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CREGIS-Q: a GIS tool to support decision making in case of aquifer contamination emergency

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ABSTRACT

GIS technology has been used for many years in environmental risk analysis due to its capability to focus on the management and analysis of geographic and alphanumeric data to support spatial decision-making (Vairavamoorthy et al, 2007). Especially in emergency management, a DSS (Decision Support System) constitutes an important task to provide quick responses, though not completely exhaustive, to immediately handle a critical scenario and limit the possible damage. In the framework of a collaboration between the Water Research Institute and the National Civil Protection Department, a customized tool called CREGIS (ContaminazioneRisorseEvento-GIS) has been developed in order to facilitate the emergency management of accidental contamination of aquifers and support decision making (Preziosi et al, 2013). The tool is aimed at both national and local authorities in order to improve response capability for a better emergency management. Originally, the tool has been developed programming Python in an ArcGIS environment; but due to the great development and dissemination of open source software, our aim is to replicate the same structure programming Python in a GIS open source environment (QGIS). The review of the tool's code is still in progress. The goal is to make the tool (now named CREGIS-Q) free and accessible to a greater number of people and stakeholders

Keywords: Decision support system, aquifer accidental contamination, GIS, Python

INTRODUCTION

The GIS capability to store, query and analyse data is a known important resource in environmental framework and can be very useful in risk analysis. The present work focuses on liquid hazard transport, which is an issue well suited to being analysed in a GIS environment (Lovett et al, 1997). When an emergency occurs, as an accidental spill happens, due for example to the overturning of a tank lorry, a bottleneck is often not only the scarce information available, but also the ability to retrieve and manage it optimally to obtain quick responses, hence support decision making. Keeping this in mind, a customized GIS tool (CREGIS-Q) has been developed to automate data processing and analysis operations (De Smith et al, 2007) in order to obtain firstly an immediate answer to alert the authorities for the resources that could be affected by the accidental event and

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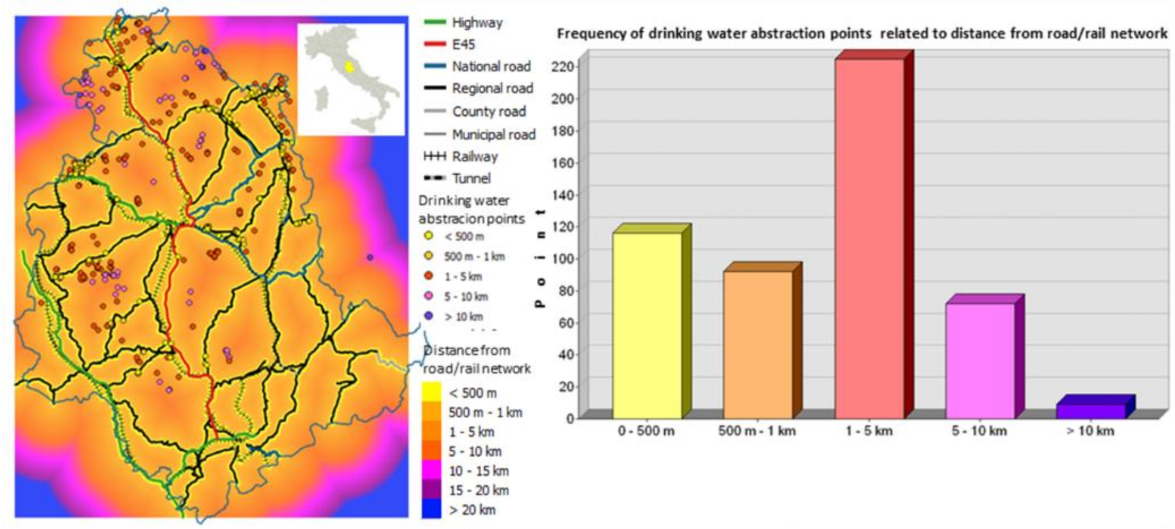
lastly to support further analysis. The latter task is performed by loading the informative layers available for the site map (hydrogeology, ground water vulnerability, hydrodynamic parameters, etc.) selecting them from larger database previously implemented as well as the contaminant properties, and providing the relevant information to be used in transport models. The tool has been designed as part of a much larger project involving also the drafting of a Best Practices protocol on the management of groundwater contamination in case of accidental events, as required by the National Civil Protection Department. The Umbria Region has been chosen as case study, representative for the presence of numerous wells used for drinkable purposes. The analysis has been carried out in collaboration with Umbra Acque s.p.a, which also provided useful data.

It is worth noting that, although the number of cases of contamination from accidental event, such as the overturning of a tank, is not very high (in particular are rare the acute events, in which the contaminant arrives in the groundwater very quickly, in the order of from few days to few months) (APAT, 2003), a spatial analysis based on the distance between road and rail networks and drinking water abstraction points evidenced that the 22% (of which 5% belong to karstified limestones) of points fall within a distance of 500 m from the viability network and the 68% (11% on karstified limestones) within a distance of 5 km (Figure1).



Drinking water abstraction points (514 points)	% on karsified limestones	Distance between road/rail network and water points	Water points belonging to karstified limestones (65 points)
22%	5%	< 500 m	40%
24%	6%	< 1 km	50%
68%	11%	< 5 km	89%

Figure 1. *Proximity analysis between drinking water abstractions point and road/rail*

This result highlights a significant proximity between the main viability and the drinking water points, especially those that fall on carbonates, which have a high vulnerability, and constitutes critical issue in the case of accidental events related to the transport of contaminants.

TOOL DESCRIPTION

CREGIS-Q is a semi-automated tool designed ad hoc to help the user to extract the main information for decision support in case of an accidental contamination event and then to quickly retrieve all the data available for performing further analysis and extract parameters useful for modelling. It works in a GIS environment; a tool scheme is shown in Figure 2

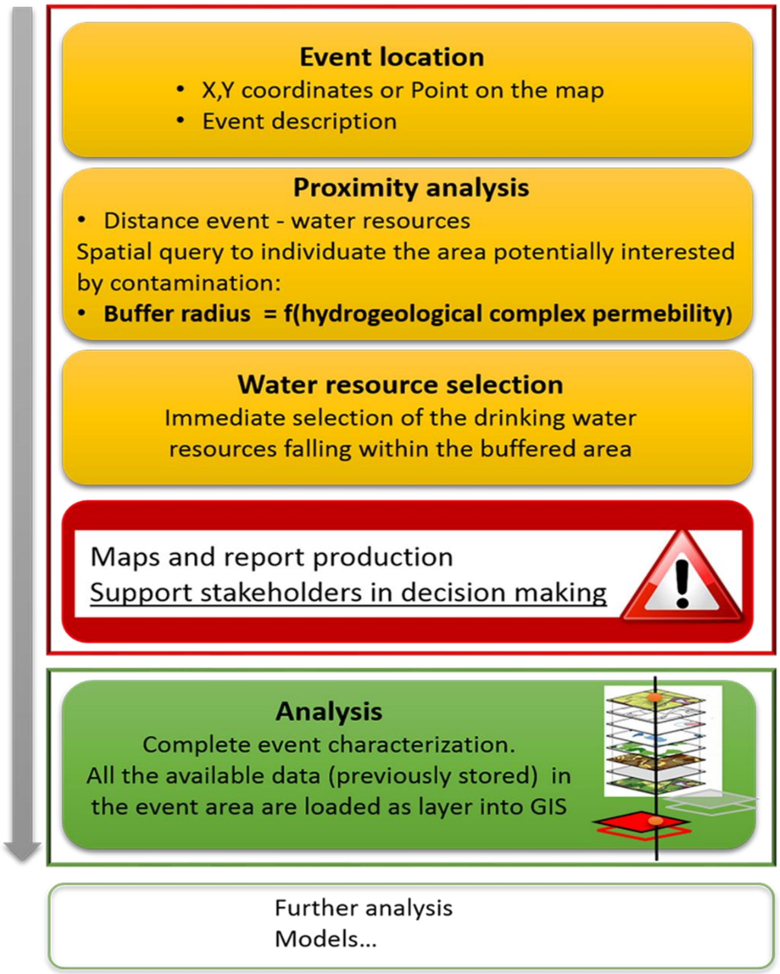


***Figure 2**. CREGIS-Q scheme*

When launching the tool the user is asked to place the contamination event location on a GIS by its coordinates. The main information regarding the event (name, description, date, operator, contaminant, etc.) are extracted and saved. Other relevant information (e.g. administrative data, lithology and hydrological complex in which the event falls) is obtained automatically by means of the GIS overlay techniques (spatial queries) and stored in database. Then, the drinking water abstraction points, which are located within a circular area (buffer) around the spill, are identified. The buffer is designated around the event, whose radius increases with the permeability of the hydrogeological complex in which the event falls (generally 1-3 km, up to 15 km for karstified limestones). After the proximity analysis is completed, a report containing all the information on the event characterization and on the water points involved is automatically generated and saved. A map is also prepared and available in pdf format to support the stakeholders in decision-making.

Finally, the tool automatically analyses all data previously stored in databases and loads in the project only those that insist on the event area, in order to provide additional data for a further characterization of the event. For example, a first estimation of the parameters to be used in transport models could be derived from the relevant layers (e.g. geological-hydrogeological maps, vulnerability maps, etc.). A refinement of proximity analysis is also available to allow a greater flexibility by letting the user able to repeat the procedure with a distance deemed appropriate based on the additional mapping study.

In order to work properly in the emergency phase, when the “time factor” is crucial and all the tasks need to be carried out you quickly, the tool needs a preparedness stage in which all basic data are collected and stored in databases. Basic cartography may include administrative data (regions, provinces, municipalities), topographic maps at different scales, traffic data, hydrography, residential areas, satellite imagery and various types of services (if you have an internet connection); these maps can be both raster and vector; for administrative data it has suggested the vector format because they are involved in the spatial overlay. Moreover, to perform the procedure a reference map for the proximity analysis and a list (provided with coordinates) of drinking water abstraction points need to be collected. The latter data is surprisingly hard to find; in fact, it does not seem to exist a homogeneous list of drinking water abstraction points in Italy. In this work, the reference map for the proximity analysis chosen is a hydrological complex map (Fried at al., 1982) and the list of water abstraction points was provided by Umbra Acque s.p.a. During the ordinary maintenance, an important task is the collection and storage of cartographic stuff to easily be retrieved by the tool in emergency. The cartography storage is generally a time-consuming work as data from various sources, size and geographic location need to be analysed, collected and georeferenced, if necessary; the task involves an accurate bibliographic research. Furthermore, in order to ensure the proper functioning of the tool, a continuous activity of maintenance and updating of databases is required.

The most common software GIS support open-source Python scripting language to develop customized tool and automate procedures. Here Python was firstly used to build CREGIS to work in ArcGIS (Tateosian., 2015); then, in order to support a wider use of the tool and to make it free, it is being designed (Lawhead, 2015) to work in an open source GIS (QGIS) environment.

the time and date a user digitized an object, the zoom level at which an object was digitized, the username, the rough position of the user at zip-code level (through IP-to location databases), the users’ equipment (e.g. mobile device, type of browser, etc.) and the URL a user visited before using a system.

RESULT AND CONCLUSION

Risk and decision analysis are often faced with problems having spatial characteristics. As a part of a best practice protocol for the emergency management of accidental spills of contaminants, a decision support tool has been implemented in a GIS environment. In the emergency management of groundwater pollution events, the aim of this application is to facilitate the pre-alert phase and successively the consultation of the available layers to support the analysis (e.g. modeling), scenario building and further decision making.

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