VILNIUS UNIVERSITY

NATURE RESEARCH CENTRE
INSTITUTE OF GEOLOGY AND GEOGRAPHY

KĘSTUTIS PAPŠYS

METHODOLOGY OF DEVELOPMENT OF CARTOGRAPHIC INFORMATION SYSTEM FOR EVALUATION OF RISK OF EXTREME EVENTS

Summary of Doctoral Dissertation
Physical Sciences, Physical Geography (06P)

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VILNIAUS UNIVERSITETAS

GAMTOS TYRIMŲ CENTRO
GEOLOGIJOS IR GEOGRAFIJOS INSTITUTAS

KĘSTUTIS PAPŠYS

EKSTREMALIŲ ĮVYKIŲ RIZIKOS VERTINIMO KARTOGRAFINĖS INFORMACIJOS SISTEMOS KŪRIMO METODOLOGIJA

Daktaro disertacijos santrauka
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INTRODUCTION

People all the time have been interested in the quality of the living environment. The society of Lithuania is not an exception. Many different parameters of living environmental quality exist. Without any doubts, one of the most important parameters is the security of the living environment. For people it is always important to know how safe the district where they live and/or their property in a particular location are.

Characteristics of the study object

While the natural conditions in the entire world and in Lithuania vary, the natural, ecological, technogenic and anthropological risks vary. These risks for the society are growing and becoming more intensive. More often the natural, anthropogenic and technogenic extreme events which happened in the last decade are the reason. In Lithuania some extreme events occurred in the last years: incidents such as squall in woods, extreme temperature differences between summer and winter, very rich precipitation, extreme winds and enormous storms in the sea. All this makes a huge damage for the people living environment, agriculture and coastline because of erosion and other reasons. For the analysis of the risks in a living environment it is compulsory to consider extreme events in the whole world because it might have a direct influence. For example, under certain meteorological weather conditions the eruption of the volcano in Iceland can make an influence on the aircrafts' traffic above the Lithuanian territory. So the ash from the volcano can make big damage for Lithuanian people and for their small enterprises. The damage made by the technological events (fires in factories, in ships, etc.) is also considered as severe damage for the nature. Furthermore, there were anthropogenic (social) events like violence of football fans which made damage in the last years as well. However, it should be noted that differently developed countries attach different importance to the issue of the risks and related quality of the living environment. Some of the developed countries, like the United Kingdom, USA, Japan, Norway, Sweden, Germany, and Australia have been making risk assessments mentioned before for a long time. Anyway, mostly the focus is on natural incidents, their pattern and forecast with the biggest interest in the speed of the response and assessment of damage. The latest technologies of the computing systems, databases, computer networks, geographic information systems, global positioning systems, etc. are increasingly used for such kind of analysis.

Considering the geographical situation of the study area and any other area in Lithuania there is a possibility to identify the risks and their damage. The residential or business environment varies and can influence itself. For this reason, there is a need for a flexible and dynamic risk evaluation system.

Practical significance of the study

For the last years, the interest particularly in the risk grade assessment increased among the various range of researchers and trainees. The usage of the latest technologies, especially the geographic information system (GIS) provides a powerful analytical tool to analyse the risk assessment in dynamic geographical systems. Using GIS as an analytical and interactive tool the results of the analysis are always relevant. In Lithuania there is a lot of specific information about the particular areas and the dominant natural and anthropogenic phenomena. This information about phenomena is saved in modern databases and presented for the through the portal of the geographic information. The constant updates of the sufficient amount of data and the internet speed open the opportunities for building a dynamic and modern technological system of risk evaluation through the web in Lithuania. A similar solution for creating a risk evaluation model has been already realized in some of the most developed countries which have reached a high technological level and have collected enough spatial (geographic) data. Usually, the investment first goes to one of the specific natural phenomena, such as earthquakes, storms, floods or forest fires. However, it is important to mention that all these models created for one natural phenomenon usually are used to guarantee the fast reaction of the rescue crew and elimination of the hazard. Nevertheless, attempts have been made to develop the risk evaluation spatial data model of the anthropogenic events. For example, USA has built a model which evaluates the risk of anthropogenic events depending on the demographic data. In the last decade cities in Western European countries came up with an analysis for modelling a risk level of various extreme events. Respectively, it is important for various institutions in Lithuania to forecast a risk of the extreme events or their synthetic aspects. It would also allow summarizing all this risk evaluation in details for the Lithuanian territory.

The criteria of extreme events were confirmed by the government of the Republic of Lithuania on 24th of February 2000 in Response No. 216 "Confirmation of the Criterion of Extreme Events". Though, Response No. 998 by the government of the Republic of Lithuania as of 24th of August 2011 rejected the criterion because of the circumstances of a real event. After the entry into force, the evaluation has been applied not for the extreme events themselves, but for the consequences of the event to the inhabitants and nature. Such evaluation is more suitable for the inhabitants and the environment to make a quick response, but not for the spatial risk modelling. Unfortunately, the main aim of such risk evaluation is still used for the economic impact reduction, but not for the spatial risk evaluation and prevention. However, the risk evaluation of extreme events by the geographical-physical criteria is still up-to-date and important for the Lithuanian economy. Similar international projects of well developed countries ensure intercommunication and help.

The research object

The research object is a complex risk evaluation system of the natural, ecological, technogenic and anthropological extreme events.

The aim of the study

The aim of the study is to develop a methodology for a complex and functioning risk evaluation system based on the geostatistical methods and up-to-date geographical and communication technologies. The purpose is to establish conditions under which the use of geographic information in the country would become intensive for making decisions related with risk management.

Study goals were the following:

1. To analyse the experience of other countries in the developing risk evaluation systems.

2. To introduce a concept and methodology to develop the cartographic information system for the evaluation of risk of extreme events (EREE).

3. To adjust the mathematical and cartographic methods for the presentation of the results of extreme risk events.

4. To develop a methodology for the creation of databases used in the evaluation of risk of extreme events and for their integration in the Lithuanian geographic information infrastructure (LGII).

5. To develop a methodology for building a raster database for threats arising out of extreme events and to produce a relevant prototype.

6. To practically implement the EREE cartographical information system and try out how it works with different Lithuanian geographical data sets.

7. To make a map prototype of the synthetic threats of the territory of Lithuania.

Defended highlights

1. The risk forecast of extreme events, namely, a complex evaluation of the threats in the country, is highly significant at all governmental levels. Unfortunately, there is practically no country in the world where it would fully function. Geostatistical methods and recent geographic information technologies allow for the possibility of such a forecast.

2. It is possible to create a scientifically and technologically approved complex information system for the evaluation of extreme risk events which is based on synthetic risk maps.

3. It is possible to accomplish the evaluation of extreme risk events by using freely available geographical data sets in Lithuania.

Originality of the work

The originality of the work is reflected in the works accomplished by the author:

- A concept and building methodology for a consistent and complex EREE cartographic information system have been developed for the first time in Lithuania.
- A prototype of the EREE cartographic information system has been built, which accuracy and sensibility are evaluated by the algorithms. The algorithm was one

part of the whole work. The model is flexible and can be adjusted for use by different experts without specific geostatistical knowledge. The results are visualized in maps and easy to understand.

- The unique methodology for the localization of extreme events has been developed, which served as the basis for producing a prototype of the raster spatial database.
- The model of the EREE cartographic information system includes the geographic information combined from different institutions on a real time basis in LGII provided tools. The provided solution may bring significant economic benefit for the country with little expenditure because of the already existing LGII technical base. Such kind of the EREE cartographic information system would motivate the institutional collaboration and wider geographic information usage in the country for making important decisions.

Approbation of results:

There are 4 scientific publications on the topic of the dissertation. 3 articles were published in databases approved by the Research Council of Lithuania and one in an international journal.

The results of the dissertation were published in the materials of 2 scientific conferences:

- International conference: 8th International Conference "Environmental Engineering" 2011 Vilnius,
- International seminar: 6th Vilnius Seminar on Cartosemiotics: “Competences in Modern Cartography” 2011 Vilnius.

Structure of the thesis:

The thesis includes the main chapters: introduction, review of the research, methodology, research results, conclusions, list of the literature resources and annexes, as recommended by Regulation No. VI-4 of the Research Council of Lithuania of 2003. The thesis analysed 115 literature sources and 67 illustrations, 19 of which are provided in the annexes.

1. EVALUATION OF RISKS OF EXTREME EVENTS

It has been more than a few decades that the risk of extreme events has been analysed. In the scientific literature risk of extreme event is defined as a consequence of interaction between dangerous incident and vulnerable elements in a society (people, buildings or infrastructure) (Burton *et al.* 1978, Blaikie *et al.* 1994, Cannon 1994, Cuttter *et al.* 2000). This interaction mostly is defined as a formula: *risk $_{(total)}$ = danger x vulnerability x elements* (Granger 1998, Granger *et al.* 1999). Moreover, there is more simple expression of extreme event where the *risk = potential danger x vulnerability* (Kumpulainen 2006). Such an expression allows analysing a connection between all mentioned elements.

Evaluation of risk of extreme events is the process of analysis the potential extreme events (risk) for the assessment of possible vulnerability and determiantion the nature and extent of the risks that may harm the people, their property and the infrastructure (UN/ISDR 2002). Usually, the scientific studies about risks of extreme events are developed in two aspects: analysis and evaluation of risk of a specific extreme event of one type or multi criteria analysis and evaluation. Nevertheless, mostly such kinds of surveys are applied only for the particular area where the risk appears.

While developing EREE systems the method of risk calculation should be taken into consideration. The studies of technogenic extreme events are based mostly on the early Farmer's (1967) and Starr's (1969) studies which later were enhanced by other scientists (Slovic *et al.* 1986; Slovic 1987, Kasperson *et al.*1988; Renn 1998, 2001; Renn, Klinke 2002). Furthermore, some studies about the evaluation of natural extreme events have been done in the last decades (Litai *et al.* 1983; Rogers 1984; Fell 1994; McDaniels *et al.* 1995, 1996; Finlay, Fell 1997; DeChano, Butler 2001; Plapp 2004).

In evaluating the risk of extreme events usually GIS is an analytical and decision model-making tool used with databases and spatial (geographic) data sets. For the extreme events and emergency situation management different GIS applications were developed in the last decades (Carrara and Guzzetti 1995, Cova 1999). For example, Chung with colleagues offered to produce a map for the areas where landslides occur. For this survey the scientists used a GIS tool to make multi criteria regression methods based on statistics of previous landslides with regard to some spatial (geographic) data sets, agricultural, geological features, etc. An Australian scientist Granger with colleagues developed a *Risk-GIS* system with the help of GIS technologies in 1998. This system can evaluate the risk in a particular area. The *Risk-GIS* model practically has been tried for evaluating risks in a few areas of Australia: Queensland State's cities of Cairns (Granger *et al.* 1999), Mackay (Middelmann and Granger 2000) and Gladstone (Granger and Michael-Leiba 2001), in a South-Eastern part of Queensland state (Granger and Hayne 2001) and in a Western part of Australia, the city of Perth (Jones *et al.* 2005). The purpose of the research was to define if the area was safe and the potential to have earthquakes, landslides, floods and cyclones was low.

Since 1984 the European Union has started to implement programs for research and technological development. The implementation of the 6th and 7th programs included a few projects (ARMONIA, ORCHSTRA, OASIS, WIN, PREVIEW). The projects were launched for the better observation and management of the evaluation of risks of extreme events.

There are some researches related to forecasting of natural extreme events in Lithuania as well. For example, prognosis of flood (Augutis et al. 2004; Simaitytė et al. 2006, 2007; Simaitytė-Volskienė 2005; 2007; Simaitytė-Volskienė et al. 2004, 2005, 2006), seismic activity (Satkūnas 2004; Ilginytė 2004; Pačėsa *et al.* 2005a, 2005b; Šliaupa et al. 2006; Pačėsa 2011; Pačėsa, Šliaupa 2011; Lazauskienė, Pačėsa 2011), storms (Alzbutas *et al.* 2009) and etc. However, it should be noted that there are no studies of extreme events risk assessment by using multicriteria analysis and the technologies of GIS and geographical information infrastructure.

The place of the EREE cartographic information system in a geographic information infrastructure

Having done the research the author identified a few advantages in using the geographical information infrastructure (GII) upon implementing the EREE cartographical information system. First of all, in order to ensure the appropriate usability of this and other multi criteria evaluation systems it is necessary to have a required, actual data and to guarantee a constant and continuous access to it. It is compulsory that the data would be geographical. Only smart GII technologies can ensure the access and provision for such data.

The EREE system must be accessible all the time and working constantly from all type of workstations regardless of the location or configuration (operating system, software, internet browser, etc.). Therefore, such system must be available through the internet and through the GII (see Fig. 1) portal.

The basis of the modern GII is a geographic information system. The term of the geographic information system is wide and covers quite a big number of technologies and processes. Moreover, it is related to a design, planning, management, transportation and analysis of other processes. The author further provides a short overview of the notion of the systems for better understanding about the importance of the EREE cartographic information system. In general, the term of the geographical information system describes any other information system with the functions of integration, storage, editing, analysis, publishing and visualization for making decisions. The user gets tools for creating geographic information applications and interactive queries, for example, a search with a possibility to set your own parameters, analysis of the spatial (geographic) information, editing the data, maps and results of all the operations (Clarke 1986).

The basic geographic terms, methods, applications are used for the analysis of the geographic information system (Goodchild 2010). The basic structures which have influence on the development and support of EREE cartographical information systems will be analysed in further chapters. It is important that the basis of this system is a cartographic decision making system. In part they are identical with a geographical information system, but other parts are unique and have their own focus. In such kind of systems the set of modified analytical tools is mostly designed for mapping the results. The final results for the user are provided in standard tools of geographic information systems. In this work the author analyses a specific cartographic decision making system – **EREE**; the need of it and possibilities in Lithuania, its benefit, efficiency, accuracy and flexibility.

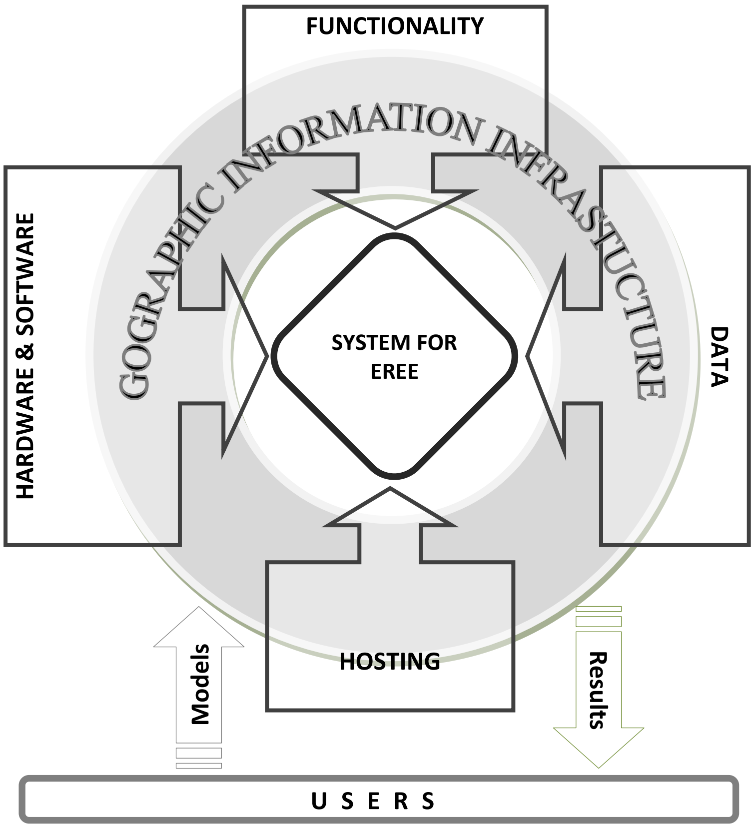

Fig. 1. EREE cartographic information system using GII.

The figure below (Fig. 2) presents a place of the EREE cartographic information system in the GII environment where the additional attention is given to the system of the risks. This kind of system is the main data provider for the EREE cartographic information system. In the following chapters the author describes the system's need and describes the methodology for the development of databases of threats. The author does not analyse the management systems of the risks, which mostly are designed for planning the prevention works and evaluation of extreme events. In the author's opinion, the solution of cartographic results might be used for operating the system.

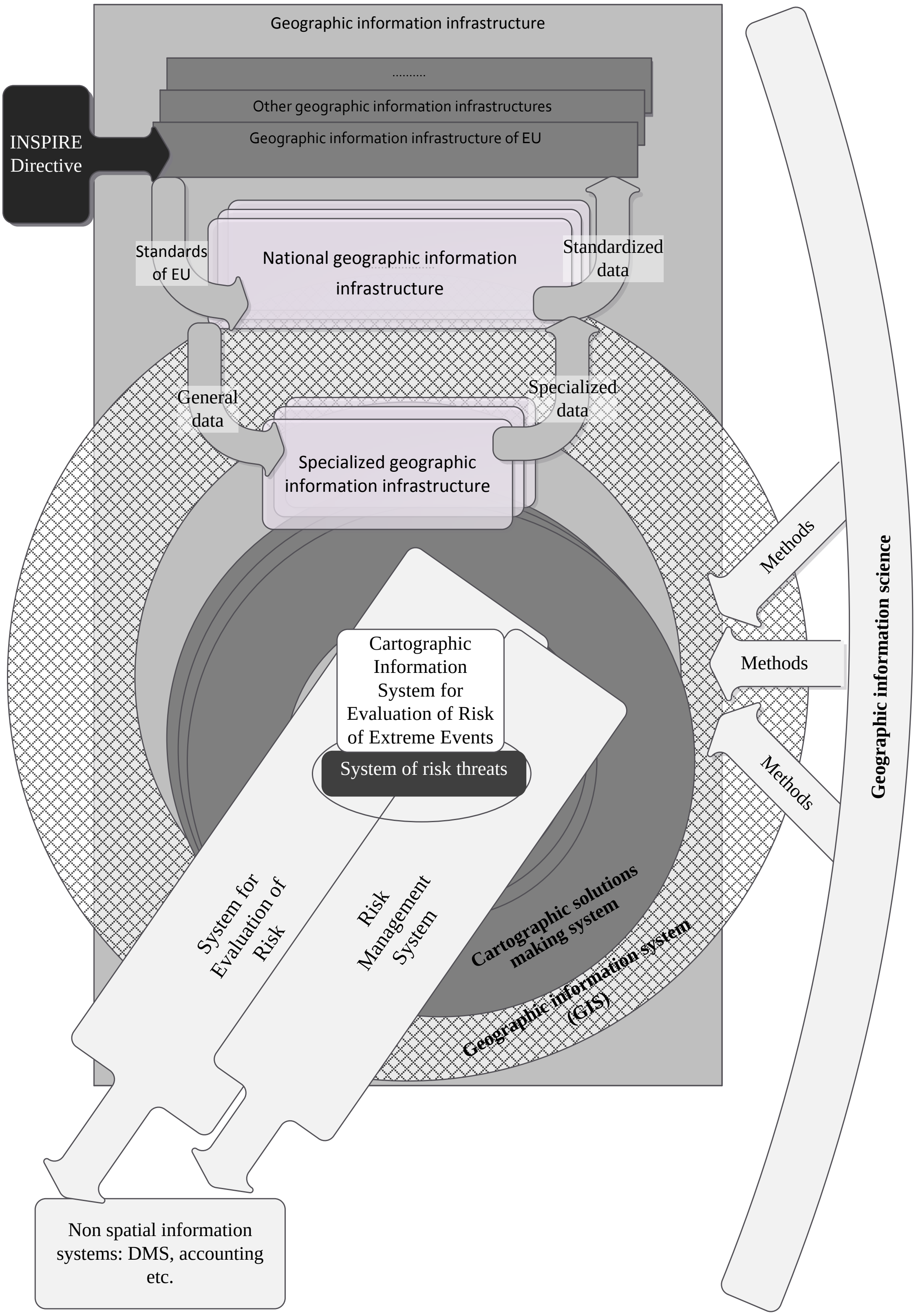

Fig. 2. Place of the EREE Cartographic Information System in GII.

To summarize the activities related with civil security systems held in Europe the author distinguishes the hierarchy of three types of the infrastructure (or systems):

1. data collections and provision,
2. evolution of the extreme events such as the EREE cartographic information system,
3. response to the extreme events and consequences elimination.

The second type of the infrastructure (or systems) cannot function without data collection and provision systems, but the third type can function independently from any other infrastructures mentioned before. In order to reach the efficiency of the quick response functions the results should be taken into consideration for the evaluation of extreme events which allows predicting the prevention. It should also be noticed that the latest scientific researches mention the civil security infrastructure more often (Mazzetti *et al.* 2009). Such infrastructures should involve all the infrastructures (or systems) mentioned by the author.

The author emphasizes that there are independent civil security systems developed in Lithuania, which solves particular types of problems. These kinds of systems are not integrated and do not work cohesively.

2. MATERIALS AND METHODS

The whole Lithuania or parts of it face the impact of extreme events. The spatial extents of the threats are defined by the databases of extreme events. The spatial threat is always areal and spatial database will be further used for the map algebra calculation. For this reason, the format of the threat's database is chosen as a raster. For each type of threat the raster layers for the whole territory of Lithuania will be made. Raster data will be made from the squared cells where each height and weight of the cell is equal to 100 meters. Speed of computing and sufficient accuracy of results influence the selection of such cell size.

The interpolation method defined by Shepard (1986) has to be used for the calculation of cells values of raster data when the place of source data is stable (for example, information from meteorological stations). Otherwise for making raster data the author chose to use kernel calculations.

For the second case the calculation of cells values of raster data must be performed in the following order when the source data are represented as points:

1. The formula for the 4th dimensional sphere data (Silverman 1986) has to be used for the calculation of kernel K:

$$K = \frac{3}{\pi}\left(1 - \left(\frac{r}{R}\right)^2\right)^2, \text{ when } \frac{r}{R} \leq 1, \text{ or } K = 0, \qquad (1)$$

where r – distance to the analysed cell, and R – radius of the analysis.

According to this function the graph below (Fig. 3) represents the distribution of the estimated values in the distance from the center of the analysed cell.

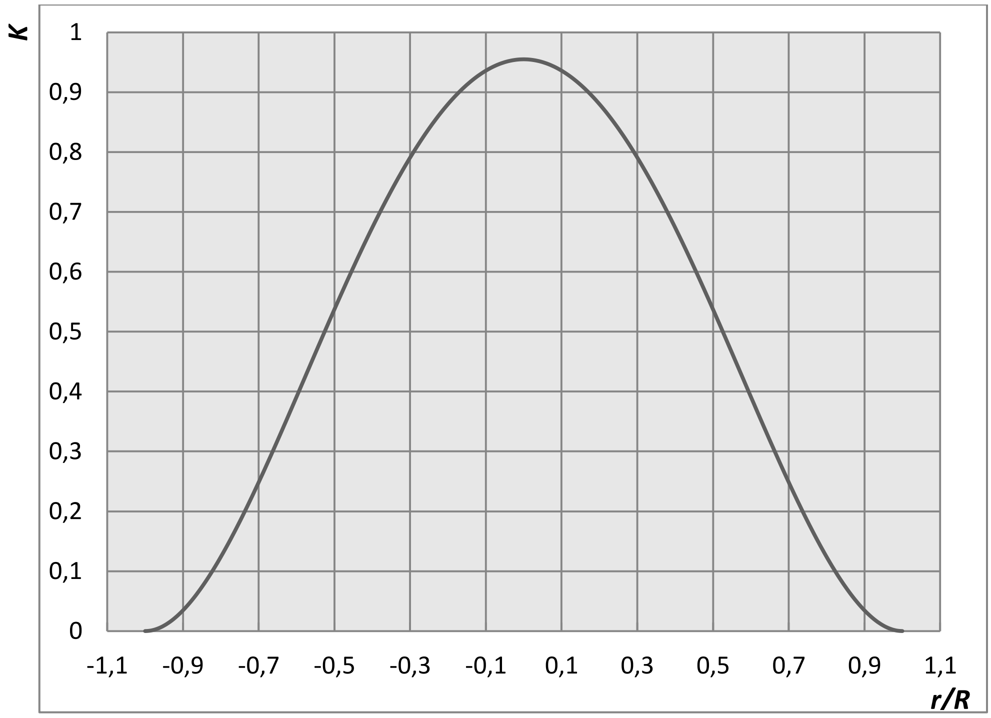

Fig. 3. Distribution of kernel values.

If the inequality $\frac{r}{R} \leq 1$ in a cell is correct for more than one point from the layer where the density is calculated, then:

$$K = K_1 + \cdots + K_n \qquad (2)$$

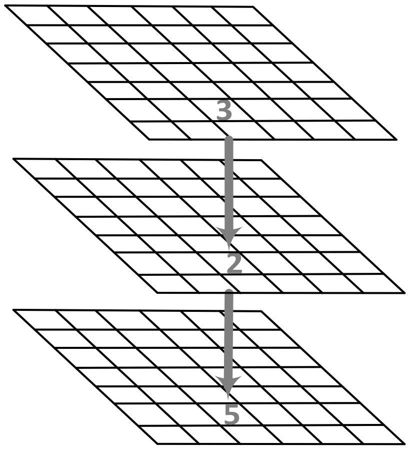

Fig. 4. Principle of kernel values aggregation.

2. Kernel's density value K_T is equal to each cell divided by the study area size:

$$K_T = \frac{K}{\pi R^2} \qquad (3)$$

3. Kernel's density value K_S with an estimated weight is calculated by multiplying Kernel's K value by weight coefficient a:

$$K_S = \frac{Ka}{\pi R^2} \qquad (4)$$

The calculation of cells values of raster data must be performed in the same order as mentioned above when the source data are represented as points. The line's kernel density value is calculated in the same way as the point's just that the raster data is created around each line. Moreover, the value of the cell is multiplied by the length of the line.

The intervals of calculated cells values may be different and vary depending on source data. Therefore, it is very important to unify scales for different sets of calculated values before creating final raster layers of threats. The task required the reclassification of the cells values. According to the statistically-based method of interval classes (method of Jenks 1967) new corresponding values are assigned in the range from 1 to 10 by every item.

The raster layer of synthetic threats is created in the assessment of all threats. In this case the weighted sum is calculated in each cell of the study area by the formula to find a value V:

$$V = \sum_{i=1}^{n} a_i k_i \text{, where } \sum_{i=0}^{n} k_i = 1, \qquad (5)$$

where a is weighted values of the cells.

For the map of the synthetic threats of the Lithuanian territory the overlay analysis is the most suitable method to integrate and evaluate different criteria from different resources analysing raster databases in order to know the distribution of the data in space.

The result of such an overlay analysis is a synthetic threats' map compiled from different maps of threats which are made from different data sources. The principal diagram of the overlay method is shown below (Fig. 5).

As it is visible from the scheme below to create such kind of a map requires many evaluation criteria and their prioritization of ratio of distributed social (anthropogenic, technological), natural and ecological threats. The ratio between the mentioned threats might be proportional or some of the components might be singled out. To this end, the operation of the weighted overlay V will be performed according to formula (5).

For the moment, the most important is to define the coefficients k for each component, that is, to prioritize it. The distribution, statistical rate and intensity of each component are already provided in the very data, and possible damage and its extent are assessed while rating the vulnerable objects, operational area and zones of threats are analysed in the further chapter.

The prioritizing is possible while making calculation and gradually increasing the priority of the components. Later each component is changed by the coefficient k. The results achieved are used to evaluate the influence of the parameters applied for the risk forecast on the study results. Meanwhile, to check the reliability of the model, the results produced are compared with the real historical extreme events.

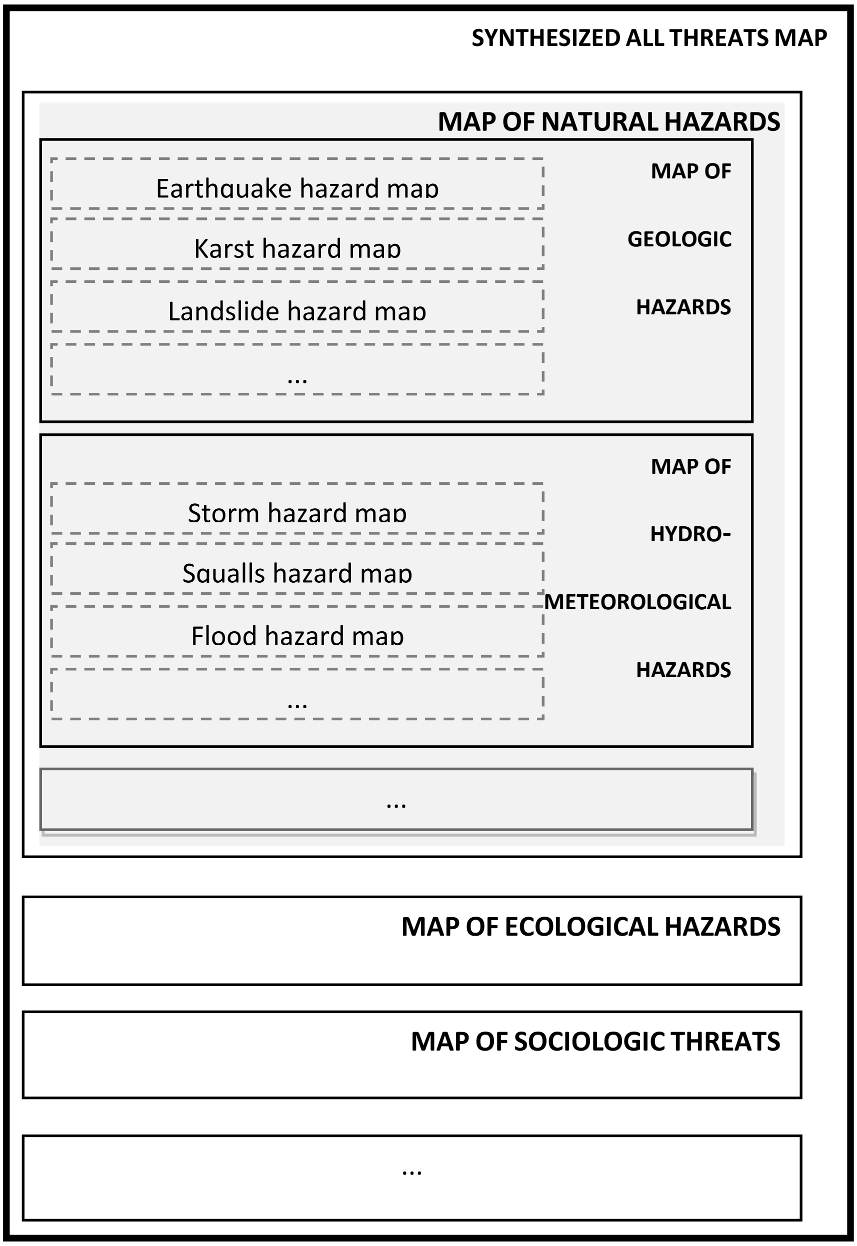

Fig. 5. Principle diagram of overlap.

The methodology of vulnerable objects' determination in threats' zones

This chapter presents the methodology of how to identify the object which falls under the zones of threats. Surely, all objects on the Lithuanian territory fall under one or another zone of the possible threat. To define exactly which objects fall under which zone it is necessary:

1. to build a database of vulnerable objects;

2. to distribute vulnerable objects by typology assigning each of them an attribute value;

3. to create the buffer zones around the vulnerable objects, namely, zones where the damage might be done for the particular objects.

The database should be saved after identification of all types of plot, linear and point types of data. For example, the plot objects are all densely settled areas (cities and small cities), crops, and forests. The linear objects are roads, pipelines, over ground electric lines, communicational lines, rivers. The point objects are special case objects like the Nuclear Power Plant in Visaginas, the Port of Klaipeda, Mazeikiai Oil Refinery, “Azotas” of Jonava and other big factories. The distribution of typological objects by sensitivity to the extreme events allows assigning the appropriate attribution information and, based on that, calculating the buffer zones around these objects.

The methodology of the analysis of threats and risks by the created model

Extreme events are important when they present a threat to people, their property, infrastructure and environment. The huge flood or drought would never make any damage in an uninhabited or empty territory. The evaluation of risk in such a case would be low. The risk would be high or even very high if such an event would happen in a dense living city with many factories or intensive agriculture (Fig. 6).

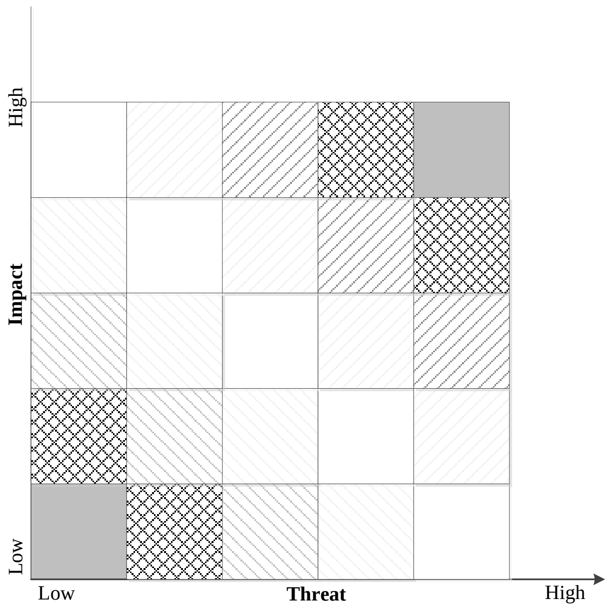

Fig. 6. Dependence of risk on the size of the threat and strength of impact.

The right forecasts or decisions of evaluation are always based on the results of the analysis of the surrounding environment. The results are closely related to the components of sustainable development. The map of the risks is based on natural and social activities and their variation in time. Such abundance and complexity of parameters as well as huge amount of alternatives, existing controversy in data and constant change in the various data on the environment may be covered and evaluated by the model of the varying map. The model at each of its stages uses methods of the spatial (geographic) data analysis necessary for this task. Figure 7 displays the principal decision making scheme after the evaluation by the designed map.

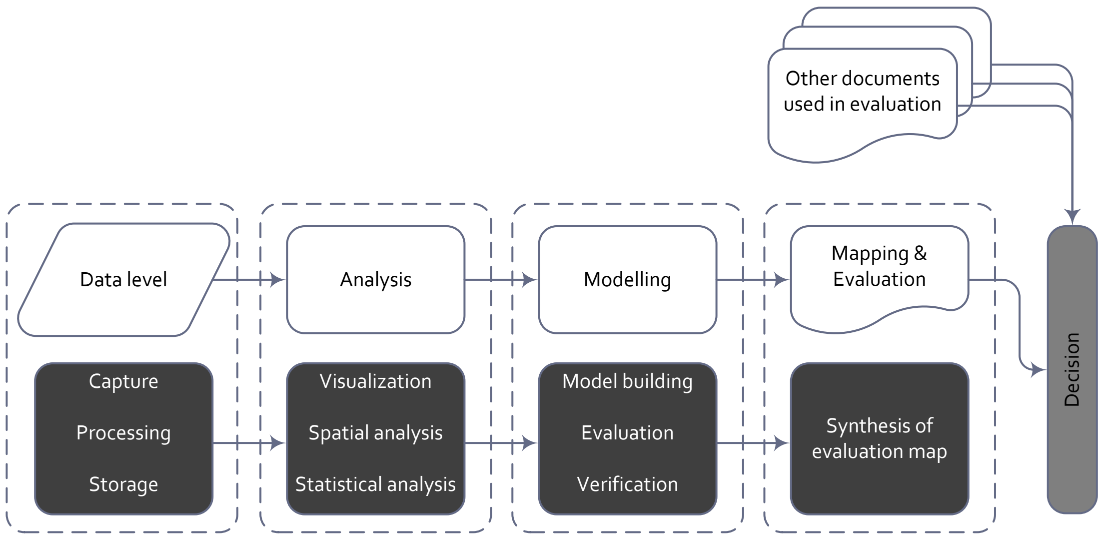

Fig. 7. Diagram of decision making based on spatial (geographic) data.

The scheme shows that various geographical technologies and methodologies might be used for the cartographic decision making systems, including EREE cartographic information system analysed by the author.

The model for the risk map comprising all the stages shown above is developed with the help of GIS software and on the basis of the earlier research by the author and other researchers. The result of the model calculations is a map of the territory of Lithuania or any study area in the Lithuanian coordinate system. The value of the risk, depending on the combination of the threat's intensity and vulnerable objects under threat, is represented in each place of the map. For the map representation the legend is provided where each combination of values is given certain intensity of a colour.

This risk map is produced after the attributive spatial merge of synthetic threats with a map of buffer zones of vulnerable objects. The scheme shows the sequence of the actions (Fig. 8).

Fig. 8. Risk mapping principal model.

The spatial and attributive data merge may lead to different combinations of threats and valuable objects, thus revealing different risks:

1. Not intensive threats and not strongly influenced vulnerable objects – lower risk.
2. Intensive threats and not strongly influenced vulnerable objects or not intensive threats and strongly influenced vulnerable objects – medium risk.
3. Intensive threats and strongly influenced vulnerable objects – big risk.

It is to see that, before the production of the risk map using the spatial attributive merge, maps of vulnerable objects (Fig. 9) and synthetic (Fig. 10) or a map of a single threat (Fig. 11) should be developed first.

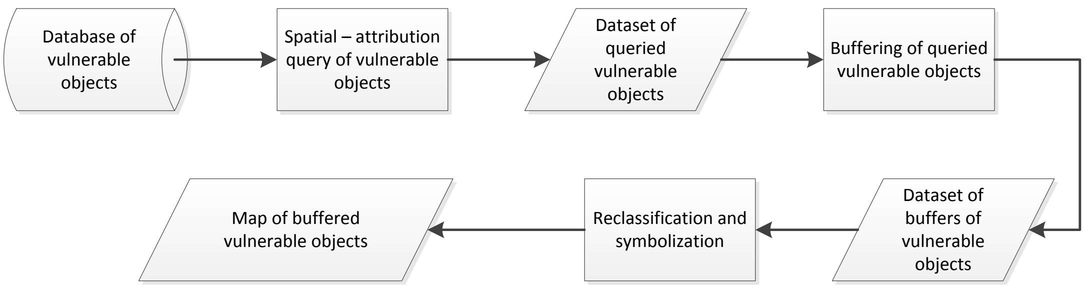

Fig. 9. Principal model of mapping vulnerable objects.

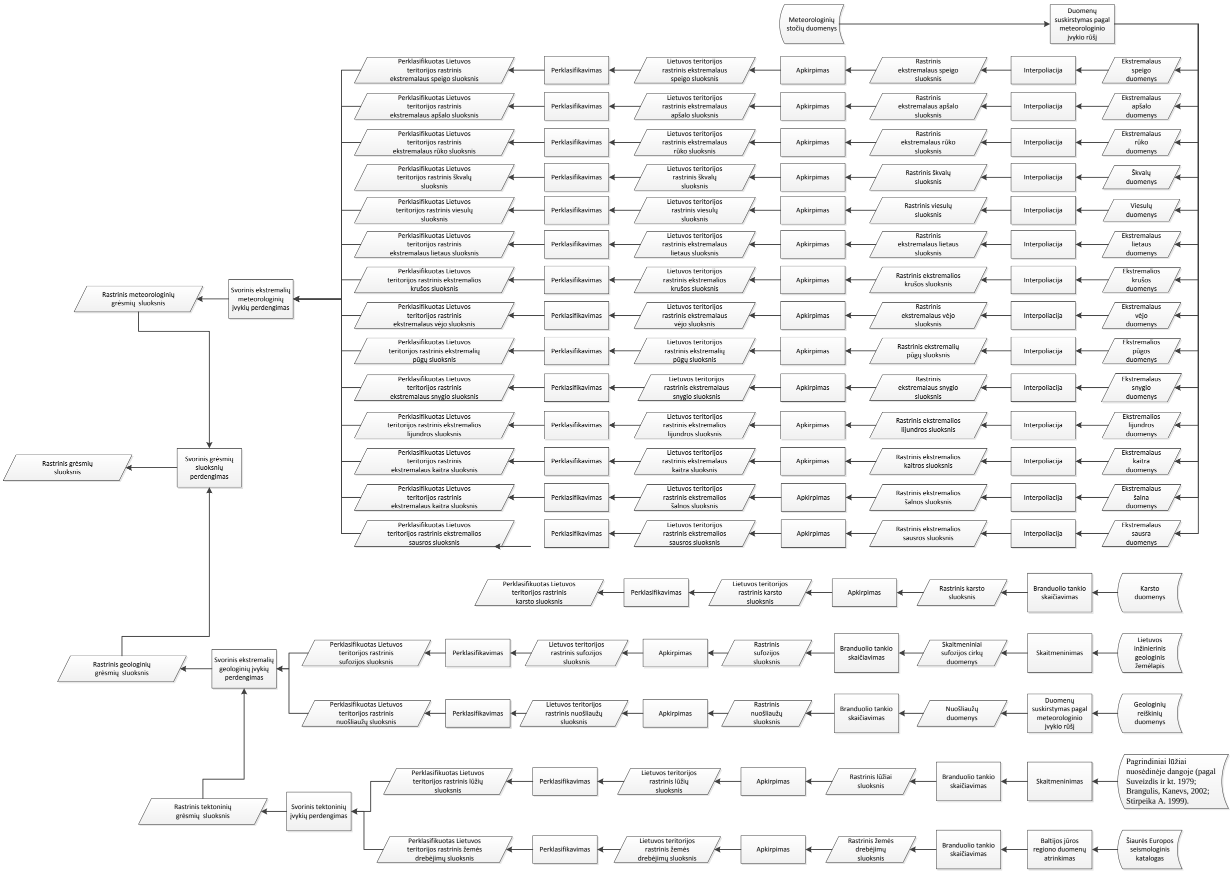

Fig. 10. Model of synthetic threat calculation.

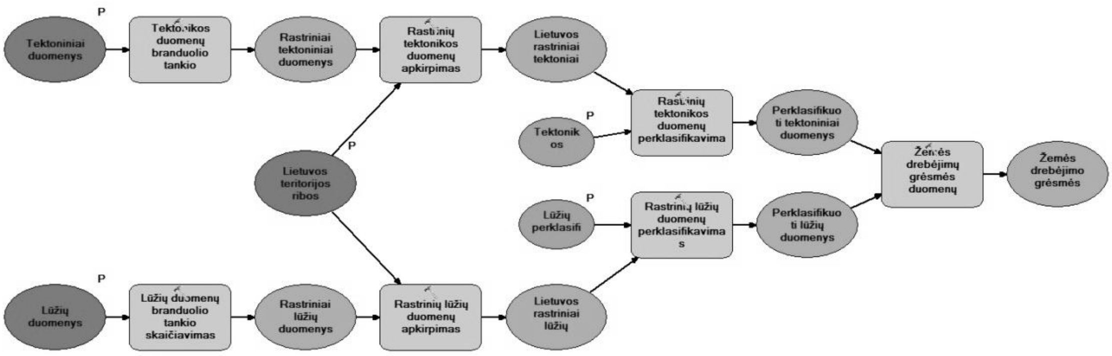

Fig. 11. Example of a model of single threat calculation.

Model for the risk evaluation GIS infrastructure in Lithuania

Geographical data for the evaluation of risks of extreme events should be divided into two parts:

- relevant for the databases of extreme events;
- relevant the databases of vulnerable objects.

The database of threats should store the data format of natural and technical extreme events. Consequently, the following data must be included in the databases of threats:

I. Information on natural events:
   1. Geological phenomena;
   2. Hydro meteorological phenomena;
   3. Events related with floes or ice drifts;
   4. People diseases;
   5. Insects invasion;
   6. Animal diseases;
   7. Plant diseases;
   8. Fish choke, wild animal and bird starvation.
II. Information on technical events:
   1. Transportation events;
   2. Industry events;
   3. Power systems' events;
   4. Hydro technical plant's, utilities system's failure;
   5. Object functioning break.
III. Information on ecological events:
   1. Pollution;
   2. Water contamination;
   3. Pollution by nuclear and/or radioactive substances;
   4. Oil spill.
IV. Information on social events:
   1. Uncontrolled crowd of people;
   2. Event in a borderland or territorial sea;
   3. Event related with a criminal or terrorist acts.
V. Information on other extreme events:
   1. Fire;
   2. Dangerous findings;
   3. Event posing danger for protected persons or protected objects.

The database of vulnerable objects should store data about objects which can suffer damage caused by the different types of extreme events mentioned above. Data in the vulnerable objects' database has been chosen to identify the location of objects or territories. It also includes data from the Lithuanian registers or cadastres, state spatial (geographic) data sets and information systems' data. The database of vulnerable objects consists of:

1. Transportation infrastructure,
2. Engineering communications,
3. Buildings and constructions,
4. Water bodies,
5. Land cover,
6. Buid-up territories,
7. Hydro technical objects,
8. Other objects,
9. Statistic data.
10. Watering places.

The principal scheme for data flows of the risk evaluation cartographic information system starts from the data collection from spatial (geographic) data sources. As mentioned above, two types of data sources are distinguished by the type of usage:

1. Data needed to create a vulnerable object database.
2. Data needed to create an extreme event database.

The third type of the data combines both (first and second) types. For this type of data source data falls under both types of databases.

The first data flow from spatial (geographic) data sources to the databases of extreme events and vulnerable objects is a single action. This is why there is a possibility to apply automatic single actions, data converting and data input from the paper archives. In order to maintain these databases the automatic infrastructure should be created which would automatically update these two different databases. Since there is a great variety of data sources and the data are saved in different formats, the most suitable model for software data transformation is ETL (Extract-transform-load).

Further, threats calculation is applied which combines all the threats into raster databases. This one and the model which will be described in the following chapter should be saved and prepared for the activation of the user's needs. This means that the user of the system is able to choose the parameters of the threats calculation. GIS software has the analogical possibilities which allow calling one model from another (Fig. 12).

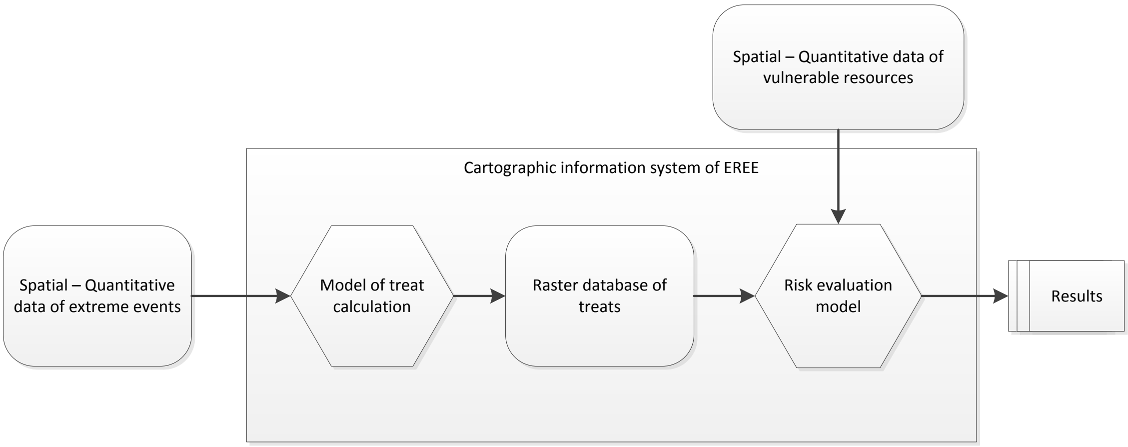

Fig. 12. Linking of computational models of risks and threats.

The data created in the raster threats database and data of the vulnerable objects database are overlaid in a risk calculation model. The result is a synthetic risk map. Then, the data can be provided for the public through the LGII portal as OGC WFS or WMS, and REST services. A little more complex process is needed for the risk calculation model as a spatial analysis service. Here, the parameters should be defined to enable the necessary change by the user. Allowing a change in a few or more parameters enables the user to calculate the risk in various methods and compare results with each other or with a standard model.

3. RESULTS

Specification of cartographic information evaluation of risks of extreme events

All the EREE cartographic information system is designed to function in the geographic information portal of Lithuania (www.geoporal.lt) (Fig. 13). The portal holds all the services by the defined functions. The basis of EREE cartographic information system is a hyper model developed according to the methodology described in the thesis. This model is accessible through the portal for everyone who has a license to use this system. The model displays the input parameters so if there is a need the user can change it. The initial data preparation is not the purpose of this work but it is necessary for testing scenarios. The hyper model is based on single specific models for the threat calculation of extreme events. In these models the researcher may change the algorithms of calculations or add new models while calculating the threats not defined in the hyper model or when applying the model for the calculation of other spatial events. The hyper model saves the intermediate and final results in a raster data format (Fig. 14). The portal's tools allow publishing maps of threats and calculated risks.

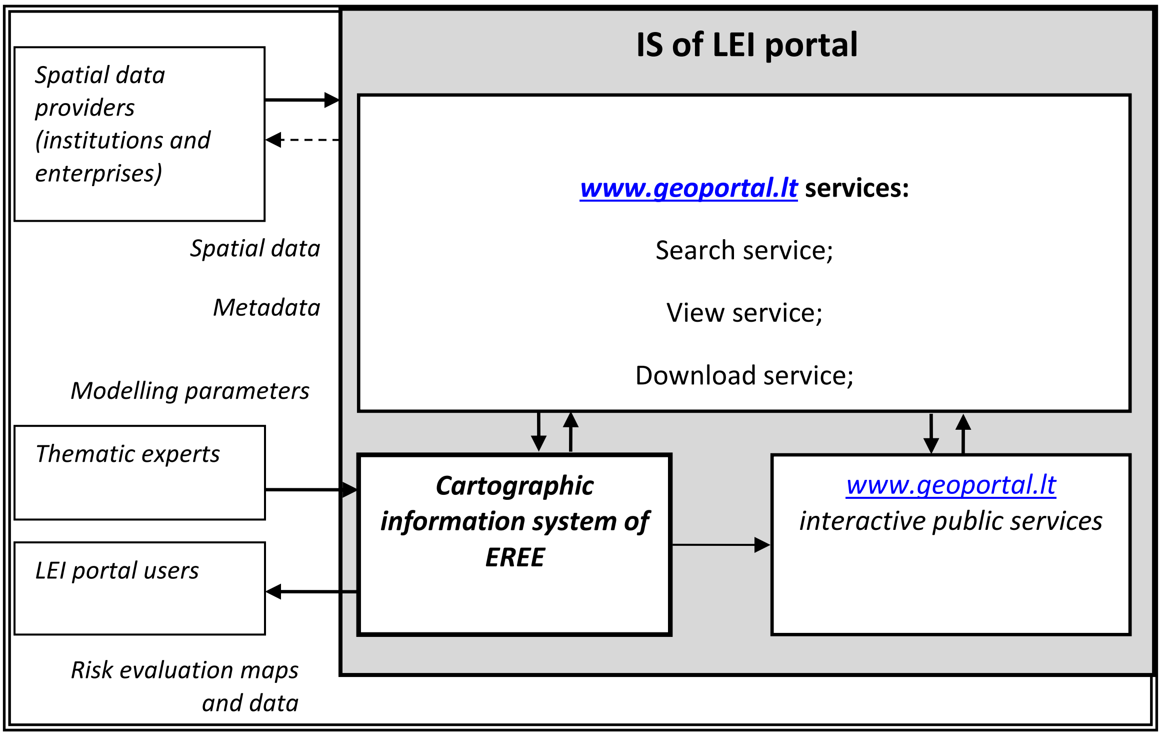

Fig. 13. EREE cartographic information system in LEI portal.

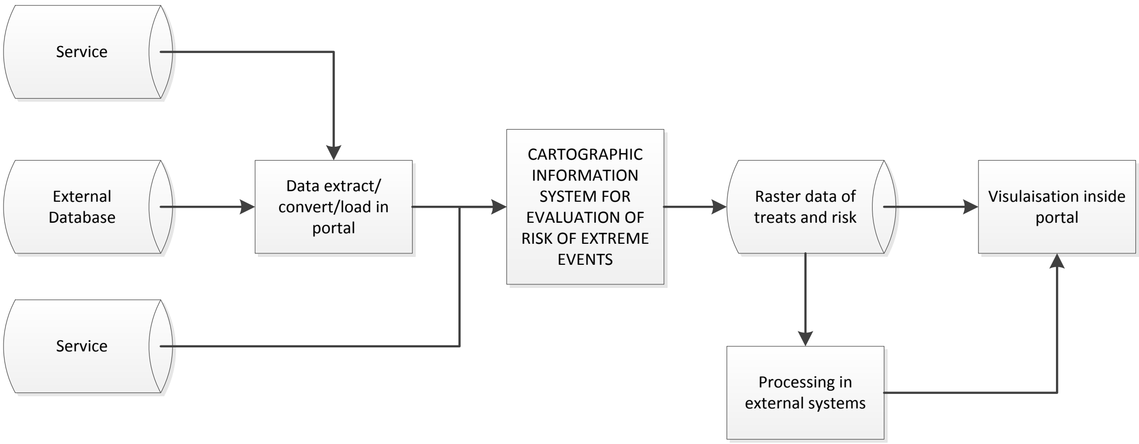

Fig. 14. Data traffic of the information system.

The EREE cartographic information system through the LEI portal tools provides the data received from the calculations. The system can provide intermediate data; data on threats of extreme events with cartographic visualization; synthetic threats data with cartographic visualization data and cartographic risks data with cartographic visualization. The data and their cartographic visualization may be published in the portal in various ways which ensures interoperability, for example, OGC, REST and in the network services (Inspire Network Services) in compliance with the INSPIRE requirements (Fig. 15).

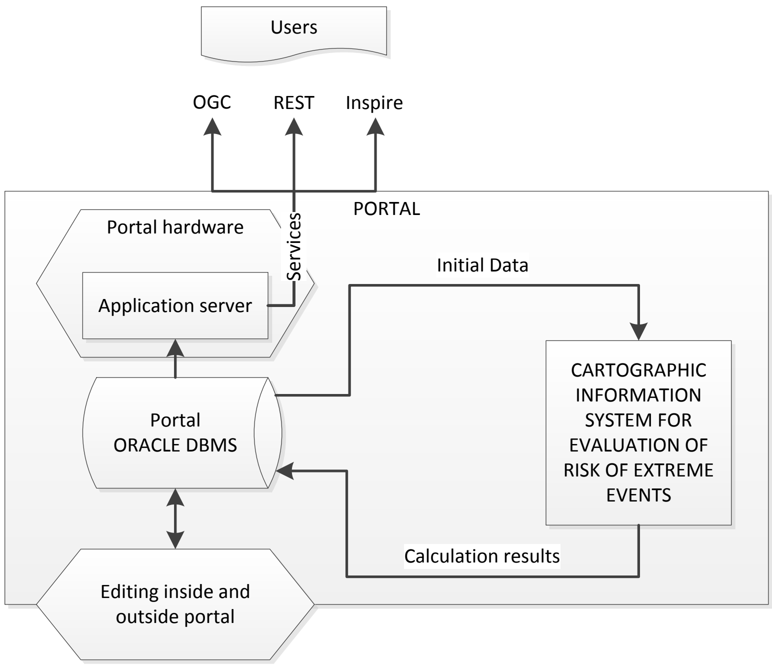

Fig. 15. Information publication for users in the EREE cartographic information system.

EREE system's testing following the model of geological and meteorological data

The raster data layers of threats of an earthquake are made from spatial records about earthquakes and geologic faults.

The process of the raster layer of threats of an earthquake is explained in the figure below (Fig. 16).

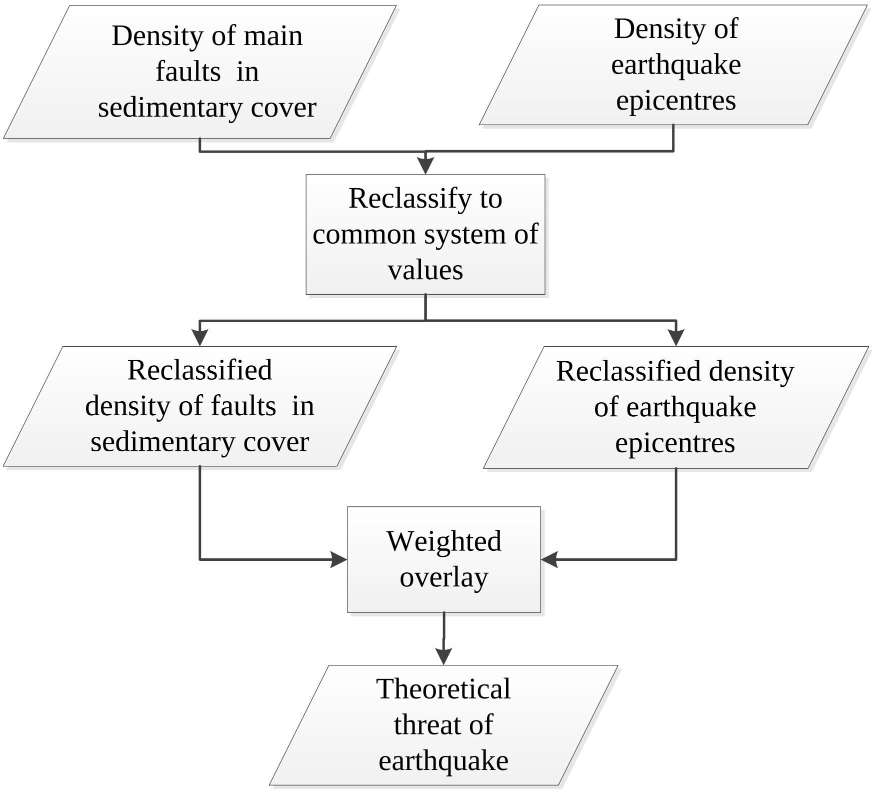

Fig. 16. Scheme of creation of a raster dataset.

The raster layer of the threat of a karst phenomenon is made from spatial records of sinkholes. With all raster layers of the analysed geological threats ranking from 1 to 10 it is possible to create a raster layer of a synthetic geological threat with an evaluation using the overlay method. For the weighted overlay the following coefficients of weights have been set up:

- the raster layer of threats of an earthquake – 0,001,
- the raster layer of a karst phenomenon with sinkholes – 0,9,
- the raster layer of landslides – 0,09,
- the raster layer of a suffusion phenomenon.

Evaluating these coefficients and using the weighted overlay method it is possible to calculate the raster layer of synthetic threats (Fig. 17).

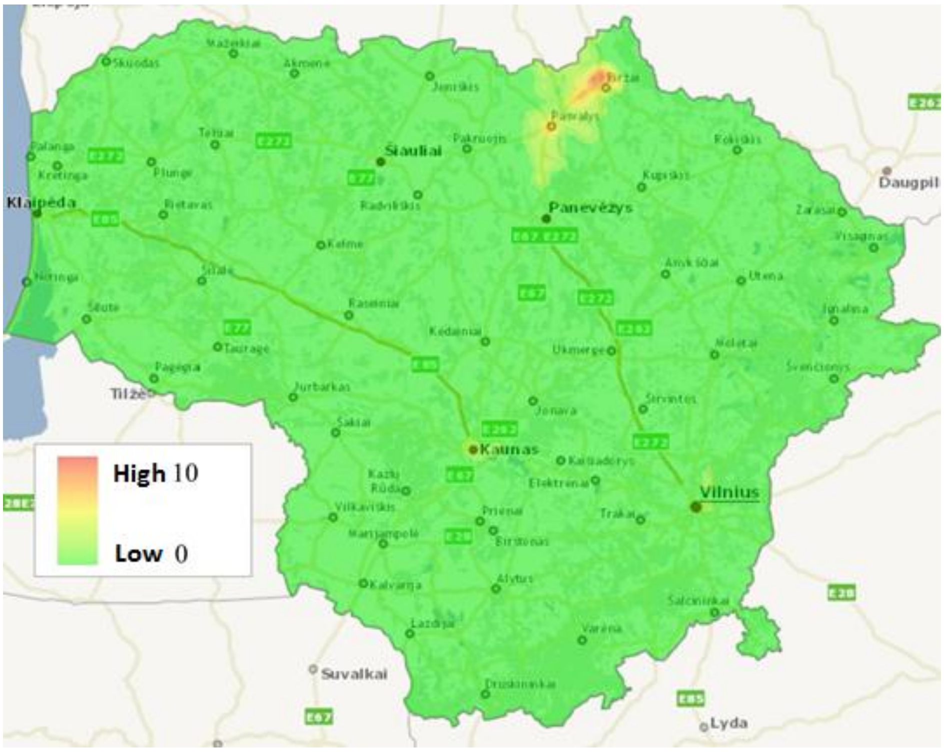

Fig. 17. Synthetic geological threat rated on a scale from 1 to 10.

Afterwards, the raster layers of meteorological threats (Fig. 18, Fig. 19, Fig. 20) are formed from the data collected in meteorological stations. In contrast to the geological extreme events the monitoring of the meteorological extreme events is performed in fixed meteorological stations. In cases when the monitoring places are fixed an interpolation is used to get the values in transitional positions.

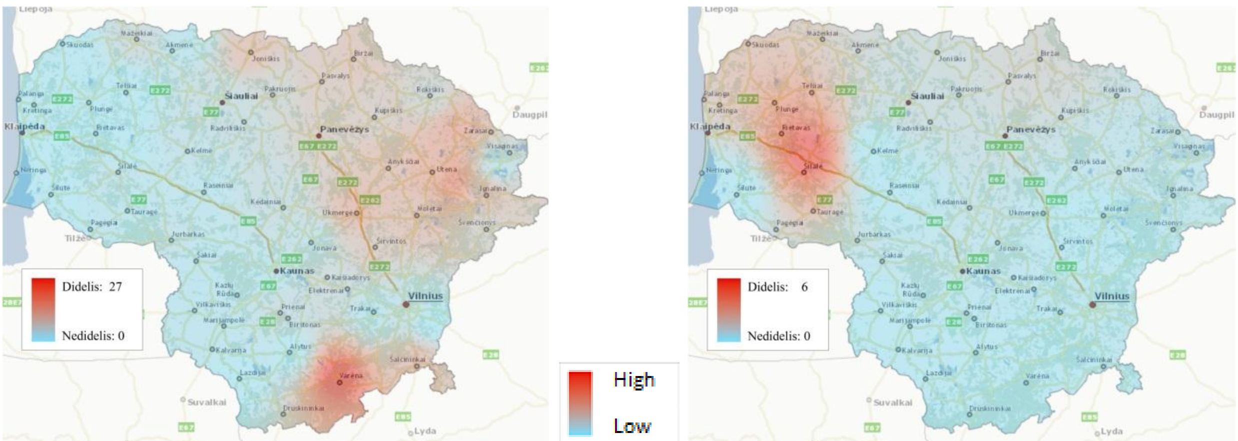

Fig. 18. Distribution of extreme cases of cold and rime.

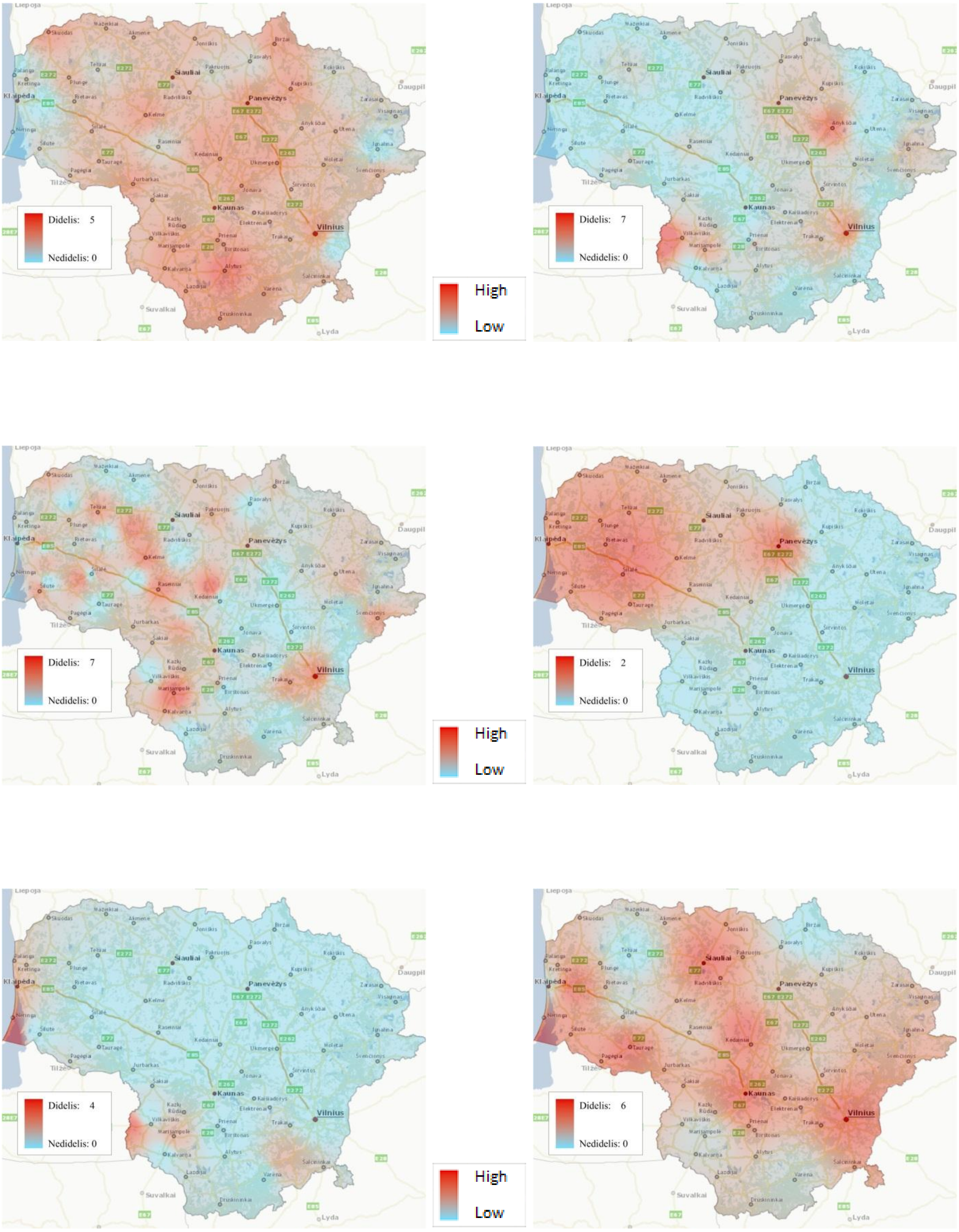

Fig. 19. Distribution of extreme cases of heat, hail, rain, freezing rain, blizzard and fog.

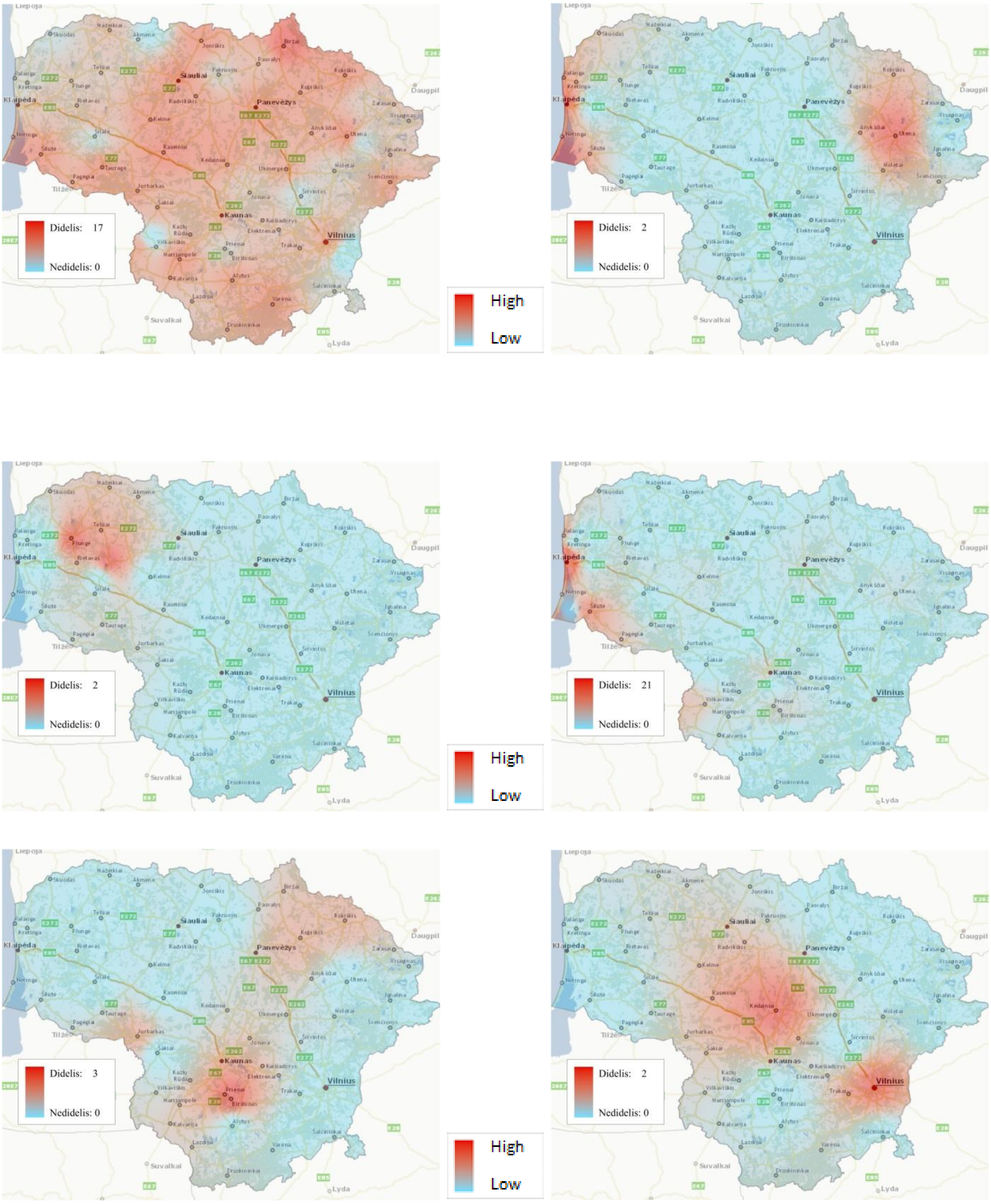

Fig. 20. Distribution of extreme cases of frost, drought, snow, wind and distribution of squalls and tornado.

The intensity of meteorological threats by the area in Lithuania is distributed quite uniformly, unlike the intensity of synthetic geological threats. The distribution allows seeing and making regions. The data was summarized using the generalization and the regions of the calculated meteorological threats were distinguished.

The meteorological threats intensity by the area in Lithuania is distributed quite uniformly not like synthetic geological threats intensity. In the distribution is possible to see and make regions. The data was summarized using the generalization and the calculated meteorological threats regions were distinguished. One may define as the regions of increased threats the seaside of Klaipeda, Joniskis and Pasvalys - Birzai, North-East region and the region of Varena. The West-Central South-West region, Vilnius -Trakai - border line and Visaginas region are defined as the regions of decreased threats. The regions of medium threats are Silute – Silale – Taurage - Pagegiai regions and North - Central South - East region.

The results led to regioning of the distribution of the general synthetic threats in the Lithuanian territory, which is not different, due to small spread of synthetic geological risk, from that of a synthetic meteorological threat (Fig. 21).

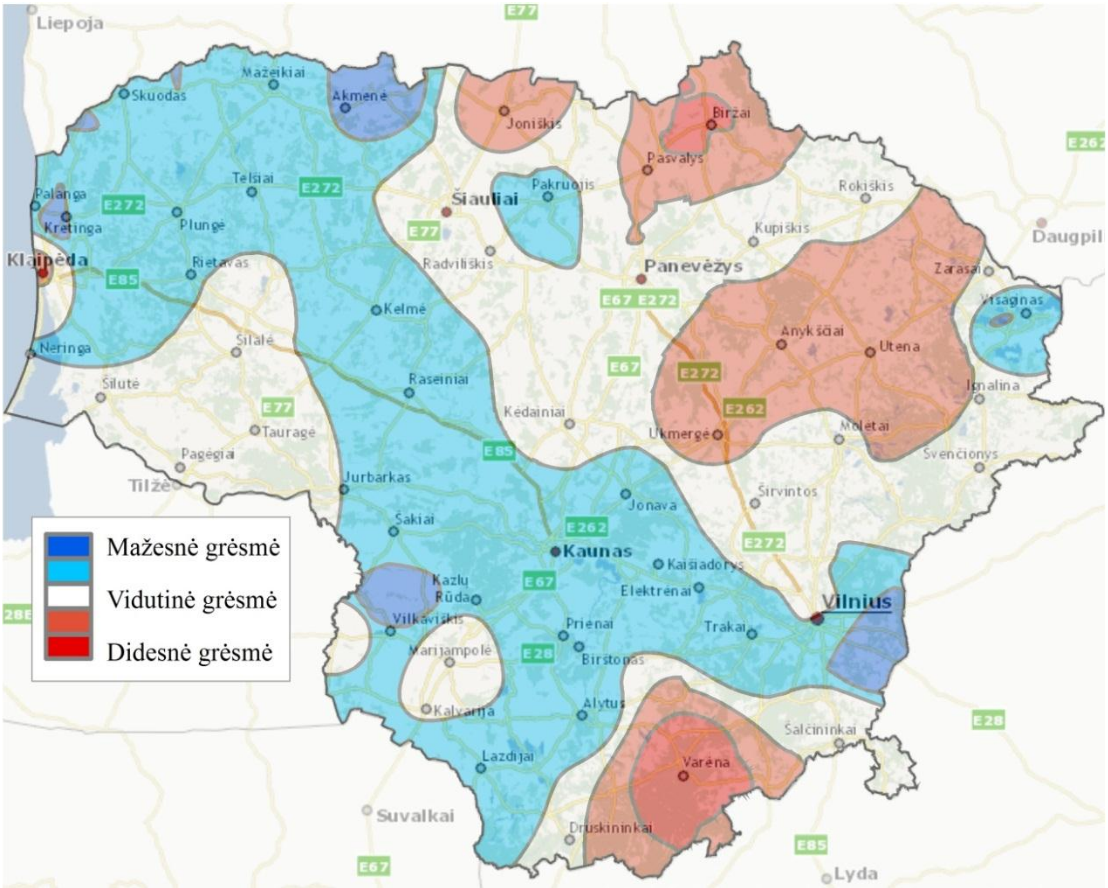

Fig. 21. Synthetic region map of general threat to the territory of Lithuania.

In the regioning of a general synthetic threat it is possible to distinguish increased threats in the district of the seaside of Klaipeda, region of Joniskis and even the calculated more intense threats in the Pasvalys and Birzai regions. There remained the North-East region and region of Varena of the increased calculated threat. West-Central-South-West region of the decreased calculated threats was integrated with the region of Vilnius – Trakai - border line. There also remained a small region of Visaginas of decreased threats and Silute – Silale – Taurage - Pagegiu regions of medium threats and a more scattered region of the North - Central South - East region. Mostly, insignificant changes have been influenced by the different data samples from the geological and meteorological threats data. For that reason the tolerance of mean square values has been changed a little bit and the regioning changed as well. The biggest changes have been made by the threats of the karst region, where the threats have been more intensive in the region of Pasvalys - Birzai. This is why the region is even better distinguished by the system.

CONCLUSIONS

Methodological conclusions

There are enough geographic data from various fields in Lithuania that could serve to evaluate and forecast the risk factors of extreme events. Before 2009 data collection and relating as well as combined use had been very complicated and possible only theoretically. However, the development of the geographic information infrastructure of Lithuania and Geographic Information Portal of Lithuania in the same year has changed the situation in essence. The EREE cartographic information system presented herein will effectively make use of the possibilities of interoperability, map publication and cooperation offered by the Geographic Information Portal of Lithuania.

As the work result, a new methodology has been developed during the work process based on the integration of different data sets. This methodology allows building and developing an exceptionally flexible and adaptable EREE cartographic information system operating in the GIS software environment. The key results produced in the system are maps summarizing one or more selected risk indicators.

The built prototypical EREE cartographic information system is original, not only on the national, but also on the global level, in that it allows relating risk factors of various types and encourages the cooperation among experts in its improvement.

The proposed model for the cartographic information system of risk management offers preconditions for relating physic and human geography risk factors of extreme events in one management and forecast system. The model enables, in contribution to the implementation of INSPIRE Directive in Lithuania, creating new geographic data, on the national level, based on the Directive Annex III.12 “Natural risk zones” (vulnerable areas characterised according to natural hazards (all atmospheric, hydrologic, seismic and wildfire phenomena that, because of their location, severity, and frequency, have the potential to seriously affect society).

The proposed model for the cartographic information system of risk management permits its development on a scientific base, with the participation of experts from relevant fields; as well as the integration of new parameters and analysis of risk in the necessary aspects.

Practical conclusions

There are multi-criteria evaluation and forecast systems that are very widely used worldwide. Nevertheless, its application in the research using geographic parameters is limited or at the experimental stage.

Most often, evaluation and management research of risk of extreme events are restricted, because of its complexity, to a small territory or one or several extreme events of the same origin as input parameters. Most of the established and operating EREE cartographic information systems are purposefully designed only to alleviate the consequences of the extreme events that already happened.

The development of the EREE cartographic information system in Lithuania creates possibilities for predicting, avoiding or reducing possible damages on the Lithuanian territories in issue. The model of the author is suitable to integrate all the data on extreme events. The system based on this model used data sets comprising only a small part of the themes, but it may, at any time, include any new data or may change the data sets already in the system.

The model for the EREE cartographic information system was tested practically with the spatial (geographic) data sets on major risky geological and meteorological events available in Lithuania. Thus, the method of the model verification was proved by the experiment. It identified that the model is not restricted to any number of types of integrated spatial (geographic) data and their sets. The reliability of the model depends on correctness and completeness of input data and on properly selected weight parameters of different risk factors that could be identified both theoretically and empirically. The system allows evaluating the model sensitivity to changes in parameter values quantitatively and visually using fast risk mapping.

LIST OF PUBLICATIONS ON THE DISSERTATION TOPIC

1. Beconytė, G.; Kryžanauskas, A.; Papšys, K.; Papšienė, L.; Stankevičius, Ž. 2009. Lietuvos geografinės informacijos infrastruktūra – kelias į bendrą geografijos metodologiją. Geografija. 45(1):1-10. ISSN 1392-1096.
2. Papšys, K. 2012. "A model of cartographic information system for evaluation of risk of extreme events". Meta-carto-semiotics. Journal for theoretical cartography // ISSN 1868-1387 // indexed in DOAJ (reviewed, accepted).
3. Papšys, K. 2012. Ekstremalių įvykių rizikos kompleksinio vertinimo kartografinis metodas. Geografija. 48(2): ISSN: 1392-1096 (reviewed, accepted).
4. Papšys, K.; Papšienė L. 2012. Possibilities of updating small-scale basic spatial data in Lithuania using generalization methods, Geodesy and cartography. 37(4): 143-148. ISSN 2029-6991 (Print), 2029-7009 (Online). (Scopus; GEOBASE; ICONDA).

PARCITIPIATION IN SCIENTIFIC CONFERENCES

1. Papšys Kęstutis. Conceptual model for generalisation of Lithuanian spatial reference data // 8th International Conference "Environmental Engineering", Vilnius, 2011/06/19-20.

2. Papšys Kęstutis. „Cartography for risk evaluation“ // 6th seminar of cartosemiotic (VU), Vilnius. 2011/04/08.

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SANTRAUKA

ĮVADAS

Visais laikais žmoniją domino jos gyvenamosios aplinkos kokybė. Ir Lietuvos visuomenė nėra išimtis. Gyvenamosios aplinkos kokybė gali būti vertinama įvairiais aspektais. Vienas svarbiausių tokios aplinkos kokybės požymių yra gyvenamosios aplinkos saugumas. Žmonėms aktualu, ar jie yra saugūs supančioje gyvenamoje aplinkoje, taip pat, ar saugus jų turimas turtas.

Tiriama problema

Saugumo svarbą taip pat rodo įvairūs tyrimai. Pavyzdžiui, Vidurio Europos gyventojų nuomonės tyrimų grupės (angl. *Central European Opinion Research Group*) užsakymu 2001 metais Lietuvoje buvo tiriama viešoji nuomonė dėl branduolinės energetikos ir jos saugumo vertinimo (Gaidys ir Rinkevičius, 2008). Šios apklausos metu 76% respondentų atsakė, kad nepritartų atominės elektrinės kaimynystės (10-20 km atstumu nuo gyvenamosios vietos) projektui. Be to, net 64% respondentų neatmetė tikimybės, jog Visagino atominėje elektrinėje gali įvykti rimta avarija.

Aplinkos saugumo vertinimą galima atlikti įvardinant rizikos, kuri dėl įvairių priežasčių gali kilti žmogaus ar jo turto saugumui, veiksnius ir įvertinant jų apraiškos mastą.

Aplinkos saugumą lemiančių rizikos veiksnių vertinimas yra atliekamas ne tik įvairiose veiklos srityse (miestų planavimo, ūkinės veiklos, energetikos plėtros, sveikatos apsaugos ir draudimo, turto draudimo ir kt.), bet ir skirtingose institucijose (kariuomenėje ir kt.), atsakingose už valstybės ir jos piliečių saugumą.

Keičiantis klimato sąlygoms, kinta ir gamtinės, ekologinės, technogeninės bei antropologinės rizikos pobūdis visame pasaulyje, žinoma, ir Lietuvoje. Dėl per pastarąjį dešimtmetį įvykusių gamtinių, antropogeninių ir technogeninių ekstremalių įvykių visuomenei kylančių grėsmių skaičius auga, jų įvairovė didėja, grėsmės tampa dažnesnės ir intensyvesnės. Pastaraisiais metais Lietuvoje fiksuojami šie ekstremalūs reiškiniai:

- škvalas, nešantis didelius nuostolius miškų ūkiui;
- vasaros ir žiemos temperatūrų ekstremumai;

- gausūs krituliai, nešantys nuostolius žemės ūkiui;
- ekstremalūs vėjai ar didelės audros, niokojančios turimą turtą; be to, dėl šių vėjų jūroje susidariusios aukštos bangos prisideda prie pakrantės ardymo proceso.

Analizuojant Lietuvos teritorijoje galinčias kilti grėsmes, taip pat būtina atsižvelgti ir į pasaulyje vykstančius ekstremalius įvykius, kurie gali tiesiogiai įtakoti Lietuvos visuomenės gyvenimo kokybę. Pavyzdžiui, susidarius tam tikroms meteorologinėms sąlygoms, išsiveržusio ugnikalnio pelenai gali ilgam sutrikdyti orlaivių eismą virš Lietuvos teritorijos ir taip padaryti nuostolių tiek Lietuvos gyventojams, tiek ir Lietuvos teritorijoje veikiančioms įmonėms. Daug nuostolių padaro ir technogeninės prigimties ekstremalūs įvykiai: gaisrai gamyklose, laivuose ir pan. Be to, pastaraisiais metais Lietuvoje nuostolių patiriama ir dėl antropogeninio (konkrečiai, socialinio) pobūdžio įvykių, pavyzdžiui, masinio sporto aistruolių siautėjimo futbolo rungtynių metu.

Reikia atkreipti dėmesį, kad rizikos veiksnių ir su jais susijusios gyvenimo kokybės, taip pat ir saugumo, vertinimas (t.y. tokio vertinimo poreikis, darbų organizavimo periodiškumas ir kt.) priklauso nuo šalies išsivystymo lygio. Kai kuriose išsivysčiusiose šalyse, pavyzdžiui, Jungtinėje Karalystėje, JAV, Japonijoje, Norvegijoje, Švedijoje, Vokietijoje ar Australijoje minėti tyrimai atliekami jau seniai. Tiek šiose, tiek kitose mažiau išsivysčiusiose šalyse dėmesys pirmiausia yra skiriamas gamtinės prigimties ekstremalių įvykių keliamos rizikos erdvinės raiškos ir dėsningumų nustatymui bei prognozavimui. Įdomu tai, kad minėtose rizikos vertinimo sistemose visada yra vertinami nuostolių ir reagavimo greičio nustatymo parametrai. Galima pastebėti, kad tokiems tyrimams atlikti vis dažniau pasitelkiamos modernios technologijos, naujausia skaičiavimo technika, duomenų bazės, kompiuteriniai tinklai, globali padėties nustatymo sistema ir kt.

Atsižvelgus į analizuojamos Lietuvos teritorijos geografines sąlygas ir ypatumus, šiai teritorijai, kaip ir bet kokiai kitai, galima nustatyti grėsmių pobūdį, numatyti grėsmių keliamą riziką, apskaičiuoti galimus nuostolius. Teisingai įvertinus ir lokalizavus rizikos faktorius, galima sukurti Lietuvos teritoriją įtakojančių rizikos faktorių vertinimo ir verčių nustatymo sistemą, kuri leistų nustatyti gyvenimo kokybės skirtumus ir panašumus bei suskirstyti Lietuvos teritoriją pagal saugumo lygį. Tokia sistema padėtų įvertinti supančios aplinkos saugumo lygį, leistų išsirinkti gyvenimui tinkamą vietą, teritorijas verslo ar žemės ūkio vystymui, netgi tinkamus tokios veiklos vystymo būdus, bei leistų nustatyti gresiančią riziką pasirinktoje teritorijoje. Iš kitos pusės, būtina pažymėti, jog, gerinant vienus gyvenamosios aplinkos kokybės aspektus, gali pakisti ar net pablogėti kiti tos pačios teritorijos kokybės ir saugumo aspektai. Pavyzdžiui, tam tikroje teritorijoje pastačius degalinę, gali pagerėti teritorijos infrastruktūros sąlygos, tačiau gali atsirasti aplinkos užterštumo rizika.

Taigi, gyvenamoji ar verslo vystymo aplinka yra nepastovi, o šios aplinkos komponentai yra tarpusavyje glaudžiai susiję ir įtakoja vienas kitą. Dėl šios priežasties tokios aplinkos saugumo lygio kaitos prognozavimui reikalinga ypatingai lanksti ir dinamiška rizikos vertinimo sistema.

Darbo aktualumas

Pastaruoju metu pastebimas ypač didelis įvairių sričių teoretikų ir praktikų susidomėjimas geografinės rizikos veiksnių apraiškos laipsnio nustatymu ir lokalizavimu erdvėje. Pasitelkiant naujausias technologijas, žinoma ir geografinės informacijos sistemas (toliau – GIS), bei išnaudojant jų teikiamas galimybes, yra daug paprasčiau, lyginant su kitomis informacinėmis sistemomis, lokalizuoti rizikos faktorius dinaminėse geografinėse sistemose, o naudojant naujausią informaciją, šis procesas galėtų būti atliekamas interaktyviai, ir taip gauti rezultatai neprarastų aktualumo.

Lietuvoje yra sukauptas pakankamas kiekis duomenų ir surinkta daug informacijos apie mūsų gyvenamos teritorijos specifiką bei Lietuvoje vyraujančius gamtinius ir antropogeninius reiškinius. Turimi duomenys yra atnaujinami, valdomi, saugomi moderniose reliacinėse duomenų bazėse bei yra prieinami geografinės informacijos portalų aplinkoje. Šie duomenys, taip pat ir Interneto ryšio sparta, leidžia sukurti dinamišką, elektroniniu tinklu pasiekiamą ekstremalių įvykių rizikos vertinimo sistemą Lietuvoje.

Panašios specializuotos sistemos jau yra kuriamos kai kuriose ekonomiškai labiausiai išsivysčiusiose šalyse, pasiekusiose aukštą geoinformacinių technologijų išsivystymo lygį ir sukaupusiose pakankamą kiekį reikiamų geografinių duomenų. Pastebėta, kad šios valstybės teikia prioritetą didžiausius nuostolius galinčių padaryti gamtinių reiškinių (žemės drebėjimų, uraganų, potvynių ar miško gaisrų) rizikos prognozavimo projektų finansavimui ir kūrimui. Be to, paprastai informacija apie visus gamtinius reiškinius nebūna integruojama į vieną sistemą, o vietoje to, kiekvienam gamtiniam reiškiniui atskleisti yra kuriamas atskiras modelis, taip siekiant užtikrinti greitą gelbėjimo tarnybų reagavimą ir įvykusios nelaimės likvidavimą. Antropogeninių ekstremalių įvykių rizikos geografiniai modeliai yra kuriami retai. Pavyzdžiui, JAV yra sukurtas antropogeninių reiškinių rizikos vertinimo modelis, kuriame naudojami demografiniai duomenys. Vakaruose paskutinį dešimtmetį yra atliekami tyrimai, siekiant modeliuoti įvairių ekstremalių įvykių riziką konkrečiuose miestuose. Besiremdamos šia užsienio šalių patirtimi, atsakingos institucijos Lietuvoje galėtų inicijuoti atskirų ekstremalių įvykių ar jų komplekso rizikos prognozavimo sistemų kūrimą, o šioje aplinkoje sukuriamus duomenis taip pat būtų galima apibendrinti Lietuvos teritorijoje tam tikru detalumu.

Ekstremalių įvykių kriterijai Lietuvoje buvo patvirtinti Lietuvos Respublikos Vyriausybės 2000 m. vasario 24 d. nutarimu Nr. 216 „Dėl Ekstremalių įvykių kriterijų patvirtinimo“ (Žin., 2001, Nr. 18-439; 2001, Nr. 37-1252; 2005, Nr. 131-4713) ir 2006 m. kovo 9 d. Nr. 241 (Žin., 2006, Nr. 29-1004, 2009, Nr. 153-6928). Tačiau 2011 m. rugpjūčio 24 d. Lietuvos Respublikos Vyriausybės nutarimu Nr. 998 "Dėl Lietuvos Respublikos Vyriausybės 2006 m. kovo 9 d. nutarimo Nr. 241 "Dėl Ekstremalių įvykių kriterijų patvirtinimo" pakeitimo" (Žin., 2011 Nr. 107-5059) buvo atsisakyta geografinio pagrindo turinčios kriterijų sistemos, kai buvo vertinamas pats ekstremalus įvykis. Pavyzdžiui, škvalu buvo laikomas toks vėjas, kurio maksimalus greitis siekia 28-32 m/s. Įsigaliojus naujai teisės akto redakcijai, vietoje pačių ekstremalių įvykių geografinio vertinimo buvo pereita prie padarinių gyventojams ar aplinkai vertinimo. Tenka konstatuoti, kad toks vertinimas labiau tinka greito reagavimo tikslams siekti, o ne rizikos raiškos erdviniam modeliavimui. Deja, geografijos interesus rizikos vertinimo srityje dažnai užgožia kitų disciplinų interesai, taigi, atliekami tyrimai paprastai skiriami ekstremalaus įvykio atveju patiriamiems nuostoliams nustatyti, o ne erdviniam įvykio rizikos prognozavimui, pasiruošimui tam įvykiui bei nuostolių mažinimo prevencijai. Visgi ekstremalių įvykių aprašymo pagal geografinius-fizikinius kriterijus ir rizikos nustatymo problema išlieka, ir tai ypač svarbu dėl Lietuvos ūkio vystymo efektyvumo. Sistemos svarbą patvirtina ir panašių projektų plėtra išsivysčiusiose šalyse ar tarpusavio pagalbai teikti kuriami tarpvalstybiniai projektai.

Tyrimo objektas

Šio darbo tyrimo objektas yra gamtinių, ekologinių, technogeninių ir antropogeninių ekstremalių įvykių rizikos kompleksinio vertinimo sistema.

Darbo tikslas ir uždaviniai

Pagrindinis šio darbo tikslas yra sukurti ekstremalių įvykių rizikos kompleksinio vertinimo metodologiją ir veikiančią informacinę sistemą, pagrįstą geostatistiniais metodais bei šiuolaikinėmis geografinės informacijos ir komunikacijos technologijomis. Tuo siekiama sudaryti sąlygas efektyvesniam valstybės geografinių duomenų panaudojimui priimant sprendimus, susijusius su rizikos valdymu.

Siekiant įgyvendinti šį tikslą buvo suformuluoti tokie **uždaviniai**:

1. Išanalizuoti įvairių šalių patirtį, kurią jos sukaupė vystydamos ekstremalių įvykių rizikos vertinimo sistemas.
2. Sukurti ekstremalių įvykių rizikos vertinimo (toliau – **EĮRV**) kartografinės informacijos sistemos koncepciją ir kūrimo metodologiją (informacijos sistemos modelį).
3. Pritaikyti matematinius ir kartografinius metodus EĮRV rezultatams apskaičiuoti ir pateikti.
4. Sukurti EĮRV naudojamų geografinių duomenų bazės kūrimo ir integravimo Lietuvos geografinės informacijos infrastruktūroje (toliau – **LGII**) metodologiją.
5. Sukurti grėsmių, kurias sukelia ekstremalūs įvykiai, rizikos rastrinių duomenų bazės kūrimo metodologiją ir šios duomenų bazės prototipą.
6. Praktiškai įgyvendinti EĮRV kartografinės informacijos sistemą ir išbandyti jos veikimą su skirtingais Lietuvos geografiniais duomenų rinkiniais.
7. Sudaryti grėsmių Lietuvos teritorijoje sintetinio žemėlapio prototipą.

Darbo naujumas ir reikšmė

Darbo naujumas atsispindi šiuose autoriaus atliktuose darbuose:

- Pirmą kartą sukurta Lietuvos teritorijai pritaikyta kompleksinės EĮRV kartografinės informacijos sistemos koncepcija ir kūrimo metodologija.

- Sukurtas EĮRV kartografinės informacijos sistemos prototipinis modelis. Jo tikslumas ir jautrumas įvertintas būtent šiam modelio vertinimui skirtais algoritmais, kurių sudarymas buvo šio darbo dalis. Sukurtas modelis yra lankstus ir gali būti plėtojamas dalyvaujant įvairių sričių ekspertams, nebūtinai turintiems specifines geostatistikos žinias. Rezultatai pateikiami žemėlapių pavidalu ir lengvai suprantami.
- Sukurta visiškai nauja ekstremalių įvykių duomenų bazės kūrimo ir duomenų tokioje duomenų bazėje kaupimo metodologija, taip sudarant prielaidas pirmą kartą vienoje duomenų bazėje surinkti ir išsaugoti visus duomenis apie ekstremalius įvykius, vykusius ar įtakojusius Lietuvos teritoriją.
- Sukurta unikali grėsmių, kylančių dėl ekstremalių įvykių, lokalizavimo metodologija ir, ja remiantis, sukurtas grėsmių rastrinių geografinių duomenų bazės prototipas.
- EĮRV kartografinės informacijos sistemos modelis apima skirtingų institucijų geografinių duomenų rinkinių sujungimą realiu laiku LGII teikiamomis priemonėmis. Kadangi autoriaus darbas glaudžiai siejasi su LGII vystymu, todėl autoriaus siūlomą sprendimą numatoma įdiegti Lietuvos geografinės informacijos (toliau – **LGI**) portale, ir tai gali atnešti valstybei didelę ekonominę naudą, žinant, kad turima LGII techninė bazė leistų integruoti sistemą su nedidelėmis finansinėmis išlaidomis. Vieningos EĮRV kartografinės informacijos sistemos integravimas paskatintų ir institucijų bendradarbiavimą, ir platesnį geografinės informacijos naudojimą valstybinės reikšmės sprendimams priimti.

Ginami teiginiai

1. Ekstremalių įvykių rizikos prognozavimas, t.y. kompleksinis grėsmės Valstybės teritorijai vertinimas, yra labai reikšmingas visuose valdymo lygmenyse, tačiau, deja, toks grėsmės vertinimo modelis pasaulyje niekur nėra išvystytas iki pilnai veikiančios sistemos. Geostatistiniai metodai ir dabartinės geografinės informacijos technologijos sudaro galimybes tokiam vertinimui atlikti ir modeliui sukurti.
2. Galima sukurti moksliškai pagrįstą ir technologiškai įgyvendinamą ekstremalių įvykių rizikos kompleksinio vertinimo informacinę sistemą, kuri pagrįsta sintetiniais rizikos žemėlapiais.

3. Naudojant Lietuvoje viešai prieinamus geografinių duomenų rinkinius galima atlikti ekstremalių įvykių kompleksinį rizikos vertinimą. Jo patikimumas gali būti padidintas keičiant rizikos vertinimo modelio parametrus ir lyginant gautus rezultatus.

Rezultatų aprobacija

Disertacijos tema išspausdintos 4-ios mokslinės publikacijos; 3-ys iš jų yra įtrauktos į Lietuvos Mokslų tarybos partvirtintas duomenų bazes.

Disertacijoje atliktų tyrimų rezultatai buvo paskelbti 2-ose mokslinėse konferencijose ir seminaruose Lietuvoje:

- 8-oje tarptautinėje konferencijoje ”*Environmental Engineering”* 2011 m. Vilniuje;
- 6-ajame tarptautiniame kartosemiotikos seminare “*Competences in Modern Cartography*“ 2011 m. Vilniuje.

Darbo apimtis ir struktūra

Darbas sudarytas iš šių pagal Lietuvos mokslo tarybos 2003 m. nutarimą Nr. VI-4 rekomenduojamų pagrindinių dalių: įvado, tyrimų apžvalgos, darbo metodologijos, tyrimų rezultatų, išvadų, naudotos literatūros sąrašo ir priedų. Darbe yra išnagrinėta 115-a literatūros šaltinių ir parengtos 67-ios iliustracijos, iš jų 19-a pateikta Prieduose.

IŠVADOS

Metodologinės išvados

Lietuvoje yra sukaupta pakankamai įvairių sričių geografinių duomenų, kurie galėtų būti panaudoti ekstremalių įvykių rizikos veiksniams vertinti ir rizikai prognozuoti. Iki 2009 m. duomenis surinkti ir susieti bei bendrai juos panaudoti buvo labai sudėtinga ir tą padaryti buvo įmanoma tik teoriškai, tačiau Lietuvos GII ir jos portalo, kaip valstybės informacinės sistemos, sukūrimas 2009 metais pakeitė situaciją iš esmės. Šiame darbe pristatyta EĮRV kartografinės informacijos sistema efektyviai išnaudos LEI portalo teikiamas technologines sąveikumo, žemėlapių publikavimo ir duomenų teikėjų bei naudotojų bendradarbiavimo galimybes.

Darbo metu buvo sukurta originali metodologija, paremta skirtingų duomenų rinkinių integravimu parenkant kiekvienam duomenų rinkiniui statistiškai pagrįstus svorio koeficientus bei ekstremalių įvykių duomenų branduolio tankio skaičiavimais. Ši metodika leidžia sukurti ir išvystyti ypatingai lanksčią ir adaptyvią EĮRV kartografinės informacijos sistemą, realizuojamą GIS programinės įrangos aplinkoje. Sistemos pagrindiniai rezultatai yra žemėlapiai, apibendrinantys vieną ar kelis pasirinktus rizikos rodiklius. Tokių žemėlapių pagrindu galima sudaryti išvestinius rizikos rajonavimo žemėlapius.

Sukurtas EĮRV kartografinės informacijos sistemos prototipas originalus ne tik Lietuvos, bet ir pasaulio mastu tuo, kad leidžia susieti įvairių tipų rizikos veiksnius ir sudaro galimybes įvairių sričių ekspertams bendradarbiauti ją tobulinant.

Siūlomas EĮRV kartografinės informacijos sistemos modelis sudaro galimybes susieti gamtinius ir visuomeninius geografinius ekstremalių įvykių rizikos veiksnius vienoje vertinimo ir prognozavimo sistemoje. Modelis sudaro sąlygas, prisidedant prie INSPIRE direktyvos įgyvendinimo Lietuvoje, sukurti valstybėje naujus geografinius duomenis Direktyvos III priedo 12 tema „Gamtinių pavojų zonos“ (ši tema apima pažeidžiamas vietoves, suskirstytas pagal gamtinio pavojaus pobūdį ir visus atmosferinius, hidrologinius, seisminius, ir savaiminių gaisrų reiškinius, kurie dėl savo vietos, stiprumo ir dažnumo kelia grėsmę visuomenei).

Siūlomas EĮRV kartografinės informacijos sistemos modelis sudaro galimybes ją vystyti moksliniais pagrindais, dalyvaujant susijusių sričių ekspertams; integruoti naujus parametrus; analizuoti riziką reikiamais pjūviais.

Praktinės išvados

Daugiakriterinio vertinimo ir prognozavimo sistemos yra populiarios ir pasaulyje plačiai naudojamos. Tačiau tyrimuose, kuriuose būtų taikomi geografiniai parametrai, daugiakriterinė analizė taikoma ribotai arba yra eksperimentinėje stadijoje.

Moksliniai ekstremalių įvykių rizikos ir jos poveikio vertinimo tyrimai dėl jų sudėtingumo dažniausiai apsiriboja santykinai maža teritorija arba vienu ar keliais tos pačios kilmės ekstremaliais įvykiais kaip įvesties parametrais. Dėl šių priežasčių dauguma įdiegtų veikiančių EĮRV kartografinės informacijos sistemų yra tikslingai projektuojamos tik siekiant sumažinti jau įvykusių ekstremalių įvykių pasekmes.

EĮRV kartografinės informacijos sistemos sukūrimas Lietuvoje sudaro galimybes numatyti galimus nuostolius vertinamose Lietuvos Respublikos teritorijose bei imtis racionalių priemonių išvengti šių nuostolių arba juos sumažinti. Autoriaus sukurtas modelis leidžia vienoje sistemoje analizuoti ir kompleksiškai vertinti įvairių tipų ekstremalių įvykių duomenis; – idealiu atveju – visų prognozuojamų rizikos veiksnių duomenis. Pasiūlyto modelio pagrindu sukurtoje sistemoje yra panaudoti tik nedidelę dalį temų apimantys geografinių duomenų rinkiniai, tačiau bet kuriuo metu galima įtraukti naujus duomenis ar pakeisti jau naudojamus sistemoje duomenų rinkinius.

EĮRV kartografinės informacijos sistemos modelis išbandytas praktiškai su Lietuvoje sukauptais pagrindinių pavojingų geologinių ir hidrometeorologinių įvykių geografiniai duomenų rinkiniais. Nustatyta, kad modelis neriboja jungiamų geografinių duomenų tipų ir jų rinkinių skaičiaus. Modelis sėkmingai pritaikytas rizikos rajonavimui ir grėsmių vertinimui. Modelio patikimumas priklauso nuo teisingų ir išsamių įvesties duomenų bei nuo tinkamai parinktų skirtingų rizikos veiksnių svorio parametrų, kurie gali būti nustatomi tiek teoriškai, tiek empiriškai. Sistema leidžia įvertinti modelio jautrumą parametrų reikšmių pokyčiams kiekybiškai ir vizualiai – greitai generuojamuose rizikos žemėlapiuose.

CURICULUM VITAE

Vardas, Pavardė: Kęstutis Papšys

Gimimo data ir vieta: 1975 m. birželio mėn. 30 d., Vilnius, Lietuva

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Išsilavinimas:

1997 – Geografijos (Visuomeninė geografija) bakalauro diplomas, Vilniaus universitetas

1999 – Geografijos magistro diplomas, Vilniaus universitetas

2006 – 2012 Vilniaus universitetas fizinės geografijos mokslo krypties doktorantūros studijos

Moksliniai interesai:

Geografijos informacijos mokslas, GIS technologijos, erdvinė analizė ir modeliavimas, erdvinių (geografinių) duomenų bazės ir infrastruktūros, distanciniai tyrimai.