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MAPPING AND VISUALIZATION OF NATURAL AND TECHNOLOGICAL HAZARDS

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INTRODUCTION

Natural and technological hazard mapping forms the base of decision-making process for the risk management by providing essential information for understanding the risk nature by the society. Hazard mapping is a process of establishing the geographical location and spatial extent to which a particular hazard phenomenon is likely to pose a threat to live of people, infrastructure, property and economic activities of the study area along the Danube River in Romania and Bulgaria. Hazard maps are elaborated using GIS as a main tool for data storage, analysis, modeling and results visualization. Maps represent different natural and technological phenomenon and processes, socio-economic circumstances and can be defined as communication products.

According to the main objectives of the ROBUHAZ-DUN project an elaboration of the specialized natural and technological hazard maps is focused on hazard features visualization in paper maps as well as in a GIS environment. The hazard maps are represented at different spatial scales, general ones for the entire Danube sector and detailed ones for selected localities and key areas, using a common GIS-based methodology. Spatial scales are selected in order to depict the most relevant levels for spatial planning and development.

This paper aims to provide a conceptual background and applied approaches for the mapping and visualization of natural and technological hazards in the studied sector of the Danube floodplain between Calafat – Vidin and Turnu Magurele – Nikopol in Romania and Bulgaria during the implementation of the ROBUHAZ-DUN project.

CONCEPTUAL BACKGROUND AND MAPPING APPROACHES

The hazard maps are kind of thematic maps that emphasize on the spatial aspects of particular hazardous phenomena or multiple hazards. They are elaborated using GIS as a main tool for data collection, management, analysis, modeling and mapping. Hazard maps identify and display the spatial variation of hazard events or physical conditions (e.g. floods, landslides, erosion, climate zones, etc). Important variables involved in mapping hazards and interpreting hazard maps include the size (scale) of the area to be mapped, the availability and completeness of data, the cost of collecting and mapping data, etc.

Hazard mapping focuses on quantitative hazard analysis. This is done in local levels increasing the details for better understanding of the nature of hazards, their sources, types, dependences and probable variations. Mapping is used to combine data on natural and technological hazards with socioeconomic data for municipalities, in order to facilitate analysis of the probability of hazard occurrence. Hazard mapping is a key element for better understanding the causes and impacts of natural and technological hazards and for finding relationships that are not apparent with analytical approaches. Based on causes and impacts of natural and technological hazards, maps are developed to display anticipated future impacts or the areas of potential damages. This facilitates communication among stakeholders in the hazard management process, such as decision-makers, land use planners and policy makers.

The assessment of the available base input data (topographic maps, satellite images, DEM, etc.) and base thematic data/layers (municipalities, settlements, roads, rivers, etc.) shows that the appropriate parameters for hazard maps of the Danube study area in Bulgaria are as follows: datum WGS84, projection: UTM, zone: 35N.

An overview of natural and technological hazards provides a preliminary evaluation of hazards typology and key areas of interest for the Danube study area. Not all hazards are relevant to the investigated region. The identification of main natural and technological hazards is based on the following criteria: 1) spatial relevance; 2) occurrence, frequency and magnitude; 3) impact and effects. The investigated hazards type list is the result of main hazards identification for the region. The research focuses on three main types of hazards:

- *Natural hazards:* Climate and Hydrological hazards;
- *Natural hazards:* Geological and Geomorphological hazards;
- *Technological hazards*: Soil and water contamination.

The individual hazard maps follow the common classification of hazard intensity according to the relative priority matrix in next five classes:

1. Very low
2. Low
3. Medium
4. High
5. Very high

If it is not possible for a particular type of hazard to distinguish between the five classes, the same classification is kept, with fewer classes in between very low and very high.

Three steps are included in elaborating the hazard map: 1) transforming the data from thematic maps into classes by assigning a weight value to each class of the parameter tables, 2) merging the corresponding values of parameter tables with thematic data to receive composite maps, and 3) preparing the hazard maps by reclassifying the composite maps into five or three classes, i.e. (very) low, medium, and (very) high (Fig. 1).

Further, an aggregated hazard and risk maps can be developed based on the ESPON 1.3.1 project on natural and technological hazards (S c h m i d t - T h o m é, 2005). To produce the aggregated hazard map, the individual hazard maps are aggregated

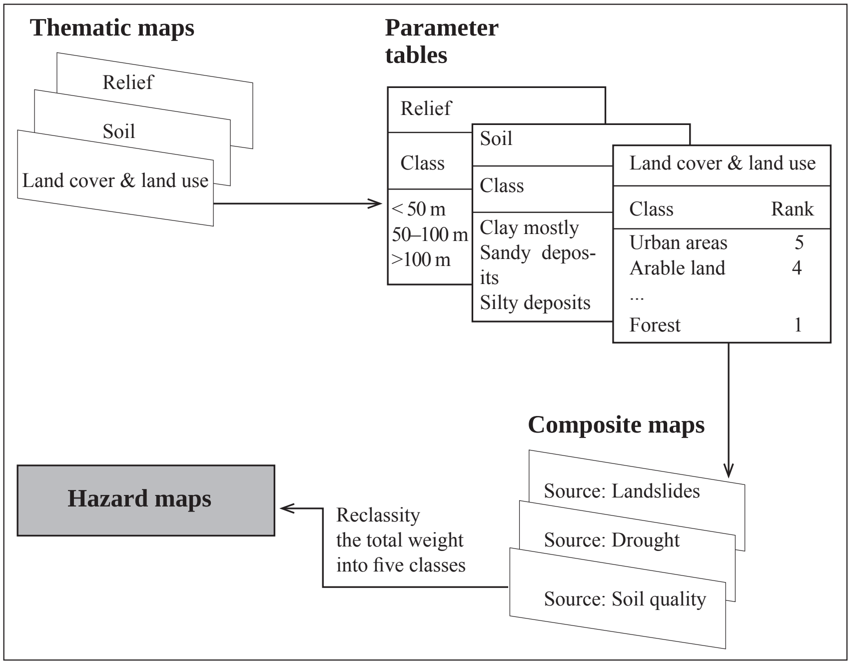

Fig. 1. Hazard mapping scheme

to one integrated hazard map by means of the addition of the several single hazard intensities (G r e i v i n g, 2006). For the task of combining vulnerability and hazard potential, a matrix is used (Fig. 2). The values of region's hazard intensity and degree of vulnerability are summed up to yield region's integrated risk value. To distinguish between a higher intensity of a hazard or a higher degree of vulnerability, different shades of the same colour are used (G r e i v i n g, 2006).

The scale issue has considerable influence on hazards assessment. On a general scale the data show mostly quantitative results and areas classification based on relative priority matrix in five classes (from very low to very high). For detailed (local) scale the site specific elements are displayed.

The scale used in hazard mapping is directly linked to the appropriateness of the application. The hazard maps for the study area are elaborated at different spatial scales, general ones for the entire study area and detailed ones for selected localities and key-areas. The hazard maps for the entire study area are developed at scale 1:50 000 and 1:100 000. The maps for floodplains and other vulnerable key areas are developed at scale 1:25 000 based on topographic maps at scale 1:5 000, digital orthophoto and satellite images, thematic maps and field work.

The scale of maps has significant influence on the legend content. Applying a perception approach the choropleth maps are most suitable to illustrate hazard on a general scale, where one value characterizes a certain geographic area. The local scale allows for a more complex legend as homogeneous areas in term of hazard classification are displayed with colours or hachures, and aditionally, given geographic units or spots of interest are pointed out by different style of lines.

HAZARD MAPS VISUALIZATION

Hazard maps are designed using a wide range of visualization techniques based on generally accepted principles for map generalization, map design and map production. Visualization serves two major purposes: data analysis and data presentation (S t r a n g e, 2007; K o l l a t, R e e d, 2007; W a g e n e r, K o l l a t, 2007).

In the context of GIS the generalization is a process of modeling with two groups of techniques – model and cartographic generalization (Mackaness et al., 2007; Mackaness, 2008; Mackaness, C h a u d h r y, 2008a). The model generalization process is applied to spatial database. It includes a set of techniques concerned with 1) selection of phenomenon according to theme, and 2) the classification, simplification and aggregation of features stored in a database for improved data processing and analysis, dataset integration, and prior to cartographic generalization. Cartographic generalization is a set of techniques applied to ensure optimal visualization of geographic phenomenon according to task (scale and theme). It increases the efficiency with which the map is interpreted, thus the techniques aim to resolve ambiguity, and to retain the quality of map's representation. In this sense S e s t e r (1999) argue that the model generalization relates mainly to the semantic and geometric data reduction and can be defined as a process of thematic and spatial abstraction, while the cartographic generalization is related to the graphical representation of objects and restrictions on map's readability and aesthetics.

Map generalization is performed through the application of available generalization operators in GIS environment, such as symbolization, simplification, smoothing, enhancement, aggregation, elimination, collapse, exaggeration, displacement, etc. Mackaness and C h a u d h r y, (2008b) define the main GIS generalization operators as follows:

- Symbolization – change of symbology according to theme (pictorial, iconic), or reduce space required for symbol.
- Smoothing – reduce angularity of the map object.
- Enhancement – emphasize characteristics of map feature and meet minimum legibility requirements.
- Collapse – reduce dimensionality of map object (area to point, linear polygon to line).
- Displacement – small movement of map objects in order to minimize overlap.
- Typification – replacement of a group of map features with a prototypical subset.

In relation to the maps visualization a set of scientific articles discusses the importance of colour scheme selection, which is based on the type of data (B r e w e r, 1994; W a r e, 2000; H a r r o w e r, B r e w e r, 2003; L i g h t, B a r t l e i n, 2004; S t e p h e n s o n, 2005; K r y g i e r, W o o d, 2005; S t o n e, 2006). H a r r o w e r and B r e w e r (2003) stress that sequential schemes, made up of intervals of one or two colors graduating from light to dark, should be used for quantitative data, with low values in lighter tints and high values in darker tints. Diverging color schemes on the other hand should be used to highlight contrasts between low and high values relative to an average value. The authors argue that the map visualization is better, if diverging schemes use a light, neutral color to represent average values and contrasting dark hues for low and high values. Categorical data is best represented with qualitative schemes, which are made up of contrasting colors that show differences without reference to magnitude

The perception of colours can be described by three dimensions: hue, lightness and saturation (B r e w e r, 1994; K r y g i e r, W o o d, 2005). The hue is used to show qualitative differences of data. The lightness (value) describes the variation of one hue from light to dark. A change of the lightness can show quantitative differences of map elements (preferably of the same kind). The saturation describes the intensity of a colour or the amount of hue in a colour of the same lightness. A change in saturation can be used in a binary scheme to illustrate the hazard intensity on a map.

Development of colour legend for hazard maps is based on hazard classes agreed in the frame of the ROBUHAZ-DUN project (Fig. 3).

CONCLUSION

The natural and technological hazards mapping is a key element of scientific program to better understand the causes and impacts of natural and technological hazards, such as landslides, floods, erosion, soil contamination etc. Mapping facilitates the identification of relationships between the distribution of natural materials and evidence of natural and technological processes, to reveal connections that would not be obvious, if relying on analytical approaches alone. As more is learned about the causes and impacts of natural and technological hazards, hazard maps are produced to show expected future impacts or to display the potential areas that would be impacted.

Hazard mapping provides input to educational programs for illustrating local hazards, to scientists studying hazard phenomena, to land use planners seeking to base settlement locations to reduce hazard impacts and to combine with other information to illustrate community risks. Hazard maps provide clear, attractive pictures of the geographic distribution of potential hazard sources and impacts. These maps frequently provide motivation for risk management actions that would be difficult to obtain without a compelling visual. Mapping hazards provides an easily accessible tool for displaying the threat to a society.

All elaborated hazard maps in the ROBUHAZ-DUN project provide information to assist local governments in developing and implementing land use management plans, decisions making for hazard areas, and risk assessment for regional planning and civil protection. Hazard mapping supply an accessible tool for reducing hazard impacts and for integrating with other information in order to form the foundation of the risk management.

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КАРТОГРАФИРАНЕ И ВИЗУАЛИЗАЦИЯ НА ПРИРОДНИ И ТЕХНОЛОГИЧНИ ОПАСНОСТИ

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(Р е з ю м е)

Картографирането на природни и технологични опасности е в основата на процеса на вземане на решения за управление на риска чрез предоставяне на важна информация за разбиране на естеството на риска за обществото. Статията представя концептуалната основа и приложените подходи за картографиране

и визуализация на природните и технологичните опасности в изследваната част на Дунавската равнина между Калафат – Видин и Турну Мъгуреле – Никопол в Румъния и България при работата по проект ROBUHAZ-DUN. Картите на опасността са съставени с използване на географски информационни системи (ГИС) като основно средство за съхранение на данните, анализ, моделиране и визуализация на резултатите.

Картографирането на опасността се фокусира върху количествения анализ на явленията. Картите са разработени въз основа на причините и въздействията на природните и технологичните опасности, за да се покажат очаквани бъдещи въздействия и зони на потенциални щети. Прегледът на природните и технологичните опасности осигурява предварителна оценка на типологията им и важните ключови участъци в изследвания район на р. Дунав. Идентификацията на главните природни и технологични опасности се основава на следните критерии: 1) пространствена значимост; 2) проява, честота и степен, 3) въздействие и последици. Съставеният списък на изследваните видове опасности е в резултат на установяването на главните опасности за района. Създаването на карта на опасността включва три стъпки: 1) трансформиране на данни от тематични карти в класове чрез определяне на тежестта на стойността за всеки клас от параметрични таблици; 2) обединяване на съответните стойности от параметричните таблици с тематични данни за получаване на синтезни карти; 3) съставяне на карти на опасността чрез рекласификация на синтезните карти в пет/три класа, т.е. (много) ниска, средна и (много) висока.

Мащабът има важно влияние върху оценката на опасността. В съответствие с основните цели на проекта картите на опасността са представени в два различни пространствени мащаба: основен мащаб за целия проучван сектор на р. Дунав и детайлен мащаб за избрани локалитети и ключови участъци. За тази цел е използвана обща ГИС-базирана методология. Пространствените мащаби са избрани така, че да бъдат най-подходящи за приложение при пространственото планиране и развитие. В основния мащаб данните показват главно количествени резултати и класификация на района въз основа на матрица за относителна оценка на опасността в пет класа (от много ниска до много висока). В детайлния (локален) мащаб се представят специфични елементи за участъка. Мащабът на картите има определящо значение за съдържанието на легендата.

За дизайна на картите на опасността са използвани различни техники за визуализация, базирани на общоприетите принципи за генерализация, проектиране и създаване на карти. Разработена е цветова легенда на картите на опасността въз основа на избраните класове на опасност в рамките на проекта.

Картите на опасността предоставят информация в помощ на местните власти в разработването и изпълнението на плановете за управление на земеползването, за вземане на решения за районите на опасност и оценката на риска за регионалното планиране и гражданската защита.

Legend of risk maps	Degree of vulnerability				
Intensity of hazard x	1	2	3	4	5
1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	8	9
5	6	7	8	9	10

Fig. 2. Classification scheme of hazard and risk maps (source: S c h m i d t - T h o m é, 2005)

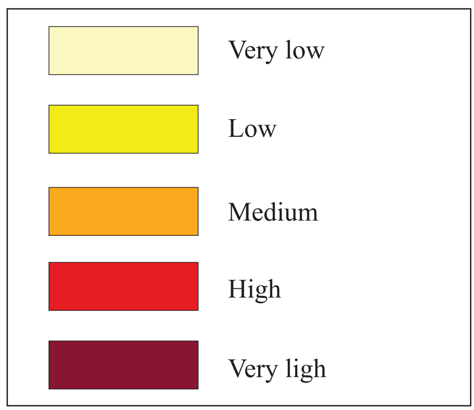

Fig. 3. Colour legend for intensity of hazard