

# Indicators for taxonomic and functional aspects of biodiversity in the vineyard agroecosystem of Southern Switzerland

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## A B S T R A C T

It is widely accepted that the concept of biodiversity embraces two essential and complementary components: taxonomic and functional diversity. Our goal is to produce a list of plant species predictive of high taxonomic and functional biodiversity values and discuss their use within biodiversity monitoring programmes. We selected a representative sample of 48 vineyard areas from Southern Switzerland, and vegetation from the ground cover was sampled from within a total of 120 sampling plots. We considered ten widely used functional traits and selected six taxonomic and functional indices. We applied a two-step analysis: (i) using Threshold Indicator Taxa Analysis (TITAN) based on the above mentioned biodiversity indices, we defined 3 groups of sampling plots with low (**L**), medium (**M**) and high (**H**) biodiversity values; (ii) using the Indicator Value analysis, we identify indicator species that are significantly associated with the above-mentioned groups and their combinations. In total, 259 vascular plants were identified across the sampling plots. As a whole, 52 species were significant indicators for groups with high and mid-to-high biodiversity values. Out of all indicator species, 24 (46%) were exclusively selected by functional biodiversity indices whereas only 10 (19%) were associated with taxonomic indices. Eighteen (35% of the total) species were selected by both types of indices. We point out that indicator species associated with two different aspects of biodiversity show a high degree of complementarity. Our results emphasize the need to consider functional aspects of biodiversity in diversity-conservation strategies when the objectives are to preserve both taxonomic diversity and ecosystem functioning.

### Keywords:

Biodiversity surrogates  
Functional indices  
Indicator species  
Switzerland  
Vineyard floor vegetation

## 1. Introduction

There is general agreement that agricultural intensification has a deep impact on biodiversity with possible cascade effects on ecosystem functions and service delivery (Millennium Ecosystem Assessment, 2005; Moonen and Bàrberi, 2008). The synergy of conservation efforts and sustainable production can be achieved by designing well-drafted and targeted agri-environmental strategies (Tscharrntke et al., 2012). Selecting reliable indicators is the crucial step in assessing the effectiveness of agri-environmental schemes with respect to biodiversity conservation and its associated services (Noss, 1990; Mace and Baillie, 2007; Teder et al., 2007; de Bello et al., 2010). *Indicators* are organisms or attributes of

communities which can be used to provide information on biodiversity status and trends (Teder et al., 2007).

Biodiversity can be measured in many different ways. Among these, taxonomic diversity and functional diversity are two essential and complementary components (Lyashevskaya and Farnsworth, 2012). Taxonomic diversity expresses the variety of species in a community. Functional diversity represents the value and range of functional traits in a community and its relation to related ecosystem functionality (Diaz et al., 2007). Some authors have highlighted that an ecosystem can be inhabited by many species, and thus reveals high species richness, while showing low functional diversity if species share the same type of traits (Gerisch et al., 2012; Moretti et al., 2009). Despite increasing research aiming to assess these components of biodiversity (e.g. Hodgson et al., 2005; Devictor et al., 2010; Cadotte et al., 2011; Sattler et al., in press), functional diversity is still scarcely included in biodiversity monitoring programmes (Woodwell, 2002; Vandewalle et al., 2010; Perrings et al., 2011).

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We assess the use of different indicator species for monitoring taxonomic and functional diversity using vineyards as a model system. European vineyards are often home to a wide range of plants, sometimes perceived as weeds (Lososová et al., 2003), which inhabit different portions of the vineyard, such as below the grapevine, in the inter-space between rows and on vegetated slopes, or in terraced vineyards only when the latter are present. The type and pressure of management practices in vineyards strongly determine the vegetation structure of these habitats. Indeed, anthropogenic disturbance has been indicated as one of the main driving forces controlling both functional and taxonomic aspects of biodiversity in vineyards (Bruggisser et al., 2010; Trivellone et al., 2012). In Swiss vineyards, ecological direct payments (subsidies) to promote a high level of biodiversity are only granted to vine-growers that satisfy a number of ecological requirements (Swiss Federal Ordinance on Direct Payments in Agriculture, OPD of 23 October 2013). Basically, a quality value for the vineyard is calculated by a monitoring scheme using a scored list of 59 non-productive plants belonging to the Red List or species of particular interest.

Our aim was to identify a list of plant species predictive of high taxonomic and functional biodiversity values. We then discuss how the selected species can be integrated for practical implementation in a monitoring scheme for the payment of subsidies to Swiss vineyards. As a case study, we selected a representative sample of vineyard areas from the Southern Alpine region of Switzerland.

## 2. Material and methods

### 2.1. Study area and experimental design

The study was conducted in 48 vineyards (hereafter referred to as study sites) distributed across the main vine growing area in Southern Switzerland (Supplementary Material A, Fig. A.1), from Ludiano (46°25'N–8°58'E) to Pedrinate (45°49'N–9°00'E), the Northernmost and Southernmost sites, respectively, ranging from 199 m to 589 m a.s.l. The area is characterized by a moist warm-temperate climate and mean annual precipitation ranging from 1600 mm (South) to 1700 mm (North), and mean monthly temperatures ranging from 0.5 °C (North) to 1.6 °C (South) in January and from 21.2 °C (North) to 23.5 °C (South) in July (Spinedi and Isotta, 2004).

The 48 study sites were selected using a design that accounted for the three main variables characterizing the vineyard agroecosystem in the study region, i.e. aspect (24 sites were exposed SE-SW; 24 sites NE-NW), slope (24 sites were on a plain: <5°; 24 sites were terraced >10°) and the dominant landscape element (>50% cover) surrounding the vineyard within a radius of 500 m (16 sites

were dominated by forest, 16 sites by settlements, 16 sites by open areas). Topography and landscape data were obtained using a 25 m cell size digital elevation model (DHM25©2004) and a swiss map in scale 1:25,000 in vector format (VECTOR25), both provided by Swisstopo and implemented with ArcGis 10 (ESRI, 2011). In this way, we obtained a full balanced design with the 48 study sites grouped among the three groups of variables as detailed in Supplementary Material A (Table A.1).

### 2.2. Vegetation sampling

Vegetation was sampled at each study site during two distinct sampling periods (June and August), in order to include plant species with early and late phenology. Five 1 m × 1 m quadrats were randomly chosen in each of the different *habitats* present within each vineyard: 2 *habitats*-on-plain, i.e. below the grapevine's rows (Row-on-plain) and on the inter-space between rows (Interrow-on-plain) and 3 *habitats*-on-terrace, i.e. on vegetated slopes (Slope-on-terrace) and the same habitats as on the plain but in terraced vineyards (Row-on-terrace, Interrow-on-terrace). We thus surveyed a total of 1200 quadrats (48 study sites × 5 *habitats* × 5 replicates). All vascular plant species rooting within each quadrat were identified and the percentage cover of each species was estimated using a decimal scale after Londo (1976). Cover of bare soil and rocks was also taken into account. Species nomenclature follows Lauber and Wagner (2009).

### 2.3. Functional traits selection

We considered ten widely used morphological and phenological characteristics of plants as functional traits, *sensu* Violle et al. (2007): plant (vegetative) height (PH), specific leaf area (SLA), leaf dry matter content (LDMC), dispersal syndrome (DS), and seed mass (Sm), obtained from the TRY database (Kattge et al., 2011), and growth forms (GF), root depth (RD), reserve (or storage) organs (RO), range of flowering (rF), and seed longevity (SI), taken from Landolt et al. (2010) (Table 1). We specifically selected traits that determine species' response to both environmental conditions and management (Lavorel and Garnier, 2002; Cornelissen et al., 2003).

### 2.4. Taxonomic and functional indices

In order to take taxonomic and functional components of biodiversity into account, we selected six distinct widely used indices. Taxonomic biodiversity was quantified using Species Richness (Ric), Simpson (Sim) and Shannon (Sha) indices (Magurran, 2004), while functional aspects of biodiversity were quantified

**Table 1**  
Median values and ranges for 10 functional traits of plants detected in the study.

Functional trait	Trait code	Type	Unit	Minimum	Median	Maximum	Nr. NA entries
Growth forms	GF	Nominal	10 Levels	1.00	3.00	8.00	0
Plant (vegetative) height	PH	Continuous	(m)	0.05	0.37	40.0	0
Specific leaf area	SLA	Continuous	(mm <sup>2</sup> mg <sup>-1</sup> )	6.28	24.8	60.8	32
Leaf dry matter content	LDMC	Continuous	(g/g)	0.03	0.20	0.45	48
Root depth <sup>a</sup>	RD	Ordinal	(cm)	1.00	2.50	5.00	17
Reserve (or storage) organs <sup>b</sup>	RO	Nominal	11 Levels	0.00	1.00	1.00	0
Dispersal syndrome <sup>c</sup> Range	DS	Nominale	3 Levels	0.00	0.33	1.00	86
of flowering	rF	Continuous	Months	1.00	3.00	12.0	0
Seed longevity	SI	Ordinal	Years	2.00	4.00	5.00	113
Diaspores mass <sup>d</sup>	Sm	Continuous	(mg)	0.00	0.95	3487	9

<sup>a</sup> Data was ordered in a meaningful sequence from 1 to 5 ranging root depth values in 9 categories from <25 cm to >200 cm.

<sup>b</sup> The dummy variable 0–1 indicates absence or presence of reserve/storage organs.

<sup>c</sup> Fuzzy coded variable.

<sup>d</sup> For Pteridophytes, a factitious value for mass of meiospore was assigned.

using Functional Richness (FRic), Functional Divergence (FDiv) (Villéger et al., 2008) and Rao's quadratic entropy (Rao) (Botta-Dukát, 2005). FRic indicates the extent of trait space occupied by a community. This was calculated based on a principal coordinates analysis from a Gower-distance matrix of pairwise distances between species in trait space. FRic was measured as the volume of a convex hull enclosing the principal coordinates of the species present in each community. Contrary to FRic, FDiv index takes the relative abundances of the species into account and it is related to how abundance is distributed within the volume of functional trait space occupied by species. Since the Rao index is the sum of trait dissimilarity among all possible pairs of species, weighted by the product of their relative abundance, it therefore includes information about the evenness of the distribution of functional traits within a community. All indices were calculated with R 2.15.1 (R Development Core Team, 2012) using all species. Functional indices were obtained using the *dbFD* function of the *FD* package (Laliberté and Legendre, 2010).

### 2.5. Statistical analysis

For each study site, we combined the species data of the five quadrats per *habitat* (Row-on-plain and -on-terrace, Interrow-on-plain and -on-terrace, Slope-on-terrace) over the two sampling periods, for a total of 120 sampling plots (i.e., 24 study sites  $\times$  2 *habitats*-on-plain + 24 study sites  $\times$  3 *habitats*-on-terrace) over the 48 study sites.

We applied a two-step analysis. In the first step, we defined groups of sampling plots with more similar values for the above mentioned biodiversity indices (see Section 2.4). Then using the Threshold Indicator Taxa ANalysis (TITAN) approach (Baker and King, 2010), we detected and quantified community thresholds (*sumz+* and *sumz-*) with regards to "biodiversity gradients" for each diversity index selected in our study. Sampling plots therefore fell into three groups: **L** (low), which indicates sampling plots with biodiversity values lower than the *sumz-* threshold, **H** (high) for those with biodiversity values higher than the *sumz+* threshold and **M** (medium) those with biodiversity values between the *sumz-* and *sumz+* thresholds. This analysis was performed for each diversity index considered in this study (more details about the TITAN analysis are given in Supplementary Material B). In the second step, we used the Indicator Value analysis (Dufrêne and Legendre, 1997) to identify plant species (hereafter indicator species) significantly associated with the above-mentioned groups and their combinations. The association of species to the sampling plot group was assessed by the Indicator Value index (IndVal) and its significance (*p*-value  $< 0.05$ ) was obtained by a randomization procedure (999 permutations) and Holm correction for multiple tests. The index is the product of two components *A* (specificity) and *B* (fidelity), where the former is the probability that a new studied sampling plot belongs to the group associated with the recorded indicator species, and the latter is the probability of finding the species in sampling plots belonging to the group. IndVal index ranges from 0 to 1 and reaches the maximum when all individuals of a species are found in a single group (high fidelity) and when the species occurs in all sampling plots in that group (high specificity). All significant indicator species with a *B* value  $< 0.25$  were removed to discard indicators that occur too rarely (i.e. in less than 25% of sampling plots) as suggested by De Cáceres et al. (2012). For each of the six biodiversity indices, only plant species associated to **H** and combined **M + H** groups were considered as indicator species of 'high' and 'mid-to-high' taxonomic or functional biodiversity. The plant species cover percentage values were log-transformed in order to reduce the influence of highly variable taxa on the Indicator Value calculations as recommended by Baker and King (2010). Finally, to assess the degree of complementarity for each

indicator species, we used the principal component analysis (PCA) based on the biodiversity indices that define a space of six dimensions and a PCA-plot to visualize the results. Two species positioned far apart on the PCA-plot are considered complementary, whereas species clustered in the multidimensional space are considered more similar in terms of represented biodiversity indices.

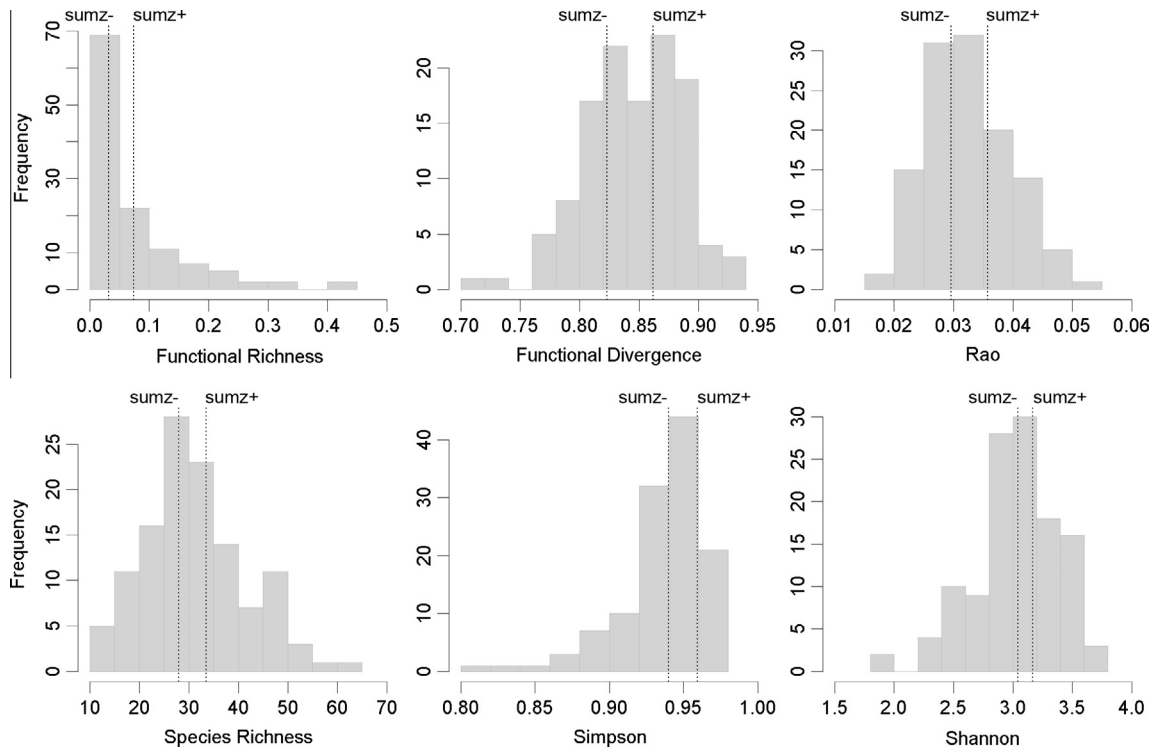
Statistical analyses were performed using R 2.15.1 (R Development Core Team, 2012). The Threshold Indicator Taxa ANalysis was run with the package TITAN (Baker and King, 2010). The Indicator Value analysis (IndVal) complemented by the multi-levels pattern analysis was performed using a "multipatt" routine in the "indic-species" package (De Cáceres and Legendre, 2009; De Cáceres et al., 2010).

## 3. Results

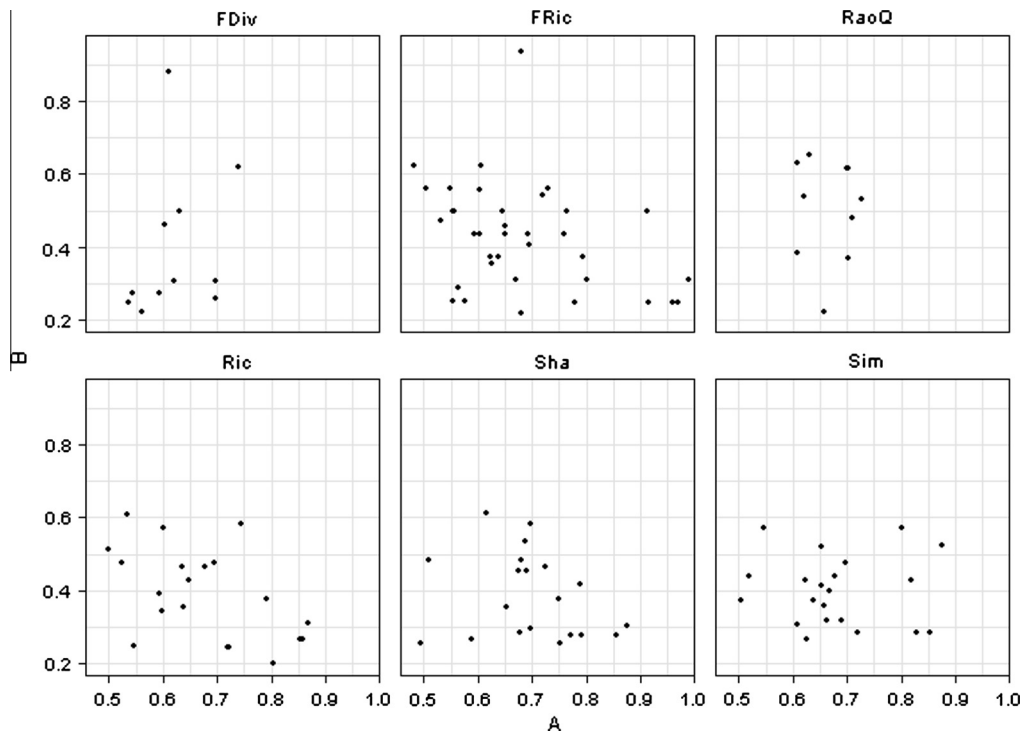
A total of 259 vascular plants were identified across the 120 sampling plots (Supplementary Material C). The two community thresholds for each biodiversity index were detected by TITAN (Fig. 1 and Supplementary Material D for details). Based on these values, three balanced groups of sampling plots were obtained. As a whole, for the six biodiversity indices considered, 52 species were significant indicators for groups **H** and **M + H** with a fidelity value  $> 0.25$ , and they accounted for 20% of the total number of species identified. Depending on the index used, between 9 and 21 indicator species were selected: Ric: 19 (=37% of the total 52 indicators), Sim: 21 (40%), Sha: 20 (38%), FRic: 24 (46%), FDiv: 11 (21%) and RaoQ: 9 (17%) (Supplementary Material E). Three indicator species (*Gallium mollugo*, *Erigeron annuus* and *Arrhenatherum elatius*) reached the highest IndVal values for taxonomic indices (Ric, Sim and Sha) as well as for functional richness. For FRic, the IndVal analysis identified *G. mollugo*, *E. annuus* and *A. elatius* as being associated with the combination of groups **M** and **H** (Ind-Val = 0.810, 0.782 and 0.763, respectively). These high IndVal scores were due to high specificity rather than fidelity. Similarly, although the species associated to the **H** group only had moderate IndVal values ( $< 0.589$ ), their specificity was high (0.638–0.934). Two indicator species for high FDiv values, *Taraxacum officinale* and *Veronica persica*, showed high IndVal scores (0.877 and 0.716, respectively), the former due to high fidelity (*B* = 0.881) and the latter due to high specificity (*A* = 0.739). In addition, both were associated to the **M + H** group only. This was also the case with indicator species for high Rao values, with *V. persica*, *Geranium molle*, *Stellaria media* and *Digitaria sanguinalis* being associated with **M + H** group. Fig. 2 shows an overview of specificity and fidelity values for indicator species associated with each of the biodiversity indices. Overall, specificity values range from 0.481 to 0.989 (mean = 0.677) and fidelity values from 0.200 to 0.937 (mean = 0.413).

### 3.1. Degree of complementarity

Out of 52 indicator species, 24 (46%) species were exclusively selected by functional biodiversity indices whereas only 10 (19%) species were only associated with taxonomic diversity indices. Eighteen (35% of the total) species were selected by both categories of indices: *Achillea millefolium*, *Anthoxanthum odoratum*, *A. elatius*, *Crepis capillaris*, *Cruciata glabra*, *E. annuus*, *G. mollugo*, *Holcus lanatus*, *Rubus fruticosus*, *Silene vulgaris*, *Daucus carota*, *Hypochaeris radicata*, *Oxalis stricta*, *Urtica dioica*, *Artemisia verlotiorum*, *Lotus corniculatus*, *Sanguisorba minor*, and *Silene pratensis*. However, 6, 9 and 7 species were exclusively selected based on FRic, FDiv and Rao, respectively; whilst 1, 3 and 1 species were exclusively



**Fig. 1.** Frequency distributions of the values of each biodiversity index for 120 sampling plots. Dotted lines represent the community threshold values (sum- and sum+) detected by Threshold Indicator Taxa Analysis (TITAN).

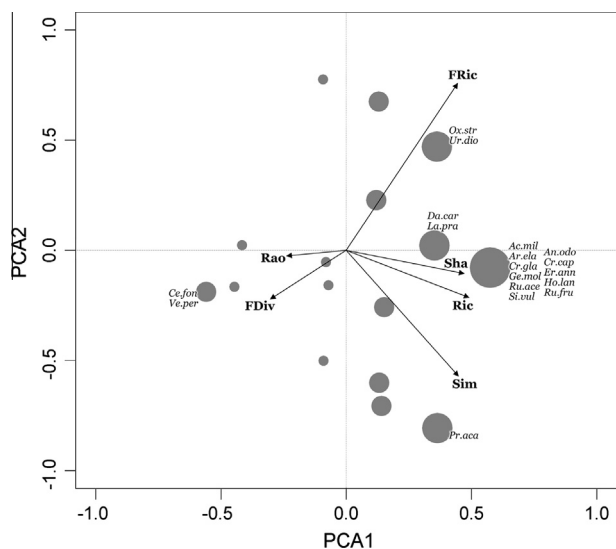


**Fig. 2.** Biplots of the specificity (A) versus fidelity (B) values of the indicator species selected by Indicator Value analysis for the 6 biodiversity indices considered (Functional Divergence – Fdiv, Functional Richness – FRic; Rao’s quadratic entropy – Rao; Species Richness – Ric; Shannon index – Sha; Simpson index – Sim). Only species associated to sampling plot groups **H** and **M + H** were plotted.

selected based on Ric, Sim and Sha, respectively (Supplementary Material F).

The PCA-biplot (Fig. 3) showed that functional (FRic, FDiv and Rao) and taxonomic (Ric, Sim, Sha) biodiversity indices were not

correlated. While the three taxonomic indices were projected close to each other, this was not the case for the functional indices. In particular, Rao and FDiv were clearly projected far from the other indices on axis 1 and FRic was separated from the taxonomic



**Fig. 3.** Biplot of the Principal Component Analysis (PCA) of selected indicator species (grey dots) and their association with the 6 biodiversity measures (arrows). Only the species most correlated to the first two canonical axes ( $n = 18$  out of 52) are shown. The 1st axis explains 54.5% and the 2nd 13.3% of the variance. *Ac.mil*: *Achillea millefolium*; *An.odo*: *Anthoxanthum odoratum*; *Ar.ela.*: *Arrhenatherum elatius*; *Ce.fon*: *Cerastium fontanum*; *Cr.cap*: *Crepis capillaris*; *Cr.gla*: *Cruciata glabra*, *Da.car*: *Daucus carota*; *Er.ann*: *Erigeron annuus*; *Ge.mol*: *Geranium molle*; *Ho.lan*: *Holcus lanatus*; *La.pra*: *Lathyrus pratensis*; *Ox.str*: *Oxalis stricta*; *Pr.aca*: *Primula acaulis*; *Ru.ace*: *Rumex acetosella*; *Ru.fru*: *Rubus fruticosus*; *Si.vul*: *Silene vulgaris*; *Ve.per*: *Veronica persica*; *Ur.dio*: *Urtica dioica*.

indices on axis 2. Two indicator species clustered on the negative side of the PCA axis 1 indicated high FDiv and Rao, whereas at the positive end of PCA axis 1, a cluster of eleven species were associated to high values in the taxonomic biodiversity indices. Two more scattered groups of indicator species were associated to Sim and FRic.

#### 4. Discussion

This study has highlighted how integrating more than one aspect of biodiversity permits the identification of complementary indicator species to cover different components of diversity. Of the 52 indicator species associated with high and mid-to-high values of taxonomic and functional biodiversity, 10 species were exclusive indicators of taxonomic indices, 24 of functional indices, and 18 of both. Functional divergence and Rao's quadratic entropy indices significantly selected the largest group of indicator species which were associated to the functional biodiversity aspect only and, at the same time, showed high complementarity towards the Functional Richness index and the three taxonomic biodiversity indices (i.e. Species Richness, Simpson and Shannon indices). This study has also shown that multiple indicator species are required to monitor diversity in general and especially functional diversity.

Given the multidimensional nature of biodiversity, selecting an optimal set of indicators of overall biodiversity is of crucial importance – and can indeed be considered the holy grail of biodiversity management. Several authors have addressed this topic based on simulated community data, e.g. Lyashevskaya and Farnsworth (2012) highlighted that species richness missed 88.6% of the total diversity, emphasising the importance of considering other biodiversity aspects as well. According to Sattler et al. (in press), the selection of umbrella species (indicator species) associated with multiple biodiversity facets provide a useful tool to promote urban biodiversity in central Europe. In our results, eighteen species were

associated to both biodiversity aspects. However, it is worth noting that only Functional Richness was weakly associated with the three taxonomic biodiversity indices (Fig. 3) as already shown by several authors (e.g. Cornwell et al., 2006; Pakeman, 2011). We believe that taxonomic diversity is correlated to functional diversity in terms of the range of traits. The fact that FDiv and Rao represent complementary components of functional diversity implies that indicator species corresponding to these indices should be included in biodiversity monitoring protocols. In an empirical investigation of a river floodplain, Gallardo et al. (2011) demonstrated that a combination of measures (i.e. functional diversity, size diversity and taxonomic distinctness) were useful in assessing environmental changes and determined their utility as relevant indicators of ecosystem biodiversity and functionality. From a conservation point of view, priorities and strategies are thus slowly moving towards a more integrated approach (Devictor et al., 2010; Villéger et al., 2010).

#### 4.1. Characterisation of the indicator species

Species identified by the Indicator Value analysis as being indicators of diversity in vineyards, typically belong to vegetation types such as low-altitude mown grasslands, dry grasslands, mesophilous forests, nutrient-poor edge habitats, or ruderal areas (Delarze and Gonseth, 2008). Unsurprisingly, a large proportion (17 in total) of species indicative of high and moderately high biodiversity, are characteristic of hay-meadows on moderately nutrient-rich, relatively moist soils (such as *A. millefolium*, *A. elatius*, or *S. vulgaris*), and are resistant to a moderate cutting regime (up to two cuts per year, e.g. *A. odoratum*, *Cerastium fontanum*), corresponding to the typical vegetation of southern Swiss vineyards. The list also includes competitive-ruderal species (CR species sensu Grime, 2001), which take advantage of vegetation gaps due to their ability to spread quickly by vegetative growth after disturbance (e.g. *Poa trivialis*). Seven plant indicator species in our list (e.g. *Carex caryophylla*, *D. carota* or *Brachypodium pinnatum*) are frequently dominant in semi-dry grasslands. These species are considered to be vulnerable to mowing (Briemle and Ellenberg, 1994). Furthermore, under a moderate mowing regime they can take up soil N and thus represent efficient N sinks to help keep the soil relatively nutrient-poor. Two species characteristic of more shady habitats (*Primula acaulis* and *Hedera helix*) were mainly recorded on vegetated slopes in terraced vineyards with a lower solar incidence. Amongst others, the indicator species *C. glabra* or *Veronica chamaedrys* are typical of nutrient poor edge habitats, occurring in structure-rich vineyards. Finally, an important group (13) of indicator species is ruderal annual and perennial weeds on meso- to eutrophic soils (e.g. *Hordeum murinum* and *S. pratensis*).

Even if the ground vegetation of a vineyard could be associated to a semi-natural pasture or an extensively managed meadow, there are slight differences with these vegetation types, due to the particular management pressure and environmental conditions which have selected physiological, morphological and dispersal life traits of plants. Accordingly, although our plant indicator species may to some extent be associated to potential natural plant communities, the reference to single species is more pertinent, as recommended by Rosenthal (2003). Moreover, plant indicator species selected by Indicator Value analysis consists of a list of species significantly associated with each target group of sampling plots, which does not mean that the species must co-occur in the same location (de Cáseres et al., 2012). For these reasons, when a new sampling plot is monitored, the greater the number of indicator species recorded, the higher the confidence of its assignment to the target group for high or mid-to-high biodiversity level.

#### 4.2. Implementation for biodiversity conservation

Payments for environmental services (PES) are a commonly used policy instrument throughout the world to help reach biodiversity conservation goals in agroecosystems (Ferraro and Kiss, 2002; Jack et al., 2008), despite the definition of PES has been for the most part implicit (Sommerville et al., 2009). An effective list of indicator species of distinct facets of biodiversity may represent a key tool to assess the status and trends of biodiversity and to quantify the ecological quality of a field (Wittig et al., 2006). Unfortunately, taxonomic diversity and vulnerability of species to extinction (Red Lists) are the only measures routinely taken into account in many biodiversity monitoring programs (Vandewalle et al., 2010). However, vulnerable species are often too rare to be considered the only important plant species when determining ecological quality (Rosenthal, 2003). In fact, in a survey carried out in Austrian meadows, Zechmeister et al. (2003) concluded that Red List species are not appropriate in evaluating intensively used agricultural meadows; moreover the authors observed no correlation between the amount of subsidies and plant species richness in the investigated meadows. In Switzerland, the biomonitoring of ecological quality of vineyards to grant subsidies to landowners is currently based on species of conservation concern, such as Red List species and species at high risk of extinction. Some difficulties might arise, though, when applying this type of biomonitoring protocol, because it mainly focuses on conservation-relevant aspects without completely reflect the importance of ecosystem services provided by the entire plant community.

The indicator species selected in our study are, instead, rather abundant and representative of each habitat type within vineyards, and they provide a complementary list of species related with two important biodiversity facets. As stressed by Vandewalle et al. (2010), in biodiversity monitoring schemes an integrated approach including different facets of biodiversity should be considered, while within biodiversity conservation strategies more than one objective should be covered. Our results emphasize the need to consider functional aspects of biodiversity in diversity-conservation strategies when the objectives are to preserve both diversity of taxa and ecosystem functioning (Cadotte et al., 2011). Finally, we suggest reconsidering the current official species list for the biomonitoring of ecological quality in vineyards in order to grant effective subsidies to landowners. In order to promote three important aspects of biodiversity, we propose to set up a list of indicators composed of two groups of species: (1) vulnerable species, as far as possible, from their own eco-geographic area using the national or sub-national Red List; and (2) the most abundant plant species associated with a high level of both taxonomic and functional biodiversity.

We believe that landowners and farmers should be motivated to maintain a traditional farming style through more focused (and possibly more understandable) subsidy policies, which encourage more eco-sustainable approaches. The willingness to implement our findings in the current monitoring protocol will inevitably have political and economical implications when evaluating possible trade-offs between conservation aspects and ecosystem functioning issues (Lavorel and Grigulis, 2012).

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