The effects of management practices and environmental variables on the biodiversity of Nardus grasslands in the National Park Hohe Tauern, Austria.

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Abstract

Introduction. A large part of the biodiversity of the Alps is linked to an interaction between the natural environment and traditional land-use practices. This study focuses on the priority habitat type of species rich Nardus grasslands (Natura 2000 Code 6230*), which is endangered, but continues to thrive in extensively managed subalpine pastures. I will specifically be looking at pastures within Austria's Defereggen valley, situated in the outer region of the Hohe Tauern National Park.

Aims. The purpose of this study is to classify the field-mapped relevés of Nardus grasslands, discern patterns within these plant communities, and assess the impacts of both management practices and environmental factors on the diversity and conservation status of this habitat type. Ultimately, my goal was to pinpoint the necessary measures to enhance biodiversity levels.

Methods. The methods employed in this study include several steps. Initially, remote sensing was utilized to identify potential study sites. Subsequently, field surveys were conducted following the hierarchical, syntaxonomic system of the Braun-Blanquet approach for vascular plants. During these surveys, data of various parameters was gathered including management variables such as land use intensity and yield, environmental variables such as altitude and slope, and the conservation status of the sites. Furthermore, on-site interviews with local shepherds were conducted to gain insight into the farming practices and the relationship between biodiversity and agriculture. Biodiversity assessment included the calculation of the Shannon-Wiener Index and the determination of the Ellenberg Indicator values for all study sites, which served as additional parameters for the statistical analysis. To classify Nardus grasslands, Twinspan analysis was employed, and identification was based in established literature, particularly the work by Mucina et al. (1993). To understand the factors influencing changes in species composition, all collected parameters were subjected to gradient analyses and ANOVA to identify the drivers responsible for these variations.

Results. All Nardus grasslands in the region were classified as the Sieversio-Nardetum strictae association, according to Lüdi 1948. My research found significant correlations between Nardus grassland biodiversity and Ellenberg indicator values for soil pH as well as type of bedrock, with higher diversity in areas with elevated soil pH. This challenges the European Habitats Directive's definition of 'species-rich' communities on siliceous substrates, suggesting that calcareous bedrock areas host greater plant diversity. The second significant correlation was found for the indicator value of nitrogen as well as land use intensity, indicating that the highest biodiversity occurs with moderately extensive to moderately intensive land management and moderate nutrients levels. Additionally, an analysis based on ecological characteristics and indicator species led to the classification of

Nardus grasslands into five subgroups within the Sieversio-Nardetum strictae category. This subgroup analysis suggests that insufficient pasture use is the key factor contributing to lower Nardus grassland diversity.
Discussion. To prevent degradation and restore the balance of Nardus grasslands, I recommend implementing a comprehensive management strategy. This study underscores that Nardus grasslands can be effectively maintained through consistent and early grazing as well as dividing pastures into subunits to enable controlled grazing, which reduces the growth of dwarf shrubs (e.g., *Rhododendron ferrugineum*), weed growth (e.g., *Deschampsia cespitosa*), and the encroachment of grasses (e.g., *Nardus stricta*). Notably, there is a growing interest among shepards and contemporary literature in utilizing small ruminants for grazing, which holds a promise for biodiversity conservation efforts.

Keywords: Biodiversity, Braun-Blanquet, Nardus Grasslands, *Nardus stricta*, Sieversio-Nardetum strictae, National Park Hohe Tauern, East Tyrol, Subalpine Pastures.

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Abbreviations

SLU	Swedish University of Agricultural Sciences
BOKU	University of Natural Resources and Life Sciences
6230*	European Natura 2000 priority habitat type of species rich Nardus grasslands
Nardus Grasslands	Nardion strictae Br.-Bl. 1926
OGD	Open Government Data
a.s.l.	Above sea level
EIV	Ellenberg indicator values
M	Moisture
N	Nutrients
R	Reaction
SWI	Shannon Wiener Index
LUI	Land use intensity

Introduction

While being relatively species-poor at larger spatial scales, temperate Europe comprises certain habitats with extreme species richness at small scales, in particular the semi-natural grasslands. Studies, like Wilson et al. (2012) found out, that besides unmanaged (natural) tropical lowland rain forest, semi-natural, oligo- to mesotrophic, temperate grasslands, managed by regular grazing proved to be the areas in the world where maximum richness has been observed. The motivations for conserving these early successional habitats are twofold. First, they are associated with high species diversity, second, these landscapes are associated with high aesthetic and cultural heritage values (Linnell et al. 2015). The term biodiversity was defined at the UN Environment Summit in 1992 as the following: "Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Secretariat of the Convention on Biological Diversity 2005).

Biodiversity is a complex phenomenon, and one of the central tasks in vegetation science is to simplify the patterns by classifying them into manageable units known as ‘plant communities’, ‘vegetation types’, or ‘syntaxa’. This study specifically utilizes the hierarchical, syntaxonomic system of the Braun-Blanquet approach for vascular plants. Vegetation classification primarily involves analyzing species and their abundance within vegetation plots, often referred to as ‘relevés’. Notably, species act as carriers of ecological information, which is important in characterizing vegetation patterns, as well as interpreting their characteristics. This species-centric approach has given rise to as scientific discipline known as ‘phytosociology’, which has employed a standardized approach to sample, describe, and classify vegetation (Mucina et al. 2016). The hierarchical system is based on a bottom-up approach of four principal ranks: Association, alliance, order and class. The association is defined as "a plant community of definite floristic composition which presents a uniform physiognomy and which grows in uniform habitat conditions" (Weber et al. 2000). Figure 1 shows the rank and determination of the system with the typical endings on the right.

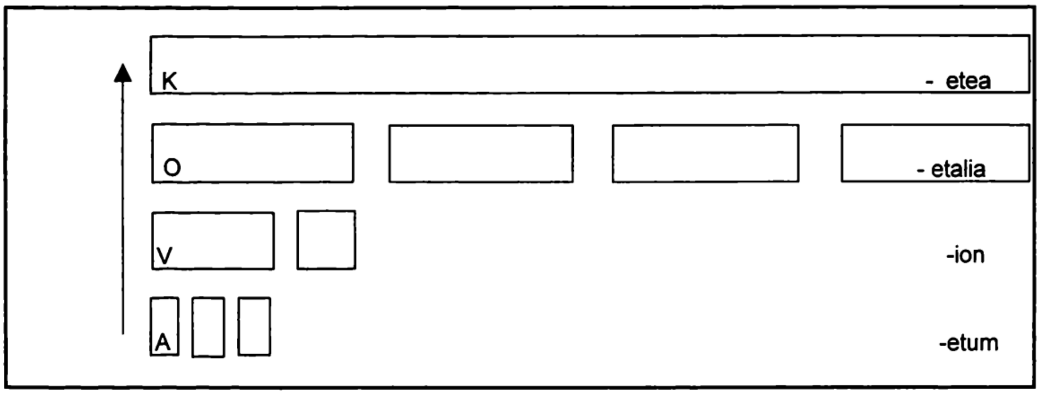


Figure 1: The rank and termination of the used classification system with K= Class, O= Order, V= Alliance and A= Association (translated from german) (Dierschke 1999).

Furthermore, I will introduce an important concept to understand and follow this study: The physiological and ecological optimum. These describe the response of a plant to a particular exogenous factor. Exogenous factors encompass the impacts of geographical location, animal, and human activities on plants. Plants are directly influenced by factors such as heat, light, water, as well as chemical and mechanical forces. Climate, topography, and soil characteristics, in contrast, have indirect effects. The physiological optimum is the location in which a plant grows best in accordance with its inherited capabilities and can be quite similar for many species. However, the ecological optimum is the location where the plant grows best in nature. This can vary and the less competitive a species is, the more its ecological optimum will deviate from its physiological one (Dierschke 1994). Understanding and managing these optimum conditions are essential for sustainable agriculture and biodiversity conservation.

1.1 Alpine grassland biodiversity

Biodiversity of mountain areas

Most European biodiversity hotspots are in mountain areas. Among the 1 148 species listed in Annexes II and IV of the Habitats Directive, 181 are exclusively or almost exclusively linked to mountains and of the 231 habitat types listed in Annex I to the Habitats Directive, 42 are exclusively or almost exclusively linked to mountains. For mountain habitat types, 21 % of natural grassland habitat types are assessed as having a favorable status, 28 % an unfavorable-inadequate status, 32 % an unfavorable-bad status, and 18 % are unknown. The current landscapes and land cover of Europe's mountain areas reflect major variations in biophysical characteristics and historical and recent land uses. While geology, geological and glacial histories, and climate have shaped the topography and influence the types of vegetation, their current land cover also reflect the activities of people — and their grazing animals (EEA 2010). So called ‘Alms’ play an important role in this.

What are Alms?

In the Alps, cattle husbandry is historically based on small herds for milk and meat production, housed in barns located in the valley during winter and moved to high pastures in the summer, as illustrated in figure 2. Pastures are gradually used at different altitudes to make use the vegetation gradients. The produced forage is the sole feed source for grazing livestock during summer and in turn, grazing is the only viable way to manage alpine pastures, where mechanical agricultural practices are not practical (Battaglini et al. 2014). Alms encompass a wide variety of vegetation communities and the challenge in their management revolves around effectively utilizing the forage while considering environmental limitations (Mainetti et al. 2023). Biodiversity on alms results from the combined interactions between natural circumstances and human influence (Chemini & Rizzoli 2003).

Figure 2: The Jagdhausalm with several stone houses and the surrounding pastures, nowadays the houses used for shepherds as well as tourism in the Defereggen valley. Photo: R. Dörner (2023).

Anthropogenic impact on biodiversity

The alps exhibit an impressive variety of habitat and climatic conditions along reduced spatial scales, reflecting a long history of human presence. The strong link between pastures and livestock has contributed to forming a cultural landscape with high aesthetic and natural value (Mottet et al. 2006). The most important roles of grazing animals are the enhancement of sward structural heterogeneity and thus botanical and faunal diversity by selective defoliation due to dietary choices. Additionally, their treading activities opens regeneration niches for gap-colonising species and the animals participate in nutrient cycling, which concentrates nutrients into ‘hot spots’ at dung and urine patches. Additionally, animals act as biotic vectors for propagule dispersal, which improves the chance of seedling emergence (Rook & Tallowin 2003). These habitats have special recognition by the EU as “High Nature Value farmland” - an indicator for the nature conservation value of agricultural areas, that can be expected to support high levels of biodiversity. Of the 231 habitat types of European interest targeted by Annex I of the EU Habitats Directive, 55 depend on extensive agricultural practices (EEA 2010). On the contrary, studies have shown that the abandonment of traditional farming practices has caused grassland degradation and forest re-growth and encroachment by shrubs with a consequent loss of biodiversity (Mottet et al. 2006).

Topographic impact on biodiversity

Additionally, to land-use, several topographic factors interact to cause high levels of diversity. The impact of climatic variables is emphasized by the harsh environmental conditions arising from factors such as aspect, elevation, and slope. Aspect determines different light exposition and soil moisture, thus representing a direct driver of the botanical composition of pastures (Yanyan et al., 2017). Increasing elevation determines a decrease in air temperature (0.65°C every 100 m) with consequent effects on vegetation productivity and growing season length (Dongdong et al. 2020). Incoming solar radiation affects energy and water balances within a landscape and slope characteristics have an important influence on the amount and rate of runoff (Beniston 2016). The most xeric sites are usually steep, southwest facing slopes where solar radiation is relatively large, and moisture is lost to downslope areas. The most mesic sites are valley bottoms at the base of northeast facing slopes where radiation is relatively small and moisture is accumulated from upslope areas (Pinder et al. 1997). In the report of the EEA (2010), Körner (2002) includes further reasons like the compression of thermal and climatic zones over relatively short distances, variations in geology and soils, and the fragmentation of mountain terrain.

Adaption strategies of plants

High mountain plants have developed various strategies to compensate for the harsh conditions. Some have forgone the production of flowers and seeds and reproduce mainly asexually through offshoots or bulbils (e.g., *Bistorta vivipara*) and others have bright petal colors to quickly attract insects for pollination (e.g., *Gentiana nivalis*). Through their small size compared to their relative at lower altitudes (e.g., *Leucanthemopsis alpina* in Figure 3), alpine plants manage to transport water from roots to leaves across shorter distances and the air is more humid and warmer near the ground with lower wind speed. The stems and leaves of e.g., *Salix reticulata* nestle close to the rock and make the most of the stored heat. Cushion plants like *Androsace alpina* reduce their surface through their hemispherical shape and rosettes, like *Sempervivum tectorum* in Figure 3, form spirally arranged leaves, so they can make optimal use of the light and grasses such as the *Carex curvula* can store heat very well (Nationalpark Hohe Tauern n.d.).

Figure 3: Left: Leucanthemposis alpina, right: Sempervivum tectorum. Photos: R. Dörner (2023).

1.2 The study area

This study in particular focuses solely on the habitat type species-rich Nardus grasslands (Natura 2000 Code 6230*), a priority habitat type for both conservation and restoration (European Commission 1992). In detail, it zooms in on the subalpine pastures of the Defereggen valley is East Tyrol, Austria, which are unique, because they are still extensively managed and located in the outer zone of the National Park Hohe Tauern.

The National Park Hohe Tauern

In 1971, the provincial governors of the federal states of Salzburg, Carinthia and Tyrol signed an agreement to set up a joint National Park. International recognition by the IUCN "category II" took place in 2001 for Carinthia and finally in 2006 for

Salzburg and Tyrol with the differentiation into a core zone, where nature can develop without human influence, and an outer zone, in which traditional management is possible. Nowadays, at 1,856 km^2, the Hohe Tauern National Park is the largest protected area in the European Alps. Over millions of years, glaciers and rivers structured the mountain relief and formed longitudinal and transverse valleys, gorges, cirques and ridges with a mosaic of habitats and climatic areas (Nationalpark n.d.). The National Park is also a Natura 2000 area and therefore has a special, Europe-wide responsibility for a large number of habitat types, animal and plant species (Hoffert 2006).

The Defereggen Valley

The examined grasslands are in the Defereggen valley in East Tyrol in Austria and includes three communities: Hopfgarten, St. Veit and St. Jakob in Defereggen (Netzdienste Defereggen n.d.). The areas used for alpine farming are all within the outer zone of the National Park, which enables further management while at the same time maintaining the conservation goals according to the guidelines of the IUCN. There are five Alms, all of which are owned by agricultural communities and managed as communal pastures with shepherds being on the alp constantly (see figure 4). A total of around 400 head of cattle are brought up per season (Aigner, 2015), while the total grazing area was calculated to approximately 37 km^2.

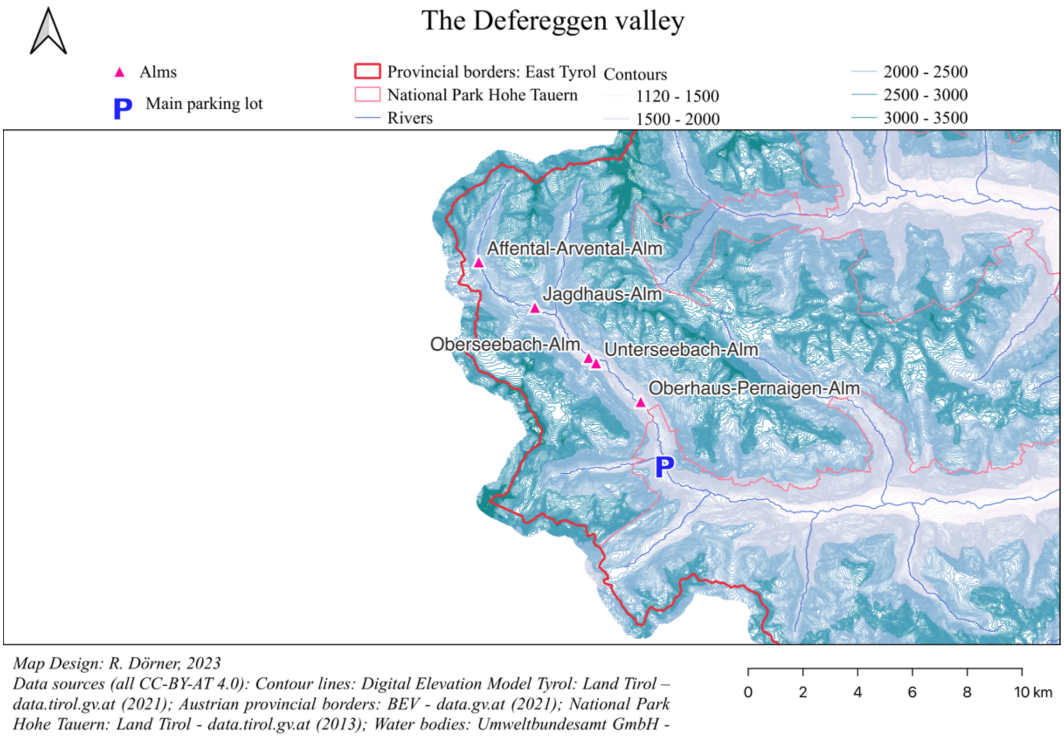


Figure 4: The Defereggen valley with its five Alms: The Oberhauser Alm (1786 m a.s.l.), Oberseebachalpe (1,900 m a.s.l.), Unterseebach-Alpe (1960 m a.s.l.), Jagdhausalm (2,009 m a.s.l) and the Arventalalm (2.189 m a.s.l.). The topography is portraits as contour lines.

History of the Defereggen valley

The oldest proven sources of evidence for local grazing in the Defereggen valley exist from pollen analysis studies since the late Neolithic period (2400 BC). This was before the climatic changes that occurred after the Bronze Age (800 BC) led to the abandonment of previous grazing. The management of alpine pastures experienced a new boom due to the medieval climate optimum (from 800 AD) until the High Middle Ages (1200 AD). The construction of many so called 'Schwaighöfe', which spread rapidly in the Defereggen Valley during the 13th century, led to a severe impairment of forest conditions. 'Schwaighöfe' refers to farms that, because of their extreme altitude can farm little or no grain and therefore must focus their attention on livestock farming. The landlord provided the dairyman with several cows or sheep and supplied the family with grain and salt, for which he received an annual tax in the form of the standardized 300 wheels of cheese in return. As early as 1300, the surrounding area was tree-free, because the need for wood to heat milk to make cheese was too large. Between 1305 and 1338 the residents received vital grain subsidies, which ensured their survival at such altitude, but still, the farms had to be abandoned whole-year farming in the second half of the 14th century and change their management to summer pastures only. The deforestation has resulted in a lowering of the tree line of the order of 200 to 350 meters as well as local soil erosion. Only in the course of climate warming (after 1860) and in connection with extensification of alpine farming (see Figure 5) the severely affected tree populations were able to regenerate (Agrargemeinschaft Jagdhausalm 2023).

Figure 5: Dairy farmers and shepherds at the Jagdhausalm around 1930. Photo: Egitz. Data source: Agrargemeinschaft Jagdhausalm (2023).

1.3 Environmental influences

1.3.1 Climate and weather

The region in this study is exposed to various climatic influences: On a continental scale, the alps lie in the overlapping area between humid temperate influence from the Atlantic northwest, dry, winter-cold, and summer-warm influence from the continental east, and winter-humid, summer-dry, and warm influence from the Mediterranean south. Weather data was obtained for the village of St. Jakob from the Central Institute for Meteorology and Geodynamics in Vienna. Figure 4 shows, that the minimum temperature, the Defereggen valley being the coldest valley in Austria, is -23 °C with the spatial average of 3 °C. 923.6 mm of precipitation fall within one year with June, July and August being the wettest months (ZAMG 2015). Nardus grasslands can be found in damp, cool locations with rather cool summers and comparatively snowy winters in Western and Central Europe (Ellenberg & Leuschner 2010). The grass, that give this habitat type its name, *Nardus stricta*, cannot tolerate frost because it partially overwinters in a green state and requires snow as heat protection (Dierschke 2001).

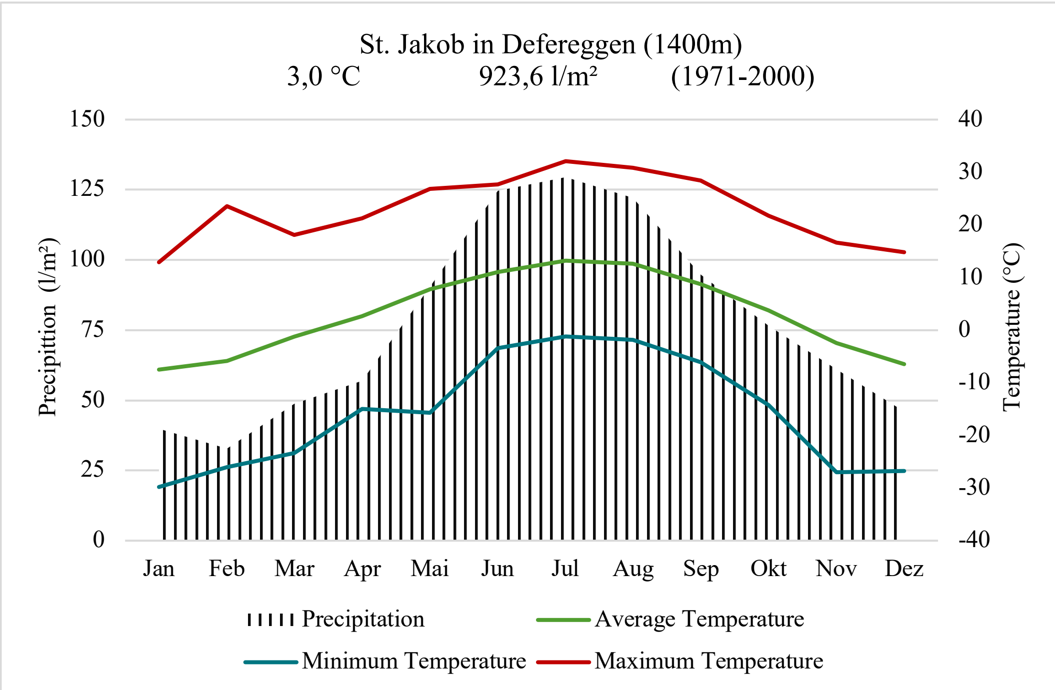


Figure 6: Yearly air temperature and precipitation in St. Jakob in Defereggen. Data source: ZAMG (2015).

1.3.2 Geology and soil

The landscape around the National Park was formed over millions of years by geological processes. The highest mountains are formed from rocks that otherwise occur in the lowest levels of the Alps (Nationalpark n.d.). The mountain ranges of the Defereggen Alps consist of multiply metamorphosed old crystalline rocks, such as mica schist, graphite schist and various types of gneiss (Hoffert 2006), while narrow strips in the Defereggen valley are a zone, which extends in an east-west direction between the Pennine and East alpine crystalline: The Matreier zone (Schmidt 1950). Figure 7 shows the surface geology of the valley with its three different geologies inside the grazed pastures: Paragneiss, Mica Schist and Chlorite actinolite epidote metamorphic rock. Chlorite actinolite epidote metamorphic rock is a metamorphic rock characterized by 50 percent or more of combined chlorite, actinolite and epidote (European Commission 2015).

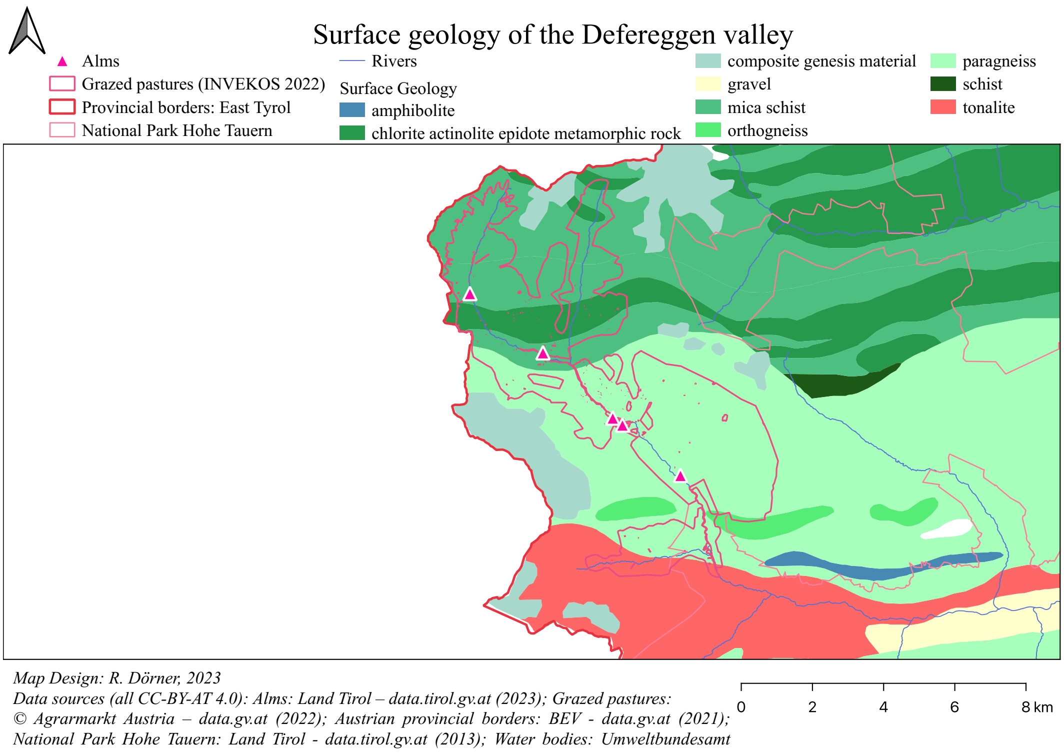


Figure 7: Surface geology of the Defereggen valley created with the cartographic model KM500 Austria by the Federal Geological Institute (GBA), based on the "Metallogenetic Map of Austria 1:500,000" by L. Weber (1997) (Geologische Bundesanstalt 2013).

Nardus grasslands are all typified by nutrient-poor soil conditions (Schelfhout 2019) and many plants in this habitat type are calcareous-avoiding with a strong tolerance for acidic soils (Ellenberg & Leuschner 2010). According to Ellmauer (2005), the habitat type requires nutrient-poor brown earths, parabrown earths, podsols, pseudogleye and gleye and a water balance ranging from moderately dry to fresh to (more rarely) moist soils. Sometimes, however, on limestone or dolomite-weathered soils, a calcareous-poor top layer can be created through leaching. The combination of different geologies, climatic extremes, and traditional grazing mean that this area is particularly important for biodiversity conservation.

1.4 Species-rich Nardus grasslands

As described above, the long history of anthropogenic impact and the climatic conditions led to plant communities dominated by low-growing grasses, sedges and dwarf shrubs in the montane and subalpine levels of mountain ranges called Nardus grasslands (Jacob 2015). In the description of the habitat types by Ellmauer (2005), the LRT 6230 “Species-rich Nardus grassland, on siliceous substrates in mountain areas (and submountain areas in Continental Europe)” includes all Nardus grasslands from the submontane to the subalpine elevation (from about 300 m a.s.l to 2.200 m a.s.l.). The European Commission (2013) defines them as “closed, dry or mesophile, perennial Nardus grasslands occupying siliceous soils in Atlantic or sub-Atlantic or boreal lowland, hill and montane regions […] vegetation highly varied, but the variation is characterized by continuity."

This habitat is inhabited by the characteristic perennial grass *Nardus stricta* (see figure 8), and other specialized, acidophilic, and oligotrophic plant species. Most Nardus grasslands are low-productivity grasslands, where regular active management is the ultimate condition of their sustainable existence. Their extent decreased significantly with the intensification of agriculture during the 20th century (Galvánek & Janák 2008). That is why today, they are only extensively found in high alpine regions (Grabherr and Mucina 1993). The largest populations in Austria are in the higher altitudes of the Central Alps with an estimated of 190.000 ha (Ellmauer & Traxler 2001), while outside the Alps the habitat type has strongly declined (Essl 2005). *Nardus stricta* can occur across wide elevation and moisture gradients, from Atlantic lowlands up to the mountain areas of continental Europe, such as the Alps, Apennines, Carpathians, and Pyrenees (Galvánek & Janák 2008), which leads to the common opinion that "hardly a problem in Alpine plant sociology is as confusing and difficult as that of Nardus societies” (Mucina et al. 1993).

Beside *Nardus stricta* Nardus grasslands host a wide range of species. These include species with rosette leaves like *Hypochaeris uniflora* and *Arnica montana* (see figure 8) as well as delicate, herbaceous species like *Galium anisophyllum* or *Campanula scheuchzeri* and dwarf shrubs like *Calluna vulgaris*, *Rhododendron ferrugineum* or *Vaccinium myrtillus* or grasses like *Avenula versicolor, Anthoxanthum alpinum* and *Avenella flexuosa*. Furthermore, rare but characteristic species such as *Nigritella rhellicani, Pseudoorchis albida* or *Ceologlossum viride* can be found and species like *Cirsium spinosissimum, Gentiana punctata* and

Deschampsia cespitosa characterise rather nutrient-rich and moist locations (Ellenberg& Leuschner 2010).

The origins of Nardus grasslands

Originally they may have arisen in snow hollows, where the meltwater lasts until early summer, as well as on boggy soils, because the stagnant water deprives the soil of oxygen (Aichinger 1953). Manz (1989) cites examples in which these grasslands come from communal shelters in distant locations, where cattle grazed the same undivided area every day. When grazing intensity decreases, animals avoid less palatable pasture areas and dead grass from previous years is littered. This leads to a further reduction in the pH and, as a result, to a demobilization of the nutrients. These are the best competitive conditions for *Nardus stricta* (Aigner 2016). Eriksson (2012) discusses the ecology of species that were favored by the development of cultural landscapes in central Europe with focus on mechanisms behind species responses to this landscape transformation. He explains, how a fraction of species may have maintained their realized niches from pre-agricultural landscapes and utilized similar niches created by landscape transformation. Human-mediated niche construction promoted niche shifts towards open habitats, and it seems that the new landscape constructed by humans favored numerous species, such as Nardus grassland species.

Figure 8: Typical Nardus grassland species like Arnica montana on the left and Nardus stricta on the right. Photos: R. Dörner (2023).

1.5 Research questions and hypothesis

The main objective of this study was to assess the Nardus grassland vegetation in the Defereggen valley in Austria. Therefore, the first research question is:

i. Which (sub)associations of Nardus grasslands are present and what trends can be identified within the plant communities?

To solve this question, I aim to classify the phytosociological relevés collected in the field and to produce a syntaxonomic scheme of the sampled vegetation to find patterns and sub-groups and characterize them by indicator species. My hypothesis for this question is, that: The association of the Sieversio montanae-Nardetum strictae Lüdi 1948 is the dominating association of subalpine Nardus grasslands pastures and as suggested by Dierschke (2001) and Oberdorfer (1978) belongs to the class of Calluno Ulicetea, which is in contrast to the common classification of Mucina et al. (1993).

The second question aims to analyze the influence of management as well as environmental parameters on the diversity as follows:

ii. What influence does local management practices (e.g., land use intensity) and environmental variables (e.g., altitude, slope) have on the diversity and the conservation status of this habitat type?

Additionally, to parameters measured in the field, I will interview shepherds on their view of appropriate management that supports local biodiversity. My hypothesis for this question is, that: The Nardus grasslands have a favorable conservation status and land use intensity has a significant impact on biodiversity. A good conservation status has been suggested by the ARGE Basiserhebung (2012a) due to the largely extensive management of alpine pastures, while no management leads to spontaneous succession and a constant impoverishment of species.

The third questions discuss environmental, conservation and management issues:

iii. What does site-adapted management mean for the study area? Which measures are required to promote biodiversity of this habitat?

I aim to give a status update on the conservation status and conclude with identifying the factors that influence the integrity of this habitat. Conclusions shall be drawn about the optimal use, so that a favorable conservation status can be maintained. My hypothesis for this question is, that: Site adapted management would mean constant and moderately extensive grazing. Recent literature like Aigner (2016) e.g., suggests diverse concepts of grazing with small livestock (sheep and/or goats) to maintain this habitat type.

Methods

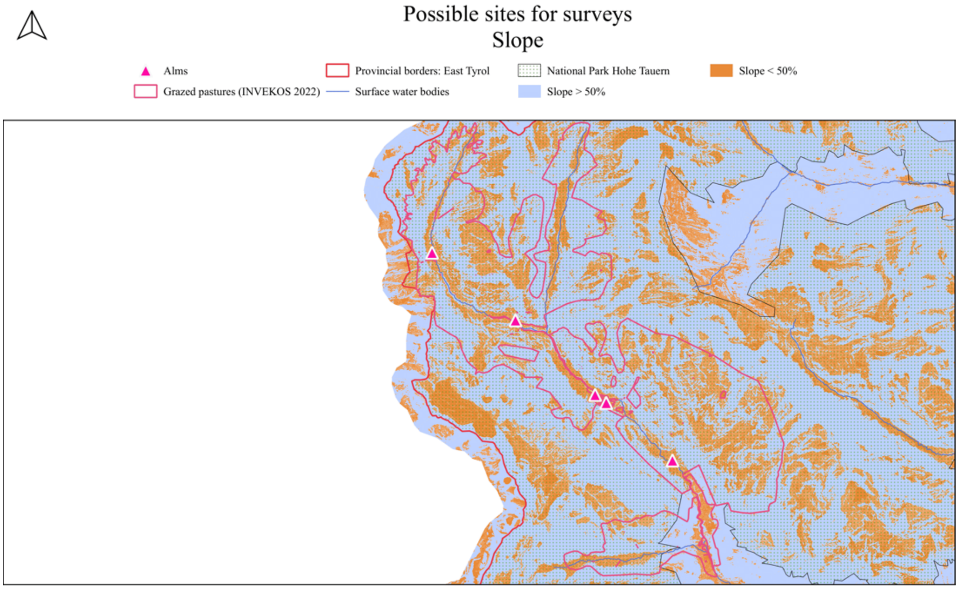
In vegetation ecology, descriptive field studies predominate. As a comprehensive survey of the pastures in the valley would go far beyond the scope of such a thesis, a methodology based on a representative sample for the area was preferred. Additionally, I have chosen measured and descriptive parameters for each chosen study site. Subjective assessment means the careful choice of study points based on subjective decisions in the field compared to a random selection or a uniform grid (Dierschke 1994).

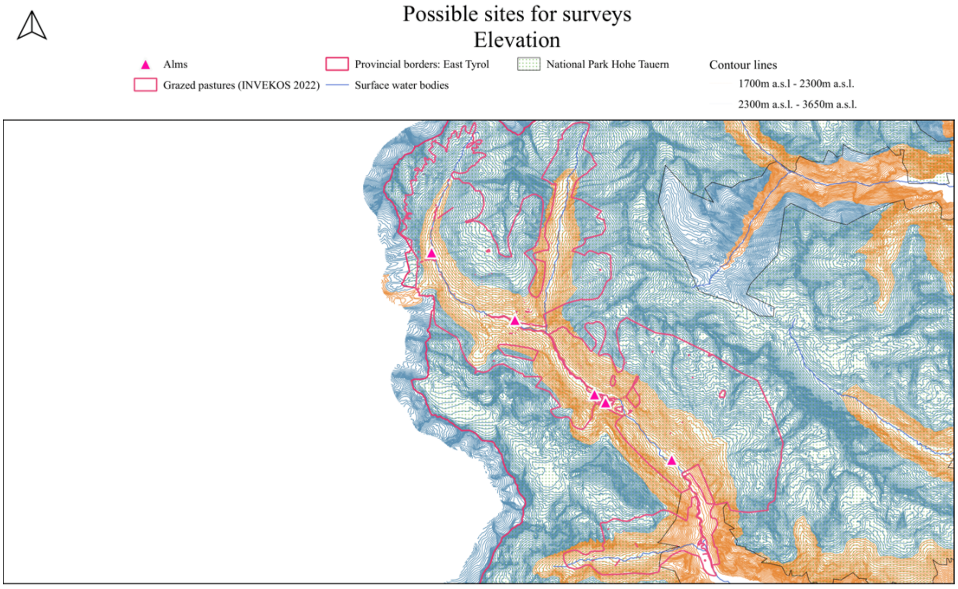
2.1 Data collection

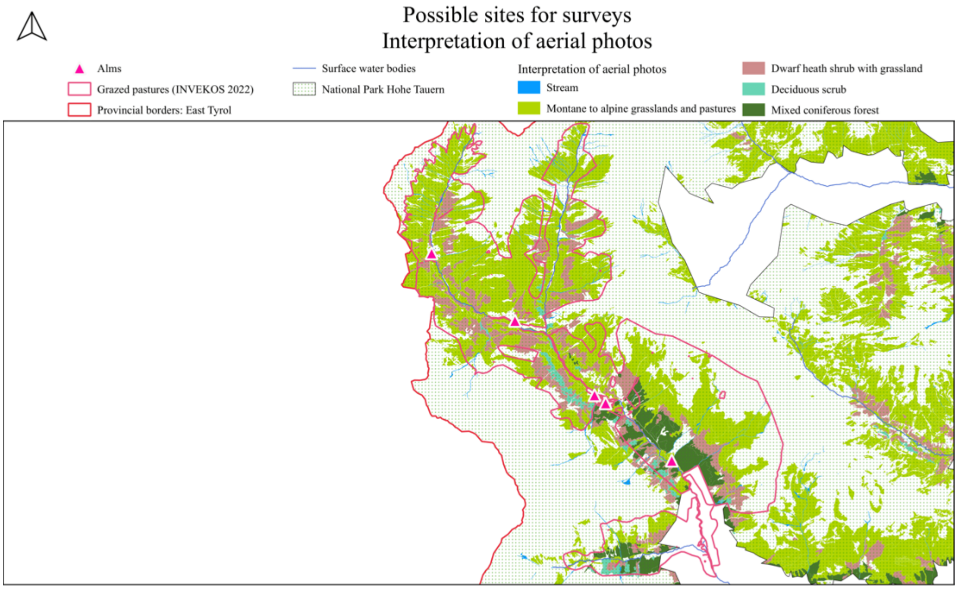
2.1.1 Via remote sensing

To reduce the possible study sites in the field, the valley was narrowed down with the help of available open-source data. Parameters, that I was interested in, are land use, land cover, slope, and altitude. For land use the INVEKOS data base of 2022 with the category "alpine pastures" was used to outline all pastures. As significant parts of the area are extremely steep, a slope of over 50% was considered unrealistic for on-site vegetation recordings. Second, most literature defines the upper limit of Nardus grasslands at an elevation of 2300 m a.s.l. Third, an aerial photo interpretation from the National Park was used, which already had the category 'montane to alpine grasslands and pastures' as can be seen in the last map of Figure 9. All three categories were then intersected using QGIS to show me the resulting areas that would match all three requirements.

Figure 9: QGIS calculation steps to narrow down possible study sites. Data sources (all CC-BY-AT 4.0): Alms: Land Tirol – data.tirol.gv.at (2023); Grazed pastures: © Agrarmarkt Austria – data.gv.at (2022) ; Austrian provincial borders: BEV – data.gv.at (2021); National Park Hohe Tauern: Land Tirol – data.tirol.gv.at (2013); Water bodies: Umweltbundesamt GmbH – data.gv.at (2021); Contour lines: Digital Elevation Model Tyrol: Land Tirol – data.tirol.gv.at (2021); Interpretation of aerial photos: Interpretationkey HIK0 of project Habitalp, database: (CIR) 1998: Land Tirol – data.tirol.gv.at (2005). Map Design: R. Dörner, 2023.


Possible sites for surveys
Slope
Alms
Grazed pastures (INVEKOS 2022)
Provincial borders: East Tyrol
Surface water bodies
National Park Hohe Tauern
Slope > 50%
Slope < 50%


Possible sites for surveys
Elevation
Alms
Grazed pastures (INVEKOS 2022)
Provincial borders: East Tyrol
Surface water bodies
National Park Hohe Tauern
Contour lines
1700m a.s.l - 2300m a.s.l.
2300m a.s.l. - 3650m a.s.l.


Possible sites for surveys
Interpretation of aerial photos
Alms
Grazed pastures (INVEKOS 2022)
Provincial borders: East Tyrol
Surface water bodies
National Park Hohe Tauern
Interpretation of aerial photos
Stream
Montane to alpine grasslands and pastures
Dwarf heath shrub with grassland
Deciduous scrub
Mixed coniferous forest

2.1.2 Via field surveys

The results from the intersection of all categories were printed onto an orthophoto and taken to the field to orientate where relevés could possibly be sampled. I tried to take surveys equally spread inside the preselected area and a few sites also outside the pre-selected area to mark where the habitat type borders other habitat types (e.g., at higher altitudes). All study sites were marked on the orthophoto map and written down as coordinates. Figure 10 shows the results with all four categories intersected and then outcome named as “possible study sites”. Figure 10 also shows the location of all 106 field study sites as points under the category “actual study sites”. In the field, the study sites were selected according to criteria to ensure comparability. Ellenberg (1956) describes the minimum area, the uniformity of the site and the homogeneity of the vegetation as the basis for vegetation mapping. Therefore, all plots were created with a size of 25 m^2, making sure that each sample area was as homogeneous as possible. The surveys were carried out between July 12, 2023, and August 15, 2023. A survey form (see Appendix 4) was filled out for each study site and the species identification was carried out with the help of common identification literature: "Flora Vegetativa" by S. Eggenberg and A. Möhl, as well as the "Exkursionsflora von Österreich, Lichtenstein, Südtirol", Volume 3 by M.A. Fischer, K. Oswald, and W. Adler.

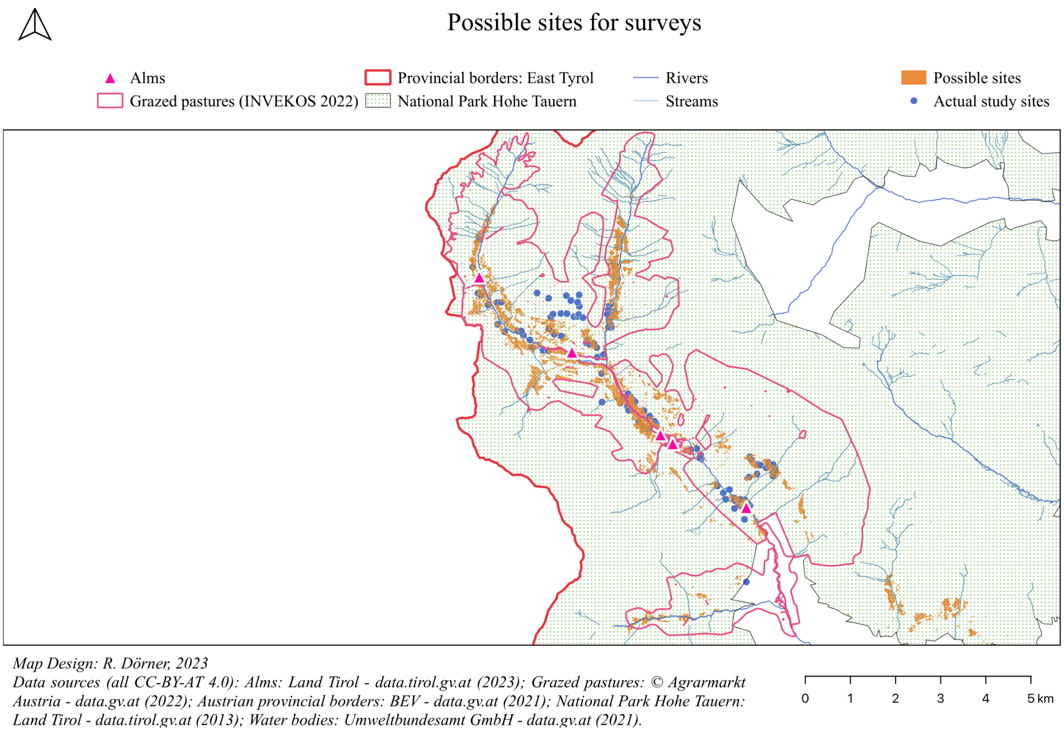


Figure 10: The results from the overlay analysis resulting in possible study sites (orange) and the actual study sites during field surveys (blue).

Assessing the cover values

Since estimating the frequency of species can be difficult, the cover values of all species were recorded using an updated version of the abundance-dominance scale of Braun-Blanquet (1964). The scale in table 1 describes the frequency based on the factor's abundance (number of individuals of a species) and dominance (degree of coverage):

Table 1: Scale according to Braun-Blanquet et. al 1964, extended by Barkman et. al (1964) in Dierscke 1994.

Scale	Dominance (%)	Abundance
5	>75 - 100	Any number of individuals
4	>50 - 75	Any number of individuals
3	>25 - 50	Any number of individuals
2m	<5 %	>100 Individuals
2b	12,5 – 25 %	Any number of individuals
2a	5- 12,5 %	Any number of individuals
2	5 - 25	Numerous
1	1 - 5	Abundant and low coverage or sparse with great coverage, 5-50 Individuals
+	<1	Spare, 2-5 Individuales
-		Rare, 1 individual

Additional data

In addition to date and recording number, the following variables were measured with the help of the app 'Outdooractive': Coordinates (in WGS 84), altitude (in m a.s.l.) and exposure. Inclination (in %) was estimated from experience and the terrain morphology was described in words. In addition, I estimated the yield (in dt/ha/year), intensity of use in five classes, the height (in cm) and the percentage of herb cover, rock cover, bare soil cover and shrub cover. The yield was estimated according to the total cover of the site and the height of the vegetation within this site. The indicators to estimated land use intensity are explained in Table 2. Unfortunately, it was not possible to estimate the exact grazing time on the pastures; thus, it is unknown how much time the livestock spent within a particular site. Each area was documented with four photographs.

Table 2: Legend to estimate the five classes of land use intensity.

Category	Description	Indicators
1	Very extensive	Thick litter layer, no dung, no signs of recent grazing, high cover values of *Nardus stricta,* dwarf shrubs.
2	Extensive	Some layer of old grasses, some dung, low nutrient indicators like *Gentiana ssp.,* medium dwarf shrubs.
3	Moderately extensive to intensive	A mosaic of grazed vegetation, some dung, possibly a blend of different species and some dwarf shrubs.
4	Intensive	More vegetation is grazed off, vegetation is shorter, more nutrients indicators like *Achillea millefolium* or *Trifolium pratense,* only small dwarf shrubs.
5	Very intensive	A lot of fresh and old dung, flattened resting areas, nutrient indicator plants like *Rumex acetosa* or *Taraxacum officinale,* no dwarf shrubs.

Assessing the conservation status of the study site

Each site was assigned a conservation status based on the EU Habitats Directive. Code 6230* Species-rich montane Nardus grasslands are listed in Appendix I of Directive 92/43/EEC, for the conservation of natural habitats and wild animals and plants, of the Council of the European Communities of 1992 to be given priority. The conservation status of a natural habitat is considered favorable (A) when "its natural range and the areas it occupies within that range are stable or expanding, and the structure and specific functions necessary for its long-term survival exist and are likely to continue to exist for the foreseeable future." A habitat is in a poor situation (B) where a "change in management or policy is required to return the habitat to favorable status but there is no danger of disappearance in the foreseeable future." A bad conservation status (C) means, that "a habitat is in serious danger of disappearing (at least regionally)" (European Commission 1992).

Indicators for assessing the conservation status in the field were identified with the help of a questionnaire (see Appendix 2). This questionnaire as well as the list of characteristic species is based on Ellmauer & Essl (2005) as well as the ARGE Basiserhebung (2012b). However, the convention applies: If species composition is "C", then the conservation status is "C".

2.1.3 Via interviews

Interviews were conducted with shepherds to obtain information on the management practices applied, their view on the biodiversity of the valley, the importance of diverse vegetation for the animals, problems with specific plants, thoughts about the future of alpine farming and possible ways to improve diversity. After trying to contact all five alms, I was able to find three shepherds on site, that were interested to have a conversation with me. They were all asked the catalog of questions (see Appendix 3 for the detailed list), which in turn was used to come up with the best possible management recommendations.

2.2 Data processing and analysis

2.2.1 Databases

Various qualities of the vegetation are derived only after the surveys. Databases like the program TURBOVEG (Hennekens & Schaminée, 2001) provide valuable help, as they draw on a wealth of information about the plants of Central Europe. Therefore, all relevés were collected in this program and the whole dataset with all its information was exported into the cornel condensed format (.cc!) and imported into another program named JUICE (Tichý 2002).

2.2.2 Vegetation analysis

JUICE was used to analyze and classify large amounts of plant-sociological data as well as to pre-organize the dataset with a so-called Twinspan analysis (Tichý 2002). Before doing this analysis, it was used to calculate two very important indices: The Shannon Wiener index and the Ellenberg indicator values.

The Shannon Wiener Index

In the field I estimated the species richness, the number of species per relevé, but for the analysis I decided to use an index, that would allow to make further statements about the study area: The Shannon Wiener Index (Formula 1). The Shannon–Wiener index is one of many indices of species diversity and is one based on the concept of evenness or equitability (i.e., the extent to which each species is represented among a sample) (Fedor & Spellerberg 2013). The lower the index, the fewer species a population has and the more it is dominated by a few species. A high value suggests high diversity with balanced dominance ratios and high structural homogeneity (Bringmann 2015).

Formula 1: Shannon Wiener Index (H_S)

$$H_s = -\sum_{i=1}^{s} P_i x log P_i$$

H_s: Shannon-Index, Pi: ni / N, P_i: proportion of individuals of i-th species in a whole community, ni: individuals of a given type/species, N: total number of individuals in a community, S: Total number of species (Frey & lösch 2010).

Ellenberg indicator values

A development of ecological groups as indicators of environmental conditions are the indicator values of Ellenberg (Ellenberg et al. 1992). The species are sorted along a gradient that is divided into several classes according to their ecological behavior, especially according to their ecological optimum (but not necessarily to their physiological requirements) (Dierschke 1994). Ellenberg compiled six categories: L = light, T = temperature, K = continentality, F = moisture, R = soil reaction and N = nitrogen. The value of one means the lowest extent of the factor in question, number nine means the highest (Ellenberg et al. 1992). To be able to recognize ecological differences, I calculated the mean values for each relevés weighted by abundance with the help of JUICE.

Twinspan analysis

Twinspan (Two-Way Indicator Species Analysis) is a numerical classification method developed specifically for hierarchical classification. The technique is based on the concept that a group of relevés will have a corresponding group of indicator species that characterize that type. Species and relevés are sorted based on a reciprocal averaging algorithm (Tichy & Holt 2006). As Miller-Aichholz (2007) explains, there are two important ordinations for the divisions: Reciprocal Averaging and Refined Ordination. The former method first carries out the division steps at the points of greatest discontinuity between the relevés. “Refined Averaging” is then used to assign groups of characteristic species. This creates a table with a diagonal structure as can be seen in figure 11. Then the data is exported from JUICE and manually modified in Microsoft Office EXCEL 2007.

The idea behind this is, that species that have similar ecological requirements are combined in groups (see example in figure 11) and thus reflect the ecological factors of each location (Tremp 2005). All relevés were identified according to “The Plant Communities of Austria” Volumes I to II by Mucina et al. (1993). The German synopsis by Dierschke (2001) of the order Nardetalia Strictae also has helpful tables for identification, however, naturally has gaps in relation to the Austrian conditions.

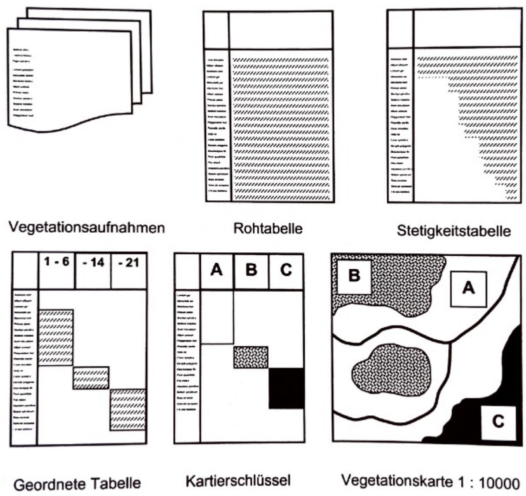


Figure 11: Schematic approach to identify differentiable species groups (Tremp 2005).

2.2.3 Statistical Analysis

Once the Nardus grasslands are classified, these datasets are analyzed with statistics, whereby biodiversity is the dependent variable, and all other parameters are the independent variables. Statistics can help to recognize connections and to decide what significance the results have (Tremp 2005). In this case, all analyses were performed using the R programming environment (R Core Team, 2019).

Gradient analysis

Analysis is not only about the question of differences between groups, but rather about the type and strength of the connection between two variables. To capture the relationships between two variables, simple correlations were carried out. This made it possible to make statements as to whether there is a connection between the variables examined and, if so, how strong it is. However, correlations cannot be used to determine which variable depend on each other and one variable can certainly depend on several explanatory variables (Leyer & Wesche 2008). A regression analysis goes one step further than correlation analysis because it aims to find a functional model between the independent and dependent variables. This makes it possible to predict one variable from the other. The correlation coefficient 'R' characterizes the quality of the fit of the observed values, i.e., how accurately one can draw conclusions from the value of one variable to the other. It ranges from 0 to 1, with higher values indicating a better fit (Tremp 2005).

Analysis of variance

A central question is whether the groups differ on average, i.e., whether the mean and/or variance are significantly different. Typical methods for such mean comparisons are the analysis of variance (ANOVA). The following terms are used according to Tremp (2005) to assess the goodness of fit and significance of the model: The RSE (Residual Standard Error) measures how precisely the model estimates the coefficient's unknown value, while smaller standard errors indicate more precise estimates. The t-value is used to assess the significance of a single coefficient, while the F-statistic assesses the overall significance of the model. Finally, the p-value (probability value) provides a measure of the strength of evidence against the null-hypothesis (the statement that there is no relationship between the studied parameters). The convention applies, that the result is highly significant ($P < 0.01$), significant ($0.01 < P < 0.05$) or not significant ($P > 0.05$).

Synoptic tables

Synoptic Tables give an overview of classified vegetation units in the data set and help understand relations among species in context with environment. A relative frequency is calculated, when the frequency of a species in the group is divided by the total number of relevés in the group (Tichy & Holt 2006). This table is helpful to identify indicator species, that are unique to the single groups of relevés. Calculation is done in JUICE.

Results

3.1 Classification of all relevés

The primary objective of the classification was to distinguish the relevés that represent Nardus grasslands. This distinction allowed for an analysis solely on Nardus grassland relevés, enabling the exploration of correlations between Nardus grasslands and various parameters. Besides Nardus grasslands, the classification resulted in four other habitats as described by the European Commission (1992) with several different associations identified according to Mucina et al. (1993). In the context of this study, all classified relevés depict areas where Nardus grassland intermingle with different habitats, at higher altitudes or with distinct geological characteristics.

Habitat Type 6230: Species-rich Nardus grasslands on siliceous substrates in mountain areas.

Alliance Nardion strictae Br.-Brl. 1926
Association Sieversio-Nardetum strictae Lüdi 1948

76 relevés were classified as this association. The class and order are discussed later in discussion chapter. Of the dominant and constant species, the following species occur: *Nardus stricta, Potentilla aurea, Arnica monatna, Phyteuma hemisphaericum, Phyteuma betonicifolium, Homogyne alpina, Potentilla erecta, Vaccinium myrtillus, Calluna vulgaris, Avenula versicolor, Hieracium lactucella, Veronica bellidioides, Carex sempervirens, Agrostis rupestris, Anthoxanthum odoratum agg., Festuca nigrescens, Hieracium pilosella, Hypchaeris uniflora, Luzula campestris agg., Rhinantus glacialis.*

Habitat Type 6170: Alpine and subalpine calcareous grasslands.

Class Seslerietea albicantis Oberd. 1978 corr. Oberd. 1990
Order Seslerietalia coeruleae Br.-Bl. In Br.-Bl. Et Jenny 1926

A total of 16 relevés were assigned to this type (Figure 12). Due to overlapping species, I was not able to identify the exact association. The characteristic taxa of the order Seslerietalia coeruleae include *Acinos alpinus, Aster alpinus, Cardus crassifolius, C. defloratus, Gymnadenia conopsea, Rhinantus glacialis.*

Habitat type 6150: Siliceous alpine and boreal grasslands.

Class Caricetea curvulae Br.-Bl. 1948
Order Caricetalia curvulae Br.-Bl in Br.-Bl. Et Jenny 1926
Alliance Caricion curvulae Br.-Bl. In Br.-Bl. Et Jenny 1926

13 relevés were found with this habitat type (Figure 12) and the characteristic species of Caricetea curvulae like *Avenula versicolor, Gentiana acaulis, Gentiana punctata, Leontodon helveticus, Phyteuma hemisphaericum, Potentilla aurea, Pulsatilla alpina subsp. Austriaca*. This includes three different associations.

Association Carici curvulae-Nardetum Oberd. 1959
Carex curvula subsp. Curvula, Nardus stricta (dom.), Avenella flexuosa and *Carex sempervirens*, *Arnica montana, Campanula barbata* and *Gentiana acaulis* can be found here.

Association Caricetum curvulae Rübel 1911
Besides *Carex curvula subsp. Curvula (dom.)* this typical grassland has characteristic species such as *oreochloa disticha*, *Veronica bellidioides*, *Agrostis rupestris, Leucanthemopsis alpina* and *Pulsatilla alpina subsp. Austriaca.*

Association Loiseleurio-Caricetum curvulae Pitschmann et al. 1980
This association inhabits windy plateaus characterized primarily by the appearance of dwarf shrubs like *Loiseleuria procumbens (subdom.), Vaccinium gaultherioides (subdom.), Vaccinium vitis-idaea* and *Vaccinium myrtillus*.

Habitat type 4060: Alpine and boreal heats.

Class Loiseleurio-Vaccinietea Eggler 1952
Order Rhododendro-Vaccinietalia Br.-Bl in Br.-Bl. Et jenny 1926
Alliance Rhododendro-Vaccinion J. Br.-Bl ex G. Br.-Bl. Et J. Br.Bl. 1931
Association Rhododendretum ferruginei Rübel 1911

The Alpine heaths with *Rhododendron ferrugineum* are a distinct monodominant community with constant species are *Juniperus communis, Vaccinium myrtillus, Avenella flexuosa, Vaccinium gaultherioides* and *Vaccinium vitis-idaea.*

Class Seslerietea albicantis Oberd. 1978 corr. Oberd. 1990
Order Rhododendro hirsuti-Ericetalia carneae Grabherr et al. 1993
Alliance Ericion carneae Rübel ex Grabherr et al.1993
Association Ericetum carneae Rübel 1911

The association is dominated primarily through *Erica carnea* itself. Particularly associated are also *Rhododendron hirsutum*, *Anthyllis vulneraria, Cardus defloratus, Globularia cardifolia, Helianthemum nummularium, Scabiosa lucida*.

No specific habitat type: Rich pastures.

Class	Molinio-Arrhenatheretea R. Tx. 1937 em. R.Tx. 1970
Order	Poo alpinae-trisetetalia Ellmauer et Mucina 1993
Alliance	Alchemillo-Poion supinae Ellmauer et Mucin 1993
Association	Deschampsio cespitosa-Poetum alpinae in Ellmauer et Mucina 1993

Six relevés were found (Figure 12), but these are not easy to classify, because of their wide ecological amplitude. The association is presented by *Deschampsia cespitosa (dom.), Ranunculus acris, Cerastium holosteoides, Rumex acetosa, Poa alpina, Phleum rhaeticum, Alchemilla vulgaris agg., Taraxacum officinale ag*

Figure 12: Left top: Colorful pasture over calcerous ground with habitat type 6170, top right: Rich pasture with a high cover value of Deschampsia cespitosa, bottom left: Alpine and boreal heaths with Rododendron hirsutum, bottom right: Typical Caricetum curvulae dominated by Carex curvula.

3.2 Red listed species

Red lists are a core part of nature conservation work, because they assign species to one of a set of threat levels. Especially, semi-dry and dry grasslands have a high proportion of Red List species (Pagitz et al. 2023). In the relevés defined as Nardus Grasslands, of the 215 species found, 69 are considered regionally endangered in Austria, e.g., *Anthyllis vulneraria, Ceologlossum viride* and *Homogyne alpina* as assessed by consulting the Red List of Species Austria (Schratt-Ehrendorfer et al. 2022). 14 species are locally endangered in East Tyrol, e.g., *Ajuga pyramidalis, Botrychium lunaria* and *Arnica montana* as assessed by the Red List of Species East-Tyrol (Pagitz et al. 2023). 29 species are under protection in Tyrol, e.g., *Aconitum napellus, Aster alpina* and *Silene acaulis* as assed with the help of the nature conservation act of Tyrol (Amt der Tiroler Landesregierung 2006). Table 15 and 16 in appendix one shows the full list of endangered and protected species with their corresponding status and describe the abbreviations to understand them.

3.3 Correlations of plant diversity in Nardus grasslands

Of the 106 relevés gathered during fieldwork, statistical analysis is exclusively conducted on 76 relevés that have been identified as Nardus grasslands.

3.3.1 Management variables and their correlation with diversity

Land Use Intensity and biodiversity

Figure 13 illustrates the relationship between land use intensity (LUI) and biodiversity. The data reveals a significant correlation between the two parameters. The calculated biodiversity is highest in areas with moderately extensive to intensive land use. Conversely, very extensive, and intensive LUI exhibits lower mean values of biodiversity, with the very extensive LUI demonstrating the lowest among all. An example for a very extensively managed grassland can be seen in Figure 14. This relevé at an altitude of 2158 m a.s.l. is dominated *Nardus stricta*. The right image shows an intensively used grassland at an altitude of 1913 m a.s.l., that is typically well grazed, bright green and, compared to the first image has no litter layer. The statistical significance is indicated by the low p-value (see Table 3) and the overall fit of this model is supported by the F-statistic and R-squared values, suggesting that the LUI explains a significant portion of the variance in biodiversity.

Table 3: Model summary for the parameters of land use intensity and biodiversity.

Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic
0.19227	0.05542	3.469	0.00088	0.4761	0.1415	0.1298	12.04

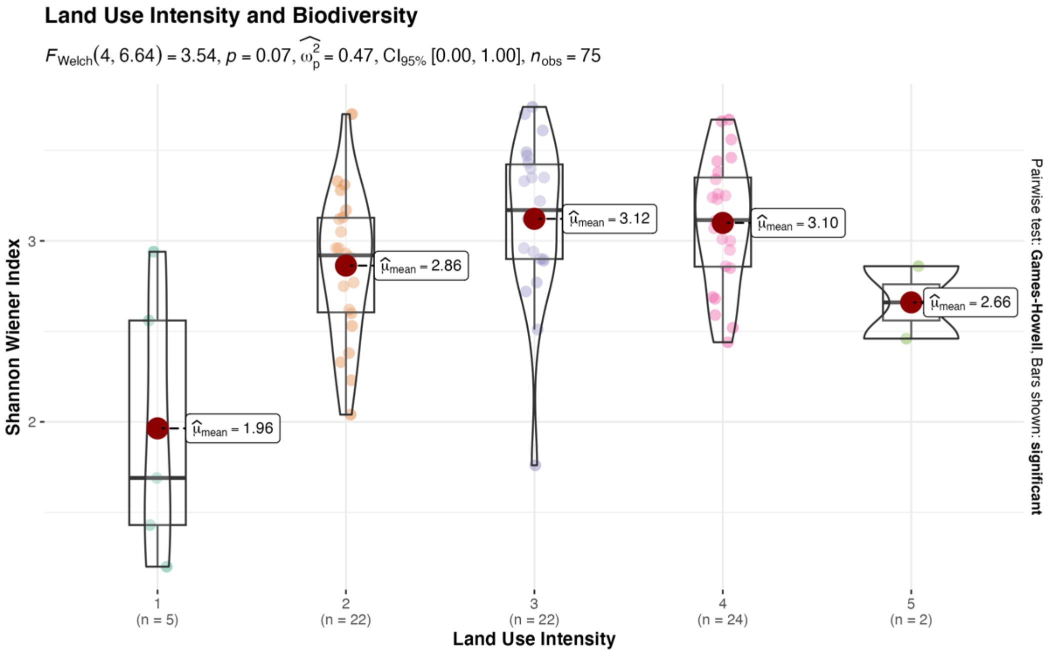


Figure 13: The land use intensity (1: Very extensive, 2: Extensive, 3: Moderately extensive to moderately intensive, 4: Intensive, 5: Very intensive) and their correlation with biodiversity. The components in a boxplot represent its characteristics. The lower side of the box is the first quartile while the upper side is called the third quartile. The line that crosses the box is the median. The lines extending are whiskers, the ends of which represent the minimum and maximum. An enhanced version of boxplots is violin plots, in which data density is visualized as smoothed histograms along the data points (Hu 2020).

Figure 14: An example of a Nardus Grassland with very extensive land use category one (relevés 14.4) and an intensive land use category 4 (relevés 7.7).

Yield and biodiversity

The linear regression analysis revealed that the estimated yield in dt/ha/year explains only a minor proportion of the variance in diversity. As such, there is insufficient evidence to support the notion that yield has significant impact on biodiversity. Schaub et al. (2020) say that in agricultural settings, plant diversity is often associated with low biomass yield and forage quality, while biodiversity experiments typically find the opposite. According to their findings, increasing plant diversity in semi-natural grasslands can have equally large positive effects on revenues as increasing management intensity and, consequently, maintaining, and reestablishing plant diversity could be a way to sustainably manage temperate grasslands. However, in my findings the high p-value (see Table 4) indicates, that yield may not be statistically significant and the overall fit of the model appears to be weak (low F-statistic and R-squared).

Table 4: Model summary for the parameters of yield and biodiversity.

Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic
0.007594	0.010388	0.731	0.467	0.5119	0.007268	-0.006331	0.5344

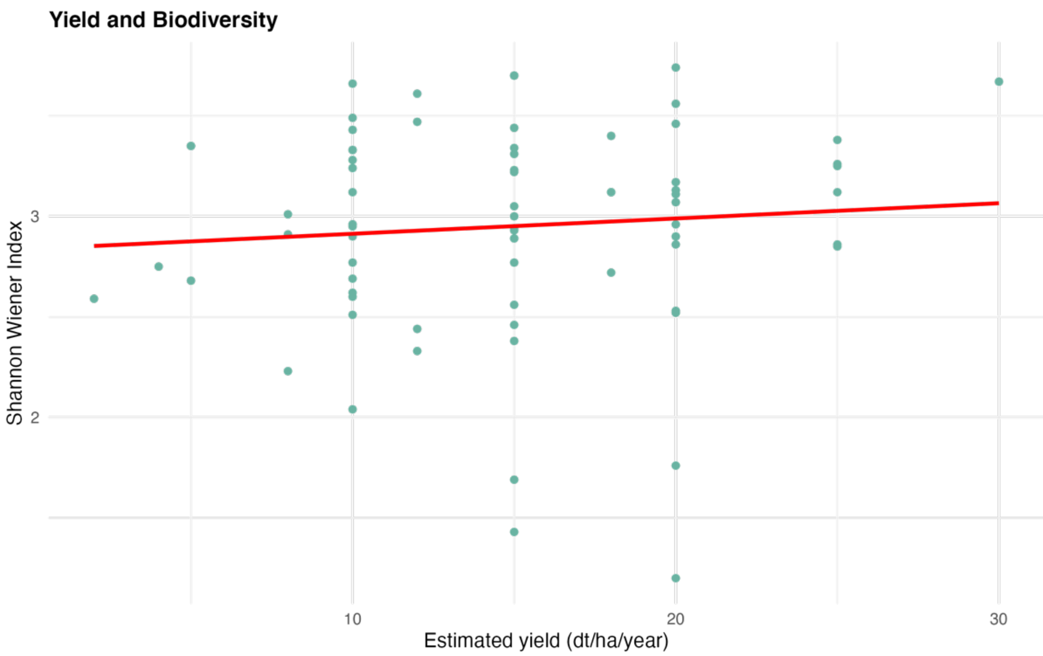


Figure 15: The estimated yield (in dt/ha/year) in relation to the biodiversity (Shannon Wiener Index).

3.3.2 Conservation status and the correlation with diversity

In the assessment of Nardus grasslands, species richness plays an important role in determining their conservation status. A habitat automatically receives a conservation status of ‘C’ if the number of characteristic species falls below six.

When considering all relevés, the mean number of species for status ‘A’ is 35.8, for ‘B’ it is 32.6, and for ‘C’ it is 24.7. As illustrated in Figure 16, biodiversity is nearly identical for conservation statuses ‘A’ and ‘B’, but significantly varies for status ‘C’. To explore this correlation further, the second graph in figure 16 portraits a similar significant relationship between conservation status and the number of regionally endangered species. Notably, all relevés with a conservation status ‘C’ have fewer than eight regionally endangered species. Looking at the statistical results in table 5, in both cases, the p-values for the variable ‘C’ are small (<0.01) indicating that the variable ‘C’ is highly statistically significant in both models. Therefore, I conclude that a conservation status of ‘C’ has a highly significant effect on both biodiversity and the number of endangered species (cf. table 6 and table 6).

A typical image of a conservation status of ‘C’ can be seen in Figure 17 on the left side. This relevé equally describes the before mentioned Nardus grasslands with a very extensive LUI and high cover of old *Nardus stricta*, easily visible by its brown color. In this case, there are only 11 species found at this relevé and the cover value of *Nardus stricta* is >75 %. A typical image for a conservation status of ‘A’ can be seen on the right side. In this case, the grassland is a colorful pasture with open soil, low-growing species in a mosaic of dwarf shrubs.

Table 5: Model summary for the parameters of conservation status and biodiversity.

	Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic	P-value
B	-0.01581	0.11456	-0.138	0.890609	0.4739	0.161	0.1377	6.91	0.001798
C	-1.04702	0.28788	-3.637	0.000515					

Table 6: Model summary for the parameters of conservation status and reg. endangered species.

	Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic	P-value
B	-0.07143	0.72469	-0.099	0.921759	2.998	0.1561	0.1327	6.66	0.002219
C	-6.48810	1.82111	-3.563	0.000656					

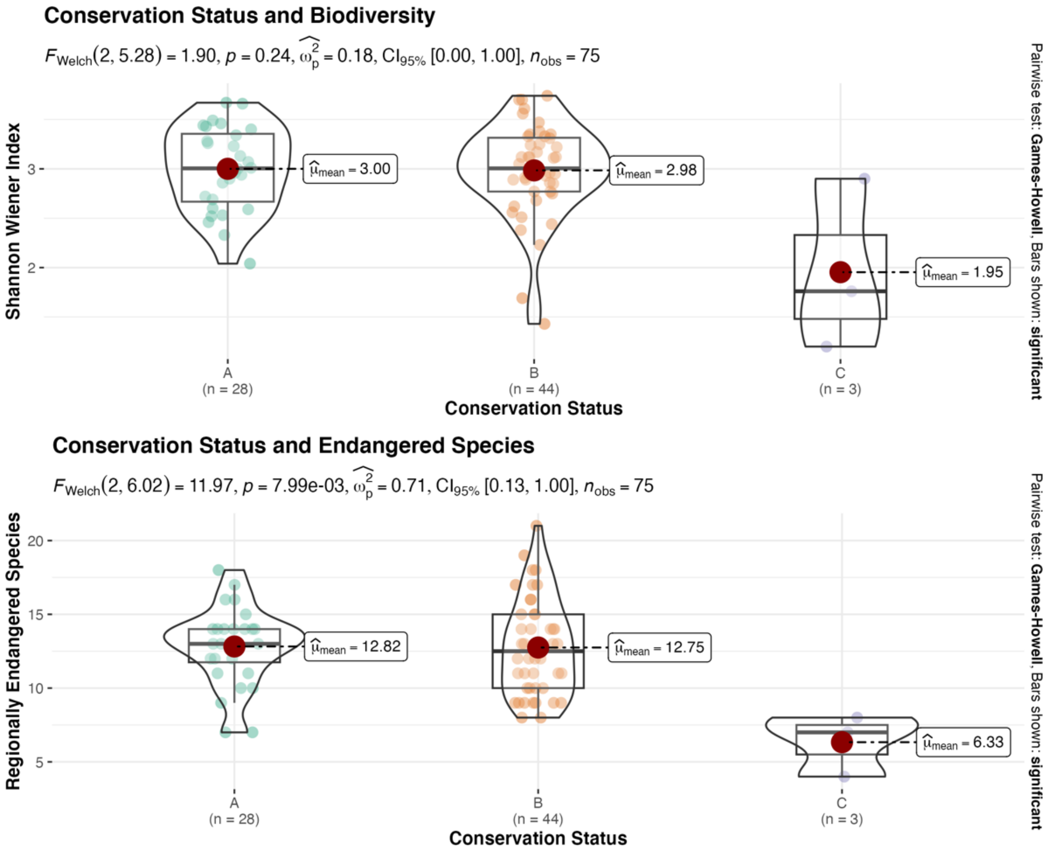


Figure 16: The correlation of the conservation status and the biodiversity (upper graph) and the number of regionally endangered species (lower graph) of Nardus grasslands.

Figure 17: Examples for study sites with a conservation status 'C' on the left (relevé 14.1) and conservation status 'A' on the right (relevé 9.8).

3.3.3 Environmental variables and the correlation with diversity

Geology

Although Nardus grasslands are said to be established mostly above silicate bedrock (Mucina et al. 1993), I incorporated 15 relevés above calcareous bedrock. The study sites are located over three different rock types: Chlorite actinolite epidote metamorphic rock, Mica Schist and Paragneiss. Mica Schist and Paragneiss are grouped together to represent silicate bedrock and Chlorite actinolite epidote metamorphic rock represents calcareous bedrock. Figure 18 suggest that the diversity is highly correlated to the bedrock, with the mean value over calcareous bedrock being significantly higher. The model summary in table 7 shows, that the predictor variable appears to be highly statistically significant, as indicated by the small p-value and explain a portion of the variance in biodiversity.

Table 7: Model summary for the parameters of surface geology and biodiversity.

	Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic
	-0.4996	0.1260	-3.965	0.00017	0.4661	0.1772	0.1659	15.72

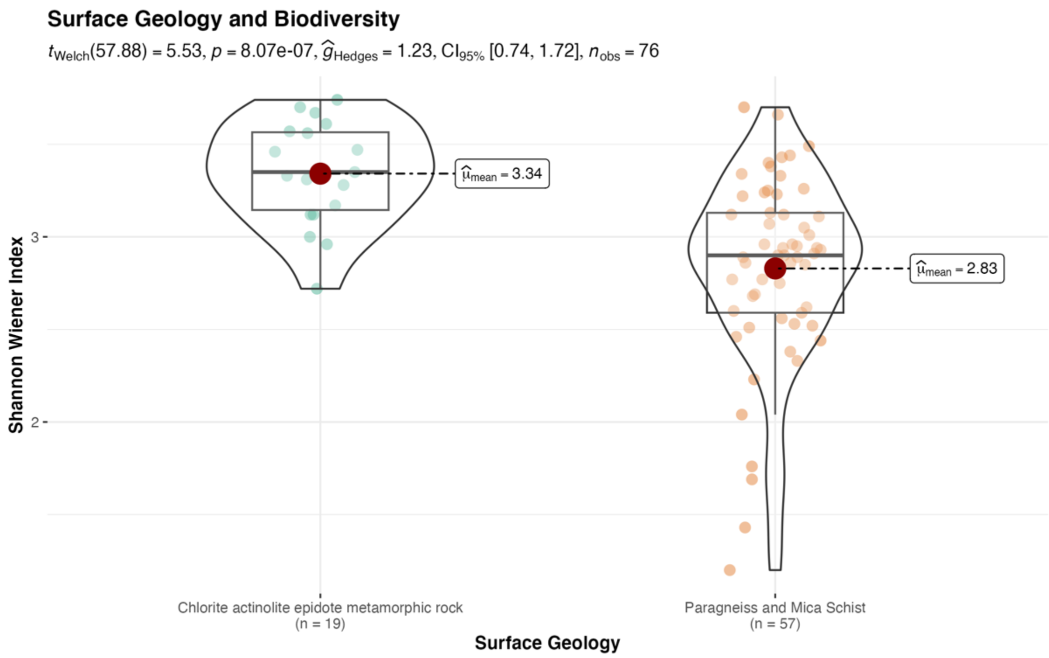


Figure 18: The correlation of calcareous and silicate bedrock and the biodiversity of Nardus grasslands.

Altitude and slope

Regarding the parameters of altitude and slope, the ANOVA analysis suggests that the regression model accounts for only a small proportion of the variance in altitude and slope concerning their correlation with biodiversity, as predicted in Figure 19. The summaries in table eight and nine indicate that, with a high p-value (>0.5), these variables may not be statistically significant and the overall fit of the model does not appear to be very strong. There is only a very slight increase in biodiversity with a decrease in altitude and an increase of slope in the study area. Nonetheless, the relevés with the significantly lowest biodiversity (SWI < 2) seem to appear only at an increased altitude.

Table 8: Model summary for the parameters of altitude and biodiversity.

Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic
-0.0006014	0.0003464	-1.736	0.0868	0.5035	0.03965	0.0265	3.014

Table 9: Model summary for the parameters of slope and biodiversity.

Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic
0.009391	0.004670	2.011	0.058	0.5001	0.0525	0.03952	4.045

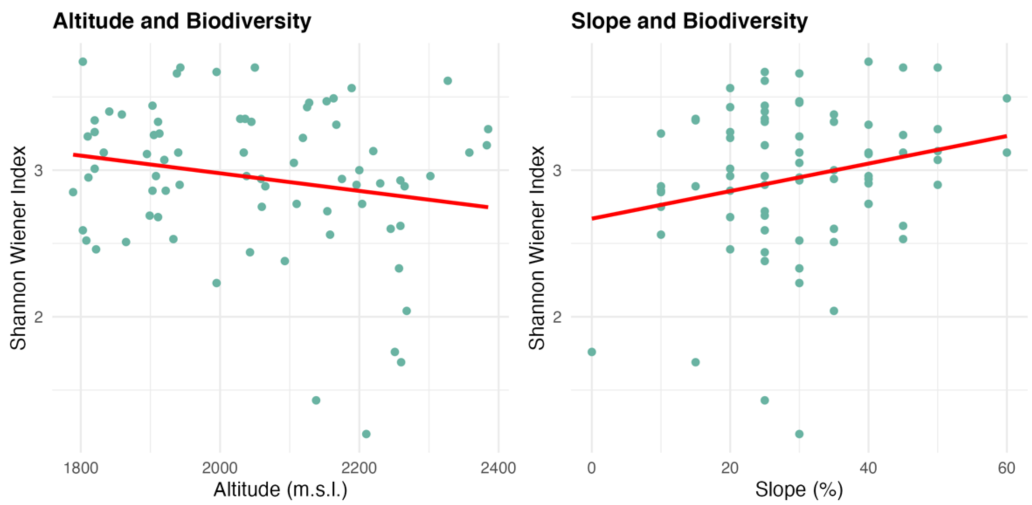


Figure 19: The correlation of altitude and slope with the biodiversity of Nardus grasslands.

Weighted indicator values and their correlation with diversity

Figure 20 represents the outcomes of three distinct regression analyses, each involving different response variables (moisture, nutrients, reaction) in correlation with biodiversity. In summary, the reaction model stands out with the lowest residual standard error (RSE), and the most significant statistic as can be seen by the lowest p-value (compare table 10, table 11 and table 12). The nutrient model is also highly statistically significant and explains a moderate amount of variance, whereas the moisture model yields the least significant results in terms of its capacity to explain variance in biodiversity. In simpler terms, the graph suggests that an increase in soil nutrients and pH may lead to an increase in diversity, while a reduction in moisture may result in a slight decrease in diversity.

Table 10: Model summary for the parameters of EIV moisture and biodiversity.

Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic
-0.7046	0.2435	-2.893	0.00502	0.4867	0.1029	0.0906	8.372

Table 11: Model summary for the parameters of EIV nutrients and biodiversity.

Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic
0.6503	0.1474	4.412	3.47e-05	0.4565	0.2105	0.1997	19.47

Table 12: Model summary for the parameters of EIV reaction and biodiversity.

Estimate	Std. Error	t value	Pr(>|t|)	RSE	Multiple R-squared	Adjusted R-squared	F-statistic
0.4360	0.0623	6.998	1.05e-09	0.3975	0.4015	0.3933	48.97

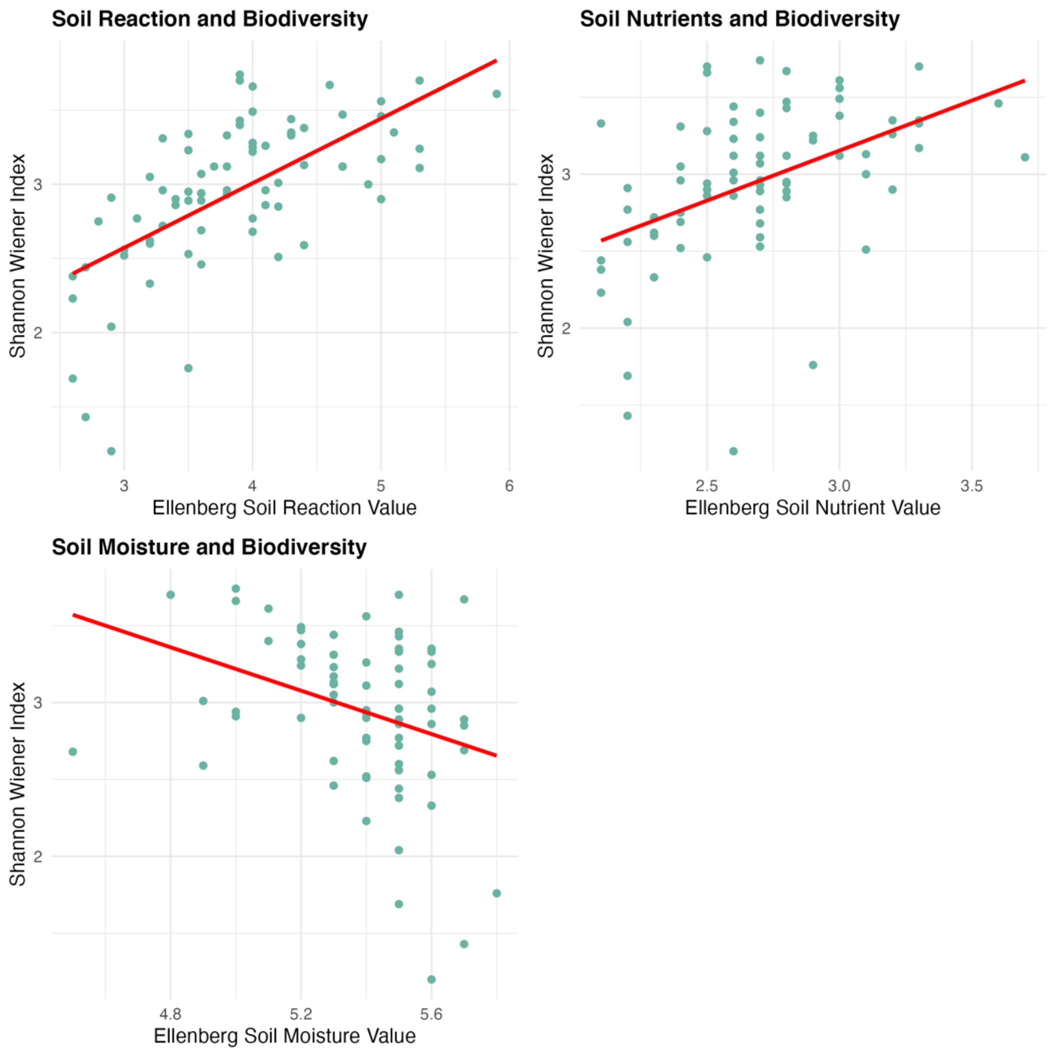


Figure 20: The correlation of the Ellenberg indicator values for R (reaction), N (nutrients) and M (moisture) and their correlation with the biodiversity of Nardus grasslands.

3.4 Classification of Nardus grassland subgroups

The grouping of Nardus grasslands is based on a second Twinspan analysis, using the initial classification of the 76 Nardus grasslands. These five groups are designated as subgroups due to their distinct ecological differences and the presence of numerous specific indicator species unique to each group. I named these subgroups Nardus grasslands N1, N2, N3, N4, and N5. The objective was to uncover patterns in species composition in relation to various parameters, with the aim of providing more precise management recommendations. To achieve this, I computed the mean values for all parameters (see table 13). Additionally, to identify characteristic indicator species for each subgroup, I selected species with a relative frequency exceeding 30% and occurring at least twice as often in the subgroup of interest than in any other subgroups. The geographic distribution can be observed in Figure 21.

Group N1 – Seslerietosum albicantis

The first group specifies a community related to calcareous bedrock above an altitudes of 2000 m a.s.l. Consequently, highly significant differences from the other groups are given for the R values. The high R value indicates a higher soil pH. Of the EIV, this group also has the highest means of N. Of all groups, they have the highest species richness (139), the highest biodiversity (SWI) and the highest number of locally protected species. Its characteristic species were identified as *Trifolium badium, Bartsia alpina, Soldanella alpina, Selaginella selaginoides, Salix waldsteiniana, Anthyllis vulvernaria* and *Gentiana nivalis,* which were almost exclusively found in these relevés. Because of the characteristic species of the class *Sesleritea albicantis*, the alpine and subalpine calcareous grasslands, the group was identified as *Seslerietosum albicantis* (as already proposed by (Lüth et al. 2011)).

Group N2 – Trifolium repens

The second group includes most of the vegetation relevés on silicate bedrock. Compared to the others, these include the most intensively managed pastures with a mean LUI of 3.5. Most relevés are located lower than 2000 m a.s.l. However, after group N1, it also has the second highest values for total number of species (126), species richness and SWI. Additionally, the mean cover of dwarf shrubs is very low (6.8 %), and they have the best value when it comes to the conservation status. The characteristic species for this group are *Trifolium repens, Phyteuma betonicifolium, Luzula luzuloides.* They have the highest frequencies of *Phleum rhaeticum* and *Agrostis capillaris*, which are characteristic species of the *Poo alpinae-Trisetetalia*, the alm pastures and meadows. *Trifolium repens* is an indicator species for pastures at lower altitudes (Mucina et al. 1993), therefor this group is given its name.

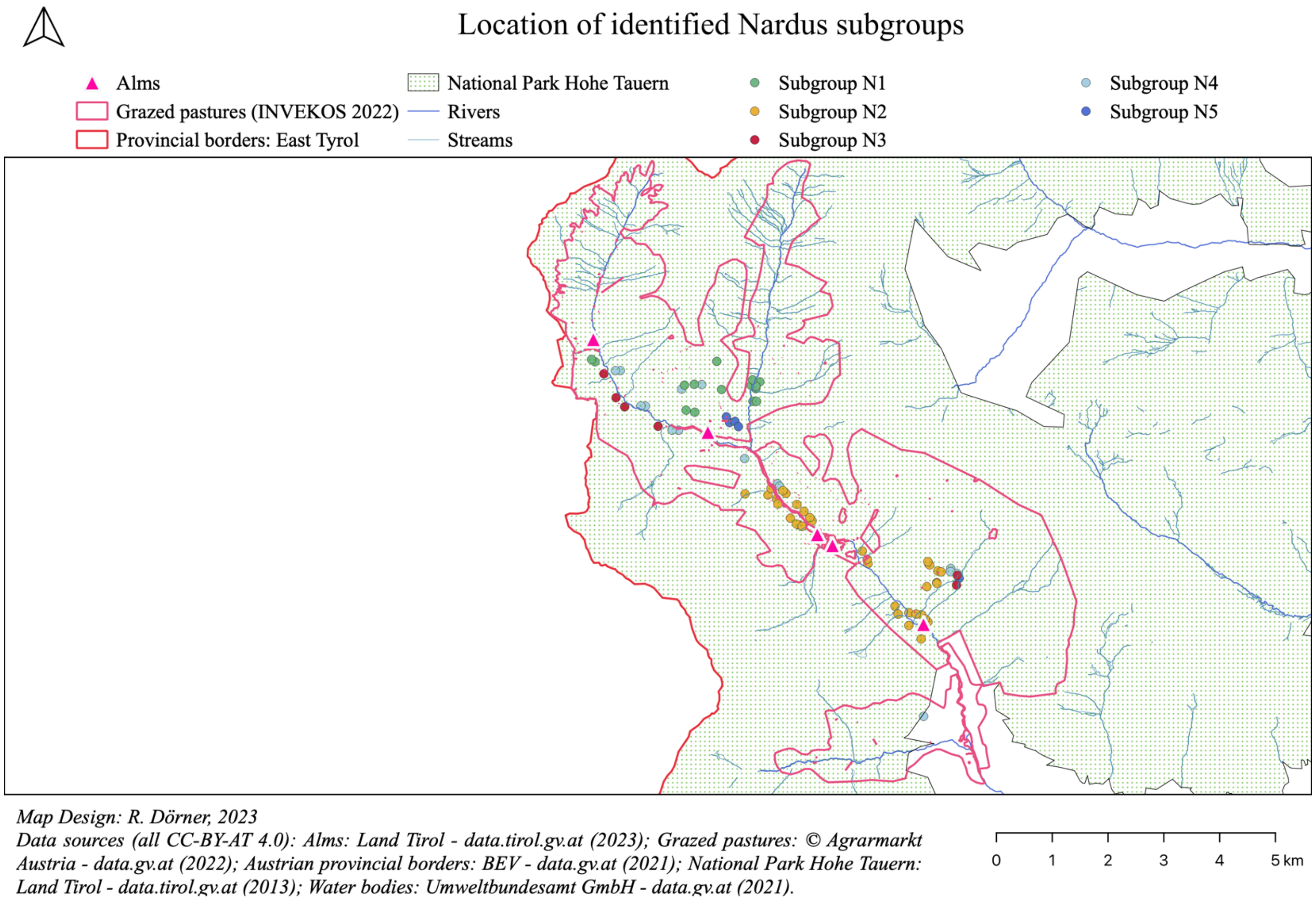


Figure 21: Location of the associated subgroups (N1, N2, N3, N4, N5) of Nardus grasslands in the Defereggen valley.

Group N3 – Sibbaldia procumbens

The third group represents a small number of pastures on silicate bedrock with moderate LUI, but on very low slopes and muss less species than the previous groups (78). They differ from the other subgroups, as they generally face more to direction of east and have the highest EIV for F (5.6). This higher value for moisture can also be seen in their species composition with their characteristic species *Juncus alpinoarticulatus, Veratrum album, Sibbaldia procumbens* and *Pyrola minor.* This group has the highest frequencies for *Deschampsia cespitosa*.

Group N4 - Vaccinietosum

The fourths group specifies pastures with extensive land use (LUI 2.2). These relevés can be separated from the other subgroups by their higher number of dwarf shrubs (19.1 %) and a mean slope of 34.1 %. These relevés have all the dwarf shrubs found during the surveys present in this group. A highly significant separation of the means of the EIVs was found for the R and N values, which are lower than in the first two groups. The characteristic species of *Loiseleuria procumbens, Diphasiastrum alpinum* as well have an individual EIV for N of one and two, and there for suggest, according to Ellenberg, that they are commonly found in areas with lower nitrogen availability. Additionally, this subgroup has and the highest number of endangered species e.g., orchids (*Gentianella rhaetica, Gentiana bavarica, Gentiana punctata, Gymnadenia conopsea*). Because of the differential species of the genus Vaccinium, which all have a frequencies higher than 50 %, this group is identified as Sieversio montanae-Nardetum strictae vaccinietosum (as already proposed by Hartl (1963) in Lüth et al. (2011)).

Group N5 – Nardus stricta

Finally, the last group represents very extensively managed (LUI 1.0) with the lowest species richness of all sub associations (17.6) and only 45 species found all together. A highly significant separation of the means of the EIVs was found for the lowest R and N values of all groups. All relevés are south facing pastures over 2300 m a.s.l. with high cover values of *Nardus stricta* and only little numbers of characteristic species such as *Hypochaeris uniflora*. Consequently, they have the worst conservation status, between ‘B’ and ‘C.

Table 13: The main environmental and management characteristics of the five local sub-groups of the association Sieversio montanae-Nardetum strictae. To calculate the conservation status was represented in numerical terms with A as one, B as two and C as three.

Local Sub-Groups	**N0**	**N1**	**N3**	**N4**	**N5**
Number of relevés	15	34	6	16	5
Number of species	139	126	78	122	45
Geology	Calcareous	Silicate	Silicate	Mixed	Silicate
Calculated parameters					
Slope (%)	32.0	30.74	15.0	34.1	24.0
Altitude (m a.s.l)	2132.3	1934.4	2163.1	2127.5	2188.2
Aspect (°)	159.0	154.2	112.5	151.8	189
Estimated parameters					
LUI	3.1	3.52	2.9	2.2	1.0
Yield (dt/ha)	13.8	15.7	15.5	12.3	16.0
Shrub cover (%)	8.4	6.8	8.5	19.1	8.8
Species richness	39.0	34.5	28.8	32.5	17.6
SWI	3.4	3.0	2.8	2.9	1.9
Conservation status	1.9	1.5	1.8	1.7	2.2
Red list of species					
Reg. endangered	13.3	12.2	10.8	14.2	9.4
Loc. endangered	2.7	3.9	2.3	3.8	2.8
Protected	5.6	3.0	3.5	4.7	3.0
Indicator values of Ellenberg (EIV)					
F = Moisture	5.4	5.3	5.6	5.4	5.5
R = Soil reaction	4.8	4.0	3.6	3.2	2.9
N = Nitrogen	3.1	2.8	2.7	2.3	2.3
Characteristic species (that have a rel. frequency of at least 30 % and at least twice as much rel. frequency than any other of the groups)					
	Trifolium Badium	*Trifolium repens*	*Juncus alpinoarticulatus*	*Loiseleuria procumbens*	*Hypochaeris uniflora*
	Bartsia alpina	*Phyteuma betonicifolium*	*Veratrum album*	*Diphasiastrum alpinum*	
	Soldanella alpina	*Luzula luzuloides*	*Sibbaldia procumbens*		
	Selaginella selaginoides		*Pyrola minor*		
	Salix waldsteiniana				
	Gentiana nivalis				

In summary, Figure 22 provides an overview of the identified subgroups and their connections to all measured, estimated, and calculated parameters. These correlations were assessed for their significance. The results indicated that among the most influential factors, the highest R-squared value (goodness of fit of the regression model) is associated with the Ellenberg indicator value of R, signifying that soil pH explains the most variance in the diversity compared to other factors. However, the LUI also emerges as highly significant. In simpler terms, these findings suggest that the diversity of Nardus grasslands tends to increase with declining pH levels and diminishing LUI. The decrease in the EIV of Nitrogen (N) can also be interpreted as an indicator of land use intensity, as it typically corresponds to higher nutrients inputs from a greater number of grazing livestock.

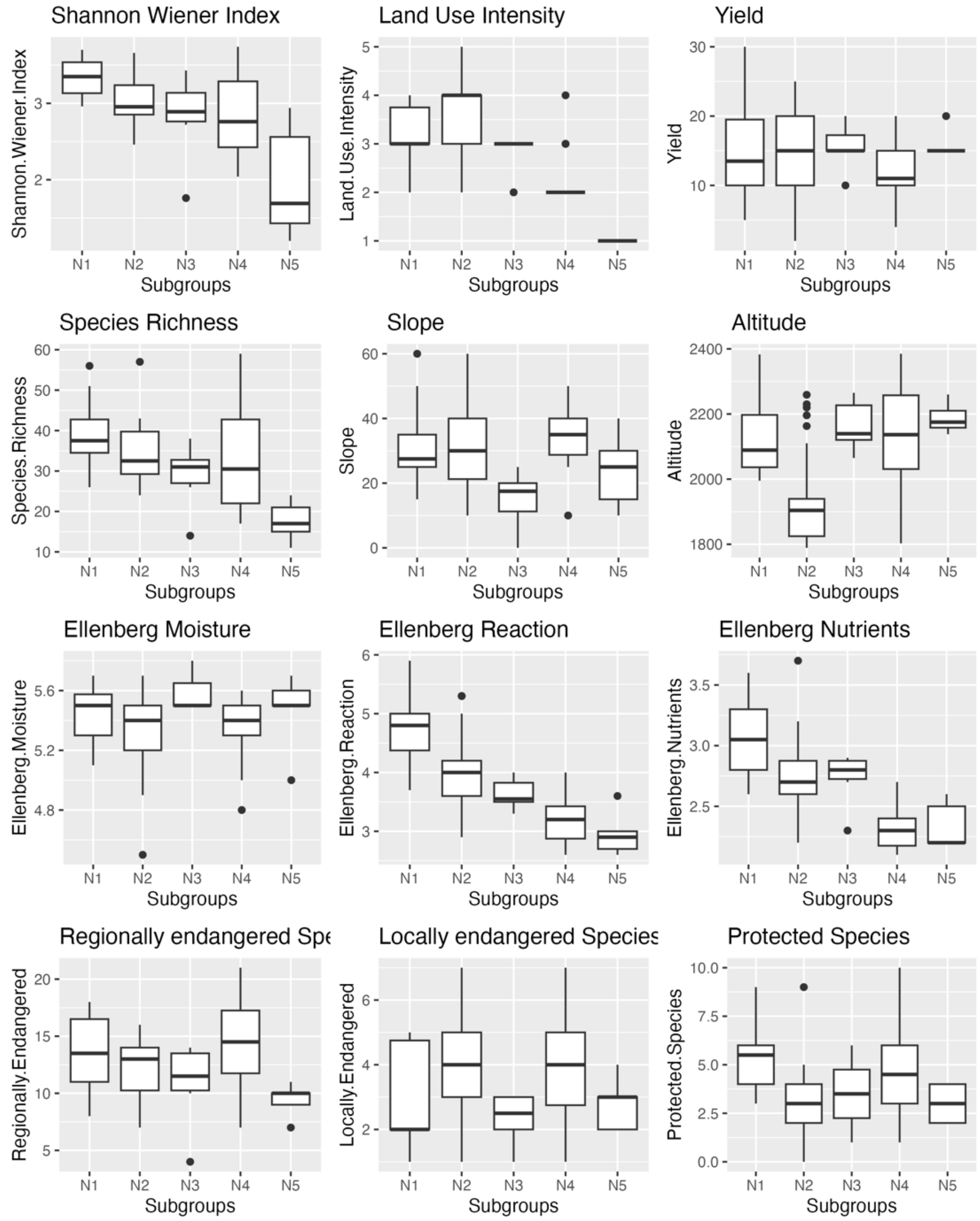


Figure 22: Management and environmental variables correlated to the Nardus subgroups N1-N5.

Discussion

The discussion serves to interpret the significance of the results and explain how the results can help to answers the research questions. I will also discuss how my results align with or differ from existing literature. But, before interpreting the meaning of the results, I would like to highlight the importance of preparatory research and remote sensing. The overlay analysis of the open government data on bedrock, land use, slope, altitude, and land cover were very helpful, because I conclude, that nearly all study sites were found within these boundaries or, at least, very close to them.

4.1 Answers to the research questions

Which (sub)associations of Nardus grasslands are present and what trends can be identified within the plant communities?

Classification of all relevés to identify Nardus grasslands

The first step to answer this research question was the classification of all relevés collected in the field. After the import of field data into the programs TURBOVEG and JUICE, the analysis with Twinspan and further classification with Excel lead to the identification of Nardus grassland relevés. Of all 106 relevés, 76 were classified as the habitat type 6230, 'species rich Nardus grasslands on siliceous substrates in mountain areas' with the association Sieversio Nardetum strictae. This association is, according to Mucina et al. (1993), the most common association of Nardus grasslands in alpine pastures of the eastern alps. The classification of the remaining relevés, that were not identified as Nardus grasslands, resulted in four main habitat types: 6170 Alpine and subalpine calcareous grasslands, 6150 Siliceous alpine and boreal grasslands, 4060 alpine and boreal heaths and rich pastures.

Reclassification of Nardus grasslands into the order of Nardetalia

With 76 relevés that were identified as Sieversio Nardetum strictae, the question if the alliance Nardion strictae belongs to the order of Nardetalia (class of Calluno-Ulicetea) or to the order of the Festucetalia spadiceae (class of Caricetea curvulae) was tested. Table 14 shows all characteristic species as given by Mucina et al. (1993) of both classes and orders as well as the calculated mean values of their relative frequencies. Nardus grasslands contain characteristic species from lowlands that are present in the order Nardetalia more frequently (18.41 %) than the character species of the Festucetalia spadiceae that are restricted to the alpine zone (11.64 %). The relevés have species of both classes and both orders, but the following speaks in favor of the classification into the Nardetalia: According to Mucina et al. (1993) the Nardetalia are subject to anthropo-zoogenic influence and this is why I suggest to integrated the alliance into the group of mainly anthropogenic vegetation. Additionally, I have found a high number of dwarf-shrubs, e.g., *Calluna vulgaris, Juniperus communis ssp. nana, Vaccinium gaultherioides, Vaccinium myrtillus,* which speaks for a classification into the class of dwarf-shrub heather (Calluno-Ulicetea). This integration into the order of the Nardetalia has already been suggested by other authors such as Oberdorfer (1959), Lüth et al. (2011) and Dierschke (2001).

Classification of sub associations of Nardus grasslands

After the relevés with Nardus grasslands were identified, a second Twinspan analysis helped to classify the Sieversio Nardetum strictae into subgroups. This grouping of species was done to make better predictions on how changing management and environmental parameters influence the species composition of these grasslands. The analysis led to five subgroups that showed enough differences in between them to justify a separation. Furthermore, I used JUICE to calculate a synoptic table with the relative frequencies (in %) of all species to identify characteristic species that would preferably occur primarily in each group. The five Nardus grassland groups are: N1, N2, N3, N4 and N5. The first division can be drawn between group N1 and the other groups by the type of bedrock. While group N1 is located on calcareous bedrock, the other groups are all located on silicate bedrock. The second division can be drawn by their LUI, while groups N2 - N3 have intensive to moderately intensive land use, group N4 - N5 have extensive to very extensive land use.

In detail, the first group N1 specifies the communities related to calcareous bedrock above 2000 m a.s.l., that differ from the other groups by the highest Ellenberg indicator values (EIV) of reaction (R) and nitrogen (N). Of all subgroups, they also have the highest values for species richness, SWI and locally protected species and are therefore very important sites for conservation. The interviews revealed that shepherds also had the best experiences with grazing on calcareous bedrock, as one said, "on calcareous bedrock, the cows eat everything". The second group N2 describes moderately managed pastures on silicate rock, and compared to the others, includes the most intensively managed pastures. However, it has the

Table 14: Character species based on Mucina et al. (1993) for the class Calluno-Ulicetea and the order Nardetalia and for the class Caricatea curvulae and the order Festucetalia spadiceae in relative frequency (in %) for all Nardus grasslands.

Calluno-Ulicetea	Rel. Frequency (%)	Nardetalia	Rel. Frequency (%)	Caricetea curvulae	Rel. Frequency (%)	Festucetalia spadiceae	Rel. Frequency (%)
Calluna vulgaris	*37*	*Nardus stricta*	*92*	*Avenula versicolor*	*20*	*Campanula barbata*	*47*
Potentilla erecta	*49*	*Arnica montana*	*61*	*Gentiana acaulis*	*48*	*Geum montanum*	*83*
Antennaria dioica	*21*	*Hieracium lactucella*	*27*	*Phyteuma hemisphaericum*	*43*	*Phyteuma betonicifolium*	*25*
Anthoxanthum odorarum	*84*	*Carex pallescens*	*8*	*Potentilla aurea*	*91*	*Crepis conyzifolia*	*1*
Carex pilulfera	*1*	*Galium pumilum*	*9*	*Pulsatilla alpina ssp. Austriaca*	*32*	*Hypochaeris uniflora*	*7*
Hieracium pilosella	*39*	*Hypercium maculatum*	*1*	*Agrostis rupestris*	*13*	*Centaurea nervosa*	*0*
Luzula multiflora	*48*	*Botrychium lunaria*	*16*	*Leontodon helveticus*	*55*	*Erigeron alpinus*	*0*
Danthonia decumbens	*0*	*Veronica officinialis*	*7*	*Gentiana punctata*	*9*	*Festuca paniculata*	*0*
Genista sagittalis	*0*	*Galium saxatile*	*0*	*Gentiana purpurea*	*0*	*Paradisea lilastrum*	*0*
Luzula campestris	*1*	*Genista tinctora*	*0*	*Phyteuma confusum*	*0*	*Plantago serpentina*	*0*
Lycopodium clavatum	*0*	*Hypericum perforatum*	*0*	*Scorzoneroides helvetiva*	*1*	*Pulsatilla alpina ssp. apiifolia*	*0*
Polygala serpyllifolia	*4*	*Thesium pyrenacium*	*0*	*Trifolium alpinum*	*0*	*Ranunculus vilarsii*	*0*
						Veronica fruticulosa	*0*
						Beradiochloa variegata	*0*
Mean percentage	*23.66*		*18.41*		*26.00*		*11.64*

second highest values for total number of species, species richness as well as SWI and, interestingly, they have best mean value when it comes to the conservation status. The third group N3 represents pastures on silicate bedrock with moderate LUI, but on very low slopes and much less species than the previous group. They differ from the other groups, as they generally face to direction of east and have the highest EIV for moisture (M). The fourth group N4 specifies pastures with extensive land use. These relevés can be separated from the other groups by their high number of dwarf shrubs and steep slope. Together with group N4, it has the lowest EIV for N. Finally, group N5 represents very extensively managed pastures with the lowest species richness of all groups. All relevés are south facing pastures over 2300 m a.s.l. with high cover values of *Nardus stricta*. Consequently, they have the worst conservation status of all groups.

What influence does management practices and environmental variables have on the diversity and conservation status of this habitat type?

Soil pH

In summary, the EIV of N and R as well as geology seem to be relatively strong predictors of diversity. The other factors (land use intensity, altitude, slope, and moisture) have weaker relationships. Reaction explains the most variance in the dependent variable and appears to be the most significant factor in predicting biodiversity. It has the highest R-squared value, indicating the strongest explanatory power, and the lowest p-value, signifying strong statistical significance. A higher value for reaction correlates with a higher diversity, meaning that relevés that contain plant species that are adapted to, or prefer, conditions that are at the higher end of the scale had a higher SWI. Connected to this is also, that the model for geology shows significant results and the sites on calcareous bedrock have a significantly higher mean value than in silicate bedrock. Pittarello et al. (2017) describes in a similar study, that Nardus grasslands on calcareous bedrock host a higher vascular plant diversity than those on siliceous bedrock. Mucina et al. (1993) add to this, that species diversity in Nardus grasslands varies, but is lowest on very acidic soils.

Nutrients

The second value that stands out the most as a highly significant predictor of diversity, is the EIV of N. All relevés had a mean N value higher than 2.1 and lower than 3.7. Considering the scale of Ellenberg, lower numbers indicate a lower preference or low tolerance. With no value bigger than four, I suggest, that at maximum, the species indicate a moderate ecological preference or tolerance for soil nutrient levels. None are highly specialized for extremely nutrient-rich soils. The average nitrogen values are also to be seen as an indicator of the land use intensity. A value of two on the other hand suggests that many species are adapted to or prefer soils with low nutrient content, or they are more specialized for nutrient poor conditions. I conclude, that the analysis shows a rise in nutrients is significantly correlated with a rise in diversity, but, I have no data for the higher end of this scale, so a high N level in the case of this study only stands for moderate nutrient levels. Duprè et al. (2010) investigated the negative impact of nitrogen deposition on species richness in acidic grasslands. They name several negative effects of nitrogen deposition on ecosystems: the influence on soil microbial processes, the toxicity to plants, the increase of sensitivity to environmental stress and the change in general resource levels. Their findings support suggest that N enrichment of grassland ecosystems is accompanied by a loss of species richness, especially dicots, whereas the relative number of grasses has strongly increased.

Land use intensity

Statistically significant is also the parameter of land use intensity. Both, very extensive and very intensive LUI have lower mean values of biodiversity. Moderately extensive to moderately intensive management in this case is strongly correlated with a higher diversity. Sites with very extensively managed pastures have the lowest diversity of all and are typically found at high altitudes. These sites are dominated by a high cover value of *Nardus stricta*. In their study Niedrist et al. (2009) conclude, that both tendencies, i.e., increasing land abandonment as well as land use intensity, have far-reaching consequences in terms of ecological, agricultural, and socio-economic aspects. They found that a decrease in land use intensity was paralleled by a marked rise in the average numbers of species. The more extensively an area is used, the higher the Shannon-Wiener index is; the maximum is reached in sporadically mown alpine meadows, while intensively used pastures show the lowest value. To better determine the land use types in agriculturally used alpine areas, other factors such as the distance from the farmhouse, availability of water for livestock and social circumstances must also be taken into consideration. Considering that most plant communities are restricted to two or three land use types (Niedrist et al. 2009), even the pastures with 'moderately intensive' land use in this study would most probably be described as 'extensive' when compared to fertilized pastures in lower altitudes. The descriptive results for the LUI are therefor to be considered only for the scope of this area.

Moisture

Furthermore, moisture also seems to have a statistically significant effect, but a much weaker one. Because the average values range from 4.5 to 5.8, the statistical significance in this case is questionable. A moisture value of five means that the plant species are adapted to or can thrive in soils with moderate moisture content, and they are not highly specialized for either extremely dry or extremely wet.

Though, the sites with lower moisture value have slightly less diversity. Pittarello et al. (2017) show, that the biodiversity parameters showed the highest values within the locations with lower precipitation. A higher water availability, associated with frequent and abundant rainfall determines optimal conditions for the growth of *Nardus stricta*, which results in an increase in its dense litter layer. Moreover, high precipitation dissolves carbonate rocks, with leaching resulting in top-soil acidification (Pittarello et al. 2017).

Yield

The statistical tests suggests that, for parameter of yield, the model does not have a strong explanatory power. There is not enough evidence that yield has a significant impact in diversity. From an agricultural point of view, Nardus grasslands give little yield, about only 11 dz/ha, with poor quality of the forage (Schechtner 1976, cited in Mucina et al. (1993)). It was according to my expectations, that yield would only differ very little between all Nardus grasslands, especially the difference would not be big enough to make any predictions. Experimental findings by Tilman et al. (2012) have uncovered how diversity of plants species in grasslands is just as crucial for their productivity as abiotic variables like disturbance and herbivory. Moreover, biodiversity became an increasingly dominant driver of ecosystem productivity through time, whereas effects of other factors either declined or remained unchanged.

Slope and altitude

Slope is statistically significant, but the effect of slope is not very strong, and the model does not explain much of the variability in diversity. This is the same result for altitude. What must be mentioned though, is the change of habitat type with altitude. With altitude of 2400 m a.s.l. the Nardus grasslands gradually change into the habitat type of *Carici curvulae-Nardetum Oberd. 1959.* These pastures already include *Carex curvula* bsides characteristic *Nardetalia* species like *Arnica montana and Campanula barbata.* At an altitude of 2500 m a.s.l. *Carex curvula* is becoming the almost sole dominant grass and the association of *Caricetum curvulae Rübel 1911* starts with characteristic species such as *Oreochloa disticha* and *Leucanthemopsis alpina.* Niedrist et al. (2009) found slope inclination to have the greatest influence on an area's land use intensity. Steeper pastures are used less intensively because livestock prefer less inclined terrain, resulting in an accumulation of faeces in these areas. Abandoned land has the strongest slope inclination of all land use types investigated; this strong inclination seems to be a key reason why these areas are no longer managed. In contrast, sea level does not appear to influence whether an area is fertilized or not. Rather, the shorter getting vegetation period on higher elevations decrease a meadow's productivity and thus the number of mowing's per year (Niedrist et al. 2009).

Conservation status

For the correlation of the conservation status with diversity, the mean value for diversity is nearly identical for a conservation status of ‘A’ and ‘B’. A conservation status of ‘C’ on the other hand is significantly lower. These results suggest that a conservation status of ‘B’ does nor necessarily indicate a loss in biodiversity at the time the relevés was taken. The most reason for a conservation status of ‘B’ in the field, was the number of dwarf shrubs present. As succession occurs slowly, a conservation of ‘B’ might indicate, that these sites are under threat in the future. Of all Nardus grasslands 44 sites were identified with ‘B’ and 26 with ‘A’. To analyze this further, the same significant relationship was found for the conservation status and the number of regionally endangered species. The sites with status ‘A’ and ‘B’ show the same mean values of endangered species, while the sites with ‘C’ only had half of these on average. This underlines the importance to maintain a favorable conservation status and avoid degradation, especially the sites considered ‘B’.

***What* does site-adapted management mean for the study area? Which measures are required to promote biodiversity of this habitat?**

Considering the results, the soil pH and geology as well as N and LUI are the most significant factors for the differing diversity in all subgroups, it is important to assess which Nardus grasslands in the valley are threatened to disappear and talk about the links between management practices and the vegetation composition to find actions to maintain or restore these threatened grasslands. I suggest focusing on the following:

- Conservation of calcareous Nardus grasslands
- Halting the succession of dwarf shrubs
- Reducing weed overgrowth on nutrient rich sites
- Reducing *Nardus stricta* overgrowth at high altitudes

Conservation of calcareous Nardus grasslands

Even if the Directive 92/43/EEC indicates that species-rich Nardus grasslands occur on siliceous substrates, these communities do occur also on calcareous bedrock, where precipitation has leached calcium from the top soil (Galvánek & Janák 2008). Such conditions have been reported in Austria (Lüth et al. 2011, Pittarello et al. 2017). The main difference between these two groups was related to the proportion of calcicole species, i.e., species having the phytosociological optimum in the *Elyno-Seslerietea* class. I conclude that there should be special attention paid to Nardus grasslands on calcareous bedrock when it comes to conservation of this habitat type.

Figure 23: Gentiana nivalis, Gentianella rhaetica on calcareous bedrock. Photo: R. Dörner (2023).

Halting the succession of dwarf shrubs

With insufficient grazing, succession processes such as the predominance of dwarf shrubs occur, which may significantly decrease the habitat's pasturing value. Below the tree line, *Rhododendron ferrugineum* often invades, together with Juniperus *communis*, *Calluna vulgaris, Vaccinium mytillus, Vaccinium vitis-idea* and *Vaccinium gaultherioides.* Alpine and boreal heaths were found especially on steep slopes. The Nardus grassland subgroup N4 describes pastures that are under the most threat of succession. Interestingly subgroup N4 also had a relatively high biodiversity and high number of endangered species. Kuussaari et al. (2009) describe how local extinction of species can occur with a substantial delay following habitat loss or degradation, such extinction debts pose a significant but often unrecognized challenge for biodiversity conservation. This phenomenon that can easily remain unnoticed but that should be considered in conservation planning, because as long as a species persists, there is time for conservation measures such as habitat restoration and landscape management.

In this case, the threats can be connected to the grazing animals. Studies have shown, that the consequence of cattle grazing alters the botanical composition of the pastures, resulting in the encroachment by non-pastoral herbaceous species, followed by shrubs giving an homogeneous land cover not suitable for grazing anymore (Lombardi 2005). Measures required to halt the succession could include grazing with small livestock like sheep and/or goats. During the interviews, the shepherds suggest, that there is an order of herding that is especially effective: sheep would be used in the beginning of the season, followed by cows and then finally horses, concluding that “diversity is possible, but diversity in plants also needs diversity in animals”. The history of the Defereggen valley shows, that sheep breeding may have played at least as important a role as cattle farming, because they were largely being used for wool production (Agrargemeinschaft Jagdhausalm 2023). Figure 24 shows an example from the valley, where one farmer herds goats to reduce dwarf shrubs. In the alpine regions, herding of sheep and goats is mostly done in areas where cattle production is not possible like steep slopes, or is not profitable anymore. Until recent times rearing small ruminants has been considered as a marginal activity. When pastures are encroached by more palatable woody species and small branches, these could become part of the diet of sheep and goats. Consequently, the possibility of controlling the invasion depends on the reaction of plants to disturbance (Lombardi 2005).

Animals potentially impair shrubs in two ways: (a) By visiting the stands, animals damage branches and seedlings and thereby thin the thickets via trampling. This is a function of body weight, which is largest for cattle. However, cattle may be too large to enter the densest stands and to visit the steepest slopes. Sheep and goats are therefore better able to penetrate the thicket. (b) More efficiently, woody plant species are damaged by debarking. If the bark of a branch is stripped all around, it dies off due to the interruption of water and nutrient transport. Sheep and goats bite off fodder using lips and teeth, whereas cattle rip off the grass mainly using the tongue (Pauler et al. 2022). The rotational grazing with animals fenced inside paddocks 24 hours also has many advantages, but unfortunately, the cost of fence installation in wide areas would exceed the salary of shepherds, moreover, the installation would be complicated by unfavourable land morphology. On the other hand, an experienced shepherd drives the flock and regulates the intensity of grazing (Lombardi 2005).

Figure 24: Goats in the Defereggen valley eating dwarf shrubs. Photo: R. Dörner (2023).

Reducing weed overgrowth on nutrient rich sites

An indicator for pastures with high nutrient values are weeds like *Rumex alpinus, Veratrum album, Deschampsia cepitosa* and *Cirsium spinosissimum.* Especially at lower altitude *Deschampsia cespitosa* is considered a big problem. The shepards confirmed continued attempts to dig out whole plants, but there are "simply too many". Wilhalm & Platzgummer (2023) describe, that *Deschampsia cespitosa* is an indicator for underutilized pastures, because the more feed is offered, the more selectively the cattle can graze and the consequences are often weed infestations (Aigner 2016). The field surveys shows that the habitats classified as Deschampsio cespitosa-Poetum alpinae are all below 2000 m a.s.l., primarily on low slopes with a cover of *Deschampsia cespitosa* of at least 50 %. Figure 25 shows an image of a site with very low slope and resting cattle and untouched stands of *Deschampsia cespitosa*. Of all subgroups, N3 would fall in danger of this trend.

Species richness of alpine pastures offers innumerable opportunities for grazing ruminants to select plant species. Pauler et al. (2020) showed, how plants with defence mechanisms (e.g., thistles) are generally avoided, concluding that forage selection by grazing cattle depends on plant traits and is a major driver of plant diversity. Selective feeding therefore may be an important driver determining the abundance of eutrophic species and dividing pastures into smaller parts by fences might be a helpful approach preventing patchy eutrophication. An alternative to fences is to increase the number of livestock per area and simultaneously decrease the time span of grazing (Rieder 2017), because a higher stocking rate is assumed to lower forage selectivity. However, Pauler et al. (2022) indicate that cattle have a more defined niche of herbaceous fodder, whereas the foraging behaviour of sheep is more opportunistic. This concurs with Sanon et al. (2007) who found that, if less herbaceous fodder was available, sheep and goats increased browsing time, whereas cattle replaced grazing by resting. This has important management implications: a higher grazing pressure could raise welfare issues for cattle, while goats and sheep have a broader spectrum of potential forage (Pauler et al. 2022).

Figure 25: Selective grazing when Deschampsia cespitosa is present. Photo: R. Dörner (2023).

Reducing Nardus stricta overgrowth at high altitudes

As altitude increases, the degradation of organic material slows down due to lower temperatures. This leads to an enrichment of raw humus and the release of humic acids and consequently in acidification of the topsoil. Grasses such as *Nardus stricta* find ideal growth conditions (Aigner 2016). The relevés show, that at higher altitudes above 2200 m a.s.l, *Nardus stricta* is the predominant grass (Figure 26). When grazing intensity decreases, a dense layer of litter forms and through negative selection, *Nardus stricta* can spread and become dominant. Furthermore, the shepherds mention, that towards the end of the season there „is not enough food for the animals “. They go on to confirm that some pastures are “basically a monoculture of *Nardus stricta*” with a couple of rare indicator species in between (e.g., *Arnica montana*). These patterns of encroachment with *Nardus stricta* can be seen in the subgroups N5. Potential measures could be that Nardus grasslands are grazed as early as possible, because when still young, even less digestible plants are eaten by livestock (Aigner 2016). The shepherds explained, that normally the first day of season this year was "relatively early" starting at the 12th of June and already the grasses were "very long". Rieder (2017) identified potential drivers of the ongoing degradation of Nardus grasslands and the observed degradation processes towards dominance of *Nardus stricta* was mainly influenced by the number of grazing periods and exposition. Specifically, pastures experiencing one single grazing period yearly had higher *Nardus stricta* cover. In pastures with many grazing days on a wide area, selective feeding by livestock is presumably high because livestock prefer feeding on plants with high nutrient content and simultaneously, they can avoid eating unpalatable species like *Nardus stricta*. Spatial heterogeneous grazing pressure consequently is necessary to reverse this. Bovolenta et al. (2008) describe, how grazing later in the year enforces the dominance of *Nardus stricta* because its nutrient levels strongly decrease during the season and it is barley eaten by livestock anymore. Lombardi (2005) conclude, that the action of grazing goats and sheep over encroaching vegetation may contribute to stop the succession to recover pastoral vegetation.

Figure 26: Grass encroachment with Nardus stricta at a high pasture. Photo: R. Dörner (2023).

Looking at long term studies, Korzeniak (2016) considered the differences between the floristic composition of past and contemporary Nardus grasslands and indicates that the duration of land use abandonment is strongly correlated with (1) the withdrawal of alpine, light-demanding species, and (2) those associated with nutrient-poor Nardus swards. Some of the species that disappear from semi-natural grasslands in early stages of succession after grazing management has ceased are e.g., *Antennaria dioica* and *Botrychium lunaria.* I can support these findings, because the very extensive relevés I mapped, do not have any of these species anymore.

4.2 Limitations and how they have affected the results

This chapter acknowledges the limitations of this study, such as constraints in data collection and methodology. First, the scale of Braun-Blanquet (1964) is often criticized for the subjectivity when selecting study sites, e.g., flowering species are often given greater weight (Tremp 2005). Using this method for field work means, that the results cannot be projected onto the whole study area and statements cannot be generalized. However, considering the problems in classification of Nardus grasslands via remote sensing as described by Hoffert (2006), this subjective approach is the best choice, because it greatly reduces the survey effort.

It is difficult to determine biodiversity in a large area since a constructed statistical mean does not correspond to reality. Indices like the SWI can lead to a significant loss of important ecological information. Furthermore, the indicator values of Ellenberg et al. (1992) do not consider that ecological behavior can vary regionally over large distances. No two plant species have completely the same location requirements and that is why the conclusion from vegetation characteristics to site properties can be problematic. Plants under competitive conditions do not reflect their physiological site preference (Tremp 2005). Furthermore, a gradient analysis can provide insights into causal relationships between vegetation and location, but the ecological behavior of the plant can never be explained by individual gradients (Dierschke 1994). Similar criticism applies to using the Red List of Species, because the number of species can give an incomplete picture. Certain species are in danger of disappearing in East Tyrol, even if they may still reach high numbers of individuals elsewhere (Tappeiner et al. 2020). For example, *Antennaria dioica* is currently not at risk due to its wide distribution and its frequent occurrence in the high altitudes of the Alps. However, there have been severe population losses in the lowlands, meaning that the species is highly endangered there. This is similar for species such as *Arnica montana* or *Ajuga pyramidalis*. Without appropriate measures, a further decline in all of these species, including regional extinction outside the Alps, can be expected (Pagitz et al. 2023).

Conclusion

To recap, the most significant parameter for biodiversity is soil pH. Even though the European Habitat Directive defines as ‘species-rich’ the communities on siliceous substrates, I highlight that the communities on calcareous bedrock, host a higher plant diversity (cf. Lüth et al. (2011), Pittarello et al. (2017)). The level of nutrients as well as the land use intensity are likewise significant indicators. Especially the results of the subgroup analysis show, that the insufficient use of pastures is the decisive factor for low diversity of Nardus grasslands, because it leads to the succession of dwarf shrubs like *Rhododendron ferrugineum*, grass encroachment with *Nardus stricta* and spread of weeds like *Deschampsia cespitosa*. The overall best conservation status is found on moderately extensively to moderately intensively managed pastures. This leads to the second conclusion, that the focus of conservation should be especially on sites with the conservation status of ‘B’, as they are in the most danger of transferring to a status of ‘C’, which was proven to have significant loss of biodiversity and protected species. The literature review, statistical analysis as well as the interviews supported the fact that Nardus grasslands can only be maintained through regular grazing. Selective grazing is a major driver of plant diversity and that is why, good grazing concepts are crucial for maintaining good pasture quality. There is an increasing interest from shepherds in small ruminants to halt the succession. However, only where profits are produced can grazing systems still exist, which makes funding programs and government initiatives to compensate for the lack of profitability a decisive factors for the conservation of this habitat type (ARGE Basiserhebung 2012a). As Chemini & Rizzoli (2003) say, the maintenance of cultural landscapes and their biodiversity depends on keeping humans in the mountains. Future research could yield valuable insights by expanding the scope to include pastures grazed by goats and comparing those findings to the results in this study. Moreover, it would be advantageous to broaden the scope of interviews beyond just shepherds to also include farmers, as they play a vital role in determining the choice of animals brought to the summer pastures. Additionally, it appears essential to investigate reasons behind the absence of small livestock herding practices. Understanding the factors preventing the adoption of small livestock herding could hold the key to biodiversity of Nardus grasslands not only in the Defereggen valley but in similar regions where these valuable grasslands persist.

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Popular science summary

The landscapes of the Alps are known for their astonishing tapestry of biodiversity, woven into the interaction between nature and traditional land-use practices. This study talks about the endangered species rich Nardus grasslands, a priority habitat still existing in the subalpine pastures of Austria's Defereggen valley, nestled in the Hohe Tauern National Parks outer zone.

The aim of this thesis was to study the nowadays rare grasslands and find out how management and environmental factors affect their biodiversity. Ultimately, I aim to find the key measures to strengthen or maintain high levels of biodiversity. The methods included remote sensing to find study sites, followed by field surveys based on the Braun-Blanquet approach for vascular plants and interviews with shepherds on farming practices and their impact on biodiversity. Biodiversity assessment involved many indicators to represent biodiversity like the Shannon Wiener Index and the Ellenberg indicator values to assess the ecological requirements and preferences of plant species. I examined these parameters to reveal the most important forces that change species composition. Analysis showed strong and statistically significant correlations between biodiversity and soil pH, bedrock type, nitrogen, and land use intensity. Furthermore, I found, all grasslands were of the association Sieversio-Nardetum strictae, the most common type of Nardus grasslands in this region of the alps. Surprisingly, higher pH led to greater diversity, challenging the existing norms for this habitat type. The most diverse areas had moderate land use intensity and moderate nutrient values. To maintain Nardus grasslands, my recommendation is a holistic management with controlled and early grazing to control shrub and weed growth. Small ruminants for grazing offer a promising future for biodiversity conservation and find growing interest among shepherds and the wider scientific community.

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Appendix 1: Full list of all endangered and protected species in all Nardus grasslands

The information in table 16 should be understood as follows:

Table 15: Legend for the Red List of species (Schratt-Ehrendorfer et al. 2022).

Abbreviation	Definition
CR	Critically Endangered
EN	Endangered
VU	Vulnerable
(L)	Lowland only
(M)	Montane only

Table 16: All protected, regionally and locally endangered species in the assessed Nardus Grasslands.

Species	Protected	Regionally Endangered	Locally endangered
Acinos alpinus		x	
Aconitum napellus	x		
Aconitum lycoctonum subsp. vulparis	x		
Aconitum tauricum	x		
Ajuga pyramidalis			VU (L)
Anemone baldensis	x		
Antennaria dioica		x	EN (L)
Anthoxanthum alpinum		x	
Anthyllis vulneraria		x	
Arnica montana	x	x	EN (M)
Aster alpinus	x		
Aster bellidiastrum		x	
Astralagus alpinus	x		
Blymus compressus		x	
Biscutella laevigata		x	
Botrychium lunaria	x	x	CR (L)
Briza media		x	
Calluna vulgaris		x	
Campanula cespitosa		x	
Carex davaliana		x	
Carex echinata		x	
Carex flava		x	
Carex leporina		x	
Carex norvegica			VU
Carex pilulifera		x	
Carex pulicaris		x	VU
Carlina acaulis		x	
Carum carvi		x	
Centaurium erythraea		x	
Ceologlossum viride		x	

Cerastium arvense		x	
Crepis conyzifolia		x	
Crocus albiflorus		x	
Dianthus deltoides		x	
Diphasiatrum alpinum		x	
Equisetum palustre		x	
Euphrasia officinalis subsp. Rostkoviana		x	
Euphrasia stricta		x	
Festuca nigrescens		x	
Galium anisophyllon		x	
Galium pumilum		x	
Galium uliginosum		x	
Gentiana acaulis	x		
Gentiana asclepiadea	x	x	
Gentiana bavarica	x		
Gentiana nivalis	x		
Gentiana punctata	x		
Gentiana verna	x	x	CR (L)
Gentianella germanica	x		
Gentianella rhaetica	x	x	CR (L)
Geranium sylvaticum		x	
Globularia cardifolia		x	
Gnaphalium norvegicum		x	
Gymnadenia conopsea	x	x	VU (L)
Hieracium lactucella		x	
Hieracium piloselloides		x	
Homogyne alpina		x	
Huperzia selgao		x	
Juncus alpinoarticulatus		x	
Luzula multiflora			VU (L)
Melampyrum sylvaticum		x	
Parnassia palustris		x	
Nardus stricta		x	VU (L)
Phleum alpinum		x	
Poa alpina		x	
Potentilla erecta		x	
Primula elatior	x	x	VU
Primula minima	x		
Pseudorchis albida	x	x	
Pulsatilla alpina	x		
Pulsatilla alpina subsp. Alpina	x		
Pulsatilla alpina subsp. Austriaca	x		
Pulsatilla vernalis	x		CR (L)
Pyrola minor		x	
Rhinantus glacialis		x	
Rhododendron hirsutum		x	
Rumex acetosa		x	
Rumex alpestris		x	
Saxifraga aizoides	x		
Saxifraga crustata	x		
Saxifrage rotundifolia	x	x	
Selaginella selaginoides			
Sempervivum montanum	x		
Sempervivum tectorum ssp. Alpinum	x		
Seseli libanotis		x	
Silene dioica		x	
Silene acaulis	x		
Thesium alpinum		x	
Thymus praecox ssp. Polytrichus		x	
Thymus pulegioides		x	
Tofielda calyculata		x	
Trollis europaeus		x	VU (L)
Vaccicium vitis-idea		x	
Vaccinium myrtillus		x	
Veratrum album		x	
Veronica officinalis		x	
Total number	29	69	14

Appendix 2: Indicators for assessing the Conservation Status of Nardus grasslands according to the Habitats Directive

Table 17: Indicator set for assessing the conservation status.

	Structure &function	A	B	C
1	Typical structure	**Complete:** Typical structures completely present; Low, open grasslands composed of species with weak competition, litter cover largely missing	**Partially:** Predominantly low, moderately closed lawns made up of predominantly low-competitive species; dwarf shrubs in small areas; slight litter cover	**Fragmented:** Closed lawns with taller species; Species-poor, mainly consisting of dwarf shrubs on larger areas, thick litter cover
2	Characteristic species	**Species rich** >= 12 Characteristic species	**Moderatly rich** >= 6 and < 11 Characteristic species	**Species poor** < 6 Characteristic species
3	Indicators of disturbance (nutrient indicators, neophytes)	<= 5%	> 5% and <= 20%	> 20%
4	Shrub layer	<= 10%	> 10% and <= 30%	> 30%
5	Direct disturbance	Not detectable or without damage <= 5%	Clearly visible > 5% and <= 20%	Significant > 20%
6	Hydrology	Site not drained	Site poorly drained	Site heavily drained

Appendix 3: Questionnaire for Shepherds

Questionnaire for Shepherds

Name of Alm

Number of shepherds

Type of Alm (Suckler cows, mother cows, cattle, sheep…)

Type of pasture management (open pasture, fenced…)

Start and end date of season.
Did these dates change?

Do animals get additional food?

Are any areas fertilized?

How did the management look like in the past and what changed since you are here?

What is biodiversity for you and how would you describe biodiversity in the Deferrenvalley compared to place you have worked previously?

What kind of management in your opinion hast to be applied to achieve the best biodiversity?

What specific plants are a problem for you and the animals?

How do you perceive the problem of the succession of dwarf shrubs?

How do you see the future of the Alm?

Appendix 4: Paper for collecting field surveys.

Datum:	Aufnahmenummer:
HOF	

NUTZUNGSEINHEIT	**AUFNAHMEFLÄCHE**	Blühaspekt:
Lage zum Hof:	Größe (m x m):	
Geomorphologie:	Kontakt:	
	Mittelrelief:	Farbaspekt:
Homogenität:	Kleinrelief:	Wüchsigkeit:
		Gräser : Kräuter (%):
	Seehöhe (m):	Dichte der Grasnarbe:
Skizze/Schnitt:	EXP+Neigung (%):	Veg.deckung (%):
		Schichthöhen (cm):
		Bewirtschaftung:

ARTEN

FFH-EHZ

Artenzahl (inkl. Moose):

r	rar (1-3 Individuen) und mit sehr geringer Deckung	
+	spärlich (3-10 Individuen) mit sehr geringer Deckung	
1	reichlich mit geringer Deckung oder spärlich mit höherer Deckung (z.B. Ampfer)	
2m	sehr reichlich, aber unter 5% Deckung	
2a	5-12,5%	1/20 bis 1/8 der Fläche deckend
2b	12,5-25%,	1/8 bis 1/4 der Fläche deckend
3	25-50%	1/4 bis 1/2 der Fläche deckend
4	50-75%	1/2 bis 3/4 der Fläche deckend
5	>75%	mehr als 3/4 der Fläche deckend

Lage zum Hof: hofnah, hoffern, hofferne Pachtfläche
Geomorphologie: Oberhang, Mittelhang, Unterhang, Kuppe, Graben, Rücken, …
Mittelrelief: konkav, konvex, wellig, intermediär
Kleinrelief: buckelig, plan, Felsausbisse, …
Wüchsigkeit: extrem mager, mager, mäßig fett, fett, sehr fett, mastig, extrem mastig
Gräser : Kräuter = relative Masseanteile (ausgewogen = 70:30)
Grasnarbendichte: sehr lückig, lückig, mäßig dicht, dicht, sehr dicht
Schichthöhen: von-bis, Angabe der wichtigsten Schichtbildner, Stärke der Schicht durch unterstreichen (einfach, doppelt) ersichtlich machen (schwach: einklammern)
Bewirtschaftung: Mahdhäufigkeit, Düngung, Heu/Silage, Alter der Wiese, …

Appendix 5: Data protection sheet for interviews

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Data collection for Master Thesis of:
Rebecca Paulina Dörner
+43 681 8144 456 39
Doernerrebeccapaulina@gmail.com

SLU ID: 19940208-T906

Information to data subjects about the processing of personal data at SLU for interviews within an independent project master's thesis

Data controller

The Swedish University of Agricultural Sciences (SLU) is the data controller for the processing of your personal data. Your contact for this processing is: Rebecca Paulina Dörner (Student).

The data protection officer at SLU can be reached at dataskydd@slu.se or by phone at 018-67 20 90.

Purpose

In order to conduct the research for a Master's Thesis, we need to collect personal data from the farmers of alpine mountain pastures in a designated study area. In this study we want to investigate the influence of local management practices and environmental variables on the biodiversity of species-rich Nardus grasslands in the Defereggen Valley, East Tyrol Austria. The purpose of the study is to create an understanding for and improve the active conservation and management of this habitat type.

The data will be collected for the following purposes:

- To analyse the interviews as part of a qualitative method and mixed methods analysis to inform the results and discussion for an MSc thesis.
- The summary of key findings and themes will be provided to community groups interested in the research project and presented in any relevant community discussions. All the findings will be anonymised and not directly related to you as an individual.
- Following the completion of research and analysis, third parties may request the data to inform further research in the spirit of open science. The data will only be shared if the third party continues the research to benefit community needs. The data shared will be anonymised and therefore cannot be connected to you as an individual.'

Mailing address: doernerrebeccapaulina@gmail.com
Phone: +43 861 814 456 39
Street address: Messerschmidtgasse 29, Top2, 1180 Wien
www.slu.se

SLU will also process your personal data as required for SLU to comply with regulations on public documents and the archives of public authorities.

Legal basis

The legal basis is consent.

The principle of public access to information

As a public authority, SLU must apply the principle of public access to official documents. This means that all official documents, including personal data, that are not considered working material are public and can be released to anyone who requests them. However, if a document contains data that is subject to confidentiality, the document will not be released.

Transfer of personal data

The data is part of a shared independent research project between BOKU University in Vienna and SLU in Uppsala.

Storing data

Your personal data will also be stored for as long as required by the Public Access to Information Act and the regulations on the archives of public authorities.

Your rights

You have the right, under certain circumstances, to have your personal data erased, corrected, or limited. You also have the right of access to the personal data being processed, and you have the right to object to the processing of your data. To exert your rights, contact dataskydd@slu.se.

Withdrawing your consent

If SLU's processing of your personal data is based on consent, you have the right to withdraw this consent.

Comments

If you have any comments on the processing of personal data at SLU, contact dataskydd@slu.se, 018-67 20 90.

If you are not happy with the answer provided by SLU, you can take your complaint to the Swedish Authority for Privacy Protection, imy@imy.se or 08-657 61 00.

Read more about the Swedish Authority for Privacy Protection at https://www.imy.se/other-lang/

Name: *Date:*

Mailing address: doernerrebeccapaulina@gmail.com Phone: +43 861 814 456 39
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Appendix 6: The percentage synoptic table of all Nardus grassland subgroups

Table 18: The percentage Synoptic table of all five Nardus Grasslands subgroups (N1, N2, N3, N4, N5) calculated by JUICE to find characteristic indicator species. Values are the relative frequencies os species in a certain subgroup. E.g., Trifolium badium occurs in nive out of 14 relevés in subgroup N1. 14 divided by nine is 0.64, which means this species has a relative frequency of 64.

Species name	**Rel. Frequency (%)**				
	Name of groups				
	N1	**N2**	**N3**	**N4**	**N5**
	No. of relevés				
	14	34	6	16	5
	Total No. of species				
	139	126	78	122	45
Nardus grasslands N0					
Trifolium badium	**64**	0	0	6	0
Bartsia alpina	**50**	9	0	6	0
Soldanella alpina	**43**	0	0	0	0
Selaginella selaginoides	**43**	6	17	0	0
Salix waldsteiniana	**36**	0	16	0	0
Cirsium spinosissimum	**36**	0	16	0	0
Gentiana nivalis	**36**	0	0	0	0
Salix reticulata	**29**	0	0	0	0
Parnassia palustris	**29**	0	0	0	0
Rhinanthus glacialis	**29**	3	0	13	0
Geranium sylvaticum	**21**	0	0	0	0
Aconitum lycoctonum subsp. vulparia	**21**	0	0	0	0
Kobresia myosuroides	**21**	0	0	0	0
Helianthemum nummularium aggr.	**21**	0	0	6	0
Silene acaulis s.l.	**21**	3	0	0	0
Tofieldia calyculata	**21**	0	0	6	0
Anthyllis vulneraria	**21**	0	0	6	0
Nardus grasslands N1					
Trifolium repens	21	**68**	0	0	0
Luzula luzuloides	7	**32**	0	13	0
Phyteuma betonicifolium	7	**44**	0	13	20
Pinus cembra	0	24	0	0	0
Hieracium murorum	0	24	0	0	0
Phleum pratense	0	12	0	0	0
Taraxacum sp.	0	12	0	0	0
Euphrasia officinalis	0	15	0	0	0
Carex flava	0	21	0	0	0
Nigritella rhellicani	0	12	0	0	0
Carex pallescens	7	12	0	6	0
Aster alpinus	7	12	0	6	0
Achillea moschata	0	18	0	0	0
Nardus grasslands N3					
Juncus alpinoarticulatus	7	0	**50**	0	0
Sibbaldia procumbens	0	0	**50**	0	0
Veratrum album	14	12	**50**	0	0
Pyrola minor	0	0	**33**	0	0
Nardus grasslands N4					
Loiseleuria procumbens	7	0	17	**50**	0
Diphasiastrum alpinum	0	0	0	**31**	0
Nardus grassland N5					
Hypochaeris uniflora	7	3	0	6	**40**
Juncus jacquinii	7	0	0	0	**20**
Pseudorchis albida	0	3	0	13	**20**
Common species of all groups					
Botrychium lunaria	36	18	0	6	0
Campanula scheuchzeri	**100**	**74**	**67**	**63**	**20**
Geum montanum	**93**	**76**	**83**	**94**	**60**
Potentilla aurea	**93**	**91**	**83**	**88**	**100**
Festuca rubra	**93**	**91**	**50**	**88**	**80**
Nardus stricta	**86**	**88**	**100**	**100**	**100**
Homogyne alpina	**86**	**56**	**67**	**63**	40
Ranunculus acris	**79**	**79**	17	13	20
Leontodon hispidus subsp. hispidus	**79**	**54**	**83**	**56**	20
Anthoxanthum alpinum	**71**	**85**	**50**	**100**	**100**

Rhododendron ferrugineum	**64**	29	**83**	**69**	**20**
Avenella flexuosa	**64**	**71**	**50**	**75**	**80**
Poa alpina	**64**	**53**	**100**	**50**	**80**
Achillea millefolium	**57**	**82**	17	13	**40**
Galium anisophyllon	**57**	21	17	19	20
Leontodon helveticus	**50**	47	**100**	**56**	**60**
Luzula alpina	**43**	**53**	**50**	**69**	**40**
Pulsatilla alpina subsp. austroalpina	**43**	12	**50**	**50**	**60**
Silene vulgaris	**43**	32	33	13	**40**
Phleum alpinum aggr.	**43**	15	17	13	20
Vaccinium gaultherioides	36	44	**67**	**50**	40
Arnica montana	36	**74**	**50**	**63**	**60**
Gentiana acaulis	36	**44**	33	**75**	**40**
Alchemilla vulgaris aggr.	**100**	**59**	**67**	25	0
Deschampsia cespitosa	**86**	47	**83**	6	0
Persicaria vivipara	**79**	29	33	50	0
Lotus corniculatus	**57**	**76**	**50**	31	0
Ranunculus montanus	**43**	32	17	25	0
Agrostis capillaris	**43**	**53**	17	19	0
Trifolium pratense subsp. nivale	**43**	35	17	13	0
Thymus pulegioides	**43**	**50**	0	19	0
Myosotis alpestris	**43**	**32**	0	19	0
Thesium alpinum	29	26	17	38	20
Festuca ovina	29	**35**	17	25	20
Phleum rhaeticum	29	53	**50**	25	40
Juniperus communis subsp. nana	21	**58**	**50**	**88**	20
Phyteuma hemisphaericum	21	53	33	**50**	20
Vaccinium myrtillus	21	35	**67**	**56**	**40**
Solidago virgaurea subsp. minuta	14	12	33	19	20
Potentilla erecta	14	62	**50**	**63**	20
Luzula multiflora s.l.	14	**57**	33	**56**	**60**
Trifolium pratense	29	**26**	33	0	20
Avenula versicolor	29	3	17	**50**	20
Calluna vulgaris	**43**	23	0	**75**	**40**
Vaccinium vitis-idaea	21	**65**	0	**63**	**40**
Euphrasia officinalis subsp. rostkoviana	43	3	50	**75**	20
Gentiana punctata	7	0	17	25	20
Pedicularis recutita	7	2	0	31	20
Carex sempervirens	0	12	17	**50**	**60**
Antennaria dioica	0	**35**	0	25	20
Pulsatilla alpina subsp. alpina s.s.	36	10	33	25	0

Crepis aurea	36	12	17	6	0
Campanula barbata	36	47	**67**	**63**	0
Trifolium hybridum	36	18	17	31	0
Viola biflora	21	**19**	17	13	0
Agrostis rupestris	21	19	17	6	0
Leontodon hispidus subsp. pseudocrispus	14	22	17	13	0
Primula minima	29	**24**	33	44	0
Galium pumilum	7	12	17	6	0
Hieracium lactucella	0	41	17	31	0
Carlina acaulis	36	44	0	6	0
Ligusticum mutellina	36	2	33	13	0
Cerastium fontanum	29	25	33	0	0
Oxytropis campestris	21	5	17	13	0
Aconitum napellus aggr.	21	10	0	0	0
Euphrasia minima	21	0	33	13	0
Veronica serpyllifolia subsp. serpyllifolia	21	10	17	0	0
Carex echinata	7	0	17	0	0
Sempervivum tectorum	0	**9**	0	6	0
Gentianella germanica aggr.	0	**6**	0	0	0
Ajuga pyramidalis	7	21	17	0	0
Pulsatilla vernalis	7	21	0	31	0
Ranunculus nemorosus	0	15	0	0	0
Rubus idaeus	0	12	0	0	0
Veronica serpyllifolia subsp. humifusa	7	12	0	6	0
Hieracium pilosella	7	**65**	0	38	0
Peucedanum ostruthium	14	12	0	13	0
Prunella vulgaris	7	30	0	6	0
Veronica bellidioides	7	31	0	**44**	0
Gentiana verna	21	18	0	6	0
Juncus trifidus	7	12	0	25	0
Arctostaphylos uva-ursi	0	8	0	19	0
Cirsium acaule	0	8	17	6	0
Gymnadenia conopsea	0	8	0	13	0
Salix herbacea	**64**	0	**50**	13	0
Gentianella rhaetica	29	0	0	19	0
Huperzia selago	21	0	17	25	0
Cerastium cerastoides	0	15	0	6	0
Carex leporina	0	0	17	13	0
Thalictrum minus aggr.	0	0	17	6	0
Carex atrata	14	0	17	6	0

Species with less than 15 % in any of the six subassociations:

Carex ferruginea, Euphrasia alpina, Rhododendron hirsutum, Carduus defloratus subsp. Crassifolius, Carex nigra, Carduus defloratus subsp. viridis, Alnus alnobetula, Briza media, Hieracium alpinum, Seseli libanotis, Silene nutans subsp. Nutans, Sempervivum montanum,Cerastium alpinum s.l., Gnaphalium sylvaticum, Festuca nigrescens, Rumes acteosa, Hieracium pilosum, Salix helvetica, Valeriana sp., Thymus praecox subsp. Polytrichus, Saxifraga aizoides, Scorzonera sp., Equisetum palustre, Carex pulicaris, Acinos alpinus, Globularia cardifolia, Luzula spicata, Phyteuma ovatum, Blysmus compressus, Sayxifraga crostata, Carex davalliana, Hieracium glaciale, Oxalis acetosella, Melamphyrum sylvaticum, Gnaphalium norvegicum, Chaerophyllum villarsii, Dianthus deltoides, Ranunculus alpestris, Primula elatior, Lotus cornicultaus var. alpicola, Galium uliginosum, Plantago major subsp. Intermedia, Hieracium piloselloides, Maianthemum bifolium, Crepis conyzifolia, Gymnocarpium Dryopteris, Carduus defloratus subsp. Tridenitus, Carum carvi, Crocus albiflours, Minuartia recurve, Carex pilulifera, Saxifraga rotundifolia, Myosotis arvensis, Carex norvegica, Veronica chamaedrys, Centaurium erythraea, Desmatodon cernuss, Campanula cespitosa, Eleocharis quinqueflora, Dryopteris filix-mas, Anthoxanthum odoratum, Thlaspi sp., Aster bellidiastrum, Trollis europaeus, Leucanthemopsis alpina, Viscutella laevigata, Gypsophila repens, Aconitum tauricum, Silene dioica, Veronica officinalis, Rumex alpestris, Ceratsium arvense, Polygala alpestris, Gentiana bavarica.

Appendix 7: Complete table of plant species

The following table shows a complete list of all plant species found on the study sites and their abundance measured according to the Braun-Blanquet scale (r, +, 1, 2a, 2m, 2b, 3, 4, 5) and (v) for species besides the 25 m^2 plot. The header data stores all the information gathered in the field and calculated afterwards like altitude (m a.s.l), slope (%), LUI, shrub cover (%) or SWI. All relevés are classified and separated horizontally by dotted lines according to their habitat type and Nardus grassland subgroups. Species, found in similar groups of relevés or with similar indicator values for e.g., moisture or calcareous tolerance were colored and organized in groups, so they table could be interpreted more easily. Due to its size, the complete plant species table is split into three parts.

Part one

Nardus Grasslands 6230																											
Nardus Subgroups						N0																					
Alpine and boreal heats 4060																											
Alpine and subalpine calcareous grasslands 6170																											
Siliceous alpine and boreal grasslandss 6150																											
Rich meadows																											
Pioneervegetation at riverside																											
No. In field				15.5	10.4	14.6	10.1	10.2	1.2	13.5	10.6	11.5	10.3	13.2	11.4	13.6	15.2	1.1	13.1	11.2	15.3	10.7	10.5	11.3	11.1	15.6	15.4
Altitude				2064	2030	2383	2038	2036	1995	2327	2050	2034	2029	2153	2045	2358	2189	2200	2128	2014	2223	2020	2044	2054	2011	2074	2238
Aspect				S	NE	S	NW	NW	NO	S	W	E	N	S	E	SW	NE	SE	SW	SE	E	W	NW	E	S	S	E
Slope (%)				10	30	25	20	25	25	25	50	60	15	30	35	40	20	35	30	50	25	45	50	40	50	45	15
Yield (dt/ha/year)				15	1	20	10	5	30	12	15	10	5	12	10	18	20	15	20	8	15	5	5	10	15	10	20
Land use intensity				3	1	2	2	3	4	3	3	2	3	3	3	3	4	4	4	2	4	3	2	4	4	3	4
Herbacous cover (%)				90	40	95	90	85	75	85	85	75	85	80	70	85	85	95	85	30	95	85	90	80	98	90	90
Shrub cover (%)				8	10	0	2	0	5	0	15	25	5	20	25	2	6	1	15	60	0	5	0	0	0	3	0
Rock cover (%)				0	50	0	10	20	25	5	15	5	10	10	0	2	1	k.a	1	5	2	20	20	25	1	3	20
Geology				M	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	M	M	A	A	A	M	M	M
Reg. Endangered species				12	9	8	11	11	17	13	14	15	10	17	14	9	17	18	13	19	12	13	14	15	15	11	8
Loc. Endangered species				2	0	2	2	1	5	4	1	5	1	5	3	2	2	2	5	3	3	1	2	3	3	1	1
Protected species				2	6	4	4	3	6	9	6	5	3	6	4	5	7	6	8	6	7	8	8	8	6	3	1
Conservation status						B	B	B	A	B	B	B	B	B	B	B	B	A	A								
Ellenberg Moisture				6.7	5.2	5.3	5.6	5.5	5.7	5.1	5.5	5.5	5.6	5.2	5.6	5.3	5.4	5.3	5.5	4.5	4.5	5.6	4.8	4.8	4.6	5	4.5
Ellenberg Reaction				5	6.7	5	4.1	5.1	4.6	5.9	5.3	3.7	4.3	4.7	4.3	4.7	5	4.9	5	6.5	6	5.7	5.9	5.9	6.6	5.9	5.8
Ellenberg Nutrients				3.1	3.7	3.3	2.6	3.3	2.8	3	3.3	2.7	3.2	2.8	3.3	2.8	3	3.1	3.6	2.9	3.2	3.1	3.2	3	3.5	3.1	3.1
Shannon-Wiener Index				2.57	3.59	3.17	2.96	3.35	3.67	3.61	3.7	3.12	3.35	3.47	3.33	3.12	3.56	3	3.46	3.37	3.09	3.57	3.47	3.43	3.56	3.17	2.6
Species richness				28	42	27	34	34	51	39	45	36	37	36	38	26	44	56	38	44	29	44	37	39	47	30	20
Species	Family	Frequency																									
Carex flava	Cyperaceae	10	Moisture	.	.	.	.	.	.	.	(v)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Equisetum palustre	Equisetaceae	2		4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex nigra	Cyperaceae	6		1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex echinata	Cyperaceae	2		.	.	.	.	.	-	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viola palustris	Violaceae	1		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Juncus alpinoarticulatus	Juncaceae	6		.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Salix hastata	Salicaceae	1	Calcerous	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix serpillifolia	Salicaceae	1	tolerant	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium uliginosum	Rubiaceae	2		.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tussilago farfara	Asteraceae	2		.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-	.	.	.	.	.
Campanula cespitosa	Campanulaceae	2		.	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Saxifraga aizoides	Saxifragaceae	7		.	+	.	.	.	-	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.
Gentiana nivalis	Gentianaceae	4		.	.	1	.	-	.	1	.	.	.	.	.	.	-	.	.	.	.	.	.	-	.	.	.
Bartisa alpina	Scrophulariaceae	18		1	.	.	.	.	+	(v)	+	.	-	.	+	.	1	+	1	1	.	+	.	.	.	1	.
Selaginella selaginoides	Selginellaceae	12		.	+	.	1	+	+	.	1	.	1	.	1	.	.	.	.	.	.	1	.	.	.	.	.
Cirsium acaule	Asteraceae	7		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.
Aconitum tauricum	Ranunculaceae	2		.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	(v)	.	.	.
Geranium sylvaticum	Geranicaceae	10		2a	.	.	.	+	.	.	+	(v)	.	.	(v)	.	.	.	2a	1	.	.	(v)	1	.	.	.
Trifolium badium	Fabaceae	19		(v)	1	1	.	+	.	2a	1	.	1	1	+	.	1	+	.	1	.	1	.	1	+	1	.
Soldanella alpina	Primulaceae	12		.	.	.	.	.	-	+	+	.	.	1	.	.	1	-	.	.	1	1	.	(v)	.	.	.
Silene acaulis	Carophyllaceae	13		.	1	.	.	.	.	1	1	.	.	.	.	.	.	+	.	.	.	1	1	(v)	.	.	.
Tofielda calyculata	Liliaceae	9		1	.	.	.	.	+	.	.	.	+	.	.	.	1	.	.	1	.	.	.	(v)	-	(v)	.
Parnassia palustris	Celastraceae	13		1	1	1	.	.	.	+	+	.	.	.	.	.	1	.	.	+	-	1	1	(v)	.	1	.
Salix reticulata	Salicaceae	8		.	.	.	.	.	.	.	1	+	.	.	.	.	1	+	.	1	.	1	.	.	.	1	.
Salix waldsteiniana	Salicaceae	10		.	1	.	.	.	.	.	1	1	.	1	1	-	.	.	.	1	.	(v)	(v)	.	.	.	.
Carex atrata	Cyperaceae	7		.	.	.	.	.	1	1	(v)	.	.	.	.	.	.	.	.	.	.	1	.	-	.	.	-
Euphrasia alpina	Orobanchaceae	6		.	.	.	.	.	.	.	.	.	.	.	2m	.	.	.	.	1	.	.	1	1	.	.	.

Thalictrum minus	Ranunculaceae	7		.	-	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	(v)	1	.	.
Anthyllis vulneraria	Fabaceae	13		1	2a	.	.	.	.	2a	.	.	.	+	.	.	2a	1	.	1	1	.	.	1	1	2a	1
Myosotis alpestris	Boraginaceae	31		.	+	1	.	+	.	.	.	1	.	+	-	.	.	.	1	.	1	.	.	1	1	.	1
Helianthemum nummularium	Cistaceae	12		.	.	.	.	.	.	1	.	(v)	.	+	.	.	1	.	.	2a	1	.	.	1	1	1	1
Astralagus alpinus	Fabaceae	7		.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	(v)	.	1	-	.	2a	2a	1	.
Thymus praecox ssp. Polytrichus	Lamiaceae	9		.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	2a	.	1	1	.	.	.
Dianthus glacialis	Carophyllaceae	2		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.
Oxytropis campestris	Fabaceae	15		.	1	.	.	.	.	1	1	.	.	.	.	.	.	.	1	1	.	1	2a	.	+	.	2a
Kobresia myosuroides	Cyperaceae	11		2a	.	.	.	.	.	1	1	.	.	.	.	2a	.	.	.	.	2a	+	2a	(v)	.	.	2b
Carex pilulifera	Cyperaceae	2	Alpine	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	.	.	.	.	.	.	.
Erica carnea	Ericaceae	1	and	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.
Rhododendron hirsutum	Ericaceae	3	boreal	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	2b	.	.	.	.	.	.	.
Biscutella laevigata	Brassicaceae	3	heats	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	1	.	.	.	.	.	.	.
Leontodon incanus	Asteraceae	1	(calcerous)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Daphne alpina	Thymelaeceae	1		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Gentiana anisodonta	Gentianaceae	1		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-	.	.	.	.	.	.	.
Globularia cardifolia	Plantagiaceae	3	Alpine	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	+	.	.
Lilium martagon	Liliaceae	2	and	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	-	.	.
Silene rupestris	Carophyllaceae	2	subalpine	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.
Dyras octopetala	Rosaceae	3	calcareous	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.
Gypsophilia repens	Carophyllaceae	4	grasslands	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	.	.	1	1	.	.	.
Aster alpina	Asteraceae	10		.	.	.	.	.	.	-	(v)	.	.	.	.	.	.	.	-	.	.	.	+	+	.	.	.
Scabiosa lucida	Caprifoliaceae	5		.	.	.	.	.	.	(v)	.	.	.	.	.	.	.	.	.	1	1	.	.	2a	2a	.	.
Carduus defloratus ssp.tridentinus	Asteraceae	4		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	(v)	.	2a	.	2b	.	.
Knuatia arvensis	Caprifoliaceae	1		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	.	.
Briza media	Poaceae	4		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	(v)	.	.	.	.	2a	.	.
Euphrasia stricta	Orobanchaceae	1		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Carduus defloratus ssp.defloratus	Asteraceae	5		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	.	.	.
Gentiana clusii	Gentianaceae	1		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Pedicularis tuberosa	Orobanchaceae	2		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.
Carduus defloratus ssp.crassifolius	Asteraceae	4		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.
Sempervivum montanum	Crassulaceae	3		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-	.	.	.	.	.	+	.	.
Saxifraga crustata	Saxifragaceae	3		.	.	.	.	.	.	(v)	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Aconitum lycoctonum ssp. Vulparia	Ranunculaceae	4		.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	(v)	(v)	(v)	.	.	.	.
Viola collina	Violaceae	1		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-	.	.	.	.
Deschampsia cespitosa	Poaceae	51	Nutrient	(v)	1	1	1	2a	1	1	1	2a	2a	(v)	1	2a	.	1	1	.	1	2a	2a	2a	.	.	.
Ranunculus acris	Ranunculaceae	58	Rich	.	-	.	1	2a	+	1	1	1	.	1	2a	.	1	-	1	.	.	1	.	.	1	.	1
Rumex acetosa	Polygalaceae	8		.	.	.	.	.	.	.	.	.	.	.	(v)	.	.	-	.	.	.	.	.	.	.	.	.
Veratrum album	Melanthiaceae	16		.	.	.	.	-	.	.	(v)	.	.	.	(v)	.	.	.	1	.	.	-	.	.	.	.	.
Phleum pratense	Poaceae	7		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Taraxacum officinale	Asteraceae	7		.	+	.	.	.	.	.	.	.	.	.	.	.	.	(v)	.	.	.	.	.	.	.	.	.
Trifolium repens	Fabaceae	30		.	.	.	.	1	1	.	.	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Phleum alpinum	Poaceae	15		.	.	.	+	1	.	1	.	.	-	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Aconitum napellus	Ranunculaceae	23		.	-	2a	(v)	-	(v)	.	.	1	.	(v)	+	.	-	(v)	.	(v)	(v)	-	(v)	+	-	.	.
Cirsium spinosissimum	Asteraceae	20		.	-	.	.	-	.	.	(v)	.	-	+	(v)	.	(v)	-	1	2a	(v)	.	1	1	.	.	.
Achillea millefolium	Asteraceae	54	Rich	.	1	1	.	.	.	.	+	1	+	1	1	.	.	+	1	(v)	.	1	+	1	1	.	.
Phleum rhaeticum	Poaceae	45	mountain	.	.	.	(v)	.	+	.	+	+	.	.	.	.	1	+	.	.	.	(v)	.	(v)	(v)	.	.
Alchemilla ssp.	Rosaceae	61	pasture	1	-	1	1	2a	2a	1	1	1	1	1	2a	1	1	2a	2a	(v)	2a	1	1	1	2a	2a	.
Rumex alpestris	Polygalaceae	9		.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trifolium pratense s. nivale	Fabaceae	31		1	1	.	1	.	+	.	1	.	1	.	.	.	2a	+	.	.	1	1	1	.	1	1	2a
Agrostis capillaris	Poaceae	30		.	.	.	.	.	+	.	.	1	.	1	+	.	.	+	1	.	.	.	.	.	.	.	.
Festuca rubra	Poaceae	78		.	+	.	2b	1	1	1	2a	2a	2a	2a	1	1	1	1	2a	.	.	1	.	2b	2a	+	.
Poa alpina	Poaceae	64		.	+	.	1	+	2a	1	.	.	+	.	1	1	1	2b	.	1	1	1	2a	2a	.	.	2b
Anthoxanthum alpinum	Poaceae	81		1	.	1	2b	.	1	.	1	.	.	1	1	1	1	2a	1	.	1	.	1	1	1	1	2a
Geum montanum	Rosaceae	83		.	.	2a	2a	1	.	1	1	2a	1	1	2a	2a	1	2a	+	.	(v)	(v)	.	.	1	.	.
Campanula scheuchzeri	Campanulaceae	81		.	.	2m	-	1	+	1	+	1	1	+	1	1	1	+	+	(v)	1	1	1	(v)	.	1	1
Potentilla aurea	Rosaceae	92		1	.	1	2a	1	1	1	1	2a	1	.	1	1	1	2a	1	.	2a	.	1	1	1	1	(v)

Ranunculus montanus	Ranunculaceae	30		.	.	1	+	1	.	.	.	.	.	1	1	.	1	.	.	.	2a	1	1	1	2a	1	2a
Leontodon hispidus ssp. Hispidus	Asteraceae	63		1	1	1	1	.	.	1	1	1	1	.	1	1	2a	+	1	1	2b	1	2a	.	2a	2a	.
Cerastium fontanum	Carophyllaceae	7		.	+	.	+	1	-	(v)	.	.	.	.	.	.	.	+	(v)	.	.	+	.	.	.	.	-
Lotus corniculatus	Fabaceae	54		(v)	.	.	1	1	1	.	1	(v)	.	+	.	.	1	2a	1	.	1	1	.	1	1	1	.
Trifolium pratense	Fabaceae	20		.	.	2a	.	.	.	.	.	.	.	.	1	1	.	.	1	.	.	.	.	.	.	.	.
Crepis aurea	Asteraceae	19		1	1	.	.	(v)	+	.	+	.	2a	.	1	.	.	1	.	.	.	.	(v)	.	.	.	.
Trifolium hybridum	Fabaceae	20		.	2a	.	1	.	.	1	.	.	.	.	1	1	.	.	2a	.	.	.	.	.	.	.	.
Polygonum viviparum	Polygalaceae	44		1	1	.	+	1	.	1	1	1	1	1	1	1	.	+	+	+	2a	1	2a	1	+	1	2b
Prunella vulgaris	Lamiaceae	15		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	(v)	.	1	-	.
Ligusticum mutellina	Apiaceae	15		1	.	-	+	1	.	.	.	.	.	.	.	.	1	+	.	.	2a	.	.	.	.	.	.
Ranunculus nemorosus	Ranunculaceae	6		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix herbacea	Salicaceae	23	Shrubs	(v)	.	.	1	+	.	1	.	.	1	1	2a	.	1	+	2a	1	(v)	.	.	1	.	1	(v)
Juniperus communis ssp. Nana	Cupressaceae	68		1	.	.	.	.	.	.	.	1	.	2a	.	.	.	+	(v)	1	(v)	.	(v)	(v)	(v)	(v)	.
Rhododendron ferrugineum	Ericaceae	64		1	+	.	.	(v)	+	.	1	2b	1	2a	2b	(v)	2a	+	2a	.	(v)	1	(v)	(v)	.	(v)	.
Calluna vulgaris	Ericaceae	49		2a	.	.	.	.	+	.	(v)	1	+	1	(v)	.	+	+	.	.	.	(v)	.	(v)	.	1	.
Vaccicium vitis-idea	Ericaceae	48		.	.	.	.	.	.	.	.	+	.	2a	.	.	.	+	.	.	.	.	.	.	.	.	.
Vaccinium gaultherioides	Ericaceae	52		1	-	.	(v)	+	+	.	.	.	1	.	1	(v)	(v)	+	.	.	.	.	.	.	.	.	.
Vaccinium myrtillus	Ericaceae	41		.	.	.	.	.	1	.	.	+	.	1	.	.	(v)	.	.	.	.	.	.	.	.	.	.
Nardus stricta	Poaceae	89	Nardus	.	.	1	3	(v)	2b	1	2a	3	2b	2a	2b	2a	2b	2a	1	.	1	2b	(v)	.	.	.	.
Arnica montana	Asteraceae	65	grasslands	1	.	.	.	.	-	.	.	1	.	(v)	1	1	.	.	+	(v)	.	.	.	.	.	.	.
Homogyne alpina	Asteraceae	68	typical	.	.	1	2a	1	+	.	2a	1	2a	1	1	1	1	1	.	.	.	.	1	1	.	.	.
Luzula multiflora	Juncaceae	49		.	.	.	.	.	2m	.	.	(v)	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Phyteuma hemisphaericum	Campanulaceae	44		.	.	.	.	.	+	.	.	.	.	.	.	-	.	.	.	.	.	.	.	.	.	.	.
Avenella flexuosa	Poaceae	69		.	.	1	1	2a	.	.	1	1	+	.	1	1	.	1	.	1	.	.	1	2a	.	.	.
Luzula alpina	Juncaceae	47		+	.	.	1	.	+	.	.	1	.	.	.	1	.	+	+	.	.	.	.	.	.	.	.
Thesium alpinum	Santalaceae	27	Nutrient	.	.	.	.	.	+	1	1	.	.	.	1	.	.	.	.	1	.	-	.	.	+	.	.
Campanula barbata	Campanulaceae	49	poor	.	.	.	-	.	+	.	.	.	.	.	.	.	-	+	-	.	.	.	.	.	.	.	.
Gentiana acaulis	Gentianaceae	48		1	.	.	.	.	+	.	+	.	1	.	.	(v)	+	-	.	+	.	.	1	.	.	.	.
Carex ferrruginea	Cyperaceae	11		2a	.	.	.	.	1	.	.	.	.	.	.	.	.	(v)	.	.	.	+	.	.	2b	+	.
Rhinantus glacialis	Scrophulariaceae	16		.	.	1	.	.	.	1	.	.	.	.	.	1	1	(v)	.	1	(v)	(v)	.	.	1	.	2b
Ceologlossum viride	Orchidaceae	4		.	-	.	.	.	.	.	.	-	.	.	.	.	.	-	.	.	.	.	.	.	.	.	.
Gentianella rhaetica	Gentianaceae	15		.	.	1	.	.	.	.	.	-	.	1	.	-	-	.	(v)	-	.	.	-	.	+	-	-
Pyrola minor	Ericaceae	2		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sibbaldia procumbens	Rosaceae	5		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Huperzia selgao	Lycopodiaceae	13		(v)	.	.	.	.	.	1	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.
Pseudorchis albida	Orchidaceae	9		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diaphasiatrum alpinum	Lycopodiaceae	5		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pedicularis recutita	Orobanchaceae	10		.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	(v)	.	.	.
Carex sempervirens	Cyperaceae	21		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	2a	.	.	-
Gymnadenia conopsea	Orchidaceae	11		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2m	.	.	.	.	-	.	.
Potentilla erecta	Rosaceae	46		1	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.
Pulsatilla alpina ssp. Alpina	Ranunculaceae	19		.	+	.	.	.	+	1	.	1	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.
Hieracium pilosella	Asteraceae	32		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	.	.	.	.	.	.	.	.
Veronica bellidioides	Plantagiaceae	25		.	.	.	(v)	-	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thymus pulegioides	Lamiaceae	33		.	.	.	.	1	.	1	.	.	.	1	.	.	1	+	1	.	.	1	1	1	.	2b	(v)
Pulsatilla vernalis	Ranunculaceae	16		.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca pseudodura	Poaceae	27		.	.	.	.	.	.	1	+	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Nigritella rhellicani	Orchidaceae	8		.	.	.	.	.	.	.	.	.	.	.	.	.	.	(v)	.	-	.	.	.	.	.	.	.
Luzula luzioides	Juncaceae	20		.	.	.	.	.	-	.	.	(v)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leontodon hispidus ssp. Pseudocrispus	Asteraceae	18		.	1	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	1	1	.	.	1	.
Antennaria dioica	Asteraceae	31		+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	(v)	.	.	.
Botrychium lunaria	Ophioglossaceae	14		.	.	.	-	.	.	+	.	.	.	-	-	.	.	.	-	.	-	.	.	.	-	.	.
Sempervivum tectorum ssp. Alpinum	Crassulaceae	9		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.
Galium anisophyllon	Rubiaceae	27		.	.	1	1	+	+	.	.	.	.	1	.	.	1	+	+	.	.	.	1	+	.	1	1
Viola biflora	Violaceae	22		.	.	.	.	.	1	.	.	(v)	1	.	1	.	.	(v)	.	.	.	1	1	+	.	.	.
Agrostis rupestris	Poaceae	17		.	.	.	1	+	.	.	.	.	+	.	.	.	.	.	.	.	1	.	.	+	1	1	.
Silene vulgaris	Carophyllaceae	39		.	+	.	.	.	-	1	1	+	.	1	(v)	.	(v)	+	(v)	(v)	.	.	1	1	+	.	.

Veronica officinalis	Plantagiaceae	5		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ajuga pyramidalis	Lamiaceae	14		.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-	.	.	.
Phyteuma betonicifolium	Campanulaceae	23		.	.	.	.	.	.	.	.	-	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carlina acaulis	Asteraceae	32		.	.	.	(v)	.	.	.	-	+	.	1	-	.	.	.	1	1	1	.	-	.	+	2a	.
Pinus cembra	Pinaceae	16		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium murorum	Asteraceae	10		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leontodon helveticus	Asteraceae	51		.	.	.	1	1	.	.	.	1	1	.	.	.	1	+	.	.	.	.	.	.	.	.	.
Pulsatilla alpina ssp. Austriaca	Ranunculaceae	36		.	.	2a	.	.	.	.	.	.	1	1	.	2a	1	.	+	.	.	.	.	.	.	.	.
Euphrasia rostkoviana	Orobanchaceae	45		.	2m	.	1	.	.	.	(v)	1	1	2m	.	.	1	+	.	1	(v)	1	.	.	1	.	1
Primula minima	Primulaceae	36		.	+	.	(v)	.	+	1	.	.	.	.	.	1	1	.	.	.	1	.	1	.	.	.	.
Avenula versicolor	Poaceae	26		.	.	1	.	.	.	.	.	1	.	1	.	.	.	.	2a	1	.	.	.	.	2a	.	.
Hieracium lactucella	Asteraceae	26		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Loisleura procumbens	Ericaceae	23	Siliceous	1	.	.	.	.	.	.	.	.	.	.	.	(v)	1	.	.	.	.	.	.	.	.	.	.
Hypochaeris uniflora	Hypericaceae	8	alpine	.	.	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Juncus trifidus	Juncaceae	19	and	.	.	2a	.	.	.	.	.	.	.	.	.	(v)	.	.	.	.	.	.	.	.	.	.	.
Arctostaphylos urva-ursi	Ericaceae	5	boreal	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gentiana punctata	Gentianaceae	15	grasslands	.	.	.	.	.	.	.	.	.	.	(v)	.	.	(v)	+	.	.	.	.	.	.	.	.	.
Hieracium piolsum	Asteraceae	11		.	.	.	.	.	.	1	.	.	.	.	.	(v)	.	.	.	1	.	.	.	(v)	.	.	.
Gentiana bavarica	Gentianaceae	7		.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Oreochloa disticha	Poaceae	1		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium glaciale	Asteraceae	4		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euphrasia minima	Orobanchaceae	15		.	.	.	.	.	.	.	+	.	1	.	.	1	(v)	.	.	.	.	.	.	.	.	.	.
Juncus jacquinii	Juncaceae	3		.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Leucanthemopsis alpina	Asteraceae	6		.	.	.	.	.	.	(v)	.	.	-	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Primula glutinosa	Primulaceae	2		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex curvula	Cyperaceae	9		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Part two

					N1													N2																					N3					
2.5	4.4	3.2	5.3	4.8	2.1	1.4	7.4	7.6	7.7	8.1	8.2	4.6	8.5	1.3	3.1	7.3	7.2	4.1	2.2	2.3	2.6	2.4	6.1	8.4	6.5	8.3	7.5	9.3	9.1	9.4	9.5	7.1	9.2	4.7	6.4	5.1	4.3	4.2	9.13	12.3	12.5	12.4	15.1	9.10
1831	1787	1779	1846	1847	1903	1922	1903	1942	1913	1895	1905	1841	1940	1938	1822	1911	1820	1808	1820	1820	1810	1833	1811	1933	2230	1920	1908	2163	2059	2196	2220	1899	2110	1859	2259	1865	1789	1803	2251	2065	2125	2119	2154	2265
SW	SW	SW	SE	S	E	SW	NE	NE	NE	SW	SW	S	SW	SW	SW	NE	NE	S	NE	NE	NE	E	W	SW	S	SW	E	SW	SW	W	SW	NE	SW	SW	S	SW	SW	SW	S	E	E	NE	NE	SW
30	15	15	10	25	25	10	20	25	10	40	45	25	45	30	20	20	20	30	15	20	30	30	30	45	40	50	25	60	35	50	50	25	40	35	30	35	10	25	0	15	20	20	25	10
30	25	30	30	30	15	25	20	20	25	20	10	18	25	10	15	5	8	20	15	25	15	18	10	20	8	20	10	10	15	10	20	10	15	25	15	10	25	2	20	15	10	15	18	15
2	3	4	2	4	4	5	4	3	4	4	4	3	3	4.5	4	4	4	4	4	4	4	4	4	2	2	4	2	3	3	3	2	4	3	4	2	3	4	4	3	3	3	3	3	2
50	80	95	98	90	70	95	80	75	85	90	85	85	85	85	85	70	80	80	70	85	70	50	70	95	85	90	75	80	85	90	90	85	90	85	85	70	98	85	99	80	80	85	90	90
40	0	0	0	0	2	0	2	0	10	0	0	2	8	0	1	6	5	10	20	10	10	40	30	2	5	3	15	3	3	10	5	5	0	10	15	1	0	0	0	20	10	15	3	3
10	0	6	0	0	k.a	k.a	15	35	3	2	15	3	3	k.a	k.a	25	24	5	k.a	10	25	20	35	1	1	2	25	5	0	0	1	15	0	20	5	25	0	0	0	10	15	10	1	5
P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	M	M	P	A	P
16	2	5	3	4	11	14	16	8	15	9	10	14	14	16	14	11	9	13	13	13	12	12	12	13	9	14	13	16	10	12	14	13	9	13	13	9	12	7	4	14	12	11	10	14
3	0	1	0	2	2	5	5	1	2	4	3	6	5	6	5	3	3	5	3	4	3	3	4	5	4	6	4	7	3	2	5	4	2	5	3	2	5	3	1	3	3	3	2	2
2	0	0	0	0	3	9	3	1	4	4	2	5	3	5	5	4	4	2	2	3	2	2	1	3	3	3	2	4	3	3	4	4	1	2	3	0	2	1	1	6	4	3	5	2
					A	A	B	C	B	B	B	A	B	A	A	B	A	A	A	A	A	B	B	A	B	A	B	A	A	A	A	A	B	B	B	B	B	A	C	B	A	B	A	B
6	6.6	6	6	6.3	5.3	5.5	5.6	5.2	5.6	5.4	5.2	5.1	5.3	5	5.3	4.5	4.9	5.4	5.5	5.4	5.3	5.3	5.4	5.6	5	5.6	5.5	5.2	5.4	5.4	5.3	5.7	5.5	5.2	5.4	5.4	5.7	4.9	5.8	5.5	5.5	5.5	5.5	5.7
3.8	5.7	5	5.6	4.8	4.3	4.1	3.4	5	4	5.3	5.3	3.9	4.7	4	3.6	4	4.2	3	3.5	4.1	3.5	3.8	3.5	3.5	2.9	3.6	3.8	4	3.6	3.4	4.4	3.6	4	4.4	3.8	4.2	4.2	4.4	3.5	3.5	3.9	4	3.3	3.6
3	3.5	3.7	4.3	3.5	2.6	2.6	2.5	3.2	2.9	3.7	2.7	2.7	3	2.5	2.5	2.7	2.6	2.4	2.6	3.2	2.6	2.6	2.8	2.7	2.2	2.7	2.7	3	2.8	2.5	3.1	2.4	2.7	3	2.7	3.1	2.8	2.7	2.9	2.8	2.8	2.9	2.3	2.7
2.72	1.16	2.37	2.27	1.91	3.44	2.86	2.86	2.9	3.25	3.11	3.24	3.4	3.12	3.66	2.46	2.68	3.01	2.52	3.34	3.26	3.23	3.12	2.95	2.53	2.91	3.07	2.96	3.49	2.94	2.9	3.13	2.69	2.77	3.38	2.93	2.51	2.85	2.59	1.76	2.89	3.43	3.22	2.72	2.89
36	10	19	14	17	43	42	29	30	38	32	33	41	38	57	34	26	29	31	43	40	43	39	31	29	24	35	29	42	32	29	36	32	28	42	33	30	30	24	14	32	38	33	26	30
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+	1	+	2a	1	+	+	+	1	.	2a	1	.	.	.	+	+	.	.	.	+	+	-	1	1	1	1	1	1	1	1	1	2a	1	1	+	+	1	2a	.	-	.	.	.	(v)
.	2a	(v)	2b	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	(v)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
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N4																N5																					
16.5	12.2	13.4	16.3	16.4	9.8	6.2	9.9	6.3	9.7	13.7	16.2	12.1	15.7	16.1	3.3	9.12	14.3	14.4	14.5	14.1	S3	S4	5.2	14.2	9.14	9.11	13.3	9.6	13.8	13.10	13.9	13.11	13.12	14.8	13.13	13.14	14.7
2204	2043	2302	2106	2167	2268	2257	1995	2245	2259	2385	1943	2060	2093	1803	1911	2260	2175	2158	2138	2210	2160	1950	1867	2180	2285	2259	2203	2242	2417	2418	2414	2443	2470	2523	2514	2554	2533
SW	NE	S	S	SW	S	S	SE	S	NW	SW	SW	NE	S	SW	NE	SW	S	SE	S	SW	SE	S	SW	S	SW	SW	S	S	S	SE	S	SE	SE	S	S	SW	S
40	25	40	30	40	35	30	30	35	45	50	45	10	25	40	25	15	40	10	25	30	45	60	45	35	30	10	35	50	25	35	35	25	35	30	35	35	25
10	12	20	15	15	10	12	8	10	10	10	15	4	15	20	10	15	15	15	15	20	15	15	3	20	1	1	3	1	10	5	5	10	3	5	5	5	2
2	4	3	2	2	2	2	2	2	2	2	2	2	2	3	2	1	1	1	1	1	2	2	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1
85	80	85	80	60	98	90	75	80	85	85	55	65	65	75	75	98	65	75	98	95	25	20	60	70	30	50	25	40	85	80	85	85	80	75	85	85	0
5	20	10	15	30	0	5	10	15	25	5	40	30	35	30	30	1	20	20	3	0	85	85	40	30	25	30	70	50	5	0	15	0	2	0	0	0	0
2	7	2	1	2	1	0	20	5	10	5	5	5	1	3	3	0	0	0	0	0	k.a	5	35	0	25	15	1	5	10	15	0	0	0	0	0	20	0
A	P	A	P	A	P	P	P	P	P	A	P	P	P	A	M	P	M	M	M	M	P	P	P	M	P	P	A	P	A	A	A	A	A	M	A	A	A
16	17	14	19	15	7	11	9	14	8	15	21	13	12	18	18	10	11	10	9	7	12	9	13	12	8	7	11	11	15	8	11	3	4	7	4	4	7
4	3	4	5	3	1	5	1	4	2	5	7	2	3	5	6	3	2	2	4	3	3	4	4	4	4	2	3	2	5	2	5	2	2	2	1	1	2
10	3	7	5	6	1	3	4	3	2	6	10	3	1	6	5	2	4	4	3	2	6	4	2	4	4	2	3	4	10	4	8	4	5	1	3	3	4
B	B	A	B	B	A	A	B	A	B	A	B	B	B	B	B	B	B	B	B	C																	
5.4	5.5	5.5	5.3	5.3	5.5	5.6	5.4	5.5	5.3	5.2	4.8	5.4	5.5	5	5.5	5.5	5	5.5	5.7	5.6	5.6	5.2	5.2	5.3	5.1	5.1	5.1	5.3	5	5.3	5.3	5.5	5.1	5.5	4.5	4.7	4.5
3.1	2.7	3.3	3.2	3.3	2.9	3.2	2.6	3.2	3.2	4	3.9	2.8	2.6	3.9	3.8	2.6	3.6	3	2.7	2.9	2.6	3.5	3.3	3.4	3	3.1	2.9	2.6	3.5	3.4	3.4	2.9	2.8	4.2	2.9	2.7	3.4
2.2	2.1	2.4	2.4	2.4	2.2	2.3	2.1	2.3	2.3	2.5	2.5	2.4	2.1	2.7	2.1	2.2	2.5	2.2	2.2	2.6	2.4	2.5	2.2	2.3	2.2	1.9	2	2	2.2	2.3	2.3	2.1	2.2	3.2	1.7	1.9	2.7
2.77	2.44	2.96	3.05	3.31	2.04	2.33	2.23	2.6	2.62	3.28	3.7	2.75	2.38	3.74	3.33	1.69	2.94	2.56	1.43	1.2	2.21	3.03	2.75	2.7	3.13	2.25	2.84	2.73	3.27	2.6	2.7	1.73	2.46	2.74	2.02	2.35	2.3
36	23	32	45	42	17	22	22	29	22	33	59	24	17	51	46	17	24	21	15	11	27	36	26	24	31	17	30	28	33	23	25	16	16	21	16	17	21
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1	2a	2a	2a	2a	2a	2a	2a	2b	2b	1	1	2a	2a	2a	1	1	2a	2a	1	1	.	.	2a	2a	1	1	1	.	2a	1	.	.	.	.	2a	1	1
1	1	2a	2a	2a	2a	2b	2a	2b	+	1	1	1	2a	-	.	2b	2a	1	(v)	(v)	1		.	1	1	.	-	1	1	2a	1	2a	2a	1	2a	2a	1

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(v)	1	+	1	1	.	1	.	2a	.	1	2b	1	2a	2a	2a	.	1	1	(v)	(v)	(v)	2a	3	3	.	.	3	3	+	.	.	.	.	.	.	.	.
2a	1	.	2a	1	.	2a	.	(v)	.	.	2b	1	1	2a	1	+	2b	.	.	.	(v)	.	2a	2a	2a	1	2b	1	1	.	1	.	.	.	.	.	.
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1	.	(v)	2b	1	.	1	.	1	.	+	-	.	2a	1	+	2a	2a	1	1	(v)	1	+	2a	2a	2b	.	1	2a	1	.	2a	1	(V)	.	2a	.	.
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