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Inferring the regional karstification degree from a multi-method approach in Pains region, MG, Brazil

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Karst systems are composed of complex underground structures of pores, fissures, fractures, and conduits of diverse sizes and forms. An intricated network of caves and drainage systems, developed by karstification of rocks with a high degree of dissolution, is the most distinctive feature of these singular systems. The dissolution process is responsible for the widening of rock fissures and fractures, enabling the permeability and, consequently, the karst network's evolution — the more interconnected and more developed, the greater the system's karstification degree. Factors such as geological and geomorphological context, rock chemical and stratigraphic composition, rock-water interaction, underground flow dynamics, and climatic conditions are determinants to assess the degree of karstification.

The study area is located in the são Miguel river basin, in the southwest of the state of Minas Gerais, Brazil, a typical karst relief marked by the presence of sinkholes, dolines, karst springs, and caves. This region comprises carbonate rocks from the Sete Lagoas Formation (Bambuí Group), where some karstic systems were developed. From a hydrogeological point of view, this geological formation corresponds to a complex karst aquifer.

This work aimed to determine the degree of karstification of three karst systems (east, west, and south) in the São Miguel river basin from a geomorphological and hydrological perspective by the association of different methods widely applied in karst regions: (i) karst spring hydrograph analysis, (ii) dye tracer tests, and (iii) GIS model to identify the potential of karstification.

Methodologically, the hydrographs and particularly the recession curves of three karst springs (S1, S2, and S3) were analyzed to identify the internal characteristics of the systems. These springs constitute the karst systems' exutories and were monitored from November 2019 to November 2020. Dye tracers tests with Rhodamine WT and Uranina were applied during the dry and rainy seasons to calculate the quantitative parameters of the underground flow (velocity and dispersivity). Finally, a field mapping of regional and local structural geology, geomorphology, and speleology was performed in order to identify and limit the areas with higher karstification potential. These regional features served as parameters for the parametric analysis through geoprocessing in GIS software.

The results of spring hydrograph analysis, particularly the first stages of the recession curve, revealed that the east and south systems have a high degree of karstification, with concentrated recharge, circulation in a turbulent regime, and rapid drainage through the unsaturated zone.

From the dye tracers technique, it was possible to map the most probable routes of the three karst systems and demonstrate that the south system presented the highest velocity values (fast flow), and the east system presented the highest seasonal variations of flow parameters. The western system presented the lowest velocities, greater dispersivity, and lower seasonal variation than the other karst system. The investigation of the karstification potentiality showed that the east system was the most karstified, proved by the presence of dolines, cave entrances, and the absence of surface drainage.

This study confirms that the association of different methodological approaches is quite valuable for determining the degree of karstification of karst systems.