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Journal:	*Botany Letters*
Manuscript ID	TABG-2018-0154.R1
Manuscript Type:	Research Paper
Date Submitted by the Author:	n/a
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Keywords:	floristic investigations, topographic maps, landscape history, beech woods, phytosociology, toponyms

Past landscape features may be captured by historical floristic data. A case study in northern Italy

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Abstract

Historical floras, i.e. lists of plant species recorded in a given geographical area, are not usually considered for capturing past landscape features. In this study, we tested the usefulness of the simultaneous use of historical floristic data and a coeval topographic map to evaluate the main features of the past vegetation landscape and the potential of such data in change detection. Our study site was the Monte Fumaiolo area (northern Italy), where historical floristic data were independently recorded by two famous botanists during the 1930s. Past floristic data were then compared with current cartographic and vegetation data.

Despite the fact that the two authors explored a comparable area, they significantly differed in the use of toponyms and in the distribution of floristic records among toponyms. This is reflected by a low floristic similarity at the toponym level between the two data sets. Nevertheless, the species classification into ecological categories allowed to highlight how the two authors recorded similar information on the landscape features. However, the use of these floristic data may have some flaws in landscape change detection.

Key words

floristic investigations; topographic maps; landscape history; beech woods; phytosociology; toponyms

Introduction

Land cover change is among the main factors affecting biodiversity and ecosystem functioning, and ecological research is increasingly addressing this topic (e.g. Millennium Ecosystem Assessment 2005; Szabó 2010; Rick and Lockwood 2013). Land cover changes are mainly evaluated on the basis of the analysis of land cover maps that can be retrieved from remote sensing images or topographic and cadastral maps (e.g. Bender et al. 2005; Gustavsson, Lennartsson, and Emanuelsson 2007).

Maps are a key source of information for reconstructing past landscapes, since they cover a longer time-span than remote sensing images. On the other hand, they usually fail to give detailed information on plant compositional features of the habitats, hindering more fine-grain analyses of land cover changes across time slices. For example, historical maps may provide information on the dominant tree species while lacking information on the composition of plant forest communities (e.g. Kienast 1993; Petit and Lambin 2002). However, besides describing past landscapes, topographic maps include fundamental information on site names, which is indispensible for georeferencing records that are retrieved from historical-ecological sources (Swetnam, Allen, and Betancourt 1999; Signorini et al. 2016; Pinna et al. 2017). These records potentially improve the information associated with topographic maps, as in the case of historical floristic data, consisting of records of species occurrence in a given site.

While studies on vegetation (i.e. quantitatively describing plant communities) are relatively recent, restricting the possibility of a direct evaluation of plant compositional changes to the last decades (Braun-Blanquet 1964; Dengler 2017), floristic data that are stored in herbarium collections and local checklists are available in Europe starting from the second half of the XVIII century (e.g. Séguier 1745; Scopoli 1760; Buillard 1776) and are increasingly used to evaluate spatial-temporal patterns of plant biodiversity (e.g. Groen, van der Meijden, and Runhaar 1994; Chocholoušková and Pyšek 2003; Chiarucci et al. 2017). When the date and collection site, and possibly the habitat type and estimates of frequency, are available for each recorded species, such floristic data may in fact represent a unique source of information for reconstructing plant composition of the habitats in the past landscapes (see also Parolo and Rossi 2008).

Unfortunately, floristic data are often characterised by the absence of an explicit and well-defined geographical framework, hindering, for example, the evaluation of the extent of the area that was actually surveyed within a given study site. Furthermore, the exploration intensity of study sites can vary depending on site accessibility and/or better attractivity for field work (i.e. historical or cultural reasons, precedent floristic investigations, high detection rates, presence of notable species), resulting in spatially biased exploration patterns (Kier et al. 2005; Chiarucci et al. 2018). If floristic data can be georeferenced, making the toponyms used in the flora coincident with those present in a topographic map, one can obtain the extent of the area explored, and the species list for each toponym may be used as a proxy of the exploration effort. Furthermore, one can even try to reconstruct the habitat composition of a landscape by using plant species as environmental indicators of habitat and/or ecology. As a consequence, these results can be coupled to a coeval topographic map and used to estimate past vegetation composition, but also to compare it with current vegetation (Geri et al. 2016). However, despite this potential, the use of floristic data in land cover change detection is scanty (see e.g. De Martis et al. 1983; Johnson and Fryer 1986; Trueman, Hobbs, and Van Niel 2013), mainly due to the lack of the simultaneous availability of historical and current floristic data.

This case study is focused on the Monte Fumaiolo area, since for this site a 1930s topographic map (scale 1:25000) is available, to which two sets of coeval floristic data can be coupled. These data were recorded by two outstanding botanists, Gustavo Bonaventura (1902-1976) and Pietro Zangheri (1889-1983), who surveyed the study area during the same time span. The floristic survey by Bonaventura was, however, specifically dedicated to the Monte Fumaiolo area, whereas the study by Zangheri was part of an investigation of a much broader area. For this reason, we considered the floristic records by Bonaventura as the main source of data and those by Zangheri as comparison data. On these bases, the main aims of our work were:

1) to determine the extent of the landscape area actually explored by the authors, detecting possible anisotropies between the two surveys;

2) to assess to what extent data provided by the two authors allow to determine the main vegetation features of a past landscape;

3) to evaluate the potential of historical floristic data in land cover change detection by comparing past and current floristic data.

Materials and Methods

Study area

The study area (Lat. 43.793589, Long. 12.084430; extent 28 km²) is located in Emilia-Romagna, in the province of Forlí-Cesena, and is comprised in the municipality of Verghereto. It corresponds to the territory surveyed by Bonaventura (see map in Bonaventura 1947, Fig. 1 [fig. 1 near here]). The area lies in the northern Apennines (fig. 1a), with elevation ranging between 730 and 1407 m a.s.l. (Monte Fumaiolo). Since 1995, it has been included in the Natura 2000 network (site code IT4080008), and is spiritually and historically attractive due to the presence of the springs of the river Tiber (sacred to the Romans) and an early XI century shrine and hermitage (Cella di Sant'Alberico). The area has a characteristic *mesa*-shaped highland morphology, determined by sandstones and biocalcarenites, which lie on and are surrounded by the Ligurian Units. The southern part of the area is characterised by marls, sometimes alternating with pelites and sandstones (Bortolotti et al. 2008). On top of the *mesa* (1000-1400 m), the forest landscape is formed by *Fagus sylvatica*, sometimes mixed with *Abies alba*. In the lower part of their altitudinal range, beech woods share semi-mesophilous species (e.g. *Cyclamen hederifolium, Euphorbia amygdaloides, Melica uniflora, Pulmonaria apennina*) with mixed oak woods, that span an altitudinal range between 740 and 1000 m and are dominated by *Quercus cerris* with a dense spiny shrub layer (e.g. *Prunus spinosa*, *Crataegus monogyna*, *Rosa canina*). Reforestations with conifers (*A. alba* and *Pinus nigra*) have been present since the 1930s. Grasslands and meadows are widespread mainly at the lower elevations, and are principally formed by *Arrhenatherum elatius*, *Cynosurus cristatus* and *Trisetaria flavescens*. They also include several species of the meso-xerophilous grasslands (e.g. *Bromopsis erecta*, *Brachypodium rupestre*), ruderal-nitrophilous species (e.g. *Daucus carota*, *Poa trivialis*, *Trifolium pratense*), and hygrophilous species (e.g. *Juncus effusus, Equisetum arvense*). Abandoned sites are colonized by spiny shrubs, *Cytisus scoparius* or *Pteridium aquilinum*. Vegetation of the eroded slopes and rocky soils mainly includes communities dominated by *Sedum album* and *S. acre*, sometimes mixed with *Asplenium trichomanes* (Pezzi et al. 2015).

Overall, the area can be defined as an agro-forestry landscape, with a stable environment, limited urbanisation and without demographic increment (Van Calster et al. 2008).

Data sources

Sources of data were:

a) for the 1930s, a small scale map of the area published in Bonaventura (1947), a topographic map by the Istituto Geografico Militare Italiano (scale 1:25000) and two sets of coeval floristic data (Bonaventura's and Zangheri's);

b) a current vegetation map and 98 related phytosociological relevés (Pezzi et al. 2015).

For the point *a*, we used two adjacent sheets (108 III NE and 108 III NO) of the 3rd Edition (Series M891) of the IGMI topographic map (Istituto Geografico Militare Italiano; www.igmi.org), dating back to 1937 (scale 1:25000). The two sheets were separately scanned and merged to obtain a single image. Then, 84 uniformly distributed Ground Control Points (GCP) were used, recognizable on the sheets from the AGEA 2008 flight (50 cm cell resolution). The selected GCP produced a co-registration error of about 13.4 m; affine (1st order) polynomial transformation was used as a warping method. To optimize the accuracy of projection and layer overlap, we used the *adjust* transformation. From the map we derived the toponym layer and a land cover map (scale of digitization 1:5000, reference system WGS84/UTM32N). The two layers were clipped on the basis of the small scale map available in Bonaventura (1947), which represented the extent of the area. Then, by overlaying the Emilia-Romagna Geological Landscape Map (1:250.000; http://geo.regione.emilia-romagna.it/geocatalogo/), we distinguished in the two layers (toponym and land cover map) the *mesa* from the remaining part of the study area.

Floristic data were derived from the lists reported in Bonaventura (1932, 1933, 1934, 1937 1938, 1947; Zangheri 1966b), who surveyed the area in the years 1931-37 (months June to

September). Species nomenclature was updated according to Pignatti, Guarino, and La Rosa (2017) and then each species was attributed to an ecological category (Table 1, Fig. 2 [table 1 and figure 2 near here]). An ecological category was intended as a group of species with similar habitat and/or ecology, that can be used as an environmental indicator. The attribution of a species to an ecological and syntaxonomical categories was performed on the basis of the habitats reported by Bonaventura (1932, 1933, 1934, 1937, 1938, 1947) and Zangheri (1966a), integrated by more recent literature (Ubaldi and Speranza 1985; Pignatti 2005; Mucina et al. 2016; Pignatti, Guarino, and La Rosa 2017). Finally, the floristic data were georeferenced by coupling each mentioned location with a point of the toponym layer. To spatialize the microtoponyms (i.e. locally used names, which are missing in the IGMI topographic map), we used the Bonaventura (1947) map and, at the same time, home-born people were interviewed. Finally, we added the following data to each point in the toponym layer: list of species, species richness, list of ecological categories, species richness by ecological category.

For a comparison, we considered Zangheri's floristic data (1966a, 1966b), these being quite synchronous to those of Bonaventura (years of collection 1928 to 1946, months May to October). First, from Zangheri (1966a, 1966b) we extracted only the toponyms included in our study area and the related species; then, we managed the data in the same way as for those of Bonaventura.

As far as current data are concerned (Pezzi et al. 2015), the legend of the vegetation map was harmonized in its content with that of the 1937 land cover map (see Electronic Supplementary Material 1). As already done for the 1937 map, the current vegetation map was subdivided into *mesa* and the remaining part of the study area. Concerning the 98 phytosociological relevés, the cover-abundance values were transformed into presence-absence, the relevés were subdivided between *mesa* and surrounding area and then each species was ascribed to an ecological category (see above). Finally, for the two sub-areas the species ascribed to each ecological category were counted.

Data analysis

We detected the potential extent of investigation by Bonaventura and Zangheri by using the *minimum convex hull* plugin of QGIS 2.18.5 (www.qgis.org). This method allows to derive a surface polygon from a set of points (the toponyms, in our case) and is widely adopted by the IUCN to obtain the extent of occurrence of a species (IUCN 2012). After calculation, *minimum convex hull* polygons for Bonaventura and Zangheri were intersected with the land cover maps of 1937 and 2015.

In R 3.3.3 (R Core Team 2017), a correspondence analysis (*vegan* package; Greenacre 2007) was performed considering the *minimum convex hull* polygons for Bonaventura and Zangheri, to detect differences in land cover types in space (contrasting between *mesa* and the surrounding area) and time (1937 versus 2015). The surface measures for each land cover type were previously transformed into frequencies, based on the pixels ascribed to each type, so as to obtain an occurrence matrix. A χ^2 test was subsequently performed on this matrix (Siegel and John Castellan Jr. 2002).

Then, Bonaventura's and Zangheri's floristic data were compared by calculating Jaccard's similarity index, taking into account the total list of species, the list of species of the *mesa* and the list of species of the surrounding area. The same procedure was applied considering the species splitted into ecological categories. A correspondence analysis (*vegan* package;

Greenacre 2007) was used to explore the pattern of species richness of the ecological categories, in the *mesa* and the surrounding area, with respect to the two authors and present data (Pezzi et al. 2015).

Results

Pattern of land cover

The Monte Fumaiolo area is divided into two sub-areas roughly equivalent in extent: the *mesa* (13 km^2) and the surrounding area (14 km^2). Here, Bonaventura recorded 22 toponyms of the 59 present in the topographic map plus 11 microtoponyms. These allowed to obtain a *minimum convex hull* polygon of 12.6 km^2 (46% of the total extent). The *mesa*, with 25 toponyms, made up 76% of the territory, whereas the surrounding area, with 8 toponyms, only 18%. Zangheri reported 20 toponyms (13 in the *mesa*, 7 in the surrounding area) coinciding with those of Bonaventura, with only one exception. As a consequence, the overlap between the two polygons was high both for the *mesa* (94%) and for the surrounding area (80%; Fig. 1b).

The pattern of the various land cover types included in the polygons significantly differed ($\chi^2 = 3551.71$, $\nu = 49$, $P < 0.000$) in space and time between the *mesa* and the surrounding area (Fig. 3 [fig. 3 near here]; first axis: 78.7%** of the variability): the former was characterized by woods (*Fagus sylvatica* forests and coniferous reforestations), the latter mainly by open areas. The second axis (17.6%** of the variability) showed the changes that occurred from 1937 to 2015. Coniferous reforestations, *Quercus cerris* forests and urban areas increased, bare rocks decreased and hedgerows almost disappeared. Grasslands and *F. sylvatica* forests appeared to be the most stable categories. This pattern was detected equally by both authors.

Pattern of floristic data

Bonaventura's floristic data included 460 species, 71 of which lacking information on collection site, since they were considered very frequent (e.g. *Brachypodium rupestre*, *Holcus lanatus*, *Lotus corniculatus*, *Trifolium repens*). The *mesa* accounted for 224 species (48.7% of the total), the surrounding area for 260 (56.5%). Only 95 species were shared between the two sub-areas (J = 0.24). Two collection sites included the majority of the species of the whole area and of each sub-area: *Fumaiolo* (33.5% of the *mesa* species), and *Balze* (69.2% of the surrounding area species). Furthermore, in Bonaventura there was a wider use of the microtoponyms with respect to Zangheri (160 occurrences versus 11). However, to attain at least 90% of the species recorded for the entire study area 16 collection sites had to be considered (Fig. 4) [fig. 4 near here].

Zangheri's floristic data included 339 species: 222 in the *mesa*, 201 in the surrounding area. Also in this case, species similarity between the two sub-areas was low (84 shared species, i.e. $J = 0.25$). A scarce overlap was found between the species lists of the two data sets ($J = 0.53$), especially when comparing the two sub-areas (J_{mesa} = 0.36; and $J_{\text{surrounding area}}$ = 0.32), or the main collection sites ($J_{Fumaiolo}$ = 0.23; J_{Balze} = 0.34). Furthermore, these two collection sites detained a higher number of species ($P < 0.001$) with respect to Bonaventura's data, and together with three other sites they held more than 90% of the total species list (Fig. 4).

The species were ascribed to 9 ecological categories; all of them were found in both authors' data (Tables 1-2 [table 2 near here]). Average data similarity between the two authors was J = 0.55 ± 0.02 for the ecological categories. The number of species for each ecological category did not significantly differ between Bonaventura and Zangheri (P = 0.941). However, the pattern of the ecological categories significantly differed when considering the sub-areas versus the authors ($\chi^2 = 48.7$, $v = 27$, $P = 0.007$) or the main collection sites versus the authors ($\chi^2 = 53.49$, $v = 27$, $P = 0.002$). The first axis (73.5%** of the total inertia) of the ordination plot (Fig. 5a) separated the *mesa* from the surrounding area. The former was characterised by beech and mesophilous mixed oak wood species (FA), grassland and meadow acidophilous species (GMc) and semimesophilous mixed oak wood species (QCb). The latter was characterised by ruderal-nitrophilous species (RN), mixed oak wood and pre-forest species (QCa). Between the two sub-areas a transition group (categories: GMa, GMb, RO) was also found. In the ordination plot, the second axis (21.4 %** of the total inertia; Fig. 5a) emphasized the differences between the two authors, which are stronger in the *mesa* than in the surrounding area.

The correspondence analysis for the collection sites (Table 2; Fig. 5b [fig. 5 near here]) highlighted the difference both between *Fumaiolo* and *Balze* (first axis: 73.5%** of the total inertia) and between the two authors (second axis: 22.1%**). In fact, the distance between the two toponyms was greater for Bonaventura than for Zangheri.

Finally, significant differences ($\chi^2 = 679.18$, $v = 45$, $P = 0.000$) were found between the historical and current records in terms of ecological categories. In the ordination plot (Fig. 5c), the first axis (54.7%** of the variability) showed the contrast between present and past records, while the second axis (40.8%**) showed that the surrounding area in 2015 was a sort of outlier. Nevertheless, the differences between the *mesa* and the surrounding area were always present, in terms both of year and of author (Fig. 5c).

Discussion

Our results indicate that the two authors investigated a similar surface area. In both cases, one landscape unit appeared explored for the most part, whereas in the other the exploration was concentrated only in a small part. However, the two surface areas were derived from an uneven number of toponyms used by each author, which in turn affected the distribution of the floristic records. Furthermore, the floristic information held for each toponym scarcely allowed the vegetation feature to be described. Nevertheless, when floristic data were referred to a landscape unit and species were attributed to an ecological category, the two floristic datasets reflected the land cover types and helped to detail them. Overall, the quality and quantity of information derived from floristic data increased when shifting from the toponym to the landscape unit and from the species to the ecological category. Starting from these considerations, the historical floristic data revealed their major potentiality in change detection when an area is deeply investigated.

Concerning the extent covered by the two authors, the *mesa* was the main focus of both floristic investigations, being explored by about 80%. Not surprisingly, the major part of the exploration attractors are in the *mesa*: the peak of Monte Fumaiolo, the medieval hermitage and the shrine of Sant'Alberico, the spring of the river Tiber, renowned for its great historical importance, and a forest area in a globally deforested context (Buldrini et al. in press). However, the floristic data by Bonaventura were scattered across a higher number of toponyms (including microtoponyms). This fact seems to reflect the purposes of each author's original survey: a local study in one case (Bonaventura 1932), and a regional in the other (Zangheri 1966a). Among the toponyms, the floristic records were unevenly split up and, in both cases, only two collection sites (*Balze* and *Monte Fumaiolo*) included the majority of the floristic information. It is well known that the irregular distribution of sampling intensity and effort is intrinsically contained in historical floristic data and hinders proper detection of the diversity patterns (Lelli, Nascimbene, and Chiarucci 2018). As a consequence, the species similarity among the two data sets increased from the collection site, to the unit and the total area level. Since a toponym provides a link between physical site and human observation and activity, the subjective perspective in using the toponyms should be considered when using historical floristic data (Conedera et al. 2007). This makes any attempt to assign a buffer zone around a toponym, or to include species lists belonging to a certain toponym into a cell of a digital grid, arbitrary (e.g. Danihelka, Niklfeld, and Šípošová 2009; Mifsud 2013; Cacciatori, Garcia, and Sérgio 2015).

The differences between the two authors were evident also when considering the species grouped into ecological categories. At the unit level, the major differences were found in the interpretation of the *mesa* with respect to the surrounding area. Considering the main toponyms, Bonaventura better differentiated them, thanks to the greater detail with which he explored the study area. Nevertheless, it is worth noting that, despite these differences, the land cover features in the *mesa* and the surrounding area were reflected by the distribution of the ecological categories in both floristic datasets and are in line with land cover types (fig. 2). So, although the floristic data were unevenly distributed within the landscape space and had several biases (i.e. lack of frequent or common species), they unequivocally reflected and detailed the landscape features when aggregated in ecological categories and are referred to landscape units.

Considering the data in a diachronical perspective, the present-day records differed from those of the past, and particularly those of the surrounding area. However, these results could be biased due to the absence of very common species (e.g. White and Walker 1997; Van der

Veken, Verheyen, and Hermy 2004) or a still imperfect floristic investigation (for details, see Buttò and Petrucciani 2009; Abbate et al. 2018). The *mesa*, in turn, seemed to be globally more stable, being in line with the landscape analysis. In any case, the past and present-day records both detected the difference between the two units in terms of ecological categories.

To summarize, historical floristic data reflect land cover types and help to detail them when they are referred to a landscape unit and species are attributed to ecological categories. However, historical floristic data have their main potential in change detection only if the landscape units are investigated in detail.

Acknowledgements

The authors gratefully acknowledge Dr. Leonardo Moretti (Fumaiolo Sentieri association), who provided them with the current map of the paths. Prof. Juri Nascimbene and Prof. Davide Ubaldi offered precious suggestions to improve the manuscript. Dr. Sara Masi helped them with the digitization of the spatial data. Prof. Giovanni Tosatti helped them with the English version of the geological notes. Dr. Michael Webb kindly revised the original English text.

Conflict of interest

The authors declare that they have no conflict of interest.

Fundings

This research was supported by academic institutional funds of the Università di Bologna (person in charge G. Pezzi).

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All the three authors collaborated together in data elaboration and interpretation and in writing the article.

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Figure captions

Fig. 1 – **a**) Location of the study area (Lat. 43.793589, Long. 12.084430). **b**) Convex hull polygons for Bonaventura (continuous line) and Zangheri (dotted line). The thin curved line distinguishes the *mesa* from the surrounding area. Black circles: toponyms cited by Bonaventura and Zangheri; black squares: toponyms cited only by Bonaventura; white triangles: toponyms present in the IGMI map of 1937, but not cited by either of the two authors. Abbreviations: *Abe*: Poggio dell'Abetía, *Aia*: Aia del Monte, *Alb*: Eremo di Sant'Alberico, *Aqu*: Monte Aquilone, *Balze*: Balze di Verghereto, *Cas*: Monte Castelvecchio, *Cel*: Cella di Sant'Alberico, *Cmo*: Casa del Monticino, *Cor*: Corbaia, *Cos*: la Costa, *Fag*: Poggio Sette Faggi, *Fal*: la Falera, *Fon*: Fontebona, *Fumaiolo*: Monte Fumaiolo, *Lag*: i Laghi, *Lis*: Fosso del Liscio, *Moc*: Monte Citorio, *Moi*: Ripa della Moia, *Mot*: il Monticino, *Nov*: Via Nova, *Ocr*: Ocri, *Pas*: Poggio del Passino, *Pet*: Fosso del Petroso, *Rad*: la Radice, *Ron*: il Ronnaio, *Sca*: le Scalette, *Sen*: Senatello, *Sga*: le Sgaline, *Sod*: i Sodi, *Ter*: Terra Rossa, *Tev*: Vene del Tevere, *Val*: Vallone presso la Cella, *Vse*: Vene del Senatello. For further details, see Electronic Supplementary Material 2.

Fig. 2 – Synopsis of the correspondences of ecological categories (squares) and land cover categories (ellipses). The land cover categories (deduced from the IGMI map of 1937) indicate, in a rough way, the general physiognomy of the vegetation; the ecological categories (attributed to the species on a syntaxonomical base) give an idea of the floristic composition of the land cover categories. The lines express the pertinence of the ecological categories to the land cover categories (continuous line: clear pertinence; dotted line: marginal pertinence). Abbreviations for the ecological categories as in Table 1.

Fig. 3 – CA plot of *mesa* (FU) and surrounding area (BA) land cover types. Changes in time (1937-2015) and by the authors (BON: Bonaventura; ZAN: Zangheri) are shown. The extent values were derived from the convex hull method. Abbreviations: Urb = urban areas; Fie = fields; Gra = grasslands and meadows; Hed = hedgerows; Qcw = *Quercus cerris* forests; Fsw = *Fagus sylvatica* forests; Ref = areas reforested with *Pinus nigra* or *Abies alba*; Roc = vegetation of eroded slopes and rocky soils.

Fig. 4 – Cumulative frequency graph for species occurrence by toponyms recorded by the two authors.

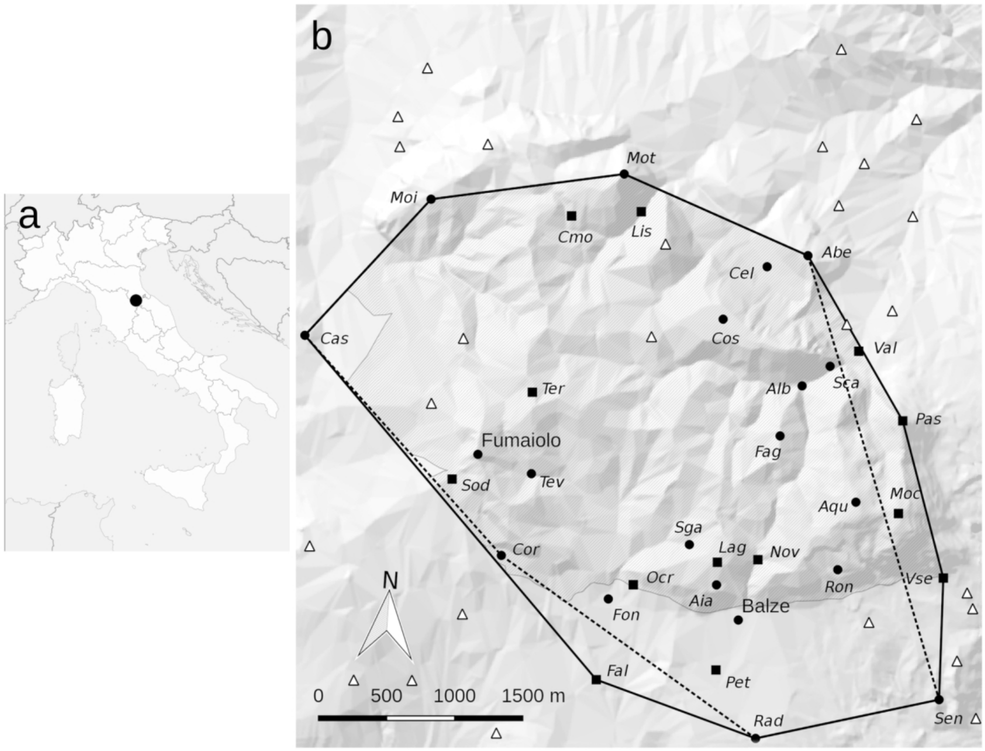
Fig. 5 – CA plots showing the distribution pattern of the ecological categories, considering: **a**) the two authors of floristic data (BON: Bonaventura; ZAN: Zangheri) versus the two landscape units (FU: *mesa*; BA: surrouding area), **b**) the two authors versus the main toponyms (*Fum*: Monte Fumaiolo; *Balze*), **c**) historical (BON, ZAN) and current (Pezzi et al. 2015) records versus the two landscape units. Abbreviations for the ecological categories as in Table 1.

Table 1. List of the ecological categories occurring in the vegetation types of the study area. Syntaxonomical nomenclature follows Mucina et al. (2016).

ECOLOGICAL CATEGORY	Syntaxonomical preference
QCa: Thermophylous species of mixed *Quercus*-dominated woods and preforestry species (these species are also found in the hedgerows – Zangheri 1966a)	*Quercetalia pubescentis-petraeae* Klika 1933, *Prunetalia spinosae* Tüxen 1952, *Cytiso sessilifolii-Quercenion pubescentis* Ubaldi (1988) 1995
QCb: Semimesophilous species of mixed *Quercus*-dominated woods (this category includes some transition species between mixed *Quercus* woods and *Fagus sylvatica* woods: see Materials and Methods)	*Laburno-Ostryion* Ubaldi 1980
FA: Mesophilous species of *Fagus sylvatica* woods and of mixed *Quercus*-dominated woods (these species are also found in mixed *Fagus sylvatica-Abies alba* stands and in pure *Abies alba* reforestations)	*Fagetalia sylvaticae* Pawłowski in Pawłowski, Sokołowski & Wallisch 1928
GMa: Grassland and meadow xerophilous species	*Festuco valesiacae-Brometea erecti* Br.-Bl. & Tüxen ex Br.-Bl. 1949
GMb: Grassland and meadow mesophilous species	*Arrhenatheretea* Br.-Bl. 1947
GMc: Grassland and meadow acidophilous species	*Calluno-Ulicetea* Br.-Bl. et R. Tüxen ex Klika et Hadac 1944
RO: Species of eroded slopes and rocky soils	*Koelerio-Corynephoretea* Klika in Klika & Novak 1941, *Asplenietea trichomanis* (Br.-Bl. in Meier & Br.-Bl. 1934) Oberdorfer 1977
RN: Ruderal-nitrophilous species	*Artemisietea vulgaris* Lohmeyer, Preising & Tüxen ex Von Rochow 1951, *Galio aparines-Urticetea dioicae* Passarge ex Kopecký 1969, *Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951
HY: Hydro-hygrophilous species	*Molinio-Juncetea* Br.-Bl. 1947 and similar classes

Table 2. Species occurrence in each ecological category for Bonaventura (BON) and Zangheri (ZAN), both in the two sub-areas (FU: *mesa*, BA: surrounding area) and in the toponyms with the highest number of recorded species (*Fumaiolo* and *Balze*). OT code indicates the species with no syntaxonomical preference. For the explanation of the abbreviations of the ecological categories, see Table 1.

Category	BON		ZAN		BON		ZAN	
	FU	BA	FU	BA	*Fumaiolo*	*Balze*	*Fumaiolo*	*Balze*
FA	47	29	51	29	18	16	43	23
QCa	10	19	15	15	2	10	15	15
QCb	18	14	14	11	7	9	13	10
GMa	26	29	20	19	8	19	18	15
GMb	15	21	26	18	4	17	23	17
GMc	11	4	9	7	7	2	9	5
RO	17	24	24	26	4	17	21	24
RN	46	85	36	55	15	63	35	47
HY	18	21	11	13	4	18	11	12
OT	16	14	16	8	6	9	12	6



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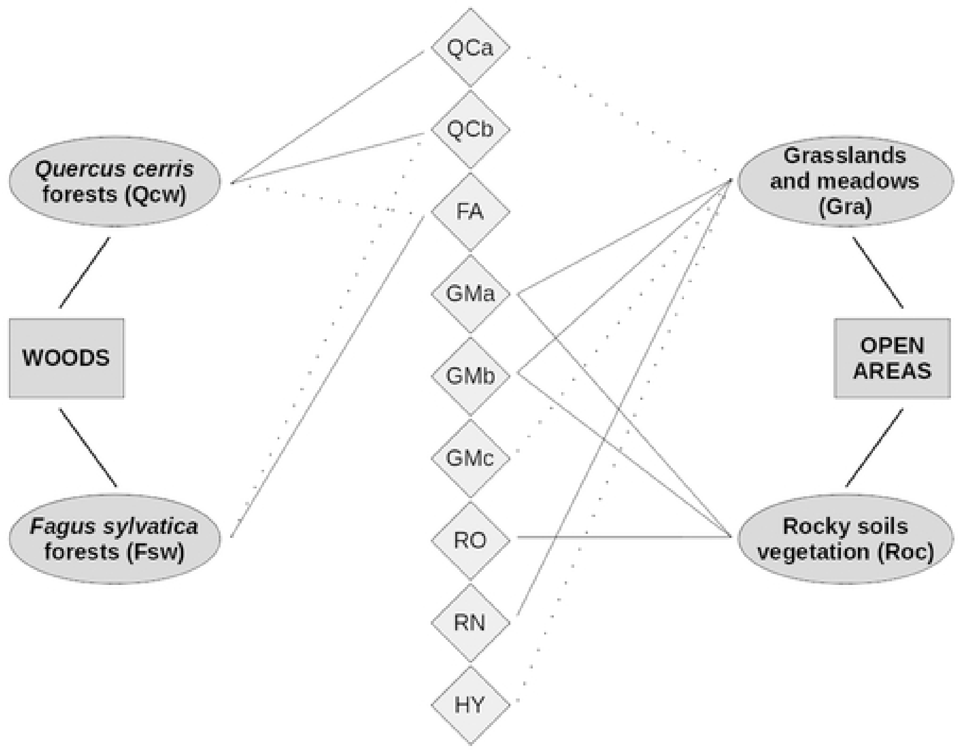

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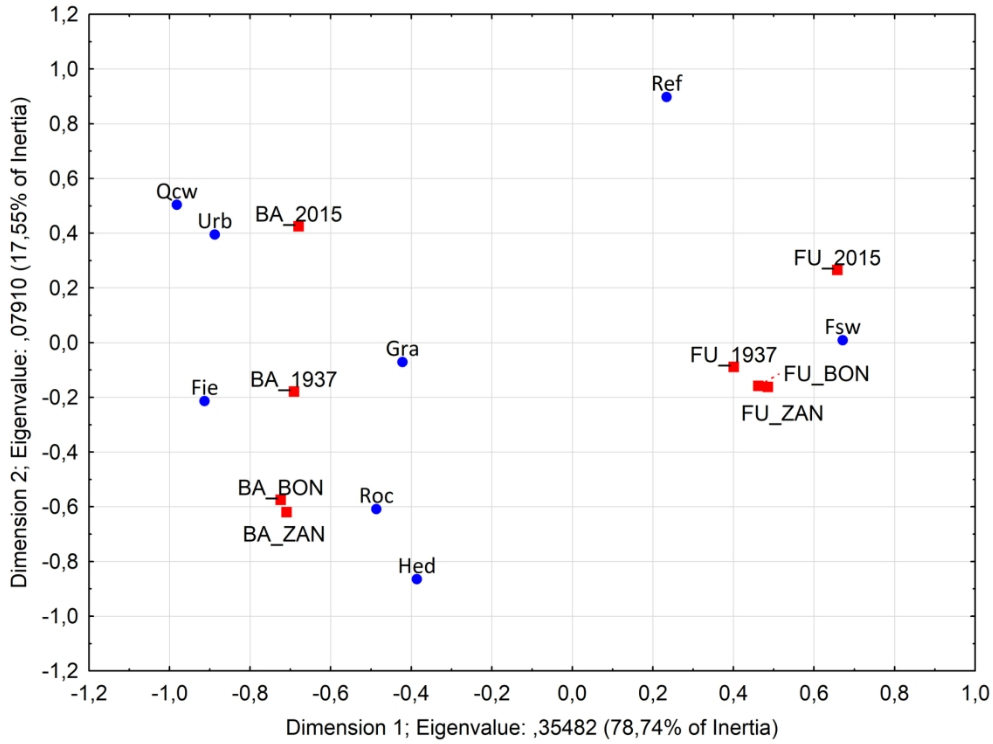

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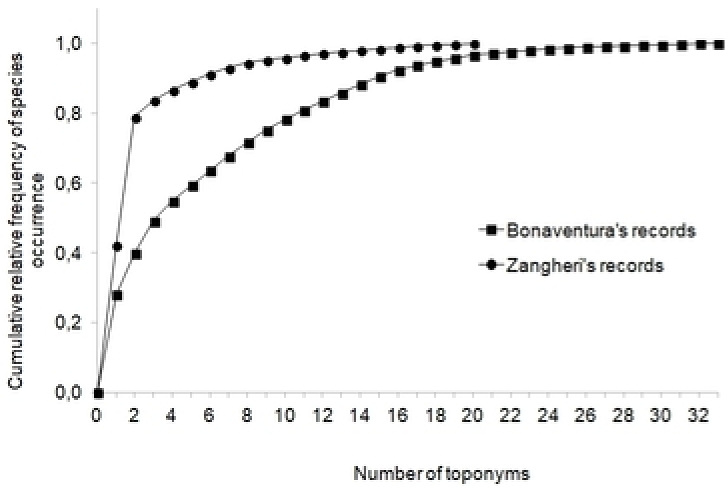

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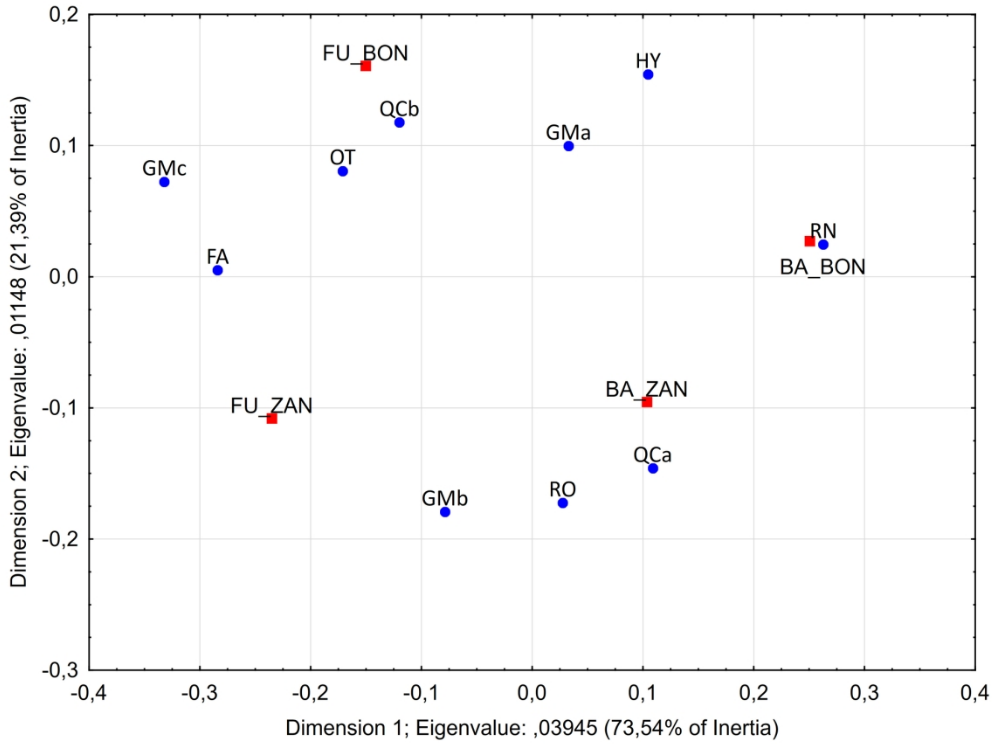

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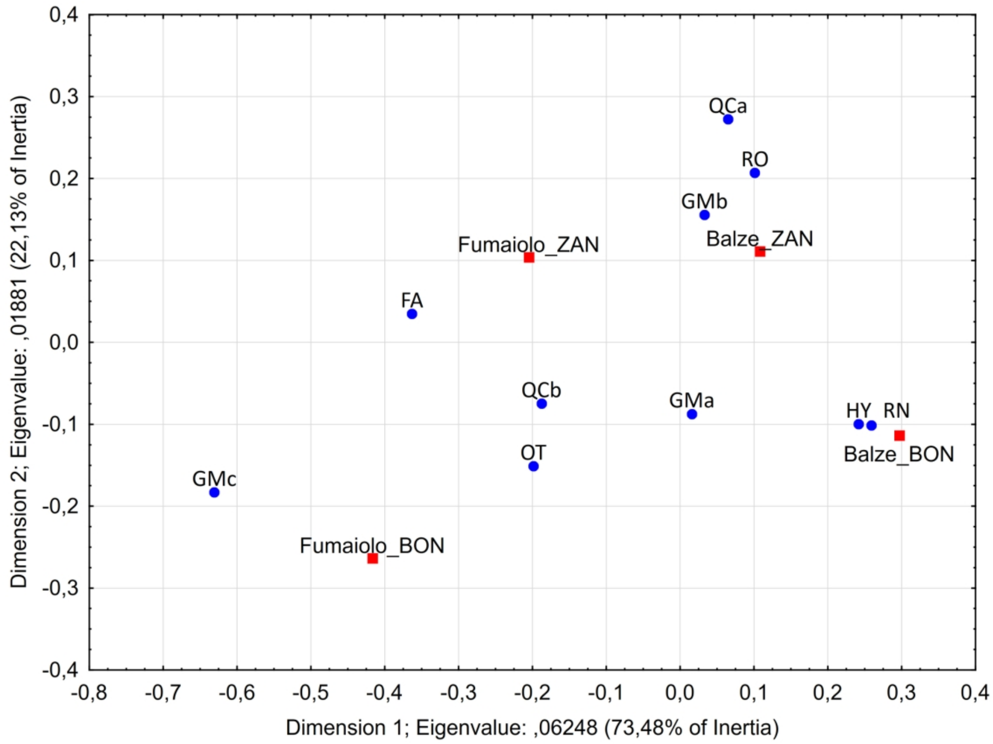

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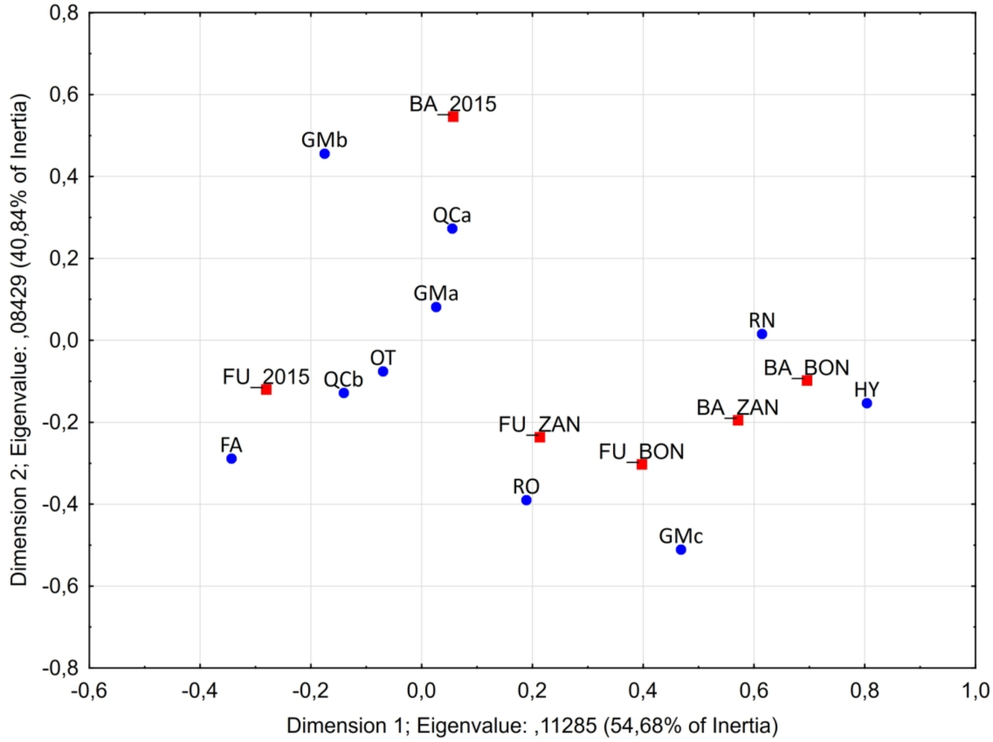

165x123mm (300 x 300 DPI)

ELECTRONIC SUPPLEMENTARY MATERIAL 1

Correspondence between land cover types used in the present study and vegetation types mapped in 2015 (Pezzi et al. 2015).

Land cover types used in the present study	**Vegetation types of the 2015 map (Pezzi et al. 2015)**
Urban areas (Urb)	Urban areas
Fields (Fie)	Fields
Grasslands and meadows (Gra)	Grasslands and meadows of the *Arrhenatheretea* Br.-Bl. 1947
Hedgerows (Hed)	-
Quercus cerris forests (Qcw)	*Quercus cerris* dominated woods of the *Ostryo-Aceretum opulifolii* Ubaldi et al. 1993 em. Ubaldi 2003 (all. *Laburno-Ostryion* Ubaldi 1980)
Fagus sylvatica forests (Fsw)	*F. sylvatica* forests or *Abies alba* and *F. sylvatica* forests of *Galeopsi-Fagetum* Ubaldi & Speranza 1985 (all. *Geranio nodosi-Fagion* Gentile 1974)
Areas reforested with *Pinus nigra* or *Abies alba* (Ref)	*Pinus nigra* dominated woods, mainly belong to the *Ostryo-Aceretum opulifolii* Ubaldi et al. 1993 em. Ubaldi 2003 *Abies alba* dominated woods, mainly belong to the *Galeopsi-Fagetum* Ubaldi & Speranza 1985
Vegetation of eroded slopes and rocky soils (Roc)	Vegetations belonging to the *Sedo-Sclerantethea* Br.-Bl. 1955 and *Asplenietea trichomanis* (Br.-Bl. in Meier & Br.-Bl. 1934) Oberdorfer 1977

ELECTRONIC SUPPLEMENTARY MATERIAL 2

List of the abbreviations of the toponyms used in this study. The complete toponym, the cartogr
The altitude data are taken from the Carta Tecnica Regionale dell'Emilia-Romagna (scale 1:50(

Abbreviation	Toponym	Source
Abe	Poggio dell'Abetía	IGMI 1937 (1:25.000)
Aia	Aia del Monte	Bonaventura, 1947
Alb	Eremo di Sant'Alberico	IGMI 1937 (1:25.000)
Aqu	Monte Aquilone	IGMI 1937 (1:25.000)
Balze	Balze di Verghereto	IGMI 1937 (1:25.000)
Cas	Monte Castelvecchio	IGMI 1937 (1:25.000)
Cel	Cella di Sant'Alberico	IGMI 1937 (1:25.000)
Cmo	Casa del Monticino	IGMI 1937 (1:25.000)
Cor	Corbaia	Home-born people interview
Cos	la Costa	IGMI 1937 (1:25.000)
Fag	Poggio Sette Faggi	IGMI 1937 (1:25.000)
Fal	la Falera	IGMI 1937 (1:25.000)
Fon	Fontebona	Bonaventura, 1947
Fumaiolo	Monte Fumaiolo	IGMI 1937 (1:25.000)
Lag	i Laghi	Bonaventura, 1947
Lis	Fosso del Liscio	IGMI 1937 (1:25.000)
Moc	Monte Citorio	Bonaventura, 1947
Moi	Ripa della Moia	IGMI 1937 (1:25.000)
Mot	il Monticino	IGMI 1937 (1:25.000)
Nov	Via Nova (alias Strada Granducale)	Bonaventura, 1947
Ocr	Ocri	IGMI 1937 (1:25.000)
Pas	Poggio del Passino	IGMI 1937 (1:25.000)
Pet	Fosso del Petroso	Bonaventura, 1947
Rad	Ca' Baticci (alias le Raticcie)	IGMI 1937 (1:25.000)
Ron	il Ronnaio	Bonaventura, 1947
Sca	le Scalette	Bonaventura, 1947
Sen	Senatello	IGMI 1937 (1:25.000)
Sga	le Sgaline	Home-born people interview
Sod	i Sodi	IGMI 1937 (1:25.000)
Ter	Terra Rossa	Home-born people interview
Tev	Vene del Tevere	IGMI 1937 (1:25.000)
Val	Vallone presso la Cella	Bonaventura, 1947
Vse	Vene del Senatello (alias Sorgente del Senatello)	IGMI 1937 (1:25.000)

raphical source of the data, the geographical coordinates and (whenever possible) the altitude are
00).

Longitude E	Latitude N	Altitude (m)
12.099624	43.801832	1161
12.092207	43.779898	1216
12.099455	43.793218	1140
12.104686	43.785644	1354
12.094289	43.777622	1088
12.053960	43.795544	1254
12.095931	43.801017	1085
12.077948	43.803976	1270
12.072499	43.781408	1318
12.092063	43.797462	1351
12.097585	43.789867	1286
12.081506	43.773394	1025
12.082376	43.778750	1103
12.070075	43.788035	1407
12.092219	43.781399	1267
12.084296	43.804397	
12.108597	43.784980	1335
12.065084	43.804794	1315
12.082635	43.806851	1348
12.095908	43.781646	
12.084614	43.779742	1129
12.108732	43.791111	1319
12.092392	43.774275	
12.096195	43.769838	1009
12.103220	43.781148	1209
12.101954	43.794568	
12.112817	43.772768	915
12.089616	43.782505	1226
12.067792	43.786349	1279
12.074864	43.792253	1323
12.075010	43.786868	1270
12.104524	43.795623	1069
12.112866	43.780809	1090

e indicated.