Groundwater as main resources of a wide semiarid region - the case of Apulian region (Southern Italy)

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Aquifer Vulnerability and Risk
2nd International Workshop

4th NATIONAL CONGRESS ON THE PROTECTION AND MANAGEMENT OF GROUNDWATER

21 - 22 - 23 September 2005
Reggia di Colorno, Parma

PROCEEDINGS

ISBN 88 – 901342 – 2 - 4

GROUNDWATER AS MAIN RESOURCES OF A WIDE SEMIARID REGION

THE CASE OF APULIAN REGION (SOUTHERN ITALY)

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Riassunto

La Regione Puglia è caratterizzata da una scarsità di risorse idriche superficiali a causa della prevalente natura carsica del territorio. Notevoli risorse idriche sotterranee sono situate negli acquiferi carsici costieri. Le acque sotterranee utilizzate per l'esigenza domestica, l'irrigazione ed il comparto industriale vengono emunte in grande quantità dal sottosuolo e la loro estrazione è aumentata nel corso degli anni; tale aspetto ancora permette lo sviluppo della popolazione locale. Le acque sotterranee sono esposte a due principali tipi di rischi di degradazione: quantitativo e qualitativo. L'analisi delle serie storiche idrologiche ha evidenziato la drammatica diminuzione di disponibilità della risorsa idrica sotterranea e l'effetto negativo in termini di qualità delle stesse.

[Parole chiave: *degradazione acque sotterranee, clima semiarido, serie storiche idrologiche*]

Abstract

The Apulian region is characterized by very low availability of surface water resources due to the its widespread karstic nature. Considerable groundwater resources are located in large carbonate coastal aquifers. Groundwater for domestic, irrigation and industrial use has been withdrawn in large and increasing quantities over the years, it still allows the development of local population. Groundwater is affected by two types of degradation risks: quality and quantity degradation. Starting by the analysis of long hydrological time series, the dramatic decreasing trend of groundwater availability is characterised and the negative effect in terms of groundwater quality is highlighted.

[Key words: *groundwater degradation, semiarid climate, hydrological time series*]

1. INTRODUCTION

Groundwater in Apulia is a very important resource in terms of regional development, given the extreme scarceness of surface water in the region. Indeed, most historians agree that the availability of groundwater close to the surface was the prime factor behind the founding of major local villages in antiquity, particularly far from the coast, as is the case of the entire Murgia area.

Groundwater is often the only available resource for diffuse water-demanding human activities in the area. Salt contamination of the Apulian groundwater, due to effects of seawater intrusion, is a well known and thoroughly investigated phenomenon (Cotecchia 1977). Nowadays, a strong connection between the increase in salt contamination and the lowering of piezometric levels, which can be ascribed to groundwater overdraft and/or a natural decrease in groundwater recharge, has been recognised in coastal aquifers. For this reason a decreasing piezometric trend highlights not only a decrease of groundwater availability but also a risk of quality degradation.

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Four are traditionally considered the main Apulian hydrogeological units (Figure 1) (Regione Puglia 1983). Apart from Apulian Tableland (*Tavoliere* hereinafter), the remaining hydrogeological units share some common features (Polemio 2000). They consist of large and deep carbonate aquifers, the predominant rock material of which is either limestone or limestone-dolomite. Aquifers are affected by karstic and fracturing phenomena, also well below the sea level, whereas intruded seawater underlies fresh groundwater owing to a difference in density. In both the Gargano Promontory (*Gargano*) and the low Murge Plateau (*Murgia*) aquifers are under pressure except on a restricted coastline strip. In the Salentine Peninsula (*Salento*), subsurface water flow under phreatic conditions is prevailing. The Salentine hydrogeological unit is the only unit which is lapped by the sea on both sides. Tavoliere hydrogeological unit consists of a large porous aquifer within a conglomerate sandy-silty succession, less than sixty meters deep with a clayey impermeable bottom.

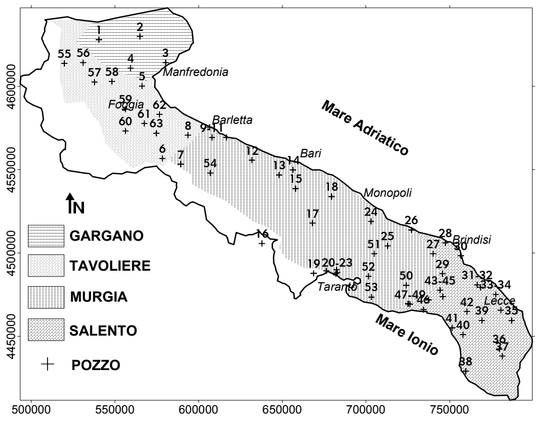

Figure 1. Hydrogeological units (Regione Puglia 1983) and selected wells. 1) Gargano, 2) Tavoliere, 3) Murgia, 4) Salento, 5) well.

2. ANALYSIS OF THE DATA

This study is based upon the analysis of time series data, mainly piezometric data, including however rainfall data and temperature measurements. The monthly hydrological data are derived from a set of piezometric, temperature and rainfall gauges managed by the National Hydrological Service (*Servizio Idrografico e Mareografico Nazionale*) or by the Irrigation Development Agency (Regione Puglia, 1983). Recent data are due to surveys directly realized by IRPI except for recent Tavoliere data (Regione Puglia, 2002; Lopez *et al.,* 2003).

Sixty three wells, or piezometric stations or gauges, were selected (Polemio & Dragone, 2004). Measurement data taken at regular intervals are available for the period running from 1973 to 1978; some data series run up to 2003 (Table 1). The data sets regarding the Tavoliere wells are available for the minimum of 17 years and for the maximum of 55 years, covering a period between 1929 and 1994.

For a better understanding of the behavior of the other significant variables of the hydrological cycle, time series of rainfall and atmospheric temperatures have been considered. The type of rainfall regime was similar throughout the region, with only one single low in July or August and one single peak data between November and February. The same holds true for the temperatures, which were recorded throughout the area as having peaks in July or August and lows between November or February.

The piezometric regime of Murgia groundwater is the same throughout the area; it shows only one peak, typical of February or March, and only one minimum, observed between July and September, the range wideness of each well being extremely inhomogeneous. The piezometric regime in the Salento area is more homogenous; the peaks are observed between November and March and the lows in July or August. In the Tavoliere area, the piezometric regime varies according to the location of the stations, depending upon whether they are located in urban areas or in farmlands. The measurements realized in urban areas show relatively low and irregular piezometric levels, probably because of water aqueduct and sewage system leaks. Conversely, the stations in farmlands show piezometric regimes which are similar and regular, with only one peak, between February and March, and only one low, during the month of September. Not much can be said with regard to the Gargano area, given the low number of stations and the short duration of the series.

The autocorralation analysis has been applied to each piezometric time series and crosscorrelation analysis has been applied to piezometric series with rainfall or temperature time series.

The autocorrelation piezometric coefficients consistently show everywhere a progressively declining trend, starting from values slightly lower than one. Consequently, Apulian groundwater should be subject to a consistent memory effect, i.e., the piezometric values recorded in any given month are strongly dependent upon the values of the previous month, the link being significant, diminishing as the time lag increases, usually not less than a three month time span; this is a characteristic feature of groundwater which is of great importance during droughts or dry spells. The Salento area and the Tavoliere have shown very strong and long-lasting memory effects, which is only further proof of the excellence of these specific hydrogeological units. The links between the piezometric and climatic variables have proved to be cross-correlated to a significant degree for a time lag of 1-4 months. The effects of precipitation are perceptible up to a maximum period of 2-3 months, whereas the best correlation with temperature is felt with a time lag of 4 months. The maximum crosscorrelation observed between piezometric level and temperature is generally greater than in the case of rainfall.

If the temperature variations are significant “to explain” piezometric variations, in some places more than rainfall, it is due to the nature of the climate, which is, overall, semiarid. In this type of climate, the temperature is significant because of two separate phenomena: the first is an absolutely natural one, i.e., evapotranspiration, which ‘regulates’ the availability of rainfall for infiltration; the other phenomenon is a man-made one, and is mainly directly linked to water demand during the summer due to high temperatures; the farms in the region extract more water from aquifers to offset water deficit (to compensate the difference between potential and real evapotranspiration).

The piezometric trend of each piezometric time series is determined as Angular Coefficient (AC) of the straight line regression. The piezometric trend, generally speaking, is widespread downward (AC negative), since there is a widespread tendency, albeit in some cases a very slow one, towards a piezometric drop (Table 1). The lowest trend to the piezometric decrement has been observed in the Salento area, which generally speaking has Angular Coefficient (AC) greater than -0.001 m/month. Minimal CA values or maximum trend to the piezometric decrement are observed in Murgia and Tavoliere areas, with the lowest values equal to -0.02 and -0.03 m/month respectively. In the Murgia and in the other hydrogeological units, the CA approaches zero the closer one gets to the coastal areas, as would be expected.

An anomalous succession of low rainfall years was recognized about from 1980 in the whole Southern Italy; after the huge drought of 1989-1991, in 1996-1997 a rainy period preceded the worst known Apulian drought of 2000-2001, finished in the second half of 2002 (Polemio & Casarano 2004).

Using the latest data of Murgia and Salento, piezometric trend has been calculated up to 2003 and compared with trend up to 1997 (Table 2).

The trend is still negative for each well. The 2003 situation is everywhere worse than in 1997 except for two wells (11% of total available time series), both located near the Ionian coast of Salento. The latest drought has worsened the quantity degradation of groundwater, notwithstanding a year of high rainfall was observed after the end of drought and before the last available measurements. The widespread trend to piezometric lowering increase the risk of salt pollution for seawater intrusion, the effects of which were already dramatic up to 2000 (Polemio 2000).

On the basis of the whole results, the more probable spatial piezometric trend of each hydrogeological unit is ranging from low to high decrease rate (Table 1).

On the basis of the trend analysis data set available the most likely piezometric trend, ending in the second half of 2002 was a very serious one, indeed, over the entire area (Table 1).

The regional trend of actual and net rainfall is also decreasing. It was evaluated the mean actual and net rainfall in the region have respectively dropped by about 10% and 30% in the latest 80 years (Polemio & Casarano, 2004).

The comparison of the results of trend analysis with those of autocorrelation and cross-correlation shows that the steady and generalized piezometric drop is not entirely due to a drop in rainfall but also to the over-exploitation of resources which plays a very clear role in this process.

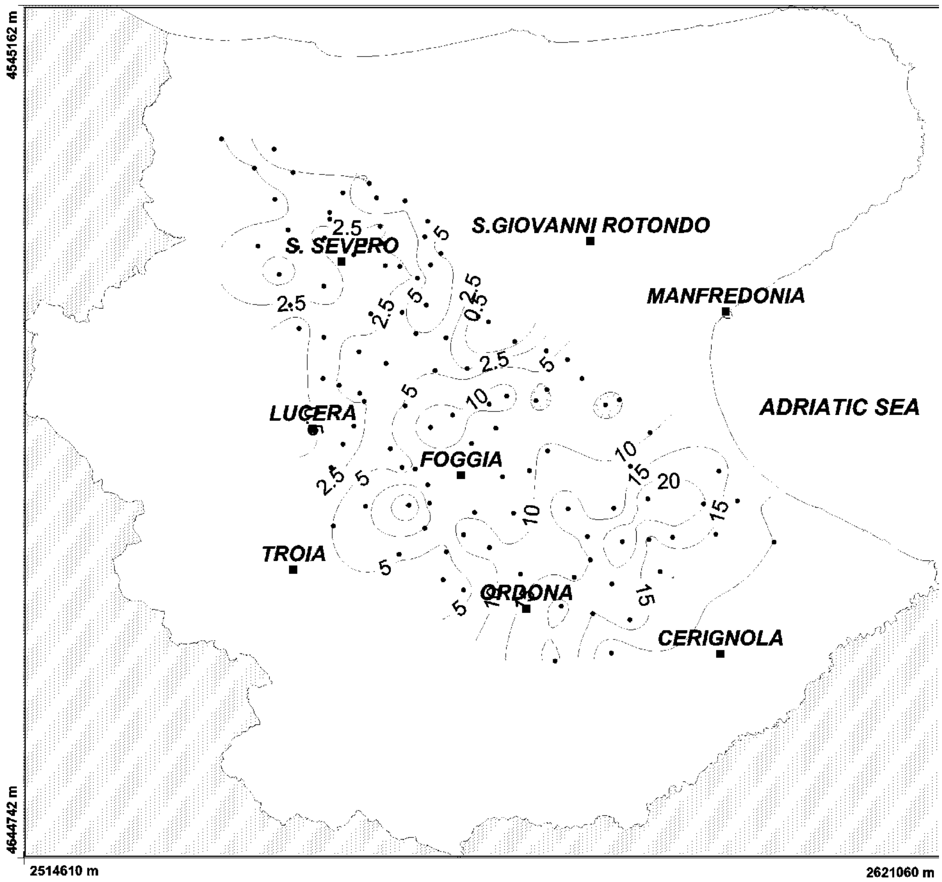

Figure 2. Piezometric decrease of Tavoliere from 1987 to 2001-2002 (m).

Table 1. Piezometric trend and data availability for each hydrogeological unit (CA as m/month).

Hydrogeological unit and number of wells	Data from	Data to	CA as minimum	Trend more probable at 2003
Tavoliere (12)	1929	1994	-0,034	High Decrease
Gargano (4)	1975	1978	-0,0026	Low decrease?
Murgia (30)	1965	2003	-0,020	High decrease
Salento (17)	1965	2003	-0,010	Decrease

Table 2 - Piezometric trend at 2003 for available time series. (SY) Starting year of measurement, (AC) AC as m/month and (VAR-CA) trend percentage variation respect to 1997.

Well	SY	AC	VAR-CA
14	1965	-0,0020	-44
26	1973	-0,0018	-318
27	1973	-0,0089	-202
29	1973	-0,0027	-32
30	1973	-0,0035	-315
31	1978	-0,0026	-178
32	1973	-0,0075	-827
33	1973	-0,0038	-118
34	1973	-0,0100	-785
35	1973	-0,0087	-252
36	1973	-0,0092	-91
38	1973	-0,0025	19
39	1975	-0,0050	-233
41	1973	-0,0007	28
42	1965	-0,0002	-210
43	1968	-0,0030	-161
44	1973	-0,0060	-24
46	1973	-0,0046	-108

3. CONCLUSIONS

The characterization of piezometric trend in the latest 30 years highlights a remarkable lowering and a widespread quantity degradation of groundwater resources in each considered aquifer.

These effects are more relevant in some inner portions of Tavoliere and Murgia. The piezometric lowering in Salento is slower but extremely risky due to the natural low piezometric level above sea level which is a characteristic of this hydrogeological unit. In this case low piezometric lowering can cause high increase of salt pollution risk due to seawater intrusion.

The lasting memory effect shows by each considered hydrogeological unit can reduce and delay but it is not able to remove completely the negative effects of long drought periods.

The whole set of results indicate a progressive impoverishment of high quality Apulian groundwater. The sustainable use of this resources should be started as soon as possible, considering these as a basis to reduce the effect of droughts periods.

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