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

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ABSTRACT

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.

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 (Tscharntke 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 (Lyashevska 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 (Sl), 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	($mm^2\ mg^{-1}$)	6.28	24.8	60.8	32
Leaf dry matter content	LDMC	Continuous	(g/g)	0.03	0.20	0.45	48
Root depth[a]	RD	Ordinal	(cm)	1.00	2.50	5.00	17
Reserve (or storage) organs[b]	RO	Nominal	11 Levels	0.00	1.00	1.00	0
Dispersal syndrome[c]	DS	Nominale	3 Levels	0.00	0.33	1.00	86
Range of flowering	rF	Continuous	Months	1.00	3.00	12.0	0
Seed longevity	Sl	Ordinal	Years	2.00	4.00	5.00	113
Diaspores mass[d]	Sm	Continuous	(mg)	0.00	0.95	3487	9

[a] Data was ordered in a meaningful sequence from 1 to 5 ranging root depth values in 9 categories from <25 cm to >200 cm.
[b] The dummy variable 0–1 indicates absence or presence of reserve/storage organs.
[c] Fuzzy coded variable.
[d] For Pteridophytes, a factitious value for mass of meiospore was assigned.