Quantitative Impact of Climate Variations on Groundwater in Southern Italy

D. Ducci and M. Polemio

1 Introduction

In Italy, groundwater provides drinking water supply, supports agricultural and industrial activities, and contributes towards rivers and lakes. About 88% of the Italian's drinking water supply is from groundwater (Polemio et al. 2013). Groundwater resources are of different entity depending on the morphological and climate variedness. In southern Italy, some region, like the Campania region (Fig. 1), consists widely of carbonate mountains (limestone and dolomite), characterized by a well-developed karst, fed by very high recharge due to high rainfall and low temperature (Barberá and Andreo 2012). On the contrary, the flat Apulian region (Fig. 1), given the extreme scarceness of surface water and the lower recharge, valuable groundwater resources are exploited with increasing rates for domestic, irrigation, and industrial uses (Polemio 2016). The increase is particularly relevant during the numerous recent drought periods, on the basis a paradoxical management criterion.

Data from 1821 to 2003 of 126 rain gauges, 41 temperature gauges, 8 river discharge gauges and 239 wells, located in Southern Italy, have been analysed to characterize the effect of recent climate change on water resources availability, focusing on groundwater resources (Polemio and Casarano 2008).

D. Ducci (✉)
Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II, Naples, Italy
e-mail: daniela@unina.it

M. Polemio
Research Institute for Geo-Hydrological Protection (CNR-IRPI), Via Amendola 122/I, Bari, Italy
e-mail: m.polemio@ba.irpi.cnr.it

M. L. Calvache et al. (eds.), *Groundwater and Global Change in the Western Mediterranean Area*, Environmental Earth Sciences,
https://doi.org/10.1007/978-3-319-69356-9_12

Fig. 1 Location of the study areas; *C* Campania; *P* Apulia

2 Data Analysis

A widespread decreasing trend of annual rainfall is observed over 97% of the southern Italy (Cotecchia et al. 2004; Polemio 2005). The spatial mean of trend ranges from −0.8 mm/year in Apulia (−10.1% of mean value in the study period), −2.44 mm/year (−17.5%) in Campania to −2.9 mm/year in Calabria (−22%). The decrease in rainfall is noticeable after 1980: the droughts of 1988–92 and 1999–2001 appear to be exceptional. On a seasonal basis, the decreasing trend is concentrated in winter; a slight positive trend is observed in summer, the arid season in which the increase is useless as it is transformed in actual evapotranspiration. Although the temperature trend is not everywhere significant and homogeneous, the temperature increase seems to prevail, especially from the eighties (Polemio and Lonigro 2015). Net rainfall, calculated as a function of monthly rainfall and temperature, shows a huge and generalized negative trend.

In Campania, the differences between the period 1951–1980 and the drier period 1981–1999 are evident (Ducci and Tranfaglia 2008). The mean annual rainfall data

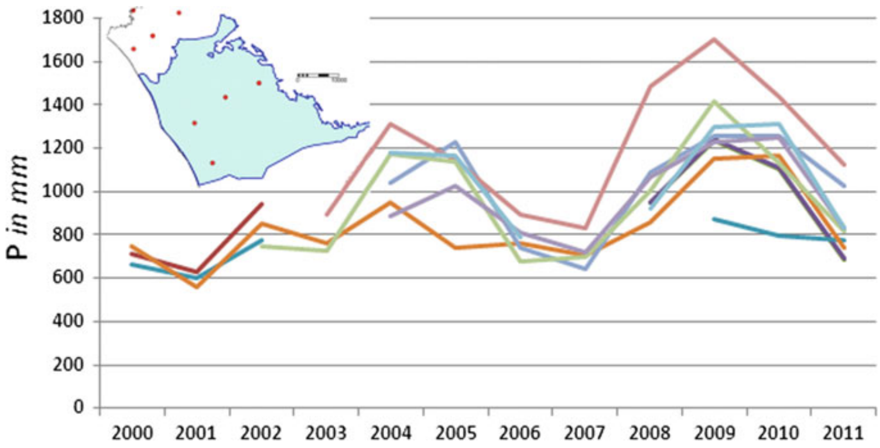

Fig. 2 Rainfall variation in rain gauge stations located in the Volturno-Regi Lagni plain groundwater body (P-VLTR GWB, Campania). On the upper left in light blue the P-VLTR GWB; in red the rain gauge stations and in black the coast of the Campania region (see Fig. 1)

show a decrease of about 15%. After 2001, the trend is increasing, but this trend is highly influenced by the period 2008–2011, very rainy, as shown in Fig. 2.

3 Piezometric Trend

The effects of recent climate variations on groundwater availability are evaluated considering 5 wide hydrogeological structures (HSs for sake of brevity), 4 in Apulia and 1, very large, in Campania. In each Apulian HS the shallow or outcropping aquifer is considered; three are constituted by carbonate rocks, one is porous, and all include coastal aquifers (Fig. 3).

The Apulian Tableland HS, hereinafter called Tavoliere HS, consists of a shallow and large porous aquifer within a conglomerate sandy-silty succession, less than sixty meters deep, with a clayey impermeable bottom (Polemio 2016). It is deep enough to allow seawater intrusion only in the vicinity of the coast. Groundwater is phreatic inland or far from the coast, in the recharge area, whereas it is confined in the remaining part of the aquifer; maximum piezometric levels reach 300 m asl.

Except for the Tavoliere, the Apulian region is characterized by the absence of rivers and the unavailability of surface water resources due to its karstic nature. Considerable groundwater resources are located in large and deep carbonate coastal aquifers as in the case of the Gargano (not considered in this study due to the low data availability), the Murgia and the Salentine Peninsula (Salento) HSs. The Murgia and Salento areas show some common features (Polemio 2016). They consist of large and deep carbonate aquifers, constituted mainly of limestone and

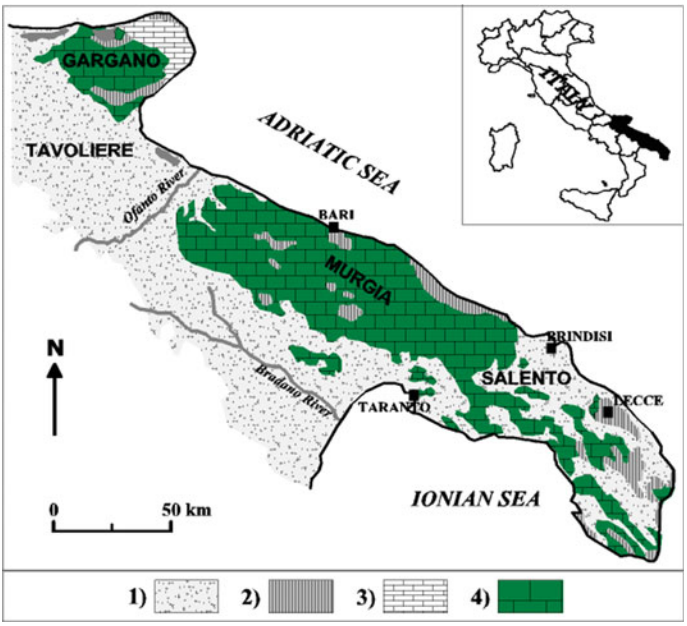

Fig. 3 Apulian schematic geological map and main hydrogeological structures (Polemio 2005, modified): (1) Recent clastic cover (Pliocene-Pleistocene); (2) Bioclastic carbonate rocks (Paleogene) and calcarenites (Miocene); (3) Scarp and basin chert-carbonate rocks (Upper Jurassic-Cretaceous); (4) Carbonate platform rocks (Upper Jurassic-Cretaceous)

dolomite rocks. Carbonate rocks are affected by karstic and fracturing phenomena, which occur also well below sea level, whereas intruded seawater underlies fresh groundwater owing to a difference in density. Confined groundwater is more widespread inland; groundwater is phreatic everywhere along a narrow coastline strip. The Maximum piezometric head is about 200 m asl in the Murgia area and 5 m asl in the Salento (Polemio 2005).

Data from fifty-eight wells or piezometric gauges are available for the three Apulian HSs, the Tavoliere, the Murgia and the Salento (Polemio and Dragone 2004) (Table 1) and for the P-VLTR GWB of Campania. The piezometric data sets regarding the Tavoliere are available for a minimum of 17 years and for a maximum of 55 years, covering a continuous period between 1929 and 1994 (Cotecchia et al. 2004). Continuous data are available from 1973 to 1978 for the Murgia and the Salento. Furthermore, sporadic recent data were collected in Apulia for the periods from 1995–1997 to from 2001–2003. The piezometric data set of Campania shows results coherent with the rest of the study area.

The spatial analysis is utilized to complete the trend analysis of piezometric data when sporadic but high density data are available.

The piezometric trend everywhere is decreasing; the continuous piezometric lowering has transformed many confined wells into phreatic wells; after that, the

Table 1 Piezometric data availability for each hydrogeological structure (HS) and straight line trend (AC, m/year). (1) The number of wells available for occasional years is higher and variable; (2) in the periods 1927–1940 and 1951–1984; (3) Determination not available due the characteristics of data set

HS/GWB	Well number	Data		Trend more probable at 2002 or 2003
		From	To	
Tavoliere	11	1929	2002	High decrease
Murgia	30	1965	2003	High decrease
Salento	17	1965	2003	Decrease
P-VLTR shallow	6	1926	1998	High decrease
P-VLTR main	100/200	1990	2003	High decrease

shallow groundwater of the Tavoliere is completely depleted in places. In terms of straight line trend, the trend everywhere is strongly negative, constituting a severe problem for groundwater discharge by wells (Table 1).

This trend was widespread confirmed by the spatial analysis of sporadic data. An almost affordable study case is due to Salento (Polemio and Casarano 2008), for which sporadic data from thirties up to 2010 are available (Fig. 4). Notwithstanding the spatial effect of the low density of measurement wells in some portion of the Salento, the worsening in the whole HS is self-evident.

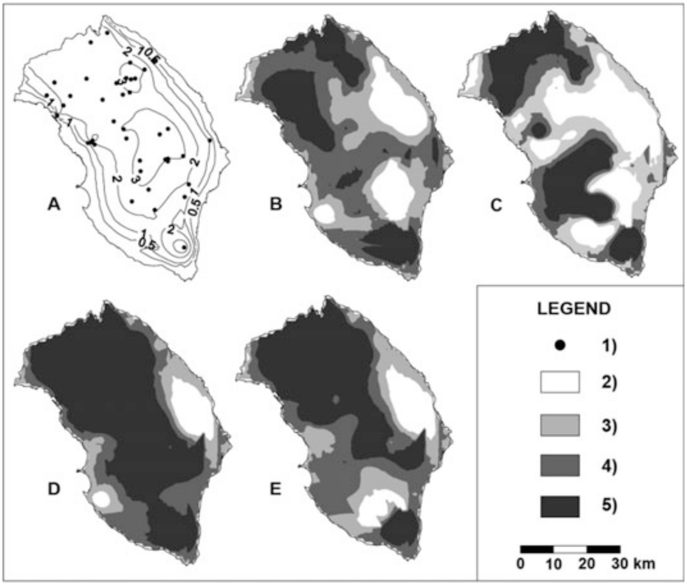

Fig. 4 Historical piezometric variations of Salento HS (**a**), Historic piezometric surface used as reference (1930, m asl); calculated Piezometric Variation (PV, m, positive values are increases) of 1976 (**b**), 1996 (**c**), 2003 (**d**), and 2010 (**e**). Legend: (1) wells; (2) PV > 0.5 m; (3) 0 m < VP < 0.5 m; (4) −0.5 m < VP < −0 m, 5) VP < −0.5 m

In Campania, the alluvial-pyroclastic groundwater body (GWB) of the "Volturno-Regi Lagni" plain (P-VLTR—1034 km^2) includes shallow aquifers, not continuous, constituted by alluvial and pyroclastic deposits, overlying the tuffs (Campanian Ignimbrite). This tuff confines or semi-cofines the main aquifer formed by alluvial, pyroclastic and marine porous sediments underlying the Campanian Ignimbrite (Corniello and Ducci 2014). The piezometric surface indicates a groundwater flow, departing from the neighboring limestone mountains, at east, and directed towards the Tyrrhenian sea, at west (Fig. 5).

At the foot of the carbonate mountains flowed out two high discharge springs (Qmed 1.3 m^3/s), located in the right lower corner in Fig. 5, almost exhausted over the last 20 years.

In P-VLTR groundwater body (Figs. 2 and 5) there are 6 wells of the shallow aquifer monitored since 1926 and until the end of nineties (Ducci and Onorati 1993). In these wells piezometric data make visible the drought period started in 1987 and finished in 1992: the mean lowering has been about 6 m and 2 wells were dried up. For the main aquifer two complete monitoring campaign were done in 1990 and 2003 (Fig. 5). The spatial comparison by GIS shows a mean lowering of 7.4 m, with peaks of 14 m. Afterwards, a campaign done in 2015 indicates almost the same levels of the year 2003 for the main aquifer, due to the constancy of the rainfall, as shown in Fig. 2.

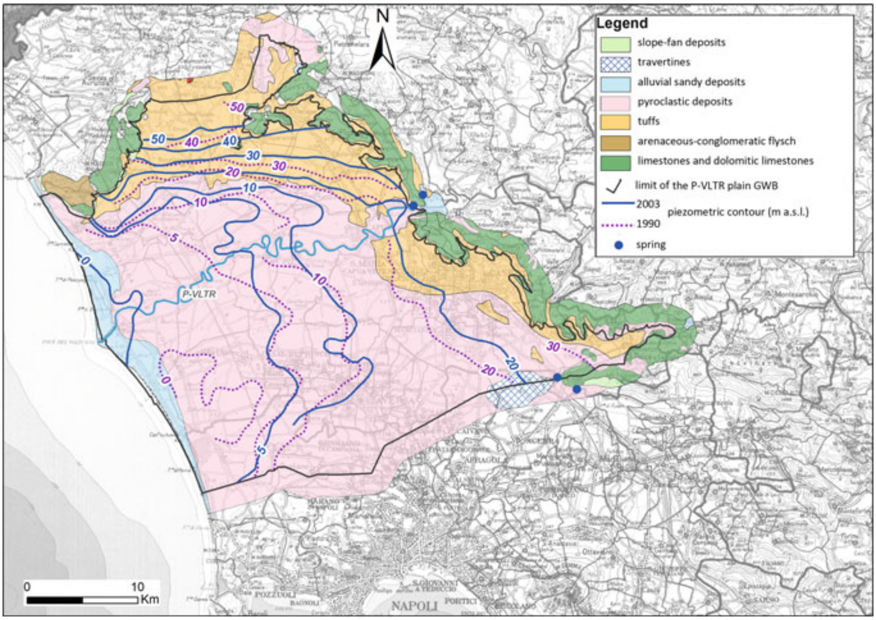

Fig. 5 Hydrogeological map of the P—VLTR GWB (Campania) highlightings the changes in groundwater levels of the main aquifer

4 Conclusion

The study deals with the climate variations recorded during many decades, observed in Southern Italy.

In Apulia the piezometric trend everywhere is decreasing; the continuous piezometric lowering has transformed in some parts the confined aquifer into phreatic and the shallow groundwater is depleted. The spatial mean of piezometric decreases almost 8 m over about 15 years.

In Campania, at the foot of the carbonate mountains some copious springs are almost exhausted over the last 20 years and the observation of piezometric data from 1990 and 2003 shows a mean lowering of more than 7 with peaks of 14 m.

The wide set of groundwater data, concerning piezometric and spring flow yield time series, shows the relevance of the overlapped effect of water demand and climate change, which is summarized by the widespread dramatic lowering of groundwater availability.

Acknowledgments We would like to show our gratitude to IAHS who provided permission to use the Figures/Table from Polemio et al. 2009.

References

Barberá JA, Andreo B (2012) Functioning of a karst aquifer from S Spain under highly variable climate conditions, deduced from hydrochemical records. Env Earth Sci 65(8):2337–2349

Corniello A, Ducci D (2014) Hydrogeochemical characterization of the main aquifer of the "Litorale Domizio-Agro Aversano NIPS" (Campania—southern Italy). J Geochem Explor 137:1–10

Cotecchia V, Casarano D, Polemio M (2004) Characterization of rainfall trend and drought periods in Southern Italy from 1821 to 2001. In Proceedings 1st italian-russian workshop "new trends in hydrology", Rende (CS), 2004, Edibios, pp. 139–150

Ducci D, Onorati G (1993) Analisi di una lunga serie di dati piezometrici in Piana Campana. Atti 2 Convegno Nazionale di Geoidrologia—Quaderni di Tecniche di Protezione Ambientale—Protezione delle acque sotterranee, Pitagora, Bologna, vol 49, pp 339–357

Ducci D, Tranfaglia G (2008) The Effect of Climate Change on the Hydrogeological Resources in Campania Region (Italy). In Dragoni W (ed) Groundwater and climatic changes. Geological Society, London, Special Publications, 288, pp 25–38. doi:10.1144/SP288.3

Polemio M (2005) Seawater intrusion and groundwater quality in the Southern Italy region of Apulia: a multi-methodological approach to the protection. In: Maraga F, Arattano M (eds) Progress in surface and subsurface water studies at the plot and small basin scale, vol 77. Paris. UNESCO, IHP, pp 171–178

Polemio M (2016) Monitoring and management of Karstic coastal groundwater in a changing environment (Southern Italy): a review of a regional experience. Water 8(4):1–16

Polemio M, Casarano D (2008) Climate change, drought and groundwater availability in southern Italy. Geol Soc Spec Pub 288:39–51

Polemio M, Dragone V (2004) La siccità e la disponibilità di acque sotterranee in Puglia. Atti dei Convegni Lincei 204:187–193

Polemio M, Dragone V, Limoni PP (2009) The piezometric stress in the coastal aquifers of a karstic region. In: Taniguchi, M., Dausman, A., Howard, K., Polemio, M., and Lakshmanan, E., (eds) Sustainability of groundwater in highly stressed aquifers, Vol 329, IAHS, Apulia, Italy, p 138–144
Polemio M, Dragone V, Romanazzi A (2013) La risorsa idrica. Sfruttamento, depauperamento dei serbatoi sotterranei e utilizzo razionale nel caso della Calabria, In: Dramis, F., and Mottana, A., eds., L'acqua in Calabria: risorsa o problema? Roma, Aracne, p 2–29
Polemio M, Lonigro T (2015) Trends in climate, short-duration rainfall, and damaging hydrogeological events (Apulia, Southern Italy). Nat Hazards 75(1):515–540