



## **Water management sustainability in reclaimed coastal areas. The case of the Massaciuccoli lake basin (Tuscany, Italy)**

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The lake of Massaciuccoli (7 km<sup>2</sup> wide and about 2 m deep) and its palustrine nearby areas (about 13 km<sup>2</sup> wide) constitute a residual coastal lacustrine and marshy area largely drained by 1930.

In terms of hydrological boundaries, the lake watershed is bordered by carbonate to arenaceous reliefs on the east, by a sandy coastal shallow aquifer on the west (preventing groundwater salinisation), while south and north by the Serchio River and the Burlamacca-Gora di Stiava channels alignment respectively. Since reclamation of the peaty soils started, subsidence began (2 to 3 m in 70 years), leaving the lake perched and central respect the low drained area, now 0 to -3 m below m.s.l., and requiring 16 km embankment construction.

During the dry summer season, the lake undergoes a severe water stress, that, along with nutrients input, causes the continuous ecosystem degradation resulting in water salinisation and eutrophication. Water stress results in a head decrease below m.s.l., causing seawater intrusion along the main outlet, and reaching its highest point at the end of the summer season (common head values between -0.40 and -0.5 a.m.s.l.).

The water budget for an average dry season lasting about 100 days was computed, considering a 10% error, in order to understand and evaluate all the components leading to the above mentioned water stress by means of several multidisciplinary activities during the years 2008-2009. They started with a thoroughly literature review, continued with hydrological, hydrogeochemical monitoring and testing (both for surface water and the shallow aquifer) and agronomical investigations (to characterize cropping systems, evapotranspiration rates and irrigation schemes). All the collected data were then processed by means of statistical methods, time series analysis, numerical modelling of the shallow aquifer and hydrological modelling.

The results demonstrate the presence of two interrelated hydrological sub-systems: the lake and the reclaimed land sub-systems, the first one showing an average 4.2 mm net daily water loss during the summer season (about 0.975 m<sup>3</sup>/s) for the years 2000-2009. Lake inflow is constituted of two main terms: an anthropogenic one related to the drainage of the reclaimed land of about 1.1 m<sup>3</sup>/s (ranging 75-81% of the total inflow); a natural one defined by recharge through rainfall, the western coastal aquifer and the eastern reliefs, accounting for 0.25 m<sup>3</sup>/s (varying 19-25% of the total inflow). On the other hand, lake water loss is mainly due to evaporation from water surface and evapotranspiration from the palustrine vegetation for around 56-61% (1.31 m<sup>3</sup>/s on average), while 13 to 15% (0.325 m<sup>3</sup>/s) is due to inefficient irrigation schemes using lake water and, being the lake perched, recharge to the reclaimed land aquifer (26 to 29%) by means of water infiltrating along the embankments (0.64 m<sup>3</sup>/s on average).

Since several springs on the eastern margin, which would flow to the lacustrine system for about 0.160 m<sup>3</sup>/s (Autorità di Bacino del Fiume Serchio, 2007), are tapped (for residential, tourism and industrial users), the anthropogenic impact on the water deficit constitutes about 50% of the total, being 34% due to irrigation and 16% to other users.

This demonstrates the naturally induced water deficit, already known by historical sources, is heavily altered by anthropogenic pressure defining a not sustainable balance between the socio-economic system and the natural one. It is then clear, that in order to reduce the water stress, a new water management strategy in the whole basin must be devised by revising and enhancing the irrigation schemes and the residential, industrial and tourism water

distribution.

**Reference**

Autorità di Bacino del Fiume Serchio, 2007. Piano di Bacino “Bilancio idrico del bacino del lago di Massaciuccoli”  
Relazione di piano. Lucca, Italy.