Characterization of the Mount Soprano-Vesole-Chianello karst aquifer in southern Italy for modeling groundwater recharge and flow

Key findings

- The integration of updated stratigraphic/structural data and their spatial modeling is key for the reconstruction of a 3D hydrogeological model of the karst aquifer.
- Monitoring discharge of the Capodifiume spring shows a constant groundwater regime.
- The spatial distribution of the soil thickness can be estimated by field measurements and correlation with land use types.
- The influence of soil covering on groundwater recharge can be assessed by the characterization of soil's hydrological properties and field monitoring of water content.

Motivation

In southern Italy, 40 karst aquifers with autonomous groundwater circulation have been identified (De Vita et al., 2018). These aquifers are formed by Mesozoic carbonate series whose involvement in the Apennine compressive tectonic phases (Miocene) has led to their hydrogeological confinement with adjoining low-permeability basins and flysch series. This geo-structural feature controls groundwater circulation, which is mainly oriented towards large basal springs (with a mean yearly discharge of up to 3.8 m³/s), favoring their tapping for feeding principal aqueduct systems. Notwithstanding the strategic relevance of karst aquifers for the social and economic development of southern Italy, current knowledge of groundwater recharge and storage/flow has not yet advanced far enough to support modeling and management under the effects of climate variability. A deeper characterization of the aquifers and understanding of processes leading to groundwater recharge and storage/flow are considered key aspects for setting up empirical or numerical models aimed at forecasting possible scenarios of groundwater availability.

Methodology

The strategy described here was applied to the Mount Soprano-Vesole-Chianello karst aquifer in Italy's southern Campania region. To advance the characterization of the karst aquifer, aspects which have been studied and the applied methods/tools are: i) reconstruction of a 3D hydrogeological model of the karst aquifer through the integration of new stratigraphic/structural data and their spatial modeling with GemPy

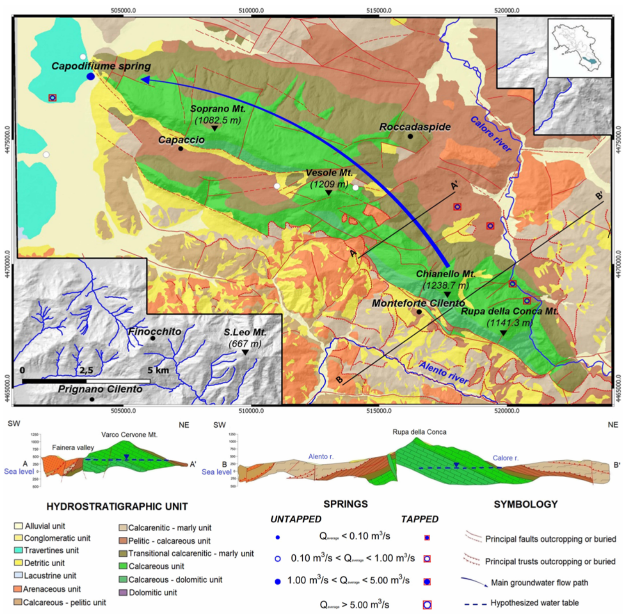

Figure 1: Hydrogeological map and cross-sections of the Mount Soprano-Vesole-Chianello karst aquifer

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GemPy

GemPy (De La Varga et al., 2019) is an open-source tool for generating 3D structural geological models in Python, which allows to create complex combinations of stratigraphical and structural features such as folds, faults, and unconformities. It was designed to consider probabilistic modeling by managing uncertainties of geological data.

(De La Varga et al., 2019) and the algorithm of the Stochastic Karst Generator (SKS; Borghi et al., 2012); ii) assessment of the groundwater regime by coupled measurements of spring discharge and monitoring the nearby water table; iii) assessment of the spatial distribution of the thickness of soils covering the carbonate bedrock, based on field measurements and spatial modeling, carried out by a supervised classification of Google Earth images; iv) assessment of the hydrological influence of soil covering on groundwater recharge by characterization of Soil Water Retention Curves and field monitoring of water content.

Results

We reconstructed the physical model of the karst aquifer by a series of activities and results: creating new hydrostratigraphic maps (CARG Project) (Figure 1), spatial modeling of their geometry with GemPy, and stochastic modeling of karst conduits with the SKS algorithm. In addition, by monitoring spring discharge, we identified a constant groundwater regime, with discharge values varying from 2.79 to 3.45 m^3/s (2019-2020) (Figure 2). Moreover, we tested a procedure for the spatial modeling of soil covering the carbonate bedrock. The method was based on the measurement of soil thickness (by driving a steel rod down to the bedrock) and assessing its variability in different land use conditions. We estimated lower values of soil thickness in denudated areas (median around 0.12 m) and greater values in wooded areas (median around 0.50 m) (Figure 3a). Afterwards, we carried out the spatial modeling of soil thickness by its correlation with land use types across the whole aquifer. Finally, by the laboratory characterization of Soil Water Retention Curves (Figure 3b), we assessed and mapped the available water depth, which we used for estimating the water budget and groundwater recharge.

Application

The approaches applied in this subproject advance the characterization of karst aquifers in southern Italy and can be used for reconstructing empirical or numerical models, simulating scenarios of climate change, and setting up a resilient management of groundwater resources. The most important lesson learnt is the not negligible role of soil coverings in groundwater recharge. This aspect, which concerns the field study of the so-called Earth's Critical Zone, is usually not analyzed in detail in hydrogeological studies. The principal limitations of this study are related to the lack of long-term time series of spring discharge and measurements of the karst aquifer's water table, which are prevented by the aquifer's high depth.

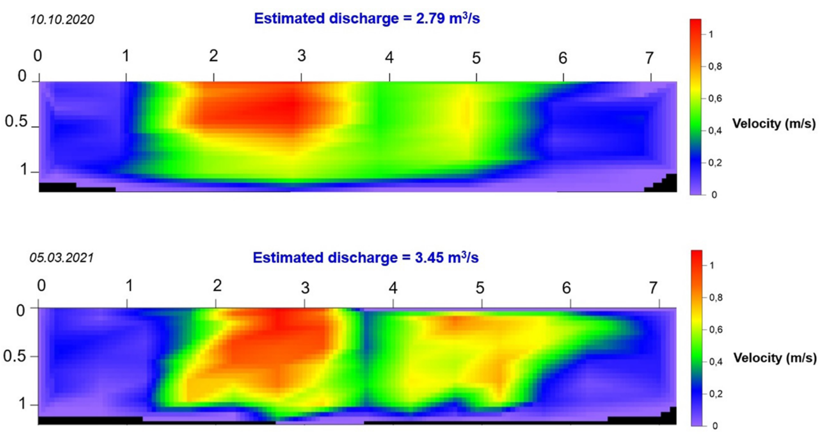
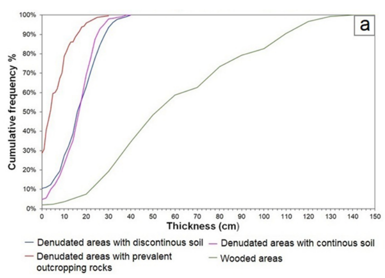


Figure 2: Flow velocity maps of two extreme discharge values, measured at the channel downstream the Capodifiume spring

Frequency of soil thicknesss



Soil Water Retention Curves

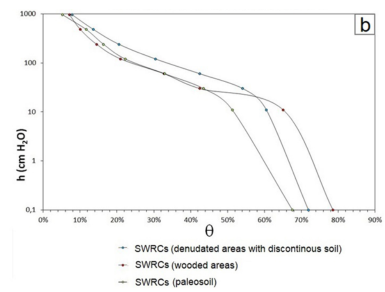


Figure 3: a) Frequency of soil thickness and b) Soil Water Retention Curves (SWRCs) in different land use types

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