+MAPS CREATED ON BASIS OF RANDOM EVENT STATISTICS

Katarzyna Kocur-Bera, Radoslaw Celmer
University of Warmia and Mazury in Olsztyn, Poland
katarzyna.kocur@uwm.edu.pl, rcellmer@uwm.edu.pl

Abstract. Random events are events that take place unexpectedly, and their occurrence was not taken into account. One group of random events are extreme events (often called catastrophic). They cause destruction or death. The sense of people safety that is impaired when events occur both random and extreme, is one of the basic needs of every human being and has a decisive impact on the functioning of each community. It is therefore important to create tools that allow accurate and legible identification and performance, scale and type of threats. This identification cannot be conducted without taking into account societal expectations. Such a tool should be hazard maps. Official statistics contains a number of data on such threats. This information shall relate in particular hazards: weather (caused by wind, snow, rain and flooding), chemical, environmental, radiological, construction, transport (by road, rail and air) and medical devices. With open access to the data it is possible to build maps of areas most threatened endearing selected areas of interest. This article aims to build hazard maps using GIS tools and statistics of random events and identify areas most at risk by using established criteria. Hazard maps allow you to support decision-making processes made during space management. They should be seen as an essential element of public security management, implemented in partnership of inter-institutional, social and help identify the optimal allocation of resources, hardware and human resources departments.

Keywords: hazard maps, random events, safety space.

Introduction

Security is one of the most valued and highly protected notions. In the contemporary world, security is a much broader concept than it has been in the past, and it applies to political, military, economic, technological, environmental, social and humanitarian contexts [1]. A hazard is generally defined as the absence of security, and it is an invariant, inevitable and, in some cases, a permanent element of human existence. It is closely related to the concept of security and constitutes one of the key categories of security [2]. Effective preventive measures require adequate identification and understanding of hazards [3]. Hazard maps are a relatively new concept that has not yet gained widespread popularity among businesses and organizations that could benefit from this tool. For this reason, hazard maps have many definitions. However, despite of the adopted approach, a hazard map is the main document, which defines boundary conditions for the implementation of security measures. A hazard map is usually defined as a list of internal and external threats of various nature (criminal, technological, natural, etc.), which influence space, property, people, processes, and information of vital significance for the security and functioning of organizations and states. The process of developing hazard maps requires a comprehensive understanding of the protected resources, populations and adverse factors of various origin. A hazard map should also identify critical processes and predict losses that could be sustained in the event of a crisis. A hazard map facilitates the selection of the most effective security measures and creates a supportive environment for involving non-security personnel in security management by increasing their awareness and pinpointing the existing problems in endangered space [4]. The process of developing a security system is simplified and the operating and economic efficiency of an organization is considerably improved, when this approach is adopted by the entire management. In accordance with the risk theory, a hazard map has two principal parameters: the financial consequences and the probability of a random event.

A growing number of organizations collect information about the number of hazards, victims and the financial consequences of random events, including the International Disaster Database (EM-DAT) and the Chief Officer of the Polish State Fire Service. International databases can be used to develop maps and charts of hazards and their consequences on a global or continental scale [5], but detailed information about specific locations and municipalities can be found only in national or regional statistical databases. A map of global natural disasters between 1986 and 2015, with a division into countries, is presented in Figure 1.

DOI: 10.22616/ERDev2018.17.N051

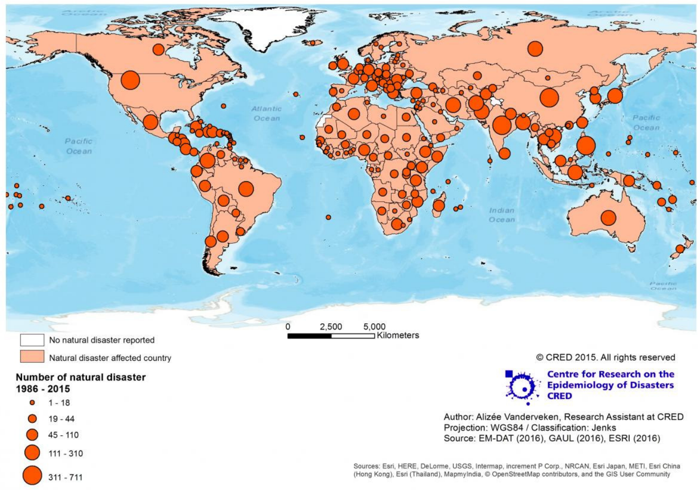

Fig. 1. **Map showing number of natural disasters in 1986-2015 in the world, divided on state [5]**

The EM-DAT database supports the generation of charts presenting the number of natural disasters (Fig. 2), technological disasters (Fig. 3) and material losses that occurred in Europe between 1900 and 2014, with a division into transport-related disasters, industrial disasters (caused by technological failures, refer to Fig. 5) and, in the natural disaster category, the type of events that caused the disaster (e.g., drought, earthquake, flood, hurricane, epidemic, etc.; Fig. 4).

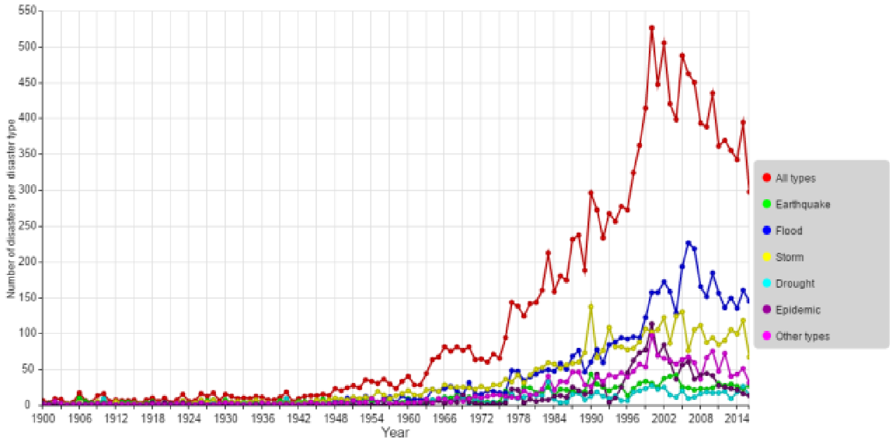

Fig. 2. **Number of natural disasters that occurred from natural causes in Europe in 1900-2014 [5]**

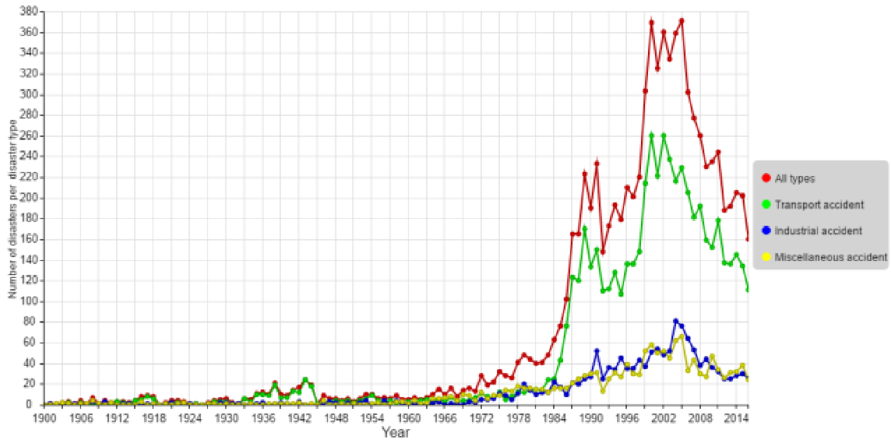

Fig. 3. **Number of natural disasters that occurred from technical causes in Europe in 1900-2014 [5]**

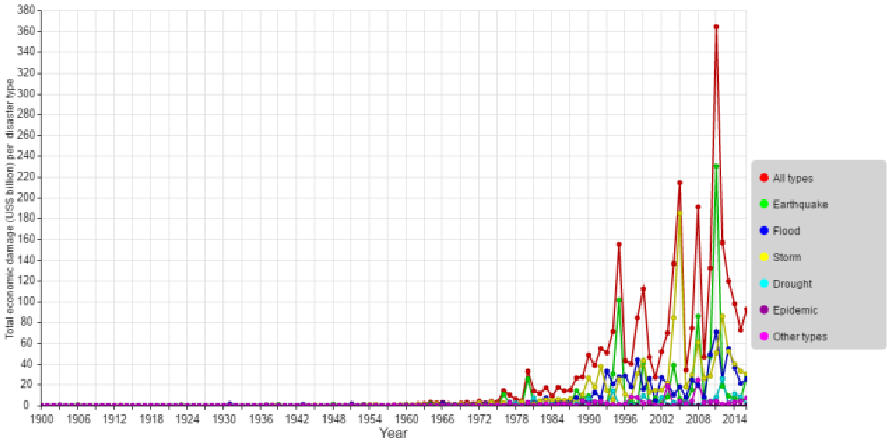

Fig. 4. **Total financial losses caused by natural disasters that occurred from natural causes in Europe in 1900-2014 [5]**

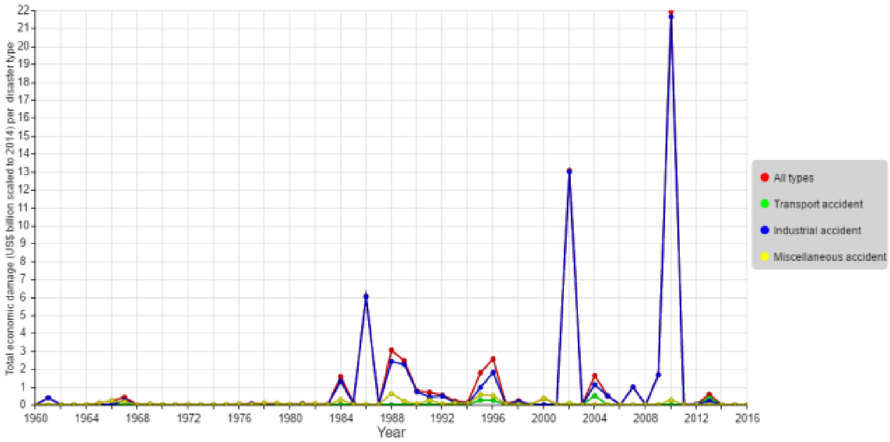

Fig. 5. **Total financial losses caused by natural disasters that occurred from technical causes in Europe in 1900-2014 [5]**

Poland also keeps relatively detailed statistical databases of hazardous events. Disaster reports are generated after every such event in agricultural areas. The reports are submitted to the authorities of municipalities, towns and cities, which sustained agricultural losses due to natural disasters and/or adverse weather events [6]. They contain information about the damaged area, financial loss, number of damaged farms, extent of damage, type of damaged crops and the owners of damaged farms. Based on the gathered data, the victims can apply for disaster loans and subsidies from the Agency for Restructuring and Modernization of Agriculture. These data are not available to the general public.

The databases kept by the State Fire Office are also a source of information about random events and natural disasters. These statistics are developed in line with the provisions of the Regulation of the Minister of the Interior and Administration of 18 February 2011 on detailed requirements relating to the organizational structure of the national firefighting and rescue system [7]. The databases contain detailed information about fire service interventions and the afflicted sites, including municipality, district, village or town, street, building/apartment number, road number, driver location sign and the site of intervention, for example, pond, lake, road, tree, forest, repair station building [8].

The aim of this study was to analyze the number, location and type of random events, which led to fire service interventions in 2014-2015. The severity of hazardous events was evaluated, spatial autocorrelations were analyzed, and the calculated indicators were used to develop hazard maps.

Materials and methods

Data for analysis were acquired from the websites of the Polish State Fire Service (number of events, financial losses, event location, etc.) and the Head Office of Geodesy and Cartography (map of the province with division into communes). The hazards reported in 2014-2015 are listed in tables, with a division into administrative units and hazard categories (code numbers). Figure drawings, diagrams and maps were developed based on the indicator of the number of hazards per square kilometer, the probability of a random event, and the distribution of the number and severity of hazards in the analyzed location. The probability of a random event was estimated based on the number of hazards reported in the analyzed period and location. Spatial autocorrelations were determined with the use of Moran's *I* on the assumption that neighbouring objects share more similarities than more distant objects. The local version of Moran's *I* is the most popular type of spatiotemporal statistics, known as local indicators of spatial association (LISA). Moran's *I* statistics are used to determine local spatial autocorrelations, the similarity of spatial objects relative to their neighbours and the significance of these correlations. Local Moran's *I* index for *i* observations is determined with the use of the below formula (1):

$$I_i = \frac{(x_i - \overline{x})\sum_{j=1}^{n} w_{ij}(x_j - \overline{x})}{\sigma^2} \tag{1}$$

where n – number of spatial objects (number of points or polygons),
x_i, x_j – variable for the compared objects,
$\overline{x}$ – average variable for all objects,
w_{ij} – elements of a spatial weights matrix,
$\sigma^2 = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n-1}$ – variance.

Local Moran's *I* index is interpreted similarly to its global counterpart. High index values point to the presence of clusters of similar values, low index values point to the presence of hot spots, and values close to the expected value $E(I_i)$ indicate that the analyzed variable is randomly distributed in space.

Results and discussion

Local hazards (other than fire) are events that are associated with the development of civilization, human activities and forces of nature and which pose a threat to life, health, property and the environment [8]. The data presented in Figure 6 indicate that the highest financial losses were sustained by the regions of Małopolska and Mazowsze. The analyses in subsequent parts of the study focused solely on the Region of Małopolska, which was characterized by the highest prevalence of selected types of hazards. The number of local hazards in the Region of Małopolska is presented in Figure 7.

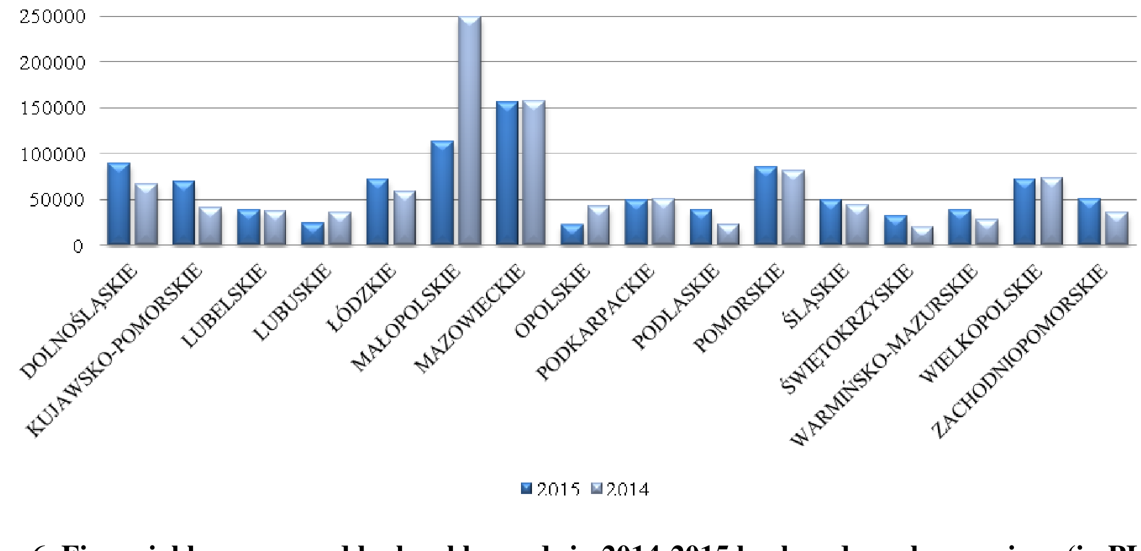

Fig. 6. **Financial losses caused by local hazards in 2014-2015 broken down by province (in PLN), source: own study based on data from [8]**

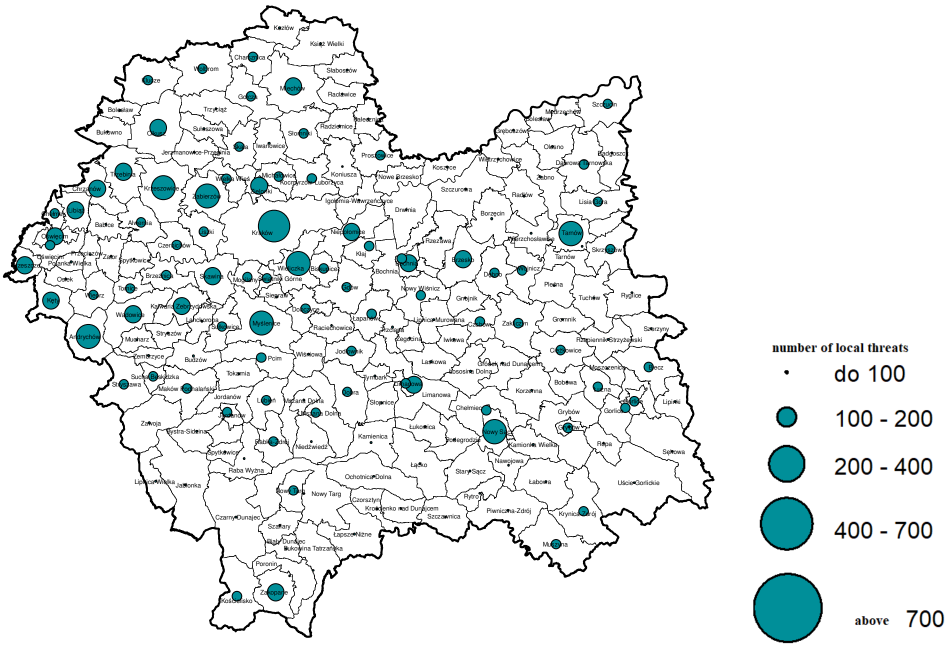

Fig. 7. **Map with division of number of local threats to province of Malopolska in 2015, source: own study**

A distinctive cluster of random events can be observed west of Kraków towards Oświęcim, the region's boundaries and Katowice (see Fig.7). The area between Kraków and Górny Śląsk is an industrial hub, and it is particularly susceptible to anthropogenic hazards. The above area is located in the mountainous region of Podhale, which implies that it is also prone to natural disasters. Clusters of local hazards are also present in the eastern part of the Region of Małopolska, in particular in the area of Tarnów and Nowy Sącz.

The areas characterized by the highest number of hazardous events in selected categories are presented in maps in Figures 8, 9. Natural disasters (weather phenomena) are predominant in Kraków and in western and north-western parts of the Region of Małopolska (Fig. 8). Kraków, the capital city of the Region of Małopolska, is a highly urbanized area; therefore, dangerous weather events exert a considerable influence on the local population.

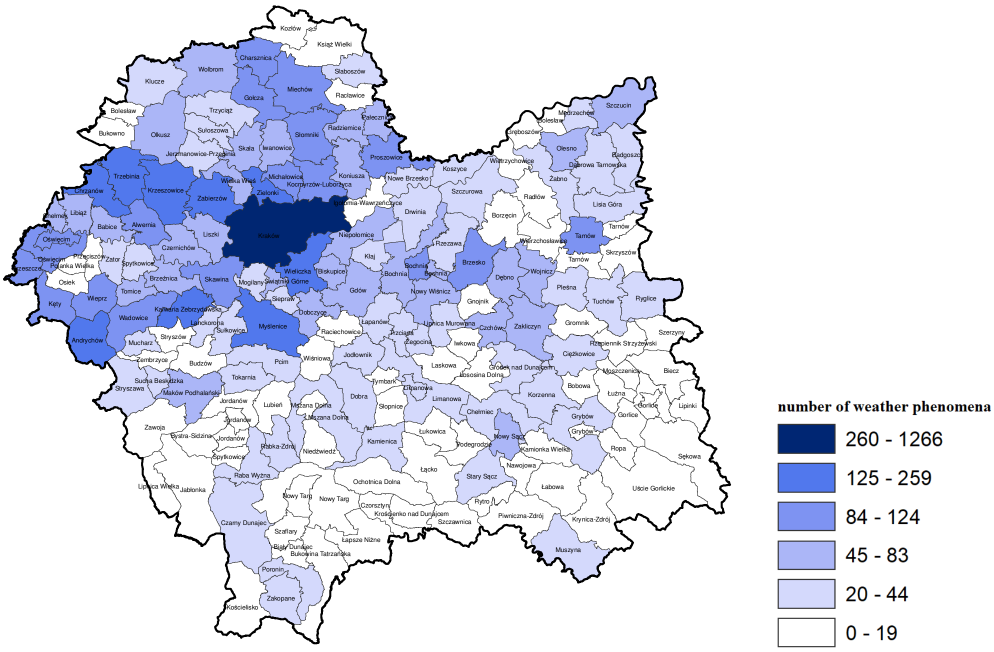

Fig. 8. **Number of random events of weather in Malopolska province in 2015, source: own study**

The analyzed statistical data can be used to determine the severity of hazards (based on the total number of random events in year or indicated time interval). The relevant threats can be subdivided into the following categories: (a) minor hazards, which do not require a large number of rescue units or specialist equipment, excluding detection and measuring equipment, in particular the identification of hazards without the initiation of rescue operations, managing operations that pose a fire hazard, managing mass events, managing landing operations, assisting fire service units, providing security services to protected persons in collaboration with the Government Protection Bureau; (b) local hazards, which involve sudden failure or damage to equipment, machines, vehicles or buildings, pose a threat to life, health, property or the environment, require the assistance of other emergency services, result in no more than 1 fatality and no more than 3 casualties, who are evacuated from the site or receive medical assistance, and involve less than 4 rescue units; (c) moderate hazards, which involve sudden failure or damage to equipment, machines, vehicles or buildings, pose a threat to life, health, property or the environment, result in no more than 2 to 3 fatalities or 4 to 10 casualties, who are evacuated from the site or receive medical assistance, and involve 5 to 12 rescue units or one specialist unit; (d) large-scale hazards, which involve a sudden, unforeseeable event, pose a threat to life, health, property and the environment, and require the assistance of rescue units smaller than a battalion; (e) catastrophic hazards or natural disasters, which involve a sudden, unforeseeable event, pose a massive threat to life, health, property or the environment, and require the assistance of rescue units with the minimum strength of a battalion [8]. Hazardous events are clustered in the area of Kraków and the adjacent municipalities, and cities of Tarnów, Nowy Sącz, Nowy Targ and Zakopane. In the Region of Małopolska, catastrophic hazards (natural disasters) were not reported, two large-scale hazards were reported in the municipalities of Skawina and Lanckorona, 183 moderate hazards, 23,864 local hazards and 6,093 minor hazards were reported in 2015. The location and intensity of hazardous events are presented in Figure 9. Hazards are clearly clustered in the north-western part of Małopolska and the capital city of Kraków.

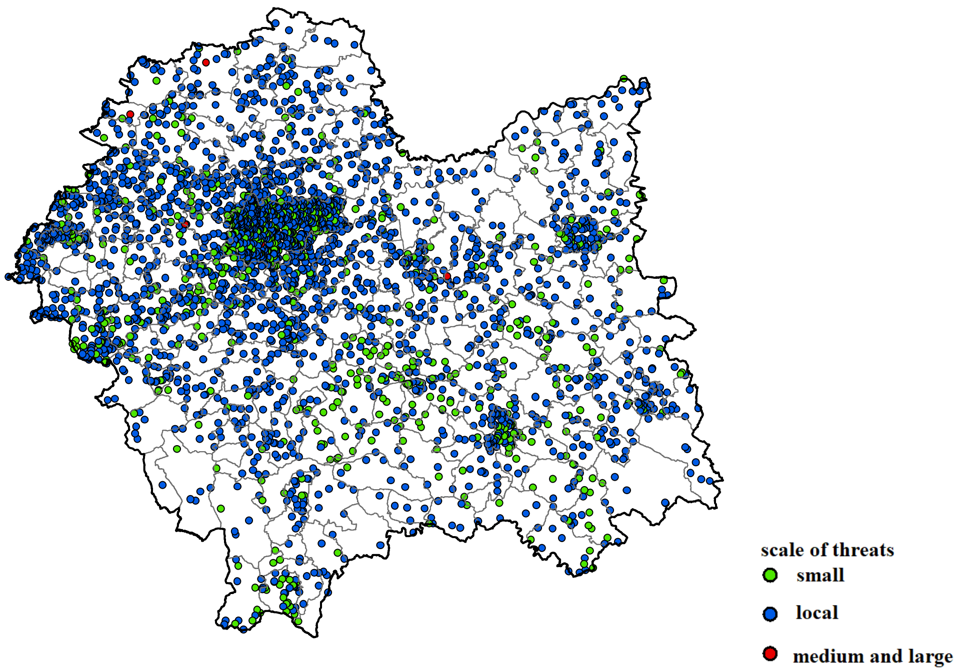

Fig. 9. **Location and intensity of hazardous events to province of Malopolska, source: own study**

Local Moran's I was used to measure the spatial autocorrelation of all losses. The spatial distribution of losses was indicative of a local spatial autocorrelation at a significance level of less than 0.05. Local Moran's I_i was used to determine clusters with high and low losses [9]. The areas, which sustained high losses, and similar areas in the vicinity (HH), the areas, which sustained low losses, and similar areas in the vicinity (LL), and municipalities, where high-loss areas are directly adjacent to low-loss areas (HL and LH) are presented in Figure 10. The city of Kraków and the adjacent municipalities are predominantly HH areas. Kraków differs considerably from the neighbouring municipalities, in particular those situated to the north. Low-loss areas (LL) and similar surrounding areas are situated mainly in the eastern part of Małopolska.

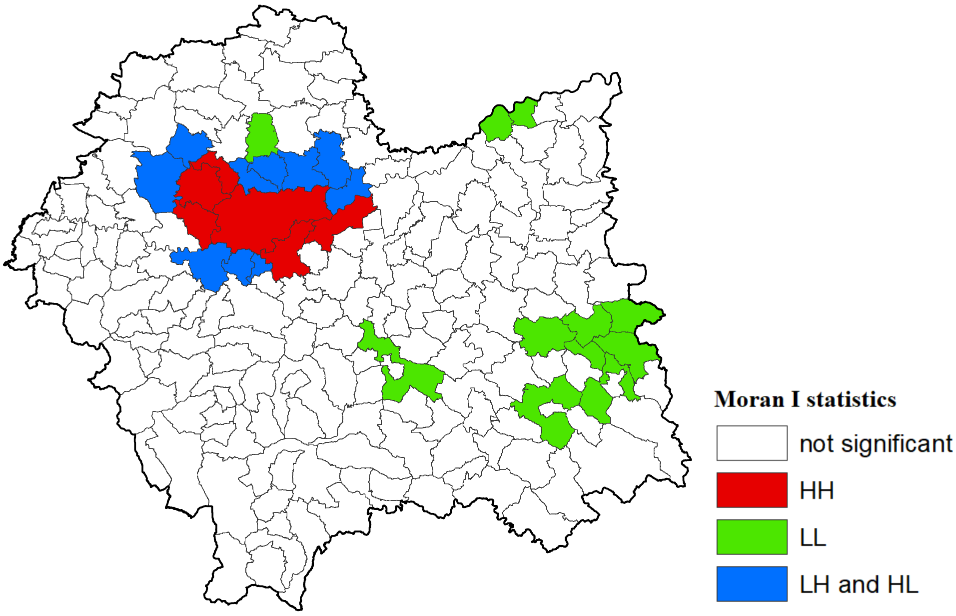

Fig. 10. **Spatial autocorrelation, source: own study**

Conclusions

The aim of this study was to analyze the number, location and type of random events, which required the assistance of the State Fire Service in 2014-2015. The severity of the reported hazards and spatial autocorrelations were analyzed, and the calculated indicators were used to develop a hazard map. The results of this study indicate that:

1. Random events occur around the world, international databases support analyses of hazards in various parts of the world, and they can be used to generate hazard maps;
2. In Poland, the State Fire Service is the main rescue service, which responds to random events;
3. The databases kept by the fire service can be used to model data and generate information about areas that are at the greatest risk of various categories of hazards;
4. The above data and the information about local environmental and anthropogenic conditions support the development of hazard maps. Hazard maps are used for various purposes, including for the allocation of rescue equipment and rescue units, in the decision-making process relating to spatial management and rural space management.

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