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Vulnerability mapping in a thermal zone, Portugal - a study based on DRASTIC index and GIS

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Abstract

The Thermal zone of Nisa is located in northeast Portugal and plays an important economical role for the region. Included in the Hesperic massif, Central Iberian Zone, it shows an intense fracturing due to the compressive tectonic movements during the Varisco Hercynian orogeny, Paleozoic. Geologically it is predominantly composed of fractured granites, with fractures often filled with clay materials. The occurrence and movement of groundwater is mainly controlled by these fractures and other discontinuities. The study catchment is characterized by low immediate yields (2 l/s) and located in a region where agriculture is the main economic activity.

Intrinsic vulnerability assessment is a key decision-making tool together with recommended monitoring and management measures for this region. The main aim of this study was to establish a management plan for regional vulnerability assessment, such as to ensure the sustainability of the long-term use of the thermal groundwater resource. The vulnerability index Drastic was computed and mapped using GIS (ArcGIS software) methodologies.

The obtained Drastic outputs suggest the existence of different regional units with vulnerability ranging from low to high (DRASTIC = 67-153). However, low values are the most common (DRASTIC= 67-119), while moderate to high vulnerabilities (DRASTIC= 119-153) are confined to small patches scattered across the study area. Future risk monitoring is a crucial tool for the assessment and management of thermal resources.

Keywords: Nisa, Aquifer system, DRASTIC index, Vulnerability mapping, GIS.

Problem description and its approach

The thermal waters of Nisa have an important role on the economic activity of local communities and also on human's welfare, as its waters has good therapeutic properties in particular for the treatment of skin diseases.

As part of the Hesperic massif, Central Iberian Zone, it shows an intense fracturing due to the compressive tectonic movements during the Varisco Hercynian orogeny, Paleozoic. Geologically it is predominantly composed of fractured granites. Fractures are often filled with clay materials, and along with other discontinuities, they control the occurrence and movement of groundwater. The study catchment is characterized by low immediate yields (2 l/s) and located in a region where agriculture is the main economic activity (Figure 1).

The thermal activities dates back to the eighteenth century as indicated by the construction of the first buildings in 1792 [3]. However, activities have not been steady over the years with periods of active development alternating with times of decline and abandonment.

The first contract, for the exploitation of the natural mineral water for a period of 50 years, was signed in 1992. That same year, the first protection perimeters for the thermal catchment were created through the delineation of three zones of influence (immediate, intermediate and broad protection areas). Hydrogeological studies were then performed to identify potential vulnerabilities of the aquifer and prevent future contamination. Because water is a scarce resource, it is imperative to develop more accurate models in order to implement more effective planning and further protection.

The mapping of vulnerability is a key step in the modeling of the intrinsic potential to contamination (IPC) of the hydrogeological system [2], because it indicates the ability of the aquifer's superficial layers to attenuate the impact of pollutants [4].

The DRASTIC [1] index is computed as the weighted sum of seven attributes (hydrogeologic indicators):

1- (D) Depth to water (Figure 3);
2- (R) Recharge;
3- (A) Aquifer media;
4- (S) Soil media (Figure 4);
5- (T) Topography (Figure 5);
6- (I) Impact of the vadose zone;
7- (C) Conductivity.

Each indicator is divided into representative classes (i) ranging from 1 (low vulnerability) to 10 (highest vulnerability rate) and assigned a weight (p) between 1 and 5 in the computation of the index [1]. The final DRASTIC index (Figure 6) is obtained using the following equation:

DRASTIC= Di x Dp + Ri x Rp +Ai x Ap + Si x Sp + Ti x Tp + Ii x Ip + Ci x Cp

The spatial distribution of each attribute and the DRASTIC index was mapped using GIS techniques. Spatial indicators were interpolated from 198 wells (Figure 2) using the Inverse Distance Weighted (IDW) algorithm. Future research will explore the impact of using kriging as interpolation technique. ArcMap 9.3.1 (ESRI) was used.

Results indicate the existence of different regional units with intrinsic vulnerabilities ranging from low to high (DRASTIC = 67-153). However, low values are the most frequent (DRASTIC=67-119), while moderate to high vulnerabilities (DRASTIC=119-153) are observed only in small patches scattered across the study area. Future risk monitoring is a crucial tool for the assessment and future management of the thermal waters.

Intrinsic vulnerability assessment of groundwater is essential in decision-making processes, aimed at planning and resource conservation in the region. The goal of this study is to assess the vulnerability of groundwater in the surroundings of Nisa Fadagosa capture and identify possible sources of contamination, using the index and subsequent Drastic vulnerability mapping, using the ArcGIS. software.

The computation of indirect influence of external factors, such as runoff variation and water infiltration over time, are of major importance to evaluate intrinsic and extrinsic vulnerabilities in future work.

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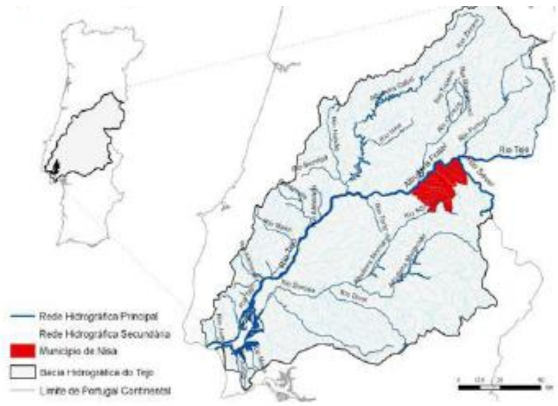
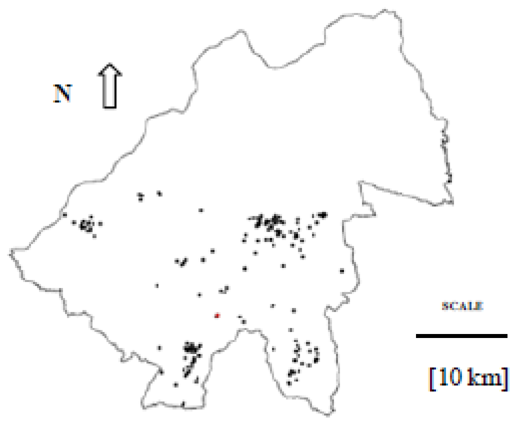
Figure 1: Study area



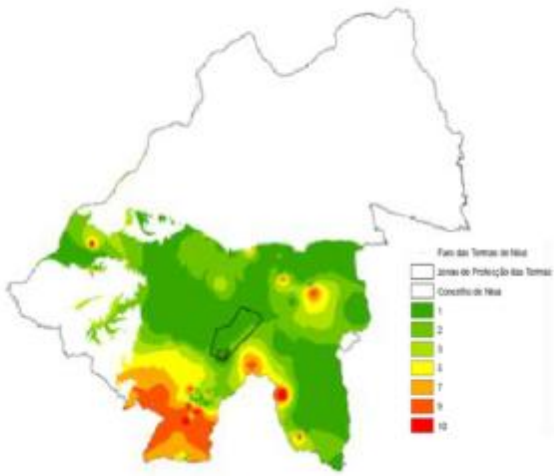
Source: LNEG, Lisbon, Portugal, 2010.

Figure 2: Location of the 198 measured Wells

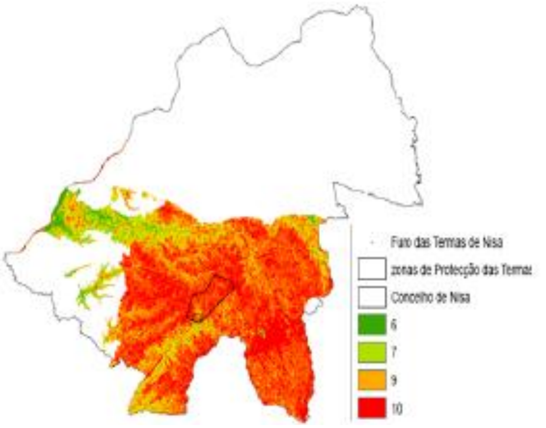


Source: Miguel M.Pais, IPCB, Portugal, 2011

Figure 3: Depth

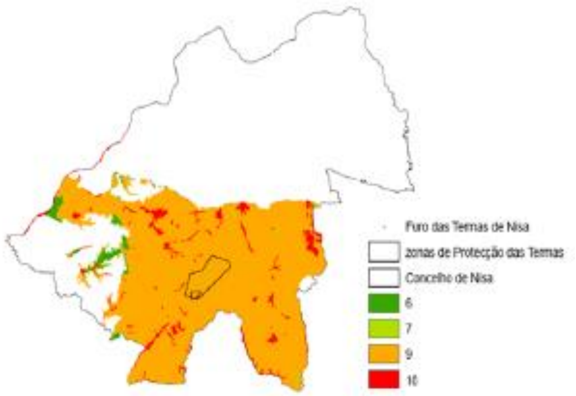


Source: Miguel M.Pais, IPCB, Portugal, 2011.
Figure 4: Soil media



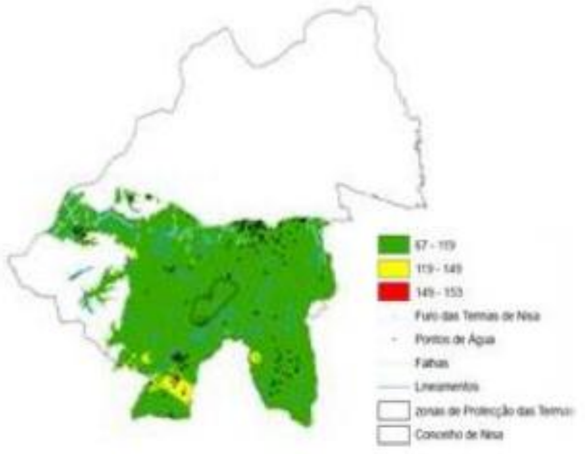
Source: Miguel M.Pais, IPCB, Portugal, 2011.

Figure 5: Topography



Source: Miguel M.Pais, IPCB, Portugal, 2011.

Figure 6: DRASTIC mapping



Source: Miguel M.Pais, IPCB, Portugal, 2011

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