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Vulnerability assessment of karst aquifers under Mediterranean climates

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Carbonate aquifers supply freshwater to about one-quarter of the world population. Their particular hydrodynamic behavior is a valuable property for groundwater extraction, on the downside, carbonate aquifers are vulnerable to overexploitation and pollution. Fractures, fissures, and typical karst features, such as conduits and vertical shafts, create high regional hydraulic conductivities and fast response times to hydrological events, complicating numerical modeling and management of carbonate aquifers in general. Here, we develop a new method to assess the vulnerability of Mediterranean karst aquifers concerning shifts in climate. Particularly, we are interested in 1) which types of karst aquifers are most vulnerable and 2) which factors have the highest impact on their climate vulnerability.

Our approach is based on a vulnerability index, which is calculated from selected indicators of aquifer behavior that refer to land cover, soil types, wetlands, water demand, current change of groundwater levels, total water volume, run-off, water exploitation index, and freshwater production. First, we calculate vulnerability indices for all karst aquifers – as identified in the World Karst Aquifer Map by the World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP WOKAM v1 database; Chen et al., 2017) – that have at least 90% of their area belonging to Mediterranean climate zones (Csa, Csb, and Csc). Then, we group these aquifers into classes representing different physical behaviors and morphological characteristics (e.g. highly karstified systems in mountainous areas).

An evident approach to investigate various aquifers in terms of their vulnerability is the development of numerical flow models. The advantage is that the boundary conditions, such as average annual precipitation and temperature, can be modified to consider different climatic scenarios. Thus, the resulting impact on water volumes and the aquifer response can be simulated accordingly. However, this approach requires large amounts of data and high computational costs.

Our method uses selected sets of karst aquifers representing different variations of Mediterranean climates (i.e. that are similar in terms of temperature and precipitation patterns). These aquifers are compared by analyzing and plotting regional climate variables versus

previously calculated vulnerability indices. By identifying and comparing climate-vulnerability relations within aquifer sets, we can mimic changes in climate for individual aquifers in line with the RCP4.5 scenario until 2050. This approach, which relies on present-day observed conditions, allows us to predict the effect of a changing climate on the vulnerability of an aquifer class without the need to develop a complex numerical model.

The results are visualized in the form of vulnerability maps and used to derive recommendations for the sustainable management of karst aquifers under Mediterranean climates.