

Plant indicator values of a high-phytodiversity country (Italy) and their evidence, exemplified for model areas with climatic gradients in the southern inner Alps

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Abstract

We tested the new Ellenberg–Pignatti indicator values in Festucetalia valesiacae communities of three valley regions (southern inner Alps: Valle d’Aosta, Valtellina, Valle Venosta/Vinschgau). In these landscape types gradients of all value types exist: light (*L*), temperature (*T*), moisture (*F/M*), nitrogen (*N*), continentality (*C*) and soil reaction (*R*). *L*- and *T*-values were extended from 9 to 12 in the database of Pignatti due to the higher intensity of these factors in the area in question; in our dataset this is especially relevant for the *L*-values.

In a spatial approach, we compared DCA results with indicator value results (presence–absence) and with climatic data for eight different plant communities. We found comprehensible results in all cases, also for the extension of the *L*-factor.

In a temporal approach, we compared relevés and their indicator values from two time windows: 1930–1950 (Braun-Blanquet) and 1990–1995 (Schwabe and Kratochwil) for six of the eight different plant communities. Both relevé types were made in the same or in similar localities, but no permanent plots existed. Mostly we found in these communities, which are said to have high “stability”, no significant changes on average for any of the indicator values. In the case of *N*- and *R*-values there was a trend of increase in the different datasets, and in some cases this trend is significant.

In general, the new database has shown the “robustness” of the Ellenberg indicator value model including the extended *L*-values, and established its usefulness for a synthetic approach in the studied valley systems. In our systems *L*-, *T*-, *F/M*- and *C*-gradients can be characterised well by means of indicator values and are an excellent tool for

Abbreviations: *L*, light; *T*, temperature; *F(M)*, moisture; *N*, nitrogen; *C*, continentality; *R*, soil reaction; Ao, Valle d’Aosta; Va, Valtellina; Vi, Valle Venosta/Vinschgau; mk, Melico-Kochietum prostratae (Ao); ok, Onosmo-Koelerietum vallesianae typicum (Ao); okp, Onosmo-Koelerietum vallesianae phleetosum phleoidis (acidophytic subassociation; Ao); ss, Stipo capillatae-Seselietum variae (Vi); cf, Carici supinae-Festucetum valesiacae (Vi); pf, Poo xerophilae-Festucetum valesiacae (Vi); df, Diplachno-Festucetum valesiacae (Va); cb, Centaureo bracteatae-Brachypodietum (Va); r., relevés

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explaining DCA results. Caution is necessary especially when correlations of different factors are intermingled in temporal approaches.

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Introduction

In the year 2005, the indicator values of the vascular flora of Italy were published, providing an example for a country comprising (sub)mediterranean, montane and alpine parts with an extremely high diversity of vascular plant species (appr. 5800 species, Pignatti et al., 2005). Italy is thus the country with the highest phytodiversity so far documented by such indicator values. Since the first proposal for indicator values was worked out by Ellenberg (Ellenberg, 1974, 1979; Ellenberg et al., 1991) for Germany and surrounding areas, datasets have become available for several Central and Western European countries (e.g. Great Britain and Eire, Poland, Switzerland) and for Hungary (Borhidi, 1993; Hill et al., 2004; Landolt, 1977; Zarzycky, 1984; Zólyomi et al., 1967; see also the review by Diekmann, 2003). For southern Europe and the whole Mediterranean area indicator values have as yet been elaborated only for the southern Aegean region (Böhling et al., 2002), not for whole countries.

The species list for the indicator values of Italy is based on the flora of Pignatti (1982). Ellenberg's values were extended in the case of light and temperature (1–12 instead of 1–9) due to the high intensity especially of these factors in the (sub)mediterranean climate (Pignatti et al., 2005). In our model area extended *L*-values are especially relevant.

The new values were worked out with the same methods as used by Ellenberg (l.c.), but are based on the experiences in Italy accumulated over 20 years (Pignatti et al., 2005). In the year 1993, successful tests were made in archaeological sites of Rome (Celesti Grapow et al., 1993); later tests were applied for the comparison of datasets referring to "global change" (Pignatti et al., 2001) and for urban sites (Fanelli et al., 2006). But nevertheless it is necessary to test the dataset further, especially in areas where all types (including continentality) are relevant.

Therefore, we apply the new indicator values to model areas in the southern inner alpine dry areas, where strong climatic gradients exist. For the dry grassland communities of the three valley regions: Valle d'Aosta, Valtellina and Valle Venosta (Vinschgau) there are phytosociological datasets available of Schwabe and Kratochwil (sampled 1990–1995, presence tables published 2004, original relevés n.p.: dataset A) and older ones of Braun-Blanquet (sampled 1930–1950, original

relevés published 1961: dataset B). Therefore these datasets make it possible to apply a spatial and a temporal approach (Fig. 1).

As depicted in the flow diagram (Fig. 1) our main questions are:

- Are mesoxeric and mesohygric gradients worked out by Schwabe and Kratochwil (2004) using ordination diagrams (A1) and climate data (A2) reflected by the indicator values as well? (using dataset A)
- The communities in the inner Alps are said to have relatively high "stability" and obviously old and new datasets are very close together – is this "stability" reflected by the comparison of indicator values in a time span of half a century as well, or are there trends of change? (using dataset B in comparison with A).

Materials and methods

Background: model area southern inner Alps

The valley regions tested here regarding plant indicator values, namely Valle d'Aosta, Valle Venosta/Vinschgau and Valtellina, are surrounded by high summits up to between 3900 and 4800 m a.s.l. and show

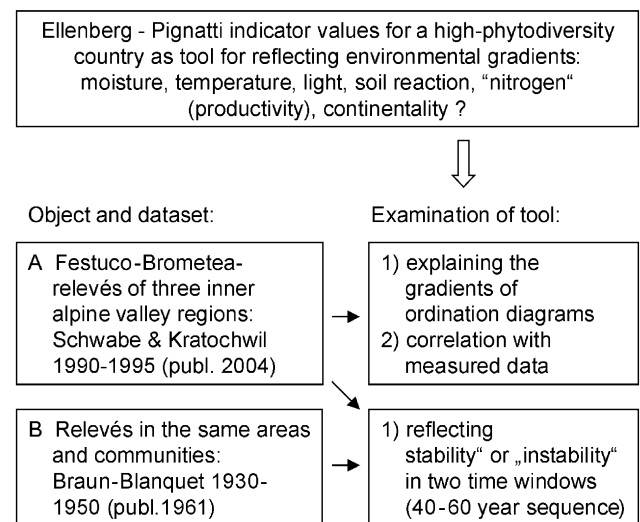


Fig. 1. Flow diagram of the object/dataset-sources and the combination with examination tools for the spatial and the temporal approach.

an orographic seclusion; therefore, they are exposed to distinctive leeward climatic effects such as low precipitation, relatively cold winters and hot summers (intrinsic climate). In the last glaciation period (Würm) moraine material was deposited, often characterised by enrichment of base-rich/calcareous material. Therefore even in the silicate rock-dominated valleys, which are in focus here, basiphytic plant species are locally present. The valley regions Valle d'Aosta and Valle Venosta/Vinschgau show these intrinsic effects in a clear way, whereas the Valtellina valley region is characterised by more moderate climatic conditions due to the effects of higher humidity in the adjacent Lago di Como-area and the only poorly developed intrinsic valley climate.

These valley regions and others in the Swiss, French and Austrian parts of the Alps are characterised by dry grassland ecosystems with many (sub)continentally distributed plant species (partly with relict distribution) belonging to the class Festuco-Brometea and the order Festucetalia valesiaca. Braun-Blanquet (1961) was the first who studied the communities in a synoptic monographic study, presenting original relevés from the first half of the 20th century between ca. 1930 and approximately 1950. We revisited most of his investigation sites in six valleys (the three in addition to the Italian parts were Valais, Rhine area near Chur and Engadin/Austrian Inn valley) and sampled phytosociological relevés mainly between 1990 and 1995. Our main focus was to sample vegetation complexes and to compare these relevés with classical ones. In the case of the vegetation complexes we were able to elaborate a CCA with our community data and precipitation/temperature data (Schwabe and Kratochwil, 2004, Figs. 35, 36).

Relevés, community types and climatic data

The relevés of the three inner alpine valley regions were taken in homogeneous plots of 50 m² by Schwabe and Kratochwil (2004). This corresponds to the relevé size most commonly used by Braun-Blanquet (1961). To answer the question of possible floristic changes in the communities in the time windows between 1930–1950 and 1990–1995 we used our datasets (A) and relevés of Braun-Blanquet (B). The time windows were analysed for those plant communities which were sampled in identical or similar localities. If relevé numbers differed between A and B we did not carry out a reduction of one dataset.

Employing the criterion of similar/identical localities we were able to compare the following communities for two time windows (precipitation and temperature data are given in the following order: average temperature July, annual average temperature, annual precipitation;

different data sources; see Schwabe and Kratochwil, 2004):

Valle d'Aosta (Ao)

Melico ciliatae-Kochietum prostratae (mk): Moraine habitats in the central part of the valley near the city of Aosta, mainly between 600 and 900 m a.s.l.; A: 14 relevés (r), B: 18 r.

Onosmo pseudoarenariae-Koelerietum vallesianae typicum (ok): Mainly rock habitats in the central valley and tributary valleys (e.g. Valpelline), mainly 600–1100 m a.s.l.; A: 18 r., B: 26 r.

Onosmo-Koelerietum phleetosum phleoidis, acidophytic subassociation (okp): Mainly 800–1100 m a.s.l.; A: 5 r., B: 9 r.

Climatic data: Aosta 583 m a.s.l.: 20.6, 10.9 °C, 575 mm; Valpelline 950 m a.s.l.: 19, 9.4 °C, 644 mm.

Valle Venosta/Vinschgau (Vi)

Stipo capillatae-Seselietum variaae (ss): Rock/schist habitats in the lower Vinschgau ("Edelvinschgau": fruit-tree growing area in the valley bottom area, including *Prunus armeniaca* cultures), mainly between Naturno/Naturns and Silandro/Schlanders 500–800 m a.s.l.; A: 12 r., B: 24 r.

Climatic data: Silandro/Schlanders 706 m a.s.l.: 19.2, 9.6 °C, 485 mm.

Carici supinae-Festucetum valesiacaae (cf): Rock/loess/grit habitats "Vinschgau Leiten" in the central valley area above Silandro/Schlanders, mostly 900–1200 m a.s.l.; A: 14 r., B: 35 r.

Climatic data: Kortsch 785 m a.s.l.: 19, 9 °C, 570 mm.

Valtellina (Va)

Diplachno-Festucetum valesiacaae (df): Rock habitats in the lower Valtellina area up to Teglio; mostly 300–600 m a.s.l.; A: 8 r., B: 10 r.

Climatic data: Sondrio 298 m a.s.l.: 21.5, 11.6 °C, 1083 mm; Teglio 871 m a.s.l.: 20, 10.2 °C, 1158 mm.

Grazing impact

B-plots: impact in all community types with the exception of df.

A-plots: extensive grazing only in some of the Vinschgau plots (Carici-Festucetum and Stipo-Seselietum).

Additionally, we analysed indicator values for two communities with more montane distribution in two of the abovementioned valley areas. The localities between A- and B-relevés differ mostly for these communities; therefore we only used the A- dataset to answer questions about environmental gradients (spatial approach).

Valle Venosta/Vinschgau (Vi)

Poo xerophilae-Festucetum valesiacae (pf): Rock habitats and stands rich in fine ground: upper valley, mostly between 1000 and 1500 m a.s.l., on southeastern slopes of the main valley and in tributary valleys (e.g., in the Münstertal/Val Müstair: Taufers and in Switzerland: Santa Maria); A: 15 r; locally grazing impact.

Climatic data: Taufers 1270 m a.s.l.: 15, 7.7 °C, 636 mm; Santa Maria 1411 m a.s.l.: 14.5, 5.1 °C, 770 mm.

Valtellina (Va)

Centaureo bracteatae-Brachypodietum (cb): Rock habitats and stands rich in fine ground; upper Valtellina and Switzerland: Poschiavo, mostly between 900 and 1300 m a.s.l., mostly no pure southern exposure; A: 12 r; mostly no grazing impact (exception: one site).

Climatic data: Sondalo 1010 m a.s.l.: 18, 9.5 °C, 895 mm.

Indicator values

We considered the factors: light (*L*), temperature (*T*), continentality of climate (*C*), moisture (*F/M*), soil reaction (*R*) and nitrogen (*N*). According to our present knowledge the nitrogen value is a general indicator for soil fertility (e.g., Hill and Carey, 1997; Hill et al., 2004) and often correlates best with phytomass production (Hill and Carey l.c.; Ertsen et al., 1998; Schaffers and Šykora, 2000) – there are often deficits in measurements (see Discussion). Additionally, Schaffers and Šykora (l.c.) worked out that *R*-values correlate best with calcium and should actually be termed “Calcium values”. Abbreviations are used according to Hill et al. (2004). The latter authors omitted *C*- and *T*-values because these do not have relevance in the oceanic climate of Britain/Eire.

There were some arguments for us to use only presence–absence data and no abundance–cover data: In the species-rich communities of our systems there are nearly no dominance stands. Some exceptions (e.g. *Stipa capillata* facies) were not relevant for this dataset. Böcker et al. (1983) already stated that with an increasing number of indicator species, abundance data are of secondary importance. Some authors recommend using only presence/absence data if older and current relevés are compared, to minimise the effects associated with different persons and to avoid the overestimation of abundance–fluctuating species. All in all the results do not differ much in species-rich systems (see the “presence–absence versus abundance” discussion in Diekmann, 2003).

We calculated averages of the indicator values in spite of their ordinal nature – as many vegetation ecologists do, knowing that in the strict mathematical sense this is not appropriate (see the discussion in

the review by Diekmann, l.c.). The practicability of this approach has been shown by many authors (Diekmann l.c.).

Multivariate ordination and statistical treatment

We carried out a multivariate data analysis for the A-relevés with help of the PC-Ord Package (McCune and Mefford, 1999). In our species-rich communities results show no difference if we use transformed data of the Braun-Blanquet scale or presence–absence data. Here we present only the latter. As the gradient length exceeds 2 SD, we used Detrended Correspondence Analysis (Jongman et al., 1987). As for the whole dataset of six inner alpine valleys (see Schwabe and Kratochwil, 2004) we used the DCA without down-weighting of rare species. To compare the DCA results best with the average indicator values and to show the gradients for certain values we elaborated Excel-based net diagrams for the values, differentiated for the communities and not vice versa. The latter was proposed by Pignatti et al. (1996), e.g., to show indicator-value-based ecograms for the comparison of woody vegetation types for Italy as a whole.

For the statistical comparison of the A- and B-relevés we used the Mann–Whitney *U*-test for independent samples.

Results

Comparison of the relevés of three inner alpine valley regions (spatial approach): ordination diagram and indicator values (A1) and correlation with measured data (A2)

In the DCA (Fig. 2) the relevés are ordered on axis 1 following the xero-mesothermic gradient from Melico-Kochietum to Onosmo-Koelerietum (Ao), followed by Stipo-Seselietum to Carici-Festucetum and to Poo-Festucetum (Vi). The two “outlier” relevés pf (axis 1 position: 350–400, axis 2: 50–100) are situated in the orcal belt of Val Müstair (tributary valley of Vi in Switzerland, 1500 m a.s.l.). The upper parts of axis 2 are characterised by more mesohygic conditions of the Valtellina relevés, reflecting on axis 1 the xero-mesothermic gradient between Diplachno-Festucetum and Centaureo-Brachypodietum (Va) as well. If the species of the DCA are analysed (not printed) the positions of the Centaureo-Brachypodietum- and the Poo-Festucetum relevés are characterised especially by Trifolio-Geranieta species (e.g. *Trifolium medium*, *Geranium sanguineum*) and more mesohygic species (e.g. *Trifolium montanum*, *Prunella grandiflora*).

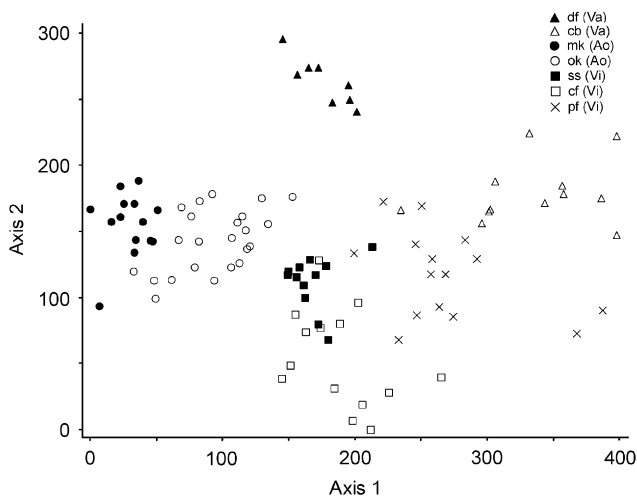


Fig. 2. DCA of all Festuco-Brometea relevés of dataset A (presence–absence data) including seven communities on association level and three valley areas: Valle d’Aosta, Valtellina, Valle Venosta/Vinschgau; eigenvalues (λ) and gradient length (100 = 1 SD); axis 1: $\lambda_1 = 0.53$; gradient length = 4.0 SD; axis 2: $\lambda_2 = 0.28$; gradient length = 3.0 SD. Coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space: axis 1: $r^2 = 0.58$, axis 2: $r^2 = 0.14$; distance measure for original distance: Relative Euclidean.

Indicator values of the same dataset (A) are presented as net diagrams for the different types (Fig. 3). The temperature value reflects the top position of mk, ok, df; in the case of the L -value the very open communities mk and ok occupy the top position, whereas the more montane types cb and pf are already rich in Trifolio-Geranieta species and show lower L -values. If the $F(M)$ -value is compared with the T -value the special position of df – combination of high temperature and higher moisture – is depicted, compared to mk, ok, okp, ss with low $F(M)$ -values. $F(M)$ - and N -values correlate. The continentality of climate is highest in the intrinsic parts of Ao and Vi, shown by the top position of mk, ss, cf and ok. Moraine material (mk, ok) and (to a lesser extent) schists and loess (ss, cf) are reflected in the R -values and become obvious in the acidic rocks of okp (acidophytic subassociation) and the other acidophytic community types: df, cb, pf.

When the DCA and the indicator nets are compared, results are very similar and the latter explains decisive factors for the position of the communities (see Discussion).

In Table 1 the whole dataset (A and B) is shown; the low standard-error values substantiate that the plots in one community have very low variation concerning each indicator value.

We found a significant correlation between the community composition and measured climatic data

reflecting a xero-mesothermic and a xero-mesohygric gradient (Schwabe and Kratochwil, 2004, Figs. 35, 36). The two axes are reflected in the DCA introduced above as well, and are explained by the values.

The R -gradient mk, ok (7.2, 7.3) to okp, ss, cf (6.6, 6.8, 6.9) is also reflected by measurements. Measured pH values (H_2O) are: mk ($n = 10$) 8.3 ± 0.16 ; ok ($n = 10$) 8.1 ± 0.19 ; okp ($n = 4$) 6.3 ± 0.1 ; ss ($n = 11$) 6.3 ± 0.12 ; cf ($n = 15$) 6.3 ± 0.12 .

Comparison of the indicator values for the time windows between 1930–1950 and 1990–1995 (temporal approach) (B)

Comparison of indicator values in the two time windows shows high similarities among the six analysed communities (Table 1). Most of the compared datasets do not show significant changes. This is true for the $F(M)$ - and T -values in general. In the case of L - and C -values there are cases of significance; but the slight differences show no general trend. The N -values of the Stipo-Seselieta varia (Vi) differ significantly from each other, and additionally other communities (cf and df) show a trend to an increase of N -values. The same is true for the R -values, which show significant differences (increase) in the case of mk, ss and cf (exception df).

In the case of the Stipo-Seselieta of the lower Vinschgau (“Edelvinschgau”) several species with N -value 1 decreased strongly ($>25\%$ presence): *Trifolium arvense* (-29%), *Calamintha acinos* (-46%), *Sedum rupestre* (-38%), *Sempervivum arachnoideum* (-34%); some species with N -values 3 and more increased in presence: 3 *Carex humilis* ($+46\%$), 5 *Asparagus officinalis* ($+58\%$).

Regarding the three communities with significant changes in R -values, there are only seven species which show strong differences of $>25\%$ in at least two datasets (Table 2). *Trifolium arvense* and *Sempervivum tectorum* decreased (R -values: 2 and 4); the other five species increased and have higher R -values (7–9). A remarkable finding is that in Valle Venosta/Vinschgau *Teucrium montanum* (R8), *Carex humilis* (R8) and *Saponaria ocymoides* form a group with strong increase (see Discussion).

The single-species analysis was expanded by depiction of average species indicator values per plot referring to the categories 1–9 (for values with significant changes): Fig. 4. By this procedure species are pooled, especially in case of the lower and higher values, to form “quasi-functional groups” (e.g. low-competitive species with N -values 1,2).

The average species numbers per N -value category and per plot are shown for the Seseli-Stipetum in Fig. 4. It is clearly visible that there is a shift from 1-, 2-values

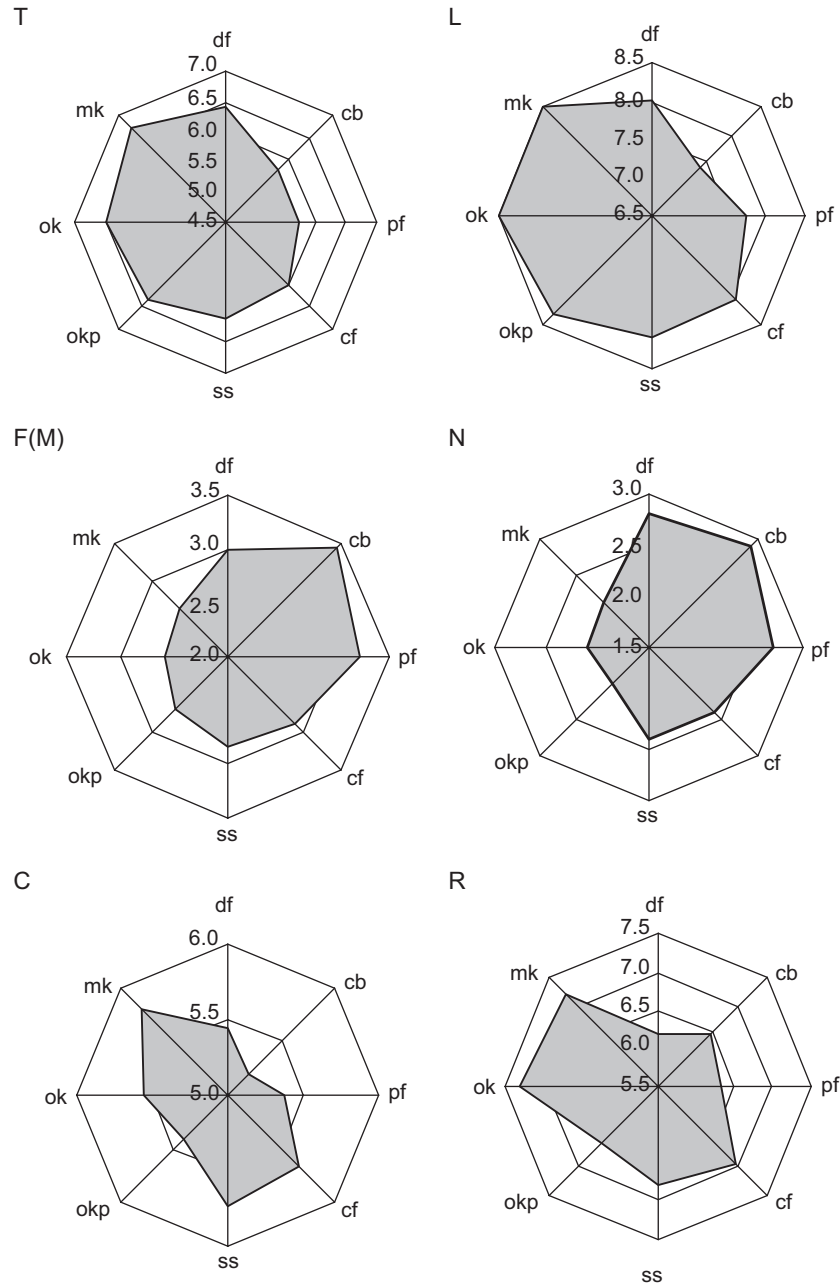


Fig. 3. Net diagrams of the average of indicator values of the plot areas and communities presented in Fig. 2. (specified data with SE, see Table 1).

in the older dataset to 3-, 4-, 5-values in the newer one, which cannot be detected with single-species analysis. High values (*N8*) increased only slightly.

For the three communities with significantly increased *R*-values, Fig. 4 shows the increase of *R7*- and *R8*-species in the case of *Stipo-Seselietum* and *Carici supinae-Festucetum* (*Vi*). In the case of the *Melico-Kochietum* (*Ao*) there is a strong decrease of *R4* (*Sempervivum tectorum*, *Poa carniolica*) and a pronounced increase of *R7* (*Stipa eriocaulis* s.str., *Tragopogon dubius*).

Discussion

Comparison of the relevés of three inner alpine valley regions (spatial approach): Ordination diagram and indicator values (A1) and correlation with measured data (A2)

Hill et al. (2004) pointed out that indicator values are means of interpreting ordinations. The pre-definition of the values makes it possible to take them as “benchmarks” (Hill et al., l.c.). According to Figs. 2 and 3

Table 1. Average of indicator values for all communities and time windows

	<i>F(M)</i>			<i>L</i>			<i>N</i>		
	Mean	SE	<i>p</i>	Mean	SE	<i>p</i>	Mean	SE	<i>p</i>
mk A	2.6	0.04	n.s.	8.5	0.05	0.01030	2.1	0.04	n.s.
mk B	2.7	0.04		8.6	0.03		2.1	0.04	
ok A	2.6	0.03	n.s.	8.5	0.06	n.s.	2.1	0.03	n.s.
ok B	2.6	0.02		8.4	0.06		2.1	0.02	
okp A	2.7	0.05	n.s.	8.3	0.12	n.s.	2.0	0.11	n.s.
okp B	2.7	0.04		8.3	0.04		2.0	0.04	
ss A	2.8	0.04	n.s.	8.1	0.03	n.s.	2.4	0.03	0.00191
ss B	2.7	0.03		8.1	0.03		2.2	0.03	
cf A	2.9	0.04	n.s.	8.1	0.05	n.s.	2.4	0.04	n.s.
cf B	2.8	0.03		8.2	0.03		2.3	0.04	
df A	3.0	0.05	n.s.	8.0	0.07	n.s.	2.8	0.12	n.s.
df B	3.0	0.02		7.8	0.05		2.6	0.07	
pf A	3.2	0.06		7.7	0.07		2.7	0.07	
cb A	3.4	0.06		7.4	0.08		2.9	0.07	
	<i>T</i>			<i>C</i>			<i>R</i>		
mk A	6.7	0.04	n.s.	5.8	0.05	0.02266	7.2	0.07	0.00116
mk B	6.6	0.04		5.6	0.04		6.8	0.06	
ok A	6.5	0.06	n.s.	5.6	0.03	n.s.	7.3	0.07	n.s.
ok B	6.6	0.05		5.6	0.04		7.3	0.08	
okp A	6.3	0.08	n.s.	5.4	0.06	n.s.	6.6	0.18	n.s.
okp B	6.3	0.08		5.5	0.05		6.5	0.12	
ss A	6.1	0.04	n.s.	5.7	0.04	0.03904	6.8	0.05	0.00202
ss B	6.1	0.03		5.8	0.02		6.5	0.06	
cf A	6.0	0.04	n.s.	5.7	0.04	0.00993	6.9	0.04	0.00001
cf B	6.0	0.03		5.8	0.03		6.5	0.05	
df A	6.4	0.06	n.s.	5.5	0.05	n.s.	6.2	0.15	n.s.
df B	6.2	0.07		5.4	0.05		6.3	0.05	
pf A	5.7	0.05		5.4	0.03		6.3	0.12	
cb A	5.7	0.07		5.2	0.04		6.5	0.06	

A: Schwabe and Kratochwil; B: Braun-Blanquet. Levels of significance refer to the comparison of A and B.

ordination results especially correlate with *F(M)*- and *T*-values, which is shown in the ordination too and can be explained by the indicator values. *N*-values correlate with *F(M)*-values. Most likely the *N*-resources of the soil are often not available to plant species in these dry grasslands because of the lack of water, as Leuschner (1989) has shown in the Alsatian Xerobrometum and which is discussed by Bobbink et al. (1998).

Indicator species of acidic or basic soils are intermingled in the DCA, probably as the hygric and thermic gradients dominate. Schwabe and Kratochwil (2004) pointed out that Trifolio-Geranieta species are not able to survive in the core areas of the lower inner alpine dry grassland communities in habitats under full isolation;

among others these species (*Trifolium medium*, *Geranium sanguineum* a.o.) and more mesophytic Brometalia species (*Trifolium montanum*, *Prunella grandiflora* a.o.) reflect the lower *L*-values of 7.4–7.7. These values correspond well to those for communities in southern Germany (Festucion valesiaca 7.7, according to Böcker et al., 1983; Xerobrometum Kaiserstuhl, counted from 17 relevés sampled by Wilmanns 1987 and published 1988: 7.9). Our communities are rich in very rare species (as, e.g., in Ao *Bassia prostrata*, in Vi *Astragalus pastellianus* and *A. excapus* and many others) and according to Diekmann (2003) “the best indicators should neither be too rare nor too common”. It may be hypothesised that species reflecting traces of vegetation

Table 2. Species with strong changes in presence between the two analysed time windows for *R*-values and the communities which are depicted in Fig. 4

<i>R</i>	Community	B% ss	A% ss	B% cf	A% cf	B% mk	A% mk
2	<i>Trifolium arvense</i>	71	<u>42</u>	63	<u>7</u>	6	—
4	<i>Sempervivum tectorum</i>	63	<u>8</u>	20	<u>7</u>	50	<u>7</u>
7	<i>Tragopogon dubius</i>	—	50	3	43	33	79
7	<i>Stipa eriocalis</i> s.l.	46	75	—	14	17	71
7	<i>Erysimum rhaeticum</i>	88	92	11	36	28	93
8	<i>Teucrium montanum</i>	42	50	31	71	—	36
8	<i>Carex humilis</i>	46	92	26	64	—	—
9	<i>Saponaria ocymoides</i>	8	67	6	43	—	—

Only those species are included which show differences of $\geq 25\%$ in two of the communities. Decreases of $\geq 25\%$ are underlined, increases of $\geq 25\%$ are printed in bold. *Stipa eriocalis* s.l. was differentiated in the A-dataset: ss, cf: subsp. *austriaca*; mk: subsp. *eriocalis*.

history or lacking dispersal ability may cause “statistical noise”, as was, e.g., discussed for island floras by Lawesson et al. (2003). Nevertheless, in our case the occurrence of the species pool of Festuco-Bornetea species in combination with differentiating and valley-specific rare species leads to the special structure of the indicator-value and DCA gradients.

In our case we were able to take climatic data as tools to test for significant correlations between ordination results and environmental gradients (Schwabe and Kratochwil, 2004, Fig. 35, 36). For the new dataset of Italy we found very good correlations between hygrometric gradients and indicator values. As many authors have shown previously, the pH gradient usually correlates well with the *R*-values (see also the review of Diekmann, 2003, and Ertsen et al., 1998). According to Schaffers and Sýkora (2000) it is best if pH (KCl/CaCl) is < 5.0 ; if it is higher, change in *R*-values is mostly only slight (curvilinear relationship). For our pH (H₂O) measurements there is a narrow correlation with *R*-values even for pH > 6 . The basic conditions in mk and ok and the more acidic sites of okp, ss and cf are well represented.

Comparison of the indicator values for the time windows 1930–1950 and 1990–1995 (temporal approach) (B)

The “robustness” of the relatively simple Ellenberg indicator model was obvious, showing nearly similar results for indicator values in the recognised time windows although different persons were involved and there were no fixed permanent plots. Some authors looked for “global change” climate impact by means of comparisons of time windows (for example Pignatti et al., 2001 in the Caricetum curvulae of the Stelvio National Park). We did not find changes by invading

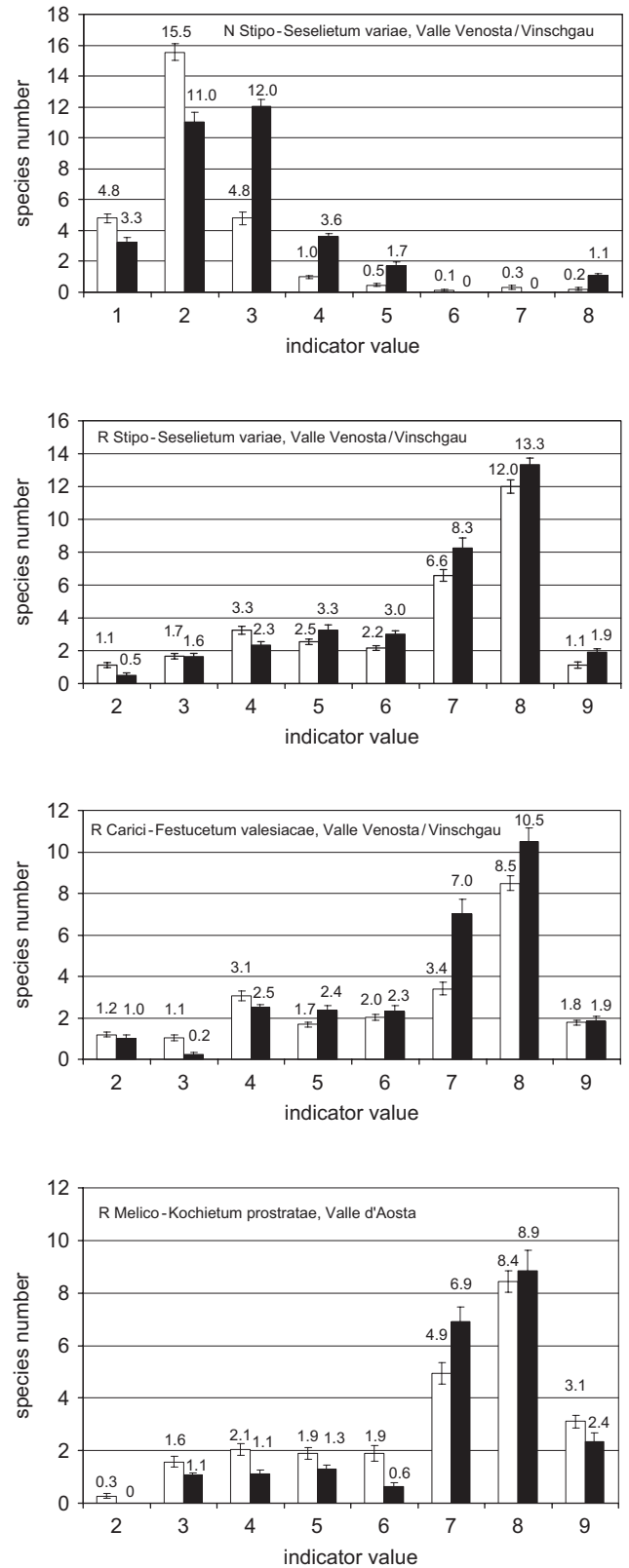


Fig. 4. (a–d) Average species number per relevé and community (with SE) according to the N- and R- indicator values. Characterised are communities and indicator values with dominant trends and significant change (see Table 1). Black columns: A – , white: B – dataset.

Mediterranean or generally frost-sensitive species (e.g. *Thymus vulgaris* or *Opuntia*) as hypothesised by some authors (see the review of Theurillat and Guisan, 2001).

N-values often have deficits in measurements (Ellenberg et al., 1991; Wilmanns, 1988); nevertheless, calibration often has shown close correlations with productivity gradients. Significant differences in the *N*-values fit into the European frame; but – concerning dry grassland – nearly all studies were made in (compared with our communities) more mesophytic Mesobromion communities, where severe reduction in species-richness and grass-encroachment was recorded especially in W Europe (see the reviews by Bobbink et al., 1998; Bobbink and Roelofs, 1995). There was no species loss and no severe *Brachypodium*-encroachment in a Mesobromion stand near Göttingen (Germany) in a period of 50 years; this area has low precipitation values of 600 mm/a (Bornkamm, 2006). In the Xerobromion of the “Kaiserstuhl” (SW Germany), which corresponds roughly – according to the Ellenberg values – to our montane communities (e.g. cb) species loss was not detected if older relevés of von Rochow (13 r.: 1942–1944) and newer ones of Wilmanns (17 r.: 1987) are compared (Wilmanns, 1988). If Ellenberg *N*-values are counted for these relevés (average 1942–1944: 2.1 versus 1987: 2.5) the possible impact of N-immissions may be masked by successional processes (increase especially of Trifolio-Geranietaea and shrub species). If all these species and some fluctuating ones are neglected, the difference in *N*-values decreases to 2.1 versus 2.3.

In our dry grassland systems (temporal approach) grass encroachment and loss of species richness was not detected; although in the montane communities *Brachypodium rupestre* is becoming more and more dominant, species richness has not yet changed (average species number cb Braun-Blanquet 40.3, Schwabe and Kratochwil 41.1; pf 35.6 versus 36.6; see Schwabe and Kratochwil, 2004).

There is a general trend towards a slight elevation of *N*-values in Vi- and Va- communities; only in the case of the Stipo-Seselietum in the “Edelvinschgau” (main fruiting-tree region of Valle Venosta/Vinschgau) it is significant. Possible explanations are increasing productivity after grazing cessation or more extensive treatment (followed by enrichment of palatable species, e.g., *Asparagus* and decrease of low-competitive species, e.g., *Trifolium arvense*, *Sempervivum*, *Sedum*), or generally eutrophication. The effects of N-immissions may be strongly reduced in the harsh environment of the dry grassland communities by lack of soil water (see above). It is remarkable that there are pronounced shifts from lower to middle values. More recent results concerning N-immissions of the whole Alps revealed especially high values in the southern fringe area of the Alps, resulting from the combination of high precipitation and higher concentrations of pollutants, but less in areas

with low precipitation values. In general the topographic complexity leads to high variability (Rogora et al., 2006).

In the case of significant changes of *R*-values, the problem arises whether it is really the *R*-values that are decisive, or if there are other, superimposed factor complexes or indirect effects. We exclude the possibility that we analysed plots with substrate differences compared with Braun-Blanquet (1961); we sampled the same site types. In the case of three communities we have significant shifts with always the same trend, in all other cases there are no significant changes. In the three communities in question, grazing impact has changed (mk: without any grazing, ss and cf: locally extensive grazing); the decrease of the low-competitive annual *Trifolium arvense* (*R*2, but *N*1 too), which depends on disturbance and seed-bank dynamics (Eichberg et al., 2006), may be caused by this development. *Sempervivum tectorum* is especially sensitive towards small-scale solifluctation caused by needle-ice in spring (Schwabe and Kratochwil, 2004), but there is no detailed knowledge about change of needle-ice processes in dry-grassland communities in the last century (see the review by Lawler, 1988).

Analysing species with strong increase (Table 2), especially notable in Vi are *Teucrium montanum* (*R* 8) and *Saponaria ocymoides* (*R* 9), which occur not only in Festuco-Brometea communities but also in scree habitats (Stipion calamagrostis) and open Erico-Pinion/Ononido-Pinion woodland (Oberdorfer, 2001; Pignatti, 1998). The latter is also characterised by a strong increase of *Carex humilis*. Therefore some successional shifts are obvious, which have not so far had any effects on light factor and species diversity.

Pykälä (2005) compared pasture types of mesic sites (grazed, restored and > 10 years abandoned) in Finland in a side-by-side comparison study and detected a significant increase of *R*-values (5.8 versus 6.4), but a decrease of *L*-values too. The author infers an increase in the *R*-value tolerance of plant species due to grazing.

Conclusion

Use of all types of the new Ellenberg–Pignatti indicator values for our model area has shown that the approach helps to develop generalisations and synthesis (van der Maarel, 1993) on the landscape level for spatial and temporal approaches. In the spatial approach all factors show the gradients which were supposed. The extension of the *L*-values for our datasets produces comprehensible results.

In the temporal approach an astonishing high stability of the systems was reflected by the values, although different persons were involved and there were no marked permanent plots. The changes in temporal

approaches have to be analysed carefully, as indicator values may interact and certain processes cannot be separated. Such recorded changes of indicator values help to detect general trends, to ask new questions and to find the key factors for such changes by further investigations.

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