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Vegetation History and Archaeobotany

Influence of human impact and bedrock differences on the vegetational history of the Insubrian Southern Alps

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Abstract. Vegetation history for the study region is reconstructed on the basis of pollen, charcoal and AMS ^{14}C investigations of lake sediments from Lago del Segrino (calcareous bedrock) and Lago di Muzzano (siliceous bedrock). Late-glacial forests were characterised by *Betula* and *Pinus sylvestris*. At the beginning of the Holocene they were replaced by temperate continental forest and shrub communities. A special type of temperate lowland forest, with *Abies alba* as the most important tree, was present in the period 8300 to 4500 B.P. Subsequently, *Fagus, Quercus* and *Alnus glutinosa* were the main forest components and *A. alba* ceased to be of importance. *Castanea sativa* and *Juglans regia* were probably introduced after forest clearance by fire during the first century A.D. On soils derived from siliceous bedrock, *C. sativa* was already dominant at ca. A.D. 200 (A.D. dates are in calendar years). In limestone areas, however, *C. sativa* failed to achieve a dominant role. After the introduction of *C. sativa*, the main trees were initially oak (*Quercus* spp.) and later the walnut (*Juglans regia*). *Ostrya carpinifolia* became the dominant tree around Lago del Segrino only in the last 100-200 years though it had spread into the area at ca. 5000 cal. B.C. This recent expansion of *Ostrya* is confirmed at other sites and appears to be controlled by human disturbances involving especially clearance. It is argued that these forests should not be regarded as climax communities. It is suggested that under undisturbed succession they would develop into mixed deciduous forests consisting of *Fraxinus excelsior, Tilia, Ulmus, Quercus* and *Acer*.

Key words: Vegetation history – *Castanea sativa* – *Juglans regia* – *Ostrya carpinifolia* – Southern Alps

Introduction

In the Southern Alps from the northern Piemonte to Lake Garda the climate is mild and humid due to its southern position and orographic rain. Temperatures reach an annual mean of 12°C and a July mean of 22°C. This favours submediterranean trees such as *Quercus pubescens, Castanea sativa, Ostrya carpinifolia* and *Fraxinus ornus*, which are hardly ever abundant in forests north of the Alps. Together with central European tree taxa, they form the species-rich forests of the southern Alps (Antonietti 1968). Because extreme winter frosts are very rare (Maggini and Spinedi 1996), some scattered stands of evergreen mediterranean trees and shrubs also occur at favoured sites, e.g. *Quercus ilex, Laurus nobilis, Erica arborea* and *Cistus salviifolius*.

The intermediate position of our study area between temperate central European and the Mediterranean is in part also traceable in the vegetation history. *Ostrya carpinifolia* and *Fraxinus ornus* immigrated early into the southern Alps (9000 and 7000 cal. B.P.), whereas *Castanea sativa* was only introduced by the Romans 2000 years ago (Zoller 1960; Schneider and Tobolski 1985; Tinner and Conedera 1995; Wick Olatunbosi 1996). Most of the thermophilous tree taxa, such as *Quercus, Tilia, Ulmus* and *Fraxinus excelsior* had already spread to the southern Alps in the Late-glacial, i.e. ca. 1000-2000 years earlier than in the northern Alps (Schneider and Tobolski 1985; Wick Olatunbosi 1996). Single pollen grains of evergreen and/or mediterranean species such as *Quercus ilex, Olea* and *Pistacia* are regularly found after ca. 3800 cal. B.C. (5000 B.P.).

New studies show that the vegetation of the southern Alps has been heavily influenced by forest fires from the Neolithic (Tinner and Conedera 1995; Wehrli et al. 1998; Tinner et al. 1999) to the present (Delarze et al. 1992; Conedera et al. 1996a; Hofmann et al. 1998). Conedera et al. (1996b) have shown that, during the 20th century, most forest fires start during the dry months (January-April), especially during periods with *Foehn* from the north, and are caused by humans.

Antonietti (1968) demonstrated convincingly that the bedrock type (calcareous versus siliceous rocks) is critical for the composition of the Insubric vegetation. The importance of this factor in the vegetation history of the Insubrian Alps has received little attention perhaps because detailed modern pollen diagrams have only recently become available for the limestone areas (Wick Olatun-

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bosi 1996; Gehrig 1997). The present study attempts a comparison of the vegetation in two contrasting bedrock areas by addressing the following issues: (1) The vegetation history on the two types of bedrock with special reference to land-use changes and the roles of *Juglans* and *Castanea,* and (2) the history of *Fraxinus ornus* and *Ostrya carpinifolia* forests.

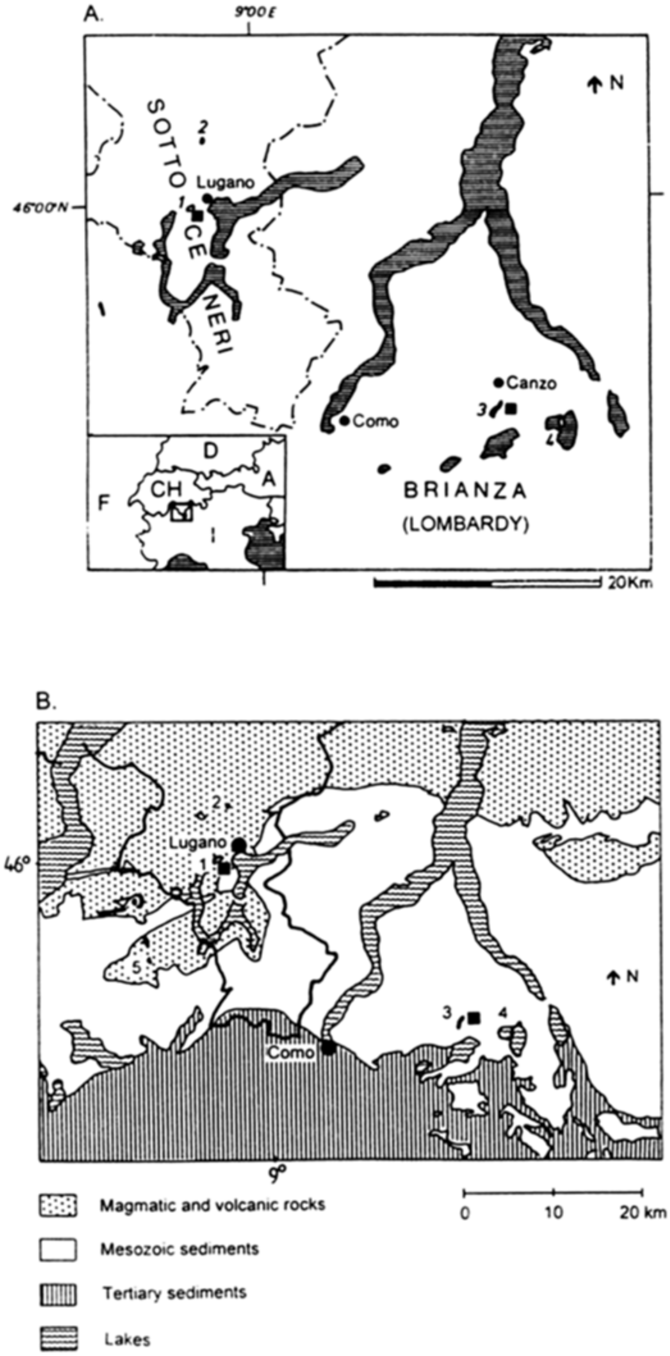


Fig. 1. Map of **A** the study region showing the main lakes (*parallel lines*) and locations of the main pollen profiles, and **B** the geology of the study region. *1,* Lago di Muzzano, *2,* Lago di Origlio, *3,* Lago del Segrino, *4,* Lago di Annone, *5,* Lago di Ganna. The sites for which new profiles are presented in this paper are indicated by a filled-in square. The inset in **A** shows the country boundaries within the study region

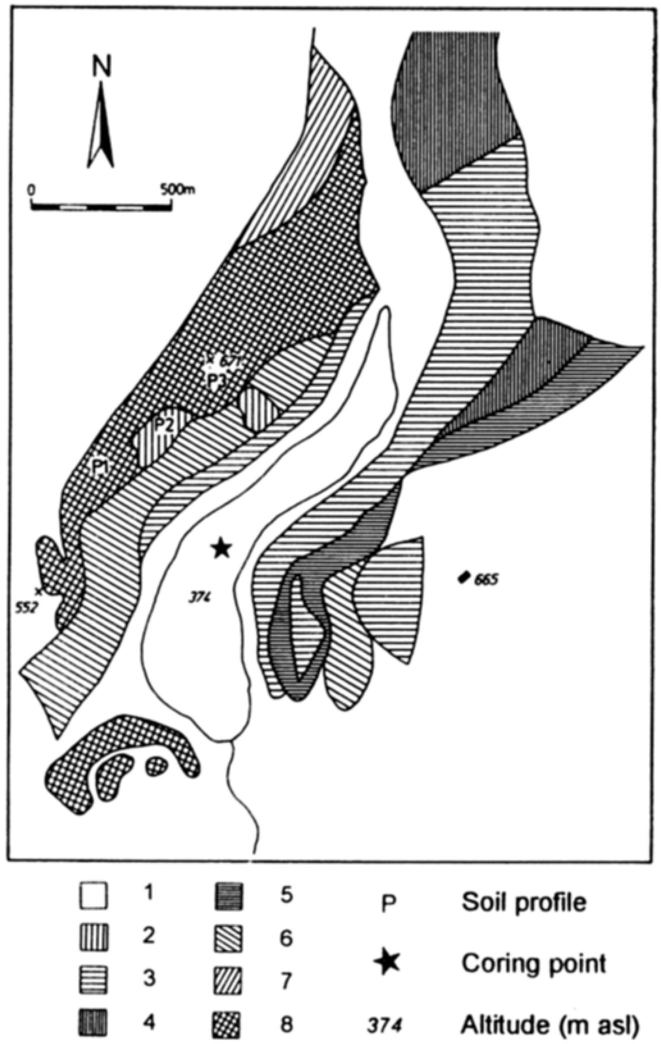


Fig. 2. Vegetation map of area surrounding Lago del Segrino. *1,* Not mapped, open water (Lago del Segrino); *2,* Open vegetation, *3, Fraxinus excelsior* dominant with *Ostrya carpinifolia* and *Tilia cordata; 4, F. excelsior* and *O. carpinifolia* dominant; *5, O. carpinifolia* dominant with *Fraxinus ornus; 6, O. carpinifolia* and *Quercus pubescens* dominant; *7, O. carpinifolia* and *Castanea sativa* dominant; 8, *C. sativa* dominant with *Q. pubescens*

Research area, its climate and vegetation

The lakes Lago del Segrino (Brianza, Italy) and Lago di Muzzano (Sottoceneri, Switzerland) are situated in the southern Alpine foreland about 30 km apart (Fig.1). Lago del Segrino (374 m asl) is at the northern edge of the Po plain. It is long and narrow, has a surface area of 0.38 km^2 and a maximum depth of 8.6 m, and is bordered by two hills (670 m and 1241 m asl). It has no inflowing stream and is fed by groundwater and some surface water. The creek leaving the lake at the southern end enters Lago di Pusiano about 2 km away. The local bedrock is calcium carbonate-rich and consists mainly of *Lias* and *Flysch* (observations in the field; also Geologische Karte der Schweiz 1:500 000, 2nd ed. 1980). According to Antonietti (1968, 1983) *Fraxinus ornus, Ostrya carpinifolia, Tilia cordata, Ulmus glabra, Fraxinus excelsior, Quercus* *petraea* and *Q. pubescens* are the most important trees on calcium carbonate-rich soils. *Castanea sativa* is the dominant tree on the acid soils of the western plateau (Fig. 2).

Lago di Muzzano (337 m asl) occupies a glacial depression in a hummocky landscape of the former Pleistocene Ticino glacier (Hantke 1983). Its surface area is 0.22 km^2 and its maximum water depth is 4.0 m. There are two inflowing creeks and the outflow in the south-west corner of the lake flows into Lago di Lugano, 1 km distant. The geology of the catchment is characterized by Quaternary deposits and siliceous rocks (Geologischer Atlas der Schweiz, sheet 69, No. 1353 Lugano 1976). *Castanea sativa* is the dominant tree in this area. Other important trees are *Quercus petraea* and *Q. pubescens, Alnus glutinosa, Fraxinus excelsior, Betula pendula, Fagus sylvatica* and *Tilia cordata.* Because of the high precipitation *Alnus glutinosa* is not restricted to littoral zones in the Insubrian southern Alps (Zoller 1960). It can even become the dominant forest tree on well-drained slope soils (Steiger 1998).

Both lakes are situated in the transitional zone from climate Cfb to Cfa (Köppen 1923). It is referred to as an Insubric climate with mild and dry winters and with maximum precipitation in spring and autumn. The sunny summers are sometimes interrupted by violent thunderstorms. At both lakes the annual mean temperature is 12°C and the annual precipitation is 1600-1700 mm. As Antonietti (1968) points out in contrast to Oberdorfer (1964), it is the bedrock (siliceous versus calcareous) and not the climate that determines the various lowland vegetation types of the southern Alps.

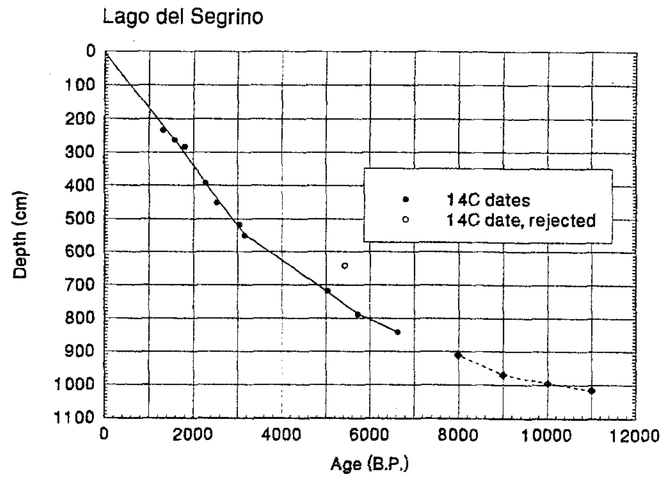
Methods

Coring, and analysis of pollen and charcoal

A modified Livingstone piston corer (Merkt and Streif 1970) was used to obtain core LS-3a in Lago del Segrino in 6.0 m water depth, and core MUZZ III in Lago di Muzzano at 2.8 m water depth. Both cores are from the profundal part of the basin. The core sections studied consist throughout of calcareous gyttja and marl in LS-3a and silty fine-detritus gyttja in MUZZ III.

The sediment was prepared using standard physico-chemical methods and with the addition of *Lycopodium* tablets for the estimation of pollen concentration (Stockmarr 1971). Pollen identification was carried out under x400 or x1000 magnification. Aids to pollen identification included the pollen reference collection at the Institute of Geobotany, and keys by Fægri and Iversen (1989), Punt (1976), Punt and Clarke (1980, 1981, 1984), Punt et al. (1988, 1995), Punt and Blackmore (1991), Moore et al. (1991) and the photomicrograph volumes by Reille (1992, 1995). In Holocene and Late-glacial samples ca. 1000 and ca. 800 pollen were counted, respectively. A total terrestrial pollen sum was used from which was excluded pteridophytes, aquatics, indeterminata and *Cannabis*-type. The results are presented as TILIA pollen diagrams (Grimm 1992).

Charcoal particles in lake sediments are indicators of past fire events (e.g. Swain 1973; 1978; Wright 1974; Clark et al. 1989). On the assumption that the vegetational history of areas around Lago di Muzzano and Lago del Segrino were heavily influenced by natural and anthropogenic forest fires, charcoal particles on pollen slides were also counted. Using x200 magnification, over 100 charcoal particles > 10 µm (or 75 μm^2) were counted and, at the same time, the added *Lycopodium* spores were also counted. This makes possible the computation of charcoal concentration. According to Tinner et al. (1998), charcoal influx values, or as an approximation charcoal concentration values, are sufficient for the reconstruction of regional fire history. The distinction of charcoal size classes or measurements of charcoal particles on pollen slides is not meaningful because some steps in preparation (sieving and decanting) reduce the number of particles that are >20 000 μm^2 which are decisive for the reconstruction of the local fire history.



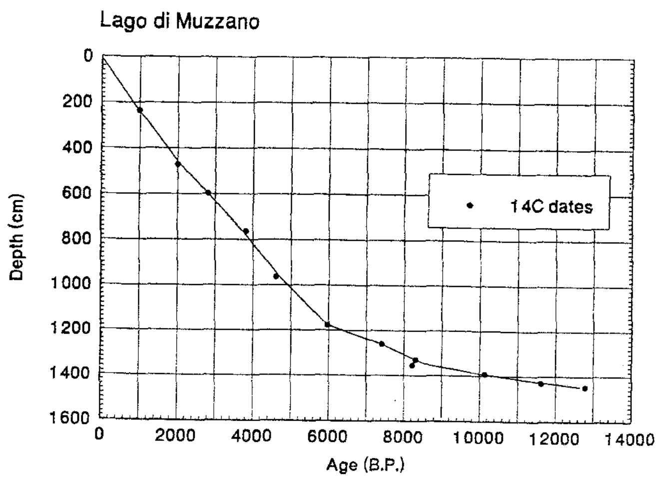


Fig. 3. Radiocarbon and pollen dating of the sediments from Lago del Segrino and Lago di Muzzano. *Unbroken line* indicates curve fitted by locally weighted regression; a *broken line* joins points dated on the basis of pollen stratigraphy

Table 1. AMS-radiocarbon dates from Lago del Segrino (LS-3a) and Lago di Muzzano (MUZ III)

^{14}C Lab. No.	Depth (cm)	Age (^{14}C y B.P., non-cal.)
Lago del Segrino		
UtC-5240	233 - 235	1310 ± 40
UtC-5241	262 - 264	1580 ± 70
UtC-5242	283 - 284	1810 ± 45
UtC-5243	391 - 395	2280 ± 40
UtC-5244	450 - 453	2520 ± 35
UtC-5245	517 - 519	3050 ± 35
UtC-5246	550 - 552	3160 ± 35
*UtC-5247	641 - 643	5420 ± 40
UtC-5248	716 - 719	5040 ± 70
UtC-5249	787 - 789	5730 ± 45
Ua-12533	841 - 843	6630 ± 70
Lago di Muzzano		
*UtC-4976	224.5 - 227.0	-40 ± 35
UtC-5620	237.0	1000 ± 60
UtC-4977	471.0 - 472.5	2010 ± 40
UtC-4978	597.0 - 598.0	2800 ± 40
UtC-5271	762.0 - 763.0	3820 ± 35
UtC-4979	963.5 - 965.0	4600 ± 60
UtC-4980	1177.5 -1178.5	5960 ± 60
UtC-5092	1260.0 -1262.0	7410 ± 70
UtC-5274	1329.0 -1330.0	8310 ± 60
UtC-5272	1354.0 -1355.0	8230 ± 80
UtC-4981	1392.5 -1394.5	10140 ± 70
UtC-5093	1429.5 -1430.5	11620 ± 50
UtC-5273	1447.0 -1448.0	12780 ± 80

* Dates regarded as unreliable and not used in construction of chronology

Radiocarbon dating

From the two cores LS-3a and MUZ III, 23 samples of terrestrial plant macrofossils were dated by the AMS method at the R.J. Van de Graff Laboratorium, University of Utrecht and one sample at the Svedberg Laboratorium, University of Uppsala. The ^{14}C results are reported according to Stuiver and Polach (1977; Table 1) and calibrated by the program CALIB Version 3.0.3c (Stuiver and Reimer 1993).

The radiocarbon ages were smoothed by locally weighted regression and the results are presented in depth-age diagrams (Fig. 3). Two dates were excluded from the regression. The date UtC-5247 is certainly too old, probably a hardwater error caused by the Mesozoic sediments of the catchment of Lago del Segrino. The date UtC-4976 is modern perhaps due to contamination (the sample was taken from the upper end of a core segment). Relative dating using pollen data (Fig. 3) was carried out by biostratigraphic correlation with radiocarbon-dated diagrams in the region (Schneider 1978; Schneider and Tobolski 1985; Wick 1989; Wick Olatunbosi 1996; Tinner et al. 1999).

Soil descriptions and vegetation mapping at Lago del Segrino

In the *Castanea* forests and their surroundings, three soil profiles were described in the field by horizon, depth, pH, skeletal content, colours and structure. The soils were classified according to the FAO-UNESCO classification. The modern woodland vegetation around Lago del Segrino was mapped. In this exercise, only the main trees or shrubs were taken into account (Fig. 2).

Results

Soil descriptions and vegetation mapping at Lago del Segrino

Soil investigations in the *Castanea* forests were described in an attempt to explain why this tree was present on calcareous bedrock. The soils, which may be classified as dystic cambisols, have a pH range of 4.5-5. The soils are therefore more acid than expected. The morainic and Mesozoic *Flysch* parent material has probably favoured the formation of acid brown earths. This explains the presence of *Castanea*-dominated forests, which normally occur only on siliceous soils.

Figure 2 gives an overview of the woodland vegetation at Lago del Segrino. On calcareous bedrock the dominant tree is *Ostrya carpinifolia,* followed by *Fraxinus excelsior, Quercus pubescens, Fraxinus ornus* and *Tilia cordata. Robinia pseudoacacia* is present in each of the mapped woodland types and in higher amounts where there is much disturbance.

Vegetation history

In total 180 and 187 pollen and spore types were identified from Lago del Segrino and Lago di Muzzano, respectively. In the percentage pollen diagrams (Figs. 4-7) the main pollen curves are shown. In Fig. 8 concentration values for selected pollen groups are plotted. A summary of the vegetation history is presented in Table 2. The correlation of the two sites is based on radiocarbon dates (Table 1, Fig. 3) and on their vegetational histories which are broadly similar though there are also some differences.

At Lago di Muzzano the record starts in the Late Glacial at ca. 14 200 cal. B.C. (13 500 B.P.) with *Betula* as the dominant tree in an open forest (pollen data not shown). This phase is not recorded in the pollen profile from Lago del Segrino, but an earlier study of the Late-glacial at this site shows that reforestation started at ca. 14 500 cal. B.C. (13 700 B.P.; Wick Olantunbosi 1996). After ca. 12 400 cal. B.C. (12 300 B.P.) *Pinus* was more abundant at both sites. At Lago del Segrino (Fig. 4) and at other localities in the southern Alps (e.g. Schneider and Tobolski 1985; Wick Olatunbosi 1996, Tinner et al. 1999), the expansion of several thermophilous mixed-oak taxa had already started during the Allerød (ca. 12 000-11 000 cal. B.C., 12 000-11 000 B.P.). At ca. 9300 cal. B.C. (10 000 B.P.), Late-glacial forests with *Pinus sylvestris* and *Betula* were replaced by temperate continental forests and shrub communities with deciduous *Quercus* species, *Corylus avellana, Tilia, Ulmus, Betula, P. sylvestris* and *Fraxinus excelsior*. Insubrian forests with *Abies alba* as an important tree dominated in the lowlands between 7300-3200 cal. B.C. (8300-4500 B.P.). This period is characterised by fluctuations of the important woodland species at both sites and there are also differences in abundance of particular trees in the two localities. *A. alba* expanded more successfully and was more abundant at Lago di Muzzano, whereas *C. avellana* was more common at Lago del Segrino. This period ended with the local extinction of *A. alba*. It disappeared from the lowlands probably on account of high fire frequency which gradually favoured the establishment of fire-tolerant alder-oak forests (Tinner et al. 1999). At the end of the late Insubrian forest period, which is characterised by a replacement of *Abies* by *Fagus* and increasing *Alnus glutinosa*-type and *Quercus* (deciduous) pollen percentages, the mixed oak forest species represented by *Tilia, F. excelsior* and *Ulmus* decreased substantially. At Lago del Segrino, the expansion of *Fagus* started earlier than at Lago di Muzzano. In general, *Corylus* was more abundant at Lago del Segrino than at Lago di Muzzano, where *A. glutinosa*-type was more important. This trend continued during the so-called 'oak-alder forests and farming' phase between 1800 cal. B.C. and A.D. 1 (3500-2000 B.P.; Table 2). In this phase, continuous agriculture is indicated by high values of anthropogenic indicators that continue into the present. The introduction of *Juglans regia* and *Castanea sativa* in Roman times initiated a phase of tree introduction and intensive farming. There are marked discrepancies between the two localities as regards abundance of plant taxa as well as an increasing floristic divergence towards the present, e.g. *Ostrya* (Figs. 4-7).

Table 2. Comparision of vegetation history at Lago del Segrino and Lago di Muzzano

Age1	Age2	LPAZs Segrino	LPAZs Muzzano	Vegetation/land use	Important taxa	Agreement
Present-A.D. 1	Present-2000	LS17-14	M17-13	Tree introduction and intensive farming (Segrino: since *c.* A.D. 1850 *Ostrya*-forests)	*Castanea sativa, Juglans regia, Quercus* (deciduous), *Alnus glutinosa, Ostrya carpinifolia,* herbs, cultivated plants and neophytes	-
A.D. 1-1800 B.C.	2000-3500	LS13-10	M13-(10)	Oak-alder forests and farming	*A. glutinosa, Quercus* (deciduous), *Pteridium aquilinum, Fagus silvatica, Betula, Calluna vulgaris,* herbs, cultivated plants	+
1800-3200 B.C.	3500-4500	LS9-8	M(10)	Late Insubrian forests	*A. glutinosa, F. sylvatica, Tilia, Quercus* (deciduous), *Corylus avellana, Fraxinus excelsior, Ulmus*	+
3200-7300 B.C.	4500-8300	LS7-(4)	M9-6	Insubrian forests	*Abies alba, Tilia, Quercus* (deciduous), *C. avellana, A. glutinosa, F. excelsior, Ulmus, Hedera helix*	+
7300-9300? B.C.	8300-10000	LS(4)-3	M5-4	Temperate continental forests and shrublands	*Quercus* (deciduous), *C. avellana, Tilia, Ulmus, Betula, Pinus sylvestris, F. excelsior*	++
9300?-12400? B.C.	10000-12300	LS2-1	M3-2	Late-glacial forests	*P. sylvestris, Betula*	++
12400?-14400? B.C.	12300-13600?		M1	Open Late-glacial forests	*Betula, P. sylvestris*	?

Age1, Cal. B.C./A.D.; Age2, B.P. (non-cal.)
LPAZs, local pollen assemblage zones; LS, Lago del Segrino, M, Lago di Muzzano
Vegetation types after Tinner et al. (1999)
Agreement between the two sites is indicated as follows:
- Increasing floristic disagreement towards present
+ Floristic agreement
++ Floristic agreement and comparable abundance of plant taxa
? Uncertain

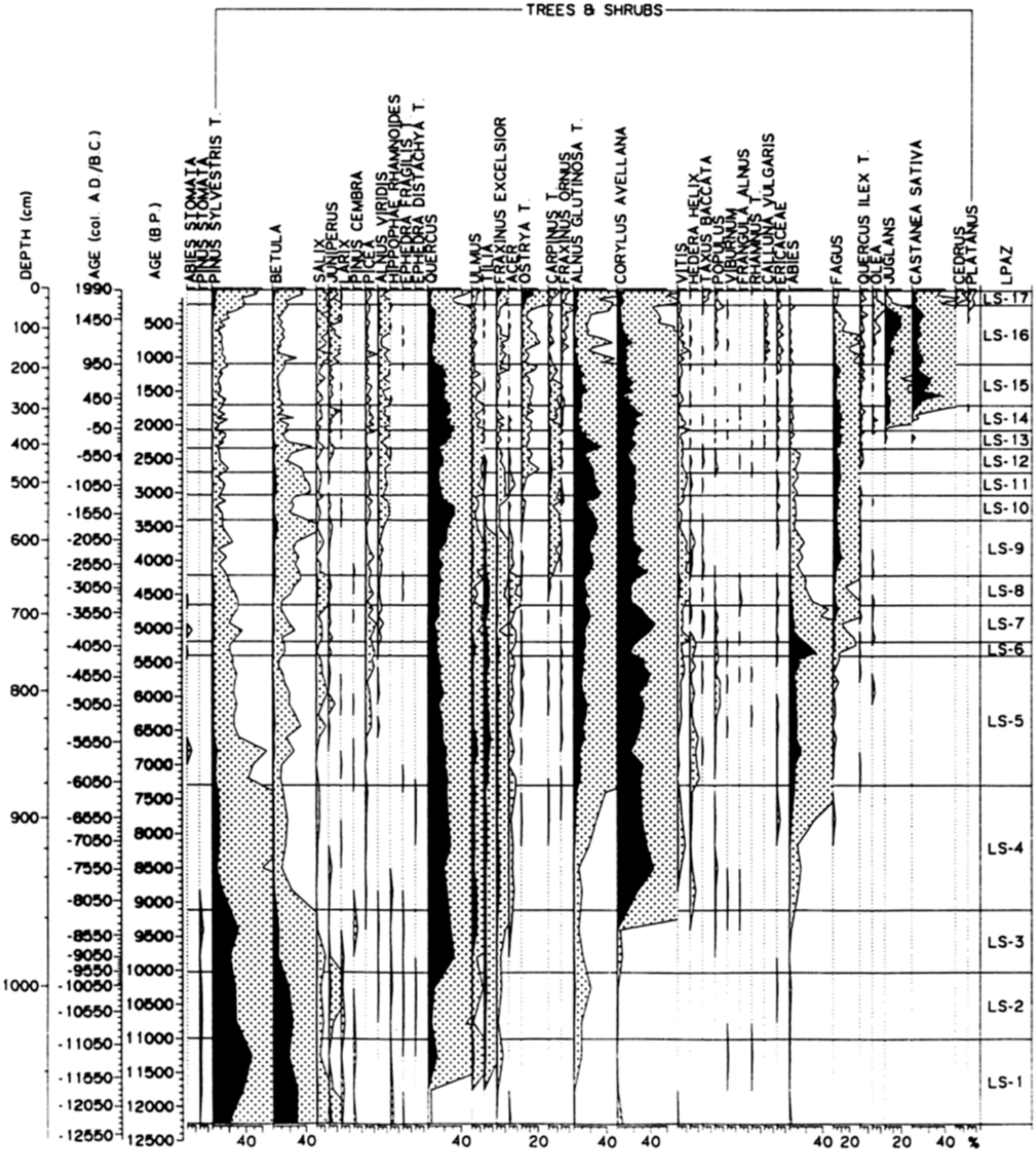


Fig. 4. Percentage arboreal pollen (AP) diagram from Lago del Segrino (selected taxa). Exaggeration x10 is indicated by stippling. Analysts: Erika Gobet and Ingrid Jansen, 1996. Pollen taxon types in this and other pollen diagrams are indicated by the taxon name followed by 'T'

Discussion

Three main phases of pre-Roman human impact

In the percentage pollen diagrams of Lago del Segrino (Figs. 4, 5) and Lago di Muzzano (Figs. 6, 7), three common pre-Roman phases of human impact with high non-arboreal pollen (NAP) values can be recognised as follows:

From ca. 3300 to 2700 cal. B.C. (4600-4100 B.P.), NAP at Lago del Segrino have very high percentage and concentration values which presumably reflect late-

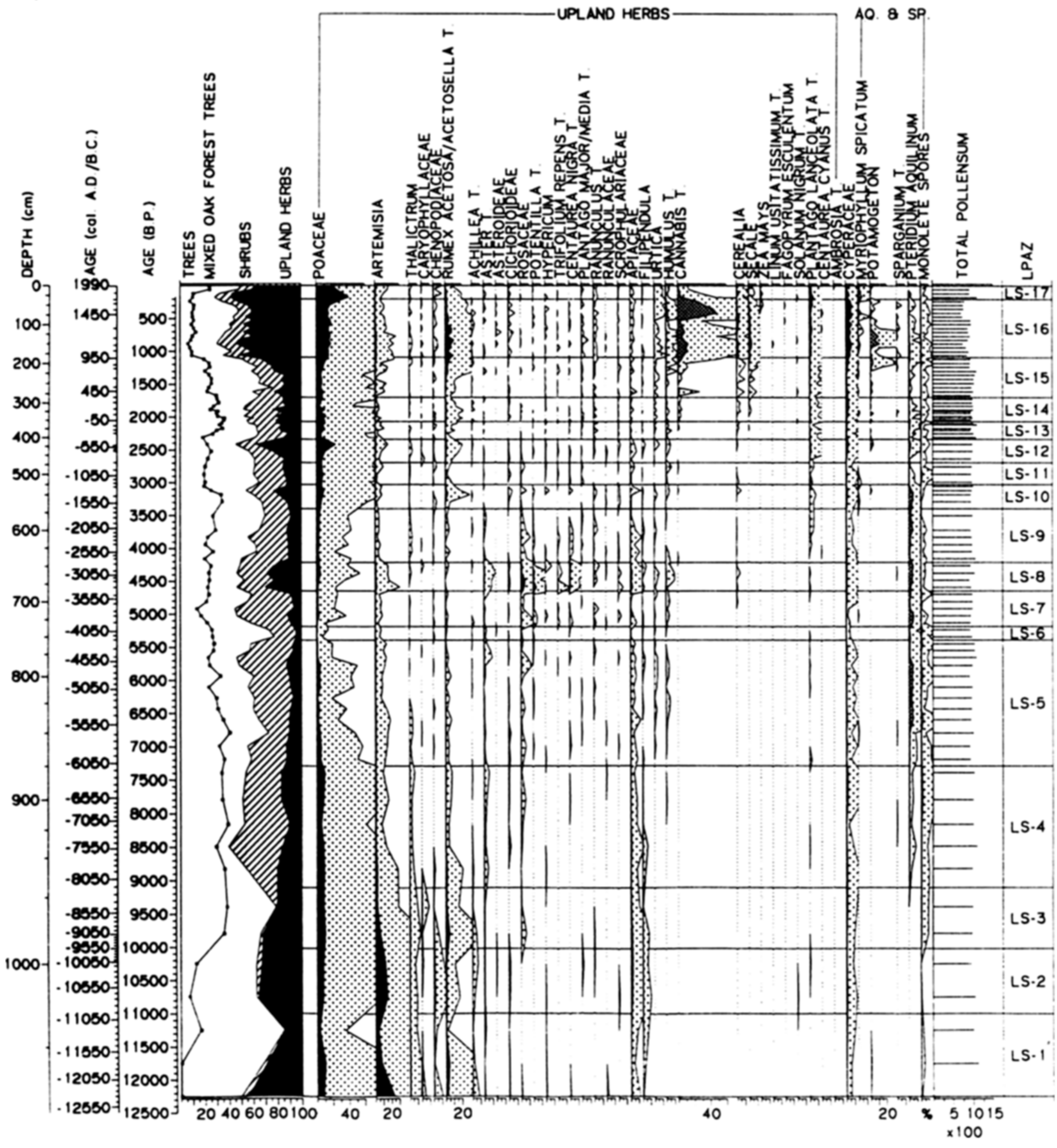


Fig. 5. Percentage non-arboreal pollen (NAP) diagram from Lago del Segrino (selected taxa). Exaggeration x10 is indicated by stippling. *Cannabis*-type and the group *AQ* (aquatics) and *SP* (spores) are excluded from the pollen sum. Analysts: Erika Gobet and Ingrid Jansen, 1996

Neolithic settlement near the lake (Castelletti, personal communication). A minor increase in NAP (percentages and concentrations) is also recognised at Lago di Muzzano at ca. 3200 cal. B.C. (4500 B.P.).

At ca. 1300 cal. B.C. (3100 B.P.), NAP (percentage and concentration values) increased at both localities. *Plantago lanceolata*-type, *Pteridium aquilinum* (and at Lago del Segrino also Cerealia) indicate major human activities during the Bronze Age.

At about 450 cal. B.C. (2400 B.P.) Poaceae and several anthropogenic indicators have high percentage and concentration values at Lago di Muzzano and Lago del

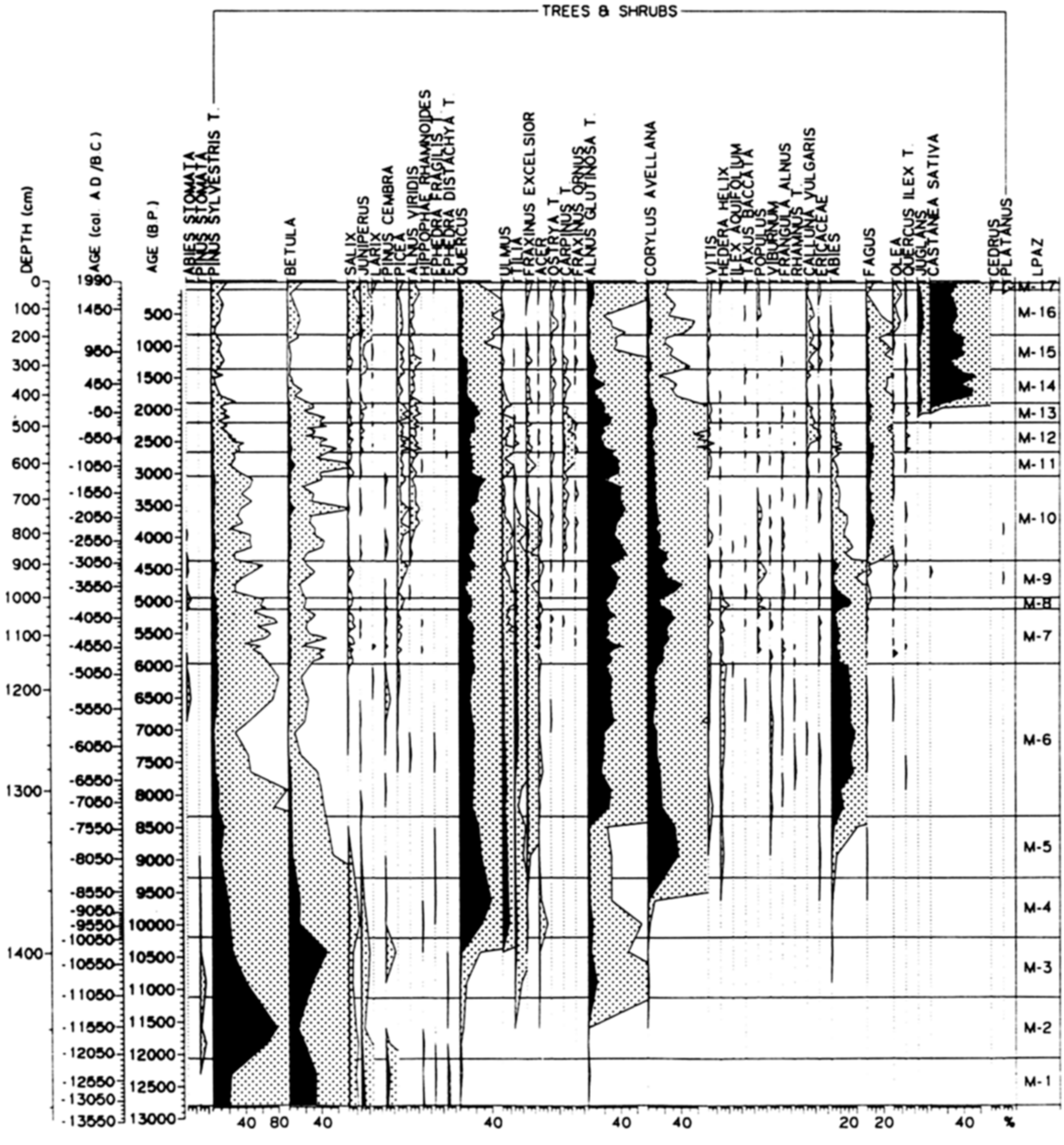


Fig. 6. Percentage arboreal pollen (AP) diagram from Lago di Muzzano (selected taxa). Exaggeration x10 is indicated by stippling. Analysts: Priska Hubschmid and Michael Wehrli, 1997

Segrino. This suggests substantial deforestation and farming activity during the Iron Age (Figs. 5, 7). The woodlands subsequently regenerate but the presence of Cerealia pollen and *P. lanceolata*-type indicate that there was still considerable human impact. High values of *Quercus* pollen could indicate that oak was favoured by the inhabitants probably on account of its mast. The Greek historian Polybios (ca. 200-120 B.C.), for instance, mentioned .the importance of acorns for pigs in the Po plain (Polybios II 15).

Introduction of Juglans, Castanea and Secale: chronological considerations

Zoller (1960) has already shown, using ^{14}C dates, that the main expansion of *Castanea* and *Juglans* in the Ticino re-

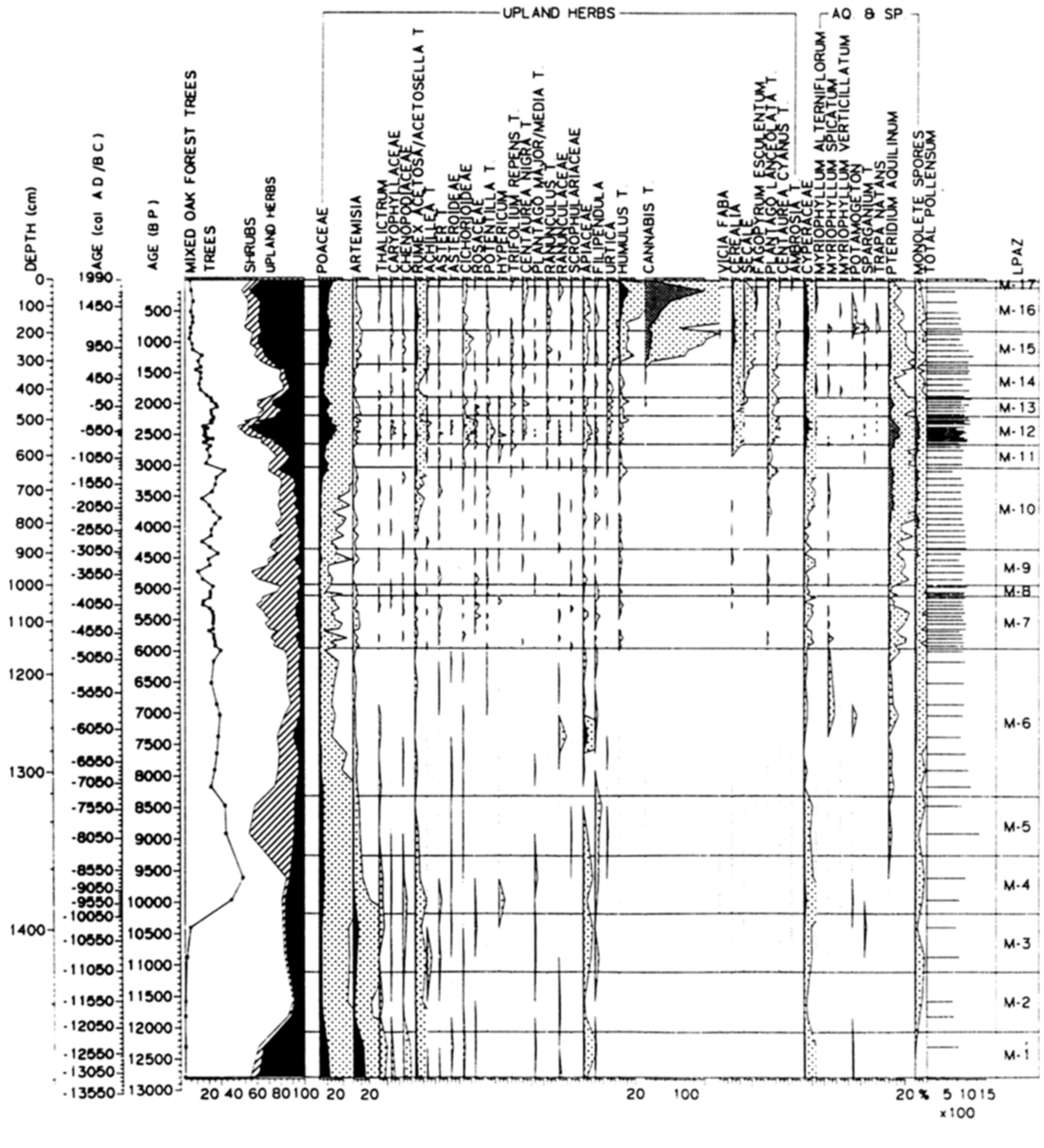


Fig. 7. Percentage non-arboreal pollen (NAP) diagram from Lago di Muzzano (selected taxa). Exaggeration x10 is indicated by stippling. *Cannabis*-type and the group *AQ* (aquatics) and *SP* (spores) are excluded from the pollen sum. Analysts: Priska Hubschmid and Michael Wehrli, 1997

gion occurred during Roman times. At Lago del Segrino the first single grains of both genera (absolute limit) appeared at an interpolated age of 290 cal. B.C. (2250 B.P.). For *Juglans* the continuous curve (empirical limit) started at ca. 40 cal. B.C. (2050 B.P.), and from ca. cal. A.D. 15 (2000 B.P.) onwards it expanded (>1%, rational limit; Fig. 9). The introduction of *Castanea* started somewhat later, as indicated by the continuous curve from A.D. 100 (1900 B.P.) onwards. After almost 200 years it achieved mass expansion (>5%). The first single pollen of *Secale* is dated to ca. 200 cal. B.C. (2150 B.P.), and from ca. A.D. 70 (1950 B.P.) onwards its pollen became more common at Lago del Segrino.

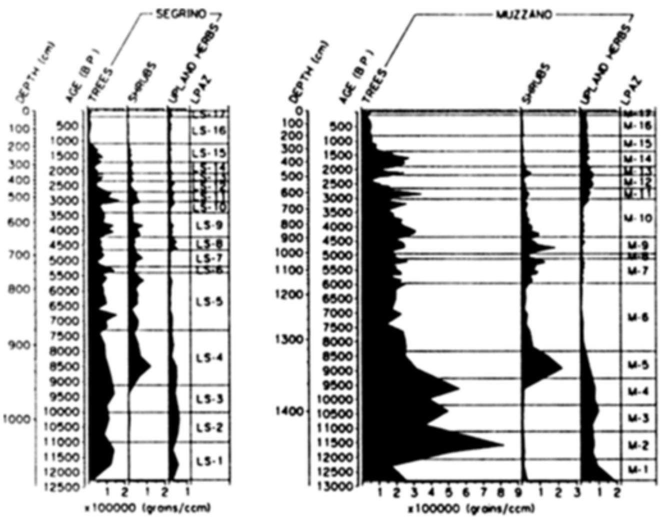


Fig. 8. Pollen concentration curves (main groups) from Lago del Segrino and Lago di Muzzano. Analysts: Erika Gobet, Ingrid Jansen, Priska Hubschmid and Michael Wehrli

At Lago di Muzzano, where for this period there is only one ^{14}C date (Fig. 10), the first *Secale* pollen record is dated at ca. 390 cal. B.C. (2350 B.P.), followed by single grains of *Castanea* at ca. 370 -300 cal. B.C. (2300-2250 B.P.). Before the onset of a continuous *Castanea* curve, the first *Juglans* pollen is recorded and its curve is continuous from the beginning. *Castanea* is continuously recorded since the beginning of the first century AD. The onset of a continuous *Secale* curve is dated to ca. A.D. 60 (1960 B.P.). The mass expansion of chestnut (*Castanea*) occurred at ca. A.D. 80 (1940 B.P.).

In Table 3 the calculated and calibrated dates for introduction (defined as the empirical limit) and mass expansion (defined as the rational limit, >5%) for *Castanea* at

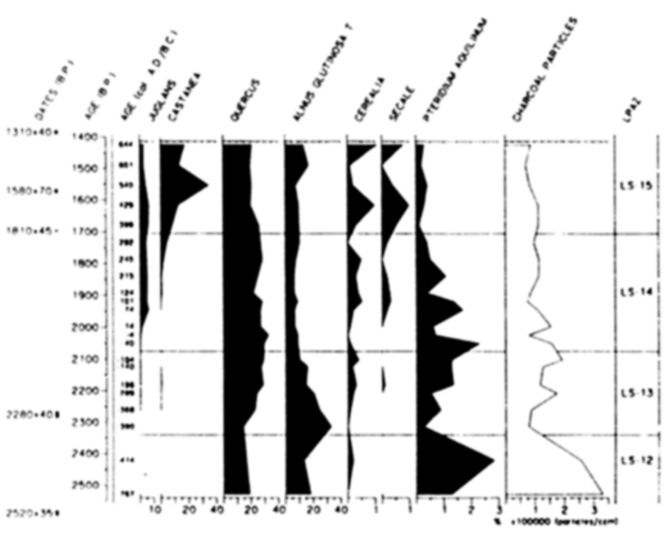


Fig. 9. Selected pollen percentage curves and charcoal particle concentration curve from Lago del Segrino. Analyst: Erika Gobet

Table 3. Introduction and spread of *Castanea sativa* in Sottoceneri and two regions within Lombardy

Locality	Introduction (continuous curve)	Mass expansion (>5%)
	Age (A.D.)	Age (A.D.)
Sottoceneri		
Lago di Origlio, 416 m asl (Tinner et al. 1999)	70	120
Lago di Muzzano, 337 m asl	1	80
Brianza		
Lago di Annone, 226 m asl (Wick unpubl.)	170	290
Lago del Segrino, 374 m asl	100	290
Valganna		
Lago di Ganna 452 m (Schneider and Tobolski 1985; Drescher-Schneider 1994)	120	450-600

Dates given are the best available estimates

five sites in the Insubrian region (Ticino and northern Italy) are given. Mass expansion in the Sottoceneri region was ca. 200 years earlier than in the Brianza region (also Figs. 9, 10). According to Schneider and Tobolski (1985) and Drescher-Schneider (1994), the rise of the *Castanea* curve and thereby the period of intensive planting of chestnut started at Lago di Ganna (ca. 20 km south-west of Lago di Muzzano) at ca. A.D. 450-600 (1600-1500 B.P.). The expansion of chestnut seems thus to be distinctly later at Lago di Ganna than in the nearby Sottoceneri (ca. 400 years, 10 km apart) and in Brianza (200 years, 40 km apart). Whether this is a local phenomenon or a dating problem is difficult to assess.

The introduction of *Castanea* and *Juglans* in the Brianza but also in the Sottoceneri can be related chronologically to Roman settlements (Figs. 9, 10). Como became a Latin colony in 89 B.C. but archeological investigations show that Roman cultural impact began to increase only at about 30 B.C. at the beginning of the reign of Augustus (27 B.C.-A.D. 14) (Stöckli 1975; Martin-Kilcher 1998). The introduction of *Castanea* and *Juglans* was probably facilitated by forest clearance involving fire, a view supported by the charcoal particle data (Figs. 9, 10).

It is likely that *Castanea* and *Juglans* survived the last Ice Age in Italy (Huntley and Birks 1983; Paganelli and Miola 1991; Birks and Line 1993), but were not able to spread spontaneously to the Insubrian region during the Holocene. However, during the pre-Roman Holocene, *Castanea* and *Juglans* pollen are known for other regions of Italy (Huntley and Birks 1983; Cruise 1990; Kelly and Huntley 1991; Brugiapaglia and de Beaulieu 1995).

Differential vegetation development on calcareous and siliceous rocks – a palaeoecological perspective

A major part of the pollen catchment of Lago del Segrino and Lago di Annone is characterized by calcareous bedrock (Wick Olatunbosi 1996). In contrast, Lago di

Muzzano and Lago di Origlio (Tinner et al. 1999) have pollen catchments dominated by acid soils (Fig. 1). *Castanea* is considered to avoid calcareous soils whereas such soils are favourable to *Juglans* (e.g. Durand and Chaumeton 1991; Ellenberg et al. 1992).

Around Lago del Segrino *Juglans* was the dominant fruit tree and at ca. A.D. 1400 it achieved 19% in the pollen record. Schneider and Tobolski (1985), Drescher-Schneider (1994) and Wick Olatunbosi (1996) state that planting of *Juglans* began before *Castanea.* Also in the Ticino, this trend is visible although the time difference is smaller and, furthermore, *Juglans* percentage values are here distinctly lower.

Conditions for *Castanea* are better in the Ticino than in the Brianza because of the siliceous bedrock (Fig.1). A total of 14 AMS ^{14}C dates on terrestrial macrofossils from Lago di Annone (Wick unpublished), Lago di Origlio (Tinner et al. 1999), Lago di Muzzano and Lago del Segrino lie in the period 650 cal. B.C.-A.D. 760 (2500-1250 B.P.). These dates prove that the mass expansion of *Castanea* where there was siliceous bedrock was earlier, faster and more successful than where calcareous rock prevailed. On the other hand, *Juglans* was favoured and more easily introduced on the calcareous soils of the Brianza. It is possible that also in Brianza – just as in the Ticino – people attempted to plant both trees in the areas cleared by fire (Figs. 9, 10) but chestnut, which performs poorly on calcareous soils, was soon replaced by *Quercus petraea* and *Q. pubescens* (LPAZ LS-14). *Castanea* was then able to grow successfully only on favourable habitats, such as acid brown earths (e.g. on Monte Scioscia near the soil profiles P1-P3, Fig. 2) and also provided that *Q. petraea, Q. pubescens* and possibly also *Corylus* were regularly cut.

Other taxa also provide evidence that different bedrock and hence soil types control long-term differential vegetation development. For instance, *Calluna vulgaris* and *Pteridium aquilinum,* which indicate acid soils (Ellenberg et al. 1992) are distinctly more common at

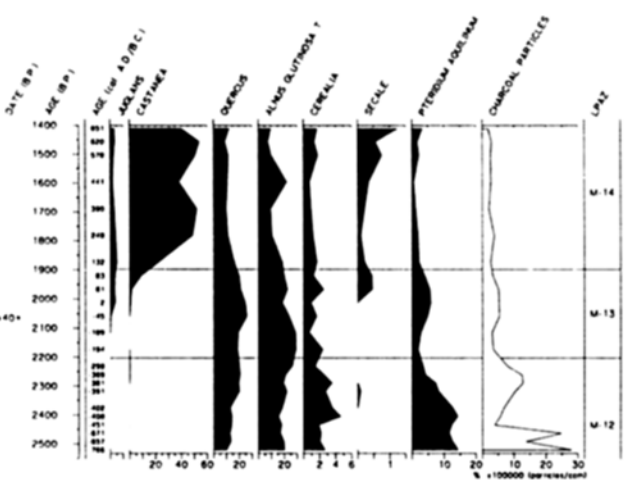


Fig. 10. Selected pollen percentage curves and charcoal particle concentration curve from Lago di Muzzano. Pollen analyst: Priska Hubschmid; charcoal analyst: Willy Tinner

Lago di Muzzano than at Lago del Segrino. In contrast, at Lago del Segrino calciphilous species such as *Myriophyllum spicatum* (cf. Ellenberg et al. 1992) or *Ostrya carpinifolia* (cf. Durand and Chaumeton 1991) have high representation.

Ostrya-dominated woodlands in the light of palaeoecological studies

Most ecologists consider *Ostrya*-dominated woodlands as typical of calcareous soils in our study region and assume that succession under natural conditions leads to *Ostrya*-dominated stands (e.g. Oberdorfer 1964; Ellenberg and Klötzli 1972; Mayer 1984; Reisigl 1996).

New palynological studies confirm that *Ostrya*-type has been present in small quantities in our study region since at least 9000 cal. B.P. but that it did not expand around Lago di Annone (Wick Olatunbosi 1996), Lago di Origlio (Tinner and Conedera 1995; Tinner et al. 1999), Lago di Muzzano and Lago del Segrino until the last century. The very high values of *Ostrya*-type pollen reported by Lüdi (1944) from Lago di Muzzano could not be confirmed by our new investigations. The strong increase in *Ostrya*-type especially in the Brianza, and also the minor values in the Ticino (Tinner et al. 1998), obviously reflect recent developments.

During the 19th century *Ostrya* began to expand at Lago del Segrino. Around 1960 the regional trend towards reforestation, dated by Tinner et al. (1998) using ^{210}Pb, is a conspicuous feature. At Lago del Segrino *Ostrya*-type, which reaches 14% (LPAZ LS-17, Fig. 4), becomes the most important AP taxon. Studies of the present-day vegetation around Lago del Segrino verified this *Ostrya carpinifolia* dominance. *Fraxinus excelsior, Corylus avellana, Quercus pubescens, Fraxinus ornus,* and (on acid soils) *Castanea sativa* are important as well (see Fig. 2). From comparison of pollen percentages from the youngest sediment and the vegetation map we can conclude that *Ostrya carpinifolia* is well represented in sediments.

At the eastern border of the Insubrian region at Lago di Gaiano (ca. 60 km east of Lago del Segrino), it was shown that *Ostrya*-type was already present at the beginning of the Holocene. Between 100 cal. B.C. and A.D. 350 (2100-1700 B.P.), its representation increased to 5-6% and remained at about this low level (Gehrig 1997). However, pre-Roman expansions are documented only for sites east and south of the Insubrian region (e.g. Beug 1964, 1965; Kral 1982; Huntley and Birks 1983; Grüger 1996).

As shown by the comparison between the vegetation map and its presence in surface sediments, *Fraxinus ornus*, an important diagnostic species of syntaxa with *Ostrya* at association level, is probably under-represented in pollen diagrams. Pollen production and dispersal are probably limited as this tree is insect pollinated. It spread to our study region at ca. 5400 cal. B.C. (6500 B.P.) but did not achieve a major expansion (remains <2%). Around Lago del Segrino it started expanding at ca. A.D. 1100 (900 B.P.), whereas on the siliceous soils of the northern Sottoceneri it was never important. In the case of *Carpinus betulus,* a continuous curve began much later, i.e. at ca. 2500 cal. B.C. (4000 B.P.), but then pollen of

Carpinus-type was present in higher amounts than that of *Ostrya*-type until ca. A.D. 1000 (1000 B.P.), when *Carpinus*-type declined (Fig. 4). During the last 100-200 years it expanded slightly, together with *Ostrya*.

A possible explanation for the palynological sequence of events may be found in the vegetation analysis carried out by Antonietti (1968). He described two forest types on calcareous rocks: (1) mixed deciduous broad-leaved forest with *Fraxinus excelsior, Acer pseudoplatanus, Tilia cordata* and *T. platyphyllos,* as well as *Ulmus glabra (Erisithalo-Ulmetum aegopodietosum* prov.), and (2) a woodland type in which *Ostrya* is dominant and *Quercus pubescens* and *Fraxinus ornus* as important components (*Helleboro-Ornetum* prov.). Between these two main forest types is a transitional association. We argue that the mixed deciduous broad-leaved forest type (*Erisithalo-Ulmetum aegopodietosum* ≅ *Asperulo taurinae-Tilietum* of Ellenberg and Klötzli 1972; see Antonietti 1983) represents the vegetation type that is least disturbed. Gradual human disturbance may have triggered a compositional shift in the forests, first in favour of *Castanea* and *Juglans,* and later in favour of *Ostrya.* The character of modern forests with *Ostrya* as coppiced stands (especially Carpinio-Ostryetum) has been referred to by several authors (Ellenberg and Klötzli 1972; Mayer 1984; Steiger 1998), but yet *Ostrya* is usually considered to be naturally dominant (e.g. Oberdorfer 1964; Mayer 1984; Reisigl 1996).

On the basis of our palynological results we suggest that the strong expansion of *Ostrya* is a very recent phenomenon on calcareous soils in the Insubric region and that it should certainly not be regarded as a climax community. Earlier authors (Bettelini 1904; Geilinger 1908, cited by Antonietti 1968) and also Antonietti (1968) recognized that *Ostrya* in the Insubric region is a woody species that was heavily favoured by human impact (mainly wood cutting) in much the same way as *Corylus.* In more recent times the abandonment of forest and meadow exploitation may also have favoured *Ostrya.*

Taking into consideration both the palaeoecological and present-day phytosociological data, we conclude that forests in the Insubric region, that are dominated by *Ostrya* (*Carpino betuli-Ostryetum* and *Fraxino orni-Ostryetum,* Ellenberg and Klötzli 1972), cannot be considered as climax forests. Under undisturbed succession these forests would probably develop into mixed deciduous forests with the components (in slightly decreasing abundance) *Fraxinus excelsior, Tilia, Ulmus, Quercus* and *Acer.* In these forests, *Ostrya carpinifolia, Fraxinus ornus* and *Carpinus betulus* would only have played a marginal role. A new palaeobotanical study (Tinner et al. 1999) suggests that under natural conditions *Abies alba* would also be co-dominant in the Insubrian region but because of anthropogenic pressure (mainly forest fires and browsing) it is sparsely present today and only at altitudes higher than 900 m asl. However, if seed sources would be available in the region, *A. alba* would probably enter again in the calcareous part of woodlands, although in smaller quantities than on siliceous soils.

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