

Palynological analyses on sediments of Lake Tovel (Trentino, Italy)

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SUMMARY - *Palynological analyses on sediments of Lake Tovel (Trentino, Italy)* - Palynological analyses on Tovel Lake sediments were conducted to reconstruct the local vegetation and land use history. Two of 30 collected cores for WP2 of SALTO project were chosen for palynological analyses: core TOV01-7, sampled in the centre of the main basin to obtain information of the vegetation development on a regional scale, and core TOV03-19, sampled in a littoral position, on local scale. The two cores of Tovel Lake encompass the recent vegetation development of the late Subatlantic: core TOV01-7 since about 900 AD, and core TOV03-19 since 1600 AD. Around 1100 AD a human impact on vegetation is recorded. Clearings in the valley bottoms are expanded and they transformed the thermophilous oak forests into farmland. Accompanied with this human interference is an intensification of the agricultural activities. During the Middle Ages an anthropogenic disturbance was caused by grazing of the local forests surrounding the lake. Between 1400 AD and 1600 AD new clearings in lower altitudes caused a decrease of *Ostrya carpinifolia* as well as an increase in *Castanea sativa* and *Juglans*, implying the plantation of orchards. Later, during the middle of the 17th to the 18th century, the mixed oak forests in valley bottom regions are cleared again, but clearings happen also in the forests surrounding the lake, indicated by a *Fagus*, *Abies* and *Picea* decrease, whereas pioneer and light demanding species expand, e.g. *Betula*, *Populus* and *Pinus*. There existed an extensive land use in the valley recorded by high values of cultural (*Hordeum-type*, *Secale*) and settlement indicators (*Artemisia*, Chenopodiaceae, Urticaceae), but also from the increase of the Gramineae, *Juniperus* and *Plantago lanceolata* as a consequence of pasture. During the 19th century the percentage curve of *Vitis* reflects the expansion of viticulture in the valley bottoms. A last remarkable change in the land use of the area happened around 1880 AD: a grazing management of the forests surrounding the lake as well as in the high altitudes is suggested by pasture indicators and respectively the expansion of *Larix*. It is conceivable that this intensified pasture utilization may cause a higher input of nitrogen into the lake and the surroundings which favors the spread of Cyperaceae in the lakeshore vegetation and *Sambucus nigra* in the forests at the beginning of the 20th century. Nevertheless, it does not seem to have a sustainable effect because in the most recent samples these eutrophic indicators are diminished.

RIASSUNTO - *Analisi palinologiche sui sedimenti del Lago di Tovel (Trentino, Italia)* - Sui sedimenti del Lago di Tovel sono state effettuate analisi polliniche per ricostruire la storia della vegetazione e dell'uso del territorio locale. Due delle 30 carote campionate per il WP2 del progetto SALTO sono state scelte per le analisi polliniche: la TOV01-7, prelevata al centro del bacino principale per ottenere informazioni sullo sviluppo della vegetazione su scala regionale, e la TOV03-19, campionata in posizione litorale per ottenere informazioni a livello locale. Le due carote del Lago di Tovel racchiudono lo sviluppo della vegetazione del tardo Subatlantico: approssimativamente, la TOV01-7 dal 900 AD e la TOV03-19 dal 1600 AD. Attorno al 1100 AD si nota già l'impatto umano sulla vegetazione: nel fondovalle il *Quercetum mixtum* subisce dei tagli ed è convertito in terre coltivabili, con un aumento dell'attività agricola. Durante il Medio Evo, un disturbo antropico locale è determinato dal taglio dei boschi. Tra il 1400 AD e il 1600 AD, il taglio alle basse quote causa una diminuzione di *Ostrya carpinifolia* e un aumento di *Castanea sativa* e *Juglans*. Tra la metà del XVII e il XVIII secolo si assiste ancora al taglio di boschi a querceto misto nel fondovalle. I tagli interessano anche i boschi limitrofi al lago e ciò è testimoniato dalla diminuzione di *Fagus*, *Abies* e *Picea* e dalla contemporanea espansione di specie pioniere eliofile come *Betula*, *Populus* e *Pinus*. L'uso estensivo del fondovalle è testimoniato dall'elevata presenza d'indicatori culturali (*Hordeum-type*, *Secale*) e antropici (*Artemisia*, Chenopodiaceae, Urticaceae), ma anche dall'aumento di Gramineae, *Juniperus* e *Plantago lanceolata* come conseguenza dell'attività di pascolo. La curva pollinica di *Vitis* testimonia l'introduzione della viticoltura in fondovalle durante il XIX secolo. Un ultimo evidente cambiamento nell'uso del territorio si registra verso il 1880 AD: tagli dei boschi attorno al lago e alle quote superiori sono testimoniati rispettivamente dalla presenza di indicatori di pascolo e dall'espansione di *Larix*. È

plausibile che l'uso intensificato del territorio per il pascolo possa aver causato, all'inizio del XX secolo, un maggior apporto d'azoto nel lago e nelle zone limitrofe, favorendo la diffusione di Cyperaceae nella vegetazione perilacustre e di *Sambucus nigra* nel bosco. Tuttavia tale situazione non sembra persistere poiché nei campioni più recenti gli indicatori eutrofici diminuiscono.

Key words: pollen, vegetation history, sediment, Tovel, Trentino, Italy

Parole chiave: polline, storia della vegetazione, sedimento, Tovel, Trentino, Italia

1. INTRODUCTION

Recent taxonomical, limnological and palaeoecological investigations on the Lake Tovel in the Adamello-Brenta National Park (Trentino, Italy) are engaged in an attractive reddening phenomenon of the lake, which was caused by bright red blooms of the dinoflagellate *Glenodinium sanguineum* March. but fails to appear since the early Sixties of the last century (Paganelli *et al.* 1981; Paganelli 1992). The reasons for the absence of the algae blooms during the past summer times are objective of a multidisciplinary project. Pollen analyses from two sediment cores of the lake basin aim to reconstruct the vegetation history and anthropogenic impact on the vegetation of the Lake Tovel area in the last 1000 years.

2. STUDY AREA

The Lake Tovel (46°15'40"N, 10°49'40"E) is a small lake (0.38 km²) located in 1177 m a.s.l. in the homonymous Tovel Valley, in the northern part of the Brenta Dolomites in the province of Trento (Fig. 1). The long and narrow valley runs in a North-South direction and meets the Non Valley in the North. The South is closed by dolomite-limestone mountains. The climate in the valley is fresh temperate of an alpine type. The area is moist continental, with polar maritime air masses, which bring precipitations all over the year and polar continental air masses, which

determine prevalent conditions of cold and dry climate during winter season.

2.1. Vegetation

In the immediate vicinity of the lake thrives a spruce forest (Piceetum) and in the moraine area north of the lake a pine (*Pinus*) forest. In higher altitudes (1800 m a.s.l.) the spruce forest is superseded by a Larici-Pinetum cembrae, which forms the forest limit in 2100 m a.s.l. Above the larch-Arolla pine forest spread alpine grasslands with *Pinus mugo* and *Vaccinium-Loiseleurietum*. The grasslands are used for pastures during the summer times.

The valley bottoms are presently characterized by fruit orchards crop and remnants of thermophilous forests (*Quercion pubescentis*) with a prevalence of *Ostrya carpinifolia* and *Fraxinus ornus*. These forests in the valley bottoms are used as coppices and are mainly composed by beech forests (52.2%), followed by the Orno-Ostrietum (30.3%), while oak-grove represents only 6.6%. In 750 m a.s.l. these woodlands give way to deciduous forests with *Quercus*, *Tilia*, *Acer*, in which also *Fagus sylvatica* appears, and in higher altitudes (1100 m a.s.l.) to a mixed conifer forest with *Fagus sylvatica* and *Abies alba*. Such a woodland adjoins also to the spruce forest, in which the lake is located. On the whole, the montane forests in the valley are composed mainly by *Picea* (55%), *Abies* (35%), *Larix* (7.3%) and *Pinus sylvestris* (2.3%).

3. METHODS

Sediment coring was carried out after a seismic investigation of the lake basin. Short sediment cores were collected with an UWITEC gravity corer and long sediment cores with an UWITEC piston corer. For further details about coring methods and the lithostratigraphic succession see Kulbe *et al.* (2006). Two of 30 collected cores were chosen for palynological analyses (Fig. 1, Tab. 1): the upper most part of the long sediment core TOV01-7, sampled in the centre of the main basin, provides information of the vegetation development on a regional scale, and the short sediment core TOV03-19, sampled in a littoral position, on local scale. Subsamples for pollen analysis were submitted already divided in 1-2 grams subsamples, preserved at 5 °C.



Fig. 1 - Topography of the Lake Tovel and position of the pollen analytically investigated cores.

Fig. 1 - Topografia del Lago di Tovel e posizione di prelievo delle carote considerate per i pollini.

Tab. 1 - Cores sampled in Lake Tovel and analyzed for pollen content.

Tab. 1 - Carote prelevate nel Lago di Tovel e analizzate per il contenuto in pollini.

Core code	Sampling date	Core position	Sampling technique	Total core length (cm)	Analyzed core length (cm)
TOV01-7	October 2001	Main basin	piston corer	734	239
TOV03-19	June 2003	Vicinity of Red Bay	gravity corer	55	55

The pollen extraction followed the method proposed by Faegri & Iversen (1989) and Moore *et al.* (1991). The decomposed subsamples were stained with fuchsin and mounted in glycerine jelly. Counting was restricted to about 400 pollen per sample and happened under the light microscope with a magnification of x400. The identification of critical pollen taxa result from the keys by Faegri & Iversen (1989), Moore *et al.* (1991), Nilsson & Praglowski (1992) and Reille (1992). The classification of pollen taxa into anthropogenic indicators follows Behre (1981) and Oeggl (1994). They are subdivided into cultivated plants (cultural indicators *sensu strictu*) and taxa which indicate human activity like rural plants (settlement indicators). The calculation of the pollen sum used for the diagrams is based on arboreal and non arboreal pollen exclusive Cyperaceae, hydrophytes, Bryophytes and Pteridophytes. The pollen data are visualized graphically in pollen diagrams as usual. For a better correlation of the pollen diagrams, a sub-division in local pollen assemblage zones "lpaz" (Cushing 1967) was undertaken.

The dating of the pollen analytical investigated sediment cores results from two data sources. The ages of upper most sediments are dated by ^{210}Pb and ^{137}Cs conducted on the cores TOV 01-5/V and TOV3-19. According to these measurements, the last 120 years encompass 12 cm in TOV 01-5/V and respectively 8 cm in TOV3-19 (Appleby & Piliposian 2006). An additional time marker for the core TOV01-7 is provided by a disturbance of the sedimentation from 64 to 94 cm caused by a rock fall dendrochronologically dated to 1597/98 AD (Oetheimer 1992).

4. RESULTS

4.1. Definition of the local pollen assemblage zones

4.1.1. Central core Tovel 1: TOV01-7 (Fig. 2)

To-1: *Quercus-Pinus* zone

Depth: 239-219 cm

Estimated age: 900-1100 AD

Upper limit: decrease of *Quercus*

Arboreal pollen reaches 90% with *Quercus* and *Pinus* predominant. *Alnus*, *Fagus* and *Picea* reach high va-

lues too. Non Arboreal Pollen (NAP) consist mainly of Gramineae, cultural (*Hordeum*-type) and settlement indicators (*Artemisia*, Chenopodiaceae, Urticaceae).

To-2: *Fagus-Abies* zone

Depth: 219-124 cm

Estimated age: 1100-1400 AD

Upper limit: *Abies* maximum

Dominant tree species are *Fagus* and *Picea*. Their curves run in the opposite direction. The zone starts with maximum values of *Fagus* and an expansion of *Abies* and *Picea*. In the middle part of the lpaz To-2, *Fagus* shows a distinct minimum, whereas *Picea* a maximum. At the same time, the cultural indicators disappear, but the anthropogenic indicators are still existent and the Gramineae and pasture indicators show a maximum. In the upper part of the lpaz To-2, *Fagus* spreads again and maintains at constant values like *Picea*. *Ostrya* shows a distinct maximum at the end of the zone. Anthropogenic indicators are evident in minor quantities.

To-3: *Picea-Fagus* zone

Depth: 62-124 cm

Estimated age: 1400-1600 AD

Upper limit: *Alnus* decrease

The prevalence of *Picea* and *Fagus* pollen sustains. *Abies* decreases after a maximum at the beginning of the lpaz To-3. In this zone *Juglans* appears in percentage values and keeps constant for the rest of the zone. The NAP shows an increasing trend, although the Gramineae are reduced in the middle of the zone. Anthropogenic indicators continue to be constant on percentage values, and a percentage curve of pasture and cultural indicators begins in the middle of the zone.

To-4: *Fagus-Gramineae* zone

Depth: 1-62 cm

Estimated age: 1600-2000 AD

Upper limit: end of core

Fagus and *Picea* are decreasing, whereas pioneer species like *Betula*, *Corylus avellana*, *Populus* and *Pinus* is increasing. *Castanea*, *Juglans* and *Vitis* show a distinct percentage curve with values up to 5%. Gramineae, pasture, settlement (*Artemisia*, *Plantago*

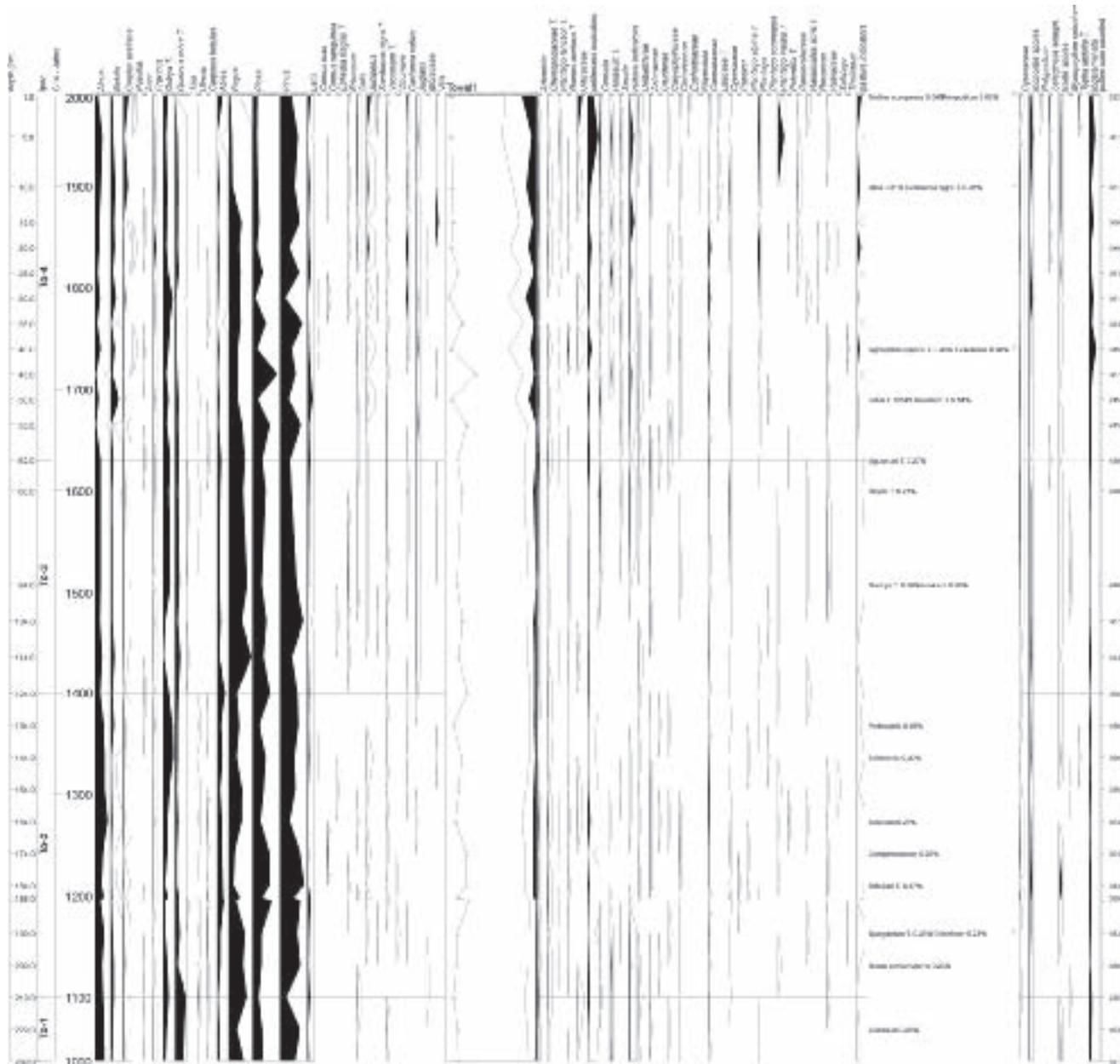


Fig. 2 - Pollen diagram of the central core TOV01-7 (Main Basin).
 Fig. 2 - Diagramma pollinico della carota TOV01-7 (Bacino Principale).

and Urticaceae) and cultural (*Hordeum*, *Vitis*) indicators strongly increase in this lpaz.

4.1.2. Littoral core Tovel 3: TOV03-19 (Fig. 3)

Lpaz Tol-1: *Fagus-Picea* zone

Depth: 55-25 cm

Estimated Age: 1600 AD-1800 AD

Upper limit: increase of *Fagus* and *Ostrya*, decrease of *Picea*

The dominant trees are *Fagus* and *Picea*, the latter

respectively from 40 to 25 cm, when *Fagus* decreases slightly. *Abies* shows the opposite trend of *Fagus* and increases together with *Picea*. *Alnus*, *Ostrya* and *Quercus* are well represented all over the zone with values below 10%.

Larix starts with insignificant values, but gradually increases during the zone and reach a respectable 5% at the end. At 40 cm depth, about in the middle of zone, *Juglans* reaches its maximum; *Castanea* is present in lower amounts. The NAP, with values about 20% at the beginning, decrease in the middle of the zone and rise then again. Gramineae and pasture indicators are poorly

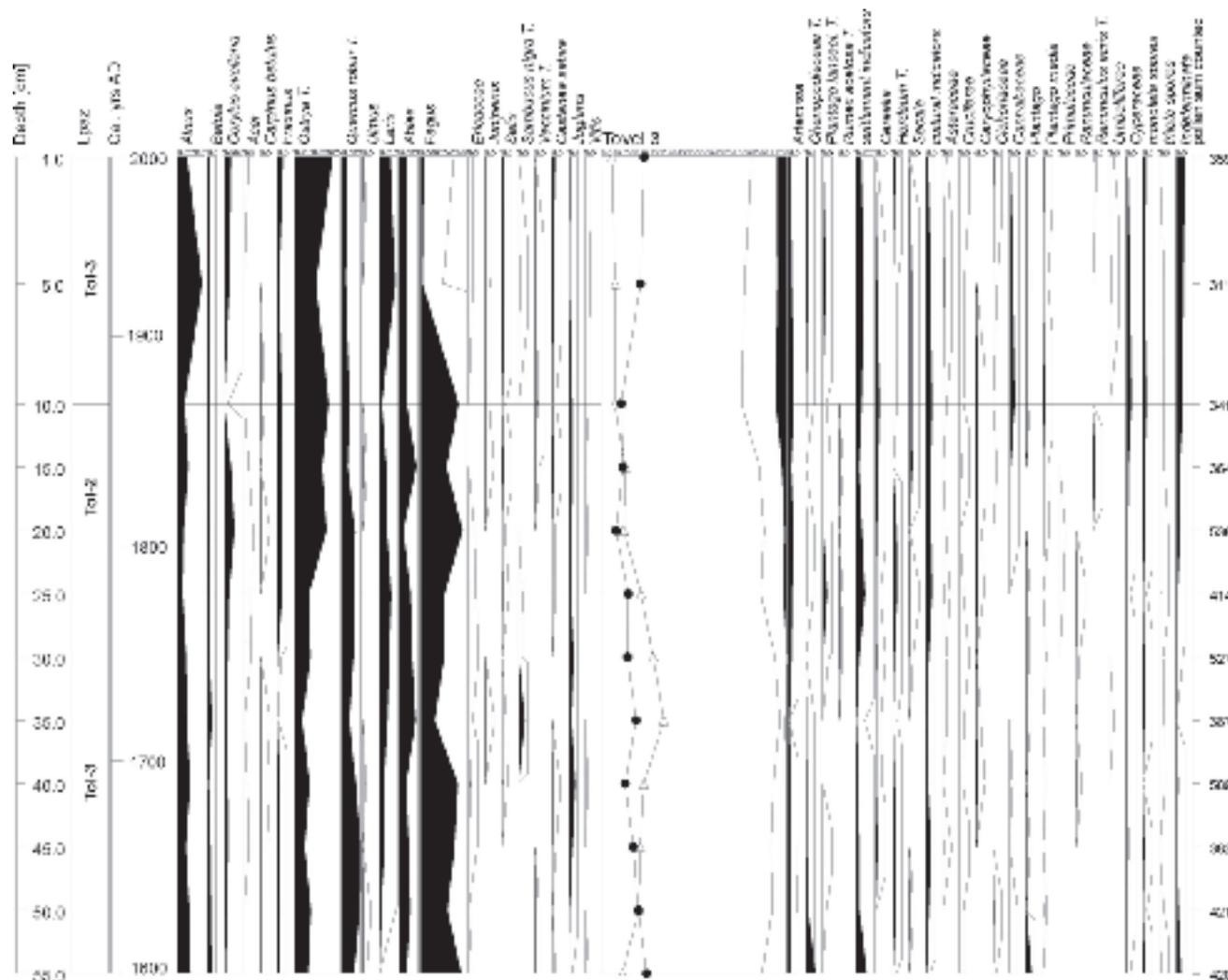


Fig. 3 - Pollen diagram of the litoral core TOV03-19.
 Fig. 3 - Diagramma pollinico della carota litorale TOV03-19.

presented. Anthropogenic and cultural indicators undergo an initial decrease, stabilizing on minimum values which on the end of this period tend to increase.

Lpaz Tol-2: *Fagus* zone
 Depth: 25-10 cm
 Estimated Age: 1800-1880 AD
 Upper limit: decrease of *Fagus*

Fagus and *Ostrya* are dominant and show a slight expansion, whereas *Picea* and *Abies* decline. *Corylus* increases as well as *Fraxinus*. A gradual increase concerns *Alnus*, *Larix* and *Quercus*, constant in the first part of this zone, successively gradually decreases. The Gramineae, although in minor quantities, show a rising trend, as well as pasture and cultural indicators, which increase as well. The anthropogenic indicators are almost constant, showing a slight flexure in the central part of the period. Cyperaceae reach their maximum towards the end of this zone.

Lpaz Tol-3: *Alnus-Ostrya-Pinus* Gramineae zone
 Depth: 10-1 cm
 Estimated Age: 1880-2000 AD
 Upper limit: decrease of *Fagus*

Alnus, *Ostrya* and *Pinus* are dominating. *Fagus* undergoes a severe reduction, decreasing from a presence of 25% to 1-2%, keeping constant values in the rest of the zone. *Abies* remains on constant 5%. *Picea* continues its gradual decrease and falls below the values of *Pinus*. Also *Quercus* keeps on decreasing gradually as evidenced in the former zone. On the contrary, *Larix* reaches its maximum values and *Corylus* and *Fraxinus* undergo a slight recovery in the most uppermost layers. Pollen of *Acer*, *Ulmus*, *Salix*, *Castanea* occurs sporadically; exiguous but constant is the presence of *Vitis*. Gramineae are present continuous and settle on maximum values of 8%. Pasture and settlement indicators increase slightly, whereas the cultural indicators, particularly the cereals, decrease.

4.2. Vegetation development

The two pollen diagrams of the Lake Tovel reveal the vegetation development for the last 1000 years. According to the size of the lake with a diameter of more than 500 m, the pollen sequences of the central core Tovel 1 are biased by a considerable regional component (Jacobson & Bradshaw 1981) and reflect the vegetation development of the whole valley. Therefore, a second core from the littoral zone out of the red bay (Tovel 3) was analyzed to gain a data source with a higher local impact, which enables a better view of the vegetation development in the immediate vicinity of the lake.

The vegetation development in the pollen diagram Tovel 1 (Fig. 2) starts with a *Quercus-Pinus* zone (lpaz To-1) with its pollen assemblage representing the mixed oak forest (*Quercetum mixtum*) from the valley bottoms, the mixed forests with *Abies*, *Fagus* and *Picea* as well *Pinus* in the montane regions and the subalpine forests with *Picea* and *Larix* in the wider vicinity of the lake. Human activity is present but not in the straight vicinity of the lake, because *Artemisia*, *Chenopodiaceae* and *Urtica* own airborne pollen, which are easily and well distributed over long distances by wind (Jochimsen 1986).

With the onset of the *Fagus-Abies* zone (lpaz To-2, Fig. 2) a severe decline of *Quercus* becomes visible, indicating an increase of human activity in lower altitudes. According to the depth age model based on the datings given above this intensification of the agricultural activities happen around 1100 AD. In the valley bottoms the mixed oak forests were cleared and transformed into farmland. In the middle part of the lpaz the clearings encompass also the montane fir (*Abies*) and beech (*Fagus*) forests. The increase of the human interference is confirmed by a distinct rise in the settlement and cultural indicators at the beginning of the lpaz To-2. As a consequence, the anthropogenic activity in the vicinity of the lake rises too and becomes visible in an increase of Gramineae, anthropogenic and cultural indicators in the second half of the lpaz To-2. The occurrence of pasture indicators (Gramineae, Campanulaceae, *Plantago lanceolata*, *P. media*, *Ranunculus acris*, *Rumex acetosa*, *Thalictrum*) suggests that the area was used for wood pasture. At the same time, higher values of Cyperaceae are recorded. At the end of the zone a spread of *Alnus* and *Fagus* is detectable and in the lower altitudes *Ostrya carpinifolia* expands showing that the anthropogenic activity is diminished but still existent around 1400 AD.

During the *Picea-Abies* zone (lpaz To-3, Fig. 2) the trend given in the previous lpaz To-2 continues. The clearings in lower altitudes are expanded, now causing a decrease of *Ostrya carpinifolia* as well as an increase in *Castanea sativa* and *Juglans*, and imply-

ing the plantation of orchards. Gramineae, settlement and cultural indicators remain on the same level like in lpaz To-2, indicating no major changes in the husbandry regime of the valley until 1600 AD.

Distinct local human impact on vegetation becomes visible in the *Fagus*-Gramineae zone (lpaz To-4, Fig. 2). In valley bottom regions again the mixed oak forests are cleared from the middle of the 17th to the 18th century. Clearances happen also in the local forests surrounding the lake, indicated by a *Fagus*, *Abies* and *Picea* decrease, whereas pioneer and light demanding species expand, e.g. *Betula*, *Populus* and *Pinus*. There exists an extensive land use in the valley recorded by high values of cultural (*Hordeum*-type, *Secale*) and settlement indicators (*Artemisia*, *Chenopodiaceae*, *Urticaceae*), but also from the increase of the Gramineae, *Juniperus* and *Plantago lanceolata* as a consequence of pasture. The increase of *Juglans*, *Castanea sativa* results most probably from the expansion of orchards and chestnut groves in the valley bottoms in the 18th century. Also the higher record of the cultural indicators like cereals (*Hordeum*-type, *Secale*) is a sign of increasing anthropogenic activity. This is confirmed by historical data, because Empress Maria Theresa from Austria introduces modern farming in the area (Giovannini 2000). During the second half of 19th century, the percentage curve of *Vitis* reflects a new expansion of viticulture in the valley bottoms. This happens after severe damage of the grapevines caused by *Oidium*, *Peronospora* and *Dactylosphaera vitifolii* after 1850 (Andreolli 1996). In recent times the vine yards were changed into apple orchards.

A last remarkable change in the land use of the area is detected in the uppermost three pollen spectra of core Tovel 1 (Fig. 2). According to the ²¹⁰Pb datings this happens around 1880 AD. The major change in the husbandry regimes combined with an expansion of the cropland happens in the valley bottoms by clearances of the forests in medium altitudes indicated in decreases of *Fagus sylvatica* and *Picea* in 15 cm depth. In the vicinity of the lake *Pinus* becomes predominant. The increasing pollen values of extra local pollen sources, e.g. *Corylus avellana*, *Juglans* and *Vitis*, indicate a distinct dissemination of these wood species in the lower altitudes. An expansion of the pasture activities during this part of the lpaz To-4 causes also the spread of *Juniperus*, *Plantago media* and *Plantago lanceolata*-type.

Amazing is also the high amount of *Larix* in this lpaz To-1 (Fig. 2). Usually, *Larix* has a poor pollen distribution and percentage values indicate a remarkable participation of the tree in the establishment of the forest (Huntley & Birks 1983). *Larix decidua* is a characteristic tree for the subalpine forests in the area and its spread indicates a human interference in the high-altitudinal forests. During clearances, *Larix* is conserved because of the light canopy and

Tab. 2 - Biostratigraphic correlation of the two cores.
 Tab. 2 - Correlazione biostratigrafica tra le due carote.

	Tovel 1	Tovel 3	Estimated age
	1-15 cm	lpaz Tol-3	2000-1880 AD
lpaz To-4	15-45 cm	lpaz Tol-2	1880-1800 AD
	45-62 cm	lpaz Tol-1	1800-1600 AD
lpaz To-3	62-124 cm		1600-1400 AD
lpaz To-2	124-219 cm		1400-1100 AD
lpaz To-1	219-239 cm		1100-900 AD

the needle mulch, which favours the growth of grass in the understory. The light stands of *Larix* are used for wood pasture. Because of the bad flight quality of the *Larix* pollen and its recent absence in the immediate vicinity of the lake, its pollen is most likely transported by water into the lake from the high altitudes.

At the same time as the expansion of farming occurs in the valley bottoms as well as in the high altitudes, there seems also to happen a local anthropogenic interference in the vicinity of the lake. Increasingly pioneer species (*Betula*, *Populus*) and indicator for disturbances (*Juniperus*, *Sambucus nigra*) are recorded in this *Fagus*-Gramineae zone. High values of Gramineae, *Plantago lanceolata*, *Plantago media* allude to wood pasture in the forests surrounding the lake at the beginning of the 20th century.

The second pollen diagram Tovel 3 (Fig. 3) resembles the vegetation development described above. According to the location of the coring point in the littoral zone nearer to the lakeshore, a higher local component of the pollen rain is expected. The core with a length of 55 cm encompasses the last four hundred years, which are reflected in the uppermost 68 cm of the central core Tovel 1. A correlation of the local pollen assemblage zones of the pollen diagram Tovel 3 with the pollen assemblage zones of diagram Tovel 1 gives table 2. On the whole, the higher local impact is detectable in a better representation of the saccate pollen of *Picea* and *Pinus*, which predominate also in the local vegetation. Still a remarkable extra local pollen component is visible in the high values of thermophilous woodland taxa like *Ostrya carpinifolia*. Nevertheless, the pollen curves reflect and confirm the land use changes given above.

5. DISCUSSION AND CONCLUSIONS

The two cores of Lake Tovel encompass the recent vegetation development of the late Subatlantic, core Tovel 1 since about 900 AD and core Tovel 3 since 1600 AD. From the very beginning a human impact on vegetation is given, although in the lower parts of the

central core Tovel 1 (lpaz To-1) it seems to be of extra local nature, deriving from the valley bottoms. During the Middle Ages a local anthropogenic disturbance is detected caused by grazing of the local forests. Arable farming is restricted to the valley bottoms. Besides changes in the tree's composition in the local forests no impact on the lake ecosystem becomes visible. This trend continues until the youngest parts of the cores. In both diagrams an intensification of agricultural activities in the valley is recorded around 1880 AD, which is reflected by the uppermost three pollen spectra. Besides clearances in the lower altitudes, also a grazing management of the forests surrounding the lake, as well as in the high altitudes, is suggested by pasture indicators and respectively the expansion of *Larix*. At the same time, a spread of Cyperaceae is reflected in the pollen diagrams. It is conceivable that this intensified pasture utilization may cause a higher input of nitrogen into the lake and the surroundings, which favors the spread of Cyperaceae in the lakeshore vegetation and *Sambucus nigra* in the forests at the beginning of the 20th century. Nevertheless, it does not seem to have a sustainable effect because in the most recent samples these eutrophic indicators are diminished.

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