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LATE GLACIAL AND HOLOCENE HISTORY OF *BUXUS SEMPERVIRENS* L. IN ITALY

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Abstract - In the course of the Holocene, plant species experienced changes in their area of distribution and population density in response to climate change, biotic processes and human activities. The combined use of modern and past distribution data provides a powerful tool for assessing the directions and the rates of the changes that took place. *Buxus sempervirens* L. (common box) is an evergreen angiosperm present in Italy with a scattered and fragmented distribution resulting from its persistence in the Peninsula through the last glacial maximum and the Holocene. *Buxus* experienced a progressive population growth in the course of the Holocene, with different modes and times from region to region, depending on the different densities of the starting nuclei of *Buxus* populations. Populations located at latitudes between 41°N and 43°N were already rather dense during the late glacial. *Buxus* increased in the course of the Holocene especially in N Italy, while it underwent a severe reduction in S Italy, to the point of disappearing from Sicily and Apulia. Our results demonstrate that the knowledge of *Buxus* history is especially important in the context of future plant distribution changes, providing a starting point for conservation action and sustainable management of biodiversity.

Key words: *Buxus* distribution, pollen, Sicily, Apulia, postglacial

Introduction

During the Holocene, plant species experienced changes in their distribution area and population density in response to climatic trends, habitat changes, biotic processes and human impact. Combined data of modern and past distribution may provide a powerful tool to assess the history of plant species, as well as the directions and rates of changes. The genus *Buxus* has been the subject of many investigations due to its importance, encompassing scientific (conservational: Zimmermann et al., 2010; palaeoecological: Wegmüller, 1984; biogeographical: Raven & Axelrod, 1974; phytochemical: ur-Rahman et al., 1991; Lorua et al., 2000), cultural (Leporatti & Ghedira, 2009), as well as economic interest (Record, 1921; Batdorf, 2006; Köhler, 2007). However, only a single study deals with the Holocene history of *Buxus* in Europe (Wegmüller, 1984), which needs to be updated.

Buxus sempervirens L. was present in Italy in the N Apennines during the evaporitic Messinian (ca. 5.9-5.6 My BP; Bertini & Martinetto, 2011). It has persisted in the Italian Peninsula until the present, while many other floral elements underwent extinction (Bertini, 2010). Thus, the present distribution is the result of a very long history, which was definitively shaped in the course of the Holocene.

The knowledge of *Buxus sempervirens* distribution in Italy is fragmented across several local/regional Floras, Herbaria and field surveys, and no review depicting its complete distribution in our country is currently available. The species was considered threatened in the IUCN 1992 Redlists, but it is not included in more recent Redlists, even though it is experiencing a severe reduction all over the country, possibly because of human impact and increasing aridity. *Buxus sempervirens* is the characteristic species of the Natural Habitat types (Natura 2000) of Community interest coded as 5110: “Stable xerothermophilous formations with *Buxus sempervirens* on rock slopes (*Berberidion* p. p.)”. However,

the species is present also in other habitats such as moist gorges and ravines with mesic conditions.
The aim of the present study is (i) to depict the area of distribution of *Buxus sempervirens* in Italy, (ii) to reconstruct its history through pollen data, (iii) to discuss possible geographic patterns of distribution in the light of ecological considerations, (iv) to verify whether *Buxus* experienced changes in frequency and distribution over the country in the course of the Holocene.

Present day biology, ecology and distribution

The phylogenetic position of the genus *Buxus* L. has been thouroughly investigated (Köhler & Brückner, 1989, von Balthazaar et al., 2000). The genus encompasses about 100 species, distributed in two major centers of diversity (Caribbean-Latin America and E Asia) and a minor one (Africa). The Asian section (*Eubuxus*) includes the "Mediterranean" taxa as western representatives (*Buxus sempervirens* L. and *Buxus balearica* Lam.).
Buxus sempervirens is an evergreen angiosperm, tree or shrub, growing up to 1-3 (2-8) m height in our country. The species is slow growing and long-living, reaching maturity only after several (3-8) years (personal observation). *Buxus sempervirens* is monoecious and with proterogynous, functionally unisexual flowers (male flower may show pistil rudiments), ambophilous (wind, insects: Diptera, Hymenoptera) and self pollinating, as well as capable of vegetative reproduction from broken or buried branches. It usually flowers from March to April, but can show a great variation of anthesis in relation to altitudinal and latitudinal gradients (personal observation). Fruits are dry, loculicidal and dehiscent capsules with leathery exocarp and persistent stylodia. Seeds, with a caruncle reduced to two small white lobes, show a local (1-5 m, balistic) to medium (3-10 m, myrmecochory) dispersal distance (Fiori & Paoletti, 1908; Debussche & Lepart, 1992; Köhler, 2007).
Buxus sempervirens occurs in most of Europe (Portugal, Spain, France, United Kingdom, Ireland, Germany, Belgium, Italy, Luxembourg, Switzerland, Austria, Italy, Slovenia, Croatia, Montenegro, F.Y.R.O.M., Albania, Serbia, Kosovo, Greece, Turkey) and in some parts of northern Africa (Morocco, Algeria) and W Asia (Georgia, Iran, Azerbaijan, Russia). In the latter countries the species is usually referred to as *Buxus colchica* Pojark. In most cases, *Buxus sempervirens* distribution is bound to particular substrates (chalks, ophiolites and tuffs), in both open (garigues) and forest areas (thermophilous and mesophilous broad-leaved deciduous and thermophilous broad-leaved evergreen forests), frequently on exposed rock slopes along river beds and moist valleys or basins.

In Italy, the current natural distribution of *Buxus sempervirens* is scattered throughout the Peninsula north of 40°N and shows a center of distribution around 42°N, in the middle of the country (Fig. 1, list of sources in Appendix 1).

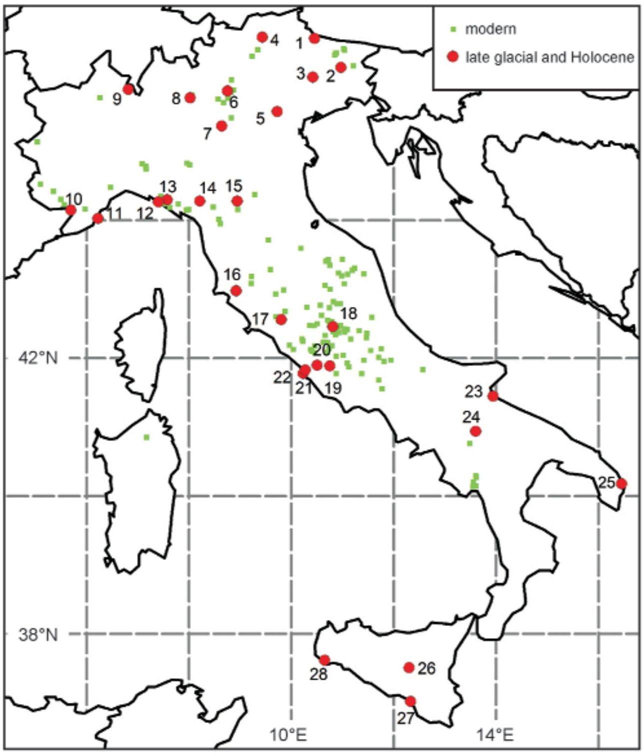

Fig.1. Location of Italian sites where pollen of *Buxus* was found (red dots), compared to its modern distribution (green squares, references in Appendix 1). 1. Dura-Moor (Seiwald, 1980; EPD); 2. Castelraimondo di Forgaria (Accorsi et al., 1992); 3. Bosco del Cansiglio (Kral, 1969); 4. Schwarzsee (Seiwald, 1980); 5. Lago della Costa (Kaltenrieder et al., 2009; Kaltenrieder et al., 2010); 6. Lago di Ledro (Beug, 1964); 7. Laghetto di Castellaro (Bertoldi, 1968); 8.Lago di Gaiano (Gehrig, 1997); 9. Lago di Ganna (Schneider & Tobolski, 1985); 10. Selle di Carnino (de Beaulieu, 1977; EPD); 11. Centa K2 (Arobba et al., 2004); 12. Sestri Levante (Bellini et al., 2009); 13. Lago di Bargone (Cruise et al., 2009); 14. Lago Padule (Watson, 1996; EPD); 15. Lago di Vrazzano (Bertoldi & Buccella, 1983); 16. Lago dell'Accesa (Drescher-Schneider et al., 2007); 17. Lagaccione (Magri, 1999); 18. Lago di Ripa Sottile (Ricci Lucchi et al., 2000); 19. Valle di Castiglione (Follieri et al., 1988); 20. Roma – Valle del Colosseo (Celant & Magri, 1999); 21. Maccarese – Lingua d'Oca-Interporto (Di Rita et al., 2010; Di Rita, pers. comm.); 22. Pesceluna (Di Rita, pers. comm.); 23. Coppa Nevigata – Lago Salso (Di Rita et al., 2011); 24. Lago Grande di Monticchio (Allen et al., 2000); 25. Lago Alimini Piccolo (Di Rita & Magri, 2009); 26. Lago di Pergusa (Sadori & Narcisi, 2001; Sadori, pers. comm.); 27. Biviere di Gela (Noti et al. 2009); 28. Gorgo Basso (Tinner et al., 2009).

At these localities *Buxus sempervirens* lives in different habitats (thermophilous broad-leaved evergreen and mesophilous broad-leaved deciduous forests; supramediterranean garigues), often on exposed calcareous rock slopes in river valleys and moist gorges or all around intermountain basins that hosted large lakes during the Pleistocene. *Buxus* is also found in volcanic gorges and ravines of Latium and Tuscany, where a particular microclimate occurs in relation to topographic effects (thermal inversion, high moisture) and, sometimes, to the presence of thermal springs (Giacchi 1974). The co-occurrence of *Buxus sempervirens* with several ferns (14 species), subtropical Tertiary relicts (zonal: *Laurus nobilis* L., *Ruscus aculeatus* L.; extrazonal: *Ilex aquifolium* L., *Daphne laureola* L.) and microthermal species (*Hepatica nobilis* Miller, *Veronica montana* L., *Euphorbia dulcis* L., *Galanthus nivalis* L.) in volcanic gorges at Parco di Veio in Latium is significant and related to long-term favorable climatic conditions (Di Domenico & Lucchese, 2007).

Most of the present-day Italian distribution data (list of sources in Appendix 1) come directly from field surveys, as part of an ongoing phylogeographic research. Other locations were derived from bibliographical sources (Natura 2000 database, national and regional floras, publications) and herbarium specimens. In this respect, it is notable the poor representation of *Buxus sempervirens* in many studies, which consider the species almost or completely absent in our country.

From a climatic point of view, the present-day Italian populations are found between a mean annual minimum temperature of 8.0 ± 5.8 °C, mean annual maximum temperature of 16.7 ± 7.5 °C and mean annual precipitation of 860 ± 122 mm. Such a wide variance suggests that macroclimate parameters are not adequate to represent the species climatic optimum and that most of the populations are located in sites where a particular microclimate occurs. Climatic parameters were extracted through interpolation of climatic grids at a resoluton of 2.5’ x 2.5’ arc-minutes (Worldclim database, www.worldclim.org) using Diva-Gis (Hijmans et al., 2004; 2005).

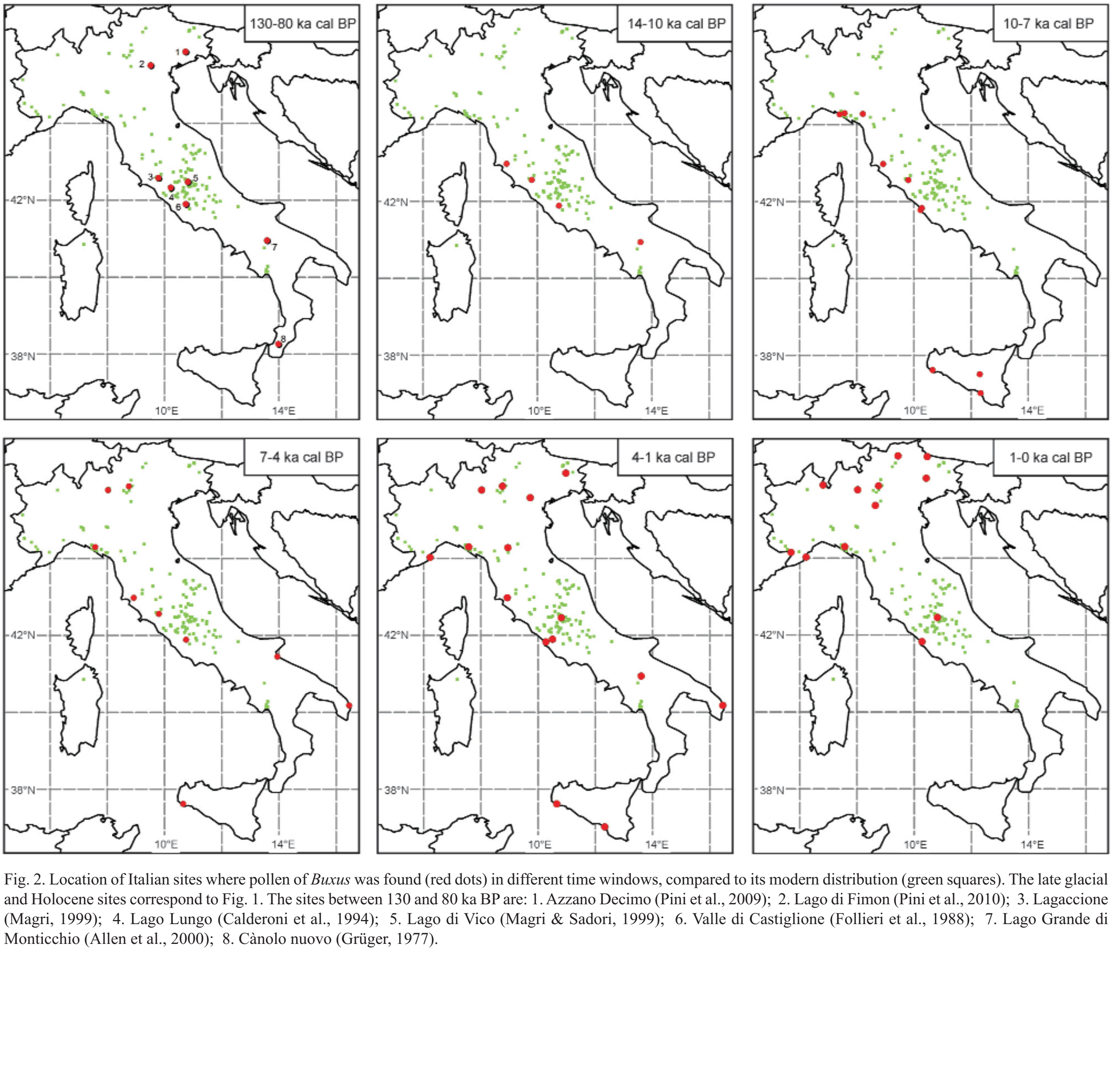

Fig. 2. Location of Italian sites where pollen of *Buxus* was found (red dots) in different time windows, compared to its modern distribution (green squares). The late glacial and Holocene sites correspond to Fig. 1. The sites between 130 and 80 ka BP are: 1. Azzano Decimo (Pini et al., 2009); 2. Lago di Fimon (Pini et al., 2010); 3. Lagaccione (Magri, 1999); 4. Lago Lungo (Calderoni et al., 1994); 5. Lago di Vico (Magri & Sadori, 1999); 6. Valle di Castiglione (Follieri et al., 1988); 7. Lago Grande di Monticchio (Allen et al., 2000); 8. Cànolo nuovo (Grüger, 1977).

Fossil record of *Buxus*

Characteristics of *Buxus* pollen

Buxus has a pantoporate pollen grain of 29-38 µm diameter, exine 2-2.5 µm thick, pori of 1.5-2 µm diamater (Beug, 2004). By comparison, Brückner (1993) reported a diameter of 18-34 µm, exine thickness of 1.2-2.5 µm and pori diameter of 0.5-3 µm. These characteristics have a great discriminating power (Wegmüller, 1984; Beug, 2004), and so we can exclude misidentification of *Buxus* pollen in the reviewed palynological studies.

Holocene pollen records of *Buxus* from Italy

Buxus pollen was found in 28 (25%) out of the 112 Holocene continental sites reviewed in the present study (Fig. 1, list of sites and references in appendix 2), although its frequency in sediments is generally very low (<1%). It is possible that *Buxus* was not reported in some of these sites because only selected taxa were shown in the published diagrams. The pollen sites are distributed as follows: 86 sites in N Italy, 17 sites in C Italy, 9 sites in S Italy; *Buxus* pollen was found in the 17%, 41% and 67% of the sites, respectively.

The Holocene history of *Buxus* in Italy is presented by grouping the pollen sites in five age classes (ages are always reported in calendar years Before Present) (Fig. 2): 14–10 ka, 10–7 ka, 7–4 ka, 4–1 ka and 1-0 ka. In Fig. 2 the location of the pollen records with *Buxus* during the forest phases preceding the last pleniglacial (130-80 ka) is also shown, for comparison with the Holocene data.

Late glacial records are located both in C Italy (Lago dell'Accesa 13.7 ka: Drescher-Schneider et al., 2007; Valle di Castiglione 13 ka: Alessio et al., 1986, Di Rita, pers. comm.; Lagaccione 11.5 ka: Magri, 1999), and in S Italy (Lago Grande di Monticchio ca. 12 ka: Allen et al., 2000). Following these early occurrences, *Buxus* appears in C Italy along the coasts of Latium (Pesceluna 9.7 ka: Di Rita, pers. comm.; Maccarese – Lingua d'Oca-Interporto 8 ka: Di Rita et al., 2010), and in N Apennines deposits (Lago di Bargone 9.9 ka: Cruise et al., 2009; Lago Padule 9.8 ka: Watson, 1996; EPD) and Liguria (Sestri Levante 8 ka: Bellini et al., 2009). Afterwards, *Buxus* becomes visible in Sicily (Lago di Pergusa 8.3 ka: Sadori & Narcisi, 2001; Sadori, pers. comm.; Gorgo Basso 8.1 ka: Tinner et al., 2009; Biviere di Gela 7.3 ka: Noti et al., 2009). *Buxus* then appears in Apulia (Coppa Nevigata - Lago Salso 6.3 ka: Di Rita et al., 2011; Di Rita, pers. comm.; Lago Alimini Piccolo 5.5 ka: Di Rita & Magri, 2009). Subsequently it is found at some sites N of the Po river, in Lombardy (Lago di Ledro 4.8 ka: Beug 1964; Lago di Gaiano 4.3 ka: Gehrig, 1997), and in Veneto (Lago della Costa 3 ka: Kaltenrieder et al., 2009; Kaltenrieder et al., 2010). Between 4 and 1 ka, *Buxus* is present in almost all regions, with new records in Latium (Lago di Ripa Sottile 2.5 ka: Ricci Lucchi et al., 2000; Valle del Colosseo in Rome 2 ka: Magri, unpublished data), in Liguria (Centa K2 ca. 1.9 ka: Arobba et al., 2004), in Emilia-Romagna (Lago di Vrazzano 1.1 ka: Bertoldi & Buccella, 1983), and in Veneto (fossil wood at Castelraimondo di Forgaria 1.9 ka: Accorsi et al., 1992). In this period a decline of *Buxus* in S Italy becomes manifest, as its presence is not recorded anymore in Sicily (after 2 ka at Biviere di Gela and 1.4 ka at Gorgo Basso), and in Apulia (after 4.1 ka at Coppa Nevigata - Lago Salso and 1.5 ka at Lago Alimini Piccolo). By contrast, *Buxus* increases in the last 1000 years N of the Po river, mostly in the pre-Alpine belt: in Lombardy (Lago di Ganna 1 ka: Schneider & Tobolski, 1985; Laghetto di Castellaro approx. 1 ka: Bertoldi, 1968), in Veneto (Dura-Moor 0.7 ka: Seiwald, 1980; EPD; Bosco del Cansiglio 0.7 ka: Kral, 1969), in Trentino Alto-Adige (Schwarzsee ca. 0.6 ka: Seiwald, 1980), and in Piedmont (Selle di Carnino 0.5 ka: de Beaulieu, 1977; EPD).

Three pollen sites show especially long records of *Buxus*: Lago dell'Accesa (13.7 and 2.8 ka), Lago Bargone (9.9-1 ka) and Gorgo Basso (8.1-1.4 ka).

The plot of the age of *Buxus* occurrences against the latitude of pollen sites (Fig. 3) shows that *Buxus* followed a latitudinal gradient in its Holocene appearance, being present since the late glacial at latitudes between 43°N and 41°N (14-10 ka, 4 sites) and then showing up in pollen sites at higher and lower latitudes. The second group of appearances (10-5 ka) took place in the N Apennines (Liguria and Tuscany) and Sicily. These were followed (5-1 ka), by several sites N of the Po river (Lombardy, Trentino Alto-Adige). Interestingly, *Buxus* appears rather early (ca. 8.5 ka) in the sites south of 38°N, which are located in areas where it does not presently occur. Considering the whole Holocene record, the number of sites where *Buxus* is found increases through time until about 2 ka. *Buxus* then disappeared from a number of sites where actually it is not present anymore. In particular, it disappeared from Sicily at 2-1.5 ka, from Apulia at 1.5 ka, and from the Veneto plain at 2 ka.

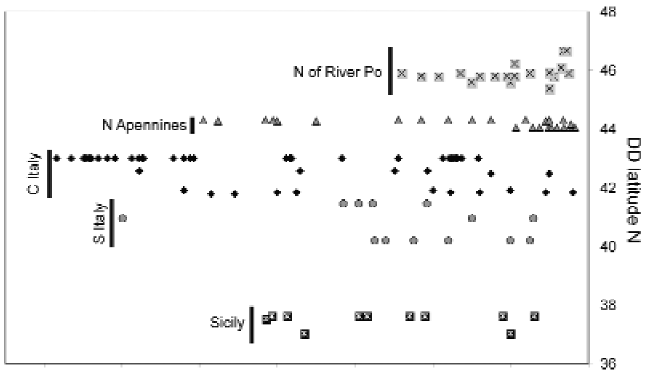

Fig.3. Age-latitude plot of *Buxus* occurrences in Italian pollen records, grouped by regional/geographical location.

Discussion

The latitudinal pattern found in the time series (Fig. 3) cannot be interpreted as a spread from C Italy towards higher and lower latitudes, which is an unrealistic scenario considering the dispersal abilities of *Buxus* (Fiori & Paoletti, 1908; Debussche & Lepart, 1992; Monestiez & Chadoeuf, 2002; Köhler, 2007). Plausibly, at the onset of the Holocene the populations in Tuscany, Latium and Basilicata were already rather dense. For this reason, the postglacial expansion of *Buxus* was detectable in these regions earlier than elsewhere. The positive and significant relationship between the abundance of *Buxus* pollen and the population density in present-day vegetation provides some support to this hypothesis. (Cañellas-Boltà et al., 2009).

Despite the delayed postglacial increase of *Buxus* populations in N and S Italy, it is most likely that *Buxus* persisted in large areas of the Italian Peninsula during the last glacial period (Fig. 2). In fact, during the forest phases preceding the last pleniglacial (130-80 ka), *Buxus* was present in all the long pollen records studied in Italy, including Cànolo Nuovo (Grüger, 1977), Lago Grande di Monticchio (Allen & Huntley, 2009), Valle di Castiglione (Follieri et al., 1988), Lago di Vico (Magri & Sadori, 1999), Lago Lungo (Calderoni et al., 1994), Lagaccione (Magri, 1999), Azzano Decimo (Pini et al., 2009), and Lago di Fimon (Pini et al., 2010). Besides, between 30 and 18 ka *Buxus* is recorded at Lago della Costa (Kaltenrieder et al., 2009) and Lago Grande di Monticchio (Allen & Huntley, 2000). In most of these sites *Buxus* is present also during the Holocene, indicating that it persisted locally through the last glacial period. However, in a number of sites *Buxus* underwent a severe reduction, so that it is not found during the Holocene at Cànolo Nuovo (Grüger, 1977), Azzano Decimo (Pini et al., 2009), and Lago di Fimon (Pini et al., 2010).

No long pollen sequences extending beyond the last glacial maximum are available from Sicily and Apulia. However, the presence of *Buxus* in these southern regions before the last glacial is most likely, considering its early Holocene appearances. The marked regional reduction of *Buxus* to the point of its disappearance was never realized by palaeobotanists, who did not interpret the fossil record in the context of its modern absence. Conversely, the absence of *Buxus* in Apulia and Sicily was never questioned by botanists, who did not consider the possibility that *Buxus* could extend so much to the south just a few millennia ago.

A point worthy of discussion is the dynamics of *Buxus* in the last 2 ka. In this period its representation increases in N Italy and vanishes in S Italy. It is very difficult to ascribe this trend to either climate change or to the possible impact of human activities. Concerning anthropogenic causes, a reduction of *Buxus* may have been indirectly caused by grazing pressure, while an increase may be linked to the ornamental interest in *Buxus sempervirens*. Regarding the grazing pressure, it is unlikely that *Buxus* was directly affected by herbivores, as the leaves are at best unpalatable (if not toxic) thanks to the presence of several alkaloids (Russel et al., 1997). For the same reason, it is possible that *Buxus* was cut down to favor livestock grazing, as evidenced for the pasturing regimes in present-day calcareous grasslands (Barbaro et al., 2004). In the respect of climate, the regions of S Italy, where *Buxus* is presently missing, were subject to a progressive desertification in the last few millennia (Di Rita & Magri, 2009), while the coeval records of N Italy, where *Buxus* increases, do not show any trend towards arid conditions (Finsinger & Tinner, 2006). Other determinant causes for the decline of *Buxus*, such as plant pathogens and intraspecific competition, cannot be ruled out. Interestingly, also *Buxus balearica* Lam. experienced a severe reduction in the course of the last few thousands of years, whose causes are still subject of debate (Yll et al., 1997).

The present study offers new hints for the sustainable management of biodiversity, showing that *Buxus sempervirens* is undergoing a severe reduction in the southern part of its range. In this respect, particular attention should be paid to the conservation of the taxon in such areas, which do not appear prone to favor a long-term persistence of *Buxus sempervirens*.

Conclusions

The use of modern distribution data in conjunction with past distributions provided new insights about the Holocene history of *Buxus sempervirens* in Italy. In particular, our approach led to the following conclusions:

- The present distribution of *Buxus sempervirens* in Italy, reconstructed using field survey, Floras and Herbarium accessions, is rather fragmented and scattered, with a center of frequency and abundance around 42°N, in the middle of the Peninsula.

- Pollen data shows that during the Holocene *Buxus* experienced a progressive population growth with different modes and times from region to region, depending on the initial densities of the nuclei of *Buxus* populations at the end of the last glacial period.

- The populations of *Buxus* located at latitudes between 41°N and 43°N are detected by pollen analyses already during the late glacial, when they were probbly already rather dense.

- In the course of the Holocene, *Buxus* populations increased especially in N Italy, where the species could take advantage of a favourable climate and possibly also of human activities because of its ornamental value.

- In S Italy *Buxus* underwent a severe reduction after 2 ka, to the point of being currently absent in Sicily, Calabria, and Apulia.
- Disentangling the causes for the reduction of *Buxus* in S Italy may provide new hints for a sustainable management of the taxon, which requires adequate protection measures in the light of its fragmented distribution and overall reduced population size.

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Appendix 1

The vast majority of modern data for *Buxus sempervirens* L. (110 occurrences) comes from field surveys by FDD and FL. Other occurrences were retrieved from Herbarium Specimens (12 occurrences, Herbaria of Sapienza and Roma Tre Universities). These data were integrated by the following Floras (18 occurrences):

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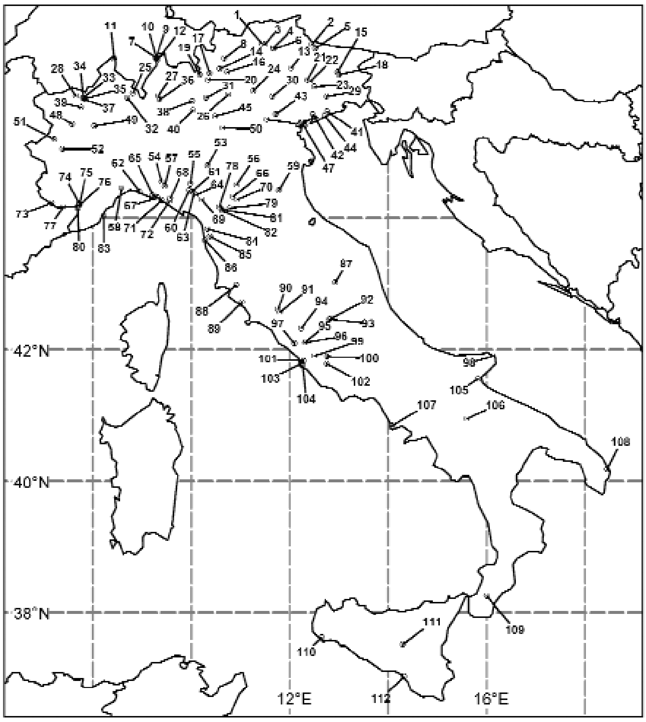
Appendix 2



List of Italian sites reviewed in the present study: 1. Schwarzsee (Seiwald, 1980); 2. Dura-Moor (Seiwald, 1980;) 3. Rinderplatz (Seiwald, 1980); 4. Sommersuss (Seiwald, 1980); 5. Comelico (Kral, 1986); 6. Pescosta (Borgatti et al., 2007); 7. Borghetto alto (Moe et al., 2007); 8. Pian Venezia (Speranza et al., 2007); 9. Val Vidrola sotto (Moe et al., 2007); 10. Lago Basso (Fedele & Wick, 1996); 11. Torbiera Ghighel (Braggio Morucchio et al., 1993); 12. Borghetto sotto (Moe et al., 2007); 13. Agordo (Dai Pra & Giardini, 2001); 14. Passo del Tonale (Gehrig, 1997); 15. Castelraimondo di Forgaria (Accorsi et al., 1992); 16. Lago Nero di Cornisello (Filippi et al., 2005a); 17. Col di Val Bighera (Gehrig, 1997); 18. Lago Ragogna (Monegato et al., 2007); 19. Pian di Gembro (Pini, 2002); 20. Palù bei Edolo (Gehrig, 1997); 21. Palughetto di Cansiglio (Ravazzi, 2002); 22. Bosco del Cansiglio (Kral, 1969) 23. Palù di Livenza (Pini, 2004); 24. Lago di Lavarone (Filippi et al., 2005b); 25. Lago di Ganna (Schneider & Tobolski, 1985); 26. Lago di Ledro (Beug, 1964); 27. Lago del Segrino (Wick, 1996); 28. Torbiera di Santa Anna (Brugiapaglia, 2007); 29. Azzano Decimo (Pini et al., 2009); 30. Forcellona (Kral, 1980); 31. Laghetti del Crestoso (Scaife, 1997); 32. Laghetto di Biandronno (Schneider, 1978); 33. Lago di Champlong (Brugiapaglia, 2007); 34. Torbiera di Champlong (Brugiapaglia, 2007); 35. Torbiera di Pilaz (Brugiapaglia, 2007); 36.Lago di Annone (Wick & Mohl, 2006); 37. Lago di Loditor (Brugiapaglia, 1996); 38. Lago di Gaiano (Gehrig, 1997); 39. Lago di Villa (Brugiapaglia, 1996); 40. Torbiera del Lago d'Iseo (Bertoldi & Consolini, 1989); 41. Fiorentina (Miola et al., 2006); 42. Ca' Tron (Miola et al., 2006); 43. Lago della Costa (Kaltenrieder et al., 2009; Kaltenrieder et al. 2010); 44. Palazzetto (Miola et al. 2006); 45. Lago Lucone (Valsecchi et al. 2006); 46. Lago di Fimon (Valsecchi et al., 2008); 47. Venezia ARS1 (Serandei et al., 2005); 48. Torbiera di Alice (Schneider, 1978); 49. Lago di Viverone (Schnerider, 1978); 50. Laghetto di Castellaro (Bertoldi, 1968); 51. Lago Falin (Caramiello et al., 1995); 52. Lago Piccolo di Avigliana (Finsinger & Tinner, 2006); 53. Parma terramara (Cremaschi et al., 2006); 54. Casanova (Cruise, 1990); 55. Berceto (Bertoldi et al., 2007); 56. Terramara di Montale (Mercuri et al., 2006); 57. Agoraie (Cruise, 1990); 58. Torbiera del Lajone (Braggio Morucchio et al., 1978; Guido et al., 2004a); 59. Bubano Quarry Est (Ravazzi et al., 2006); 60. Lagdei (Bertoldi, 1980; Bertoldi et al., 2007); 61. Lago Baccio (Mori Secci, 1996); 62. Val Bisagno (Montanari et al., 1997); 63. Prato Spilla C (Lowe, 1992); 64. Prato Spilla A (Lowe, 1992); 65. Rapallo (Bellini et al., 2009); 66. Pavullo nel Frignano (Vescovi et al., 2007); 67. Chiavari (Guido et al., 2004b); 68. Lago di Bargone (Cruise et al., 2009); 69. Lago Padule (Watson, 1996);

70. Vrazzano (Bertoldi & Buccella, 1983); 71. Sestri Levante (Bellini et al., 2009); 72. Lago Capello (Bertoldi et al., 1986); 73. Laghi dell'Orgials (Ortu et al., 2006); 74. Pian Marchisio (Ortu et al., 2008); 75. Rifugio Mondovì (Ortu et al., 2008); 76. Torbiera del Biecai (Ortu et al., 2008); 77. Lago del Vei del Bouc (Finsinger, 2001); 78. Lago Pratignano (Watson, 1996); 79. Ospitale (Watson, 1996); 80. Selle di Carnino (de Beaulieu, 1977); 81. Lago del Greppo (Ravazzi et al., 2006); 82. Lago Nero (Mori Secci, 1996); 83. Centa K2 (Arobba et al., 2004); 84. Lago di Massaciuccoli (Colombaroli et al., 2007; Mariotti Lippi et al., 2007); 85. Pisa (Bellini et al., 2009); 86. Arno M1 (Ricci Lucchi et al., 2006); 87. Colfiorito (Brugiapaglia & de Beaulieu, 1995); 88. Lago dell'Accesa (Drescher-Schneider et al., 2007); 89. Ombrone (Biserni & van Geel, 2005); 90. Lago di Mezzano (Sadori et al., 2004); 91. Lagaccione (Magri, 1999); 92. Lago Lungo (Calderoni et al., 1994); 93. Lago di Ripa Sottile (Ricci Lucchi et al., 2000); 94. Lago di Vico (Magri & Sadori, 1999); 95. Stracciacappa (Giardini, 2006); 96. Lago di Martignano (Kelly & Huntley, 1996); 97. Caldara di Manziana (Biondi et al., 1998); 98. Lago Battaglia (Caroli & Caldara, 2006); 99. Roma – Valle del Colosseo (Celant & Magri, 1999); 100. Valle di Castiglione (Alessio et al., 1986; Follieri et al., 1988); 101. Maccarese – Lingua d'Oca-Interporto (Di Rita et al., 2010); 102. Lago Albano (Lowe et al., 1996; Mercuri et al., 2002); 103. Pesceluna (Di Rita, pers. comm.); 104. Portus (Sadori et al., 2010); 105. Coppa Nevigata – Lago Salso (Caldara et al., 1999, Di Rita et al., 2011); 106. Lago Grande di Monticchio (Allen et al. 2000); 107. Lago d'Averno (Grüger & Thulin 1998); 108. Lago Alimini Piccolo (Di Rita & Magri, 2009); 109. Cànolo Nuovo (Schneider, 1985); 110. Gorgo Basso (Tinner et al., 2009); 111. Lago di Pergusa (Sadori & Narcisi, 2001); 112. Biviere di Gela (Noti et al., 2009).

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