Chapter 45
Multi-Criteria Decision Analysis for Identifying a Suitable Location for Groundwater Pumping Wells

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ABSTRACT

The paper presents the methodology for the combined use of GIS-based multi-criteria analysis and simulation-optimisation modelling for management of the groundwater resources of the Dore river basin in France. The study identifies the suitable location and maximum discharge for the new groundwater pumping wells. The multi-criteria analysis (MCA), with the help of GIS-based geospatial analysis, was performed to identify those areas suitable for pumping wells by considering different criteria, such as hydraulic conductivity, land use, river aquifer exchange, depth to water, and geomorphology. Different criteria were selected with the help of regional experts and stakeholders. For the study area, the groundwater flow model was developed. Further, new pumping wells in the suitable zones, those identified by MCA, were considered and a simulation-optimisation technique was used to identify the maximum discharge from those wells. Finally, the results obtained from both the methods were to finalise the potential zone. The developed methodology proves to be a more realistic approach to identifying new locations for pumping wells.

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1. INTRODUCTION

The demand for water at the industrial, agricultural and domestic levels is continuously increasing and, correspondingly, limited fresh water resources are shrinking. The European Union has established a community framework for water protection and management. In this framework, member states must analyse the characteristics of each river basin district, the impact of human activity on water resources and the economic analysis of water use. The management plans of recommendations should be executed in order to protect and enhance groundwater resources, protect them from pollution and ensure a balance between installing new pumping wells and designing protected areas. The above-mentioned objectives must be achieved no later than 2015.

Selection of a suitable location for the development of new pumping wells is a challenging task when taking of pollution and potentiality of the area into consideration. With the advancement of GIS technology, a multi-criteria analysis method is becoming a powerful tool for decision makers to analyse and solve the problems which are based on multiple criteria. MCA methods are used to assist decision makers in either ranking a known set of alternatives for a problem or making a choice among this set while considering the conflicting criteria (Sumathi, 2007; Keeney & Raiffa, 1976; Zeleny, 1982; Figueira et al., 2005).The integration of MCA techniques with GIS has significantly advanced the map overlay analysis for site suitability analysis (Carver, 1991; Banai, 1993 R. Banai, Fuzziness in geographic information systems: contributions from the analytic hierarchy process, International Journal of Geographical Information Systems 7 (1993), pp. 315–329. Full Text via CrossRef | View Record in Scopus | Cited By in Scopus (41)Eastman, 1997; Malczewski, 1999). An integrated approach incorporating the application of GIS and MCA methods have been employed for the suitability analysis of landfills in an urban matrix by Sumathi (2007), Lin and Kao (1998), Allen et al. (2002), and Kontos et al. (2005). In a preliminary, GIS was normally involved for employing a set of criteria in order to catalogue an area into defined classes by creating buffer zones around the geographic features to be protected. All map layers were then intersected so that the resulting composite map contains two suitable and unsuitable areas. As per the literature review, the authors did not find the study on the combined use of the MCA approach with the genetic algorithm model in conjunction with groundwater model. Moreover, the present work augments the simulation-optimisation approach with the use of MCA method coupled with geographical information system.

In this paper, first the detail of the study area is presented. Then, the development of methodology is explained with a detailed explanation of multi-criteria analysis, groundwater simulation-optimisation modelling, objective function and constraints. Finally, the results and conclusion of the study are presented.

2. METHODOLOGY

2.1. Location of Groundwater Extraction Wells

Figure 1 shows the flow chart for the proposed methodology for the evaluation of a suitable location for groundwater pumping. In the first step, the Intrinsic Potentiality Index (IPI) was calculated using five parameters that control the groundwater potentiality, i.e., depth to water, hydraulic conductivity, aquifer river exchange, geomorphology and land use. The name of the criteria and their weight and rating are summarised in Table 1. Two exclusion criteria were also considered to keep the suitable location away from a potential polluted area. These criteria include the distance from the treatment site and the vicinity to an industrial centre. Various buffers to these areas were developed and used as a mask