

Wittig, Burghard; Waldmann, Theresa; Diekmann, Martin (2007)*:* Veränderung der Grünlandvegetation im Holtumer Moor über vier Jahrzehnte. In *Hereynia N.F.* (40), pp. 285–300, checked on 8/10/2014.

Zerbe, Stefan (Ed.) (2009)*:* Renaturierung von Ökosystemen in Mitteleuropa. Heidelberg: Spektrum, Akad. Verl.

8. Appendices

8.1 Appendix 1

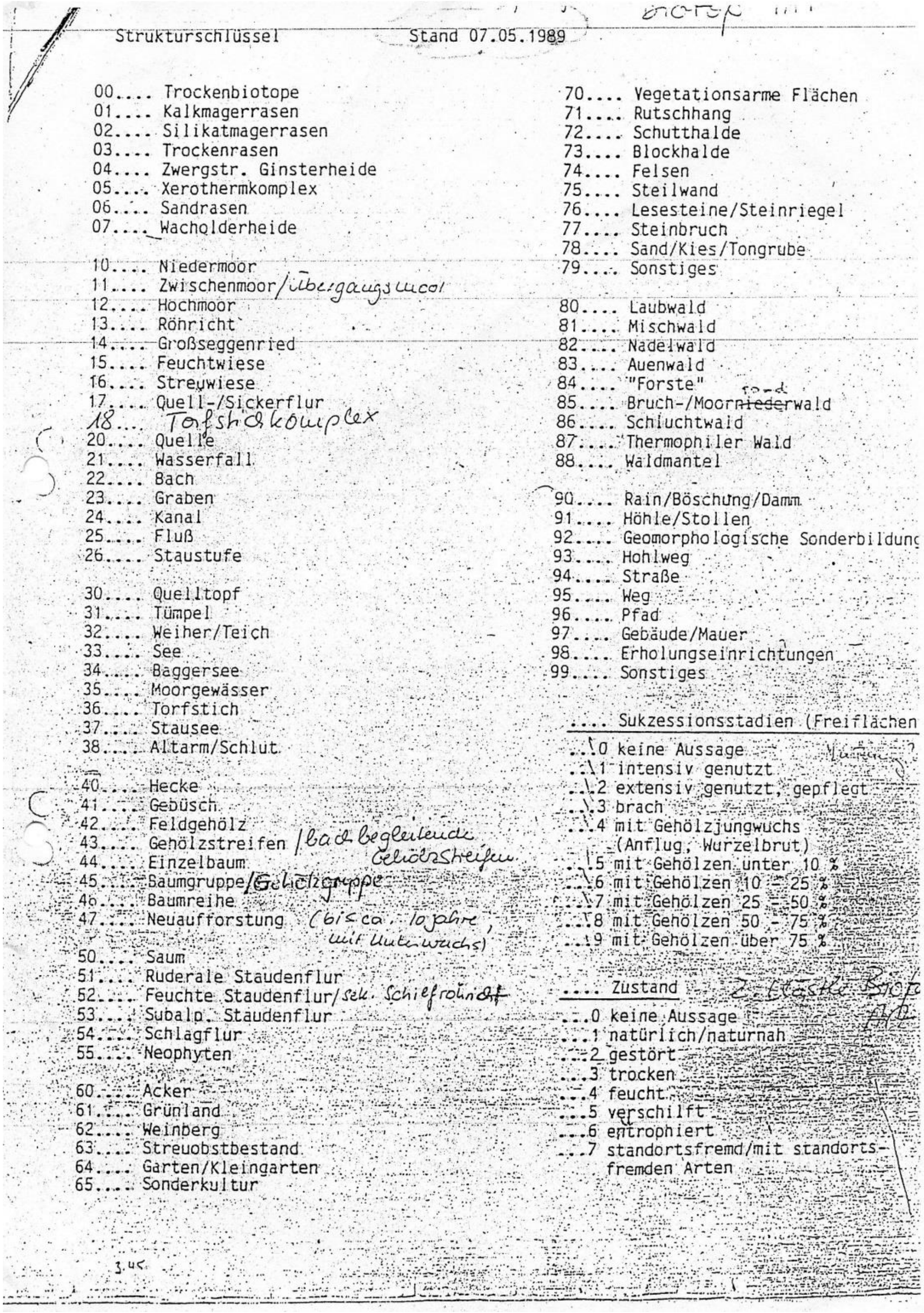
Table 9. *Red list Baden Württemberg status for all plant species found in the nature reserve "Bodenmöser". V = early warning list, 3 = endangered, 2 = highly endangered, 1 = going extinct..*

Scientific name	german name	Red list BW status
Aconitum napellus	Neuberger Eisenhut	V
Andromeda polifolia	Rosmarinheide	3
Arnica montana	Berg-Wohlverleih	2
Aster bellidiastrum	Alpenmaßliebchen	V
Bidens cernuus	Nickender Zweizahn	3
Blysmus compressus	Flache Quellsimse	2
Bromus racemosus	Traubige Trespe	3
Carex appropinquata	Schwarzkopf-Segge	3
Carex canascens	Grau-Segge	V
Carex davalliana	Davalls Segge	3
Carex diandra	Draht-Segge	2
Carex echinata	Stern-Segge	V
Carex elongata	Walzen-Segge	V
Carex flava	Echte Gelbsegge	V
Carex hostiana	Saum-Segge	2
Carex lasiocarpa	Faden-Segge	3
Carex lepidocarpa	Schuppenfrüchtige Gelbsegge	3
Carex limosa	Schlamm-Segge	2
Carex nigra	Braune Segge	V
Carex pulicaris	Floh-Segge	2
Carex tomentosa / C. filiformis	Filz-Segge	3
Centaurea pseudophrygia	Perücken-Flockenblume	3
Chenopodium glaucum	Graugrüner Gänsefuß	V

Cirsium rivulare	Bach-Kratzdistel	V
Crepis mollis	Weichhaariger Pippau	3
Crocus albiflorus	Weißer Safran	1
Dactylorhiza incarnata	Fleischrotes Knabenkraut	3
Dactylorhiza majalis	Breitblättriges Knabenkraut	3
Dactylorhiza traunsteineri	Traunsteiners Knabenkraut	2
Dianthus superbus	Prachtnelke	3
Drosera intermedia	Mittlerer Sonnentau	2
Drosera longifolia / D. anglica	Langblättriger Sonnentau	2
Drosera rotundifolia	Rundblätriger Sonnentau	3
Epilobium palustre	Sumpf-Weidenröschen	V
Epipactis palustris	Sumpf-Stendelwurz	3
Equisetum variegatum	Bunter Schachtelhalm	2
Eriophorum angustifolium	Schmalblättriges Wollgras	3
Eriophorum latifolium	Breitblättriges Wollgras	3
Eriophorum vaginatum	Moor-Wollgras	V
Gentiana asclepiadea	Schwalbenwurz-Enzian	3
Gentiana verna	Frühlings-Enzian	2
Gymnadenia conopsea	Mücken-Händelwurz	V
Gymnadenia odoratissima	Wohlriechende Händelwurz	3
Herminium monorchis	Elfenstendel	2
Hieracium lactucella	Geöhrtes Habichtskraut	V
Homogyne alpina	Grüner Alpenlattich	2
Hydrocotyle vulgaris	Wassernabel	2
Iris sibirica	Sibirische Schwertlilie	2
Juncus alpinoarticulatus	Gebirgs-Binse	V
Juncus filiformis	Faden-Binse	V
Leucojum vernum	Frühlingsknotenblume, Märzenbecher	V
Lilium bulbiferum (N)	Feuer-Lilie	1
Liparis loeselii	Glanzstendel	2
Lonicera caerulea	Blaue Heckenkirsche	3
Lycopodiella inundata	Sumpfbärlapp	2
Lysimachia thyrsiflora	Strauß-Gilbweiderich	3
Menyanthes trifoliata	Fieberklee	3
Orchis morio	Kleines Knabenkraut	3
Orchis ustulata	Brand-Knabenkraut	2
Parnassia palustris	Herzblatt	3
Pedicularis palustris	Sumpf-Läusekraut	2
Peucedanum palustre	Sumpf-Haarstrang	3
Phyteuma orbiculare	Kugel-Teufelskralle	3
Pinguicula vulgaris	Gewöhnliches Fettkraut	3

Pinus mugo	Bergkiefer	R
Pinus rotundata	Moor-Kiefer	3
Platanthera bifolia	Weiße Waldhyazinthe	V
Polygala amarella	Sumpf-Kreuzblume	V
Potentilla palustris/ Comarum palustre	Blutauge	3
Primula farinosa	Drüsige Schlüsselblume	2
Primula veris	Arznei-Schlüsselblume	V
Pyrola rotundifolia	Rundblättriges Wintergrün	3
Pyrus pyraster	Wild-Birne	V
Ranunculus lingua	Zungenhahnenfuß	2
Ranunculus montanus	Echter Berg-Hahnenfuß	2
Rhynchospora alba	Weiße Schnabelsimse	3
Rhynchospora fusca	Braune Schnabelsimse	2
Rumex aquaticus	Wasser-Ampfer	3
Rumex hydrolapathum	Riesen-Ampfer	V
Salix repens	Kriech-Weide	3
Scheuchzeria palustris	Blasenbinse	2
Schoenus ferrugineus	Rostrotes Kopfriet	3
Schoenus nigricans	Schwarzes Kopfried	2
Scorzonera humilis	Niedrige Schwarzwurzel	3
Selinum carvifolia	Kümmel-Silge	3
Senecio cordatus	Alpen-Greiskraut	V
Senecio paludosus	Sumpf-Greiskraut	V
Thalictrum aquilegiifolium	Akeleiblättrige Wiesenraute	V
Thelyptris palustris	Sumpf-Lappenfarn	3
Thymus serpyllum	Sand-Thymian	2
Tofieldia calyculata	Gewöhnliche Simsenlilie	3
Traunsteinera globosa	Kugelorchis	1
Trichophorum alpinum	Alpen-Wollgras	2
Trichophorum cespitosum	Gewöhnliche Rasenbinse	V
Trollius europaeus	Trollblume	3
Utricularia intermedia	Mittlerer Wasserschlauch	2
Utricularia vulgaris	Echter Wasserschlauch	2
Vaccinium oxycoccos	Gewöhnliche Moosbeere	3
Vaccinium uliginosum	Gewöhnliche Moorbeere	V
Vaccinium vitis-idaea	Preiselbeere	3
Veratrum album	Grüner Germer	V
Viola palustris	Sumpf-Veilchen	V

8.2 Appendix 2



Strukturschlüssel Stand 07.05.1989

00.... Trockenbiotope
01.... Kalkmagerrasen
02.... Silikatmagerrasen
03.... Trockenrasen
04.... Zwergstr. Ginsterheide
05.... Xerothermkomplex
06.... Sandrasen
07.... Wacholderheide

10.... Niedermoor
11.... Zwischenmoor/Übergangsmoor
12.... Hochmoor
13.... Röhricht
14.... Großseggenried
15.... Feuchtwiese
16.... Streuwiese
17.... Quell-/Sickerflur
18.... Torfstichkomplex
20.... Quelle
21.... Wasserfall
22.... Bach
23.... Graben
24.... Kanal
25.... Fluß
26.... Staustufe

30.... Quelltopf
31.... Tümpel
32.... Weiher/Teich
33.... See
34.... Baggersee
35.... Moorgewässer
36.... Torfstich
37.... Stausee
38.... Altarm/Schlut

40.... Hecke
41.... Gebüsch
42.... Feldgehölz
43.... Gehölzstreifen/bachbegleitende Gehölzstreifen
44.... Einzelbaum
45.... Baumgruppe/Gehölzgruppe
46.... Baumreihe
47.... Neuaufforstung (bis ca. 10 Jahre, mit Unterwuchs)

50.... Saum
51.... Ruderale Staudenflur
52.... Feuchte Staudenflur/sek. Schilfröhricht
53.... Subalp. Staudenflur
54.... Schlagflur
55.... Neophyten

60.... Acker
61.... Grünland
62.... Weinberg
63.... Streuobstbestand
64.... Garten/Kleingarten
65.... Sonderkultur

70.... Vegetationsarme Flächen
71.... Rutschhang
72.... Schutthalde
73.... Blockhalde
74.... Felsen
75.... Steilwand
76.... Lesesteine/Steinriegel
77.... Steinbruch
78.... Sand/Kies/Tongrube
79.... Sonstiges

80.... Laubwald
81.... Mischwald
82.... Nadelwald
83.... Auenwald
84.... "Forste"
85.... Bruch-/Moor~~niederwald~~wald
86.... Schluchtwald
87.... Thermophiler Wald
88.... Waldmantel

90.... Rain/Böschung/Damm
91.... Höhle/Stollen
92.... Geomorphologische Sonderbildung
93.... Hohlweg
94.... Straße
95.... Weg
96.... Pfad
97.... Gebäude/Mauer
98.... Erholungseinrichtungen
99.... Sonstiges

.... Sukzessionsstadien (Freiflächen)

...0 keine Aussage
...1 intensiv genutzt
...2 extensiv genutzt, gepflegt
...3 brach
...4 mit Gehölzjungwuchs (Anflug, Wurzelbrut)
...5 mit Gehölzen unter 10 %
...6 mit Gehölzen 10 - 25 %
...7 mit Gehölzen 25 - 50 %
...8 mit Gehölzen 50 - 75 %
...9 mit Gehölzen über 75 %

.... Zustand

...0 keine Aussage
...1 natürlich/naturnah
...2 gestört
...3 trocken
...4 feucht
...5 verschilft
...6 eutrophiert
...7 standortsfremd/mit standortsfremden Arten

Figure 30: Structure key with biotope types and identification number (Schwertle 1987).

8.3 Appendix 3

Pflege - Schlüssel Stand: 28.03.89

Pflegemaßnahmen "Mn"

100 Mahd extensive Grünlandbewirtschaftung
110 Aushagerungsmahd (Extensivierung landw. Nutzflächen)
120 Aushagerungsmahd (Zurückdrängung von Schilf, Hochstauden)
Spätmahd 130 ~~Streumahd~~ in Feuchtgebieten
140 Spätmahd in Trockenbiotopen
150 Schilfmahd (z.B. Bodensee)
160 Sonstiges

200 Gehölzpflege
210 Gehölzjungwuchs entfernen
220 Gehölzbestand entfernen (100%)
230 Gehölzbestand verlichten
231 auf 90% der Fläche
232 75%
233 50%
234 25%
235 10%
240 Bestandspflege von Feldgehölzen
250 Bestandspflege von Hecken
260 Bestandspflege von Gebüschen
270 Einzelgehölzpflege (Sanierung, Schnitt)
280 Entfernung von standortsfremden Gehölzen

300 Pflege von Streuobstbeständen
310 Streuobstpflege mit Mahd
320 Streuobstpflege mit Beweidung

400 Gewässerpflege
410 Unterhaltungsmaßnahmen Fließgewässer
411 Grabenpflege (Räumen)
412 Sicherungsmaßnahmen Fließgewässer
420 Unterhaltungsmaßnahmen stehender Gewässer
421 Entkrautung
422 Entschlammung

500 Sukzession (Flächen ohne Pflege)
510 Sukzession
520 vorläufig keine Pflege

600 Schafbeweidung
610 Schafbeweidung in Hütehaltung
620 Schafbeweidung in Koppelhaltung

700 Renaturierung und Gestaltung
710 Geländemodellierung
720 Neupflanzung von Gehölzen
730 Verpflanzung von Gehölzen, Einzelbäumen
740 Neuanlage stehender Gewässer
750 Renaturierung stehender Gewässer
760 Renaturierung Fließgewässer
770 Wiedervernässung
780 Sonstiges

800 Pflegemaßnahmen im Wald

900 Sonstige Maßnahmen
910 Unterhaltung von Wegen und Pflegegassen
920 Neuanlage von Wegen und Pflegegassen
930 Beseitigung von Abfall
940 Beseitigung von landwirtschaftlichen Ablagerungen (Mist, Mähgut...)
950 Beseitigung von Zäunen, Bauten...
960 Schutzvorkehrungen
970 Einrichtungen zur Information der Öffentlichkeit und Erholungsvorsorge
980 Beseitigung von Neophyten
990 Umwandlung von Acker in Grünland (Einsaat)

Pflegeaufwand "A"
0 keine Aussage (z.B. keine Pflege)
1 niedrig (mit einfachen Maschinen, einfaches Gelände
2 mittel (mit Spezialmaschinen)
3 hoch (Handarbeit)

Pflegeturnus "T"
0 nach Notwendigkeit und Absprache mit der BNL, Einzelfallregelungen, Sonderfälle
01 einmalig
02 3x jährlich
03 2x jährlich
04 1x jährlich
05 alle 2 Jahre
.
13 alle 10 Jahre
14 mehr als 10 Jahre

Pflegezeitpunkt "Zp"
0 wird zum erforderlichen Zeitpunkt vor Ort entschied
01 ab Januar
02 ab Februar
.
13 außerhalb der Vegetationszeit bis 28. Feb. (Gehölzp
14 am Ende der Vegetationsperiode, frühestens ab Mitte
15 während eines festgelegten Zeitraumes

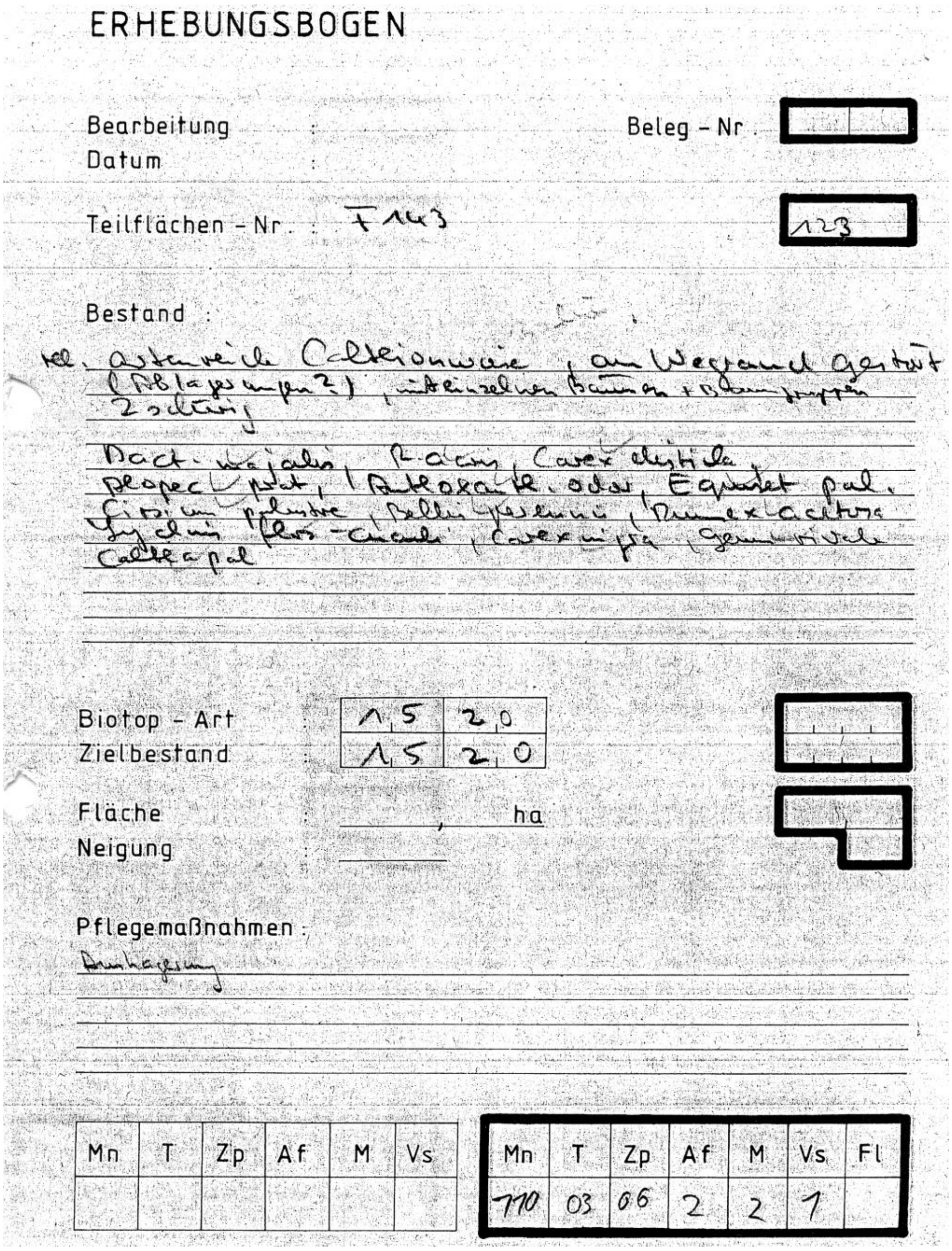
Pflegeausführung "Af"
0 wird zum erforderlichen Zeitpunkt vor Ort entschiede
1 mit Handgeräten (z.B. Spaten, Schaufel, Sense, Freischneidegerät, Balkenmäher, Motorsäge)
2 mit Mähgeräten, einschl. Geräten zum Schwaden und La (z. B. Motormäher, Mähraupe, Schlepper)
3 Grabenfräse
4 Großmaschinen (Bagger, Planierraupe u.ä.)

Pflegemodus "M"
0 keine Aussage
1 Vorbereitungspflege
2 Dauerpflege
3 nicht verfügbare Fläche (Privatfläche mit Nutzungsre
4 Durchführung nach anderen Programmen
5 erst nach Durchführung einer übergeordneten Maßnahme

Vorrangstufe "Vs"
0 keine Klassifizierung (z.B. Sukzession)
1 sehr wichtig
2 wichtig
3 weniger wichtig

Figure 31: Maintenance key from 1987 (Schwertle 1987).

8.4 Appendix 4


ERHEBUNGSBOGEN

Bearbeitung :

Datum :

Beleg - Nr. :

Teilflächen - Nr. : F 143 | 123

Bestand :

Tl. artenreiche Calthionwiese, am Wegrand gestört (Ablagerungen?), mit einzelnen Bäumen + Baumgruppen
2 schürig

Dact. majalis, R. acris, Carex disticha, Peucedanum pal., Anthoxanthum odor., Equisetum pal.
Cirsium palustre, Bellis perennis, Rumex acetosa
Lychnis flos-cuculi, Carex nigra, Geum rivale
Caltha pal.

Biotop - Art : 1,5 | 2,0

Zielbestand : 1,5 | 2,0

Fläche : ____ , ____ ha

Neigung : ____

Pflegemaßnahmen :

Aushagerung

Mn	T	Zp	Af	M	Vs

Mn	T	Zp	Af	M	Vs	Fl
110	03	06	2	2	1	

Figure 32: Exemplary datasheet of 1987 mapping.

8.5 Appendix 5

Table 10. *List of all Species with name synonymes and Indicator values by Ellenberg et al. (2001).*

Species names used by JUICE	Synonymes	Indicator values by Ellenberg		
		Moisture	Reaction	Nutrients
Acer campestre	Acer campestre L.	5	7	6
Acer pseudoplatanus	Acer pseudoplatanus L.	6	x	7
Achillea millefolium agg.	Achillea millefolium L. s.str.			
Aegopodium podagraria	Aegopodium podagraria	6	7	8
Agrostis canina	Agrostis canina L.	9	3	2
Agrostis stolonifera	Agrostis stolonifera L.	7	x	5
Ajuga reptans	Ajuga reptans L.	6	6	6
Alchemilla vulgaris agg.	Alchemilla vulgaris aggr.			
Alisma plantago-aquatica	Alisma plantago-aquatica L.	10	x	8
Alliaria petiolata	Alliaria petiolata (M. Bieb.) Cavara & Grande	5	7	9
Alnus glutinosa	Alnus glutinosa (L.) Gaertn.	9	6	x
Alnus incana	Alnus incana (L.) Moench	7	8	x
Alopecurus geniculatus	Alopecurus geniculatus L.	8	7	7
Alopecurus pratensis	Alopecurus pratensis L.	6	6	7
Angelica sylvestris	Angelica sylvestris L.	8	x	4
Anthoxanthum odoratum	Anthoxanthum odoratum L.	x	5	x
Anthriscus sylvestris	Anthriscus sylvestris (L.) Hoffm.	5	x	8
Aquilegia vulgaris	Aquilegia vulgaris L.	4	7	4
Arrhenatherum elatius	Arrhenatherum elatius (L.) J. & C. Presl	x	7	7
Artemisia vulgaris	Artemisia vulgaris L.	6	x	8
Astrantia major	Astrantia major L.	6	8	5
Avenula pubescens	Helictotrichon pubescens (Huds.) Pilg.			
Bellis perennis	Bellis perennis L.	5	x	6
Betula pendula	Betula pendula Roth	x	x	x
Betula pubescens	Betula pubescens Ehrh. s.l.	8	3	3
Betula spec.	Betula spec.			
Bistorta major	Polygonum bistorta L.	7	5	5
Blysmus compressus	Blysmus compressus (L.) Link	8	8	3
Briza media	Briza media L.	x	x	2
Bromus hordeaceus	Bromus hordeaceus L.	x	x	3
Bromus racemosus	Bromus racemosus L. s.l.	8	5	5
Callitriche spec.	Callitriche spec.			
Caltha palustris	Caltha palustris L.	9	x	6
Calystegia sepium	Calystegia sepium (L.) R. Br.	6	7	9

Campanula patula	Campanula patula L. s.l.	5	7	5
Campanula rotundifolia	Campanula rotundifolia L.	x	x	2
Capsella bursa-pastoris	Capsella bursa-pastoris (L.) Medik.	5	x	6
Cardamine pratensis	Cardamine pratensis L.			
Cardamine pratensis agg.	Cardamine pratensis aggr.			
Carex acuta	Carex gracilis Curtis	9	6	4
Carex acutiformis	Carex acutiformis Ehrh.	9	7	5
Carex appropinquata	Carex appropinquata Schumach.	9	9	4
Carex brizoides	Carex brizoides L.	6	4	3
Carex canescens	Carex canescens L.	9	4	2
Carex cespitosa	Carex cespitosa L.	9	6	4
Carex davalliana	Carex davalliana Sm.	9	8	2
Carex diandra	Carex diandra Schrank	9	6	3
Carex disticha	Carex disticha Huds.	9	8	5
Carex echinata	Carex echinata Murray	8	3	2
Carex elata	Carex elata All.	10	x	5
Carex flacca	Carex flacca Schreb.	6	8	4
Carex flava	Carex flava L.			
Carex flava agg.	Carex flava aggr.	9	8	2
Carex hirta	Carex hirta L.	6	x	5
Carex hostiana	Carex hostiana DC.	9	6	2
Carex muricata	Carex muricata L.	4	x	6
Carex nigra	Carex nigra aggr.	8	3	2
Carex ovalis	Carex leporina L.	7	3	3
Carex pallescens	Carex pallescens L.	6	4	3
Carex panicea	Carex panicea L.	8	x	4
Carex paniculata	Carex paniculata L.	9	6	4
Carex pulicaris	Carex pulicaris L.	9	4	2
Carex rostrata	Carex rostrata Stokes	1	3	3
Carex vesicaria	Carex vesicaria L.	9	6	5
Carpinus betulus	Carpinus betulus L.	x	x	x
Carum carvi	Carum carvi L.	5	x	6
Centaurea jacea	Centaurea jacea L. s.l.	x	x	x
Cerastium fontanum	Cerastium fontanum Baumg. s.l.	5	5	5
Cerastium fontanum	Cerastium holosteoides Fr.	5	5	5
Chaerophyllum hirsutum	Chaerophyllum hirsutum L.	8	x	7
Cirsium oleraceum	Cirsium oleraceum (L.) Scop.	7	7	5
Cirsium palustre	Cirsium palustre (L.) Scop.	8	4	3
Cirsium rivulare	Cirsium rivulare (Jacq.) All.	7	8	5
Colchicum autumnale	Colchicum autumnale L.	6	7	x
Convolvulus arvensis	Convolvulus arvensis L.	4	7	x

Cornus sanguinea	Cornus sanguinea L.	5	7	x
Crataegus monogyna agg.	Crataegus monogyna Jacq.	4	8	4
Crataegus spec.	Crataegus spec.			
Crepis biennis	Crepis biennis L.	6	6	5
Crepis mollis	Crepis mollis (Jacq.) Asch.	5	5	5
Crepis paludosa	Crepis paludosa (L.) Moench	8	8	6
Cynosurus cristatus	Cynosurus cristatus L.	5	x	4
Dactylis glomerata	Dactylis glomerata L.	5	x	6
Dactylis glomerata agg.	Dactylis glomerata aggr.			
Dactylorhiza incarnata	Dactylorhiza incarnata (L.) Soó s.l.	8	7	2
Dactylorhiza maculata	Dactylorhiza maculata (L.) Soó	8	x	2
Dactylorhiza majalis	Dactylorhiza majalis (Rchb.) P. F. Hunt & Summerh.	8	7	3
Deschampsia caespitosa	Deschampsia caespitosa (L.) P. Beauv.	7	x	3
Eleocharis palustris	Eleocharis palustris (L.) Roem. & Schult.	10	x	?
Elymus repens agg.	Elytrigia repens	x	x	7
Epilobium ciliatum	Epilobium ciliatum Raf.			
Epilobium hirsutum	Epilobium hirsutum L.	8	8	8
Epilobium montanum	Epilobium montanum L.	5	6	6
Epilobium palustre	Epilobium palustre L.	9	3	2
Epilobium spec.	Epilobium spec.			
Epipactis palustris	Epipactis palustris (L.) Crantz	9	8	2
Equisetum arvense	Equisetum arvense L.	x	x	3
Equisetum fluviatile	Equisetum fluviatile L.	10	x	5
Equisetum palustre	Equisetum palustre L.	8	x	3
Eriophorum angustifolium	Eriophorum angustifolium Honck.	9	4	2
Eriophorum angustifolium agg.	Eriophorum angustifolium aggr.			
Eriophorum latifolium	Eriophorum latifolium Hoppe	9	8	2
Euonymus europaea	Euonymus europaeus L.	5	8	5
Eupatorium cannabinum	Eupatorium cannabinum L.	7	7	8
Euphrasia rostkoviana	Euphrasia rostkoviana Hayne s.l.	x	x	4
Fagus sylvatica	Fagus sylvatica L.	5	x	x
Festuca pratensis	Festuca pratensis Huds. s.l.	6	x	6
Festuca pratensis agg.	Festuca pratensis aggr.			
Festuca rubra	Festuca rubra L. s.l.			
Festuca rubra spec.	Festuca rubra aggr.			
Ficaria verna spec.	Ranunculus ficaria L.			
Filipendula ulmaria	Filipendula ulmaria (L.) Maxim.	8	x	5
Frangula alnus	Frangula alnus Mill.	8	4	x

Fraxinus excelsior	Fraxinus excelsior L.	x	7	7
Galeopsis tetrahit	Galeopsis tetrahit L.	5	x	6
Galium album	Galium album Mill.			
Galium aparine	Galium aparine L.	x	6	8
Galium mollugo	Galium mollugo L.			
Galium mollugo agg.	Galium mollugo aggr.			
Galium palustre	Galium palustre L.	9	x	4
Galium uliginosum	Galium uliginosum L.	8	x	2
Gentiana asclepiadea	Gentiana asclepiadea L.	6	7	2
Gentiana verna	Gentiana verna L.	4	7	2
Geranium palustre	Geranium palustre L.	7	8	7
Geum rivale	Geum rivale L.	8	x	4
Geum urbanum	Geum urbanum L.	5	x	7
Glechoma hederacea	Glechoma hederacea L. s.l.	6	x	7
Glyceria fluitans	Glyceria fluitans (L.) R. Br.	9	x	7
Glyceria fluitans agg.	Glyceria fluitans aggr.			
Glyceria maxima	Glyceria maxima (Hartm.) E. Holmb.	1	8	9
Gymnadenia conopsea	Gymnadenia conopsea (L.) R. Br.	7	8	3
Gymnadenia conopsea agg.	Gymnadenia conopsea aggr.			
Heracleum sphondylium	Heracleum sphondylium L. s.l.	5	x	8
Holcus lanatus	Holcus lanatus L.	6	x	5
Hypericum maculatum	Hypericum maculatum Crantz s.l.	6	3	2
Hypericum perforatum	Hypericum perforatum L. s.l.	4	6	4
Hypericum tetrapterum	Hypericum tetrapterum Fr.	8	7	5
Hypochaeris glabra	Hypochaeris glabra L.	3	3	1
Iris pseudacorus	Iris pseudacorus L.	9	x	7
Iris sibirica	Iris sibirica L.	8	6	2
Juncus acutiflorus	Juncus acutiflorus Hoffm.	8	5	3
Juncus alpino-articulatus	Juncus alpino-articulatus Chaix	9	8	2
Juncus articulatus	Juncus articulatus L.	9	x	2
Juncus compressus	Juncus compressus Jacq.	8	7	5
Juncus conglomeratus	Juncus conglomeratus L.	7	4	3
Juncus effusus	Juncus effusus L.	7	3	4
Juncus filiformis	Juncus filiformis L.	9	4	3
Juncus inflexus	Juncus inflexus L.	7	8	4
Juncus spec.	Juncus spec.			
Juncus tenuis	Juncus tenuis Willd.	6	5	5
Knautia arvensis	Knautia arvensis (L.) Coult.	4	x	4
Lamium album	Lamium album L.	5	x	9
Lathyrus pratensis	Lathyrus pratensis L.	6	7	6

Leontodon autumnalis	Leontodon autumnalis L.	5	5	5
Leontodon autumnalis agg.	Leontodon autumnalis aggr.			
Leontodon hispidus	Leontodon hispidus L. s.l.	5	7	6
Leucanthemum vulgare	Chrysanthemum leucanthemum L.			
Ligustrum vulgare	Ligustrum vulgare L.	4	8	3
Linum catharticum	Linum catharticum L.	x	7	2
Listera ovata	Listera ovata (L.) R. Br.	6	7	7
Lolium perenne	Lolium perenne L.	5	7	7
Lonicera xylosteum	Lonicera xylosteum L.	5	7	6
Lotus corniculatus	Lotus corniculatus L. s.l.	4	7	3
Lotus uliginosus	Lotus uliginosus Schkuhr	8	6	4
Luzula campestris	Luzula campestris (L.) DC.	4	3	3
Luzula campestris agg.	Luzula campestris aggr.			
Luzula multiflora	Luzula multiflora (Ehrh.) Lej.	5	5	3
Lychnis flos-cuculi	Lychnis flos-cuculi L.	7	x	x
Lysimachia nummularia	Lysimachia nummularia L.	6	x	x
Lysimachia vulgaris	Lysimachia vulgaris L.	8	x	x
Lythrum salicaria	Lythrum salicaria L.	8	6	x
Marchantia polymorpha	Marchantia polymorpha L.			
Medicago lupulina	Medicago lupulina L.	4	8	x
Medicago polymorpha	Medicago polymorpha L.	3	7	5
Mentha aquatica	Mentha aquatica L.	9	7	5
Mentha longifolia	Mentha longifolia (L.) Huds.	8	9	7
Menyanthes trifoliata	Menyanthes trifoliata L.	9	x	3
Molinia caerulea	Molinia caerulea (L.) Moench	7	x	2
Myosotis palustris	Myosotis palustris Hill	8	x	5
Nardus stricta	Nardus stricta L.	x	2	2
Nasturtium officinale agg.	Nasturtium officinale R. Br.	1	7	7
Orchis morio	Orchis morio L.	4	7	3
Paris quadrifolia	Paris quadrifolia L.	6	7	7
Parnassia palustris	Parnassia palustris L.	8	7	2
Pedicularis palustris	Pedicularis palustris L.	9	x	2
Persicaria amphibia	Persicaria amphibia (L.) Delarbre	11	6	4
Persicaria maculosa	Persicaria maculosa Gray	5	7	7
Petasites albus	Petasites albus (L.) Gaertn.	6	x	5
Phalaris arundinacea	Phalaris arundinacea L.	8	7	7
Phleum pratense	Phleum pratense L.	5	x	7
Phragmites australis	Phragmites australis (Cav.) Steud.	1	7	7
Picea abies	Picea abies (L.) H. Karst.	x	x	x
Pimpinella major ssp.	Pimpinella major (L.) Huds.	5	7	6

major				
Pimpinella saxifraga spec.	Pimpinella saxifraga L.			
Pinguicula vulgaris	Pinguicula vulgaris L.	8	7	2
Pinus sylvestris	Pinus sylvestris L.	x	x	x
Plantago lanceolata	Plantago lanceolata L.	x	x	x
Plantago major spec.	Plantago major L. s.l.			
Platanthera bifolia	Platanthera bifolia (L.) Rich.	5	7	x
Platydictya confervoides	Platydictya confervoides (Brid.) Crum			
Poa annua	Poa annua L.	6	x	8
Poa pratensis	Poa pratensis L.	5	x	6
Poa trivialis	Poa trivialis L. s.l.	7	x	7
Polygala amara agg.	Polygala amara L.	4	8	2
Polygala amarella	Polygala amarella Crantz	9	9	1
Polygonum aviculare agg.	Polygonum aviculare L.	4	x	6
Potentilla anserina	Potentilla anserina L.	6	x	7
Potentilla erecta	Potentilla erecta (L.) Raeusch.	x	x	2
Primula elatior	Primula elatior (L.) L. s.l.	6	7	7
Primula elatior	Primula elatior (L.) L. s.str.			
Primula farinosa	Primula farinosa L.	8	9	2
Primula veris	Primula veris L. s.l.	4	8	3
Prunella vulgaris	Prunella vulgaris L.	5	7	5
Prunus avium	Prunus avium L.	5	7	5
Prunus padus	Prunus padus L. s.l.	8	7	6
Prunus spinosa	Prunus spinosa L.	4	7	x
Pteridium aquilinum	Pteridium aquilinum (L.) Kuhn	5	3	3
Quercus robur	Quercus robur L.	x	x	x
Quercus robur agg.	Quercus robur aggr.			
Ranunculus aconitifolius	Ranunculus aconitifolius L.	8	5	6
Ranunculus acris agg.	Ranunculus acris aggr.	6	x	x
Ranunculus falcatus	Ranunculus falcatus L.			
Ranunculus flammula	Ranunculus flammula L.	9	3	2
Ranunculus repens	Ranunculus repens L.	7	x	7
Rhamnus catharticus	Rhamnus catharticus L.	4	8	4
Rhinanthus alec-torolophus	Rhinanthus alectorolophus (Scop.) Pollich	4	7	3
Rhinanthus minor	Rhinanthus minor L.	4	x	3
Ribes spec.	Ribes spec.			
Rubus idaeus	Rubus idaeus L.	x	x	6
Rumex acetosa	Rumex acetosa L.	x	x	6
Rumex aquaticus	Rumex aquaticus L.	8	7	8
Rumex obtusifolius	Rumex obtusifolius L.	6	x	9

Salix alba	Salix alba L.	8	8	7
Salix aurita	Salix aurita L.	8	4	3
Salix caprea	Salix caprea L.	6	7	7
Salix cinerea	Salix cinerea L.	9	5	4
Salix fragilis	Salix fragilis L.	8	6	6
Salix nigricans	Salix nigricans Sm.			
Salix purpurea	Salix purpurea L. s.l.	x	8	x
Salix repens spec.	Salix repens L. s.l.			
Salix spec.	Salix spec.			
Salix triandra	Salix triandra L.	8	7	5
Sambucus nigra	Sambucus nigra L.	5	x	9
Sanguisorba officinalis	Sanguisorba officinalis L.	6	x	5
Sanguisorba officinalis agg.	Sanguisorba officinalis aggr.			
Scirpus sylvaticus	Scirpus sylvaticus L.	8	4	4
Scrophularia umbrosa	Scrophularia umbrosa Dumort.	9	8	7
Scutellaria galericulata	Scutellaria galericulata L.	9	7	6
Senecio alpestris	Senecio alpestris Gaudin			
Senecio alpinus	Senecio alpinus (L.) Scop.	6	8	9
Senecio aquaticus	Senecio aquaticus Hill	8	4	5
Senecio jacobaea	Senecio jacobaea L.	4	7	5
Silene dioica	Melandrium rubrum Garcke	6	7	8
Solanum dulcamara	Solanum dulcamara L.	8	x	8
Sorbus aucuparia	Sorbus aucuparia L.	x	4	x
Stellaria alsine	Stellaria alsine Grimm	8	4	4
Succisa pratensis	Succisa pratensis Moench	7	x	2
Taraxacum officinale	Taraxacum officinale Weber			
Taraxacum sect. Ruderalia	Taraxacum officinale aggr.	5	x	8
Thalictrum aquilegiifolium	Thalictrum aquilegiifolium L.	8	7	7
Thymus pulegioides spec.	Thymus pulegioides L. s.l.			
Tilia cordata	Tilia cordata Mill.	5	x	5
Tofieldia calyculata	Tofieldia calyculata (L.) Wahlenb.	8	8	2
Tragopogon orientalis	Tragopogon orientalis L.	5	7	6
Tragopogon pratensis	Tragopogon pratensis aggr.	4	7	6
Trifolium dubium	Trifolium dubium Sibth.	4	6	4
Trifolium pratense	Trifolium pratense L. s.l.	5	x	x
Trifolium pratense agg.	Trifolium pratense aggr.			
Trifolium repens	Trifolium repens aggr.	5	6	6
Trisetum flavescens	Trisetum flavescens (L.) P. Beauv.	x	x	5
Trollius altissimus	Trollius europaeus L.	7	6	5

Typha latifolia	Typha latifolia L.	1	7	8
Urtica dioica	Urtica dioeca L.	6	7	9
Valeriana dioica	Valeriana dioica L.	8	5	2
Valeriana officinalis	Valeriana officinalis L.	8	7	5
Valeriana officinalis agg.	Valeriana officinalis aggr.			
Veratrum album spec.	Veratrum album aggr.			
Veronica anagallis-aquatica	Veronica anagallis-aquatica L.	9	x	6
Veronica arvensis	Veronica arvensis L.	x	6	x
Veronica beccabunga	Veronica beccabunga L.	1	7	6
Veronica chamaedrys	Veronica chamaedrys L.	5	x	x
Veronica serpyllifolia	Veronica serpyllifolia L. s.l.	5	5	5
Viburnum lantana	Viburnum lantana L.	4	8	4
Viburnum opulus	Viburnum opulus L.	x	7	6
Vicia cracca	Vicia cracca L. s.l.	6	x	x
Vicia sepium	Vicia sepium L.	5	6	5

8.6 Appendix 6

Table 11. *Biotope type names in German original and English translation.*

Biotope type (ger.)	Biotope type (engl.)
Intensivgrünland	Intensively used grassland
Nasswiese	Wet meadow
Streuwiese	Litter meadow
Gebüsch feuchter Standorte	Shrubberie of moist conditions
Gebüsch mittlerer Standorte	Shrubberie of medium conditions
Hochstaudenflur	Tall forbs community
Röhricht	Reeds
Flutrasen	Temporarily flooded grassland
Zierrasen	Lawn
Bruchwald	Swamp forest
Straße, Weg oder Platz	Path or Street
Kleinseggenried basenreicher Standorte	Small sedge fen of base-rich conditions
Großseggen-Ried	Tall sedge fen
Wirtschaftswiese mittlerer Standorte	Cultivated grassland of medium conditions