Importance of *Nardion* grassland quality for orthopterans: a case study in the Swiss northern Prealps

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Importance of *Nardion* grassland quality for orthopterans: a case study in the Swiss northern Prealps

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1 Abstract

Species-rich *Nardion* grasslands (species-rich *Nardion strictae*) cover large areas in European mountain ranges and represent a priority habitat type harbouring rare plant and insect species. They are currently under threat showing a dichotomous degradation trend where either the tough grass *Nardus stricta* or eutrophic plant species become dominant, leading to a disappearance of specialised *Nardion* plant species. While the plant community changes occurring along these two degradation trends have been fairly well described, knowledge about the response of the inhabiting invertebrates is scare. In this study, we first assessed the main factors determining the orthopteran assemblage within *Nardion* grasslands, and second the impact of the two *Nardion* grassland degradation trends on them.

Vegetation relevés, farmer interviews, soil analyses and orthopteran surveys were performed within 20 species-rich and 28 degraded *Nardion* grasslands in the Bernese Prealps, Switzerland. Orthopteran density was assessed with a biocenometer (1 m^2 circular net) and species richness with an additional visual and acoustical survey.

Overall, mean orthopteran species richness (± standard deviation) per *Nardion* grassland = 7.0 (± 2.3), and density = 1.0 (± 0.8) m^{-2}. In pastures, results showed that orthopteran species richness depended on the vegetation structure, which was measured at plot-scale comparing minimal and maximal vegetation heights (mean orthopteran species richness was 6.2 ± 2.0 in pastures with a low vegetation heterogeneity and 8.1 ± 2.3 within highly heterogeneous pastures), whereas density was higher within pastures with tall swards. We found the highest orthopteran species richness and density within south-exposed pastures, which were associated with plant species-rich *Nardion* grasslands too. Ensifera species richness was negatively correlated with altitude. We found evidence for negative impacts of both *Nardion* grassland degradation trends on the orthopteran community; the dominance of *N. stricta* reduced the orthopteran density and dominance of eutrophic plants negatively impacted orthopteran species richness. Additionally, signs of abandonment (presence of dwarf shrubs) had further detrimental effects on the orthopteran community. A factor associated with the *Nardion* grassland degradation trends was altitude: dwarf shrub cover increase was more pronounced at high elevations whereas eutrophic plant dominance was more severe within the lower montane zone.

In grazed *Nardion* (pastures), we recommend reducing *N. stricta,* eutrophic plant and dwarf shrub cover in order to restore and conserve *Nardion* grasslands and to favour their orthopteran assemblage. In meadows, where degradation was found to be a minor problem, we refer to previous studies recommending uncut areas to foster orthopterans by creating more heterogeneous vegetation structure, which was the most important factor determining orthopteran species richness in this study.

Key words: alpine, biodiversity, conservation, dry meadows and pastures, grassland degradation, *Nardus stricta*, Orthoptera

2 Introduction

Species-rich *Nardion* grasslands (species-rich Nardion strictae according to Delarze *et al.* 2015) occur in most European countries and make up a large proportion of protected alpine grasslands (Galvànek & Janàk 2008). They are currently under threat mainly due to changes in management practices as intensification or abandonment and are a priority habitat in Europe (Galvànek & Janàk 2008). In addition to rare *Nardion* grassland specific plant species as *Gentiana pannonica* these grasslands harbour rare butterflies like *Maculinea alcon* (Galvànek & Janàk 2008; Delarze *et al.* 2015). In Switzerland, species-rich *Nardion* grasslands occur above 1000 m in the Alps and in the Jura mountains (Delarze *et al.* 2015) . They develop on acid, nutrient-poor and shallow soil, which consist of calcareous or siliceous substrate (Delarze *et al.* 2015). These semi-natural grasslands are usually extensively managed meadows or moderately used pastures (Eggenberg *et al.* 2001; Delarze *et al.* 2015). *Nardus stricta,* a horst forming grass species, is the most dominant plant species in *Nardion* grasslands. Because of its robust, dry and nutrient-poor leaves, it is only eaten by livestock in its early life stages (Meisser *et al.* 2014). Further on, it has an extremely dense root system, limiting the invasion of other plant species and can therefore reach a coverage of up to 80 – 90 % within a grassland (Maag, Nösberger & Lüscher 2001). This extreme dominance of *N. stricta* is one degradation trend of species-rich *Nardion* grasslands often observed in Europe causing a loss of their agricultural and conservation value (Galvànek & Janàk 2008; Delarze *et al.* 2015). Furthermore, some *Nardion* grasslands suffer from an invasion of eutrophic plant species constituting a second degradation trend (Delarze *et al.* 2015). Finally, a less *Nardion* grassland specific degradation trend is land abandonment, which takes place due to the low agricultural productivity of these extensive grasslands and leads to secondary succession of these grasslands (Galvànek & Janàk 2008). While the plant community changes occurring along the degradation trends have been fairly well described, knowledge about the response of the inhabiting invertebrates is scare (Isern-Vallerdu & Pedrocchi 1994) and needs further research. The aim of this study was to investigate the importance of *Nardion* grassland quality for representatives of higher trophic levels, in this case orthopterans. Orthopterans living in dry and hot grasslands are endangered in Switzerland because of agricultural intensification and habitat loss (Baur *et al.* 2006). Besides conservation concerns of orthopterans themselves, they are known to have an important functional role in multi-trophic food webs. For many vertebrates like birds, lizards or bats and invertebrates such as spiders, mantis or digger wasps, they are a very nutrient-rich prey (Baur *et al.* 2006). By feeding on highly competitive plant species like grasses and legumes orthopterans constrain their dominance and assist to maintain plant species richness (Unsicker *et al.* 2010). Further on, they are known to respond sensitively to human induced disturbances, hence represent good indicators for land-use changes (Baldi & Kisbenedek 1997; Andersen *et al.* 2001).

The research questions of this study are: (1) Which factors generally determine orthopteran assemblages in *Nardion* grasslands?; (2) How does *Nardion* grassland degradation through an increase in cover of *Nardus stricta* or eutrophic plant species affect orthopterans? and (3) What is the difference between mown and grazed *Nardion* grasslands in terms of orthopteran species richness and density? To answer these questions, we performed vegetation, soil, management and orthopteran surveys in 52 *Nardion* grasslands in the Bernese Pre-Alps.

3 Materials and methods

3.1 Study site and experimental design

Between 2011 and 2014, the canton of Berne revised the inventory of all species-rich *Nardion* grasslands (BIOP Support 2015). This control revealed that from originally 169 species-rich *Nardion* grasslands 63 are degraded according to Eggenberg *et al.* (2001). The vegetation of degraded grassland was either strongly dominated by *N. stricta* or eutrophic species and was lacking typical *Nardion* grassland species (for details see Fig. 1). From the inventory in 2014, 52 *Nardion* grasslands (36 pastures and 16 meadows) were selected as study sites. They were all on calcareous substrate and situated in six different regions/valleys in the Bernese Pre-Alps (Diemtigtal, Kandertal, Tschingel, Lenk, Niesen, Zweisimmen, see Fig. 2). The annual rainfall of these regions was 1338 mm between 1981−2010 (Bundesamt für Meterologie und Klimatologie 2016). The average size of the studied *Nardion* grassland sites was 2.2 ha (range: 0.3 – 17 ha) and altitude ranged from 1000 to 2013 m. The mean minimal distance between two grasslands was approximately 1.25 km. Based on the inventory of the canton of Berne, the pastures were divided into three categories: species-rich, *N. stricta* dominated and eutrophic species dominated pastures. Selected triplets always consisted of one pasture per category within the same region. To balance the design for elevation, the same numbers of triplets below and above the median elevation (1620 m) were selected. Because only eight declassified meadows were listed, all were considered in this study. Six of the declassified meadows were dominated by *N. stricta* and two were dominated by eutrophic species. For each of the declassified meadows, a species-rich meadow in the same or nearest region (if none in the same region) and in the same elevation range (1000 – 1620 or 1620 – 2013 m.) was randomly chosen for comparison. After visiting all 52 selected grasslands, four meadows had to be discarded because their management has been abandoned more than 10 years ago (this forested grassland is not comparable with the other grasslands) or the grassland was wrongly classified (e.g. did not harbour *N. stricta*). Further on, the visitation made plain that one meadow was converted into a pasture. Finally, 48 (37 pastures and 11 meadows) of the 52 intended grasslands were investigated (Table A2).

3.2 Vegetation survey

To assess the current state of the *Nardion* grasslands, vegetation surveys on all 48 grasslands were performed adopting the methods used for the Swiss inventory of dry meadows and pastures (Eggenberg *et al.* 2001). Within a representative area of the grassland, a 3-m radius sampling plot (28.26 m^2) was randomly placed and all vascular plants present in the plot were recorded and their absolute cover estimated. Based on the vegetation survey, we classified the grasslands into species-rich or degraded *Nardion* grasslands according to the federal classification criteria. Within degraded grasslands, two types were differentiated: grassland dominated by *N. stricta* (*N. stricta* cover > eutrophic species cover) or grasslands dominated by eutrophic species (eutrophic species cover > *N. stricta* cover).

3.3 Orthopteran sampling

Orthopteran density (number of individuals per m^2) was assessed with a biocenometer constructed out of a net and two plastic rings with a ground area of exactly 1 m^2 (Humbert *et al.* 2012). 12 1-m^2 samples were taken along one or two diagonals depending on the shape of the grassland study site with a minimal distance of 10 m in between and with a 10 m buffer to the edges of the grassland. Adult orthopterans were identified to species level while nymphs (larvae) were simply classified into their sub-order (Caelifera or Ensifera). Furthermore, the grasslands were scanned visually and acoustically for orthopteran species present but not caught in the biocenometer for at least 20 minutes by two people. The sampling took place during sunny and warm days in August 2016 between 10 am and 6 pm. In every second biocenometer-catchment the vegetation height was measured using an A4 clear plastic sleeve. The plastic sleeve was dropped from a height of 1 m and the minimal and maximal vertical distance from the border of the sleeve to the ground were measured.

3.4 Environmental and management variables

By interviewing the farmers, information on current management practises applied in 2016 and from the past was collected. Table A3 summarizes the posed questions and the possible types of answers.

The soil content of phosphorous, nitrogen, carbon and sulphur was measured. 10 soil samples of 10 cm depth were taken on a transect crossing the vegetation plot. The soil was dried overnight in an oven at 105° C, grounded and sieved (mesh size < 1 mm). 10 g of soil were mixed with 25 ml of 0.01 molar calcium chloride (CaCl) solution and the pH of the suspension was measured after two hours. To get the plant accessible phosphorous concentration, only the phosphate content in the soil was measured with the Olson method (Pansu & Gautheyrou 2007). Total organic carbon, nitrogen and sulphur were measured with a CNS elemental analyser (vario EL cube, Elementar) on 12 mg of homogenized and dried samples.

Furthermore, the exposition and slope were measured within each vegetation plot with a compass and a water level. The exact position of the vegetation plot was localized with a GPS device and the altitude was obtained from ArcGIS.

3.5 Quality index

A *Nardion* grassland quality index, ranking grasslands according to their quality, was defined as continuous index containing four different aspects. It sums up the Shannon index of the total vegetation survey (Sv) and of the *Nardion* indicator species (Si) and subtracts the *N. stricta* cover (N) and the cover of other unfavourable species (U) which are mainly eutrophic species. The definition of *Nardion* indicator species and unfavourable species is adopted from Eggenberg et *al.* (2001) (Table 1). In this definition, *Nardion* indicator species are specialized, acidophil species typically growing in oligotrophic habitats characterized by *N. stricta* (species-rich *Nardion strictae*) whereas eutrophic species are more common species which are adapted to eutrophic soil conditions normally crowing in grasslands dominated by *Arrhenatherum elatius*. Since *N. stricta* cover is only a negative attribute if it is strongly dominating the vegetation, it was subtracted if its cover exceeded the threshold of 24.3 %. (24.3 is the median of the mean *N. stricta* cover of degraded pastures = 26.8 and the mean *N. stricta* cover of species-rich pastures = 21.9) Only the difference between the *N. stricta* cover and the threshold was subtracted. Each of these four parameters were standardized with the 95 percentile of the values from all grasslands (range: 0–1) and combined into the quality index based on the method proposed by Hering et *al*. (2006):

$$Quality\ index\ = \frac{Sv + Si - \ N - \ U}{4} \quad (\text{Eq. } 1)$$

The quality index ranges from zero to one, one being the best possible quality and zero the poorest. In other words, a quality index of one represent a grassland with a high Shannon index of the overall vegetation and of *Nardion* indicator species, a *N. stricta* cover lower or equal to 24,3% and absence of eutrophic species. To calculate the Shannon index of vegetation survey and of the *Nardion* indicator species, the function ‘diversity’ from the package ‘vegan’ in R was used in R (Oksanen *et al.* 2016). Relative covers for all plant species (i. e. the absolute cover of species cover divided by the total vegetation cover) were calculated and used for the quality index and all other analyses.

3.6 Data analysis

The pastures and meadows were analysed separately due to the unequal replicate numbers (37 pastures, 11 meadows) and to be able to give distinct management recommendations for pastures and meadows.

3.6.1 Pasture analysis

To identify the factors influencing orthopteran species richness, density and Ensifera species richness in *Nardion* grasslands a two-step model selection approach and final correlation analysis was performed.

The first step of the model selection procedure was a pre-selection of all explanatory variables showing a trend ($P < 0.1$) on the orthopteran response variables in univariate linear mixed effect (lme) models of the package ‘nlme’ (Pinheiro *et al.* 2016) to reduce the number of explanatory variables (Guyot *et al.* 2017). All variables were tested linearly but also quadratic. The orthopteran density, area, number of grazing days, livestock units and travel time were log + 1 transformed and proportions as *N. stricta* cover, eutrophic species cover, nitrogen concentration and dwarf shrub cover were arcsin square-root transformed (Guyot *et al.* 2017). All quadratic terms were transformed with the ‘poly’ function of the ‘stats’ R-package to get two separate terms for the model selection (R Core Team 2014). The variables were standardized with the ‘scale’ function by subtracting the variable mean from each value and dividing it by the standard deviation resulting in values around zero and a standard deviation of one. The variables showing a trend were checked for collinearity and discarded if the Spearman correlation | rs | > 0.6, whereby the biologically more meaningful variable was kept. The remaining variables used for one of the three model selection procedures are indicated in the last column of Table 2.

Secondly, model selection was performed for each response variable with the function 'dredge' of the package 'MuMIN' by using the Akaike's Information Criterion corrected for small sample size (AICc) (Bartoń 2015). We calculated marginal and conditional R^2 values for all candidate models with the function 'sem.model.fits' of the package 'piecewiseSEM' (Lefcheck 2015) to show the goodness of the model fit following Nakagawa & Schielzeth (2013). The marginal R^2 represents the variance explained by the fixed, whereas the conditional R^2 represents the variance explained by the fixed and the random effect (Nakagawa & Schielzeth 2013). The competitive models within Δ AIC < 2 (Table 3) were averaged with the function 'model.avg' of the of the package 'MuMIN' (Bartoń 2015). We chose the zero method of model averaging as proposed by Grueber *et al.* (2011) with the aim of determining the factors with the largest effect. The resulting key factors for orthopteran species richness, density and Ensifera species richness are listed in Table 4. The relative importance of each key variable, defined as the sum of all AICc weights of the models in which the variable occurs and the variable's significance, assessed as the estimate confidence interval not including zero (Burnham & Anderson 2002) can be found beside. All models met the model assumptions, which were tested with Tukey-Anscombe plots and residual plots. To visualize the effect of the key variables, partial residuals of the model were plotted. In case of quadratic variables, augmented partial residual plots were used (Mallows 1986).

For the final correlation analysis, we tested correlations among all variables to better understand the mechanisms behind the direct effects of the key factors (Section 5.1) but also to investigate the two *Nardion* grassland degradation trends (Section 5.2). Correlations were tested for significances and visualized with the function ‘corrplot’ of the package ‘corrplot’ (Fig. 5, Wei 2013). One of the key variables (nitrogen in the soil) showed only correlations with other soil parameters and elevation, which are not likely to explain orthopteran species richness alone. The fact that ‘nitrogen in the soil’ had high regional differences urged us to test the influence of the explanatory variables on soil nitrogen with univariate lme models with ‘Region’ as random factor. The resulting p-values are indicated in the section 4.1.1.

3.6.2 Comparison of pastures and meadows

The orthopteran and Ensifera species richness as well as the explanatory variables were compared among the two management practices (grazing and mowing) using univariate lme models with ‘Region’ as a random factor. For this analysis, orthopteran density and vegetation height were not reliable because they were strongly influenced by the time when the orthopteran survey occurred in relation to the mowing event. The strong effect of the mowing event on the orthoperan abundance was shown by other studies (Humbert *et al.* 2012). Vegetation height is also highly dependent on the mowing event and thus both variables were not included in the management comparison analysis. We analysed meadows separately as well but the statistical power (n = 11) was too low to show any relevant effects.

All analyses were performed in RStudio Version 0.98.1028 (R Core Team 2014).

4 Results

In total, we found 1398 individual orthopterans from which 579 were adults or subadults (last larval stage) belonging to 8 Ensifera and 14 Caelifera species. The most common Ensifera species were *Metrioptera saussuriana* (on 35 of 48 grasslands), *Decticus verrucivorus* (25) and *Roeseliana roselii* (16) and the most common Caelifera species were *Pseudochortippus parallelus* (48), *Omocestus virudulus* (43) and *Euthystira brachyptera* (38). Furthermore we observed *Arcyptera fusca* (6, Fig. 4) and *Psophus stridulus* (5), which are classified as "vulnerable" on the Swiss Red List of Orthoptera (BAFU & CSCF 2007). On average we recorded 7.1 species per grassland and 1 individual per m^2 on pastures and 6.5 species per grassland and 0.75 individuals per m^2 on meadows. The mean vegetation height in pastures was 14.6 cm (± 0.73 cm) and 11.3 (± 1.52 cm) in meadows.

4.1 Pastures

4.1.1 Identification of the most important factors

The model selection and averaging provided key factors explaining orthopteran species richness and density as well as Ensifera species richness (Table 4). The relevance of each key factor can be quantified by the confidence interval not including zero and the relative importance. In the following these key factors are presented.

The **vegetation height** was found to have the highest relative importance for orthopteran species richness and density in all three model averaging outputs (Table 4). Pastures with large vegetation height differences harboured many orthopteran species, whereas their density was high within tall vegetation (Fig. 6).

Another key factor was **exposition to south** occurring in two-thirds of all competitive models (Table 3) and having a high relative importance for all three response variables (Table 4). In south-exposed pastures, orthopteran species richness and density were significantly higher than in north-exposed ones. Figure 5 showed that south-facing slopes correlated positively with high vegetation height differences, high plant species richness and high cover of other grasses than *N. stricta*. In pastures exposed to the north, high *N. stricta* and dwarf shrub cover were found.

Pastures with a **soil nitrogen** content of 0.6% harboured a high overall orthopteran species richness (Fig. 7a). According to Figure 5 the amount of soil nitrogen positively correlated with elevation and negatively with Ensifera species richness. In acid soils we found a high nitrogen concentration (lme model with 'Region' as random factor, $P = 0.058$). The cover of the plants on nitrogen-rich soil was dominated by dwarf shrubs ($P = 0.068$) and rarely by eutrophic plant species ($P = 0.029$, Fig. 7b). Figure 5 shows a significant negative correlation between dwarf shrubs and pH and a non-significant positive relationship between eutrophic plant cover and soil pH.

Elevation was the last key factor retained in the model selection showing negative correlation with Ensifera species richness. Although the confidence interval of the estimate included 0 (Table 4), it was found to have a $P < 0.1$ (Fig. 5). Elevation is positively correlated with the *Nardion* grassland quality index and negatively with vegetation height.

4.1.2 Degradation of *Nardion* grasslands

According to Figure 5, overall species richness and density did not differ among different *Nardion* grassland qualities. The *Nardion* grassland quality index was retained in the competitive models of the Ensifera species richness model selection showing a significant negative correlation (Table 3 and 4, Fig. 8a). According to Figure 5, high-quality *Nardion* grasslands occurred most often at high altitudes (Fig. 8b). The vegetation in high quality *Nardion* grassland was found to be shorter and covered by many dwarf shrubs, but only by low *N. stricta* cover. Pastures with a low number of grazing days were characterized by a high *Nardion* grassland quality. In our study the mean number of grazing days was 49 days with a minimum of 10 and a maximum of 150 days per year. A low number of grazing days was highly correlated with having two separate grazing periods in spring and autumn instead of a long one in summer.

Figure 5 shows no significant correlation between the eutrophic plant cover and the orthopteran community. In contrast, high covers of *N. stricta* were linked with a low orthopteran density (Fig. 9), but there was no effect on orthopteran species richness. Lastly, we found that pastures dominated with dwarf shrubs harboured only few orthopteran individuals and only few Ensifera species.

4.2 Differences between pastures and meadows

There was no difference between pastures and meadows regarding orthopteran or Ensifera species richness besides a non-significant trend of higher Ensifera species richness in pastures than in meadows (Fig. 10). The cover of *N. stricta* was higher (P = 0.037) in pastures than in meadows.

5 Discussion

Apart form an old study (Isern-Vallerdu & Pedrocchi 1994), specific knowledge about orthopterans in *Nardion* grasslands is lacking. This study shows that degraded *Nardion* pastures, i. e. *Nardion* grasslands dominated by *N. stricta*, eutrophic plants and/or dwarf shrub harboured lower orthopteran species number and density than *Nardion* pastures in better ecological states. Next to these *Nardion* grassland specific factors, southern exposition and high vegetation height differences were highly correlated with a rich orthopteran community and should be considered when protecting *Nardion* grasslands.

These findings provide additional reasons to protect species-rich *Nardion* grasslands since not only the *Nardion* specific plant species (Rieder *et al.* 2017) but also representatives of higher trophic levels suffer under *Nardion* grassland degradation.

The following subsections, address the main questions asked in the introduction on: factors generally determining orthopteran assemblages (5.1), impact of *Nardion* grassland degradation on orthopterans (5.2) and comparison of mown and grazed *Nardion* grasslands in terms of orthopteran species richness and density (5.3), before concluding (5.4) and stating some management recommendations (5.5).

Often the orthopteran suborders Caelifera and Ensifera show distinct reactions on management changes and have different requirements on their environment (Baur *et al.* 2006; Braschler *et al.* 2009; Marini *et al.* 2009b), thus responses of Ensifera specifically are additionally discussed.

5.1 Key factors determining orthopteran assemblages

5.1.1 Vegetation height

In pastures we found that vegetation height and its difference are crucial for orthopteran species richness and density. For orthopteran density, vegetation height was found to be one of the two most important factors: Within tall vegetation high orthopteran density was found because it provides enough food for many individuals and shelter against predators (Dennis, Young & Gordon 1998; Gardiner *et al.* 2002; Marini *et al.* 2008). Gardiner *et al.* (2002) found an optimal vegetation height for *Chorthippus* species densities at 10 – 20 cm, thus the mean vegetation height of 14.6 cm in the present study lies within this optimal range and has therefore no negative effects on orthopteran density via the microclimate.

For orthopteran species richness, vegetation height difference was found to be more important than vegetation height alone. High vegetation height differences indicate a high structural heterogeneity, whereby tall vegetation *per se* (until a certain height) often offers more structure than short swards (Dennis, Young & Gordon 1998; Jerrentrup *et al.* 2014). According to the habitat heterogeneity hypothesis, a structurally diverse vegetation provides different habitats for various species (Dennis, Young & Gordon 1998), which could be shown in this study and by several others (Wettstein & Schmid 1999; Jerrentrup *et al.* 2014). Ensifera species richness showed an even stronger response on vegetation height difference in the present study. This could be due to their preference for tall and highly structured vegetation (Marini *et al.* 2009b; Buri, Arlettaz & Humbert 2013), which is regarded as a strategy to evade predators for whose they are a preferred pray due to their large body size (Harvey & Gardiner 2006).

5.1.2 Exposition to south

In south-exposed *Nardion* pastures, orthopteran species richness and density are higher than in north-facing slopes. The vegetation in south-exposed pastures is species-rich and harbours only a low cover of *N. stricta* and dwarf shrubs. This is consistent with previous studies: to be physiologically active and to have a proper egg development high temperatures, found at south-facing slopes, are required (Baur *et al.* 2006; Weiss, Zucchi & Hochkirch 2013; Sutcliffe *et al.* 2015). Next to direct effects of the higher solar radiation, the high plant species richness within south-exposed pastures is beneficial for generalist orthopteran fitness and density (Franzke *et al.* 2010; Unsicker *et al.* 2010). Additionally, the tough and nutrient-poor grass *N. stricta* (Fitter & Hay 2002; Meisser *et al.* 2014) is no favourable food source according to Franzke *et al.* (2010) observing selective feeding of *Chorthippus parallelus* which avoids tough grass species. Further on, Isern-Vallerdu & Perocchi (1994) and Blumer & Diemer (1996) suggested that orthopterans feed on *N. stricta* if they have no alternative, but it might be avoided if more palatable grass species are available. A second reason for low species richness and density within north-exposed pastures are dwarf shrubs having adverse effects on orthopterans by creating cold and wet microclimate when reaching too high successional stages (Marini *et al.* 2009a; Koch *et al.* 2015).

5.1.3 Soil nitrogen

We found that orthopteran species richness was highest at an intermediate soil nitrogen content of around 0.6% (Fig. 7a). This relationship is most probably driven by an indirect effect via the plant community by changing the food quality or microclimate (Van Wingerden, Musters & Maaskamp 1991; Franzke *et al.* 2010). Nitrogen availability for plants is strongly depending on the soil pH: at low soil pH which is typical for *Nardion* grasslands, nitrogen might be present in an immobile form but is not available for plants and accumulates consequentially (Gregory & Nortcliff 2013). This can be explained by the fact that soil nitrogen can only be taken up by plants in form of ammonium (NH_4^+) or nitrate (NO_3^-) (Gregory & Nortcliff 2013), but both forms are only available in very low amounts below a soil pH of 4.5, which was often found in the present study (pH 3.2 - 5.2). The availability ammonium is supressed since the cation uptake (as NH_4^+) below a soil pH of 4 to 5 is nearly impossible due to osmotic reasons (Gregory & Nortcliff 2013). Nitrate, the second nitrogen source for plants, is not available below a pH of 4.5 because the nitrification process through autotrophic bacteria producing NO_3^- does no longer take place (Fitter & Hay 2002).

In acid soils with high nitrogen content, we found dwarf shrubs to be dominant (Fig. 7b). This is not surprising since many of the dwarf shrubs species found (e.g. blueberry) are acidophilic (Baltisberger, Nyffeler & Widmer 2013). In contrast, eutrophic plants were reaching highest covers at low nitrogen levels where soil pH is nearly neutral. This seems to be contradictive to the definition of eutrophic species, which are most competitive at high amounts of nitrogen. But since these plants are not as well adapted to acidity as acidophilic species (e.g. *N. stricta* or blueberry), they cannot access nitrogen in acid soil and occur more often at intermediate to high pH (Delarze *et al.* 2015). Conceivably, eutrophic plant species exploit the available nitrogen leading to a low nitrogen level in the soil at slightly acid to neutral pH (Fig. 7b). Generally, dwarf shrubs reach high expansions at high elevations (Tasser & Tappeiner 2002) whereas eutrophic plant species are more frequent within the montane than in the subalpine zone (Parolo *et al.* 2011), which is in agreement with the high soil nitrogen levels at high elevations in our study.

Regarding orthopterans, this indicates that they show a low diversity in grasslands either dominated by eutrophic plants or dwarf shrubs. Both vegetation types create unfavourable dense, cold and wet microclimate (Van Wingerden, Musters & Maaskamp 1991; Marini *et al.* 2009b; Koch *et al.* 2015).

5.2 Effect of **Nardion** *grassland degradation on orthopteran community*

Contrary to our expectations, high *Nardion* grassland quality does not generally enhance the orthopteran community. Ensifera species richness was even found to be lower in high quality patches. High quality *Nardion* grasslands occur often at high elevation where orthopteran species richness is found to be low due to cold and harsh conditions (Wettstein & Schmid 1999). Elevation may be the main mechanism driving the negative relationship between Ensifera species richness and the *Nardion* quality index. The altitude-species richness relationship may also explain the negative correlation between nitrogen in the soil and Ensifera species richness, since the nitrogen content was much higher within soil of high altitudes. Additionally, the low vegetation height and the large proportion of dwarf shrubs in high *Nardion* quality grasslands are unfavourable for Ensifera species since they are known to be reliant on tall vegetation (Marini *et al.* 2009b; Buri, Arlettaz & Humbert 2013).

The degradation of *Nardion* grasslands shows a dichotomous trend: Either species-rich *Nardion* grasslands get strongly dominated by *N. stricta* or eutrophic plant species (Parolo *et al.* 2011). Looking at these two degradation trends, we found that an increase in *N. stricta* cover is more severely impacting orthopterans than an increase of eutrophic plants, since only in the former case we found a direct effect on orthopterans. As already mentioned, the low plant species richness within *N. stricta* dominated pastures and the unpopularity of *N. stricta* as a food source could lead to a decrease in orthopteran density (Blumer & Diemer 1996; Franzke *et al.* 2010; Unsicker *et al.* 2010). Moreover, we found that the higher the cover of eutrophic plants was, the more plant species were present in pastures which is again favourable for the orthopteran density (Franzke *et al.* 2010; Unsicker *et al.* 2010). Thus, the eutrophic plant dominance in pastures might not be detrimental for orthopteran density.

Contrastingly, in pastures with a low soil nitrogen level and a high cover of eutrophic plants, we found only few orthopteran species. Therefore, it is possible that an increase of eutrophic plant species has no negative impact on the orthopteran density but on species richness. Potentially, the direct negative impact of eutrophic plant increase on orthopteran species richness is masked by the fact that eutrophic plant dominance is more severe within the montane zone (Rieder *et al.* 2017) where orthopterans are more species-rich than at higher altitudes (Wettstein & Schmid 1999).

A third degradation threat *Nardion* grasslands face is too low intensity land-use or even land abandonment (Galvànek & Janàk 2008). Although it is not the main focus of this paper, it is important to mention that secondary succession could have detrimental effects on orthopterans: We found that the cover of dwarf shrubs is negatively correlated with orthopteran density and Ensifera species richness. Additionally, in soil with a high nitrogen content and a high dwarf shrub cover we found only few orthopteran species. This is in line with literature where pastures with high dwarf shrub covers are avoided by orthopterans (Koch *et al.* 2015). Thus, we think that shrub encroachment through too low land-use or even abandonment would have a negative impact on orthopterans within *Nardion* grasslands.

5.3 Differences between mowing and grazing for orthopterans

The direct comparison of the management does not show significant differences for either one of the three orthopteran response variables presumably due to the very disparate sample sizes of 11 meadows and 37 pastures. We only see a slight trend of a reduced Ensifera species richness in meadows, which is in line with previous studies: low to intermediate grazing intensities provide structural heterogeneity, which is favourable for orthopterans (Dennis, Young & Gordon 1998; Baur *et al.* 2006; Dumont *et al.* 2009; Fabriciusova, Kanuch & Kristin 2011). This is in line with our finding of vegetation heterogeneity being the most important key factor for species richness. However, *N. stricta* coverage was found to be higher in pastures than in meadows leading to a large amount of unpopular food for orthopterans (Blumer & Diemer 1996).

Next to indirect effects of the vegetation, the management practise itself affects the orthopteran community. It is widely known that mowing has detrimental effects on orthopterans (Braschler *et al.* 2009; Buri, Arlettaz & Humbert 2013). Several studies show that mowing late in the season (e.g. in September) or even in a supra-annual manner is favourable for orthopterans (Wettstein & Schmid 1999; Gardiner & Hassall 2009; Marini *et al.* 2009b).

Overall, we think that *Nardion* pastures are more suitable for orthopterans than meadows, because they provide high vegetation heterogeneity and need no disadvantageous mowing event. But since *Nardion* meadows showed a lower degradation frequency than pastures (Rieder *et al.* 2017), we propose to adapt meadow management to the demands of orthopterans and change pasture management in a way to ensure its floristic quality.

5.4 Conclusions

Overall, we found high orthopteran species richness and density within south-exposed pastures due to high temperature and favourable vegetation. In addition, species richness is high within heterogeneous vegetation providing different habitats, whereas the density is higher within tall swards. Low amounts of dwarf shrubs and eutrophic species, which occur at intermediate soil nitrogen levels are favourable for orthopteran species richness. An increasing *Nardion* grassland quality does not ensure benefits for the orthopteran community. However, we found evidence for negative impacts of both *Nardion* grassland degradation trends, namely that the dominance of *N. stricta* and of eutrophic plants negatively affect the orthopteran community.

5.5 Management guidelines

To favour orthopterans in *Nardion* grasslands we propose to apply a management, which reduces both *Nardion* grassland degradation trends, e. g. the dominance of *N. stricta* and eutrophic plants. According to Rieder, Humbert & Arlettaz (2017) best management practice found to reduce *N. stricta* dominance in pastures was a low number of grazing days, in other words, having 2 disparate grazing periods in spring and autumn instead of a long one in summer. We think that this management practice is also favourable for orthopterans due to the *N. stricta* reduction and because the first grazing period ensures the structural heterogeneity of the pasture and the orthopterans are undisturbed during the time between the two grazing periods. To reduce the cover of eutrophic plants, alternating fencing to equalize grazing pressure might be a management option, but should be tested experimentally (Rieder *et al.* 2017). It is important to consider the altitude when addressing *Nardion* grassland degradation: eutrophic plant species are a big problem at low elevations (montane zone) whereas at high elevations secondary succession with dwarf shrubs is becoming more problematic.

To reduce the detrimental effect of the mowing machine in *Nardion* meadows, we propose to keep an uncut area within the meadow as suggested by Buri *et al.* (2013). An associated management practice is already applied in certain regions: In traditionally known “Eger Mähder” the meadows are divided in two parts were both parts are mown alternately every two years, but it should be tested whether the supra-annual mowing cycle has negative effects on the vegetation.

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7 References

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Table 1: List of plant species, which are good indicators for species for species-rich *Nardion* grasslands and the ones that are unfavourable in these grasslands according to the classification criteria (Eggenberg *et al.* 2001). In this study, eutrophic species represented the biggest part of unfavourable species. In the list below, the species defined by Eggenberg *et al.* (2001) are only listed if they occurred at least once in the vegetation surveys.

Indicators for species-rich *Nardion* grasslands	**Eutrophic plant species**		**Other unfavourable plant species**
Antennaria dioica	*Anthriscus sylvestris*	*Taraxacum officinale*	*Briza media*
Arnica montana	*Arrhenatherum elatius*	*Trifolium repens/thalii*	*Centaurea scabiosa*
Astrantia minor	*Carum carvi*	*Trisetum flavescens*	*Helictotrichon pubescens*
Campanula barbata	*Cynosurus cristatus*	*Veronica chamaedrys*	*Leucanthemum vulgare*
Crepis conyzifolia	*Dactylis glomerata*	*Agrostis capillaris*	*Fragaria vesca*
Gentiana punctata	*Festuca arundinacea*	*Bellis perennis*	*Luzula sylvatica*
Geum montanum	*Festuca pratensis*	*Festuca rubra aggr.*	*Trifolium medium*
Hieracium lactucella	*Galium album*	*Alchemilla vulgaris*	*Vicia sepium*
Hypochaeris uniflora	*Heracleum sphondylium*	*Chaerophyllum villarsii*	
Leontodon helveticus	*Holcus lanatus*	*Crepis aurea*	
Meum athamanticum	*Knautia arvensis*	*Geranium sylvaticum*	
Nigritella rhellicani	*Lolium multiflorum*	*Phleum alpinum aggr.*	
Potentilla aurea	*Phleum pratense*	*Poa alpina*	
Pseudorchis albida	*Pimpinella major*	*Polygonum bistorta*	
Ranunculus villarsii	*Poa pratensis*	*Ranunculus tuberosus*	
Sempervivum montanum	*Poa trivialis*	*Silene dioica*	
Trifolium alpinum	*Ranunculus acris*	*Trollius europaeus*	
Viola lutea	*Rumex acetosa*		

Table 2: Detailed information on all recorded variables. The explanatory variables that showed a trend ($P < 0.1$) on one of the orthopteran response variables (species richness, density or Ensifera species richness) and did not correlate with another explanatory variable (Spearman correlation coefficient < 0.6) were included in the model selection. In the last column it is indicated, in which model selection the variable was included.

Variables	Variable type	Recording method	Definition	Trend on orthopteran response ($P < 0.1$)
(A) SITE VARIABLES				
Elevation	Continuous	Field data	Meters above sea level	Ensifera richness
Slope	Continuous	In the field	Slope of the grassland where the vegetation survey was done [%].	
Area	Continuous	ArcGIS	Area protected by the Bernese government [m^2]	
Exposition	Continuous	Field data	Exposition recorded with a compass [degree] and cosine-transformed to disentangle north/south [-1:1]. A value close to -1 means south-exposed	All response variables
(B) MANAGEMENT VARIABLES				
Time of first grazing	Continuous	Interview	Date at which the livestock is put on the grassland for the first time in the year [0 : 365].	
Days of grazing	Continuous	Interview	Sum of days the livestock was grazing.	
Livestock unit per area	Continuous	Interview/ ArcGIS	Livestock unit per total area grazed	
No. grazing periods	Continuous	Interview	Livestock once (summer pasture) or more than once (spring and autumn) on the grassland [1:3]	
Travel time	Continuous	Interview	Time the farmer needs to reach the grassland [min]	
Fertilization	Categorical	Interview	Is or was there any type of fertilizer applied on the grassland [no/yes]	
Mowing date (meadows)	Continuous	Interview	Date at which the meadow is cut	Not included in pasture analysis
(C) SOIL VARIABLES				
pH	Continuous	Dissolved in $CaCl_2$	Acidity of the soil (acid: [1-6], neutral: [7] and alkaline: [8-14])	Total & Ensifera species richness
Carbon	Continuous	CNS-analysis	Carbon concentration in the soil [% of weight]	(Correlation with N)
Nitrogen	Continuous	CNS-analysis	Nitrogen concentration in the soil [% of weight]	Total & Ensifera species richness
Sulphur	Continuous	CNS-anaylsis	Sulphur concentration in the soil [% of weight]	(Correlation with N)
Phosphate	Continuous	Olson method	Amount of phosphate in the soil [mg/l]	(Correlation with pH)
C/N-ratio	Continuous	CNS-anaylsis	Ratio of carbon and nitrogen in the soil	

(D) VEGETATION VARIABLES				
Plant species richness	Continuous	Field data	Number of plant species per plot	
Shannon index of the plants	Continuous	Vegan package in R	Plant species richness weighted with the cover, 'vegan' R-package	(Correlation with plant species richness)
***N. stricta* cover**	Continuous	Field data	Cover of *N. stricta* in the vegetation plot	Density
Eutrophic plant species cover	Continuous	Field data	Cover of eutrophic plant species (Table 4) in the vegetation plot	
Quality index	Continuous	Field data	(Plant shannon index + Shannon index of *Nardion* grassland indicator species – *N. stricta* cover > 24 % – eurtrophic plant species) / 4 (Table 4)	Ensifera species richness
Grasses	Continuous	Field data	Cover of all Poaceae and Cyperaceae without *N. stricta* in the plot	Density
Dwarf shrubs	Continuous	Field data	Cover of all dwarf shrubs in the plot: *Calluna vulgaris, Erica carnea, Vaccinium myrtillus, V. uliginosum and V. vitis-idaea,*	Species richness & density
Vegetation height	Continuous	Field data	Lowest and highest point of the clear A4 plastic sleeve was measured, mean of 6 measurements. Minimal, maximal and mean vegetation height intercorrelate with a Spearman correlation coefficient > 0.8. Minimal vegetation height was used in the model selection since mean and maximal vegetation correlated highly with vegetation height difference whereas minimal vegetation height does not.	All response variables
Vegetation height difference	Continuous	Field data	Measured with disk method: Maximal height - minimal height, mean of 6 measurements	All response variables
(E) ORTHOPTERAN SURVEY VARIABLES				
Weather	Categorical	Field data	Weather condidtion at the orthopteran survey: sunny or sunny & cloudy	Density
Intactness	Categorical	Field data	Condition of the grassland at the orthopteran survey: mown, grazed or still intact	
(F) RANDOM FACTOR				
Region	Categorical	ArcGIS	6 geographical regions: Diemtigtal, Kandertal, Tschingel, Lenk, Niesen, Zweisimmen	All response variables
(G) RESPONSE VARIABLES				
Orthopteran species richness	Continuous	Field data	Number of orthopteran species found per grassland	
Orthopteran density	Continuous	Field data	Number of orthopteran individuals caught with the biocenometer. Only adults and subadults	
Ensifera species richness	Continuous	Field data	Number of Ensifera species found per grassland	

Table 3: Results of the most competitive models explaining orthopteran species richness and density (incl. Ensifera species richness only). All competitive models within Δ AICc of 2 are listed according to the lowest AICc, which is corrected for small sample sizes. The goodness of fit of each model is indicated by the R^2: the conditional R^2 represents the proportion of variance explained by the fixed and random effects combined whereas the marginal R^2 represents only the proportion of variance explained by fixed effects (Nakagawa & Schielzeth 2013).

Response variable	**Competitive models (Δ AICc < 2)**	**Df**	**AICc**	**ΔAICc**	**Weight**	**Marginal R^2**	**Conditional R^2**
Species richness	Veg. height difference	4	100.6	0.00	0.298	0.231	0.424
	Veg. height difference + Exposition	5	101.2	0.53	0.221	0.287	0.480
	Veg. height difference + Nitrogen + $Nitrogen^2$ + Exposition	7	101.5	0.84	0.195	0.447	0.599
	Exposition + Nitrogen + $Nitrogen^2$	6	102.0	1.35	0.152	0.369	0.556
Density	Exposition + Minimal vegetation height	5	98.7	0.00	0.532	0.448	0.532
Ensifera species richness	Veg. height difference	4	106.2	0.00	0.344	0.241	0.321
	Veg. height difference + Exposition	5	107.6	1.32	0.177	0.287	0.397
	Veg. height difference + Elevation	5	108.2	1.92	0.131	0.289	0.360
	Veg. height difference + Exposition + Quality index	6	108.2	1.93	0.139	0.348	0.473

Table 4: Output of model averaging of the competitive models from Table 3. The zero method according to Grueber *et al.* (2011) was used to find the variables having the largest effect on the response variables.

Response variable	Parameter	Estimate	Uncond. standard error	Confidence interval	Relative importance
Orthopteran species richness	(Intercept)	-0.102	0.226	(-0.564, 0.361)	-
	Veg. height difference	0.330	0.203	**(0.100, 0.700)**	0.83
	Exposition	-0.258	0.227	**(-0.716, -0.066)**	0.66
	Nitrogen	0.002	0.082	(-0.259, 0.270)	0.40
	Nitrogen^2	-0.172	0.227	**(-0.698, -0.167)**	0.40
Orthopteran density	(Intercept)	-0.099	0.182	(-0.471, 0.273)	-
	Exposition	-0.609	0.119	**(-0.609, -0.853)**	1
	Vegetation height	0.347	0.124	**(0.347, 0.094)**	1
Ensifera species richness	(Intercept)	-0.062	0.202	(-0.474, 0.350)	-
	Vegetation difference	0.455	0.156	**(0.138, 0.771)**	1
	Exposition	-0.115	0.169	(-0.586, 0.002)	0.39
	Elevation	-0.041	0.108	(-0.5345, 0.051)	0.17
	Quality index	-0.050	0. 127	**(-0.593, -0.011)**	0.17

Figure 1: Definition of the federal criteria for the assessment of species-rich and degraded *Nardion* grasslands (Baltisberger, Nyffeler & Widmer 2013). The assessment is divided into two steps: first the grassland must fulfil both aspects of the main criteria (in meadows only one aspect must be fulfilled). Second, one aspect of the subcriteria must be fulfilled and if both, main- and subcriteria are fulfilled, the grassland is classified as species-rich *Nardion* grassland. The definition of unfavourable species and *Nardion* indicator species is shown in Table 1.

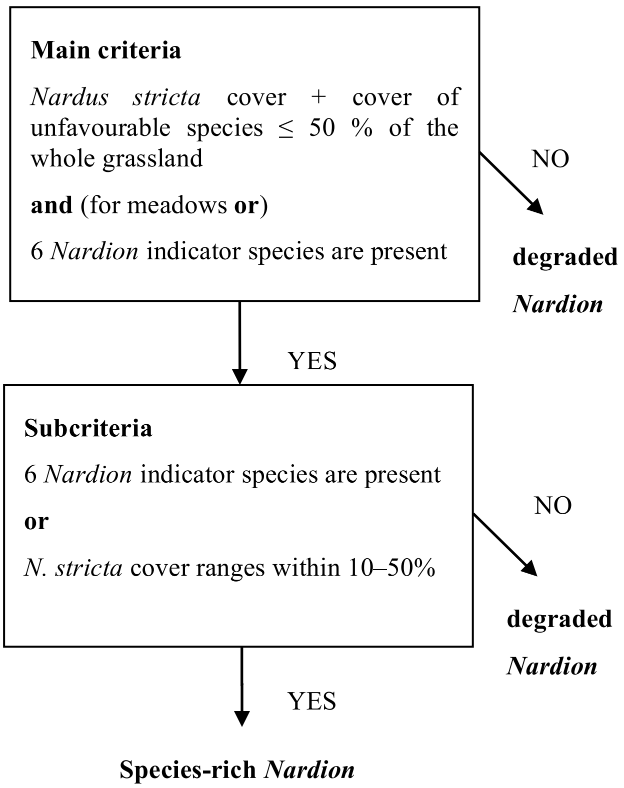


Figure 2: The study site is in the Northern Pre-Alps of the canton Berne and is divided into the six regions/valleys Zweisimmen, Diemtigtal, Lenk, Niesen, Kandertal and Tschingel. Sources: World Topographic Map (ESRI) and https://www.weltkarte.com.

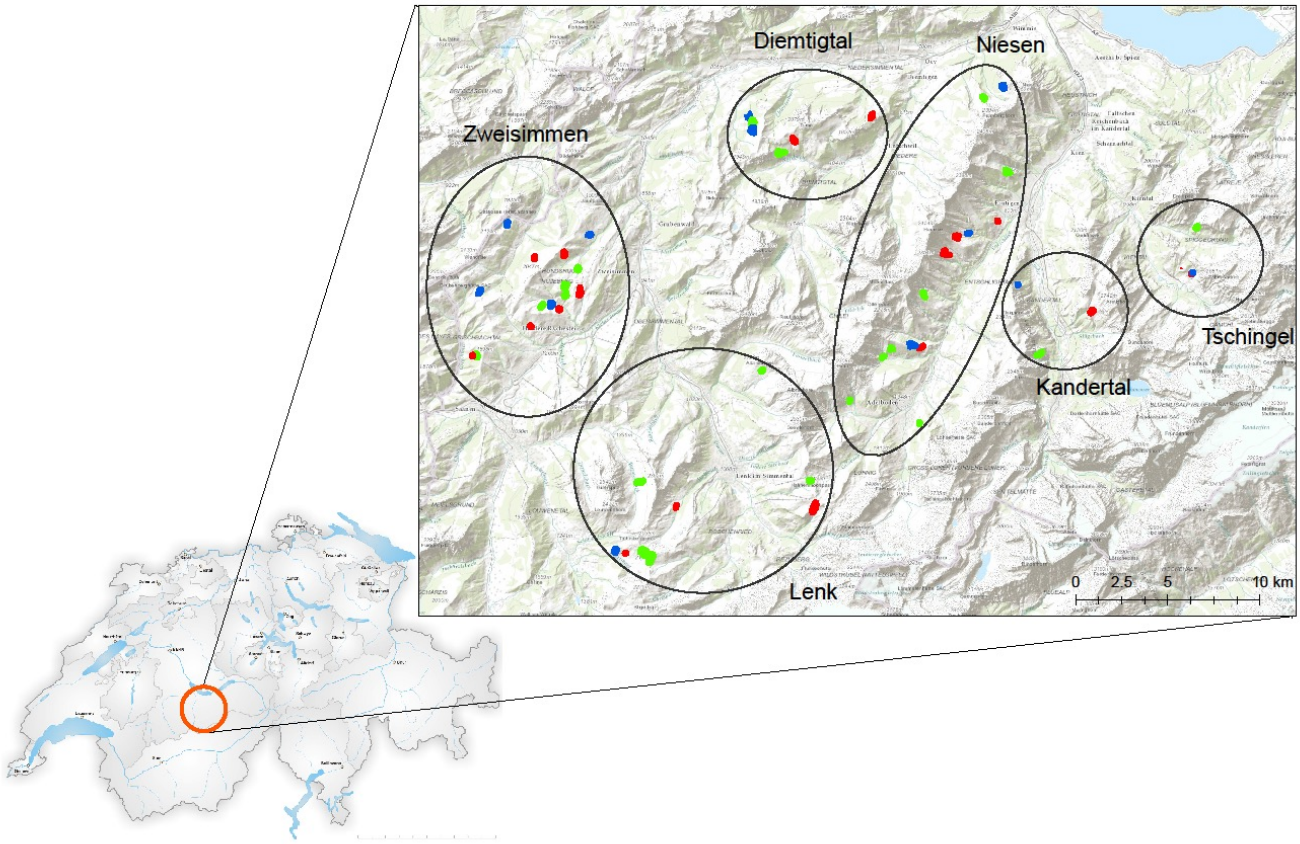


Figure 3: Ortopteran density was assessed with a biocenometer with a ground area of 1m^2. On each grassland, two people performed 12 biocenometer catchments with an additional visual and acoustical survey for at least 20 minutes.

Figure 4: *Arcyptera fusca* is listed as 'vulnerable' on the Swiss Red List of Orthoptera and was observed in 6 of 48 *Nardion* grasslands.

Figure 5: Correlation plot of all variables of the pasture analysis. A coloured background is indicating that the p-value of the correlation test is smaller than 0.1. A red background means a negative, whereas a blue background means a positive correlation between the two variables.

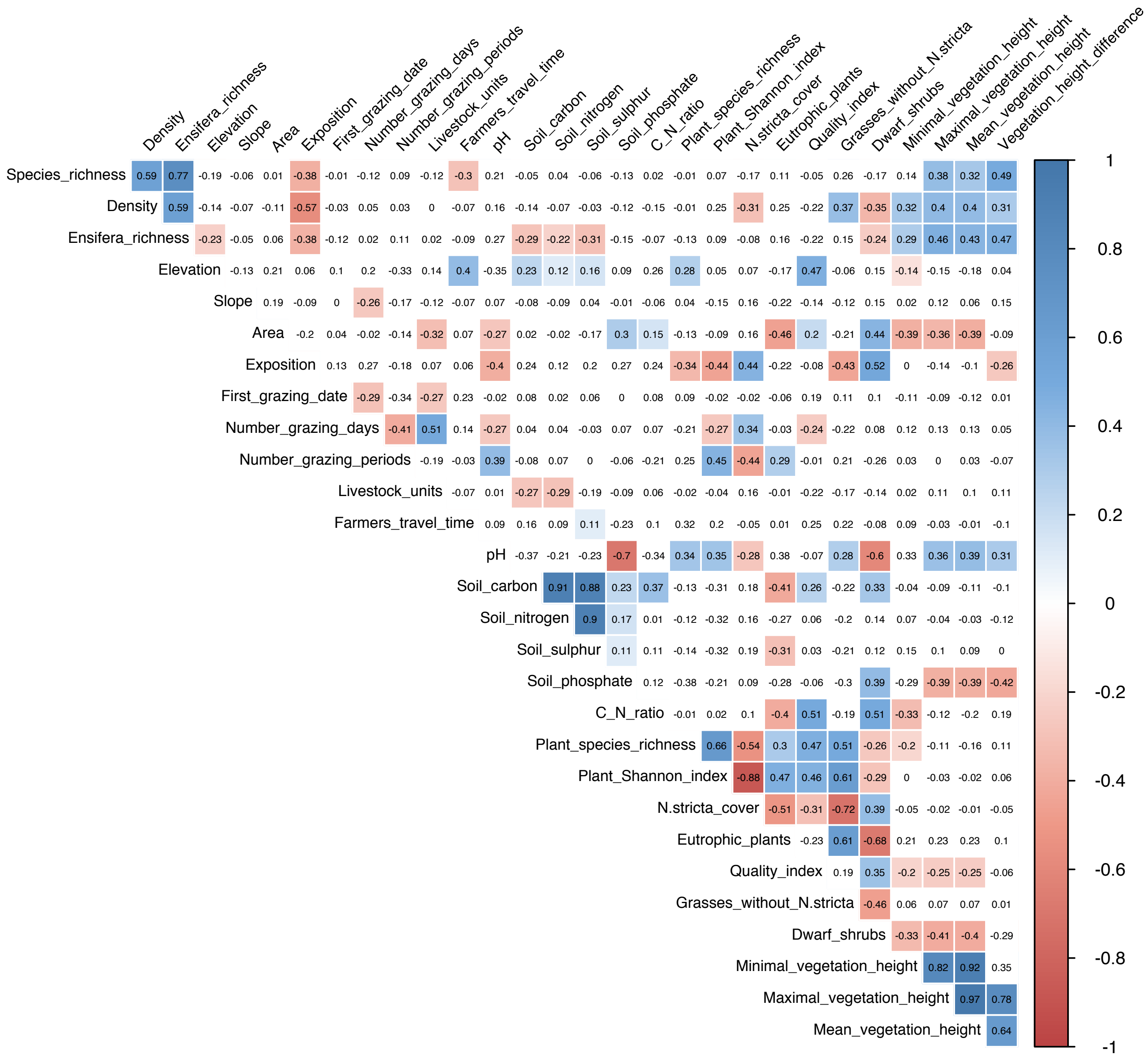


Figure 6: Vegetation height the most important key variable determining the orthopteran assemblage in Nardion grasslands. a) High vegetation height difference leads to high orthopteran species richness whereas b) orthopteran density is increasing with vegetation height. Both plots are partial residual plots of the best competitive models resulting from model averaging. The geographical region of each survey is indicated with different symbol shapes.

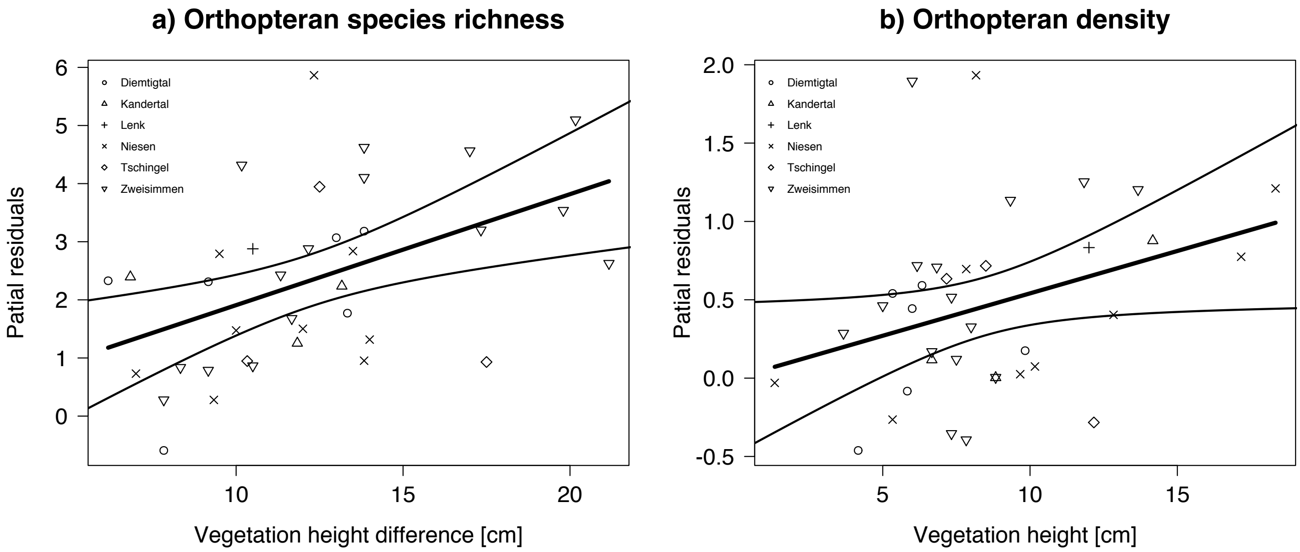


Figure 7: Nitrogen content in the soil is a key factor for orthopteran species richness: a) orthopteran species richness is highest at intermediate soil nitrogen content of 0.6%, where b) dwarf shrub and eutrophic plant covers are low. Plot a) is an augmented partial residual plot (Mallows 1986) built on the best competitive model from model averaging containing nitrogen in the soil and plot b) shows the effect of the standardized values of dwarf shrub (P = 0.063) and eutrophic plant cover (P = 0.027) as well as soil pH (P = 0.050) on the nitrogen concentrations in the soil. The geographical region of each survey is indicated with different symbol shapes.

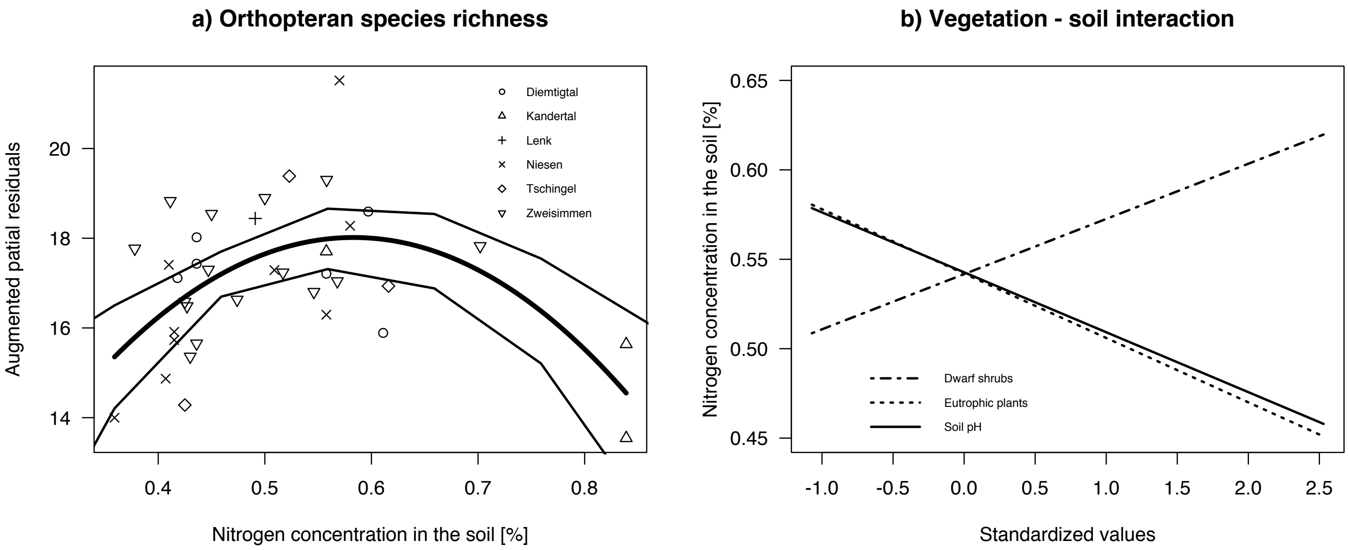


Figure 8: Ensifera species richness is negatively correlated with the quality of *Nardion* grasslands. This relationship in plot a) can mainly be explained by b) the high quality *Nardion* grasslands, which occur often at high altitudes and thus unfavourable for some orthopteran species due to the harsh conditions. Plot a) is a partial residual plot of the best model containing the *Nardion* grassland quality index and plot b) is built on a linear mixed effect model with 'Region' as a random factor, which is indicated by the symbol shapes ($P < 0.001$).

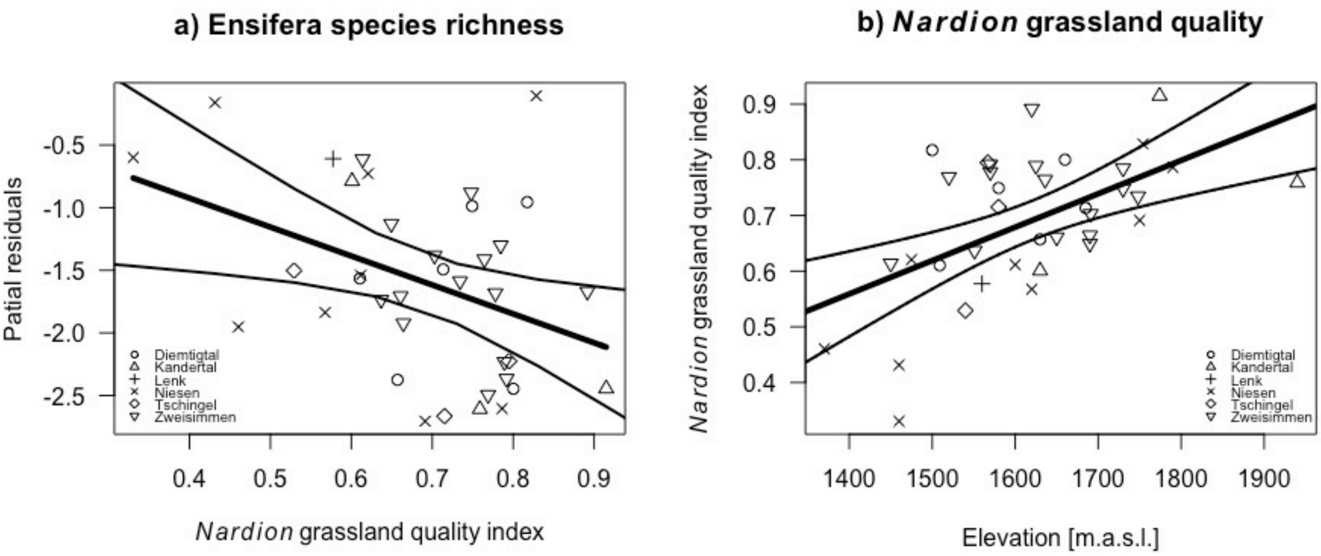


Figure 9: The *Nardion* grassland degradation trend of a dominance of *Nardus stricta* has a negative effect on the orthopteran density. The plot is built on a linear mixed effect model with 'Region' as a random factor, which is indicated by the sybol shape (P = 0.038).

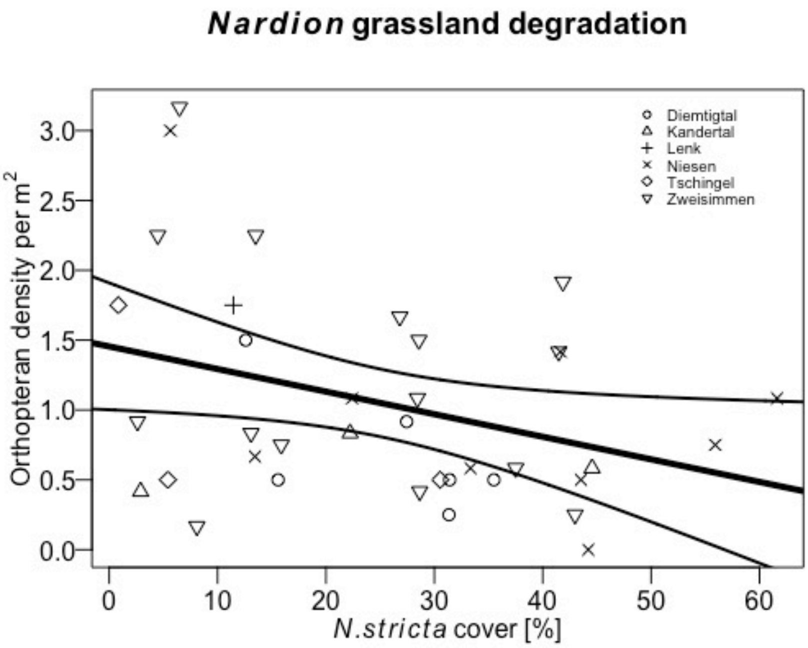
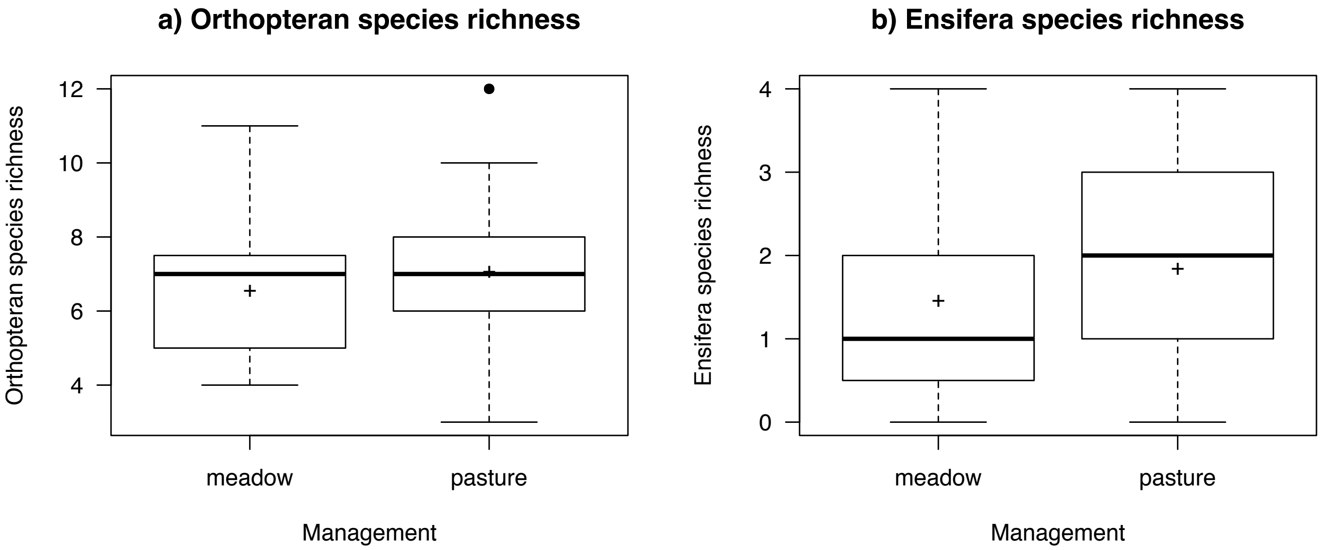


Figure 10: The management had neither a significant effect on a) overall orthopteran species richness nor on b) Ensifera species richness. Both plots are built on linear models ($P > 0.1$, ns) and the sample size was 37 for pastures and 11 for meadows.



8 Appendix

Appendix A: Description and detailed information of the study sites and on the questionnaire to interview farmers on management practises.

Appendix B: ArcGIS file with detailed information on the location of the study site.

Appendix A

Table A1: Inventory of the canton of Berne for all *Nardion* grasslands sorted by management practise (pastures or meadow) and status (species-rich or degraded) in 2014.

Management practise	**Species-rich *Nardion* grasslands**	**Degraded *Nardion* grasslands**	**Total**
Meadow	60	7	67
Pasture	46	56	102
Total	106	63	169

Table A2: Detailed information on all investigated grasslands. X- and Y-Coordinates are indicted in the Swiss coordinate system CH1903. Identification numbers are given by the cantonal authorities to identify the grasslands. Exposition and slope were measured in the centre of the vegetation survey. After visiting all grassland, five meadows were discarded and the specific reasons are indicated in the last column.

Landuse	Identification number	Elevation [m. a. s. l]	Area [ha]	Exposition [°]	Slope [°]	X-Coordinate	Y-Coordinate	Reasons for exclusion
Pasture	5591	1370	0.1346	83	21	312986	158004	-
Pasture	621	1450	1.0645	125	20	592362	157899	-
Pasture	3601	1460	1.1093	285	24	608847	151911	-
Pasture	3600	1460	2.6777	249	32	609847	155911	-
Pasture	1522	1475	2.3010	150	40	2614983	1161365	-
Pasture	620	1500	1.9282	112	21	607696	164443	-
Pasture	1676	1509	4.1733	172	23	602633	162331	-
Pasture	792	1520	0.4881	260	31	558990	151332	-
Pasture	266	1540	0.2984	318	38	624442	156076	-
Pasture	8513	1551	1.5868	150	22	591052	154604	-
Pasture	3539	1567	1.2429	186	21	625292	158258	-
Pasture	1838	1570	0.9793	86	30	590685	153866	-
Pasture	1836	1570	1.4231	28	12	590259	154150	-
Pasture	6163	1580	15.2520	320	30	609847	151911	-
Pasture	541	1580	0.4613	236	39	625056	156831	-
Pasture	1563	1600	3.3096	61	30	611691	156167	-
Pasture	8510	1620	3.0682	124	24	591818	154739	-
Pasture	5592	1620	2.2975	63	23	612267	157809	-
Pasture	790	1625	1.4799	298	21	586205	151405	-
Pasture	5860	1630	2.6439	210	19	603452	163033	-
Pasture	8503	1630	0.3287	36	10	619651	153789	-
Pasture	7789	1636	1.3712	74	18	591714	156076	-
Pasture	1835	1650	0.6383	22	30	590243	154008	-
Pasture	8506	1660	4.8706	268	38	601224	163642	-
Pasture	211	1685	4.99	268	21	601215	164056	-
Pasture	4633	1690	0.9732	312	22	589379	156642	-
Pasture	7806	1690	0.7923	141	21	587852	158535	-

Pasture	8229	1691	2.7143	134	38	590967	155053	-
Pasture	4625	1730	1.9568	119	28	590957	156882	-
Pasture	4638	1730	1.6970	108	18	586310	154746	-
Pasture	1834	1748	1.4012	98	20	589476	154032	-
Pasture	8348	1750	2.7753	242	36	614771	165879	-
Pasture	3863	1754	1.8438	98	22	610499	154692	-
Pasture	843	1774	1.8430	131	22	616710	151420	-
Pasture	8371	1790	1.1653	252	20	613745	165261	-
Pasture	837	1940	2.1942	88	32	615596	115175	-
Meadow	3998	1000	0.2858	90	42	614484	158667	No *N. stricta*
Meadow	3592	1475	0.5629	120	43	608254	151249	-
Meadow	2996	1512	0.4097	95	33	610240	147638	-
Meadow	265	1530	0.3419	230	30	625022	155762	-
Meadow	3596	1558	1.6181	80	43	608720	151734	-
Meadow	1826	1560	0.6185	232	32	589190	152913	Pasture, usedin pasture analysis
Meadow	132	1580	0.3606	184	38	609931	151926	No meadow
Meadow	3629	1585	0.6809	24	39	606482	148955	-
Meadow	8469	1640	0.4330	92	32	597031	143095	-
Meadow	4587	1660	2.5735	184	22	593752	140732	-
Meadow	2999	1680	0.4036	232	8	594287	140591	-
Meadow	2657	1724	2.6172	252	30	595045	144451	Encroach-ment
Meadow	1263	1885	0.9944	172	10	601777	150581	-
Meadow	1220	1925	1.3498	218	4	604313	144553	-
Meadow	4606	2000	6.1736	144	38	604578	143105	No *N. stricta*
Meadow	1791	2013	17.6061	240	24	595578	140327	-

Table A3: Questionnaire used to investigate the management practises of pastures and meadows. The objectives are the variables used for the analysis and the questions used to retrieve the information on them are listed. For each question, a defined type of answer was possible which is indicated in the last column.

Objectives	**Questions**	**Possible answers type**
Type of livestock (pastures)	What kind of livestock is grazing the respective area?	Categorical (cow, cattle(one year old cows), calf, horses, goats, lamas); multiple answers are possible
Number of livestock units (pastures)	How many animals of each kind are grazing the respective area?	Continuous, sum off the multiplication of the coefficient times the number of the respective livestock divided by 100 (Der Schweizerische Bundesrat 2017) Coefficients: cow= 1, cattle = 0.40, calf = 0.33, horse = 0.70, lama=0.17, goat = 0.17
Grazing periods (pastures)	How many grazing periods are applied?	Categorical (one, two or more)
Time of first grazing (pastures)	At what date does the first grazing of the year occur?	Continuous (integer number between 1-365)
Travel time	How many minutes does it take the farmer to reach the grassland from your place of residence?	Continuous (minutes)
Incentives for farming	What are your incentives for managing the respective area?	Categorical (traditional reasons, financial subsidies, yield, stop encroachment, others); multiple answers are possible
Application of fertilizer	Do you currently fertilize the grassland (2016)?	Categorical (yes, no)
Management intensity before	How was the management intensity before the current management?	Categorical (higher, lower, equal)
Time span the management of 2016 was already applied in the past	Since how many years do you manage the grassland with the management practise applied in 2016?	Continuous (years)
Number of cuts (meadows)	How many times do you cut the meadow within one year?	Continuous
Time of the first cut (meadows)	When do you cut the meadow?	Continuous (integer number between 1-365)

9 Erklärung

gemäss Art. 28 Abs. 2 RSL 05

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Studiengang: Master

Titel der Arbeit: „Importance of *Nardion* grassland quality for orthopterans: a case study in the Swiss northern Prealps“

LeiterIn der Arbeit: Dr Jean-Yves Humbert und Prof. Dr Raphaël Arlettaz

Ich erkläre hiermit, dass ich diese Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen benutzt habe. Alle Stellen, die wörtlich oder sinngemäss aus Quellen entnommen wurden, habe ich als solche gekennzeichnet. Mir ist bekannt, dass andernfalls der Senat gemäss Artikel 36 Absatz 1 Buchstabe r des Gesetzes vom 5. September 1996 über die Universität zum Entzug des auf Grund dieser Arbeit verliehenen Titels berechtigt ist. Ich gewähre hiermit Einsicht in diese Arbeit.

Ort/Datum Unterschrift