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Using a binary logistic regression method and GIS for evaluating and mapping the groundwater spring potential in the Sultan Mountains (Aksehir, Turkey)

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SUMMARY

The purpose of this study is to produce a groundwater spring potential map of the Sultan Mountains in central Turkey, based on a logistic regression method within a Geographic Information System (GIS) environment. Using field surveys, the locations of the springs (440 springs) were determined in the study area. In this study, 17 spring-related factors were used in the analysis: geology, relative permeability, land use/land cover, precipitation, elevation, slope, aspect, total curvature, plan curvature, profile curvature, wetness index, stream power index, sediment transport capacity index, distance to drainage, distance to fault, drainage density, and fault density map. The coefficients of the predictor variables were estimated using binary logistic regression analysis and were used to calculate the groundwater spring potential for the entire study area. The accuracy of the final spring potential map was evaluated based on the observed springs. The accuracy of the model was evaluated by calculating the relative operating characteristics. The area value of the relative operating characteristic curve model was found to be 0.82. These results indicate that the model is a good estimator of the spring potential in the study area. The spring potential map shows that the areas of very low, low, moderate and high groundwater spring potential classes are 105.586 km^2 (28.99%), 74.271 km^2 (19.906%), 101.203 km^2 (27.14%), and 90.05 km^2 (24.671%), respectively. The interpretations of the potential map showed that stream power index, relative permeability of lithologies, geology, elevation, aspect, wetness index, plan curvature, and drainage density play major roles in spring occurrence and distribution in the Sultan Mountains. The logistic regression approach has not yet been used to delineate groundwater potential zones. In this study, the logistic regression method was used to locate potential zones for groundwater springs in the Sultan Mountains. The evolved model was found to be in strong agreement with the available groundwater spring test data. Hence, this method can be used routinely in groundwater exploration under favourable conditions.

1. Introduction

The occurrence and movement of groundwater are controlled mainly by the porosity and permeability of the surface and the underlying lithology (Shahid et al., 2000). In general, the occurrence and movement of groundwater, especially in fractured bedrock aquifers, in a given area is governed by many factors, such as the topography, lithology, geological structures, fracture density, aperture and connectivity, secondary porosity, groundwater table distribution, groundwater recharge, slope, drainage pattern, landforms, land cover, climatic conditions, and the interrelationships among these factors (Greenbaum, 1992: Mukherjee, 1996: Oh et al., 2011). The conventional methods used to prepare groundwater potential zones are mainly based on ground surveys (Ganapuram et al., 2009). In recent years, a Geographic Information System (GIS) has been an important development in the field of information and it is used for spatial data management and manipulation. With the advent of remote sensing and GIS technologies, the mapping of groundwater potential zones within each geological unit has become an easy procedure (Jain, 1998; Singh and Prakash, 2003). There have been many studies performed on groundwater evaluation using GIS and Remote Sensing (Chowdhury et al., 2009; Ganapuram et al., 2009: Jaiswal et al., 2003; Jha et al., 2007; Nobre et al., 2007; Prasad et al., 2008; Saha et al., 2010; Saraf et al., 2004; Shahid et al., 2000; Sener et al., 2005; Solomon and Quiel, 2006; Tweed et al., 2007). Oh et al. (2011) has summarised many groundwater evaluation studies. However, many researchers have evaluated groundwater potential zones (Chi and Lee, 1994; Dar et al., 2010; Ghayoumian et al., 2007; Gogu et al., 2001; Gaur et al., 2011; Krishnamurthy and Srinivas, 1995; Murthy, 2000; Rao, 2006; Sener et al., 2005; Sreedevi et al., 2005; Srininivasan and Subramanian, 1999), and many of these studies applied probabilistic models (Arthur et al., 2007; Chenini et al., 2010; Chenini and

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Ben Mammou, 2010; Chowdhury et al., 2009; Corsini et al., 2009; Ghayoumian et al., 2007; Gupta and Srivastava, 2010; Masetti et al., 2007; Murthy and Mamo, 2009; Oh et al., 2011; Zhang and Cheng, 2002; and Srivastava and Bhattacharya, 2006). Numerous studies have described the application of the logistic regression method for landslide susceptibility and hazard mapping (Dai et al., 2001; Lee, 2005; Lee and Choi, 2003; Lee and Dan, 2005; Lee and Min, 2001; Lee and Sambath, 2006; Lulseged and Hiromitsu, 2004; Nefeslioglu et al., 2008; Oh et al., 2009, 2011; Pradhan and Lee, 2010; Pradhan et al., 2010; Suzen and Doyuran, 2004; Yesilnacar and Topal, 2005). In addition, the logistic regression method has been applied to examine ground subsidence hazard mapping (Kim et al., 2006; Lee et al., 2010) and regional or local assessements of nitrate and pesticide contamination (Nolan et al., 2002; Teso et al., 1996; Tesoriero and Voss, 1997). Although the logistic regression method has been applied to examine landslide susceptibility mapping, ground subsidence hazard mapping, and regional or local assessments of nitrate and pesticide contamination; this approach has not yet been used for mapping of potential groundwater springs. This paper presents the result of a comprehensive study on the location of potential groundwater spring analyses and mapping groundwater spring potentials conducted in part of the Sultan Mountains of Turkey using the logistic regression method and GIS. The mapping of potential groundwater springs and their effects on the occurrence of groundwater spring-related factors, such as geological and hydrological (lithology, lineament, drainage systems, and relative permeability of lithologies), topographical (slope angle, slope aspect, elevation, and curvature), and landuse/land cover (distance from drainage pattern and settlement areas) were evaluated using GIS and field observations. There have not been studies conducted on the mapping of potential groundwater spring evaluations using logistic regression methods. The preparation of the groundwater spring potential map (GSPM) will be useful for successful urban planning. Assessing the GSPM with limited background information and data is a constant challenge for engineers, geologists, planners, landowners, developers, insurance companies, and government entities. However, groundwater spring potential maps provide useful information to planners in selecting suitable areas to implement development schemes.

2. The study area

The study area is located west of Akşehir in central Turkey. It covers an area of approximately 373.112 km^2. The study area extends from latitude 4229,000 to 4258,000 m north and from longitude 349,000 to 369,000 m east. Fig. 1 shows the location map of the study area. The region exhibits distinctly mountainous topographical features. The geological, geomorphological, and hydrogeological environment of the study area is favourable to spring activity.

3. Materials and methods

There are four main steps involved in GSPM analysis: (1) data collection and construction of a spatial database for the relevant

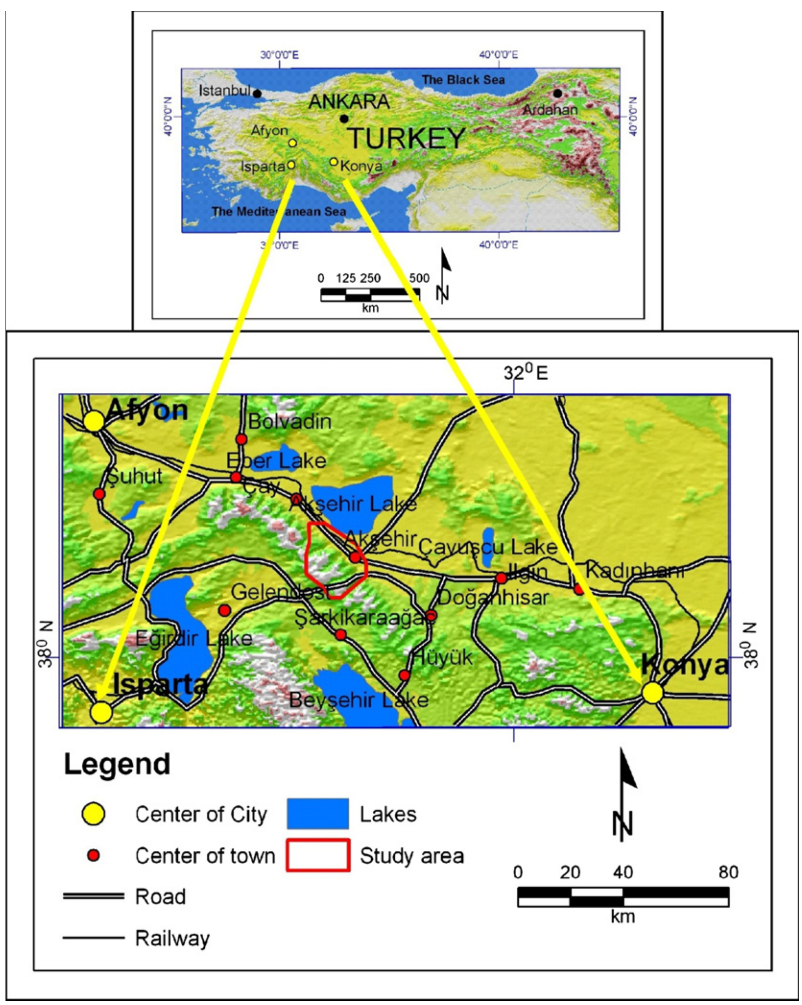

Fig. 1. Location map of the study area.