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RESEARCH PAPER

Long term changes of the inner-alpine steppe vegetation: the dry grassland communities of the Vinschgau (South Tyrol, Italy) 40–50 years after the first vegetation mapping

Maximilian Lübben[1], Brigitta Erschbamer[1]

1 *Department of Botany, University of Innsbruck, Innsbruck, Austria*

Corresponding author: Maximilian Lübben (m.luebben@posteo.de)

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Abstract

Aims: The Vinschgau is the driest inner-alpine valley in the Eastern Alps and harbours a unique steppe vegetation. We studied these dry grassland communities and aimed to answer the following questions: Which plant communities can be found currently? Do the syntaxa described by Braun-Blanquet in the 1960s still prevail in the area? Has there been any change in species composition over the last 40–50 years? **Study area:** Along an approximately 40 km transect, the south-facing slopes of the Vinschgau valley (South Tyrol, Italy) from Mals to Plaus were investigated. **Methods:** For the classification, 92 relevés were sampled in 2019 and compared with 76 relevés from the 1960s and ´70s by means of vegetation tables and ordinations (Detrended Correspondence Analysis). **Results:** Based on our investigation, the majority of dry grassland communities can be classified as *Festuco-Caricetum supinae*. Three subassociations were defined by the dominant species *Stipa capillata*, *Bothriochloa ischaemum* and *Stipa pennata* agg. The comparison of new and old relevés shows an increase in species from the class *Sedo-Scleranthetea* (e.g. *Trifolium arvense*, *Erodium cicutarium*) and the association *Artemisieto-Agropyretum*. In addition, ruderal elements (e.g. *Erigeron annuus*, *Convolvulus arvensis*) have also migrated into dry grasslands. A shift in the dominance over time can be recognized as well. In particular, *Festuca rupicola* and to some extent also *Stipa capillata*, have increased in abundance and frequency. **Conclusions:** We suggest to include the investigated closed dry grasslands in the alliance *Festucion valesiacae*. The rank of the character species at association, alliance and order level should be re-analysed. In order to obtain a better syntaxonomic overview of western and eastern alpine dry grassland communities in relation to Eastern European dry grasslands, a comprehensive study is absolutely necessary. Furthermore, long-term vegetation dynamics and vegetation change need to be studied in more detailed future studies.

Taxonomic reference: Fischer et al. (2008).

Syntaxonomic references: Mucina et al. (2016) for syntaxa from alliance to class level; Braun-Blanquet (1961) for associations.

Abbreviations: agg. = aggregate; cf. = confer (means ‘compare’); DCA = Detrended Correspondence Analysis; s. lat. = sensu lato; s. str. = sensu stricto

Keywords

biodiversity, *Festuco-Brometea*, *Festucetalia valesiacae*, inner-alpine steppes, syntaxonomy, vegetation change

Introduction

The Eurasian steppe belt is the largest steppe region and stretches from the Amur in the east to the Hungarian basin in the west (Hurka et al. 2019). Generally, the Eurasian steppe vegetation harbours a unique and species-rich flora (Dengler et al. 2012; Wilson et al. 2012) and is a key habitat for several animal species (cf. Calaciura and Spinelli 2008; Zulka et al. 2014), especially for insects such as butterflies (WallisDeVries and van Swaay 2009), as well as wild bees, grasshoppers and beetles (WallisDeVries et al. 2002). At the same time, steppes are highly threatened mainly by land use change, e.g. agricultural intensification or abandonment (Habel et al. 2013; Török et al. 2016). A further impact by the ongoing environmental and climate change can be assumed as well (Janssen et al. 2016; Wesche et al. 2016). In contrast to the Eastern steppes, which depend on macroclimate, the Central European steppe vegetation is primarily determined by special edaphic and microclimatic factors. In Central Europe, hence, xerophytic vegetation often has a small expansion and disjunct distribution. These inherently small-scale dry grasslands can be considered as "primary" dry grasslands. The anthropogenic transformation of the landscape, in particular through deforestation of thermophilic woodlands followed by grazing or mowing, led to an area expansion of these "primary" dry grasslands. These dry grasslands, created by anthropogenic influence, make up a significant proportion of the current area of the steppe vegetation in Europe and can be referred to as "secondary" dry grasslands. The exact distinction between primary and secondary dry grasslands is not always possible, however, and this classification is subject to debate (Pott 1996; Ellenberg and Leuschner 2010; Hurka et al. 2019). Outside the Eurasian steppe belt, therefore, there are only azonal islands of steppe vegetation, for instance in central and southern Germany, in Lower Austria and in the inner-alpine dry valleys in the Central Alps (Hurka et al. 2019). The steppe vegetation in these valleys was defined as "Inneralpiner Trockengürtel", i.e. inner-alpine dry belt, by Braun-Blanquet (1961, Figure 1) extending from the Durance valley (France) near the Provence across the Vinschgau (South Tyrol, Italy) northeast to Styria (Austria). These valleys harbour a unique steppe flora. Beside (sub)mediterranean species which occur widely in these dry grasslands, especially Eastern steppe species can reach very far to the west in the inner-alpine dry valleys and often have their western-most occurrences in the region (Braun-Blanquet 1936, 1961; Wagner 1941; Ellenberg and Leuschner 2010; Dengler et al. 2020). The origin and evolution of the extra-zonal steppe vegetation is much discussed (Hurka et al. 2019). A recent study (Kirschner et al. 2020), however, pointed out, that some inner-alpine steppe species are phylogenetically largely independent from their eastern relatives so that these steppes can be seen as a relict steppe vegetation. Within the inner-alpine dry belt, the valleys differ in the strength of the continental climate so that there are extreme and more moderate dry valleys (Figure 1), hence, the flora and plant communities differ between the valleys as well (Braun-Blanquet 1961; Schwabe and Kratochwil 2004). In the driest valley of the Eastern Alps, the Vinschgau, dry grasslands mostly occur along the south-west to south-east facing slopes, the so-called "Vinschgauer Leiten", over approximately 40 km from Mals to Naturns-Plaus (Braun-Blanquet 1961). In addition to the special climatic conditions (Schenk 1949, 1951), especially the lower precipitation on the south-facing slopes, grazing is a primary factor for the occurrence and distribution of these highly diverse communities (Braun-Blanquet 1961; Strimmer 1968; Ellenberg and Leuschner 2010). The interest of botanists for the unique steppe vegetation in South Tyrol resulted into a number of scientific studies at the beginning of the 20th century (citations in Peer 1980). However, apart from the general syntaxonomic overview of the entire inner-alpine dry vegetation by Braun-Blanquet (1961), which still represents the most comprehensive classification of the inner-alpine xerophytic vegetation so far, and the more recent and more ecologically focused overview by Schwabe and Kratochwil (2004, 2012), there are only few phytosociological studies on a regional scale. Recently, inner-alpine dry grasslands in Switzerland were studied (Dengler et al. 2019, 2020) and new syntaxonomical classifications on the European level for the class *Festuco-Brometea* were published (Willner et al. 2017, 2019). However, none included data from the Vinschgau.

In the past, three local scientists were concerned with vegetation mapping and ecophysiological investigations (Strimmer 1968, 1974; Florineth 1973, 1980; Köllemann 1979, 1981), building up the most comprehensive description for the steppe vegetation of Vinschgau. Several other publications were dedicated to selected communities (e.g. Staffler and Karrer 2001; Wilhalm et al. 2008) or floristical research (e.g. Wilhalm 2007; Wilhalm et al. 2007; Zippel and Wilhalm 2009).

Due to the essential impacts on vegetation, such as climate change (Gobiet et al. 2014), land use change (Lüth et al. 2011) and atmospheric nitrogen input (Willner et al. 2019), it is doubtful whether the actual Vinschgau dry grassland communities still correspond to the syntaxa described by Braun-Blanquet (1961) and to the communities outlined by the three local scientists 40 to 50 years ago. Already Schwabe and Kratochwil (2004) have noticed ruderalization trends. Therefore, considerable alterations of the communities may be expected.

In the present study we aimed to repeat the relevés performed in the 1960s and 1970s by the three local authors Strimmer (1968), Florineth (1973) and Köllemann (1979). We visited the sites together with them and they identified quite precisely the localities of their relevés in the field and on their vegetation maps. A total of 76 old relevés of typical dry grasslands were then selected and repeated in 2019.

First, we were interested to check if the character species of the syntaxa described by Braun-Blanquet (1961) are still valid. Second, we compared old and new relevés by means of vegetation tables and ordinations and

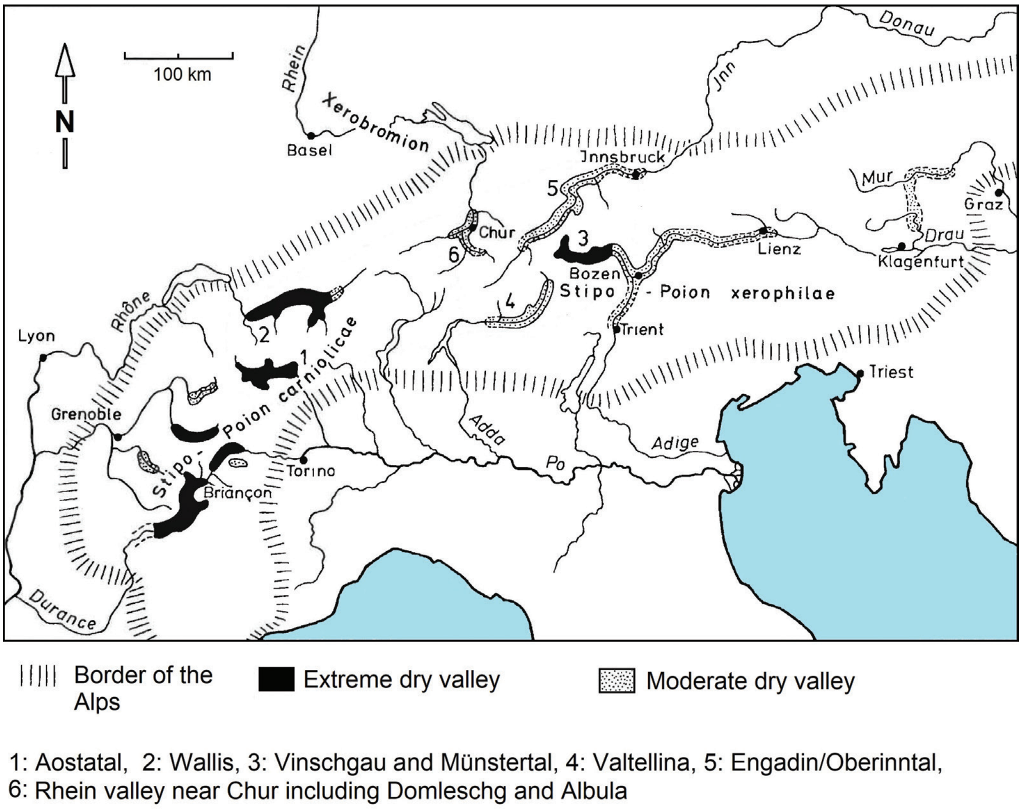

Figure 1. Distribution of the inner-alpine dry valleys (with friendly permission by Angelika Schwabe-Kratochwil, according to Braun-Blanquet (1961), modified by M. Lübben) and the two alliances (*Stipo-Poion carniolicae* and *Stipo-Poion xerophilae*) described by Braun-Blanquet (1961, see also Mucina et al. 2016).

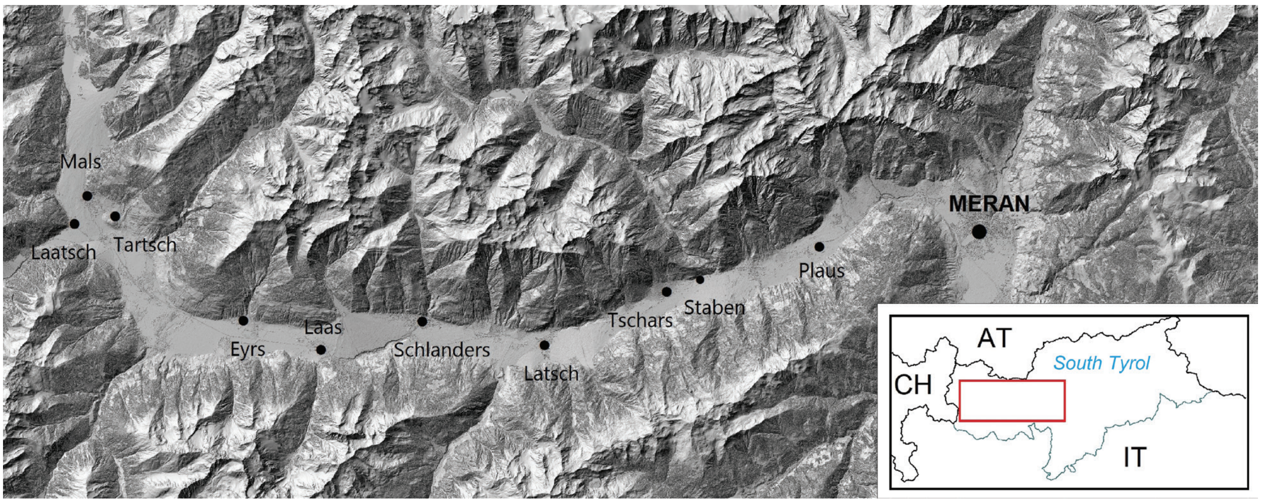

Figure 2. The investigated study area in the Vinschgau (South Tyrol, Italy) at the south-facing slopes from Mals and Laatsch to Plaus, spanning a length of approximately 40 km (Source: Office for Geology and Building Materials Testing of the Autonomous Province of Bolzano and ISPRA (big map); Eurostat (https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units) EuroGeographics for the administrative boundaries (small map)).

analysed the species composition qualitatively as well as quantitatively. The following hypotheses were outlined: (i) Species composition changed considerably in the last 40–50 years; (ii) The number of ruderal elements (Schwabe and Kratochwil 2004) further increased; (iii) Succession tendencies towards shrub vegetation are visible.

Study area

Over the approximately 40 km long transect from Mals to Plaus (Figure 2) the valley bottom of the study area slopes down from approximately 1,000 m to 550 m above sea level (Strimmer 1968). Also, the steepness of the slopes increases continuously from west to east. This leads to the fact that dry grasslands in Vinschgau continuously give way to a bush forest (*Fraxinus ornus*, *Quercus pubescens*) as well as afforestations by *Pinus nigra* and *Robinia pseudacacia* (Köllemann 1979). Precipitation is very low (Schenk 1949, 1951); it amounts to around 500 mm in Schlanders (Figure 3). Geologically, the south-facing slopes belong to the "Austroalpine unit" ("Ostalpin" in German), which consists of various metamorphic rocks such as mica schists and paragneisses. Quartz phyllites, amphibolites, orthogneisses, and marbles also occur (Mair 2010; Keim et al. 2017). The soils consist essentially of sandy clay sediments and typically form pararendzines with predominantly neutral or slightly basic pH (Strimmer 1968; Florineth 1973; Staffler et al. 2003).

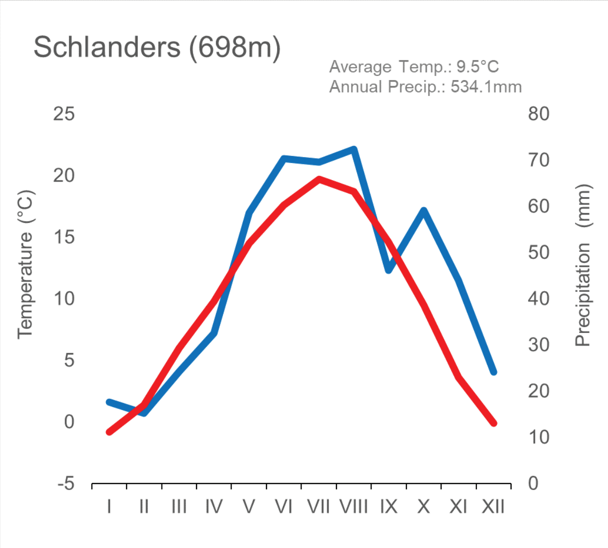

Figure 3. Climate diagram from Schlanders (1981–2010) based on data from the 3PCLIM-project (Source: www.3pclim.eu). The red line shows the monthly mean temperature and the blue line the precipitation. Overall, there is an average temperature of 9.5°C and an annual precipitation rate of approximately 530 mm.

In the 1960s and ´70s mostly all of the lower slopes in Vinschgau were used as pastures (Braun-Blanquet 1961; Strimmer 1968). Due to a change in agricultural policy, including the afforestation of dry grassland sites (Strimmer 1968; Feichter and Staffler 1996; Staffler and Karrer 2005, 2009; Wilhalm et al. 2008), the areal extent of dry grasslands has decreased. The remaining dry grassland areas are still used as pastures for goats, sheep and even cattle.

Methods

Field sampling

Together with Dr. Strimmer, Prof. Dr. Florineth and Dr. Köllemann, 76 relevés were selected from their studies, relocated in spring 2019, and new relevés were sampled in June 2019. Since it became apparent during the field inspections that there are currently only a few dry grassland occurrences in Dr. Köllemann's study area and that these were hardly accessible, only the area between Mals and Staben was investigated. Due to the lack of GPS information, a congruent resurvey was not possible. The old relevés could not be spatially assigned exactly to one plot but to larger areas or slopes, thus, a "one-to-one" comparison of old and new plots was not possible. The comparison, therefore, was more focused on the vegetation type so that all 92 new relevés from June 2019 were compared with the 76 old ones in order to investigate the general changes in the species spectrum. Our relevés were sampled using the same cover scale as the three initial investigators (i.e. Braun-Blanquet 1951) to ensure methodological consistency and to compare the relevés as best as possible. As mentioned above, because of the lack of GPS data for the old relevés, the comparison of old and recent relevés does not have the rank of a permanent plot study. Nevertheless, despite some uncertainties in plot relocation, resurveys are a robust enough method to assess vegetation changes over time (cf. Kopecký and Macek 2015).

Mosses and lichens were not recorded. In the first mapping, plots of 100 m² were used for the Vinschgau dry grasslands (according to Mueller-Dombois and Ellenberg 1974). In this work we decided to use the same plot size in order to be able to compare the plots as well as possible and to minimize uncertainties in plot relocation. In some cases, the size of the plots had to be reduced because of the topography (e.g. rocks, hedges and shrubs, afforestation) and in order to ensure best possible homogeneity. GPS coordinates were recorded from the plot centre by using a Garmin Etrex 10. The elevation (m above sea level) was noted simultaneously to the GPS coordinates. In addition, the upper left and lower right corners (viewed up the slope) of each plot were also marked using a steel plate (10 cm × 10 cm). The inclination (°) was determined with a Suunto PM-5/360 PC clinometer and the exposition (°) with a Recta Type DP 10 compass.

Vegetation classification

The raw table with the relevés from 2019 was sorted iteratively using the frequency of the species as a phytosociological characteristic. Relevés with similar floristic composition form a group which is characterized by character and differential species (Braun-Blanquet 1964; Dierschke et al. 1973; Dierschke 1994). Since all site factors find expression in the floristic composition of the plant community, such table can be interpreted floristically, syndynamically, and synecologically (Tüxen 1970, 1974). More importance was given to the higher cover values of *Bothriochloa ischaemum*, *Stipa capillata* and *S. pennata* agg. which reflect mainly physiognomic and structural aspects, when sorting the table. These species mainly characterize different ecological and physiognomical "formations" of dry grasslands in the study area (Figure 4).

Therefore, the term "subassociation" was defined more widely in this work by taking greater account of these physiognomical and structural aspects (cf. Westhoff 1967; Hurka et al. 2019). The sorted relevé table with subdivisions below association level is shown in Suppl. material 1, according to which a synoptic table (Table 1) was compiled (Dierschke 1994). The raw table is provided in Suppl. material 2 and Suppl. material 3. Similarly, an individual relevé table with the entire dataset (new and old relevés) was sorted to highlight the floristic differences between 2019 and the 1960s/70s. Based on this dataset, a synoptic table (Table 2) was created. Species groups with diagnostic value were listed and indicated by D1, D2.... in all tables to characterize variants of the plant communities below the association level.

Statistical analysis

In addition to the vegetation tables, a Detrended Correspondence Analyses (DCA) was performed in R (R Core Team 2020) version 4.0.3 by using the VEGAN package (Oksanen et al. 2020) in order to analyse the relevés quantitatively. To minimize the problem of an unduly high influence of rare species on the results, a downweighting was carried out by using the function 'decorana ()' with the value iweigh = 1 (Leyer and Wesche 2008; Dormann and Kühn 2011; Oksanen 2015). The Braun-Blanquet scale was converted into the mean abundance values (r → 0.01, + → 0.5, 1 → 2.5, 2 → 15.0, 3 → 37.5, 4 → 62.5) following Dierschke (1994). For further interpretation of the DCA ordination axes, the environmental parameters altitude, aspect and slope inclination were analysed and fitted via the function 'envfit ()' with permutations = 999 (VEGAN package). Only significant parameters were added post hoc on the scatter plot.

Floristical nomenclature and syntaxonomy

The nomenclature of the plant species follows Fischer et al. (2008). If possible, plants were identified at the species or subspecies level. Because of the fact that many species showed only vegetative parts or were in an inadequate condition for proper identification, some (sub)species were grouped into aggregates in case of doubt (marked with 'agg.' in the tables). The following aggregates were used: *Verbascum chaixii* agg. (*Verbascum chaixii* subsp. *chaixii*, *V. chaixii* subsp. *austriacum*), *Thymus praecox* agg. (*Thymus praecox* subsp. *praecox*, *T. praecox* subsp. *polytrichus*), *Thymus pulegioides* agg. (*Thymus pulegioides* subsp. *pulegioides*, *T. pulegioides* subsp. *carniolicus*), *Hieracium pilosella* agg. (*Hieracium pilosella* s.str., *H. pilosella* subsp. *velutinum*), *Stipa pennata* agg. (*Stipa pennata* s. str., *S. eriocaulis* subsp. *eriocaulis*, *S. eriocaulis* subsp. *austriaca*, *S. epilosa*), *Veronica verna* agg. (*Veronica verna* s.str., *V. dillenii*).

Due to a few floristic peculiarities in the Vinschgau, some taxa should be considered closer: *Festuca valesiaca* (2n = 2x = 14) and *Festuca rupicola* (2n = 6x = 42) belong to the *Festuca valesiaca* aggregate. *F. valesiaca* s. str. is, in addition to the microscopic sclerenchyma features, characterized vegetatively by hair-thin and darker blue-green, frosted leaves. The leaf of *F. rupicola* usually has a larger leaf cross-section (typically 0.6–0.7 mm), which can be practiced relatively quickly visually and haptically. Furthermore, it is often characterized by a comparatively warmer shade of green (although a blue-green colour, as is mandatory for *F. valesiaca*, is common). In the Vinschgau also higher-ploidy forms occur which can differ significantly from these two types in their vegetative characteristics. In addition to the number of chromosomes these characteristics primarily concern height, leaf width, leaf cross section and spikelet dimensions. In dry grasslands of lower and middle locations, the two octoploid species *F. bauzanina* (s. str.) and *Festuca bauzanina* subsp. *rhaetica* occur as well (Thomas Wilhalm, pers. comm.; Kiem 1987; Wilhalm et al. 2006; Fischer et al. 2008). However, these "atypical" *Festuca* species were not investigated further. In general, the identification of the *Festuca* species was based on macroscopic and often (by necessity) on mentioned vegetative characteristics and collected herbaria material.

From the *Stipa pennata* complex four elements occur in South Tyrol: *Stipa pennata* s. str. (quite common), *Stipa eriocaulis* (by far the most common species, with subspecies subsp. *eriocaulis* and subsp. *austriaca*), *S. epilosa* (very rare). The taxonomic value of these clades is the subject of current research (Thomas Wilhalm, pers. comm.; Wilhalm et al. 2006). According to Florineth (1973) only *Stipa eriocaulis* occurs in Vinschgau from the aggregate *Stipa pennata*. Schwabe and Kratochwil (2004) indicate *Stipa austriaca* as well as transitional forms to *S. eriocaulis*. Since an exact species identification within this complex was not always possible without any doubt, in this study the species and subspecies are therefore listed under *Stipa pennata* agg.

The delimitation between the (sub)species within the genus *Thymus* is not clear in every case. In our investigation this particularly concerns e.g. the alliance character species *Thymus serpyllum* subsp. *carniolicum* (= *T. pulegioides* subsp. *carniolicus*) (WFO 2021). Generally, hybrids are also very common in the genus *Thymus*, so that the identification is quite difficult (Fischer et al. 2008; Jäger 2017). In many cases it was not possible to identify subspecies so that the two aggregates *Thymus pulegioides* agg. and *T. praecox* agg. are used in this study.

According to Fischer et al. (2008), *Scabiosa columbaria* s. str. is missing in South Tyrol and in the Inner Alps. Plants that correspond to *S. columbaria* in terms of identification or combinations of characteristics are thus to be interpreted here as primary hybrids between *S. triandra* and *S. lucida* and listed under *S. columbaria* s. lat.

Hieracium pilosella s. str. and *Hieracium velutinum* are included in the *Hieracium pilosella* agg. (Fischer et al. 2008). In general, this aggregate is very rich in form and includes hybrid populations (Wilhalm et al. 2006). According to Dengler et al. (2019), *H. velutinum* differs also from *Hieracium pilosella* s. str. ecologically, as it occurs on much drier sites. In this work the species is listed as *Hieracium pilosella* agg.

Syntaxonomy and classification were essentially based on Braun-Blanquet (1961), Mucina and Kolbek (1993a) and Schwabe and Kratochwil (2004). The mentioned character species in the Suppl. material 1 and in Table 1 as well as the nomenclature of the associations are based essentially on Braun-Blanquet (1961). The nomenclature of the high rank syntaxa followed Mucina et al. (2016).

Results

Syntaxonomy of the new relevés

Based on the character species *Astragalus exscapus*, *Carex liparocarpos*, *Festuca rupicola*, *F. valesiaca*, *Oxytropis xerophila*, *Petrorhagia saxifraga*, *Potentilla pusilla*, *Pulsatilla montana*, *Silene otites* and *Stipa capillata* dry grassland communities recorded in 2019 (Table 1 and Suppl. material 1) can be assigned to the order of continental dry grasslands, *Festucetalia valesiacae* in the *Festuco-Brometea* class. Furthermore, from the alliance *Stipo-Poion xerophilae* only the relatively constant *Centaurea stoebe* can be mentioned. *Poa molinerii* (= *Poa xerophila*) occurred only in one relevé. At the association level, the *Festuco-Poetum xerophilae* and the *Festuco-Caricetum supinae* were identified.

The ***Festuco-Poetum xerophilae*** could be documented in only five relevés from the northwest of the study area, near Laatsch (Figure 2). It extends between approximately 1,000 m and 1,100 m a.s.l. on relatively steep, east to south-east exposed slopes. The association can be characterized by *Achillea nobilis* and, to a lesser extent, *Thesium linophyllon*. The species group *Anthoxanthum odoratum*, *Bromus erectus*, *Pimpinella saxifraga*, *Potentilla argentea* (D1, Table 1) as well as some taller shrubs such as, *Prunus spinosa* and *Rosa* sp. distinguished this association from the other investigated dry grasslands. *Poa molinerii* was not present in this community.

The ***Festuco-Caricetum supinae*** (87 relevés) occurred on the south-west to south-facing slopes from Tartsch near Mals approximately to Staben-Plaus (Figure 2) with an elevation range between 560 m and 1,400 m a.s.l. These areas were almost all identified as pastures that are still used or were used in the past, extending on more even areas (e.g. at Laas). The *Festuco-Caricetum supinae* can be divided into three subassociations (Table 1): with *Stipa capillata* (*stipetosum capillatae*), with *Bothriochloa ischaemum* (*bothriochloetosum ischaemi*), and with *Stipa pennata* agg. (*stipetosum pennatae*). The DCA (Figure 5) clearly shows the correlation of inclination for the *stipetosum pennatae* and of altitude for the two other associations, particularly for the *bothriochloetosum ischaemi*. It also highlights "outlier relevés", which can be seen as transitional stages between subassociations.

Table 1. Synoptic table of the dry grassland communities in the Vinschgau (South Tyrol, Italy) with all relevés from 2019. Values are percentage frequencies. Only companion species with frequency > 15% are stated. I = *Festuco-Poetum xerophilae* (col. 1); II = *Festuco-Caricetum supinae*; II.1 = subassociation *stipetosum capillatae* (cols. 2–4); II.2 = subassociation *bothriochloetosum ischaemi* (cols. 5, 6); II.3 = subassociation *stipetosum pennatae* (cols. 7, 8). The name giving species *Stipa capillata*, *Bothriochloa ischaemum* and *Stipa pennata* agg. are indicated in bold. Variants (D1–D7, cols 2–8) were identified based on the similarity of the species composition: *Veronica verna*-variant (cols. 2, 5), typical variant (cols. 3, 6, 8), species-poor variant (col. 4), *Melica ciliata*-variant (col. 7). Abbreviations: AC = association character species, agg. = aggregate, cf. = confer (means 'compare'), juv. = juvenile, KC = class character species, OC = order character species, s. lat. = sensu lato, sp. = species, ssp. = subspecies, VC = alliance character species.

Vegetation type	I		II.1		II.2		II.3	
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Number of relevés	5	12	25	8	13	8	9	12
AC1: *Festuco-Poetum xerophilae*								
Achillea nobilis	100	–	–	–	–	–	–	–
Thesium linophyllon	80	33	12	–	31	–	–	8
D1								
Bromus erectus	60	25	16	–	8	13	11	8
Pimpinella saxifraga	80	–	4	–	8	–	–	–
Prunus spinosa	60	8	–	–	–	–	–	–
Potentilla argentea	40	8	–	–	8	–	–	–
Anthoxanthum odoratum	40	–	–	–	–	–	–	–
AC2: *Festuco-Caricetum supinae*								
Astragalus onobrychis	20	92	84	13	100	88	100	58
Carex supina	–	67	80	25	100	75	78	33
Achillea tomentosa	–	67	28	50	77	38	11	25
D2								
Artemisia absinthium	–	75	8	–	38	–	–	–
Buglossoides incrassata	20	58	4	–	31	–	–	–
Erodium cicutarium	–	50	4	13	38	–	–	–
Convolvulus arvensis	–	50	4	–	8	13	–	–
D3								
Veronica verna agg.	20	92	44	63	77	38	11	8
Trifolium arvense	100	75	12	88	85	13	11	25
Trifolium campestre	–	50	–	13	77	13	11	–
Plantago lanceolata	–	58	8	–	46	13	–	–
Turritis glabra	40	50	12	–	69	–	–	8
D4								
Silene nutans	–	–	16	–	–	13	–	–
Plantago media	–	8	16	–	–	13	–	–
Carduus nutans	20	–	20	–	8	–	–	–
Achillea cf. *collina*	–	–	8	–	–	13	–	–
Trifolium repens	–	–	8	–	–	–	–	–
D5								
Erigeron annuus	–	–	–	75	–	13	–	8
Chondrilla juncea	–	25	16	50	–	–	11	8
Quercus pubescens juv.	–	–	–	38	–	–	–	8
Prunus mahaleb	–	–	8	38	8	13	–	–
Filago arvensis	20	17	12	50	8	–	–	8
D6								
Melica ciliata	40	42	8	13	15	13	100	–
Allium sphaerocephalon	100	25	8	25	23	13	67	8
D7								
Scorzonera austriaca	–	–	8	–	–	–	–	25
Ephedra helvetica	–	–	–	–	–	–	–	17
Telephium imperati	–	–	–	–	–	–	–	17
Seseli pallasii	–	–	–	38	–	13	–	17
Kengia serotina	–	–	–	13	–	–	–	25
VC: *Stipo-Poion xerophilae*								
Centaurea stoebe	80	67	52	100	85	50	44	42
Thymus pulegioides agg.	–	17	–	–	31	–	11	–
Verbascum chaixii agg.	–	–	4	–	–	–	–	17

Vegetation type	I		II.1		II.2		II.3	
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Number of relevés	5	12	25	8	13	8	9	12
Poa molinerii	–	–	–	–	–	13	–	–
OC: *Festucetalia valesiacae*								
Potentilla pusilla	100	83	96	75	100	100	100	83
Festuca valesiaca	80	83	84	88	92	88	78	83
Festuca rupicola	80	58	88	100	69	100	89	83
Stipa capillata	80	100	100	100	62	88	44	25
Petrorhagia saxifraga	80	75	36	88	77	75	100	75
Silene otites	100	58	56	75	85	63	56	42
Carex liparocarpos	20	33	32	63	8	13	22	33
Pulsatilla montana	40	8	8	–	23	–	–	8
Astragalus exscapus	–	8	16	–	15	13	–	–
Oxytropis xerophila	–	–	4	–	–	25	–	–
KC: *Festuco-Brometea*								
Veronica spicata	100	17	16	25	69	38	–	17
Galium lucidum	100	42	44	25	15	–	44	58
***Stipa pennata* agg.**	100	33	16	50	8	25	100	100
Artemisia campestris	80	100	92	88	100	88	100	100
Phleum phleoides	100	92	88	88	85	75	78	75
Koeleria macrantha	80	83	84	75	100	50	100	67
Thymus praecox agg.	100	67	96	63	77	100	67	67
Verbascum lychnitis	60	67	76	63	54	63	44	25
Alyssum alyssoides	60	83	56	25	85	50	89	50
Arenaria serpyllifolia	60	83	52	50	92	63	67	–
Bothriochloa ischaemum	20	75	40	88	100	88	78	50
Stachys recta subsp. *recta*	60	50	40	13	8	38	78	50
Carex humilis	60	42	16	13	15	50	22	33
Lotus corniculatus	20	42	32	–	31	–	–	8
Astragalus glycyphyllos	–	25	4	–	–	–	–	–
Fumana procumbens	–	8	44	50	23	75	22	50
Helianthemum nummularium subsp. *obscurum*	20	–	24	75	8	13	33	58
Medicago minima	40	42	32	38	23	25	11	17
Clinopodium acinos	20	33	4	–	62	13	33	17
Companion species								
Sempervivum arachnoideum	100	50	56	75	85	88	67	92
Hieracium pilosella agg.	100	50	68	25	54	100	44	50
Teucrium chamaedrys	100	42	56	75	23	13	44	67
Erysimum rhaeticum	60	83	40	13	77	63	44	25
Sempervivum tectorum	40	25	32	63	46	38	78	92
Dianthus sylvestris	80	42	36	25	46	75	44	67
Plantago strictissima	80	58	44	–	46	63	22	–

Vegetation type	I		II.1		II.2		II.3	
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Number of relevés	5	12	25	8	13	8	9	12
Sedum montanum s. lat.	100	58	12	25	31	25	78	33
Scabiosa columbaria s. lat.	–	25	36	50	38	38	56	17
Teucrium montanum	20	25	40	–	23	50	44	42
Berberis vulgaris	60	50	40	–	15	50	11	33
Chenopodium album	–	33	24	38	54	13	11	8
Medicago falcata	40	58	28	25	8	–	–	17
Juniperus communis	–	25	28	–	23	13	33	25
Sedum sexangulare	20	17	12	–	38	25	–	17
Lactuca perennis	40	17	12	–	8	13	22	25
Euphorbia cyparissias	–	8	8	38	15	13	22	8
Tragopogon dubius	20	33	8	–	23	–	22	–
Carex caryophyllea	20	17	16	25	15	–	–	–
Saponaria ocymoides	–	8	12	–	15	–	33	17
Veronica prostrata	–	25	4	–	31	–	–	–
Arabidopsis thaliana	60	8	4	–	15	13	–	–
Anthericum liliago	–	–	4	13	15	–	22	17
Viola cf. *kitaibeliana*	–	33	4	–	15	–	–	–
Rosa cf. *micrantha*	20	8	8	–	–	13	11	–
Rosa sp.	20	8	4	–	15	–	11	–
Allium lusitanicum	–	–	12	–	–	13	–	17
Asplenium septentrionale	40	8	–	25	–	13	–	–
Fraxinus ornus juv.	–	–	–	13	8	–	22	17
Phelipanche bohemica	20	17	–	–	–	–	22	–
Securigera varia	20	–	4	–	15	–	11	–
Bromus japonicus	–	–	–	25	15	–	–	–
Robinia pseudacacia juv.	–	–	–	–	–	–	11	25
Poa angustifolia	20	8	4	–	–	–	–	8
Astragalus vesicarius subsp. *pastellianus*	–	–	–	–	–	–	11	25
Descurainia sophia	–	25	–	–	8	–	–	–
Echium vulgare	–	17	–	–	8	–	–	–
Torilis arvensis	–	–	–	25	8	–	–	–
Hypericum maculatum	–	–	–	–	23	–	–	–
Calina acaulis	–	17	4	–	–	–	–	–
Verbascum nigrum	–	17	–	–	–	–	–	–
Silene vulgaris	20	–	–	–	–	–	11	–
Linaria angustissima	20	–	–	–	–	–	–	8
Trifolium alpestre	20	–	–	–	–	13	–	–
Cuscuta epithymum	40	–	–	–	–	–	–	–
Vicia tetrasperma	–	–	–	25	–	–	–	–
Geum montanum	20	–	–	–	–	–	–	–

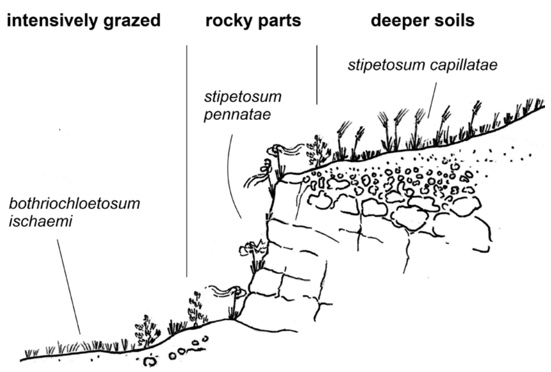

Figure 4. Idealised scheme of the ecological occurrence of the three subassociations of the *Festuco-Caricetum supinae* (cf. Strimmer 1974). The *bothriochloetosum ischaemi* occurs mainly in intensively grazed areas, very often on the foot slopes, especially near the village Mals, and sometimes on terraces as well. The *stipetosum pennatae* characterize the rockier slopes, rocky pulpits and occurs sometimes on rocky parts within the plain areas. The subassociation *stipetosum capillatae* mostly occur on deeper soils, often on terraces and form very often dense vegetation layers. (Created by M. Lübben).

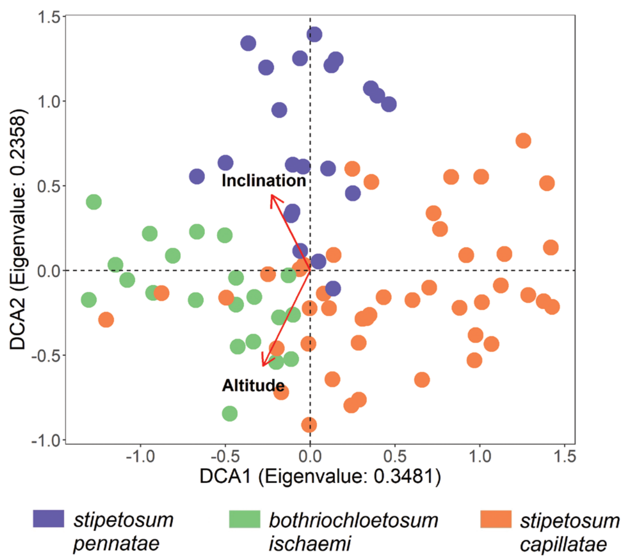

Figure 5. Ordination (DCA) of the *Festuco-Caricetum supinae*. Three subassociations are shown, characterized by the dominant species *Stipa capillata*, *Bothriochloa ischaemum*, and *Stipa pennata* agg. Transitions between the subassociations are visible.

Subassociation *stipetosum capillatae*

The subassociation with *Stipa capillata* was found on low mountain terraces and lower slopes with deeper soils. The community was grass-rich and very often contained tall herbs (Figure 6). Beside *Stipa capillata*, a particularly high abundance of *Festuca rupicola* and *F. valesiaca* was obvious. The character species of the *Festuco-Brometea* class, such as *Artemisia campestris*, *Koeleria macrantha* and *Phleum phleoides*, were also frequently present. Three variants were identified: the variant with *Veronica verna*, a typical variant and a species-poor variant in which the association character species were less frequent. In the *Veronica verna*-variant *Artemisia absinthium*, *Convolvulus arvensis* or *Plantago lanceolata* and some annuals such as *Buglossoides incrassata*, *Trifolium arvense* and *Veronica verna* itself occurred (D2, D3 in Table 1). The typical variant was mainly characterised by the high abundance of grass species such as *Festuca rupicola*, *F. valesiaca*, and *Stipa capillata*. In few relevés of this variant more mesophilic species such as *Achillea* cf. *collina*, *Trifolium repens* and *Plantago media* occurred. In the species-poor variant almost all character species of the *Festuco-Caricetum supinae* were lacking. In addition, ruderal species such as *Chondrilla juncea*, *Erigeron annuus* and *Filago arvensis* occurred with high abundance (D5 in Table 1). It has to be mentioned that *Bothriochloa ischaemum* occurred with higher abundance and frequency in this variant as well (Table 1).

Figure 6. Subassociation *stipetosum capillatae* (Photo: M. Lübben).

Subassociation *bothriochloetosum ischaemi*

This subassociation dominated on the heavily grazed areas of the terraces and the lowest slopes, especially near Mals. The more open and very low-growing vegetation was dominated by *Bothriochloa ischaemum*, *Festuca valesiaca*, *Potentilla pusilla* and *Thymus praecox* agg. (Figure 7). *Alyssum alyssoides*, *Arenaria serpyllifolia* and *Artemisia campestris* were also recorded. Overall, the herb layer of this subassociation was open. Even here two variants were identified. The *Veronica verna*-variant was represented by *Trifolium arvense*, *T. campestre*, *Veronica verna* and to some extent also by *Plantago lanceolata*, *Turritis glabra* (D3 in Table 1). *Artemisia absinthium*, *Buglossoides incrassata* and *Erodium cicutarium* (D2 in Table 1) were still present but not very dominant. In the typical variant, almost all species from the *Veronica verna*-variant were absent or occurred less frequently. Only *Festuca rupicola*, *Fumana procumbens*, *Hieracium pilosella* agg. and *Thymus praecox* agg. were more frequent. *Poa molinerii* was present only in this variant.

Figure 7. Subassociation *bothriochloetosum ischaemi* (Photo: M. Lübben).

Subassociation *stipetosum pennatae*

The subassociation *stipetosum pennatae* characterized the rockier slopes, which were at great risk of erosion, and on rocky outcrops so that the canopy layer showed more gaps (Figure 8). The highly dominant *Stipa pennata* agg. separated the community from the other subassociations (Figure 5, Table 1). The character species of the order, i.e. *Festuca rupicola*, *F. valesiaca* and *Potentilla pusilla* were present. *Artemisia campestris*, *Koeleria macrantha*, *Phleum phleoides*, and *Thymus praecox* agg. were also frequent. *Stipa capillata* was found a few times and with low cover values. *Bothriochloa ischaemum* occurred just as frequently, but with barely abundance as well. Two variants were identified: the *Melica ciliata*-variant and the typical variant. Within the *Melica ciliata*-variant (D6 in Table 1) *Melica ciliata* and *Allium sphaerocephalon* were highly dominant. In the typical variant these two species were missing, and the character species *Astragalus onobrychis* and *Carex supina* of the *Festuco-Caricetum supinae* were significantly

Figure 8. Subassociation *stipetosum pennatae* (Photo: M. Lübben).

less abundant than in the *Melica ciliata*-variant. In addition, in some relevés of this variant *Kengia serotina*, *Scorzonera austriaca* and *Seseli pallasii* occur (D7 in Table 1).

Vegetation change over the last 40–50 years

The comparison of new and old relevés showed a clear vegetation change. Over the last 40–50 years, a large group of species newly immigrated (D1 in Table 2). The following species achieved a higher constancy in the immigrating group: *Chenopodium album*, *Erodium cicutarium*, *Plantago lanceolata* and *Trifolium campestre* (Table 2, cols. 1–2). Together with these species, a number of sporadically occurring species were also new, such as *Astragalus glycyphyllos*, *Descurainia sophia* (Table 2, cols. 1–2), *Erigeron annuus* (Table 2, cols. 2–4) and *Silene nutans* (Table 2, col. 3) together with a bunch of species with very low occurrence. Some species such as *Arenaria serpyllifolia*, *Artemisia absinthium*, *Buglossoides incrassata*, *Festuca rupicola*, *Trifolium arvense*, *Turritis glabra* and *Veronica verna* agg. (D2, Table 2) showed a higher constancy in the new relevés and appeared rarely in the old ones. Among them, *F. rupicola* with its highest constancy clearly separated the new and old relevés. The species group only present or dominating in the old relevés contained grassland species and a few shrubs (D3, Table 2). The diagnostic species of inner-alpine dry grasslands were found with slightly diverging constancy (D4, Table 2) or with equal constancy (D5, Table 2) in the new and old relevés.

The quantitative analysis of the relevés (DCA ordination) confirmed the discrimination of old and new relevés (Figure 9). The separation basically follows DCA axis 1, reflecting the floristic differences.

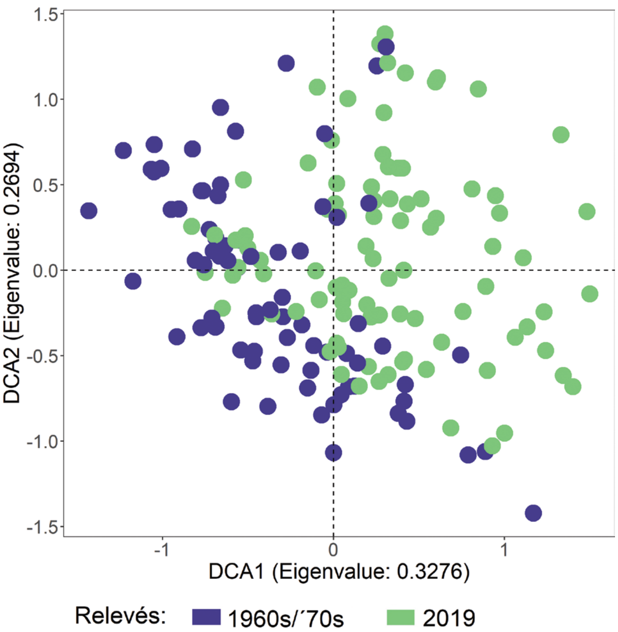

Figure 9. Ordination (DCA) of the old relevés (1960s / ´70s) and new relevés (2019).

Table 2. Synoptic table of the dry grassland communities in the Vinschgau (South Tyrol, Italy) from 2019 in comparison to the 1960s/´70s. Values are percentage frequencies. The columns 1 to 9 show the different relevé groups based on the similarity of the species (2019, cols. 1-5; 1960s/70s, cols. 6–9). Different species groups (D1 – D5) were identified which separate the new and old relevés. The floristical shift over time is illustrated by these groups. In D5 species are stated which do not show a clear change over time in their frequencies. Only species with frequency > 15% are stated in this group. Abbreviations: agg. = aggregate, cf. = confer (means "compare"), juv. = juvenile, s. lat. = sensu lato, sp. = species.

Sampling period			2019				1960/70		
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Number of relevés	17	16	19	17	23	15	24	26	11
D1									
Camelina microcarpa	6	–	–	–	–	–	–	–	–
Lolium perenne	6	–	–	–	–	–	–	–	–
Medicago sativa	6	–	–	–	–	–	–	–	–
Geum montanum	6	–	–	–	–	–	–	–	–
Reseda luteola	6	–	–	–	–	–	–	–	–
Silene vulgaris	6	6	–	–	–	–	–	–	–
Descurainia sophia	18	6	–	–	–	–	–	–	–
Astragalus glycyphyllos	18	6	–	–	–	–	–	–	–
Bromus japonicus	12	13	–	–	–	–	–	–	–
Linaria angustissima	6	–	–	6	–	–	–	–	–
Papaver dubium	6	6	–	6	–	–	–	–	–
Torilis arvensis	6	6	–	6	–	–	–	–	–
Viola cf. *kitaibeliana*	29	6	–	–	4	–	–	–	–
Plantago lanceolata	65	19	11	–	–	–	–	–	–
Erodium cicutarium	59	13	5	–	–	–	–	–	–
Trifolium campestre	59	44	–	6	4	–	–	–	–
Chenopodium album	47	50	21	–	13	–	–	–	–
Arabidopsis thaliana	18	6	5	6	9	–	–	–	–
Anthericum liliago	6	13	5	18	4	–	–	–	–
Rosa cf. *micrantha*	6	–	11	12	4	–	–	–	–
Plantago media	6	–	21	–	4	–	–	–	–
Taraxacum laevigatum	6	–	16	–	4	–	–	–	–
Phelipanche bohemica	12	–	–	6	9	–	–	–	–
Poa angustifolia	12	–	–	6	4	–	–	–	–
Asplenium septentrionale	6	–	–	18	9	–	–	–	–
Prunus spinosa	12	–	–	–	9	–	–	–	–
Lactuca serriola	6	–	5	12	–	–	–	–	–
Erigeron annuus	–	25	5	18	–	–	–	–	–
Quercus pubescens	–	13	–	6	4	–	–	–	–
Sanguisorba minor	–	13	–	–	4	–	–	–	–
Senecio inaequidens	–	13	–	6	–	–	–	–	–
Vicia tetrasperma	–	13	–	–	–	–	–	–	–
Orobanche artemisiae-campestris	–	6	–	–	–	–	–	–	–
Ononis spinosa	–	6	–	–	–	–	–	–	–
Salvia pratensis	–	6	5	–	–	–	–	–	–
Veronica fruticans	–	–	5	6	4	–	–	–	–
Silene nutans	–	–	26	–	–	–	–	–	–
Achillea cf. *collina*	–	–	16	–	–	–	–	–	–
Trifolium repens	–	–	11	–	–	–	–	–	–
Myosotis stricta	–	–	5	–	–	–	–	–	–
Carlina vulgaris	–	–	5	–	–	–	–	–	–
Anchusa arvensis	–	–	5	–	–	–	–	–	–
Cynoglossum officinale	–	–	5	–	–	–	–	–	–
Lonicera xylosteum	–	–	5	–	–	–	–	–	–
Cerastium semidecandrum	–	–	5	–	–	–	–	–	–
Kengia serotina	–	–	–	24	–	–	–	–	–
Viscaria vulgaris	–	–	–	18	–	–	–	–	–
Quercus petraea	–	–	–	6	–	–	–	–	–
Ulmus minor	–	–	–	6	–	–	–	–	–
Carduus defloratus	–	–	–	6	–	–	–	–	–
Trifolium alpestre	–	–	–	6	4	–	–	–	–
Cuscuta epithymum	–	–	–	–	9	–	–	–	–
Bromus tectorum	–	–	–	–	9	–	–	–	–
Anthoxanthum odoratum	–	–	–	–	9	–	–	–	–
Telephium imperati	–	–	–	–	9	–	–	–	–
Aster alpinus	–	–	–	–	4	–	–	–	–
Ononis natrix	–	–	–	–	4	–	–	–	–

Sampling period			**2019**					**1960/70**	
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Number of relevés	17	16	19	17	23	15	24	26	11
D2									
Artemisia absinthium	71	–	–	6	13	–	4	–	9
Buglossoides incrassata	76	–	–	–	–	–	–	–	9
Turritis glabra	59	38	11	–	13	–	8	–	–
Chondrilla juncea	18	19	5	35	–	–	4	–	9
Trifolium arvense	82	88	–	41	22	7	38	12	9
Sedum sexangulare	29	6	21	–	22	–	–	15	9
Veronica verna agg.	76	100	32	18	22	–	4	–	–
Arenaria serpyllifolia	82	75	74	24	39	7	–	–	–
Festuca rupicola	71	69	89	88	91	13	–	27	36
D3									
Saponaria ocymoides	18	6	5	12	17	47	33	4	9
Rosa sp.	6	13	–	–	13	60	38	4	9
Oxytropis pilosa	–	–	–	–	–	13	4	–	–
Onosma helvetica subsp. *tridentata*	–	–	–	–	–	13	13	–	–
Asparagus officinalis	–	–	–	–	–	7	13	–	–
Orobanche gracilis	–	–	–	–	–	7	–	–	9
Veronica teucrium	–	–	–	–	–	7	–	–	–
Phelipanche arenaria	–	–	–	–	–	–	8	–	–
Cirsium sp.	–	–	–	–	–	–	4	–	–
Clinopodium alpinum	–	–	–	–	–	–	4	–	–
Medicago lupulina	–	–	–	–	–	–	4	–	–
D4									
Stipa pennata agg.	24	38	–	82	74	73	8	35	27
Alyssum alyssoides	82	69	42	29	87	47	29	15	36
Achillea tomentosa	76	63	21	29	17	53	54	19	55
Berberis vulgaris	35	6	53	6	52	93	79	4	9
Juniperus communis	24	6	32	–	39	80	92	12	9
Hieracium pilosella agg.	65	25	79	29	87	73	92	81	9
Dianthus sylvestris	47	31	37	41	74	80	83	81	36
Plantago strictissima	65	13	53	–	52	67	88	92	64
Teucrium montanum	29	13	42	24	48	80	88	62	–
Thymus praecox agg.	71	75	100	59	91	87	75	88	82
Stipa capillata	82	81	100	59	65	80	83	88	82
Bothriochloa ischaemum	71	94	42	71	57	93	92	81	64
Centaurea stoebe	88	75	47	47	57	87	92	88	73
D5									
Artemisia campestris	94	100	95	88	96	100	96	85	100
Potentilla pusilla	88	88	95	94	96	93	83	96	100
Festuca valesiaca	82	88	95	71	87	73	100	96	100
Astragalus onobrychis	82	69	89	59	78	100	79	85	82
Phleum phleoides	94	94	79	82	74	73	79	69	64
Sempervivum arachnoideum	71	69	58	71	87	80	96	65	36
Koeleria macrantha	88	88	68	100	70	80	75	46	36
Petrorhagia saxifraga	71	88	47	76	65	100	83	62	45
Silene otites	71	75	42	47	78	93	88	50	27
Carex supina	71	69	74	47	65	33	50	50	64
Erysimum rhaeticum	88	50	32	24	57	80	67	23	18

Sampling period			**2019**					**1960/70**	
Column number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Number of relevés	17	16	19	17	23	15	24	26	11
Carex humilis	35	13	26	24	35	67	58	85	36
Verbascum lychnitis	59	63	89	35	48	53	25	8	27
Sempervivum tectorum	35	31	16	88	70	93	33	12	18
Teucrium chamaedrys	41	38	47	53	65	73	50	4	18
Galium lucidum	29	31	26	24	74	67	58	15	27
Scabiosa columbaria s. lat.	47	25	26	41	30	53	75	38	–
Fumana procumbens	18	38	37	53	35	73	54	27	–
Stachys recta subsp. *recta*	29	25	47	47	48	73	38	4	9
Veronica spicata	41	38	11	18	39	20	29	46	45
Sedum montanum s. lat.	53	13	11	41	61	60	33	12	–
Helianthemum nummularium subsp. *obscurum*	6	25	11	65	30	73	50	15	9
Medicago falcata	53	13	32	6	13	27	46	31	36
Allium sphaerocephalon	24	25	–	29	43	40	33	8	18
Lotus corniculatus	53	19	21	6	9	13	50	27	–
Carex liparocarpos	35	38	26	24	22	–	–	31	36
Clinopodium acinos	41	31	5	18	17	40	33	4	18
Melica ciliata	35	19	–	24	39	40	17	8	18
Medicago minima	29	31	37	29	17	–	13	–	9
Tragopogon dubius	29	19	–	18	4	27	25	8	18
Bromus erectus	29	13	11	6	17	33	17	–	9
Thesium linophyllon	41	13	11	–	22	7	17	4	9
Carex caryophyllea	29	19	11	6	–	–	4	31	18
Astragalus exscapus	6	13	16	–	9	–	4	38	9
Euphorbia cyparissias	12	13	11	12	17	13	17	–	–
Filago arvensis	12	19	11	18	9	–	13	8	9
Carduus nutans	12	–	26	–	–	7	33	4	9
Lactuca perennis	6	13	5	24	26	13	4	–	–
Verbascum nigrum	6	6	–	–	–	–	–	42	27
Galium verum	6	6	5	–	–	27	25	8	9
Thymus pulegioides agg.	24	13	–	–	4	13	13	12	–
Allium lusitanicum	–	6	11	6	9	27	13	4	–
Pulsatilla montana	12	13	11	–	13	–	–	15	–
Pimpinella saxifraga	12	–	5	–	13	–	21	8	–
Seseli pallasii	–	6	–	24	4	20	13	–	9
Calina acaulis	12	–	5	–	–	–	8	19	18
Oxytropis xerophila	–	–	11	–	4	–	13	19	9
Astragalus vesicarius subsp. *pastellianus*	–	–	–	6	13	13	21	4	–
Convolvulus arvensis	35	–	–	6	9	7	4	–	9
Prunus mahaleb	–	19	11	–	9	–	17	–	–
Securigera varia	6	6	5	–	9	7	17	–	–
Veronica prostrata	24	13	5	–	4	–	–	4	9
Potentilla argentea	6	–	–	–	13	7	4	4	18
Scorzonera austriaca	–	6	–	12	9	27	–	–	–
Fraxinus ornus juv.	6	–	–	18	9	–	–	–	9
Robinia pseudacacia	–	–	–	18	4	7	4	–	9
Lappula squarrosa	6	–	16	6	–	–	4	–	–
Achillea nobilis	6	–	–	–	17	–	–	–	9
Echium vulgare	18	–	–	–	–	–	–	–	9

Discussion

Validity of Braun-Blanquet's (1961) syntaxonomy

Following Braun-Blanquet (1961), our relevés from 2019 were clearly included in the order *Festucetalia valesiacae* (class *Festuco-Brometea*). The alliance affiliation (*Stipo-Poion xerophilae*) was less justifiable, because only one character species – *Centaurea stoebe* – connected the relevés to this alliance. Even if we consider the order character species *Festuca rupicola* (cf. Mucina and Kolbek 1993a) as a character species for the alliance *Stipo-Poion xerophilae*, doubts on the validity of the *Stipo-Poion xerophilae* may be raised. Dengler et al. (2019) defined it as "rocky grassland alliance". In our study, *Poa xerophila* (valid species name = *Poa molinerii*) was recorded in only one relevé. Therefore, we suggest to skip this alliance for most of Vinschgau dry grasslands and to classify them as *Festucion valesiacae*, similarly to Mucina et al. (2016) and Dengler et al. (2019, 2020). These authors outlined the Eastern European *Festucion valesiacae* as "non rocky grassland of the Swiss inner-alpine valley" and we highly agree to use this definition also for the investigated Vinschgau' dry grasslands.

On the association level, we were able to identify two associations (*Festuco-Poetum xerophilae* and *Festuco-Caricetum supinae*). According to Braun-Blanquet (1936, 1961), the *Festuco-Poetum xerophilae* holds an intermediate position between the *Koelerio-Poetum xerophilae* from the Engadin (Switzerland), which has less xerophytes, and the *Festuco-Caricetum supinae*. In our investigation, we have a very small database for the *Festuco-Poetum xerophilae* with only five relevés. Nevertheless, the community is clearly separated by the character species *Achillea nobilis* and *Thesium linophyllon* from the *Festuco-Caricetum supinae*. Braun-Blanquet (1961) described two subassociations for the *Festuco-Poetum xerophilae*: *Erysimum rhaeticum*-subassociation and *Carex humilis*-subassociation. In addition, in the *Carex humilis*-subassociation two variants were mentioned by Braun-Blanquet (1961): one with *Pulsatilla montana* and one with *Bromus erectus*. Both species were recorded also in the 2019 relevés. However, discrimination of variants is by no means justifiable with only five relevés. Due to the unique occurrence of *Astragalus onobrychis*, the absence of *Achillea tomentosa* and *Carex supina*, the relevés are negatively separated from the *Festuco-Caricetum supinae* (cf. Schwabe and Kratochwil 2004). However, for a precise validation of this association more relevés are needed.

The *Festuco-Caricetum supinae* was well represented (87 relevés). The association is well justified by the character species. This holds also for the subassociations, based on the dominance of *Bothriochloa ischaemum*, *Stipa capillata* and *Stipa pennata* agg. Nevertheless, as our investigation points out, the three subassociations were floristically closely related and showed transitions. A mosaic distribution of different dry grassland "fragments" and fluent transitions of dry grassland communities in Vinschgau were already mentioned by Strimmer (1968, 1974) so that the subassociations in this study should not be considered as "strictly" delimited units. Furthermore, it has to be mentioned that Braun-Blanquet (1961) did not describe a plant community with *Stipa pennata* for the Vinschgau (cf. Schwabe and Kratochwil 2004). Finally, there were still remaining doubts about the affiliation of some relevés (Table 1, col. 8; Suppl. material 1, relevé numbers 87–92) to the association *Festuco-Caricetum supinae*. In these relevés character species of this association had a very low frequency (AC2, Table 1). To some extent, these relevés are related to the *Stipo capillatae-Seselietum variae* (cf. Schwabe and Kratochwil 2004) via *Scorzonera austriaca*, *Ephedra helvetica*, *Telephium imperati* and *Seseli pallasii* (= *S. varium* var. *levigatum*) (D7, Table 1). Most of these relevés come from Staben, at the eastern end of the investigated dry grassland transect. The border between the *Festuco-Caricetum supinae* and *Stipo capillatae-Seselietum variae* was set by Braun-Blanquet (1961) near Schlanders (cf. Schwabe and Kratochwil 2004). Further investigations have to prove whether the *Stipo capillatae-Seselietum variae* still occurs in Vinschgau.

On the whole, a more precise determination of some species on the subspecies level could perhaps lead to a more exact delimitation of the associations, subassociations and variants. A comprehensive phytosociological study of the entire inner-alpine steppe vegetation is definitely needed to gain a better syntaxonomical overview and classification in the context of western and eastern dry grassland communities (cf. Mucina et al. 2016).

Changes of species composition after 40–50 years

Over the last 40–50 years, considerable changes in species composition were recognized. The abundance and constancy of *Stipa capillata* and – to a weaker extent – of *Stipa pennata* agg. increased, while that of *Bothriochloa ischaemum* slightly decreased. The most impressive increase was shown by *Festuca rupicola*. These changes of the character species have to be interpreted with caution. Especially for *Festuca rupicola*, determination problems in the past cannot be excluded. According to our own observation, *F. rupicola* inhabits more mesophilic and deeper soils, while *F. valesiaca* grows dominantly on shallower and drier soils. The different requirements of the two species were already mentioned by Hroudová-Pučelíková (1972) and Florineth (1980). Braun-Blanquet (1961) found *F. ovina* subsp. *sulcata* (= *F. rupicola*) in the Vinschgau only a few times with a low frequency and mainly in the *Festuco-Poetum xerophilae* (Braun-Blanquet 1961; Kiem 1987).

Besides these uncertain changes, ruderalisation trends, mentioned already by Schwabe and Kratochwil (2004) seem to continue. An increase of annuals (e.g. *Arenaria serpyllifolia*, *Veronica verna*) and ruderal species (e.g. *Artemisia absinthium*, *Convolvulus arvensis*, *Erigeron annuus*) was found in our study sites similar to studies in Switzerland (Dengler et al. 2019). Some relevés show a relationship to the ruderal fringe community of the *Artemisieto-Agropyretum*, so immigration of species from this community towards dry grasslands can be assumed. The *Artemisieto-Agropyretum* is also floristically very close to the *Festuco-Brometea* (Kielhauser 1954; Braun-Blanquet 1961; Mucina 1993; Mucina and Kolbek 1993a). The occurrence of some ruderal species (e.g. *Artemisia absinthium*) may thereby also be related to former land use. Thus, these species can also be considered as indicators of land use change over time.

We also recognized that species from the *Sedo-Scleranthetea* class (e.g. *Erodium cicutarium*, *Trifolium campestre*; D1, Table 2) have immigrated to dry grasslands or increased their abundance. In general, the *Festuco-Brometea* and *Sedo-Scleranthetea* classes are floristically strongly related to each other. Several species are common in associations of the order *Festucetalia valesiacae* as well as in the order *Sedo-Scleranthetalia* (cf. Braun-Blanquet 1955, 1961; Korneck 1975; Mucina and Kolbek 1993b) such as *Allium lusitanicum*, *Alyssum alyssoides*, *Sedum album*, *Sempervivum arachnoideum* and *S. tectorum*.

Ecological factors and anthropogenic influence

According to our investigation the three subassociations of the *Festuco-Caricetum supinae* generally inhabit different parts in the Vinschgau. The subassociation *stipetosum pennatae* occurs on rockier and usually steeper areas, while the *bothriochloetosum ischaemi* stocks on heavily grazed pastures and the *stipetosum capillatae* grows mainly on deeper soils (Figure 4). We only analyzed the correlation of altitude, aspect and slope inclination with the floristic variation among subassociations. Despite the significance of inclination and altitude, these two environmental parameters cannot entirely explain the occurrence of these subassociations. The DCA (Figure 5) clearly shows the correlation of inclination for the *stipetosum pennatae*, which confirms our observation. However, there are sufficient reasons to assume that there is some other causal relationship behind the significancy of altitude: the *bothriochloetosum ischaemi* subassociation essentially characterizes the heavily grazed areas. These occur coincidentally more often near Mals (Figure 2), situated in the higher-altitude Vinschgau; i.e. the parameter altitude is probably a "pseudo-link", the different species compositions of the subassociation being more explained by the grazing intensity than by altitude. Considering this and taking into account that Vinschgau dry grasslands are also an anthropo-zoogenic habitat, management and especially grazing intensity seem to be more important in this case (cf. Braun-Blanquet 1961; Florineth 1973; Strimmer 1974; Köllemann 1981).

It is known that, in addition to ecological factors, changes in management, i.e. over- or undergrazing respectively abandonment of use, strongly influence species composition and community changes in steppe vegetation (Walter and Breckle 1994; Dúbravková and Hajnalová 2012; Korotchenko and Peregrym 2012; Rachkovskaya and Bragina 2012) and inner-alpine dry grasslands (Strimmer 1968, 1974; Florineth 1973; Köllemann 1981; Schwabe and Kratochwil 2004; Boch et al. 2019; Nota et al. 2021). Schwabe and Kratochwil (2012) mentioned that the succession processes in the inner-alpine dry valleys (primarily bush encroachment) take place very slowly. According to our own observation, shrubs (i.e. *Berberis vulgaris*, *Juniperus communis*, *Ligustrum vulgare*) grow mainly in the fringe of pastures and in rocky parts. Especially on areas and slopes with a tall and dense vegetation layer, presumably due to less grazing, shrubs and sometimes even seedlings of tree species (e.g. *Fraxinus ornus*, *Quercus pubescens*) appear. Clonally growing species such as *Hippophae rhamnoides* or *Prunus spinosa*, which often occur at the edge of the grasslands, may easily invade the grasslands. This could be observed even at small scale (e.g. near fences) especially where grazing intensity was obviously reduced. In addition, the lack of litter removal and lower soil disturbance as a consequence of lower grazing intensity or abandonment affect the floristic composition of dry grasslands in the long term (Ruprecht 2012). There is also evidence that *Stipa capillata* increased as a consequence of lower grazing intensity in dry grasslands and steppes (Strimmer 1968, 1974; Florineth 1973; Walter and Breckle 1994). According to our own observations and former investigations (Braun-Blanquet 1961; Strimmer 1968) *Festuca valesiaca* is very grazing tolerant. We found *F. valesiaca* more dominant in intensively grazed sites than *F. rupicola*, so that the latter seems to be slightly less tolerant against grazing. To what extent the three subassociations could be seen as different stages of succession, needs to be investigated. Additionally, the influence of other environmental factors such as temperature, precipitation, nutrient availability, etc. on the floristic composition needs to be studied in future. Furthermore, natural variations in cover values between years (Strimmer 1968, 1974; Gigon 1997), can be relatively high in dry grasslands, and, in contrast, vegetation changes in the long term should be analysed to disentangle the processes of land use change and climate change.

Conclusion

Our investigation shows that current dry grassland communities in the Vinschgau can be identified mainly as the *Festuco-Caricetum supinae* (order *Festucetalia valesiacae*). We suggest to include the investigated dry grasslands to the alliance *Festucion valesiacae*. Although the presented classification is sufficiently justified, the delimitation of the associations and subassociations still needs further discussion. Likewise, the rank of the character species at association, alliance and order level should be re-analysed. A comprehensive study is definitely needed not only to gain a better syntaxonomical overview of western and eastern alpine dry grassland communities but also to evaluate their relation to Eastern European dry grasslands. Especially, relevés from different years and over the whole season of one year are necessary for a more precise classification of the inner-alpine steppe vegetation, to be able to estimate the fluctuations in abundance between years. In addition, a more precise identification of some (sub)species could lead to a more exact delimitation on association-, subassociation- and variant level. The current classification and delimitation of dry grassland communities of the class *Festuco-Brometea* is neither uniform nor free of contradictions (cf. Mahn 1986; Mucina and Kolbek 1993a; Oberdorfer and Korneck 1993; Dierschke 1997; Ellenberg and Leuschner 2010; Willner et al. 2017, 2019) and needs a revision. Many questions also remain regarding the vegetation dynamics. Our data indicate that Vinschgau dry grasslands have changed floristically over time. In particular, the more mesophilous *Festuca rupicola* has increased its frequency and abundance. *Stipa capillata* also shows a positive trend over time. This floristic shift seems to be related to a lower grazing intensity. However, further studies are necessary to obtain a more detailed picture of dry grasslands in Vinschgau and their dynamics. In view of environmental and climate change, interdisciplinary approaches seem promising to obtain more comprehensive knowledge about dry grassland communities and their dynamics in general.

Author contributions

M.L. performed the fieldwork, did the statistical analysis, and wrote the first draft of the manuscript. B.E. supervised the work and improved the drafts of the manuscript.

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E-mail and ORCID

Maximilian Lübben (Corresponding author, m.luebben@posteo.de)
Brigitta Erschbamer (Brigitta.Erschbamer@uibk.ac.at)

Supplementary material

Supplementary material 1
Sorted relevé table of dry grassland communities in the Vinschgau (South Tyrol, Italy) from 2019 (*.xlsx)
Link: https://doi.org/10.3897/VCS/2021/65217.suppl1

Supplementary material 2
Raw table of the relevés of dry grassland communities in the Vinschgau (South Tyrol, Italy) from 2019 (*csv)
Link: https://doi.org/10.3897/VCS/2021/65217.suppl2

Supplementary material 3
Raw table of the relevés of dry grassland communities in the Vinschgau (South Tyrol, Italy) from 2019 (*pdf)
Link: https://doi.org/10.3897/VCS/2021/65217.suppl3