GIS, Visualization and Spatial Analysis for Major Hazards in Europe

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SUMMARY

The paper reports some recent developments made using GIS for mapping and visualizing major hazards in Europe. In order to support European policies and decision making relating to major hazards it is necessary to have an overview of the locations and types of the relevant hazards in the European Union and Candidate Countries. Such an overview should support the main technological hazards and natural hazards as well as the risk receptors which are considered to be of high priority, such as population and nature reserves. Owing to the different spatial and temporal characteristics of different hazards, and the different working traditions in the different countries, development of a fully comprehensive system is a complex challenge. A prototype system has therefore been set up to serve as a test-bed for methodology development. Example visualizations showing areas potentially susceptible to combinations of natural and technological hazards, and results of preliminary spatial analyses are reported.

KEYWORDS: *Risk Management, Hazard Mapping, Visualization, Spatial Analysis.*

INTRODUCTION

The paper describes some recent developments in GIS for Hazard Mapping, Visualization, and Spatial Analysis related to Natural and Technological Hazards in Europe. These developments have been made within the activities of the "Major Accident Hazards Bureau" and the "Natural and Environmental Disaster Information Exchange System" both of which are hosted at the European Commission's Joint Research Centre at Ispra, Italy.

The Major Accident Hazards Bureau (MAHB) is dedicated to scientific and technical support for the actions of the European Commission in the area of the control of Major Industrial Hazards. The mission of the Bureau is to assist other services of the Commission, and in particular Directorate General Environment in the implementation of European Union policy on the control of major hazards and the prevention and mitigation of major accidents. Since 1982, when the Original Seveso Directive (Council Directive 82/501/EEC) was approved by the Council of Ministers after the serious chemical accident at Seveso, there has been Community provision for the control of major industrial hazards. The Natural and Environmental Disaster Information Exchange System (NEDIES) is a project aimed at supporting EU policies, in the area of prevention, mitigation and management of natural risks and accidents. Again the policies supported are mainly those of DG Environment.

The MAHB and NEDIES activities are carried out in close synergy, and in order to fulfil their aims in supporting European Policies relating to major hazards it is necessary for them to have an overview of the locations and types of the relevant hazards in the European Union and Candidate Countries. This need has stimulated the development of a Hazards Overview Prototype for Europe (HOPE) which is described in the next section. Building on the information layers assembled in HOPE it has been possible to make some experiments in the use of spatial analysis techniques to derive values for criteria which can be used to rank areas which are subject to hazards. Ranking methods can be chosen to suit particular decision makers needs or policy priorities. By making use of CommonGIS (Andrienko et al, 2002), which has in-built functionality for multi-criteria decision support, a ranking of sites or areas can be quickly established and the sensitivity to chosen weightings can be explored through a user friendly interface.

A HAZARDS OVERVIEW PROTOTYPE FOR EUROPE – HOPE

In order to support European policies and decision making relating to major hazards a basic minimum requirement is to have an overview of the locations and types of the relevant hazards in the European Union and Candidate Countries. However, owing to the very different natures of the various natural and technological hazards concerned, the development of a fully comprehensive system is clearly a complex challenge. The different types of hazards have very different characteristics with regard to their spatial extents and their time behaviour, and the different thematic communities which have assessed them have developed their own techniques for monitoring, analysing and representing them on maps. Methods also vary across different countries of Europe making it difficult to obtain harmonized data sets covering all the countries. These considerations led to the proposal to establish a simple prototype system, with an initially limited number of layers, in order to better understand the problems and needs for such a system and to identify where are the data gaps and the needs for European Commission support towards harmonisation efforts. Information layers on some of the most important receptors, or vulnerabilities, such as population, should also be included. HOPE has therefore been initially assembled by searching for and integrating useful geo-referenced data sets for Natural Hazards, Technological Hazards and Risk Receptors for the whole of the EU and the candidate countries. Since we were aiming for an overview for the whole of Europe a nominal scale of the order of 1:1 million, was chosen, or a resolution in the region of 1km – 250m for gridded data. However if useful data is available outside but near this range it is included and used when appropriate – for example CORINE Landcover (Wyatt et al, 1988) data is available for most of the concerned countries with a grid resolution of 100m. The information layers initially assembled are summarised in the following sub-sections.

Natural Hazards

For Seismic hazard, GSHAP, the Global Seismic Hazard Assessment Programme (GSHAP, 1992) has produced a grid of values of peak ground acceleration expected at 10% probability of excedence in 50 years. For Floods, the Dartmouth Atlas of Global Flood Hazards (Dartmouth, 2003) provides information on recent floods detected by the MODIS sensor and other satellite data. Summary information on the extents of floods for recent years (1993 –2003) is provided in the form of rasters (.jpg files) and for specific events vector shape files can be obtained on request. Layers for other important natural hazards, such as forest fires or landslides should be added as they become available through ongoing work programmes at the JRC.

Technological Hazards

The Seveso Plants Information Retrieval System (SPIRS, 2003) hosts data on over 6000 industrial plants in Europe which must comply with the Seveso Directives. The information includes latitude and longitude and some basic attributes on the types of plants and classes of substances present. For Nuclear Plants the United Nations Environment Programme (UNEP, 2003) provides a global dataset on 109 nuclear sites, with latitude and longitudes and some details on number of reactors, power, and operating status in 1999. For Oil and Gas Pipelines vector layers are provided in the European Commissions internal GISCO dataset. Mineral Extraction sites and Dump Sites are provided as one the classes of the CORINE Landcover data. For Transport Networks major networks are provided as vector layers in the Commission's GISCO data base.

Risk Receptors

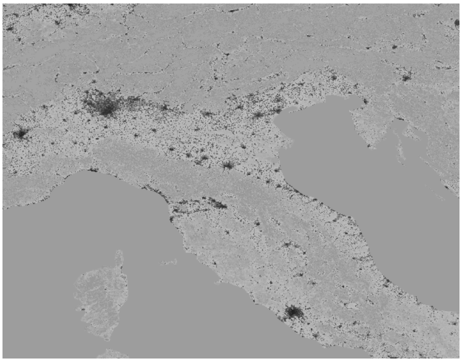
The LANDSCAN project (LANDSCAN, 2002) provides population data for whole globe, on a grid of 30" x 30" in latitude and longitude based on model using: census counts, road proximity, slope, landcover and nightime lights (from satellite data). The most recent version is updated for 2002. Urban areas, also useful as another indication of where the population resides, are taken from the CORINE landcover classes "Continuous Urban" and "Discontinuous Urban". For Nature reserves the CORINE Biotopes dataset is a point dataset, indicating positions by latitude and longitude, with attributes on area and species present. For Water bodies again these are obtained from the CORINE Landcover data which includes classes: peat bogs, marshes, salt marshes, coastal lagoons. Also the GISCO coverage: "Water Pattern" provides vector data on rivers and lakes at scale 1:1m. Other supporting layers such as major cities, with populations, and administrative boundaries, are included to assist navigation and visualization.

The GIS software used is Arc-View which is the "standard" desktop GIS for use in the European Commission together with the Spatial Analyst extension. Also CommonGIS is used to provide additional interactive visualization possibilities, useful grid analysis functions and a multi-criteria decision aid.

EXAMPLE VISUALIZATIONS

This section provides several example visualizations generated with HOPE which illustrate its usefulness in obtaining a Europe-wide overview, and highlighting areas where possible combinations of hazards might occur.

The first example in Fig. 1 illustrates just the LANDSCAN population data, viewed using CommonGIS, and in which population values greater than a chosen threshold (which can be interactively varied) are shown in a scale of red, while values below this threshold are shown in a scale of green.



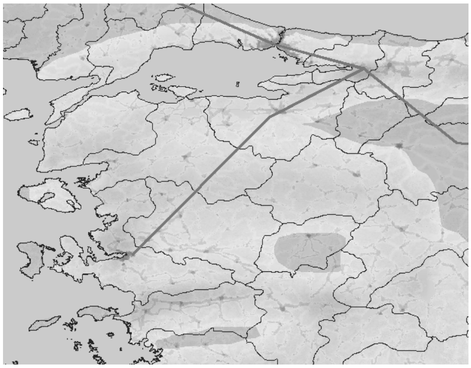


Figure 1(left): Visualization of LANDSCAN population data, and *Figure 2(right):* Visualization of Seismic acceleration (above an interactively chosen threshold), with LANDSCAN population data, and major gas pipeline route in Turkey.

The population data described above can also be visualized over other layers in CommonGIS using transparency. The example in Fig 2 shows the population data viewed with transparency over the seismic acceleration data for an area in Turkey. A threshold has been applied for the values of acceleration such that only areas above this value are revealed in yellow. The vector data showing the line of a major gas pipeline is also superimposed; this gives the possibility to identify areas which are populated and subject to a potential combination of seismic and technological hazards.

The visualization in Fig 3 shows a combination of the population data, seismic acceleration (with a different threshold) and flooded areas (with floods of 1998 and 2003) for an area on the border between Greece and Turkey. In this way it is possible to identify populated areas which may be subjected to both potential flooding and seismic acceleration above the chosen threshold.

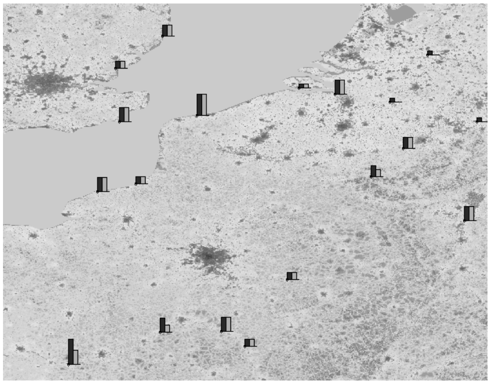


Figure 3(left): Visualization of recent floods, seismic acceleration threshold and LANDSCAN population data for an area on the border between Greece and Turkey.

Figure 4(right): Visualization of attributes of Nuclear plants and population data. Bars represent the number of reactors and the number of active reactors.

Other visualizations can be prepared using appropriate layer combinations and CommonGIS functions for attribute display, such as vertical bars, graduated circles or pie charts e.g. as in Figure 4 above. Having this overview for the whole of Europe and candidate countries, with the possibility to pan and zoom, is a useful aid to identifying areas worthy of further investigation.

APPLICATION TO LAND-USE PLANNING

Land use planning must take account of the presence of both natural and technological hazards. With regard to industrial hazards a key aspect for planning is the distance between industrial plants presenting potential dangers and inhabited areas, and this is addressed by the SEVESO directive. Safety distances and considerations of land use configurations are also important for emergency planning (Gow and Kay, 1987). Using the data assembled in HOPE it is possible to examine the overall situation in the countries covered with respect to proximity of the industrial plants to urban areas or to the CORINE biotopes (areas of particular natural sensitivity). Using spatial analysis it has been possible to make histograms of the distributions of distances of the SEVESO plants from the perimeters of the urban areas. The method involves first creating a grid representing distance from grid cells to borders of urban areas, and then transferring the distances as attributes to the points representing the plant locations. Figure 5 shows the preliminary results for two different countries. The peak in the distribution for Country A is between 1000m and 1500m, and fewer than 10% of plants lie in first 500m bin. But the peak for country B is in the first 500m bin, showing that a much higher percentage (approx. 40%) of the plants are located within 500m of urban areas. This would appear to reflect different approaches to urban planning and safety distances in the past in the two countries.

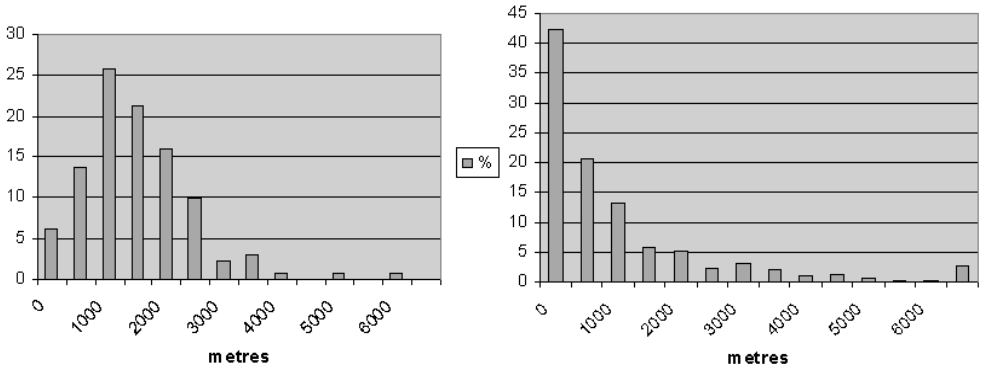


Figure 5: Comparison of histograms of distances from SEVESO plants to Urban areas for two countries, A (left) and B (right).

CONCLUSIONS

HOPE has provided a useful test-bed for developing approaches to combining and visualizing hazards data for the whole of Europe and Candidate Countries. By assembling several data layers on natural and technological hazards, together with important risk receptors it has been possible to test methods for visualization and spatial analysis applied to combinations of hazards and receptors in a context covering the whole of Europe. It has also been illustrated how spatial analysis can be used to generate summary information for countries which is useful for land use planning considerations related to technological hazards. Areas for case studies or further investigation can be identified, and tests made to evaluate user-defined criteria for risk management policy support.

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