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FARMERS MITIGATION AND ADAPTATION OPTIONS TO SALINITY IN SICILY (ITALY)

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ABSTRACT Groundwater salinisation is a growing issue in Italian coastal areas. Agriculture plays a crucial role by increasing water extraction and consumption especially in areas where intensive irrigated horticulture is widespread. In areas close to the coastline, aquifers over-exploitation can often cause salt water intrusion. Groundwater increased salinity affects productivity of irrigated crops and in the long term could contribute to secondary soil salinisation. Nevertheless, in some areas salinity has been conditioning agricultural productions from decades, but farmers are still able to cultivate by actively managing soil and water resources. An example is Licata plain, in Sicily, where farmers have been undertaken to adopt multiple strategies to mitigate salinity effects and adapt. Water salinisation in the plain is the result of complex interactions. Not only are cultivated areas close to the sea, but the plain is crossed by the Imera River whose water shows high levels of salinity. The river water chemical composition is determined by the solubilization process of gypsum rocks that are widespread along the river basin. Intensive agriculture is increasing pressure on soil and water resources and farmers have thus to deal with the damages they are causing. Farmers have been adapting for decades to high soil and water conductivity by adopting a mix of strategies that include crop and cultivar choice, rotation, irrigation methods, water storage, water mix, and desalinisation. A survey of farmers strategies was carried out together with well surveys and spatial salinity assessment, comparing wells data over forty years.

Keywords: desertification, mitigation, adaptation, water salinity, groundwater, coastal aquifer.

INTRODUCTION During the last decade, the increased exploitation of the underground resources has produced a fast agricultural and socioeconomic development in regions where alternative surface water resources were insufficient. At the world scale, almost 50% of the population lives within 60 km from the shoreline (Oude Essink, 2001). In these coastal aquifer systems, when the rate of abstraction and recharge of groundwater quantity are not in balance, a lowering of the groundwater table obviously occurs with the direct consequence of triggering saltwater intrusion phenomena. Among the principal causes of the acceleration of the salt water intrusion processes in the coastal aquifer

systems there are: i) the relative sea level rise; ii) coastal erosion phenomena; iii) the variation of the river flow (decrease of the alimentation of the aquifer system); iv) human activities (groundwater over-exploration); and v) climatic changes (es. decrease of the precipitation; increase of the evapotranspiration). Salinity is a well known issue in Sicily and is widespread both along the coastal areas, due to the overpumping of acquifers causing sea water intrusion, and the central part of Sicily due to the hydrogeological conditions (Favara et al., 2000). The Southern Imera river crosses Sicily from North to South. Its spring is on the Madonie chain and its water runs for 132 km to the South, until Licata. The Licata plain is a cultivated area where specialized horticulture is the main economic activity. The Imera river is a potential irrigation source for Licata farmers, but its water cannot be used due to its high salts content (Selvaggi et al., 2010). Moreover groundwater resources are limited in quantity and quality and farmers are forced to adopt multiple strategies such as saving, storing and mixing water.

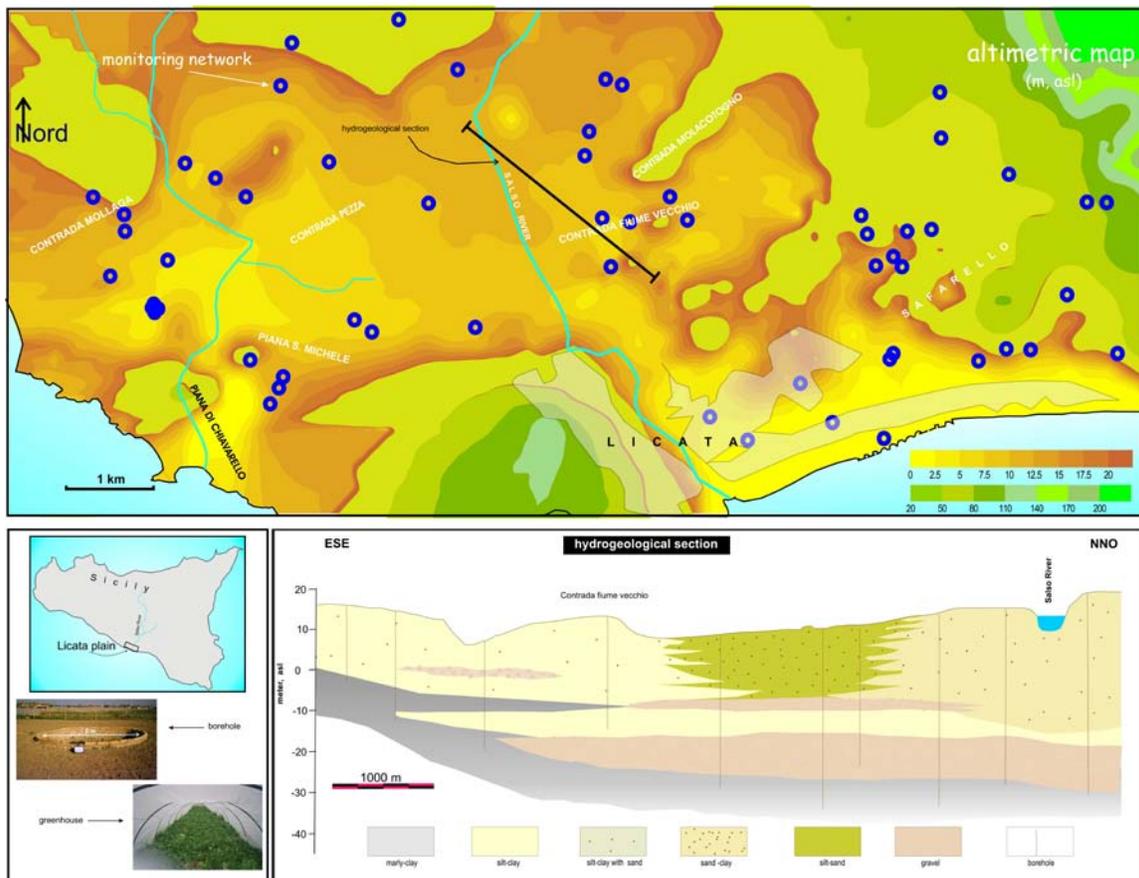


Figure 1: Licata plain: investigated area and its location in the southern sector of Sicily, altimetric model; monitoring network and hydrogeological section.

Accordingly, hydrological, hydrogeological and chemical investigation have been integrated in the analysis of the alluvial coastal aquifer system of Licata for a best evaluation of the influence of the climatic changes and water resources degradation in the farmer activities (Fig. 1). The first human record within the Licata territory is as old

as Late Neolithic. Due to the numerous sulphur mines occurring within the surrounding region, the Licata harbor represented an important trade centre of the Mediterranean till the end of the XX century. The major hydrographic feature of the region is represented by the Southern Imera River, also called Salso River. The natural changes of the river bed, its delta area and the nearby coastal sector, have strongly influenced the evolution of the landscape and produced altimetric variations spanning from 0 to 50 m above sea level. In the 70's a previous aquifer assessment have been carried out by a complete survey of more than 100 wells along the plain. All data are available but they are printed as a list and identified by coordinates and there are no maps showing and integrating the results. The aim of our work was to map all available data and to compare them with a more complete and recent surveys performed in 2004 and 2005.

AQUIFER SYSTEM The Licata plain is largely farmed and almost completely covered by greenhouses, where two productive cycles are carried out every year (autumn-winter and spring-summer), while cultivations need two-three watering per week. Accordingly, in order to satisfy such a large amount of water resources, several boreholes have been excavated. These wells are commonly of large diameter, up to 5 m, rarely exceeding the 10 m-depth and generally built with stones. They are located both inside and outside the greenhouses and exploit an unconfined, or locally semiconfined, aquifer developed within the alluvial deposits of the Salso River. This aquifer mainly consists of sandy or silt-sandy lenses, locally as coarse as gravels, generally 1 to 10 m thick and hydraulically interconnected (Rapti-Caputo, 2005). The feeding sources for the aquifer are mainly two. Firstly, there is the infiltration of the precipitations whose mean annual value is about 454 mm (1926-2005), showing oscillations between 206 and 1091 mm. Secondly, the aquifer is laterally fed by the Salso River during the flooding periods. Indeed, in Italian the word Salso means “salty”, thus suggesting that local people was aware of the high salinity of the flowing water. This perception is also clearly documented by measured values of the electrical conductivity as high as 2000 to 14000 $\mu\text{S}/\text{cm}$ (at 20 °C). These high values are due to the fact that the river largely drains the Messinian evaporitic deposits largely outcropping in the hydrographic basin (the so-called “gessoso-solfifera” Formation) (Roda, 1971).

WATER ANALYSIS During May 2005, the water level and the chemico-physical parameters of the water were measured in 45 wells while the ionic concentrations of Ca, Mg, K, Na, Cl, SO_4 , HCO_3 e NO_3 were subsequently obtained in the laboratory from the collected samples. The measurements of the depth-to-water show variations between 0.5 and 7 m. In particular, the higher depth-to-water values are observed within the central sector of the plain, while the lower ones were measured in the northwestern sector of the plain and east of Licata. The measured values are due to the combined effect of both the lithological and geometric characteristics of the aquifer and the amount of pumping. The contribution of pumping is likely to be minimal because the measurements have been carried out in wells that were not exploited for one day and therefore the aquifer could be considered in stable conditions. The only exception is represented by the bore-hole located west of “Contrada Molacotogno” area, where the measurements were performed with the aquifer in semi-static conditions. The electrical conductivity of water (measured in situ and referred to 20 °C) shows variations between 1 and 12 mS/cm (Fig. 2). The minimum values of this parameter are observed in the central and western sectors of the

plain, while the highest values measured east of Licata are likely due to the intrusion of marine salty water. The mixing phenomena between the freshwater from the aquifer and the marine water are confirmed by the occurrence of elevated concentrations in chlorides and sodium up to 4000 mg/l and larger than 1500 mg/l, respectively.

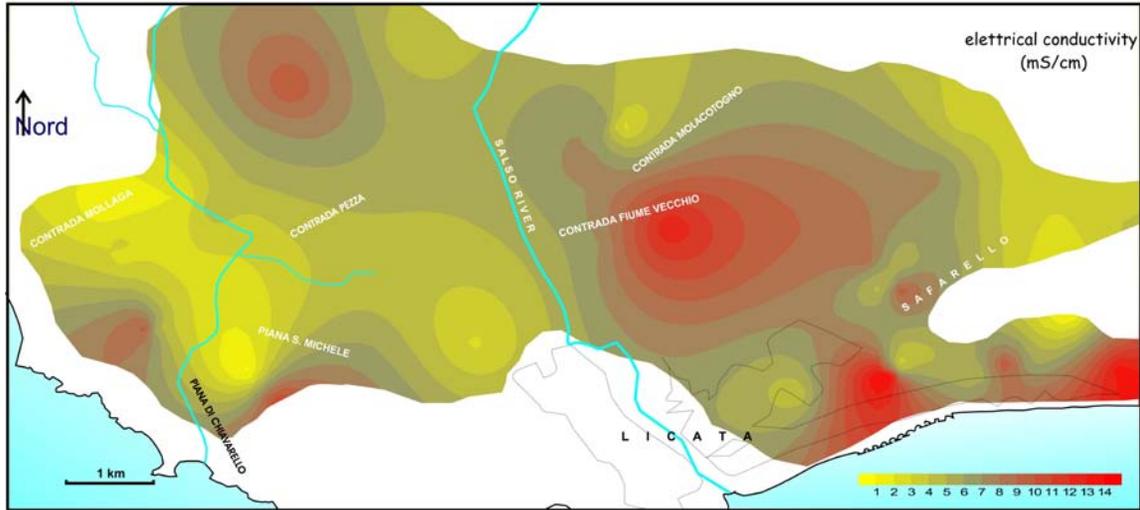


Figure 2: Space distribution of the electrical conductivity (mS/cm at 20°C; for the location of the monitored wells see Fig. 1).

The index of the sodium absorption ratio (SAR) shows changes between 2 and 15 with a mean value equal to 6.2. In about 50% of the samples, this index has values between 8 and 12 (Fig. 3), therefore emphasizing the occurrence of C3-S1 and C4-S1 water categories in the north and east of the investigated area, respectively. In contrast, in the central sector the occurrence of C4-S2, C4-S3 and C4-S4 water categories indicate an underground resource not suitable for irrigation purposes.

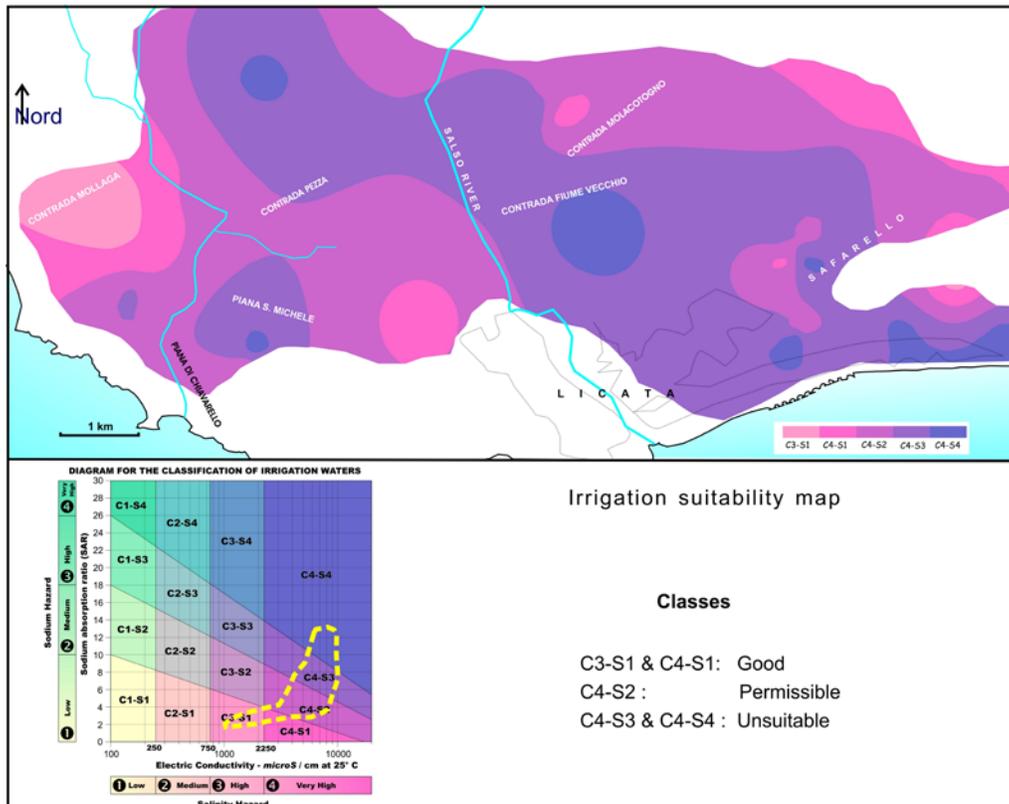


Figure 3: Irrigation suitability map and relative diagram.

HISTORICAL DATA. Data collected from previous studies shows that salinity is not a recent issue. The analysis of old data (1970) about all wells and springs monitored by CMP showed that the average conductivity was higher than 4.5 mS/cm with a minimum of 1.0 and a maximum of 20. We analysed the old wells taking into account all information available about position, quote, diameter and depth with the aim to select a homogeneous group which could be used to produce conductivity maps. The aim was to compare information available at that time with our surveys ((Rapti-Caputo, 2005).

CONCLUSION Main results show that salinity was a relevant issue also in the 70s and that farmers deal with low water quality from a long time. Over time they selected a mix of strategies that could be used to mitigate salinity and to adapt to low water quality. Along the Licata Plain, according to soil and water characteristics, we could observe differences on cultivated crops, greenhouse typology and rotations. Basically all farmers collect and store water during the rainy season by little ponds. During the irrigation period they mix pond good quality waters with wells low quality water according to specific crop salinity tolerance. Moreover they adapt by choosing crops and cultivars that are more tolerant as tomato or cucumber. Furthermore in areas where salinity is very high they alternate, year by year, rainfed crops, as wheat and artichoke, with irrigated crops under temporary tunnels. So they can keep an equilibrium between salt leaching and salt accumulation processes and avoid to stop cultivation. Those and other tricks are the day by day options Licata farmers are using to manage low water quality and continue agricultural activities. Future changes in water collection and storage systems,

improvement of irrigation methods, evolution of desalination technology and availability of new tolerant cultivars could help farmers to deal with climate change scenarios and adapt to the projected “increasing precipitation variability and decrease by 10-30% over some dry regions at mid-latitudes” (AA.VV., 2007).

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