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FULLY-AUTOMATIC LANDSLIDE SUSCEPTIBILITY ANALYSIS
BY GEOGRAPHICAL INFORMATION SYSTEM (GIS):
A CASE STUDY IN ŞAVŞAT CITY, TURKEY

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Abstract
In the literature, different methods and parameters were used to produce the most accurate Landslide Susceptibility Map (LSM) in each of the studies. In this study, it was aimed to produce a GIS-based LSM by the The Frequency Rate (FR) method in the selected study area, to calculate the accuracy of the produced LSM and to perform all these operations fully-automatically. In line with this purpose, user-interface programs were developed in the GIS environment. The FR method that is commonly used in the literature and gives high accuracy was used to produce an LSM. Slope, aspect, elevation, lithology, distance to fault, distance to river, Normalized Difference Vegetation Index (NDVI), land use and rainfall parameters were taken into account to produce the LSM. Consequently, the accuracy of the LSM obtained by the FR method was calculated to be 89%.

Keywords: GIS, Landslide, Landslide Susceptibility Analysis, User Interface Program

INTRODUCTION

Natural disasters cause many losses of life and property. One of the natural disasters that cause the loss of life and property in Turkey is the landslide. It is observed that almost every province in Turkey is affected by landslides at certain degrees [1]. The Black Sea region is the most important region where landslide potential is the highest in Turkey. In today's technology, the losses caused by landslides can be decreased by determining the landslide areas and planning the environment accordingly. These areas can be determined by landslide susceptibility analyses. The aim of the landslide susceptibility analysis is to decrease the effects of the landslide by determining dangerous and risky areas [2]. Hazard maps contain information about the identification of natural events and the estimation of the occurrence of such natural events in the future [3]. Therefore, the production of a high quality LSM is very important for natural disaster management.

Many different methods are applied for the LSM which is produced via Geographical Information Systems (GIS). There are two basic steps in this process. One of these steps is the selection of the method and the determination of other parameters to be used. When the literature is examined, it is observed that LSMs are produced by applying different methods. Easy to use, and carried out with complex mathematical operations methods have been used. One of the commonly used methods for the preparation of LSM is the GIS-based Multi-Criteria Decision Analysis (MCDA) method [4], [5]. The Logistic Regression (LR) and Geographical Weighted Regression (GWR) [6], Regression Tree (RT) and LR methods have been used recently [7]. Erenen et al. [8] created the LSM in Şavşat district of Artvin province using the LR, GIS-based MCDA and Association Rule Mining (ARM) methods. Colkesen et al. [9] compared with the LR method using the kernel-based Gaussian Process Regression (GPR) and Support Vector Regression (SVR) methods. Chen et al. [10] applied the Naive Bayes Tree (NBTree), Kernel Logistic Regression (KLR) and Alternating Decision Tree (ADTree) methods.

The statistical methods commonly used in the literature determine the correlation according to landslide areas by evaluating the factors affecting the landslide. Guzzetti et al. [11] classified the methods by summarizing many studies on landslide susceptibility in the literature. It was stated that probability-based studies were carried out in many of them. One of the statistical methods frequently used in the preparation of LSMs is the LR method...
Terranova et al. [16] examined the rainfall factor together with other factors with this method. The Frequency Rate (FR) method is a commonly used method that is easily applied and provides high accuracy [17], [18], [19]. In this study, it was aimed to produce a GIS-based LSM using the FR method, which is usually emphasized to give the most accurate result in the literature and to determine its accuracy. The surroundings of Şavşat district of Artvin (Turkey) province, which is one of the regions with the highest landslide risk, was selected as the study area (Fig. 1). Consequently, landslide susceptibility analysis was performed in the study area.

One of the most important topographic parameters affecting the formation of landslides is the slope of the land. Areas with more roughness increase the landslide risk. The slope map of the study area was produced in the GIS environment (Fig. 2). Aspect (Fig. 2), which is included in topographic parameters, is one of the important factors affecting the landslide [22], [23]. This parameter should be considered for the landslide susceptibility analysis. The fault map (Fig. 2) produced by MRE [24] was used within the scope of this study. The degree of the saturation of slopes is an important criterion for a landslide (distance to river). The distance of slopes to the river also affects this situation. Rivers cause landslides with erosion on hillsides or slopes, by saturating the substances forming the slopes [25], [26]. The river system of the study area was determined in the ArcGIS 10.3 program using the DEM data (Fig. 2). Land use is among the environmental factors that are mostly affected by environmental factors such people etc. The usage purpose of the land use data is among the important parameters used in applications since it affects the landslides. Therefore, the classification was made using the Landsat 8 (2016) satellite images, and the land use map was created (Fig. 2). Depending on many parameters such as humidity, vegetation cover, organic matter content, and the season in which the rainfall occurs on slopes with heavy rainfall, the material in slopes with the dominant aspect reaches saturation more quickly compared to other slopes. This also causes pore water pressure to reach saturation [27].

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**Figure 1. Study Area**
Accordingly, the risk of landslide increases. The Black Sea region, where the study area is located, is a region exposed to heavy rainfall in the climatic sense, and the rainfall factor was taken into account because landslide incidents are more frequently observed on rainy days (Fig. 2). Another parameter which was considered in the study is lithology (Fig. 2). This parameter, which is among the geological factors, is an important parameter commonly used for landslide formation because the structures with
different features have different susceptibility for landslide formation. Vegetation (Fig. 2) is among the important environmental factors used to investigate landslide susceptibility as it retains the soil. In particular, it prevents soil from sliding in sloped areas.

**Figure 3.** The user interface program developed for producing the LSM

**Production of the LSM Using the Frequency Ratio Method**

The frequency ratio method is applied by investigating the relationship between past landslide locations and the subclasses of each factor. In this method, the relationship of the subclass with the landslide inventories is used. The FR values are calculated. Then, these calculated values are transferred to the GIS environment. The LSM is created using the FR values. The LSM is obtained by calculating the Landslide Susceptibility Index (LSI) by adding the FR values assigned to each layer one after the other.

\[
LSI = FR_{\text{slope}} + FR_{\text{aspect}} + FR_{\text{elevation}} + FR_{\text{fault}} + FR_{\text{river}} + FR_{\text{ndvi}} + FR_{\text{lithology}} + FR_{\text{land use}} + FR_{\text{rainfall}}
\]

(1)
The accuracy of the LSM created should be calculated. The accuracy analysis was performed with the test landslides that were determined at the very beginning of the study. LSM's "high" and "very high susceptible" classes were used.

**Figure 4.** The user interface program developed for accuracy assessment of the LSM

**User-interface Programs Developed for Producing the LSM and Accuracy Assessment**

The user-interface program (Fig. 3) developed in accordance with 9 parameters considered in the study automatically creates each of these parameter maps by loading the appropriate inputs. For example, the river system is created automatically from the DEM input data, and the buffer zone analysis is automatically performed on it. This includes an application valid for all parameters. Furthermore, the developed user-interface program ensures that all maps are cut according to the same study area and their spatial resolutions are the same with the coordinate system. As it is known, it is essential that the said features of all maps should be same while the latest maps are being overlaid, and the user-interface program provides it. The user-interface program was developed so that the values obtained with the FR and other similar methods (such as WOFE) after creating all the maps could be entered into the system with reclassification as input. This allows that the developed user-interface program could be used for similar methods (WOFE, etc.) except for the FR method. In addition to the LSM-producing user-interface program, a user-interface program calculating the accuracy of this map was also developed (Fig. 4). The inputs of the program are the existing landslide areas in the study area with the LSM obtained as an output from the previous model.

**RESULTS AND DISCUSSION**

In this study, the LSM was created by taking into account the slope, aspect, elevation, lithology, distance to fault, distance to river, NDVI, land use and rainfall parameters (9 parameters) and by applying the FR method (Fig. 5). According to the results obtained, high and very high landslide areas were found to be consistent along the fault and river line. The maximum landslide risk was observed in clastics and carbonate formations along with the volcanite and sedimentary rocks from the lithological units (upper middle Eocene). On the other hand, this study confirms the statement of Gökçe et al. [1] that the Eocene volcanites in the Eastern Black Sea region are suitable areas for the formation of landslides. When the land use was taken into account, it was observed that the risk of the landslide increased in agricultural and
residential areas with a high human effect. The high landslide risk was also determined on the slopes facing moderately sloping northeast with increased moderate elevation. It was indicated by Terrarona et al. [16] in landslide susceptibility analysis studies that the rainfall is also an important triggering factor. According to the findings obtained in this study, the maximum landslide risk was found in areas with the highest average rainfall, and the opinions of Terrarona et al. [16] were also confirmed. The accuracy of the LSMs directly affects the accuracy of each study (urban planning, disaster management, etc.) to be carried out depending on these maps. Therefore, the accurate production of LSMs is extremely important.

Figure 5. LSM produced by the FR method
The accuracy of the LSM produced in this study was obtained to be 89%. This accuracy value obtained is consistent with other similar studies in the literature. User-interface programs that can be used easily by everyone, that fully-automatically produce the LSM with the required 9 parameters in any landslide area and that fully-automatically calculate the accuracy of this map produced were used for the landslide susceptibility analysis. Thus, it was ensured that long-lasting complex geographic investigation and analysis operations were performed easily.

CONCLUSION

In this study, as it has been emphasized by many researchers in the literature, the FR method has been used for the LSM production since it is easy to apply and provides higher accuracy. With the developed method, the LSM of the study area in Şavşat district of Artvin (Turkey) province was determined fully automatically with 89% accuracy. On the other hand, this study is the first LSM of Şavşat district produced by the FR method using 9 parameters. Besides, it was ensured that the landslide susceptibility analysis in any location of the world could be easily performed with user-interface programs developed in the GIS environment. After the data related to the parameters used have been added to the user-interface program as the input data, the LSM is fully-automatically produced within a few minutes, and the accuracy of this LSM is determined. When it is considered from this point of view, this study has originality.

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Changes in the financial results of corporations in cities in Eastern Europe ...
CHANGES IN THE FINANCIAL RESULTS OF CORPORATIONS IN CITIES IN EASTERN EUROPE

Abstract
Major corporations represent an important aspect of economic life that affects the rank of a city on the international stage. The purpose of the study is to determine the financial results and sectoral differentiation of cities home to the largest corporate headquarters in the region often described as Eastern Europe. This determination was made based on revenue and net profits generated by 500 major corporations with their headquarters in Eastern Europe in the years 2008 and 2015. Research has shown that revenue and net profit of key corporations in the region slightly increased despite the downturn triggered by the global financial crisis in 2008 and 2009. The largest number of firms and also the best financial results were noted in Prague, Warsaw, and Budapest. At the same time, the close proximity of the original 15 EU states yields a positive impact on corporate presence – the number of corporations increases with decreasing distance to the former EU boundary. History also plays an important role in the presence of major corporations in Eastern Europe. The largest number of corporations are found in countries that were independent prior to 1990. The next largest group of countries in this study consists of states formerly part of the Soviet Union. Finally, the smallest number of large corporations are found in countries formerly part of Yugoslavia.

Key words: headquarters, central europe, cities, corporate finance

INTRODUCTION
Cities in Central and Eastern Europe experiencing political and economic change since 1989 are examined in the context of their transition from socialism to capitalism in effect since the early 1990s. However, the development of cities in this region is largely also determined by other processes such as physical modernization, non-political shifts, and globalization [1], [2]. In the early 1990s the economies of countries in this part of Europe experienced collapse mainly due to the political collapse of their main trading partner – the Soviet Union. Until 1991 fifteen republics of the Soviet Union were closely integrated via a centralized Soviet economic model with other countries in Central and Eastern Europe. Following political and economic collapse in Russia in the early 1990s, other countries in Central and Eastern Europe experienced faster economic bounce than did former Soviet republics [3]. Many former state-owned companies, especially those in the heavy industrial sector, went bankrupt, being replaced by dynamically growing private companies partly financed by foreign capital. The period experienced a mass-scale privatization of state-owned enterprises, with the new shareholders being large corporations headquartered outside of Central and Eastern Europe [4].

A free market economy was introduced in Central and Eastern Europe, which led to the acceleration of globalization processes in the region. Both globalization and the integration of the region with the European Union produced a significant impact on the growth of cities in terms of their spatial structure, main functions, and spatial processes and corresponding processes in their peripheral areas [5]. Many post-socialist countries in the region have also experienced suburbanization since the early 1990s. All countries in Central and Eastern Europe have experienced the migration of big city residents to suburban areas on a larger scale than before 1989. This process further accelerated in the last decade or so making urban decentralization a key feature of urban growth in the region [6], [7]. It is the view of many researchers that suburbanization represents one of the main processes impacting post-socialist
cities in Central and Eastern Europe in the 21st century [8], [9], [10], [11].

The most important companies operating in the region during the socialist period were located within city limits – most often close to city centers. The first main signs of industrial and service deconcentration occurred in the 1990s [12], [13]. Only a few world-leading companies are headquartered presently in this part of Europe [14], [15]. These companies are often described as world command and control centers [16]. Companies of this type are discussed for Central and Eastern Europe in [17].

The purpose of the paper is to discuss financial performance results for the largest global corporations by city, country, and groups of countries headquartered in the region of Central and Eastern Europe.

DATA

The study presents the economic potential of cities in Central and Europe via the financial performance of the largest companies tallied by the Deloitte Corporation in its Deloitte Central Europe Top 500 Report for the years 2008, 2012, and 2015. The Deloitte report has been published every year since 2008 and covers the largest 500 corporations with a headquarters in Central Europe – the report is based on corporate revenue. The main list does not include the banking and insurance sectors, which are examined by Deloitte in a separate publication. An examination of the largest corporations in cities implies that the two sectors cannot be excluded. Hence, 50 companies from each of the two sectors were added to the top 500 list creating a top 600 list of the largest corporations in the region of Central Europe [18]. The Deloitte top list report covers the following countries: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Kosovo, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Serbia, Slovakia, Slovenia, Ukraine. Russia and Belarus are not included due to problems in obtaining data from these two countries and certain problems with the credibility of the data that are [19]. In the present study, corporation data for cities were aggregated for each studied metropolitan area in Central and Eastern Europe.

METHODS

The index of innovativeness for cities discussed in this study is based on another index known as the potential of international position (PIP) index, which is in turn based on the standardized deviation of sales revenue (RS) and net income (IN). In addition, a city’s potential also reflects the number of corporate headquarters located in each city [20].

$$\text{PIP} = \frac{z_{RS} + z_{NI}}{2}$$

where

$$z_{RS} = \frac{z_{RS} \cdot 100}{\max(z_{RS})}$$

$$z_{NI} = \frac{z_{NI} \cdot 100}{\max(z_{NI})}$$

CORPORATE HEADQUARTERS
IN CENTRAL AND EASTERN EUROPE

Since 2008 the largest number of headquarters of the largest companies in Central Europe has been found in Warsaw. However, the number of corporate headquarters in Warsaw declined from 110 in 2008 to 97 in 2015. Prague was the next largest corporate headquarters city in the region with 60 HQs in 2015. Budapest was third in line with 51. The next top spots belonged to Bucharest, Bratislava, Kiev, and Ljubljana. The overall pattern is that of capital cities winning the top spots in terms of the number of corporate headquarters. The largest number of headquarters are found in Poland – and the first 20 cities in the ranking. In addition to Warsaw, Poland boasts seven other cities in the top 20. The predominant pattern is reversed in Ukraine, with 56 headquarters in 2008 and 54 in 2012 and
only 32 in 2015. Kiev lost the largest number of corporate headquarters in the period 2012 – 2015. The same was true of Ukrainian cities located to the east of Kiev. This is most likely true due to the armed conflict between Russian and Ukraine in eastern Ukraine and Russia’s annexation of the Crimean peninsula in southern Ukraine (Fig. 1).

Figure 1. Number of corporate headquarters in cities in Central and Eastern Europe in the period 2008 – 2015 (top 20 cities).
source: Author’s own work based on Deloitte Central Europe Top 500 Reports

However, the number of corporate headquarters does not correlate with a city’s potential of international position (PIP). Yet, in the case of the most important cities in the studied region, it is possible to observe a similar pattern between both sets of values. The highest PIP value of 100 was noted for Warsaw in 2008 and again in 2015. Prague was ranked second during the study period having surpassed Warsaw in 2012 despite a smaller number of corporate headquarters.

Figure 2. Potential international position index values (PIP) for the period 2008 – 2015
source: Author’s own work based on Deloitte Central Europe Top 500 Reports

The largest increases in PIP values during the period 2008 – 2015 were noted for the following Polish cities: Płock (+15.0), Kraków (+12.6), Wrocław (+6.9), Poznań (+5.3). A large change in
PIP was also noted for the Czech city of Mladá Boleslav (+7.6). The largest decline in PIP value was noted for two Ukrainian cities – Kiev (–38.0) and Donetsk (–20.3). The third largest decline was noted for the Polish city of Lubin (–8.4) (Fig. 2).

The number of corporate headquarters was the largest in Poland for each of the studied years. The number of HQs in Poland declined slightly to 197 in 2012, but then increased to 213 in 2015. Poland held 35.5% of all top-ranked HQs in Central Europe in 2015. The Czech Republic was ranked second in 2015 with 93 HQs; however, Hungary was ranked second in terms of PIP. The number of corporate headquarters declined only in Poland and Bulgaria in Group 1 in the period 2008 – 2015. However, the group as a whole gained HQs rising from 466 to 492 (+5.6%). On the other hand, PIP values rose markedly for Poland, Hungary, and Bulgaria. Of the group 1 countries, Poland is the leader as manifested by the fact that 82% of the examined corporations have established a presence in Poland for the group 1. The number of HQs in Group 2 is much smaller, and it declined from 79 in 2012 to 55 in 2015.

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Table 1. Number of headquarters and index values by country and group of countries

| Country/Region             | No of Headquarters | PIP index summary |
|----------------------------|--------------------|-------------------|
|                            | 2008   | 2012   | 2015   | 2008   | 2012   | 2015   |
| Bulgaria                   | 15     | 9      | 12     | -12.70 | -4.27  | -3.23  |
| Czech Republic             | 85     | 107    | 93     | 29.81  | 57.41  | 20.81  |
| Hungary                    | 73     | 75     | 78     | 2.40   | -14.38 | 21.30  |
| Poland                     | 218    | 197    | 213    | 1.72   | 21.17  | 57.25  |
| Romania                    | 44     | 46     | 57     | -6.85  | -22.15 | -16.81 |
| Slovakia                   | 31     | 35     | 39     | 7.36   | -1.90  | -4.53  |
| **GROUP 1 total**          | 466    | 469    | 492    | 21.75  | 35.88  | 74.79  |
| Estonia                    | 4      | 3      | 5      | 1.01   | -1.40  | -0.23  |
| Latvia                     | 7      | 6      | 4      | -1.98  | -0.01  | -0.51  |
| Lithuania                  | 13     | 16     | 14     | -3.78  | -5.44  | 0.10   |
| Ukraine                    | 57     | 54     | 32     | 12.38  | 5.32   | -48.68 |
| **GROUP 2 total**          | 81     | 79     | 55     | 7.62   | -1.53  | -49.33 |
| Bosnia and Herzegovina     | 0      | 2      | 2      | -6.73  | 0.11   |
| Croatia                    | 18     | 17     | 19     | 3.02   | 1.80   | -3.52  |
| Rep. of Macedonia          | 1      | 1      | 1      | -3.53  | -3.96  | -2.12  |
| Serbia                     | 8      | 7      | 7      | -11.91 | -8.85  | -8.79  |
| Slovenia                   | 26     | 25     | 24     | -16.96 | -16.60 | -11.15 |
| **GROUP 3 total**          | 53     | 52     | 53     | -29.37 | -34.35 | -25.46 |

*source: Author’s own work based on Deloitte Central Europe Top 500 Reports*
of Ukrainian companies may have been filled with the companies headquartered in countries classified as Group 1 (Tab. 1).

RESULTS:
There is a significant number of large companies in Central Europe; however, few of them play an important role in the world economy. Some Central European companies are simply regional affiliates of corporations headquartered outside of the studied region. However, there are also major companies in Central Europe that are headquartered in the region. The largest number of corporate headquarters are found in Warsaw, which despite a decline in their number has remained a leader in this field in Central Europe surpassing Prague and Budapest. Research has shown that the number of corporate headquarters does not necessarily correlate with the potential international position index – the largest increase in which was noted for Polish and Czech cities. On the other hand, Ukrainian cities suffered the largest declines.

One third of the examined top-ranked corporations are headquartered in Poland, although this number has experienced a small decline. On the other hand, the next two countries in line, the Czech Republic and Hungary, experienced an increase in the number of corporate headquarters during the study period. By far the “strongest” countries in the study were those that existed as independent states after World War II (Group 1). On the other hand, Group 2 (former USSR republics) and Group 3 (former Yugoslavia) countries had a similar number of top-ranked corporate headquarters during the study period. Yet, in terms of PIP index values, Group 3 surpassed Group 2 in 2015. The main cause of this is the armed conflict between Russia and Ukraine. This is why many companies located in Ukraine have lost their spot on the Deloitte list of top companies in Central Europe.

The case of Ukraine shows that an armed conflict – regardless of its actual size – may strongly impact the financial performance of the largest companies headquartered in a conflict-ridden country. This is true even when the company headquarters is not located in the conflict zone itself – as seen in the case of the Ukrainian capital city of Kiev.

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THE GIS MODELING OF THE TERRAIN FAVORABILITY FOR THE PLACEMENT OF CONSTRUCTIONS IN THE AREAS WITH HYDRO-GEOMORPHOLOGICAL RISK

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Abstract
The placement of constructions in the areas subjected to hydrogeomorphological hazards is a global issue. Problems of hydrogeomorphological risk are registered between the communes of Broșteni and Poiana Teiului. For the analysis of the construction’s favorability, we analyzed the following elements: the elevation model of the terrain, the declivity, the usage of the land, the depth of the terrain’s fragmentation, and the terrain’s vulnerability to floods. The map of the slopes, together with the guide for the application of the construction’s placement regulations, highlight the morphological favorability for the placement of constructions. The map of land usage was realized based on the orthophoto map realized in 2012, and on the topographic and cadastral plans (1981) on a 1:5000 scale. The distribution of the categories of usage in the territory represents a significant parameter for the evaluation of the susceptibility of the manifestation of hydrogeomorphological processes with a negative impact. The map of flooding risk was realized in order to highlight the destructive potential of the floodplains, with a probability of 1% and 5%. The depth of the terrain fragmentation reflects the altitudinal steps from the level of the minor river bed towards the meadow section and towards the slope so that the favorability of the construction will be highlighted (according to the legal stipulations). The placement of constructions in the proximity of the minor river bed can be observed. This is due to the existence of large slopes on the largest part of the valley sector. Unfortunately, the lower meadows of the terraces do not represent the most favorable placement location of houses, because they are subject to floods, especially to the associated ones (rising levels of water and thaw formation).

Keywords: floods, major river bed, reservoir, thaw formation, villages

INTRODUCTION
Hydric risks in large river basins are some of the most frequent threats associated with natural hazards [1, 2]. In the first place, for the optimal management of these situations, it is required to realize the detailed cartographic materials, which will highlight the areas that are most vulnerable to the risk phenomena [3-5]. These thematic maps and detailed plans facilitate the development of specific strategies and measures that can lower the impact of natural events [6].

The spacing of the territories affected by the overflowing waters during floods is highly important in the plans of regional and local improvement of the territory. The risk of flooding is a subject that is extremely well studied at both a national [7-19] and international [20-29] level because the material damage and loss of human life caused by these events are very high [30, 31].

This study aims to delimitate the areas favorable to construction from the areas that are unfavorable, in order to be able to highlight whether the current placement of the construction is in the area with a hydro-geomorphologic risk potential, and to intervene in the future with measures that are in accordance with the safety of the population. Throughout the study, we aim to discover the graphic representation of the land use in relation to the slope of the land and the floodplains with different probabilities (0.1%, 1%, 5%).
STUDY AREA
The Bistrita River springs from the Rodnei Mountains, at an altitude of 1850 meters, and it is located in North-eastern Romania, in the Eastern Carpathians [32]. The area proposed for study is located at roughly the middle of the distance between the spring of the river and its spill into the Siret River, between the town of Brosteni (47°14′39″ N lat. - 25°55′26″ E long.) and Poiana Teiului (47°6′42″ N lat. - 25°55′26″ E long.), on the territory of the Neamț and Suceava Counties. Located on the north-eastern side of the country, Bistrița is in a fully temperate area which is dominated by a temperate continental climate with weak oceanic influences. Thus, the relief of the region has evolved within the fluvial modeling system. The Carpathian landscape crossed by the Bistrița River is made up of medium mountains. The general character is given by the orientation of the peaks in accordance with the great structural lines on the NW – SE direction. The landscape fragmentation is accentuated, being constant at an altitude of approximately 700-900 meters (Fig. 1).

Figure 1. The localization of study area

METHODOLOGY
Throughout this study, we used the following software: ArcGIS 10.2, SAGA Gis, Global Mapper 17, R2V, Microsoft Office 365. The database needed for the creation of the study consists of the following raster and vector cartographic materials: topographic plans (1:5000), cadastral plans (OCPI Neamț), the digital elevation model of the ground (realized based on the 1:5000 topographic plans), Digital Terrain Model (DTM) obtained using LIDAR technology (with a 5 m DTM resolution), Orthophoto map 2012 in 1970 stereographic projection, floodplains (0.1%, 1%, 5%) – ABA Siret [33-42]. In order to highlight the areas with a slope favourable to the placement of houses, it was necessary to have a cartographic support which would serve as a basis for calculating the necessary parameters. The digital elevation model, obtained through the digitalization of the elements of relief from the 1:5000 topographic plans, represent the base of this study. The topographic plans were taken from OCPI Piatra Neamț. The next phase consisted in the vector representation of all the categories of land usage, in order to identify the relative frequency of the land surfaces placed according to the current norms. The floodplains with three probabilities (0.1%, 1%, and 5%) were taken from ABA Siret and are used in order to highlight the territories affected by flooding risks. In order to map the areas favourable to construction according to the slope of the land, it was necessary to realize a map of the slopes, reclassified on four classes (class 1 – maximum favourability, class 2 – restrictive favourability, classes 3 and 4 – totally unfavourable). The map of the fragmentation depth was realized in order to highlight the altitudinal steps and their layout in the territory. After identifying the maximum and minimum altitude on the same surface, it was possible to validate whether the area was favourable for construction in accordance with the calculated relief energy. An important phase of this study consisted in the overlapping of the floodplains with the thematic layers obtained. This phase was necessary for highlighting the areas that are favourable for construction from a geomorphological point of view, but with hydrologic restrictions caused by the flood risk susceptibility.
RESULTS AND DISCUSSIONS
After the maps were created, the four classes of favorability on construction were delimited. The analysis was realized in the extreme classes: 1 and 4 (favorable and unfavorable). The 1st class, with a slope of 0° to 4.5°, represents maximum favorability for house placement, with no restrictions. It can be observed that the highest favorability is on the lower terraces of the meadows (with an altitude of 5 to 10 m from the minor river bed) and isolated, on the higher terraces. The 2nd and 3rd classes, with a slope of 4.5° to 13.5°, are mainly encountered on the terraces with a higher altitude and on the slopes. The 4th class, with a slope higher than 13.5°, where house placement is impossible, occupies the largest surface in the area of study and it is dominated by forests, pastures, and grasslands.

Figure 2. Land use and the relative frequency of flooded surfaces; a. Land use in an area with a favourable declivity; b. Land use in an area with an unfavourable declivity; c. Relative frequency of flooded surfaces in an area with favourable declivity; d. Buildings in an area with favourable slope, e. affected by flood

Figure 2a presented on the following page, highlights the usage of land in an area with a favourable declivity. This graph was obtained as a result of crossing two thermal layers: the vector polygons obtained from the reclassified map of the slopes and the land usage. This graph highlights the relative frequency of the categories of usage in the areas with a favourable slope. The percentage
values represent the surface occupied by each category of usage in this area with reduced slope, favourable to house placement. The arable land occupies the largest part of the surface (44.86%), followed by yards and other related constructions. The degraded land is located mainly in the proximity of the minor riverbed of the Bistrița River, in areas with water erosion. Here, the declivity is at its lowest point, which is why the damaged land occupies a significant territory of the total surface with the favourable inclination (12.75%). The smallest percentage of the surface is occupied by forests and pastures, their distribution being more common in an area with a higher slope, specific to the mountain area.

The distribution of the categories of usage suggests the unfavorability of housing placement in this area with high declivity, of more than 18° (>30%) (Fig. 2b). Of the total surface with unfavourable slope, 0.19% is occupied by constructions. Due to the restricted space of the areas with low declivity, in this unfavourable zone, the arable land consists of only 4.19%. Grasslands and forests are currently the main categories of land usage in this area.

The construction of houses in the area with a high slope requires high expenditures because an additional resistance structure must be created. Access paths are difficult to create, and because of this reason, there is a tendency for houses to be created in a more favourable declivity area, notably in the river beds and on the lower terraces.

**Figure 3.** Cartographic representation of the favorability of building placement and of flood band with 0.1%, 1%, and 5% probabilities: a. Broșteni and Neagru; b. Haleasa and Lungeni; c. Mădei and Pârâul Cârjei; d. Popești, Frumosu, and Pârâul Fagului; e. Borca and Sabasa; f. Soci

It has been demonstrated that although the meadow of the Bistrița river and its associated terraces have a slope that is favorable to house placement and agricultural activities, a large part of the area is...
susceptible to flooding, with different probabilities (0.1%, 1%, 5%). By intersecting three thematic strata (the area with favorable declivity, the usage of land, and the floodplains) all the types of land usage susceptible to flooding are highlighted (Figure 2c). The arable land occupies the largest floodable surface in the sector with a slope lower than 4.5° (17.57% in the case of the floodplains with a 1% probability, and 28.22% in the case of the floodplains with a probability lower than 0.1%). The total number of constructions from the whole study area is 17,861 (Figure 2d). Out of these, 10,008 are placed in an area with favorable slopes, and the other 7,853 are placed in areas with restrictions regarding the construction of houses (due to the high slopes). Of the 10,008 constructions placed in a favorable area from a geomorphological perspective, by crossing the floodplains with the 1% flooding probability, it was proven that 3,701 of them are at risk of flooding. (Fig. 2e). The 0.1% flooding probability can affect 5,617 constructions from the total of 10,008 placed correctly from a geomorphological point of view (favorable slope). The floodplains with a 5% probability intersect 508 constructions.

Figure 4. Flood risk maps within mountain sector of Bistrita River
The overlapping of land usage and floodplains with the slope classes revealed the areas favorable to construction from a hydro-geomorphological perspective. The town of Broșteni is located in a favorable area because the declivity is low and the flooding risk is insignificant (Fig. 3a). The floodplain of 1% completely affects the lower meadow terrace (2-3 m) in Hâleasa, and the 0.1% spreads over the 5 m terrace, affecting most of the constructions (Fig. 3b). The slope favorability for construction is extended on a large surface, but the houses are placed in an area with a hydrologic risk. The 0.1% floodplain covers 75% of the village of Mădei, and the 1% floodplain covers 50% of it. This shows that most of the houses were placed wrongly, without taking into consideration the risk of flooding (Fig. 3c). In Pârâul Cârjei there is a flooding risk only on the 5 m terrace, the rest of the town being placed safely on the 10 m terrace. Popești is located on the 45 m terrace. From a declivity perspective, this village is placed in the second class of slope favorability (4.5° – 9°) but there are no chances of it being affected by flooding (Fig. 3d). On the other hand, the village of Frumosu is almost completely floodable, especially during winter, especially due to the freeze-thaw phenomena. The village of Sabasa is placed on an alluvial area, favorable to house placement in a proportion of 80% (Fig. 3e). The 1% and 0.1% floodplains enter the 5 m terrace surface and 63 constructions become susceptible to flooding, out of which 26 are houses. The most critical situation is in the Soci locality, in the Borca commune, located on a terrace with an altitude of 5 m (Fig. 3f). The whole village is placed on an area that is favorable from a geomorphological perspective (small declivity: between 0° and 4.5°). But at the same time, from a hydrologic perspective, the whole area with a favorable slope is susceptible to flooding on a 0.1% probability.

The 0° – 4.5° slope class (which occupies 28% of the studied area) is almost continuous in the longitudinal profile of the river. It corresponds to the sector of meadows and lower terraces. The value range is between 4.5° and 18° and corresponds to the joining surfaces (slopes, terraces), to the upper terraces and the secondary interfluves (that were caused by erosion by the tributaries of the Bistrița River), all being inclined towards the valley. The areas with inclinations ranging between 18° and 35° occupy a significant surface in the Bistrița Valley, in the Broșteni – Poiana Teiului sector. The greater share of these surfaces with high declivity is in the proximity of Borca (Bistrița Mountains) and on the left slope, an almost all of its length. The high slope of the land favors the violent flow of Bistrița’s tributaries, favoring strong floods.

We have opted for a qualitative risk assessment of the floods. Firstly, this involved the identification of risk receptors, and secondly the assessment of the vulnerability of the identified objects that are exposed to flooding, taking into account the depth of the water and the potential damage caused to the flooded objectives, as well as the impact on the considered risk receptors (Fig. 4). In this case, the water from abundant precipitation and transported in floods represents the hazard. The villagers, houses, and the land represent the vulnerable factor that generates the risk phenomena. The high risk degree is suggested by the large surface of yards and of constructions that are at risk of flooding with the probabilities of 0.1%, 1%, and 5%.

CONCLUSIONS
After analyzing the cartographic materials and the related graphs it is noticed that in the proximity of the minor riverbed of the Bistrița River the following categories of land usage are predominant: yards, constructions, and arable land. The houses are located on the lower meadow terraces. The surfaces with reduced declivity favor their placement from a geomorphologic perspective, but at the same time, from a hydrologic perspective, they are susceptible to flooding. The surface that does not imply a hydro-geomorphological risk is very restricted. More than half of the total number of houses are placed in an area with a risk potential. The mountain area from Bistrița Valley does not permit the placement of houses on the slopes because of the large geo-declivity and of the difficulty of creating access paths. The optimal solution for preserving the current situation of the constructions is the appropriate damming of the Bistrița River and the improvement of river torrents (the river torrents causing floods more frequently than the main river). The best solution, excluding the current one, is to completely avoid the placement of houses in the proximity of the river.

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Forming and disappearance of small retention system in the postindustrial area – case study from the central...
FORMING AND DISAPPEARANCE OF SMALL RETENTION SYSTEM IN THE POSTINDUSTRIAL AREA – CASE STUDY FROM THE CENTRAL SECTION OF THE KAMIONKA RIVER VALLEY (CENTRAL POLAND) SINCE THE 18TH CENTURY

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Abstract
The Kamionka Valley is an old industrial area located in the northern part of the Świętokrzyskie Province. From the early Middle Ages was mined here iron ore and processed in forges located on the river. Many forges was operating also in Suchedniów located in middle section of the river. For over the last centuries, in this area the river have been occurred many anthropogenic changes related to human impact. Industry, based on mining and metallurgy, developed here as part of the Old Polish Industrial District and the Central Industrial District. Their activities contributed to numerous changes in the riverbed and the construction of water reservoirs creating system of small retention in Kamionka. Most changes on the river took place in time of high activity of the forges (from 18th to the first half of the 20th century). Changes in industrial activity reduce the number of ponds on the river led to an increased risk of flash floods, which perfectly illustrates the events taking place downstream of the Suchedniów reservoir dam (1974 and 2010).

Keywords: Holy Cross Mts., Kamionka river, human impact, flash floods, small retention, forges

INTRODUCTION
The Kamionka river valley is located in the northern part of the Świętokrzyskie Province. Iron ore was mined here from the early Middle Ages, which was processed in forges. Those forges was operating also in Suchedniów town located in middle section of the river. Kamionka is the right tributary of Kamienna river. The entire catchment area is located on the Suchedniów Plateau. Kamionka is a meandering river with a length about 17 km and an average slope 5%/oo[1]. During the last centuries, in its middle section of the river there have been occurred many anthropogenic changes related to industrial activity. Industry, based on mining and metallurgy, developed here as part of the Old Polish Industrial District and then Central Industrial District. Suchedniów was established here as a small settlement. First historical data of it come from years 1224[2] and from 1510 come first information about the forge operating on the river [3]. Their activities contributed to numerous changes in the riverbed and the construction of water reservoirs creating system of small retention in Kamionka basin. At the turn of the 19th and 20th century, the forges on Kamionka river were abandoned. In their place was built water mills using old hydrotechnical infrastructure. To the half of the 20th century numerous small ponds were drained and replaced with larger reservoirs for retention purposes.

The further expansion of the city contributed to regulating the riverbed which resulted in the disappearance of the flood plain on some sections of Kamionka river valley (just like downstream of the Suchedniów reservoir dam). Changes in the water cycle in the Kamionka river basin introduced by man led to the emergence of new catastrophic events on the river.
AIM OF THE STUDY AND METHODS
The article focuses on the analysis of anthropogenic changes at Kamionka and their impact on the development of the Suchedniów area in recent centuries.

An analysis of archival materials (old topographical maps, Suchedniów situational plans, photographs) were compared with the results of the field observations of the studied area. There were used maps and archival materials from the 18th century (some of information are from 16th century) to the first half of the 20th century. A large part of these materials comes from private collections of the people living in Suchedniów, as well as from the "Suchedniów Lexicon" [3]. The results of these studies have allowed the location of former hydrotechnical objects and their remnants on Kamionka river in this area. Also was made an analysis of modern hydrotechnical facilities in Suchedniów and their impact on the development of the city. In 2017 there was begin a works leading to deepening reservoir in the Suchedniów. In fact this moment was used to made extensive analysis of forms and sediments of this hydrotechnical object.

Figure 1. The research area with the location of former industrial and mill reservoirs on the archival map First Military Survey (1763-1787) - West Gallizien (1801-1804)

The presented results are a part of research on anthropogenic changes of forms and sediments in the Holy Cross Mountains valleys carried out in the Department of Geomorphology, Geoarcheology and Environmental Management of the Institute of Geography Jan Kochanowski University in Kielce in project BS 612 480 "Funkcjonowanie środowiska geograficznego regionu świętokrzyskiego w warunkach zmian klimatu i narastającej antropopresji/Functioning of the geographical environment of the Świętokrzyskie region in the conditions of climate change and increasing of human impact" led by T. Kalicki.
HISTORICAL CHANGES
Since Prehistoric times, and later in the Middle Ages, mining and metallurgy based on iron ore, which lies in the Triassic deposits, played an important role in the development of this area. To the west of the investigated area developed Prehistoric metallurgy using furnaces known as bloomeries [4]. The first information of forges operating in the Suchedniów area came from the beginning of the 16th century [3]. On Kamionka river at that time there were at least 7 forges [5]. Those forges use Kamionka river as proper source of energy. The processed iron ore came from mines located in nearby hills where are until today preserved many buried mining shafts. Local forests were also used as a source of charcoal, which were burned in the forges.

Suchedniów was a large mining and industrial center. The industrial and urban infrastructure was modernized by Stanisław Staszic [3]. Numerous embankments, channels, dams and ponds were built, which were an integral part of the infrastructure of the forges [5], [6]. The remains of the old infrastructure of those forges are still clearly visible in the center of Suchedniów (dry channel or ground shaft near the city park). Created ponds near the old forges have not been preserved to this day, but they are clearly visible on topographic maps from the turn of the 18th and 19th century (First Military Survey 1763-1787 - West Gallizien 1801-1804) (Fig. 1). These reservoirs are also visible on many other sheets from later years, as well as on old photographs and town plans. Archival materials document the dynamics of changes taking place during the last centuries on Kamionka river. They show, among others formation and disappearance of the Suchedniów water reservoir [1](Fig. 2). In 1863, as a result of insurgent actions, Suchedniów was completely burnt by the Muscovites. However, the hydrotechnical infrastructure of forges and mills was quickly rebuilt. The forges was used until the end of the 19th century. Some of water mills was using remaining hydrotechnical infrastructure of old forges. To the half of the 20th century water mills were no longer used in this area. This meant that up to the middle of the 20th century, many smaller ponds in Kamionka disappeared. In modern times most of the mills have been destroyed (Baranów), while the rest have been restored (Berezów and Jędrów).

Figure 2. Schematic sketch of the modern Suchedniów reservoir with the boundaries of previous ponds and location of the former riverbed

PRESENT-DAY CHANGES
In the second half of the 20th century, many water mills were abandoned or dismantled, and nearby ponds were drained. The traces of the former hydrotechnical infrastructure (shafts, channels,
Forming and disappearance of small retention system in the postindustrial area – case study from the central …

foundations of mills and forges) remained visible in the relief and landscape. Sometimes in the place of old forges was build later a larger factories (e.g. at Suchedniów). This action lead to the disappearance of small watercourses, just like Pstrążnica, small left-side tributary of Kamionka river [7], [8], [9]. North of Suchedniów, there is also a embankment of a 19th century narrow-gauge railway, which was transported iron ore from the nearby mines and wood to the sawmill [3]. Currently, the track has been disassemble and the remaining embankment separates the flood plain into two parts.

In the places where forges and mills was working on the river forming anthropogenic anastomoses as a result of industrial activity in the Kamionka. In such sections the river flows simultaneously with a natural channel and at least one anthropogenic channel (e.g. at Baranów) [10]. These anastomoses also functioned in historical times, that is visible in archival maps from last centuries. This type of river bed development also occurs on many other rivers of the Old Polish Industrial District, e.g. on the Wierna Rzeka [11]. In the second half of 20th century the small typical industrial ponds were abandoned for the benefit of larger retention and touristic reservoirs purposes, e.g. the reservoir built in 1974 at Suchedniów and at Rejów.

In 2005, the course of the river was changed near the campsite at the Sports and Recreation Center in Suchedniów. A several-hundred-meter-long channel was dug, which Kamionka flows into the reservoir, and the natural riverbed section has been buried. Present-day there is a small haven in the former estuary [1].

The current hydrotechnical infrastructure on Kamionka does not provide full retention possibilities. This led to the occurrence of sudden catastrophic events on the river, such as flash floods. They took place, for example in the Rejów reservoir in 1939 [12] as well in Suchedniów in 1974 [3], [13]. Shortly after completion of the construction works of the Suchedniów reservoir due to the overfilling of it, the shaft was broken near the dam. This lead to create a flood wave on the river downstream from the reservoir. The traces of these floods are visible on a short section of river downstream of the reservoir, where is accumulated the coarsest material (rocks, concrete fragments, sandstone pebbles) [14]. [15]. Recent research confirms the lowering of the retention functions of the reservoir due to its silting and shallowing. This was caused, among others, by construction of the S7 expressway, of which embankments were incised by Kamionka. This led to the include a large amount of material into river transport, which was accumulated in the reservoir at Suchedniów. The result of this process was the formation of a clear inland delta at the estuary of the river into the reservoir [16], [17]. Decreasing the flood potential of the Suchedniów reservoir lead to the occurrence of further catastrophic events [1].

![Figure 3. The channel made in the sediments of the modern Suchedniów reservoir with visible layers of sediments of the previous reservoir, covered with sandy mega ripple marks from the flood in 1974 (photo P. Przepióra in 2017)](image-url)
In 2017 started works lead to deepen the reservoir at Suchedniów. The aim of this work is to restore the reservoir's retention capabilities by sediments dredging from its bottom, removing deposits, creating new reservoir slopes and repairing the dam. The moment when reservoir become dry gave the opportunity to start research on the sediments and forms accumulated from the beginning of its existence. During this work was discovered remains of the previous reservoir (probably from the beginning of the 20th century) as the distinct, dark layer of mud. This material was covered by 1.0-1.5 m diameter, sandy mega ripple marks left by the flood caused by the breaking of the dam in 1974. All those layers are covered with sediment deposits of the modern reservoir.

CONCLUSIONS
The presented area perfectly presents the high level of anthropogenic changes on the river caused by industrial activity. Most changes are visible near the Kamionka riverbed in the Suchedniów area. Mining and metallurgical activities within the Old Polish and Central Industrial Districts contributed to the creation of many water mill ponds on Kamionka river.

Most changes on the river took place from the 18th to the first half of the 20th century, when most metallurgical plants and water mills were active in here. Kamionka was regulated, especially in the middle section, as a result of the construction of many channels, reservoirs and a change in the direction of the river's flow. Human activity on the river contributed to the formation of anthropogenic anastomoses, functioning in historical times, and locally also in modern times. Reducing the number of ponds on the river led to an increased risk of flash floods, which perfectly illustrates the events taking place downstream from the dam in Suchedniów reservoir (1974 and 2010).

Present-day, various investments are being carried out in Suchedniów on Kamionka to improve the hydroelectric infrastructure possibilities, as well as their tourist assets. These investments also enabled the discover in the sediments the old ponds remains. These discoveries confirms the disappearance of small retention which appear on many cartographic materials from the last centuries.

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EVALUATION OF THE PROPAGATION TIME OF A THEORETICAL FLOOD WAVE IN THE CASE OF THE BREAKING OF CATAMARASTI DAM, BOTOSANI (ROMANIA)

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Abstract
Storage lakes represent an important source of water for the areas with a high deficit of hydrologic balance (ex: Moldavian Plain from NE of Romania). This region holds an important number of lakes that allow the storage of water during periods with rainfall shortage. At the same time, they play an important role in the protection of localities against floods. In addition to the benefits that these lakes have, they can also represent a risk factor for the localities situated in the downstream region, in case of dam collapse. In Romania it is widely known the catastrophic event from 1991 when Belci Dam situated on Tazlău River was breached, causing an entire neighborhood from Onesti City to be flooded. The present study focuses on Catamarasti Lake which has a maximum water volume of 12 million cubic meters, the dam being located 3 km upstream of the first locality and the periphery of Botosani City. The proximity of the inhabited areas makes the dam break scenario to be a probable event, therefore the identification of the propagation time of a possible flood wave is essential towards the creation of a system for the protection of the population. The dam break simulation and the quantification of the propagation time of the entire water volume on Sitna river valley is made using HEC-RAS, based on a LiDAR digital elevation model, using the 2D simulation method. In this case, having a likely floodable surface as well as the time in which the flood can reach the nearby localities, there were identified the risk exposed households located in the floodplain, in the vicinity of the river.

Keywords: dam, HEC-RAS, lake, management, simulation

INTRODUCTION
The absence of water in certain regions, the very high probability of flooding or the necessity for generating electric power are some of the main reasons which stood at the basis of the human desire to store water in lakes. Anthropic lakes have the capability to bring a multitude of benefits to the nearby population and settlements, but at the same time the existence of these water bodies can represent a great risk for the populations and settlements located downstream [1]. This risk exists through the possibility of the dam (behind which the stream water accumulates), to be breached or to break [2]. One of the most recent events of this type, which implied a dam being exposed to breaking, was the event from February, 2017, at Oroville Lake from California, USA, when a number of approximately 188 000 persons were evacuated. This particular event was one fortunate scenario, because no casualties were recorded [3]. In contrast, perhaps the biggest disaster of this kind was the one that took place in China, when the Banqiao and Shimantan dams breached in 1975, causing the loss of over 171,000 human lives, 26,000 from flooding and the other 145,000 from famine and water-related disease [4]. Until present, a number of over 2000 dam breaks that had different impacts on society have been recorded, and most of the events of this kind were registered between 1900 and 2000, when the construction of dams has seen an acceleration, due to the ever-increasing need of such hydrostructures [1], [2]. In Romania, a single hydrotechnical accident of high amplitude was registered, in July 1991, when the Belci Dam, constructed on Tazlau river, breached...
Other similar events took place during the 2000s, when two dams from the mining area of Maramures County breached, the lakes discharging a volume of approximately 200,000 m$^3$ of cyanide, and contaminated water and 40,000 tons of tailings in the tributaries of Tisa river, representing an unprecedented ecological disaster for Romania and the neighboring countries [6].

At a global scale, earth dams are the most frequent, having higher probabilities of breaching than other types of dams. The most common reasons for the failure of earth dams are overtopping and piping [1], [2]. In Romania, there are a few thousands of lakes and ponds, with a volume of water that is held by an earth dam and in case of a dam breach, the highest damage is associated to the lakes with high water volumes, discharged after a dam failure [7].

The Romanian Register of Big Dams contains a list of dams which are already built (containing a number of 246 dams, from which 84 are earth dams, 96 are earth dams or gravity dams, 5 are mobile dams and earth dams, others being of different type), or in construction, mentioning that the height of the dam is greater or equal to 10 meters, or the volume is greater or equal to 1 million m$^3$ [8].

The high number of earth dam lakes in Romania and the recent hydrotechnical accidents led to the need of a case study involving an earth dam of high dimensions, namely Catamarasti Dam, built in 1979 on Sitna River, upstream of the metropolitan area of Botosani City, putting at risk an important number of people from the vicinity. The analysis which was carried out was a 2D unsteady flow modelling, using HEC-RAS 5.0.3 for a theoretical breach, that can appear in the earth dam, thus evaluating the impact that a dam break generated flood can have on the inhabited area, located downstream of this reservoir.

STUDY AREA

The study area is defined by Sitna river valley, downstream of Catamarasti dam, on an approximate length of 6 km. Catamarasti Lake is part of Sitna river basin, a right-side tributary of Prut River, which is located in the North-Eastern part of Romania, occupying an area in the Central and Southern part of Botosani County. Sitna river basin occupies an area of 943 km$^2$, the river stretching for a length of 78 km, with an average flow rate of 2.16 m$^3$/s. Catamarasti Lake is placed on Sitna river, on the administrative area of Mihai Eminescu commune, in the upper part of the basin, at an approximate distance of 3 km North of Botosani City (Fig. 1).

The lake is an artificial waterbody with a non-rock/gravel padded type of bottom, a length of 2.6 km and a surface of 160 hectares, with a homogenous earth dam and clay sealing, a height of 15 meters, and a length of 540 meters, being constructed in the year of 1979. The spillway of the dam is composed of two parts: a spillway with free discharge at the top, and a system of penstocks at
The spillway discharge is of 154 m$^3$/s. The main purpose of the lake is mainly for irrigation, fish farming and flood attenuation [8], [9]. The region where the attention was focused on is represented by Sitna river valley downstream of Catamarasti Dam, an area mostly used for pastures and agricultural land. Because the dam is at 3 kilometers upstream of Botosani periphery and other settlements, and the river is very close to these inhabited areas, the potential damages caused by a sudden dam break, would be catastrophic.

**METHODOLOGY**

In order to run the dam break simulation, a numerical terrain model that replicates to a very high fidelity the in-field reality, had to be used. For the purpose of obtaining a high-quality modelling, the most suitable terrain data that could be used was in the form of LiDAR Digital Elevation Model, at a spatial resolution of 1 meter [10]. Before any geometry data could be generated, the data was first converted into Hierarchical Data Format (hdf) and imported into HEC-RAS environment. For the dam break analysis, geometric data and water volume of the lake were required. The first phase of the analysis consists in defining the geometry layers for the area of study. This step implied the digitization of the lake, using the Storage Area option, and the use of 2D Flow Area to define the downstream area (Fig. 2), where the output from the dam breach will be simulated [11].

The mesh generated by the 2D Flow Area option acts similarly to the cross-sections used mostly in 1D simulations, with the difference that this option can better use the elevation of the DEM by modifying the computation cell spacing, which implies the changing in size of the mesh cells. Due to the highly unsteady nature of the dam break flood, low sized cells were considered. Some additional corrections needed to be done in the mesh, to eliminate some imperfections, like adding additional points where is needed and removing some points for the mesh, to be correctly used in the analysis. Concerning the input data for the storage area, the maximum volume of water which the lake can hold was considered for the simulation, namely 12 million m$^3$.

As a final element of the geometric input to the dam break model, to specify the dam and the physical characteristics of it, the option SA/2D Area Conn was used, modelling the dam as a weir. This option also allowed for the upstream and downstream geometric data to be connected through the modelled dam. To be able to model a dam breach in HEC-RAS, failure mode, breach size and breach time needed to be entered. After the dam was digitally reconstructed, the breach parameters were inserted into the breach plan data, selecting the overtopping failure mode of the dam and 30 minutes time for the breach to form [11]. The shape of the breach was assumed to have a rectangular form.

The assumptions regarding the boundary conditions, as a part of the analysis, are also critical, as far as dam break modelling is concerned, as they
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could directly affect the extend of downstream flood water. These boundary conditions need to be properly selected and, at the same time, to be able to accurately represent the site conditions. In a more complex analysis, detailed hydrologic data is needed to be able to model a more realistic scenario of a dam break flood, like inflow data [12]. In this study, the boundary conditions which were taken into account were: Elevation-Volume data (to represent the storage upstream of the dam), and Normal Depth (for the downstream boundary conditions).

For the dam break flood simulation, Manning values of 0.06 for the floodplain were used, considering the fact that the area downstream of Catamarasti dam is covered by pastures and agricultural land. These values were selected based both on generalized reviewing of the land use situation and aerial imagery of the area. Based on the geometric and boundary conditions data, the dam break simulation was run, for a time period of 12 hours, choosing a computation interval of 10 seconds and a mapping interval of 1 minute, for the dam break flood model to be more stable [11].

**RESULTS AND DISCUSSIONS**

The primary pursuit of this analysis was identifying the propagation time of a dam-break generated flood wave, which is essential for the development of human protection systems, and ultimately, for warning the authorities and population downstream of the dam, for proper and rapid measures to be taken in case of imminent disaster. Due to the placement of the dam in the vicinity of Botosani City and other localities, the analysis was made by considering the worst-case scenario, namely the failure of Catamarasti dam at full capacity, that of 12 million m³ of water volume.

The final products of the unsteady analysis carried out in HEC-RAS 2D module represent a series of maps showing the velocity of the flood water in the affected areas and the overlay of the dam-break generated flood on top of the affected areas. The cartographic materials were created using ArcGIS. The first result (Fig. 3) shows the velocity of the water in the flooded areas, in Cismea and Rachiti villages and across the northern side of Botosani City periphery. After the dam was theoretically breached, the resulted flood wave arrived, first in Cismea village, in approximately 40 minutes, entering the village with a speed of 6 m/s. Starting from this point, the velocity of the water started to drop, recording maximum flow speeds of 4.8 m/s in Botosani City periphery, entering the city with speeds of 4.2 m/s, rapidly decreasing towards small values and 4 m/s in the affected areas from Rachiti.
village, the velocity continuing to drop towards downstream, exiting the urban area of Botosani City, with simulated flow speeds at a maximum of 4.4 m/s.

Concerning the damages generated by the flood, a map showing the potentially damaged constructions and households across the affected areas was made (Fig. 4). The total number of households and building damaged by the generated flood is 336, with a number of 82 households damaged in Cismea Village, a total of 125 households in Rachiti Village, and 129 affected households in Botosani City. The counted households and buildings which were affected may not seem that high, but considering the city and nearby villages, and in the case of a broader damage analysis, the affected objectives would include other elements, like streets, bridges, the economic purpose of the buildings, etc. For this analysis, the variable chosen to highlight the magnitude of this scenario was the number of affected buildings and constructions.

As a final cartographic product of the dam break analysis, a map with the flood water depths was generated, as it can be seen below in Fig. 5. As it can be observed, the values of the flood water depth are spanning in a range between 0.001 meters, to 14.755 meters, the generated values dropping on an upstream-downstream direction and also towards the side limits of the flood. The maximum depth of the water is located at the entrance into the inhabited area, concentrated mainly in the middle region of the flooded area, where Sitna River flows. Because the river valley widens towards downstream, implicitly, the flood extends, it covers larger portions of land and inhabited zones, the most affected parts being the periphery of Botosani City, where the depth values are the highest, covering the largest portions among the three inhabited areas. The total area covered by the generated flood in the inhabited areas, counts a surface of 195.026 hectares. Regarding the area covered for each of the villages with the simulated water, the flooded surface in Cismea village counts 47.44 hectares, 30.49 hectares in Rachiti village, and 46.75 hectares in Botosani City. Overall, the dam break analysis revealed that, in case of such an event, a large portion of land can be affected by floods, involving a high number of affected households, with high velocities and depths, which would represent an important argument for the authorities towards the development of a protection system, and warning for the vulnerable population located downstream, in case such scenario would actually manifest in the future.
CONCLUSIONS

Dam break analysis is a complex process, requiring intensive study for a good understanding of how the mechanisms related to computer simulations function. For a reliable analysis, accurate elevation and hydrological data are needed. Concerning the methodology of simulating a dam-break flood, the 2D module of HEC-RAS 5.0.3 proved to be a suitable environment for this analysis, having multiple options for detailed and complex flood studies.

![Figure 5. Water depth following the simulated dam break flood in the areas of Cismea and Rachiti Villages and Botosani City periphery](image)

The study area chosen for this exercise was relevant, due to the proximity of settlements to an earth dam, which could potentially represent a risk for the population living downstream, in case of dam failure. The results were significant, offering detailed insight to the potential outcome of a hydrological event of this kind, and at the same time, underlying the importance of developing a safety plan for the exposed population. By taking into account the results of the present study, the authorities could use the findings, for the development of an efficient strategy, regarding the warning of the population in case of disaster and for better managing of the potential damages caused by a dam break scenario.

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