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Modelling environmental variables for geohazards and georesources assessment to support sustainable land-use decisions in Zaragoza (Spain)

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ABSTRACT

Land-use decisions are usually made on the basis of a variety of criteria. While it is common practice to integrate economic, ecological and social (triple bottom line) criteria, explicit geoscientific factors are relatively rarely considered. If a planned land use involves an interaction with the geosphere, geoscientific aspects should be playing a more important role in the process. With the objective to facilitate a sustainable land-use decision-making a research project was initiated. The area around the city of Zaragoza, in the Ebro Basin of northern Spain, was chosen due to its high degree of industrialisation and urbanization. The area is exposed to several geohazards (e.g., sinkholes and erosion) that may have significant negative effects on current and future land uses. Geographical Information System (GIS) technologies are used to process the complex geoscientific information. Further GIS analysis comprised the creation of an erosion susceptibility map that follows the ITC (International Institute for Geo-Information Science and Earth Observation) system of terrain analysis. The agricultural capability of the soil was determined using the Microleis System. We identify geomorphologic units that show high susceptibility to erosion and high agricultural potential and suggest a method to implement this information in a land-use planning process. Degraded slopes developed upon Tertiary rocks show the highest susceptibility to erosion and low values of agricultural capability, whereas the flat valley bottoms and irrigated flood plains have the highest values of agricultural capability.

1. Introduction

One of the principal challenges for the 21st century is supporting the sustainable development of large cities. However, the relationship between economic development and environmental sustainability is complex. For instance due to the rapid pace of urban development, interactions with the geosphere have largely been ignored in the peripheral parts of Zaragoza city (Fig. 1). This development has led to the destruction of significant infrastructure due to land subsidence, the misuse of valuable agricultural land, the destruction of valuable natural areas, and an increasing contamination of aquifers. The United Nation's Agenda 21 (http://www.un.org/esa/sustdev/) suggests that all countries should undertake an appropriate national inventory of their land resources, establish a land information system, classify land resources according to their most appropriate uses, and identify environmentally fragile or disaster-prone areas for special protection measures. Although land-use decisions are usually made on the basis of triple bottom line criteria, geoscientific aspects are rarely considered or are regarded as being of less importance (Marker, 1998; Hoppe et al., 2006). However, most georesources, especially raw materials, are inherently non-renewable resources; if we use these resources today, future generations cannot use them again. The consideration of geoscientific aspects therefore deserves more attention.

To fulfil land management functions, the tools to be used must be updatable, multiscalar, and contain a wide rage of data concerning the environment; i.e., physical, biotic, and anthropogenic aspects and their interrelations. From this viewpoint, a geographic information system (GIS) is required (Amadio et al., 2002). In recent years, the development of Spatial Decision Support Systems (SDSS) has proved to be a considerable aid in efforts to solve the land-use conflicts that commonly arise in sustainable land-use management schemes. Such systems combine the benefits of GIS tools and decision support techniques, making them suitable in supporting the sustainable development of urban areas via land-use suitability analysis. Based on the above, the area surrounding Zaragoza, which represents a large and growing urban nucleus, merits closer investigation in terms of geoscientific factors. Thus, a research project was initiated to develop a methodology which will facilitate the geohazards and georesources assessment and the decision-making of different land-use patterns under geoscientific aspects in a semi-arid environment of the Ebro

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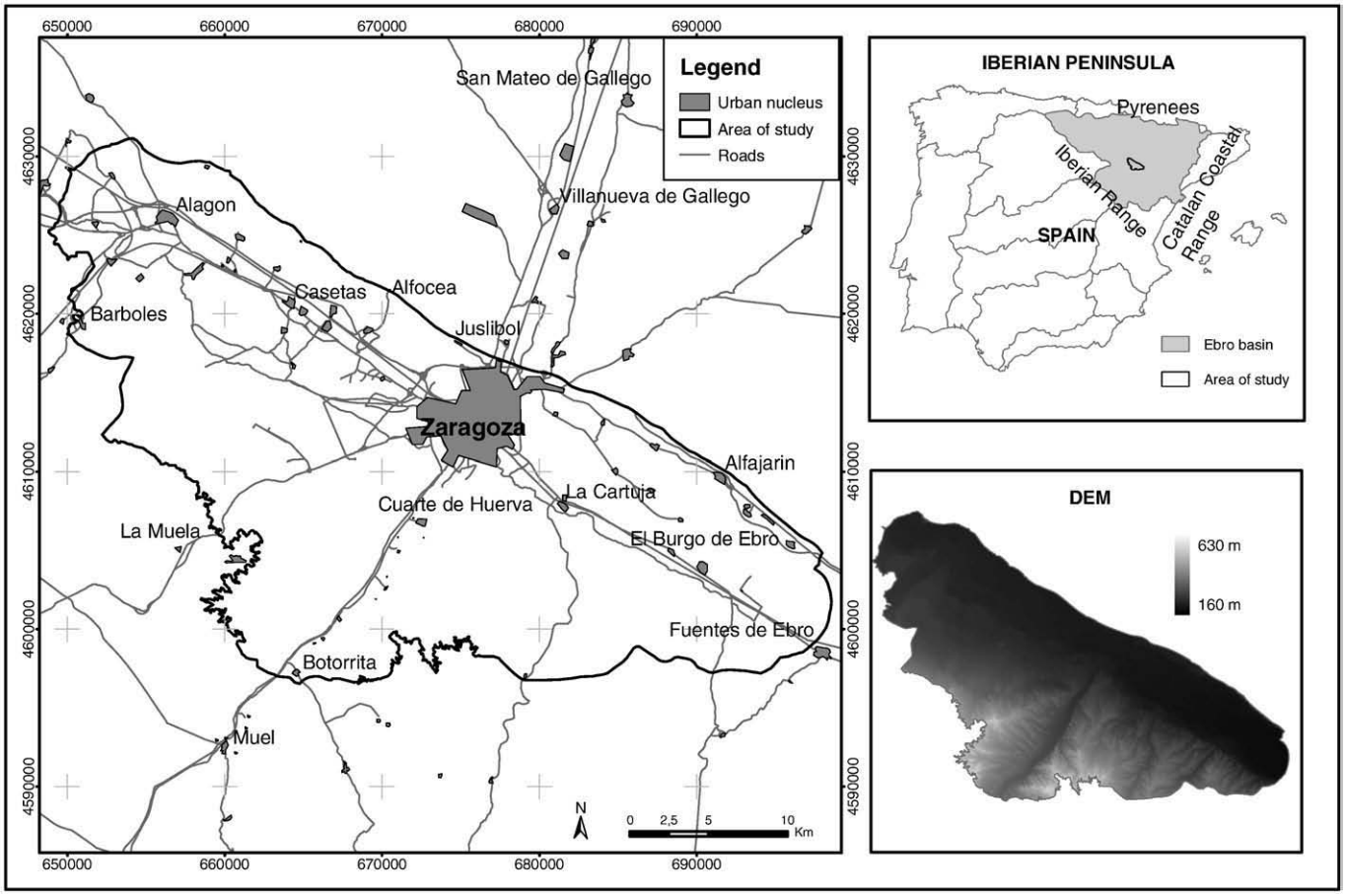

Fig. 1. Location maps of the study area.

Basin, in the surroundings of Zaragoza. It was our aim to perform a land-use suitability analysis to identify the most appropriate pattern for future land uses, according to specify preferences to maintain a sustainable development. Fulfilling this main objective implies that diverse secondary objectives must be carried out. These are:

- Characterization of the study area and collection, analysis and treatment of available information for its introduction into a GIS environment.
- Geohazards and georesources detection, description and modelling with the help of GIS and 3D techniques (when no previous models exist). The final objective of these models is to serve as criterion maps for the land-use suitability analysis.
- Land-use suitability analysis by means of SDSS.

Fig. 2 shows the project workflow. The first step involved the gathering of as much information as possible regarding factors such as geology, geomorphology, soils, vegetation, and land use; this information was then entered into a GIS. The land was then evaluated with respect to the geohazards of erosion, doline susceptibility, and groundwater vulnerability (see Lamelas et al., 2007a, 2008), as well as with respect to georesources consisting of sand and gravel deposits (Lamelas et al., 2007b), agricultural capability, and other resources such as natural areas that are of value from an environmental and scientific viewpoint because the environment contains essential habitats for the conservation of species that in some cases are in danger of extinction. Different models at a regional scale (between 1:50,000 and 1:100,000) were developed using different methodologies to evaluate hazards and resources. The different models were then used as spatial criteria (criterion map) in a decision support system (DSS) and integrated into a GIS (Lamelas, 2007; Lamelas et al., 2007b), thereby forming a SDSS that provides various suitability maps for different land-use forms (sand and gravel extraction, irrigated land, industrial areas and urbanization).

In the present study, we report on one of the secondary objectives, modelling of geoscientific aspects of erosion susceptibility and agricultural capability using diverse land-use evaluation methodologies. 3D modelling techniques have been used for groundwater vulnerability, doline susceptibility assessment and sand and gravels deposits evaluation (e.g. Hoppe et al., 2006; Lerch and Hoppe, 2007; Lamelas et al., 2007a,b, 2008). However, in the following sections we would like to explain in more detail the general methodology of the project as it extremely determines the development of the above mentioned models.

1.1. Data collection

As a first stage, all of the information regarding factors such as geology, geomorphology and hydrogeology, land cover, soil properties, climate, infrastructure, protected areas, and areas worth protecting was collected and integrated into the GIS database ArcGIS 9.1 (ESRI, 2005). The type of data to be collected depends on the objectives of the study, and these objectives may change over time, thereby determining the dynamic nature of data collection. At this stage, an appropriate conceptualisation of the GIS database is of great importance. The compilation of information includes the tasks of searching for the best information available, analysing its characteristics, introducing information into a GIS, and creating new digital information by digitising paper maps or analysing aerial photographs. A parallel task is the gathering of methodologies for land evaluation modelling.