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ORIGINAL PAPER

An assessment methodology to combine the preservation of biodiversity and cultural heritage: the San Vincenzo al Volturno historical site (Molise, Italy)

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Abstract The interaction between natural, archaeological and agricultural elements is evident in many historical sites, such as the Medieval Benedictine Monastery of San Vincenzo al Volturno, located in an area of great agricultural and environmental value. Biodiversity issues are rarely considered in archaeological conservation and vice versa. This paper describes an assessment methodology for the evaluation of the natural and historical value of a site, necessary for a proper evaluation and as a preparatory step to aid decision-making and planning. In the analysed area, our findings showed an interesting floristic and vegetational heterogeneity, which were extremely valuable from a conservation point of view. Few alien species were found. Comparison with protected or endangered species and habitat lists led to the identification of a series of areas in need of more active protection, including arid grasslands presenting high biodiversity and attributable to the 6210* European Habitat. A cultural landscape evaluation was based on archaeobotanical and historical data, and it shows an interesting mosaic system. An assessment of the interaction between natural vegetation and monuments showed minimal impact from wall vegetation but a high potential risk due to wood colonisation in an area with unexcavated buildings. The usefulness of such an approach in the management of an archaeological site is that it offers an opportunity for optimisation: a proper evaluation can reduce the risk of damage and the presence of the archaeological park allows for protection and highlights natural valuable elements.

Keywords Cultural landscape · Nature conservation · Plant biodiversity · Management plan

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Introduction

Man and nature are the main forces among those which influence and shape landscapes (Farina 2000; Ellis 2015; Plieninger et al. 2016). These two components act together and their interaction is particularly evident in the Mediterranean basin, where human activities such as pastoralism and agriculture have strongly modified natural ecosystems over millennia (Blondel 2006; Mercuri 2014), often leading to the creation of significant cultural landscapes (Baiamonte et al. 2015). These provide identity and character to a territory and can be considered of primary importance for the relationship between natural biodiversity and historical, social and economic heritage (Antrop 2005).

The ongoing abandonment of many rural areas (Sluiter and de Jong 2007; Cramer et al. 2008) in Italy highlights the urgency for action to preserve cultural landscapes, and this is even more relevant when the conservation of archaeological sites is involved. Archaeological sites in rural areas display a clear interaction between natural processes and human activities (Mercuri et al. 2010, 2015; Sadori et al. 2015), as do other mosaic landscapes based on a combination of agricultural and semi-natural areas, constituting a valuable pool for biodiversity (Clergue et al. 2005). The positive role of archaeological sites on biodiversity has already been observed, especially in urban contexts where they can constitute green areas, with a higher plant richness than the rest of the city that depends on the type of management practices and diversity of micro-habitats (Caneva et al. 2002). In general, the natural component of these sites benefits indirectly from policies designed to protect the archaeological heritage (Lucchese and Pignatti 2009). In such areas, the preservation of the archaeological element should not imply aggressive management routines (i.e., by promoting extensive use of herbicides) and the importance of floristic biodiversity should not be underestimated, to avoid archaeological areas become devoid of spontaneous vegetation (Caneva et al. 1995; Ceschin et al. 2016).

The role of plants in archaeological areas is, indeed, controversial (Crow and Moffat 2005). Plants contribute to the biodiversity of the area, are an essential component of most landscapes, and can also affect microclimate conditions (by influencing solar radiation, humidity and temperature). They can have, however, negative effects on ancient buildings and structures, putting their maintenance at risk (Celesti-Grapow and Blasi 2004; Caneva et al. 2015), particularly in the case of damage caused by tree roots (Signorini 1996; Caneva et al. 2009; Ejgreen Tjelldén et al. 2015). Despite this, botanical planning philosophies, and the conservation and educational aspects of plants in such contexts, are rarely considered, and very few contributions deal with such topics when analysing archaeological landscapes (Caneva 1997; Papafotiou and Kanellou 2009; Motti and Stinca 2011; Minissale and Sciandrello 2015; Pecchioni et al. 2015). Furthermore, these works often focus on urban areas, whereas many archaeological sites are located in the countryside (Deák et al. 2016): here research is frequently directed on lichens, cyanobacteria or algae (Caneva et al. 2005; Bartoli et al. 2014). In such rural areas, often poorly maintained, the need for planning able to enhance both environmental and cultural values is even stronger.

The aforementioned interaction between natural, archaeological and rural elements in the Medieval Monastery of San Vincenzo al Volturno, located in an area of great agricultural and environmental value, was fully understood by the cultural heritage protection authorities, who promoted this study. The aim of this research is to enhance the assessment of plant biodiversity and understand the botanical value of the archaeological area and its surroundings, using such information in planning the management of the site. Any approach, even those aimed at influencing regional or national policies, cannot overlook

the local context in which it is applicable and effective. The modus operandi described here is a methodological proposal aimed at an improved organisation of the research needed for management purposes. The methodology fits into a framework of growing awareness: from a botanical point of view, increasing attention is paid to the environmental value of vegetation in a natural context and, especially, in anthropic or semi-natural situations (Baiamonte et al. 2015; Bagella et al. 2016; Cerabolini et al. 2016; Deák et al. 2016); from an archaeological prospective, the role of green cover is increasingly seen as an important element, both in a positive and a negative sense, when managing sites and monuments (Caneva et al. 2015; Ejgreen Tjelldén et al. 2015; Bartoli et al. 2016). In addition, the importance of an inter-disciplinary and holistic approach to environmental studies, especially for Mediterranean historical and current landscapes, is widely recognised (Holmgren et al. 2016; Izdebski et al. 2016; Mercuri 2014). Although we focus on a specific study area, we apply a general model of evaluation of natural components for cultural heritage conservation which could be used in other similar contexts.

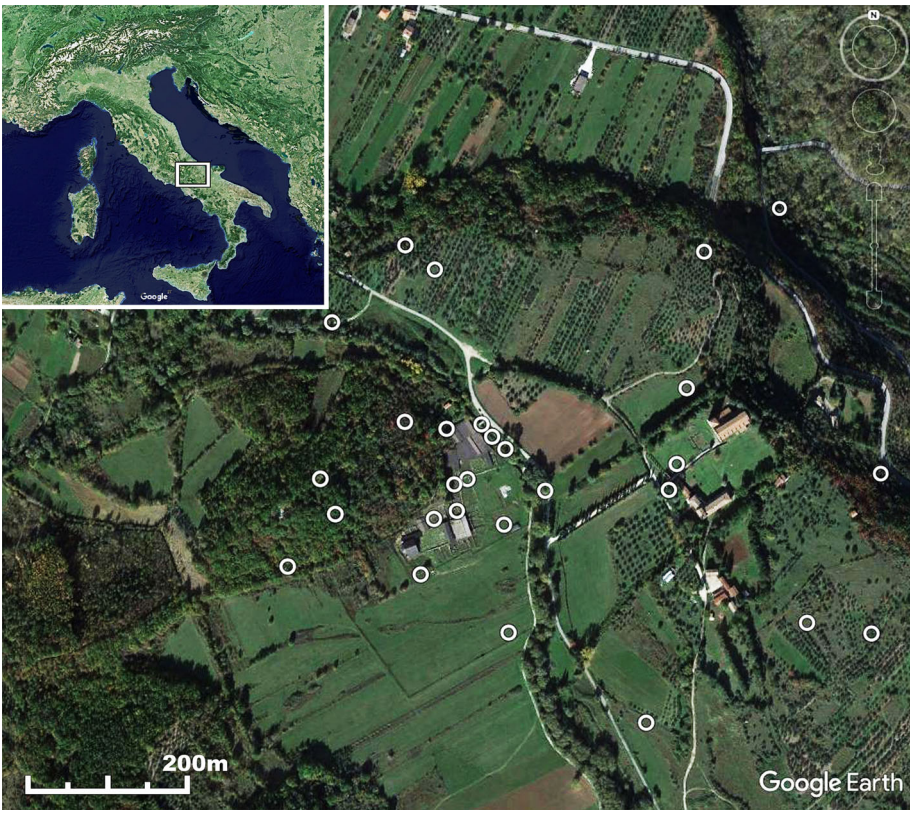

Fig. 1 Location of the study area and sampling points (from Google Earth)

Study area

The area under investigation is located in east central Italy (Fig. 1). It includes the archaeological park, the new abbey, the section of the River Volturno adjacent to the excavation site, some cultivated areas and woodlands near the historical complex, and it covers a total of about 40 hectares. In the archaeological park, the great Benedictine Monastery of San Vincenzo al Volturno was founded around the eighth century AD on the site of a Roman settlement, in an attractive natural setting between the municipalities of Rocchetta a Volturno and Castel San Vincenzo (Isernia, Molise—Central Italy), near the source of the River Volturno and on the edge of the National Park of Abruzzo, Lazio e Molise. This interesting and little known medieval historical site, after being plundered by the Saracens, was definitively abandoned between the eighteenth and nineteenth centuries, after having been incorporated in the abbey of Montecassino. Over the centuries, several buildings were modified or replaced and, until recently, the new abbey was home to a group of American nuns (Testa 2011; Marazzi 2012). Archaeological surveys in the site begun during the twentieth century and revealed a series of significant historical discoveries and interesting findings that shed light on the customs and traditions of the life at the monastery, including remains of food that provided clues as to the monks' diet and local agricultural activities (Hodges 2011).

From a climatic and geographical point of view, the area falls within the temperate bioclimatic region (Rivas-Martínez et al. 2004; Blasi and Michetti 2005; Blasi et al. 2011); with average annual rainfall around 1330 mm, and average temperature around 13.6 °C (source: Management Plan SCI "IT7212128—Fiume Volturno dalle sorgenti al Fiume Cavaliere") (Fig. 2). The historical site is on the Rocchetta a Volturno plain, around 550 meters above sea level, with an extensive travertine bedrock created by the Capo Volturno spring (Brancaccio et al. 1986), on the slopes of the Mainarde hills.

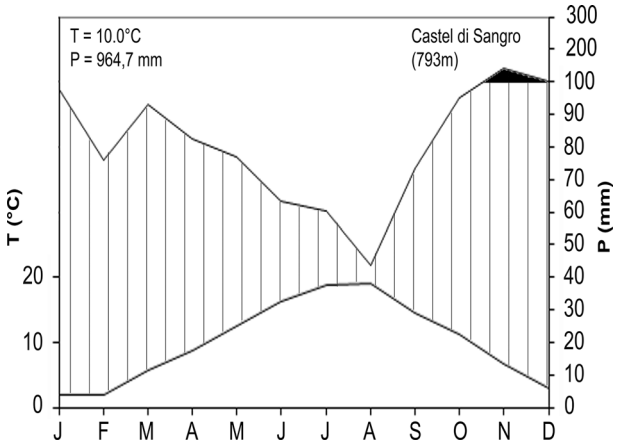

Fig. 2 Thermo-pluviometric diagram (1998–2014) according to the Castel di Sangro (AQ) weather station (processed with Microsoft Office Excel)

Materials and methods

The parameters used to assess the natural, historical and landscape value of the area followed a methodology previously proposed by Caneva (1997), which is now applied for the first time to a rural historical area:

- We evaluated the floristic and vegetation features by taking into consideration floristic and phytosociological analyses of spontaneous and introduced species and communities, and through the assessment of floristic biodiversity. Data were collected during the months of June/July 2015 and May 2016 using a phytosociological approach (Géhu and Rivas-Martínez 1981) and we performed 29 *relevés*. Species were initially identified using "Flora d'Italia" (Pignatti 1982) and specific works for problematic *taxa* (i.e., Moraldo 1986 for the genus *Stipa*); nomenclature refers to The Plant List (2013) Version 1.1 (http://www.theplantlist.org/) and to The International Plant Names Index (2015) (http://www.ipni.org/) for unresolved names, family names were checked following the updated version of APG IV (2016). For each species, the life form and chorological type were reported in accordance with Pignatti (1982). Cluster analysis and PCA for quantitative (abundance) data were performed using Past Software to highlight similarities between communities and recognise plant types. Identification was based on "Plant Communities of Italy: The Vegetation Prodrome" (Biondi et al. 2014) and other works (Biondi et al. 1988, 1992, 2006; Blasi 2010); nomenclature for plant communities follows Weber et al. (2000).
- We evaluated the natural value of each species and community (the estimation was based on conservation interest, rarity, vulnerability, endemism, strict linkage with specific habitats). The natural value of the species was assessed considering their presence in specific laws (local, national and international) and scientific literature: the conservation value was assessed using International Directives (Habitats Directive 92/43/EEC and CITES—Convention on International Trade in Endangered Species of Wild Fauna and Flora) and National and Regional Red Lists (Conti et al. 1992, 1997), the Molise Regional Law (l.r. 23 febbraio 1999, no. 9) lists a series of species considered Rare or Vulnerable for the Molise region, and other lists for endemic/rare species (Lucchese 1995, 1996). We consulted pertinent and recent literature for obtaining information on communities' distribution (Biondi 2005; Biondi et al. 2009; Celesti-Grapow et al. 2010; Genovesi et al. 2014; Paura et al. 2010). The close linkage with specific habitats was obtained comparing our results with all the above lists. We identified critical situations for biodiversity conservation assessing the presence and distribution of exotic species and their invasiveness (i.e., four cores of *Ailanthus altissima* were geo-referred and described). The natural value of each community was assessed through a visual comparison between data collected during the field surveys and the maps of the Potential Natural Vegetation (PNV) based on "La Vegetazione d'Italia – Carta delle Serie di Vegetazione (1:500.000)" (Blasi 2010). The degree of interest of each *syntaxa* (vegetation unit) was based on the list of protected habitats according to the Council Directive 92/43/EEC. A comparison with data from the Management Plan of the Site of Community Importance (SIC IT7212128) (now SAC—Special Area of Conservation) was also performed.
- We performed a bibliographical research to evaluate the historical context and archaeological value, with reference to a large literature on the history of the abbey, records of archaeological excavations (i.e., Del Treppo 1956; Hodges 2011; Hodges and Marazzi 1995; Testa 2011; Valente 1995) and the results of archaeobotanical

examinations of plant material found during the excavation of the kitchen area (Carannate et al. 2007, 2008).

- We analysed the interaction (real and potential) between the natural vegetation and archaeological elements focusing on a number of potential threats. We essentially identified the points of contact between plant parts and artefacts or ancient buildings and we then assessed the degree of threat of each plant (i.e., taking into account their aggressiveness, way of growth, type of roots). We mainly focused on plants directly growing on monuments (both herbaceous and woody) and those (especially trees and shrubs) developing near them (Signorini 1996; Caneva et al. 2009). Our analysis particularly addressed wall vegetation colonising archaeological ruins and the oak forests growing on the hill on the N-W side of the enclosed complex.
- Finally, we evaluated the overall value as described in detail in Caneva (1997) and in the results.

Results

Floristic and vegetation features

A total of 301 species and 59 families were recorded in the area: the most common families were Asteraceae, Fabaceae, Poaceae, Rosaceae and Lamiaceae. The average number of species *per* survey was 28, with a minimum of four and a maximum of 58 in each survey; wetlands and walls resulted as the poorest in biodiversity, while grasslands resulted as the highest as regards plant diversity. The normal biological spectrum showed Hemicryptophytes (43%) as having the highest incidence, followed by Therophytes (22%) and Phanerophytes (17%). The normal chorological spectrum revealed a strong prevalence of Euri-Mediterranean (35%) and Euro-Asiatic (29%) taxa, followed by Steno-Mediterranean (9%), Widespread (8%) and Palaeotemperate (8%) taxa.

Direct observations and statistical analyses led to the identification of three principal types of vegetation (Fig. 3):

(1) *Oak forests and mixed woodlands* They were found to be characterised by the presence of *Quercus pubescens* and can be described as belonging to the *Roso sempervirentis-Quercetum pubescentis sigmetum* and *Carpinion orientalis* alliances, with interesting species and habitats from a conservation point of view. The endemic *Digitalis lutea* subsp. *australis* was found in these habitats; three species of orchids, listed in the CITES Appendix II, were detected: of these *Himantoglossum adriaticum* is also protected under the Habitats Directive (Annex II); *Ruscus aculeatus* (Annex V Habitats Directive) was also recorded in these woodlands. These woodlands can be considered a priority habitat according to the Council Directive: "Eastern white oak woods", code 91AA*. In these habitats we found two neophytes species: the invasive *Ailanthus altissima* and *Juglans nigra* (casually introduced). RIPARIAN VEGETATION was also ascribed in this type of vegetation: it resulted quite common and dominated by *Salix* species. Notable is the presence of *Populus* X *canadensis*, an alien species native to North America (Conti et al. 2005). In a syntaxonomic analysis, such communities can be ascribed to a *Salicetum albae* association, that includes riparian and mature forest vegetation growing in areas subject to regular flooding. Such communities can also be associated with a Council Directive habitat named "*Salix alba* and *Populus alba*

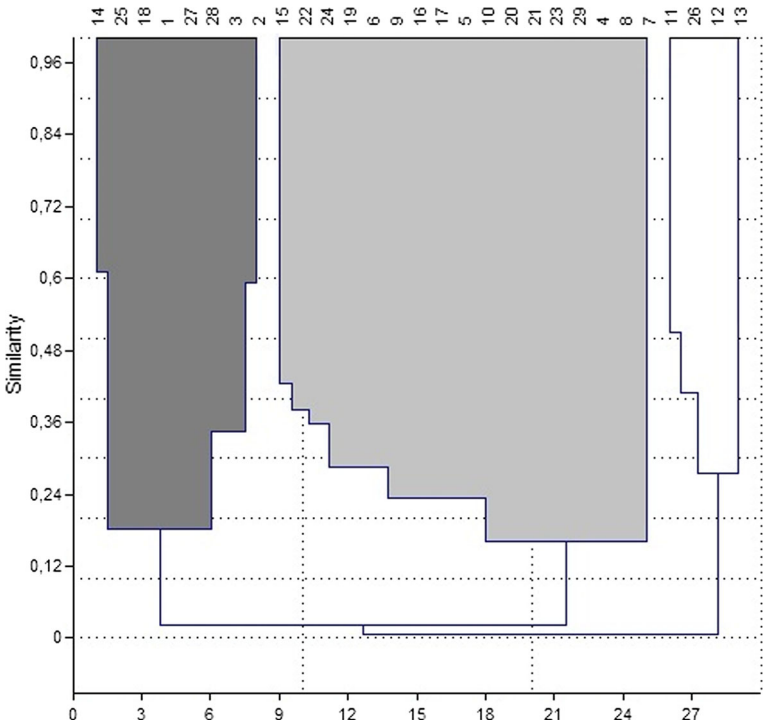

Fig. 3 Cluster analysis on species abundance data showing the three principal types of vegetation. Dark grey: oak forests and mixed woodlands (including riparian vegetation); Light grey: grasslands; White: aquatic vegetation (processed with Past, https://folk.uio.no/ohammer/past/)

galleries", cited under the code 92A0. SCRUBLANDS. These communities dominated by brooms, can be ascribed to the *Spartium juncei-Cytisetum sessilifolii* association, which describes scrublands that are the previous successional stage of the climax vegetation of the area. These communities are often found as ecotones of the woodland communities that represent the Potential Natural Vegetation of calcareous and marly-sandy substrates in sub-Mediterranean mesotemperate bioclimates. In these grasslands, interesting is the presence of the endemic species *Phleum hirsutum*.

(2) *Mesophilic and arid grasslands* The mesophilic grasslands can be classified as belonging to the *Molinio-Arrhenatheretea* class; they grow on flat areas with alluvial substrates, which resulted from the recurrent flooding by the River Volturno, and are home to a rich meadow vegetation, typified by the presence of two endemic species (*Linaria purpurea* and *Phleum hirsutum*) and three orchids listed in the Appendix II of CITES (*Anacamptis morio*, *Anacamptis pyramidalis* and *Orchis purpurea*). The invasive neophyte *Helianthus tuberosus* was also found. Arid grasslands can be classified as belonging to the *Phleo ambigui-Bromion erecti* alliance, which describes secondary grasslands hosting many species of high conservational and biogeographic value: the endemic species *Phleum hirsutum*, *Cerastium tomentosum*, *Sideritis italica*, *Stipa apertifolia* (also protected by Molise Regional Law 23 febbraio 1999, no. 9) and orchids listed in the Appendix II of CITES (*Anacamptis morio*, *A. pyramidalis*, *Ophrys sphegodes* and *Orchis antropophora*). Arid

grasslands can be seen as early successional stages of the above mentioned woodlands and scrublands, corresponding to the *Roso sempervirentis-Quercetum pubescentis sigmetum* and can be assigned to a Council Directive priority habitat defined as "Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)", cited under the code 6210*. They occur on evaporitic and calcareous substrates and were found to be the richest in biodiversity in the study area.

(3) *Aquatic vegetation* It occurs along the River Volturno and includes two protected species: *Carex riparia* and *Iris pseudacorus*, listed respectively as Rare and Endangered by the Molise Regional Law (23 February 1999 no. 9) on threatened flora. Aquatic vegetation belongs to the *Phragmito-Magnocaricetea* class, which includes perennial communities colonising fluvial areas on eutrophic to meso-oligotrophic soils.

Wall vegetation, excluded from our statistical calculations, due to its extremely poor and sparse cover, was dominated by *Sedum* species. Such vegetation can be described as belonging to the *Sedo albi-Scleranthetea biennis* class, with some species belonging to the *Parietarietaea* class.

The landscape, which can be defined as a cultural landscape considering that has not being altered for a long time (Fig. 4a), can be described as a mosaic with vast grasslands, both mesophilic and arid, scrublands and re-colonising forests, with wetlands along the River Volturno (Fig. 4b). The area has great potential for farming and livestock rearing, and today the landscape is still dominated by cultivated lands, especially young, poorly maintained, olive groves and ploughed land, often used for cattle grazing. This mosaic does, however, include the presence of older olive trees, probably representing the remains of ancient plantations. These are also present on the slopes of hills, between the stands of oaks and hornbeams of the mixed forests, demonstrating that once those areas, which have now been re-colonised by natural vegetation, hosted extensive olive groves. The widespread presence of olive groves is explained by the preference of olive trees for well-drained soils such as the altered travertine substrates that form the framework of the Rocchetta a Volturno plain (the study area is situated at the edge of the plain). Cereal crops are prevalent along the River Volturno due to the presence of hydromorphic soils. There are also heterogeneous fruit orchards within this mosaic, such as orchards of cherries, apples, walnuts and plums. The constant presence, and dominance, of the natural component is enhanced by the proximity of the River Volturno and its SAC "IT7212128—Fiume Volturno dalle sorgenti al Fiume Cavaliere" established as a SCI in 1996 within the Natura 2000 network (Council Directive 92/43/EEC) and recently designed as a Special Area of Conservation (Decree of the Ministry of the Environment of March 16, 2017).

Evaluation of the natural value

A comparison with lists of protected and endangered species revealed the presence of interesting taxa from a conservation and biogeographic point of view. For instance, six endemic species were recorded (Table 1), while we found only few alien taxa: *Ailanthus altissima*, *Helianthus tuberosus*, *Juglans nigra* and *Populus* X *canadensis. A. altissima*

Fig. 4 The San Vincenzo al Volturno site. **a** the new abbey and the ancient "Portico dei pellegrini" (pilgrim's arcade); **b** plant communities along the River Volturno with the Mainarde mountains on the background; **c** ninth century frescoes inside the "Crypt of Epifanio"; **d** young forest formation growing on ancient buildings on the "Colle della Torre" knoll

Table 1 Species of conservation and biogeographic value and habitats where the plant was found

Species	Value	Habitat
Anacamptis morio	App. II CITES	Mesophilic and arid grasslands
Anacamptis pyramidalis	App. II CITES	Mesophilic grasslands
Carex riparia	Rare (reg. list)	Wetlands
Cerastium tomentosum	Endemic (Italy[a])	Arid grasslands
Digitalis lutea subsp. *australis*	Endemic (Italy)	Re-colonising woodlands
Himantoglossum adriaticum	Ann. II Hab.D.; App. II CITES	Oak forests
Iris pseudacorus	Vulnerable (reg. list)	Wetlands
Linaria purpurea	Endemic (Italy)	Mesophilic grasslands
Ophrys sphegodes	App. II CITES	Re-colonising woodlands and arid grasslands
Orchis anthropophora	App. II CITES	Arid grasslands
Orchis italica	App. II CITES	Re-colonising woodlands
Orchis purpurea	App. II CITES	Mesophilic grasslands
Phleum hirsutum	Endemic (Italy)	Scrublands, mesophilic and arid grasslands
Ruscus aculeatus	Ann.V Hab.D.	Oak forests and re-colonising woodlands
Sideritis italica	Endemic (S-central Italy)	Oak forests, re-colonising woodlands, scrublands and arid grasslands
Stipa apertifolia	Endemic (S-central Italy); Rare (Reg. List)	Arid grasslands

[a]Cultivated but spontaneously growing in Italy

forms small but expanding woodlands grown during events of recolonisation. We found four of these during the surveys:

(1) Young individuals not yet fertile spread in an area of about 50 square meters, along one pedestrian path;
(2) Some fertile individuals, spread in an area of about 50 m^2;
(3) Mature *A. altissima* with numerous suckers;
(4) Re-colonisating *A. altissima* patches.

This species represents a major issue, because of its fast growth and diffusion, its adaptability and the difficulty in controlling it. The species is often observed in archaeological areas (Mastroroberto 1989; Di Tomaso and Kyser 2007), and due to the aggressiveness of its root system (Kowarik and Säumel 2007), the plant can cause serious damages to ancient buildings. Furthermore, *A. altissima* pollen is recognised as an allergen (Ballero et al. 2003; Blumstein 1943) and this is an important aspect to consider when planning the botanical structure of a site. This Asiatic species has a high invasive potential and, if not curbed, can represent a major threat to the conservation of historical sites. Very hardy and adaptable to any environment, it quickly colonises fallow and disturbed lands, slopes, railways, roads and the edges of streams and it can reach the sub-mountain range, often at the expense of native species. *A. altissima* has long been recognised as a troublesome species all over Europe, and many authors have dealt with its invasiveness and dangerousness both in Continental Europe [i.e., Böcker and Kowarik (1982) for Germany,

Drescher and Ließ (2006) for Austria, Tokarska-Guzik (2005) for Poland], and in Mediterranean countries [i.e., Caneva (1991), Arnaboldi et al. (2002) and Carta (2005) for Italy, Krigas and Kokkini (2004) for Greece].

In the study site, we found many orchids, endemic or protected plants. For instance, we recorded *Anacamptis morio, A. pyramidalis*, *Himantoglossum adriaticum*, *Ophrys sphegodes*, *Orchis antropophora*, *O. italica*, *O. purpurea*; the orchid family is protected by CITES and species belonging to this family are listed in its Appendix II. *Himantoglossum adriaticum* is also listed in Annex II of the Habitats Directive. There is a significant presence of *Cerastium tomentosum*, *Digitalis lutea* subsp. *australis*, *Linaria purpurea*, *Phleum hirsutum*, *Sideritis italica* and *Stipa apertifolia*, all Italian endemics. We found three species that are listed in Annex I of the Molise Regional Law 23 February 1999 no. 9, governing the threatened flora: *Linaria purpurea*, *Stipa apertifolia* and *Iris pseudacorus*, identified as R (Rare), R and V (Vulnerable), respectively.

We also found interesting communities from a conservation point of view (Table 2). These can be referred to habitats of the Council Directive 92/43/CEE. In particular, oak forests and mixed woodlands of the *Carpinion orientalis* alliance can be identified with the priority habitat 91AA* "Eastern white oak woods", typified by the thermophilic character of the Italian peninsula but, at the same time, showing a similarity with those in the Balkans. Arid grasslands present in the vicinity of the archaeological area can be assigned to the priority habitat 6210(*) "Semi-natural dry grasslands and scrublands facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)": typical secondary habitats that were preserved thanks to the survival of traditional agro-pastoral activities and characterised by a high floristic diversity, the dominance of Poaceae and, as in this case, the abundance of orchid species. Finally, riparian vegetation can be assigned to the 92A0 "*Salix alba* and *Populus alba* galleries" habitat: azonal riparian forests of the Mediterranean basin (Biondi et al. 2009; European Commission 2013). All three abovementioned

Table 2 Plant communities and their conservation value

Vegetation type	Community	Habitats directive
Oak woods and mixed forests	*Carpinion orientalis* All.	91AA*: Eastern white oak woods
Scrublands	*Spartio junceiCytisetum sessilifolii* Ass.	–
Mesophilic grasslands	*Molinio-Arrhenatheretea* Cl.	–
Arid grasslands	*Festuco valesiaceae-Brometea erecti* Cl.	6210(*): Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)
Aquatic vegetation	*Phragmito australis-Magnocaricetea elatae* Cl.	–
Riparian vegetation	*Salicion albae* All.	92A0: *Salix alba* and *Populus alba* galleries
Wall vegetation	*Sedo albi-Scleranthetea biennis* Cl.	–

communities were also identified in the Management Plan (dating back to December 2015) of the SAC with which our study area partially overlaps.

On a small scale, the Potential Natural Vegetation in the area is represented by the *Daphno laureolae-Querco cerridis sigmetum*, a mesophilic series linked to the Temperate Region and characterised by Turkey oak and Downy oak formations. Such woodlands are related to marly-peltic substrates on mature soils between 500 and 800 m a.s.l. On a more detailed level, however, the existence of a highly permeable substrate, such as travertine, creates more arid conditions that can better fit with a Mediterranean phyto-climatic context. Therefore, the Potential Natural Vegetation should, most likely, be identified with the *Roso sempervirentis-Querco pubescentis sigmetum*: a Downy oak dominated forest, often in association with deciduous species such as *Fraxinus ornus*, *Acer campestre* and *Carpinus orientalis*. In this context, the woody vegetation observed reflects, in reality, the climax vegetation of the area. The same applies to bushes (*Spartio juncei-Cytisetum sessilifolii* association) and xeric grasslands of the *Phleo ambigui-Bromion erecti* alliance, which fit in the intermediate mantle and herbaceous communities of the same *sigmetum*.

Historical context and archaeological value

The historical and archaeological value of this site is undeniable: San Vincenzo al Volturno was one of the largest monasteries in Europe and represents the continent's most extensive Early Medieval site (Hodges and Marazzi 1995). In particular, the "Crypt of Epifanio", discovered accidentally by a farmer in 1832, is one of the masterpieces of the religious culture in Early Medieval Europe, with the most important cycle of ninth century frescoes (Fig. 4c). It miraculously survived the Saracen invasion and the ravages of time (Valente 1995). Archaeological excavations, begun in 1979, have brought to light a forgotten history, which began in the fifth century AD, representing an essential *tessera* of our past, history and culture.

Interesting information collated with our bibliographical research came from archaeobotanical analyses of plant remains from the kitchens of the ancient monastery, unearthed between 2001 and 2002 (Carannate et al. 2007, 2008). Such material has been dated to the last period of activity of the Monastery before the Saracen invasion (which occurred on 10th October 881) and consists in remains of fruits and seeds (Marazzi and Gobbi 2007). Archaeobotanical data confirm the mainly vegetarian diet of the monks (as prescribed by the Benedictine Rule); the most abundant remains were identified as parts of *Vitis vinifera*, *Sambucus* cfr. *ebulus* and *Juglans regia*; legumes such as *Vicia faba* and *Lens* sp. were also plentiful. Cereals were mainly used for bread-making, and many leftovers of *Triticum* spp. and *Hordeum* sp. were recorded; remains of *Prunus* sp., *Olea europaea* and *Corylus avellana* were also abundant (Carannate et al. 2007, 2008). Around 20 animal species and 20 plant taxa were found in various contexts inside the kitchen area, and such evidence leads us to hypothesise a complex multicultural system, although we are still unsure whether this reflects the actual life of the Monastery or it is evidence of foodstuffs brought in from external farms (Marazzi and Gobbi 2007).

Interaction of natural vegetation with ancient buildings and archaeological elements

No significantly critical situations for the cultural heritage were observed within the study area, as tree species are practically absent inside the historical site; in addition, we only found sparse wall vegetation. In addition, this wall vegetation was mainly composed of

small herbaceous species of the *Sedo albi-Scleranthetea biennis* class, which describes pioneer communities typically growing on rocky surfaces (Biondi et al. 2014). An issue of concern could be the expanding stands of *Ailanthus altissima*, as mentioned above.

A situation of high potential risk was observed in "Colle della Torre" (Fig. 4d), a little knoll on the N-W side of the historical site. The hill is covered by a *Quercus pubescens* forest, associated with other tree species, such as *Fraxinus ornus*, *Carpinus orientalis* and *Acer campestre*. This can be considered a young forest formation (average height does not exceed 8-10 meters) colonising ancient olive groves, which are mostly declining due to the growth of new vegetation. Even the shrub layer, formed mostly by *Cytisophyllum sessilifolium*, *Emerus major*, *Spartium junceum*, *Prunus spinosa* and *Rubus ulmifolius*, advocates for the young age of these formations. The knoll hosts a series of archaeological remains, including a dormitory and a cemetery which have already been excavated, and at least two buildings not yet brought to light, one of which is thought to be a church. The woodland growing on these ancient buildings can be a serious threat for the conservation of such historical remains, because of the interaction between vegetation roots and buried structures (Mastroroberto 1989; Signorini 1996).

The overall evaluation of the interest

A general evaluation of the interest of the area is shown in Fig. 5, which represents the methodological approach followed and suggested for archaeological areas. Table 3 resumes the results obtained following the proposed methodology.

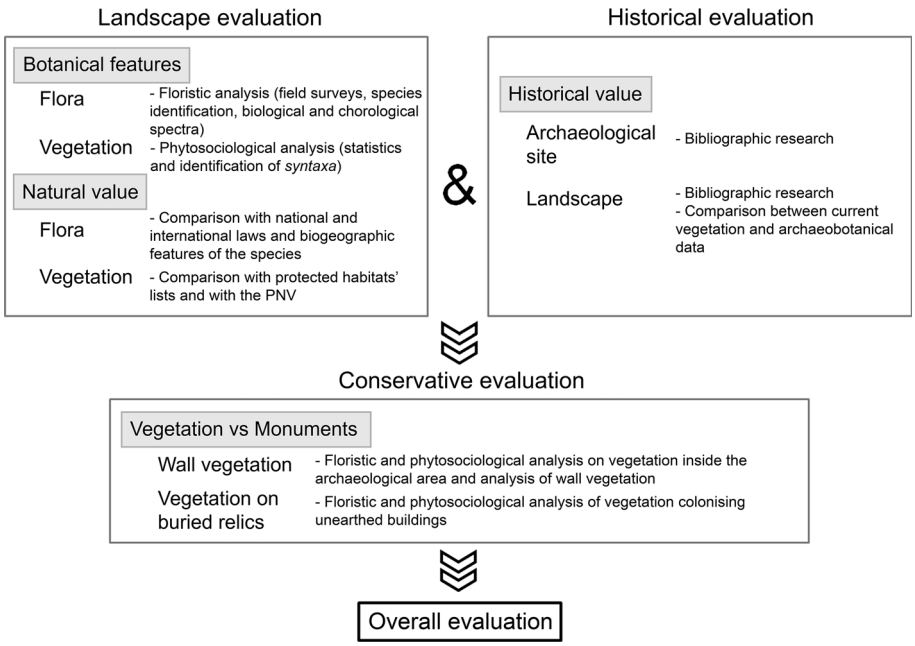

Fig. 5 Methodological approach suggested for the assessment of the overall value of archaeological sites in rural areas

Table 3 Results obtained following the proposed approach

Landscape evaluation		
Botanical features	Flora	301 species (59 fam.) Average number of spp./survey: 28 (min. 4, max. 58) Hemicryptophytes and Euri-Mediterranean prevail
	Vegetation	Three main types of vegetation Oak forests and mixed woodlands (including riparian vegetation and scrublands) Grasslands (both mesophilic and arid) Aquatic vegetation
Natural value	Flora	16 species of conservation value 6 endemics 4 alien species
	Vegetation	3 habitats listed in the Habitat Directive (2 priority habitats) Communities congruent with the PNV (potential natural vegetation)
Historical evaluation		
Historical value	Archaeological site	The biggest Early Medieval site in Europe One of the most important cycle of frescoes of the IX Century
	Landscape	Mosaic rural landscape
Conservative evaluation		
Vegetation versus monuments	Wall vegetation	No arboreal vegetation inside the archaeological area Wall vegetation poor and herbaceous Stands of *Ailanthus altissima* nearby the site
	Vegetation on buried structures	High potential risk due to the re-colonising woodlands growing on buried structures
Overall evaluation for a management plan		
Activities aimed at the protection of the identified relevant species, preservation of the cultural landscape, periodic maintenance of vegetation, removal of the invasive species and of trees with aggressive growth from the proximity of the archaeological site		

Discussion

Our results suggest that, in the management of an historical site within a natural area, we should consider the preservation of both the natural component and the historical/artistic value (Caneva 1997). This holistic approach agrees with the spirit of new international programs and initiatives, such as the UNESCO-SCBD "Joint programme on the links between biological and cultural diversity" (2010) and the core principles of the Florence Declaration (2014). These initiatives underline the importance of implementing projects aimed at safeguarding biological and cultural diversity because of their relevance for future generations and their importance for related ecosystem services; for this reason, UNESCO promotes initiatives on a regional, national and local level with the same goals in mind. Once the key elements have been identified (Fig. 5), it becomes possible to design the most appropriate actions to protect and enhance the site's main characteristics.

Considering our aim to apply a holistic approach to a real situation, the investigated site proved to be an interesting case-study due to its great biological diversity, historical value and rural context (Table 3). The first point worth considering concerns the botanical context: the floristic richness we had expected was confirmed and resulted linked to many factors, including the mosaic framework of the landscape (Amici et al. 2015), the vicinity

of a protected Natura 2000 site, and the presence of the archaeological area, influencing management practices and conservation policies that guarantee a certain degree of safeguarding from anthropic pressure (Lucchese and Pignatti 2009); the same conditions promote an interesting biodiversity even at a community level. In a wider concept, the landscape in its totality appears to be formed by a series of distinct areas (low impact agricultural areas, grasslands, scrublands, forests, riparian vegetation); such mosaic frameworks, especially in traditional rural zones, are now universally recognised as being of great natural and conservational value, hosting a rich botanical, zoological and environmental diversity. The position of traditional agriculture is particularly interesting, because of its close connections and mutual influence with biodiversity (Taffetani 2008; Taffetani et al. 2006; Agnoletti and Rotherham 2015; Baiamonte et al. 2015; Duflot et al. 2015; Bagella et al. 2016; Cerabolini et al. 2016). It was also found that many habitats included in Annex I of the Habitats Directive can only exist with the help of low-intensity agricultural management: these habitats include, for instance, the priority habitat *6210 "Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)", the maintenance of which is seen as being closely dependent on the type of agricultural management (Halada et al. 2011; Viciani et al. 2014).

The identification of communities and data on the Potential Natural Vegetation provide information on which species would be most suitable for re-vegetation projects. According to our study, the most suitable communities would be grasslands, both mesophilic and arid, since they host 207 species, corresponding to 69% of the entire biodiversity recorded in the study area. The arid grasslands were extremely rich in species of conservational value, including orchids, making this an EU priority habitat; they also host scattered patches of the endemic *Stipa apertifolia*, protected by the regional law. Such formations, as mentioned previously, depend heavily on the type of management practices and are intimately linked to activities typical of traditional agriculture. In the case of San Vincenzo, the role of agriculture acquires even more significance due to its historical and cultural value: in the area corresponding to the ancient kitchens archaeological excavations revealed many organic remains that can be considered evidence of a past agrarian landscape. In addition to a few mammals, bird and fish bones, many plant parts and remains of various species were identified (Carannate et al. 2007, 2008). Historical sources describe the rural environment during the Middle Ages as being composed by a series of small and medium-sized fields, which were tended by the owners themselves; wheat, barley, millet, olive groves and vineyards were the most common crops (Del Treppo 1956). A further point of interest concerns ecosystem services and the complex links that connect them with agricultural practices and biodiversity (Dale and Polasky 2007; Maes et al. 2012; Harrison et al. 2014). The maintenance of ecosystem services and of the traditional rural landscape involves multiple factors: ecological, economic, environmental, social, historical and cultural (Agnoletti 2014). An analysis of the floristic composition, structure and distribution, makes it possible to identify those situations which are critical for the protection of monuments. Risk factors are mainly related to woody plants close to the historical structures, since they can jeopardise their stability with the growth of roots (Signorini 1996; Caneva et al. 2009), and to wall vegetation, which can degrade a substrate both on a mechanical and chemical level (Mishra et al. 1995; Bartoli et al. 2016). In anthropic areas, threats to biodiversity due to human activities and land-use changes can be many, and the effects are often irreversible: i.e., "green management techniques" within archaeological areas, when carried out indiscriminately and with a widespread use of herbicides for vegetation control, may affect the natural quality of the area but can also influence the overall aesthetic value of the landscape (Casella and Vurro 2013). In a rural landscape, another risk is represented by

grazing activities: intensity, density and type must therefore be carefully screened, assessing costs and benefits. Sometimes grazing plays a positive role for the biological diversity, preserving grassland formations and preventing the natural evolution of the vegetation towards scrublands and woodlands, maintaining at the same time the mosaic landscape (Halada et al. 2011; El Aich and Waterhouse 1999). On the other hand, continuous trampling has serious effects on soil texture, and therefore on its framework and permeability and, consequently, on vegetation cover (Li et al. 2008). Last but not least, livestock feeding practices exert a decisive influence on the kind and extent of potential damage on vegetation (Jauregui et al. 2008; Wehn et al. 2011). Finally, an evaluation of the ecosystem services derived from agriculture, forestry and pastoralism, in synergy with cultural heritage conservation, seems a further fundamental step in defining a management plan.

The guidelines which have been applied at the San Vincenzo al Volturno site can, with the appropriate amendments, be valid and effective even in other historical areas and cultural landscapes. The flora and vegetation analysis makes it possible to identify the most interesting species and communities and to recognise critical situations, providing a clear and complete picture of the study area. Such analysis allows to identify a site's particular characteristics and critical factors, in order to achieve a better organisation of the botanical planning: the comparison with current national and international legislation, and with species and habitat lists related to conservation and biogeographic priorities, also provides an overview of the site. Knowing the spatial distribution of specific plants or communities makes more informed and careful planning possible, and allows to plan ad hoc interventions.

Conclusions

The approach proposed in this paper arises from a growing interest and awareness about the importance of vegetation management in archaeological areas, and is aimed at achieving a planning strategy in which the natural and cultural elements of the areas can enhance each other. The assessment methodology proposed here, proved to be suitable as a starting point for a management plan, aimed at protecting both biodiversity and cultural heritage. In fact, due to the intricate interaction between nature and archaeological artefacts, we highlight the need for an accurate and scientific knowledge of the ecological features of historical sites and monumental areas, which can help to decide upon the best solutions.

The approach proposed here allows to identify the specific characteristics of the study area and the critical issues arisen from the mutual influence between natural and historical components. We suggest that, in the future, more complete management plans would be necessary in order to improve resource quality, quantity and sustainability. The usefulness of the proposed approach in the management of an historical site is in its potential for optimisation: a proper evaluation can reduce the risk of damage to monuments, and the presence of an archaeological park makes it possible to protect and highlight elements of floristic and vegetation value.

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