Are Cichorieae an indicator of open habitats and pastoralism in current and past vegetation studies?

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Abstract - Cichorieae, one of the six tribes of the sub-family Cichorioideae (Asteraceae), produces a well-recognizable fenestrate pollen type. In the Mediterranean area the significance of high percentages of Cichorieae pollen from archaeological layers is still questioned. We assessed the presence of Cichorieae as indicators of open habitats and pasturelands in current plant communities, by comparing data on vegetation composition with pollen spectra from two Hellenistic sites of Basilicata (southern Italy): Difesa San Biagio in the low valley of the river Bradano, and Torre di Satriano in the Lucanian Apennines. We also analysed the pollen morphology bringing to the discrimination of size classes within the fenestrate type of Cichorieae.

Pollen spectra from the archaeological sites have low forest cover (7% on average); Asteraceae and Poaceae are prevalent; Cichorieae account to ca. 23%; coprophilous fungal spores are varied and have high concentrations. In surface soil samples collected near the sites, Cichorieae pollen is about 12%. In current vegetation types, an increasing abundance of Cichorieae was observed from saltmarshes, forests and shrublands to open habitats and grasslands. This is coherent with the actual land cover around the study sites and the findings of the archaeological sample that points to an open landscape dominated by pastures and cultivated fields. Our integrated approach confirmed that today Cichorieae are common in secondary pastures and in some types of primary open habitats of southern Italy: hence, high percentages of this pollen can be considered a good indicator of these habitats even in past environment reconstructions.

Keywords – archaeological sites, Basilicata, Mediterranean, palaeoecology, phytosociological database, pollen morphotypes

INTRODUCTION

Land-use and climate shape vegetation and landscape. This is especially evident in the Mediterranean basin where a cultural-ecological continuum contributed to the development of agricultural practices that has been visible during the last millennia (Mercuri & Sadori 2014). Besides crop cultivation, forest management and clearance, animal breeding and pastoralism are among the primary agents that have transformed the Mediterranean landscape.

Past evidence of such ancient practices is found in palaeoenvironmental records and in organic deposits of archaeological sites (Lowe et al. 1994; Branch & Marini 2013; di Lernia et al. 2013; Orengo et al. 2014). Most of the traces left by animals are in the chemical elements that enriched sediments, or in the effect of browsing on soil and plant communities (e.g. Bakker 1998; Blasi et al. 2009; Mercuri et al. 2010; Papanikolaou et al. 2011; Farris et al. 2010a; Hillbrand et al. 2014).

In general, land exploitation by humans produced changes that are visible in the archaeobotanical records studied from Eastern (Van Zeist & Bakker-Heeres 1982; Hillman 1984; Bakker et al. 2012; Willcox et al. 2012), Southern (Giraudi et al. 2013; Zapata et al. 2013), Western (Jalut et al. 2000; Zapata et al. 2004; Ejarque et al. 2010) and Central Mediterranean area (Branch et al. 2005; Sadori et al. 2011; Mercuri 2014). In Italy, anthropogenic pollen indicator curves increase during the last three millennia when the trend of Cichorieae follows Poaceae, *Plantago* and *Urtica* in off-site diagrams (Mercuri et al. 2012: p.358).

Cichorieae, one of the six tribes of the sub-family Cichorioideae (Asteraceae family; ICN 2014), produces a well-recognizable pollen type that many palaeoecologists consider a good marker of the action of herbivores on vegetation (Hjelle 1999; Mazier et al. 2006; Ejarque et al. 2011).

The significance of Cichorieae in pollen records from Mediterranean context is still controversial. The high percentage of Cichorieae is usually explained by two different interpretations: a) selective corrosion (Bottema 1975; Dimbleby 1985; Di Rita & Magri 2009; Triantaphyllou et al. 2010) resulting in the overrepresentation of pollen with high-resistant exines in little conservative, alkaline and poor sediments, like some layers from archaeological sites; b) presence of pastures (Birks et al. 1989; Behre 1986) in which these pollen grains are abundant as they are linked to herbivore action and animal browsing leading to a certain selection of plants. For example, Cichorieae pollen are included in the Local Pastoral Pollen Indicators (LPPI) by Mazier et al. (2009), and in the Pollen

Disturbance Index (PDI) by Kouli (2014).

In 2010, two papers have demonstrated that the over-representation of Cichorieae cannot rely only on selective corrosion and oxidation of exine: i) Lebreton et al. proved through an experimental approach that oxidation does not generate any artificial over-representation of a specific pollen taxon, including Cichorieae; ii) Mercuri et al. compared Cichorieae and indeterminable pollen percentages, and calculated that an increase of Cichorieae does not correspond to an increase of deteriorated pollen. They both concluded that the presence of Cichorieae can reasonably be interpreted as pasture indicators.

In Mediterranean and arid zones, Cichorieae pollen is found in records describing environments that had developed under a long-time human pressure. Besides the above mentioned anthropogenic pollen indicators, indicating the spreading of human-influenced environments, their significance as indicators of pasturelands is suggested by the co-presence of coprophilous fungal spores in the same samples (Kouli et al. 2009; Mercuri et al. 2010).

This paper will appraise the value of Cichorieae as indicator of open habitats and pasturelands by assessing the incidence of Cichorieae in current plant communities of southern Italy. This will contribute to clarify the meaning of high rates of Cichorieae pollen found in Mediterranean records including archaeological sites. In particular, the central Mediterranean region of Basilicata was selected for a comparison of past and current contexts due to two main reasons: i) The availability of recently published pollen analyses from several archaeological sites (Mercuri et al. 2010; Florenzano & Mercuri 2012); ii) The features of this region that preserves a fairly intact evidence of ancient agricultural practices despite the occurrence of more deep land-use transformations during the last two centuries (Morano 1994; Pontrandolfi 1999). Basilicata displays a high diversity of environmental features and vegetation types, belonging either to Mediterranean and Temperate biochores (e.g. Blasi 2010; Fascetti et al. 2013).

The aim of this paper is to assess if a higher incidence of Cichorieae species is present in modern grassland communities linked to human activities and pastoralism, a hypothesis already proposed for the interpretation of pollen deposits from archaeological sites but never tested on the current vegetation of southern Italy. This paper proposes an integrated discussion of the main results obtained from palaeoecological and ecological studies carried out in the region: the presence of Cichorieae in pollen and vegetation composition spectra is evaluated according to the joint interpretation of the past and current data.

MATERIAL AND METHODS

Study area (Figure 1)

The Basilicata region lies in the southern Apennines between the Ofanto river in the north and the Mt. Pollino (2248 m a.s.l.) massif to the south. Most of the territory is mountainous (47%) or hilly (45%). The region also has a short coastline to the southwest on the Tyrrhenian Sea and along the Ionian Sea to the southeast. Mediterranean bioclimate prevails along the coast, whereas the inner areas display a Temperate climate with continental features. Rainfall has a typical Mediterranean regime, with rainy winters and dry summers; minimum annual values are recorded in the Metaponto coastal plain (532 mm) close to the Ionian Sea, and maximum ones (up to 2000 mm) are shown in the mountain area along the Tyrrhenian Sea. Phytoclimatic belts range from the Dry Thermo-Mediterranean zone along the Ionian coast to the Hyperhumid Orotemperate zone (Blasi & Michetti 2007) of the highest mountains. The dominant Potential Natural Vegetation (PNV, *sensu* Farris et al. 2010b) is broadleaved deciduous forests, spanning from xeric white oak Mediterranean communities (e.g. *Oleo-Quercetum virgilianae)* to Temperate oceanic microthermal beech forests (*Ranunculo brutii-Fagetum sylvaticae*); however, most of the territory is occupied by the Mesotemperate Turkey oak vegetation series of *Lathyro digitati-Quercetum cerridis* (see also Di Pietro et al. 2010).

The region has a heterogeneous plant cover, with large forests and secondary pastures in the mountains, and cereal crops and olive orchards in the hilly landscape. Due to mild temperature regime and water availability, the Ionian coastal plain is characterized by intensive fruit farming and horticulture.

The archaeological context and studied sites

The central and eastern parts of the Basilicata region have well-preserved archaeological sites belonging to different chronological phases (Bronze age, Hellenistic, Roman and Medieval periods) that have been investigated by archaeologists since the '70s. Pollen and plant macroremains have been analysed with the aim of obtaining reconstructions of plant landscape, land-use and diet (Costantini 1983; Novellis 2009; Florenzano 2013). The palynological investigations have contributed to palaeoenvironmental reconstructions providing details for the vegetation history recorded from terrestrial off-site cores on a supraregional scale (e.g. Allen et al. 2002; Joannin et al. 2012). Based on both microscopic grazing indicators and archaeological evidence, environmental reconstructions stress the importance of pastoralism in the past economy of these lands (Florenzano & Mercuri 2012; Florenzano et al. 2013). Two archaeological sites, covering from the 6th to the 1st

century BC, were selected for this study (Figure 1).

The site of Torre di Satriano (TS; 930 m a.s.l.; 40°34'13"N, 15°38'15"E) is placed on an isolated steep relief north-west of the city of Potenza, between the Melandro and the Platano torrents. The site is located along one of the main routes ("Trazzera degli stranieri") from the Tyrrhenian to the Ionian coast, today also used for transhumance towards the summer mountain pastures. An open landscape characterizes the area, with pastures (*Brachypodium rupestre* (Host.) Roem. & Schult., *Bromus erectus* Huds., *Dactylis glomerata* L., *Trifolium pratense* L.), sparse shrubs (e.g. *Spartium junceum* L.), arable land and small *Quercus cerris* L. forest fragments. Phytoclimate is Oceanic-Semicontinental Mesotemperate Humid; the dominant PNV is represented by Turkey oak deciduous forest of *Lathyro digitati-Querco cerridis sigmetum.*

TS was a settlement organized in groups of huts and developed since the mid-8th century BC. An outstanding dwelling (*Anaktoron*), discovered on the northern slopes of the hill (Osanna et al. 2009) was probably a centre of power from the mid-5th to the beginning of the 4th century BC. Its owner must have been a leading figure within the local community, its power being linked to the control of the main routes connecting inland areas to the coast and used by shepherds with flocks. Pollen samples were taken from the *Anaktoron* and its adjacent productive area.

The site of Difesa San Biagio (DSB; 180 m a.s.l.; 40°30'21"N, 16°40'51"E) lies in a hilly landscape in the lower valley of Bradano, close to the Metaponto plain. Bioclimate is Oceanic Mesomediterranean Dry. The most favourable landforms were transformed to arable land for extensive cereal-growing; the steep hill sides dissected by erosion are covered with Mediterranean maquis vegetation with *Pistacia lentiscus* L., *Thymus capitatus* (L.) Hoffmanns. & Link, *Cistus monspeliensis* L. associated with grasses and annual herbs; rare woods of *Quercus pubescens* s.l. and shrublands with *Pyrus spinosa* Forssk. occur. The plantations of *Pinus halepensis* Mill. are widespread to control erosion. PNV is represented by thermophylous oak forests of *Lauro-Quercenion pubescentis*; Mediterranean maquis and evergreen forests with *Quercus ilex* L. and *P. halepensis* should represent the edaphoxerophilous aspects on well drained coarsy substrata (*Quercetalia ilicis*). Depending on morphotypes, the dominant species in the badlands are *Lygeum spartum* L., *Camphorosma monspeliaca* L., and *Atriplex halimus* L., being the PNV constituted by primary sparse grasslands, halophytic shrublands and Mediterranean maquis (e.g. *Camphorosmo monspeliacae-Lygeetum sparti, Camphorosmo-Atriplicetum halimini, Helictotricho convoluti-Pistacietum lentisci* (Corbetta et al. 1991, Di Pietro & Misano 2010, Di Pietro et al. 2010).

DSB was a rural settlement established on a terrace during the Hellenistic age (D'Andria & Roubis 1999). Two houses (α and β) dated to the 4th-1st century BC were sampled for pollen analysis. The archaeological finds from house β - i.e. large jars for food storage, millstones for cereals, and a stone press for olives - testify an intense cultivation activity. Regular exchanges and trade with the Greek civilization are evident from black glazed pottery which was produced in the nearby colony of Metapontum, and found in house α. House β was mainly a producer site, while house α was probably the residence of the leading family of the village.

Palynological analyses

Eleven samples from DSB and four samples from TS were selected for pollen and NPP analyses. Moreover, 3 surface soil samples were taken near the two sites (2 from DSB, and 1 from TS) from a pasture area in order to check the incidence of Cichorieae in the current pollen rain.

About 6-8 g of sediment per sample were subject to chemical treatments including sieving with a nylon sieve and heavy liquid separation with sodium metatungstate hydrate (Florenzano et al. 2012a). *Lycopodium* tablets were added to calculate concentrations (pollen or NPPs per gram = p/g or npp/g). In archaeological samples, pollen and NPPs were identified in the same slides, at 400x and 1000x magnification, with the help of atlases/keys and the reference pollen collection of the Laboratory of Modena. A mean of about 300 pollen grains and 100 NPPs per sample were counted. Pollen sum includes all pollen counted. In surface soil samples, only Cichorieae were counted over the total pollen grains.

Pollen preservation is quite different in the two archaeological sites. Pollen grains from TS samples are well preserved, being only a few records crumpled or folded. Pollen from DSB samples shows deteriorated exines, mainly because of post-depositional disturbance that however has not caused an evident selective preservation (Mercuri et al. 2010).

Pollen morphology of Cichorieae

Cichorieae have fenestrate pollen (Faegri & Iversen 1989; syn. echinolophate). This is the only case in the subfamily of Cichorioideae, whose other pollen grains are indeed tricolporate and echinate like those occurring in the Asteraceae family. This pollen was described by Wodehouse (1935) as comprising an outer exine that is raised in a pattern of echinate ridges (lophae) surrounding depressions (lacunae). Within the tribe, *Scorzonera humilis* type has echinate pollen (lacunae absent; Blackmore 1984), and it is not included in the fenestrate pollen type. Pollen morphology bringing to the discrimination of morphotypes within the fenestrate type of Cichorieae is described on the basis of lacunae (Chester & Raine 2001), dimensions (Florenzano et al. 2012b), and on the combination of the two previous characters (Blackmore 1984; Wang et al. 2009).

Cichorieae are easy to identify even when they are broken or fragmented. However, there is hardly any species distinction within the subtribe. The longest axis ranges between 15 µm and 62 µm (Blackmore 1984; De Leonardis et al. 1992; Osman 2006; Wang et al. 2009, and reference collection) and some sub-categories are proposed as the whole grains may be easily measured during routine analyses (Florenzano et al. 2012b; Table I). A minimum of 50 well-preserved and whole pollen grains of Cichorieae were measured at 400x magnification in the samples from the two sites here studied.

Current vegetation data and methods

To achieve more detailed palaeoenvironmental reconstructions, we tried to link the Cichorieae pollen morphology to current vegetation types characterized by a high presence of Cichorieae in Basilicata. We used the Basilicata vegetation database (Rosati et al. 2012) that to date includes data from about 2000 relevés, carried out over a period of time ranging from 1972 to 2013 (published and unpublished data). We considered for inclusion in the database phytosociological relevés or other vegetation plots containing records of vascular plants species composition and an estimate of species cover. Vascular plants nomenclature follows Conti et al. (2005). A relevés classification was obtained by using a modified Two Way Indicator Species Analysis (TWINSPAN) included in JUICE software (Tichý 2002; Roleček et al. 2009). In the analyses we set four pseudo species cut levels (0%, 5%, 25%, 50%) and total inertia as a measure of heterogeneity. For each vegetation type, we calculated the weighted cover percentage at family level (and to subtribe only for Cichorieae).

The analyses on current vegetation provided information on floristic composition of the vegetation types for the area spanning from Basilicata to Apulia, south Campania, and north Calabria, in southern Italy.

RESULTS

The incidence of Cichorieae in pollen spectra

Cichorieae are significant in the past and current pollen spectra analysed (Figures 2,3). In archaeological sites, they represent one quarter of the total pollen (22% in TS, and 26% in DSB, on average), and in the modern samples they are half of this value (12%). According to the size groups (Table I), classes of 18-25 µm and 26-44 µm are prevalent. The incidence of the smallest size, < 18 µm, is quite variable but relatively low being around 10% in surface soil and DSB samples. On the opposite side, the highest size, ≥ 45 µm, is similarly low and with comparable values (always < 2%)

in past and surface soil samples.

Pollen spectra from the archaeological sites (Figure 4), which are relevant to understand the main palaeoenvironmental context, are also marked by other features besides Cichorieae:

i) Forest cover is very low (7% on average): woody plants include low percentages of *Pinus*, broadleaved trees (deciduous *Quercus*, *Corylus*; and *Carpinus betulus* found only at TS), and elements of the Mediterranean maquis (e.g. *Quercus ilex* type, *Olea* and *Phillyrea*). There are some interesting traces of *Castanea* in TS, while *Alnus* is found in a few samples of DSB.

ii) Wet environments are only reported in TS, with the presence of Cyperaceae (5%) and other hygro-hydrophytes (*Phragmites australis* cf., *Typha/Sparganium*, *Sagittaria*, *Nymphaea* cf. *alba*).

iii) Asteraceae and Poaceae - indicating open habitats - are prevalent (35%), *Plantago* is a significant evidence of trampled areas, while the nithrophilous *Urtica* is rare. Chenopodiaceae, which include plants common in saline or alkaline soils of badlands, are high in DSB (11%) and absent in TS samples.

iv) Among the cultivated herb plants, cereals are well attested at TS (6%), and only in traces at DSB. Fabaceae, which can include fodder plants, are common in both sites, but their amounts are more significant in TS (4%) than in DSB spectra (0.5%).

vi) Coprophilous fungal spores are varied and have high concentrations; in particular, the ascospores of *Sordaria* type and *Chaetomium* are known to be quite common in the dung of herbivores (van Geel et al. 2003), and *Sporormiella* type includes obligate coprophilous fungi (Ahmed & Cain 1972). Coupled with the archaeological and pollen data, they are evidence of local grazing or breeding activities.

Cichorieae rate in current vegetation

By means of TWINSPAN clustering, we identified in the dataset 20 main vegetation types in the Basilicata dataset (Table II). These approximately correspond to class/order level of the syntaxonomical classification, ranging from subalpine shrublands to marine dunes vegetation.
Data analyses show that the presence of Cichorieae is highly variable in current vegetation.
A very low presence (< 1%) is found in forest and shrubby vegetation (except for the MRS type discussed below); a low presence (< 2%) is registered in wetlands, cliffs and dune vegetation. High values are observed in open, secondary or naturally disturbed habitats, such as the Mediterranean river bed communities. The highest values (~ 7-8%) are observed in pastures and open vegetation types. Apparently, an exception is represented by Mediterranean riparian shrubland on braided river (*Nerio-Tamaricetea*) - MRS, showing almost 5% of Cichorieae, but it can be explained by the fact

that those communities naturally grow interspersed between NVM (nitrophilous vegetation of Mediterranean muddy river banks) and MRG (Mediterranean river bed vegetation on gravels). Cichorieae species reach > 3% only in six vegetation types (MRG, TPS, NVM, MRS, BXV, MDG) in modern relevés. The pollen of some of the species that characterise those six vegetation types are described in literature: this permits to infer more precisely some taxa within the routine identification carried out during pollen analyses (Table III).

DISCUSSION

In past pollen spectra, Cichorieae are significant in open landscapes. Below, the main features of the palaeoenvironmental reconstruction of the two archaeological sites are reported to understand their archaeobotanical contexts. Data interpretation is based on the multidisciplinary archaeological studies and pollen analyses discussed by Florenzano and Mercuri (2013: TS) and Mercuri et al. (2010: DSB).

Then the main features of vegetation types currently present in the region are reported. A comparison between the vegetation types with Cichorieae and pollen morphology of these plants is proposed.

The archaeo-palynological reconstructions (Figure 4)

Torre di Satriano (5th - 4th century BC) - Pollen points to an open landscape dominated by pastures and cereal fields. Woody plants include mainly *Pinus*, broadleaved trees and some Mediterranean maquis. Cyperaceae, other hygro-hydrophytes and algal elements suggest that wet environments were present near to the site. It is noteworthy that nowadays, most of the aquatics, such as *Nymphaea*, have disappeared from the area (Gavioli 1947; Conti et al. 2005).

The significant amount of cereal pollen found in all samples (*Avena/Triticum* group: up to 10%) suggests that plants were transported (and processed?) in the site, and that probably cereal fields were grown not far from the site. Fabaceae, including *Trifolium* type, *Astragalus* type and *Lotus*, either cultivated or growing wild on set-aside land, were both used for fodder and useful for regenerating soils after some year of cereal cultivation. The dominance of Cichorieae, Poaceae and Asteraceae in the pollen spectra suggests that pastoral activity has been well spread during these earlier times.

Difesa San Biagio (4th - 1st century BC) - Pollen points again to local open landscape. Forest cover is represented by traces of Mediterranean evergreens and pines, or by a mixed wood with deciduous *Quercus* and *Ulmus* on shady slopes. Pollen of the hygrophilous tree *Alnus* possibly arrived from long-distance transport from streams or river shores. Differently from TS, moisture-requiring herbs are absent suggesting wet environments were not distributed near to the site. Also cultivated lands would not have spread next to the houses because groves/orchards and fields have low percentages. The prevalent vegetation was grassland with Poaceae and dry-tolerant herbs/shrubs such as Cichorieae and other Asteraceae, and Chenopodiaceae; Brassicaceae, Fabaceae and Ranunculaceae were fairly common too. These pollen taxa, together with significant amount of spores of coprophilous fungi, again indicate grazing in the area. In general, pastoral activity was noteworthy in the last phase of occupation of the site (Late Hellenistic age) in addition to olive trees and cereal cultivation (Florenzano 2013).

Cichorieae in current and past vegetation

The analysis of the vegetation database regarding the Basilicata territory shows a gradient of abundance of Cichorieae from saltmarsh environments, to forests and shrubby and open grassland vegetation (Table II).

The mean percentage of Cichorieae obtained from relevés of current vegetation points to a preference of these plants for open environments and pastures, in agreement with the general palaeoenvironmental interpretation. Cichorieae in modern pollen samples reflect some specific vegetation types (Figure 2): i.e., secondary mesophilous pastures (*Molinio-Arrhenatheretea),* dry grasslands (*Festuco-Brometea*) and sub-nitrophilous vegetation of fallow fields (*Artemisietea vulgaris*) are widespread around TS; Mediterranean therophytic or hemicriptophytic grasslands (e.g. *Helianthemetea guttati*, *Lygeo-Stipetea*) are frequent on clayey slopes or badlands, and garrigues on gravels and conglomerates *(Cisto-Micromerietea*) around DSB.

Cichorieae does not seem to be linked only to the human effects but they could be attributed also to natural distribution of specific plant communities. This is the case of the three primary vegetation types linked to the Mediterranean river environment MRG, NVM and MRS (Mediterranean riparian shrubland on braided rivers-*Nerio-Tamaricetea*, Table II) growing in environments frequently disturbed by the action of flooding water.

At DSB, the archaeopalynological dataset describes an open landscape along with high Cichorieae (up to 40%; Figures 3,4); this feature suggests a long-term local grazing or breeding activities. In fact, this may have produced the clearing of vegetation and increased the effects of the fluvial dynamics on the riparian vegetation. Also the good values of Chenopodiaceae (11%), a clear indicator of badland vegetation due to the common presence of *Atriplex, Beta, Camphorosma, Suaeda*, point out that sheep and cattle grazing was probably facilitated by the natural presence of open habitats in the site.

Pollen morphology and vegetation types

Although the pollen identification is difficult, i t may be useful to link the Cichorieae pollen morphology to specific vegetation types (Table III). The identification never reaches the plant species level except for *Cichorium intybus* (in TPS, NVM, see below).

The smallest *Hieracium* pollen type may refer to the species *H. pilosella* and *H. pseudopilosella*, that are frequent in the TGL – Temperate dry grasslands on limestone (*Brometalia erecti*), and in the SS - subalpine vegetation (*Pino-Juniperetea/Seslerion apenninae*).

The most represented Cichorieae pollen types belong to *Taraxacum officinalis* group and *C. intybus* group within the *C. intybus* type (Blackmore 1984). Though having a very similar exine sculpture, *C. intybus* is easily noticeable thanks to its large size (≥ 45 µm - *Scolymus* type; Florenzano et al. 2012b). *Cichorium intybus* is considered a characteristic species of synanthropic vegetation, being mainly associated to fallow fields (included in TPS, Table II) sub-nitrophilous pastures (NVM), and to grazed meadows (Ejarque et al. 2011). In phytosociology it is considered a species of pioneer ruderal and nitrophilous sunny communities, growing on rich soils in Mediterranean and temperate territories (i.e. *Artemisietea vulgaris;* Rivas-Martínez et al. 2002).

Within the vegetation types listed in Table III, the coenoses characterized by *Cichorium intybus,* certainly related to grazing/breeding activities are TPS (*Arrhenatheretalia* and *Artemisietalia*), and NVM (*Artemisietea vulgaris*).

CONCLUSIONS

Cichorieae are common in open habitats, mainly pasturelands, in current plant communities. Therefore, in pollen-based environmental reconstructions, Cichorieae (the tribe of Cichorioideae used as synonym of fenestrate pollen) can be considered one of the most important pastureland or grazing indicators. Their pollen grains are often abundant in spectra from central and southern Europe, their over-representation being properly linked to grazing activity rather than selective deterioration.

The discrimination of size classes within the Cichorieae pollen may help to refine palaeoenvironmental reconstructions. In particular, in the present study we assess that the large size pollen (≥ 45 µm) belongs to *Cichorium intybus,* which is mainly associated to fallow fields and sub-nitrophilous pastures and was rare in the studied sites. The medium size class includes most of the species in modern vegetation types, they actually prevail in past and current pollen spectra but result a low-informative general group. Nevertheless, the Cichorieae medium-size pollen is a good indicator of herbaceous vegetation and open environments mainly connectable to secondary pasturelands. The small size (< 18 µm) includes *Hieracium* species, it is relatively less distributed and has lower percentages in pollen spectra.

The present study shows that, even if Cichorieae are common in many habitats of southern Italy, they prevail in secondary pastures and some types of primary open habitats. The recovery of high percentages of this pollen is, therefore, a good indicator of these habitats even in past environments. The archaeobotanical analyses of the two sites TS and DSB support this interpretation. They are quite different for present land cover, bioclimate (Mediterranean vs. Temperate), lithomorphology and Potential Natural Vegetation types. However, in both sites, the action of herbivores has had important effects on vegetation throughout the ages, and in particular during Holocene times this should be linked to domestic animals.

The data set - combining pollen from archaeological sites and plants from current habitats in the region - supports the idea of the importance of the ancient pasture farming as a major agent of landscape transformation in this Mediterranean region. The proposed comparative approach, integrating the study of fossil records and current vegetation habitats, can benefit palaeoenvironmental interpretation (Mercuri et al. 2013). Therefore, future development of these research topics should include the study of long-term pollen records.

Acknowledgements

We acknowledge Prof. Massimo Osanna and Dr. Dimitris Roubis (Scuola di Specializzazione in Beni Archeologici di Matera - Università degli Studi della Basilicata) who kindly provided us with archaeological samples and information. Prof. Joseph C. Carter (Director of ICA - University of Texas at Austin) greatly contributed to our comprehension of the archaeological background and history of the study region. Our warmest thanks go to the two anonymous referees for the fruitful comments to the first version of the paper.

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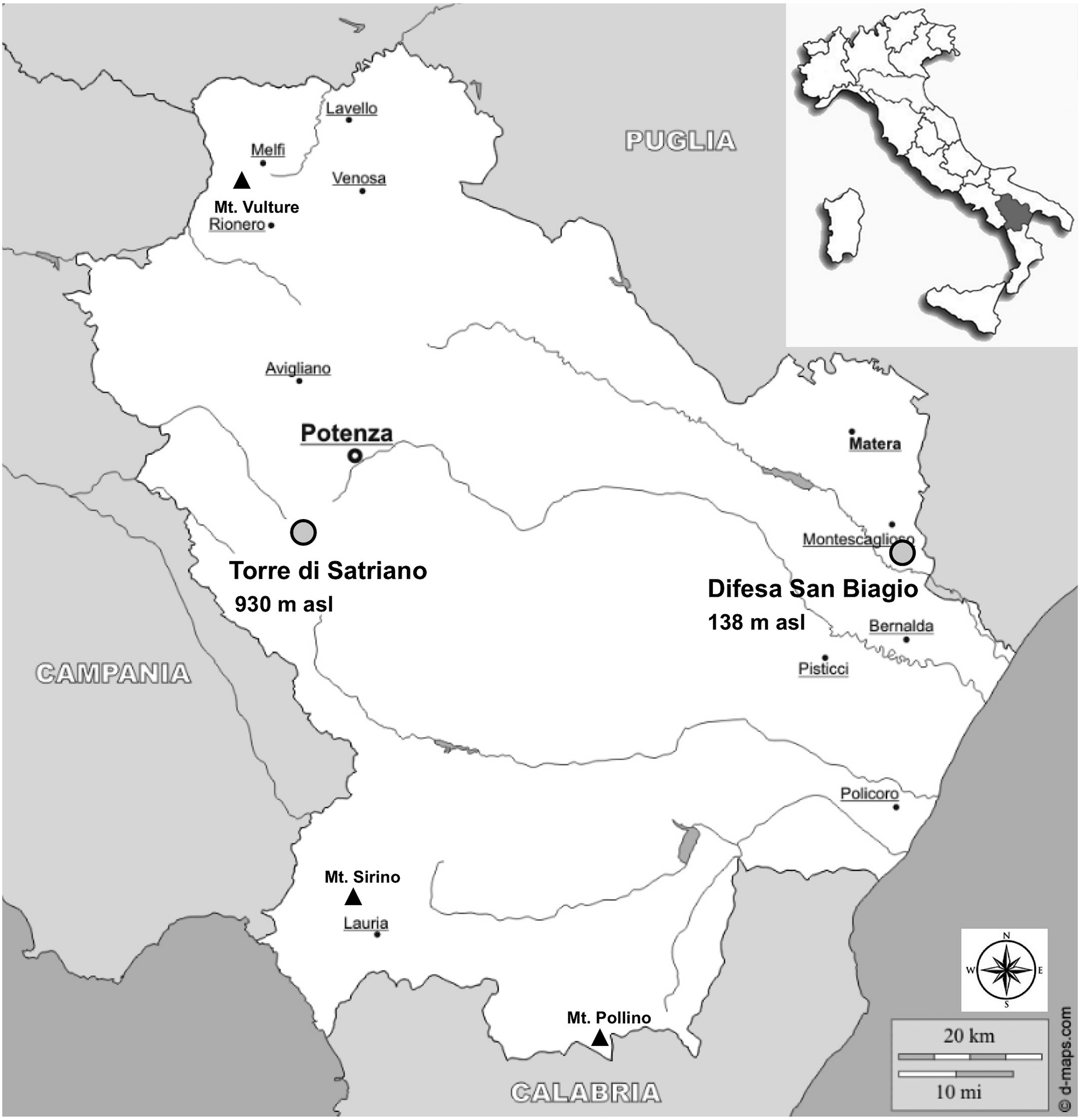
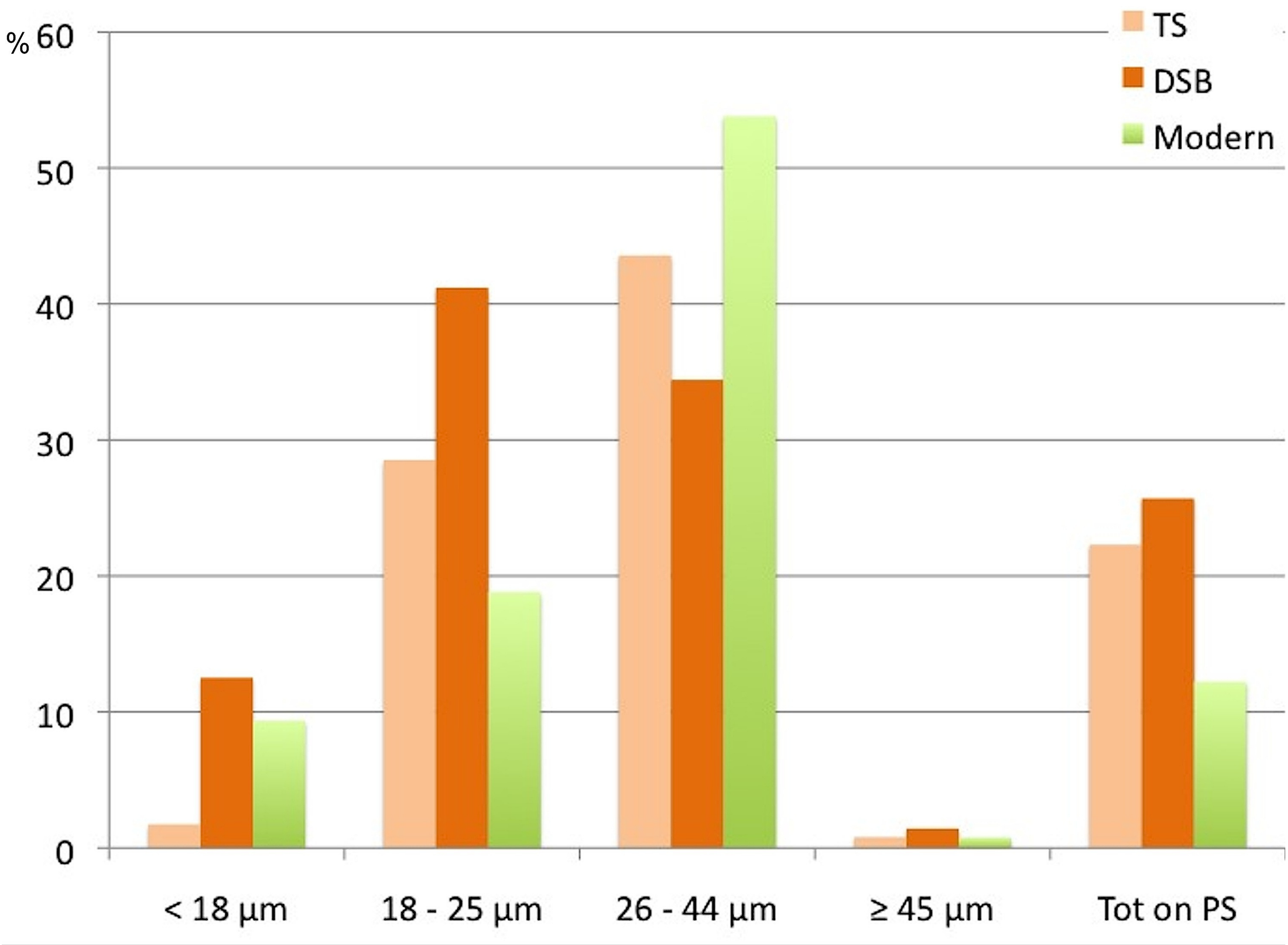


PUGLIA
Lavello
Melfi
Venosa
Mt. Vulture
Rionero
Avigliano
Potenza
Matera
Montescaglioso
Torre di Satriano
930 m asl
Difesa San Biagio
138 m asl
Bernalda
Pisticci
CAMPANIA
Policoro
Mt. Sirino
Lauria
Mt. Pollino
CALABRIA
N
W
E
S
20 km
10 mi
© d-maps.com



%
60
50
40
30
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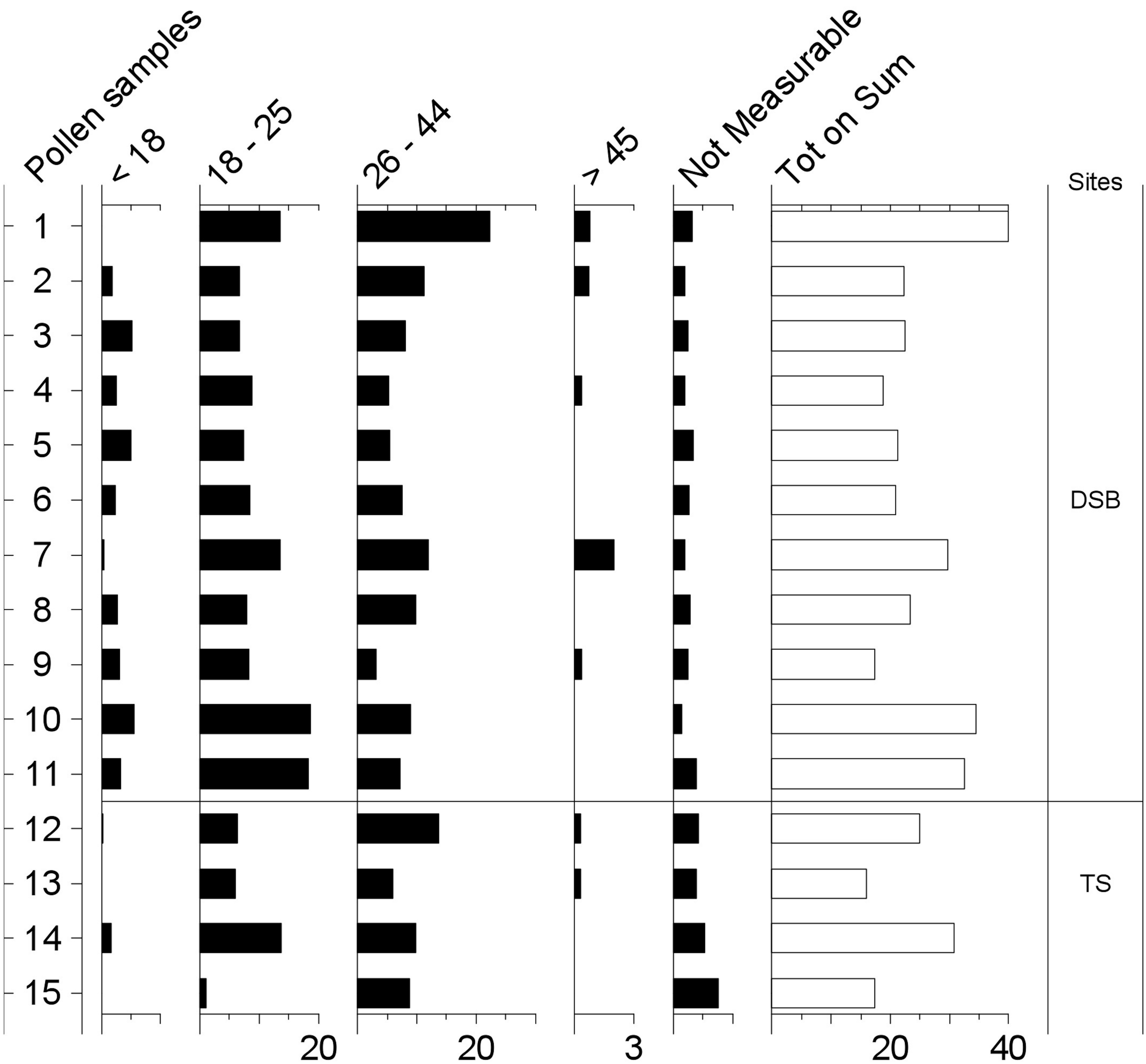
TS
DSB
Modern
< 18 µm
18 - 25 µm
26 - 44 µm
≥ 45 µm
Tot on PS



Pollen samples
< 18
18 - 25
26 - 44
> 45
Not Measurable
Tot on Sum
Sites
1
2
3
4
5
6
7
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9
10
11
12
13
14
15
DSB
TS
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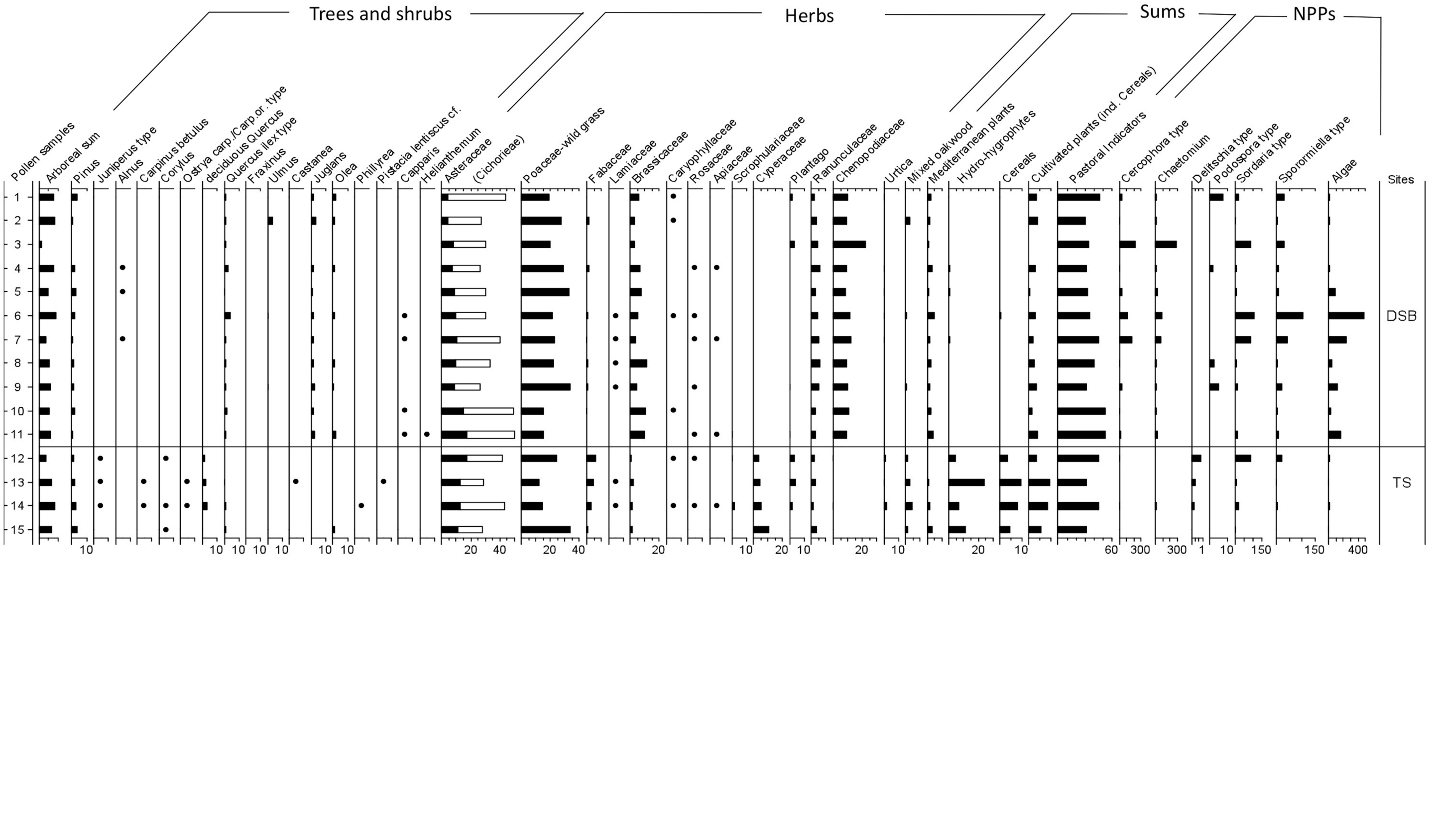
20
3
20
40


Trees and shrubs
Herbs
Sums
NPPs
Pollen samples
Arboreal sum
Pinus
Juniperus type
Alnus
Carpinus betulus
Corylus
Ostrya carp./Carp.or. type
deciduous Quercus
Quercus ilex type
Fraxinus
Ulmus
Castanea
Juglans
Olea
Phillyrea
Pistacia lentiscus cf.
Capparis
Helianthemum
Asteraceae
(Cichorieae)
Poaceae-wild grass
Fabaceae
Lamiaceae
Brassicaceae
Caryophyllaceae
Rosaceae
Apiaceae
Scrophulariaceae
Cyperaceae
Plantago
Ranunculaceae
Chenopodiaceae
Urtica
Mixed oakwood
Mediterranean plants
Hydro-hygrophytes
Cereals
Cultivated plants (incl. Cereals)
Pastoral Indicators
Cercophora type
Chaetomium
Delitschia type
Podospora type
Sordaria type
Sporormiella type
Algae
Sites
DSB
TS

Chester & Raine 2001	**Blackmore 1984; Wang et al. 2009**	**Florenzano et al. 2012; Osman 2006; De Leonardis et al. 1992**	**Included taxa**
Hieracium type	------	*Hieracium* type (< 18 µm)	*Hieracium* p.p., *Tolpis* p.p.
------	------	small pollen grains (18-25 µm)	*Andryala*, *Hieracium* p.p., *Tolpis* p.p.
Lactuca type	*Lactuca sativa* type	medium pollen grains (26-44 µm)	*Catananche, Chondrilla, Cichorium* p.p., *Crepis, Geropogon, Hedypnois, Hyoseris, Hypochaeris, Lactuca, Lapsana, Leontodon, Picris, Prenanthes, Reichardia, Rhagadiolus, Scorzonera villosa columnae (De Leonardis et al. 1992), Sonchus, Taraxacum, Urospermum; Cicerbita, Launaea and Willemetia* (not in the flora of Basilicata)
Sonchus type	*Sonchus oleracerus* type		
Taraxacum type	------		
Cichorium type	*Cichorium intybus* type		
Scolymus	------	*Scolymus* type (≥ 45 µm)	*Cichorium* p.p., *Scolymus, Scorzonera* (excl. *S. humulis*), *Tragopogon*
Scorzonera laciniata type	*Scorzonera laciniata* type		
Scorzonera hispanica type	*Scorzonera humilis*		
Tragopogon	*Tragopogon pratensis* type		
------	*Arnoseris minima*	------	------

Vegetation types	*Cichoriea e*	*Asteracea e*	*Poaceae*	*Plantagin aceae*	*Urticacea e*	*Fabaceae*	*Chenopo diaceae*
MRG - Mediterranean river bed vegetation on gravels (Cisto-Micromerietea /Helianthemetea)	8,2	23,07	19,44	2,45	0	17,3	0
TPS - Temperate pastures and fallow fields on siliceous substrata (Arrhenatheretalia, Artemisetalia)	7,12	8,08	33,69	6,27	0	15,6	0
NVM - Nitrophilous vegetation of Mediterranean muddy river banks	6,08	6,99	14,25	2,25	0	19,4	0,4
MRS - Mediterranean riparian shrubland on braided rivers (Nerio-Tamaricetea)	4,96	0,82	15,18	0,72	0,01	3,7	0
BXV - Badlands xeric vegetation (Lygeo-Stipetea)	4,93	3,68	38,35	2,56	0	20,7	15
MDG - Mediterranean dry grasslands on limestone (Helianthemetea, Lygeo-Stipetea, Scorzonero-Crysopogonetalia)	3,03	5,88	60,15	0,29	0	4,9	0
WV - Wetland vegetation (Phragmito-Magnocaricetea)	1,88	1,51	18,1	0,01	0	17,4	0
TGL - Temperate dry grasslands on limestone (Brometalia erecti)	1,45	3,26	37,4	3,01	0	12,7	0
HSV - Hygrophilous shrub vegetation of badlands gullies (Nerio-Tamaricetea)	0,78	3,23	37,35	0	0	0	8,1
SQF - Submediterranean/Temperate Quercus cerris, Q. pubescens and Q. frainetto forests (Teucrio-Quercion cerridis)	0,68	1,49	9,65	0,11	0,001	7,2	0
MCL - Mediterranean chasmophytic vegetation on limestone cliffs (Asplenietea)	0,42	1,84	6,82	0,17	6,62	0,37	0
TMF - Temperate mesophilous Quercus cerris or Fagus sylvatica forests (Fagetalia sylvaticae)	0,29	1,32	3,7	0	0,0006	1,6	0
MQF - Mediterranean Quercus virgiliana/Quercus trojana forests (Quercetalia pubescentis)	0,1	0,32	5,66	0	0,1	0,1	0
MDV - Marine dune vegetation (Ammophiletea)	0,08	14,94	37,48	0	0	7	0,17
MMF - Mediterranean mixed forests (Quercetalia ilicis; Quercetalia pubescentis)	0,06	0,06	4,28	0,09	0,002	2,9	0
MCV - Mediterranean chamaephytic vegetation (Cisto-Micromerietea)	0,05	0,12	9,2	0,01	0	24	0
SS - Subalpine shrublands (Pino-Juniperetea)	0,02	0,75	5,61	0,007	0,44	2	0,02
MM - Mediterranean maquis (Oleo-Ceratonion)	0,02	0,82	5,79	0,04	0	8,7	0,1
TSF - Temperate swamp forests (Alnetea glutinosae)	0,01	0,16	2,23	0,00	1,72	0	0
SV - Saltmarsh vegetation (Salicornietalia, Limonietalia, Juncetalia)	0	2,56	29,78	0,07	0	5,3	24,2

Phytosociological relevés		*Pollen morphology*	
Vegetation types	**Cichorieae species**	**Cichorieae pollen**	**Pollen type by size** (Florenzano et al. 2012)
MRG	*Chondrilla juncea*	*Chondrilla juncea* range size: P=24 µm; E=32 µm (De Leonardis et al. 1992)	Medium pollen grains (26-44 µm)
	Crepis neglecta	*Crepis* range size: P=29-39 µm; E=32-48 µm (Blackmore 1984). *Cichorium intybus* group (within *Cichorium intybus* type) - Echinolophatae, and narrow equatorial ridges with one row of echinae acicular, much shorter than the height of the ridges. Polar area with 4-15 isolated central echinae. Total of 15 lacunae (Blackmore 1984)	
	Hypochaeris achyrophorus	*Hypochaeris* range size: P=27-36 µm; E=32-44 µm (Blackmore 1984). *Taraxacum officinalis* group (within *Cichorium intybus* type) - Echinolophatae, and narrow equatorial ridges with one row of echinae acicular, much shorter than the height of the ridges. Polar area with 4-15 isolated central echinae. Total of 15 lacunae (Blackmore 1984)	
	Hypochaeris radicata		
TPS	*Hypochaeris achyrophorus*	See above *Hypochaeris achyrophorus*	Medium pollen grains (26-44 µm)
	Cichorium intybus	*Cichorium intybus* range size: P=41-48 µm; E=51-59 µm (Blackmore 1984). *Cichorium* type - Ectoapertures colpi, each divided into 1 poral and 2 abporal lacunae by 2 pairs of short continuous ridges. Paraporal lacunae 2 per mesocolpium. Polar lacunae absent, polar area ranging from a triradiate ridge to an extensive echinate region; total of 15 lacunae. Polar area small with 1± (2)± 4 isolated central echinae (Chester & Raine 2001).	*Scolymus* type (≥ 45µm)
NVM	*Chondrilla juncea*	See above *Chondrilla juncea*	Medium pollen grains (26-44 µm)
	Helminthotheca echioides (syn. *Picris echioides, Crepis echioides*)	*Picris echioides* range size: P=31-44 µm; E=37-45 µm (Blackmore 1984). *Taraxacum officinalis* group (within *Cichorium intybus* type) - Echinolophatae, and narrow equatorial ridges with one row of echinae acicular, much shorter than the height of the ridges. Polar area with 4-15 isolated central echinae. Total of 15 lacunae (Blackmore 1984)	
	Picris hieracioides	*Picris hieracioides* range size: P=31 -36 µm; E=36-41 µm (Blackmore 1984). See above *Helminthotheca echioides*	
	Sonchus asper	*Sonchus* range size: P=28 µm; E=43 µm (Blackmore 1984). *Sonchus* type - Ectoapertures colpi, often divided into lacunae by constrictions or short paired ridges. Colpi each divided into 2 abporal lacunae by a central constriction or pair of ridges. Two e quatorial lacunae per mesocolpium. Poral lacunae 3 in each of the extensive polar areas; total of 21 lacunae (Chester & Raine 2001)	
	Cichorium intybus	See above *Cichorium intybus*	*Scolymus* type (≥ 45µm)
MRS	*Lactuca serriola*	*Lactuca serriola* range size: P=30-37 µm; E=35-43 µm (Blackmore 1984). *Lactuca* type - Ectoapertures colpi, each divided into 1 poral and 2 abporal lacunae by 2 pairs of short continuous ridges. Paraporal lacunae 2 per mesocolpium. Polar lacunae absent, polar area ranging from a triradiate ridge to an extensive echinate region; total of 15 lacunae. Polar area not more than a triradiate ridge usually with one row of echinae, abporal and paraporal lacunae extending almost to the poles (Chester & Raine 2001)	Medium pollen grains (26-44 µm)
BXV	*Geropogon glaber*	*Geropogon glaber* range size: P=35-40 µm; E=40-46 µm (De Leonardis et al. 1992). *Geropogon* type - Ectoapertures colpi each divided into 1 poral and 2 abporal lacunae by 2 pairs of short continuous ridges. Total of 15 lacunae (Osman 2006)	Medium pollen grains (26-44 µm)
	Sonchus oleraceus	*Sonchus oleraceus* range size: P=32-41 µm; E=32-46 µm (Blackmore 1984). See above *Sonchus asper*	
	Scorzonera hispanica glastifolia	*Scorzonera* range size: P=42-58 µm; E=44-62 µm (Blackmore 1984). *Scorzonera hispanica* type - Ectoapertures colpi, each divided into 2 abporal lacunae by a central constriction or pair of ridges. Two equatorial lacunae per mesocolpium. Abporal lacunae extending to an expanded spiny polar area, or to a polar lacuna. Polar lacunae 1 per pole, large, hexagonal; total of 20 lacunae (Chester & Raine 2001)	*Scolymus* type (≥ 45µm)
	Scorzonera laciniata	*Scorzonera laciniata* range size: P=42-58 µm; E=44-62 µm (Blackmore 1984). *Scorzonera laciniata* type - Ectoapertures colpi, often divided into lacunae by constrictions or short paired ridges. Colpi each divided into 2 abporal lacunae by a central constriction or pair of ridges. Two equatorial lacunae per mesocolpium. Abporal lacunae extending to an expanded spiny polar area. Polar lacunae absent, extensive echinate polar areas present; total of 18 lacunae (Chester & Raine 2001)	
MDG	*Crepis corymbosa*	See above *Crepis neglecta*	Medium pollen grains (26-44 µm)
	Hypochaeris achyrophorus	See above *Hypochaeris achyrophorus*	
	Scorzonera villosa columnae	*Scorzonera villosa columnae* range size: P=35-42 µm; E=39-44 µm (De Leonardis et al. 1992). See above *Scorzonera laciniata*	Medium pollen grains (26-44 µm)

Legends

Table I – Pollen morphotypes of Cichorieae according to different authors; the emphasis is on the dimension. The last column reports the genera that were described in relevant literature.

Table II – Composition of the identified vegetation types, showing families that usually indicate open habitats. Vegetation types are sorted according to the percentage of Cichorieae. Data are expressed in percentage values.

Table III – Vegetation types (labels refer to Table II) showing the highest values of Cichorieae (> 3%), and description of pollen morphology of Cichorieae species identified in each vegetation type according to different authors. Pollen size range is determined by measuring the maximum diameter length. P = polar view; E = equatorial view.

Figure 1 - Location map of the Basilicata region, including the two archaeological sites (Torre di Satriano and Difesa San Biagio).

Figure 2 – Incidence of four size classes of Cichorieae in past and current pollen rain from archaeological (TS, DSB) and surface soil (Modern) samples, respectively. The histograms show the percentage of each Cichorieae pollen class (broken and not measurable pollen grains are not reported) considering the Total Cichorieae Sum as 100%. The last group of histograms shows the mean value of Cichorieae in the same spectra calculated as percentage on the Pollen Sum (Tot on PS). Broken and not measurable pollen grains are only included in the Tot on PS.

Figure 3 - Incidence of four size classes of Cichorieae (see the text) from 15 samples of the two archaeological sites (TS, DSB): the histograms show the mean percentage of each Cichorieae class calculated on the Total Pollen Sum.

Figure 4 – Percentage pollen diagram from the archaeological sites Difesa San Biagio (DSB, 11 samples) and Torre di Satriano (TS, 4 samples). Selected pollen taxa were grouped into sums useful for land-use reconstructions: a) mixed oakwood (*Carpinus*, *Corylus*, *Ostrya/Carpinus orientalis* type, deciduous *Quercus*, *Ulmus*); b) Mediterranean plants (*Cistus*, *Helianthemum*, *Olea*, *Phillyrea*,