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URBAN HYDROGRAPHY AND BLUESPOTS MAP OF CRAIOVA (ROMANIA)

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Abstract: The global climate change imposes new strategies of prevention and protection against the effects of urban flooding. The main goal of this paper is the identification of areas exposed to flooding risk in the Craiova city, and the study was structured in two sections. In the first part we aimed to identify the changes of the hydrography in the Craiova city from the beginning of its urban expansion and the hydrotechnical works realized for flooding protection from the 19th century until now. The reconstruction of the hydrography was based on the cartographic documents elaborated since the second half of the nineteenth century and on the previous research concerning the city's design, water supply and sewage system. In the second part we realized a Bluespots map comprised of the areas and the buildings possibly exposed to the risk of flooding during heavy rainfall periods. The Bluespots map was automatically obtained with the Cloudburst extension of ArcGIS, being based on DEM data and the cadastral map of the city, after a method firstly applied by the Danish government to assess flood risk areas due to Cloudburst phenomena in Copenhagen.

Keywords: urban hydrography; Craiova; Bluespots; Cloudburst; flooding risks

Introduction

The effects of urbanization in the urban hydrological processes are visible through the change of the surfaces that cover the city area (Yamashita, Watanabe, & Shimatani, 2016) and the accelerating runoff flow velocity (Weng, 2001; Li & Wang, 2009) thus increasing the urban flood risks (Chen, Zhou, Zhang, Du, & Zhou, 2015; Mahmoud & Gan, 2018). The global climate change induced a growth in the frequency and intensity of extreme events, such as extreme precipitation that combined with urbanization and land use change will cause even more severe floods and damage to urban areas in the near future (Liang et al., 2017; Jamali et al., 2018; Zare & Talebbeydokhti, 2018). Since floods have the potential to cause major losses, it is important to identify areas exposed to floods (Oubennaceur, Chokmani, Nastev, Lhissou, & Elalem, 2018) and include them in local strategies for flood prevention that should comprise

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measures such as constructions of river dikes, flood forecasting and warning, hazard and risk maps, etc. (Tingsanchali, 2012).

Urban pluvial floods are in many cases caused by insufficient or poor drainage in collecting the rain water during high intensity rainfalls (Tingsanchali, 2012), when free flow to the underground drainage network becomes pressurized and the water level rises above - ground causing surcharge in manholes or sewer inlets (Jamali et al., 2018). Minor flooding, with a more frequency than a major flooding, could appear even during periods with moderate rainfall (Cherqui, Belmeziti, Granger, Sourdril, & Le Gauffre, 2015), but in a cloudburst, the urban flooding occurred creates more important economic losses and dysfunctionalities.

Taking this into account, we tried in this study to identify the urban areas of the Craiova city with potential risk of flooding. In the first part of the paper we identified the changes supported by the urban hydrographic network and the protection hydrotechnical works achieved between the end of 19th century and present, and in the second section we realized the Bluespots map which includes areas that will be affected in the case of extreme rainfall event and the buildings touched by these areas.

The study area

The city of Craiova is situated in the south of Romania, at the contact between the piedmont and the plain, on the Jiu terraces and floodplain (Figure 1). The west limit of the city is represented by the River Jiu and the north limit by its tributary, Amaradia. Altitudinal, the surface of the city extends between 69 m in the Jiu floodplain and 199 m in the East limit.

The core of the urban settlement expansion was positioned on the first Jiu terrace, while nowadays the city is expanding on the entire complex of the terraces but also in the floodplain, which was covered mostly by swamps at the end of the 19th century (Albă, Zamfir, Boengiu, Șoșea, & Mititelu Ionuș, 2017). The climate characteristics of the zone are the Continental Temperate Climates with some influences from the Sub-Mediterranean Climate, the annually average temperature is 10.9 ºC and the rainfalls have a monthly average of 50.8 l/m². The trend of the average annual amount of rainfalls is an increasing one, the smallest annual value recorded was 292.9 l/m² in the year 1958 (Marinică, 2006) and the biggest value of 1 080 l/m² in the year 2005, while the multiannual average is 530.8 l/m².

The highest monthly rainfall quantity was registered in the month of October 1972 — 238.3 l/ m² and the maximum rainfall amount registered in the last 24 hours was in the month June 1972 — 84.8 l/ m².

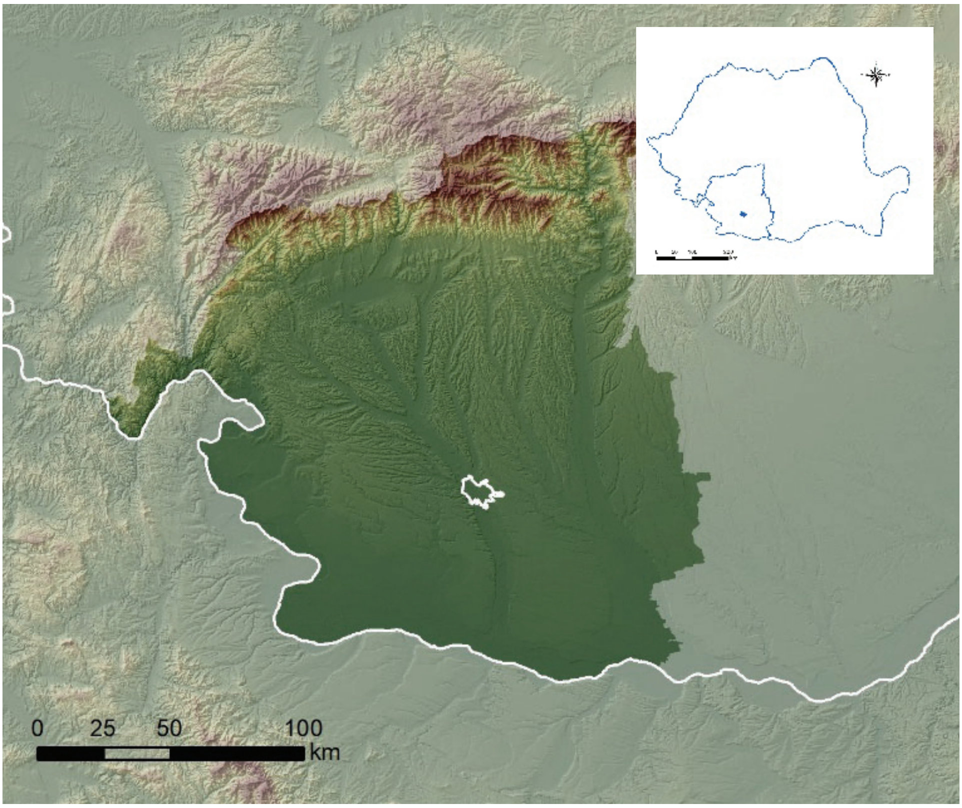

Figure 1: Localization in S-W Oltenia Region and Romania map (Source: C. D. Albă, after ANCPI, 2018)

The hydrographic element with the highest influence over the city is the Jiu River, with a multiannual discharge in the Craiova area of 85.6 m³/s, but which has also registered exceptional discharge, like the one from October 1972 with 2,000 m³/s at the hydrometric station Podari, near Craiova.

Materials and methods

A. The reconstruction of the hydrography and hydro-technical works that started at the end of the 19th century was elaborated after the study of previous research concerning the city's design, water supply and sewage system, studies on groundwater and surface water resources in the area of Craiova (Nicolaescu et al., 1997; Avram et al., 1998; Ciobotea et al., 1999; Savin, 1990; 2000), but also using cartographic documents elaborated since the second half of the nineteenth century: The Second Military Survey 1856–1859, Charta României Meridionale 1864; Craiova Plan in 1905; Planurile Directoarede Tragere 1903–1925; Topographic Map of Romania 1:25,000, 1974. The hydrographic map of Craiova in the year 2018 was processed on the basis of field observations and current orthophotos.

B. The identification of the areas from the central part of the city, with flooding risks, has been materialized by configuring the Bluespots map. The achievement of this map was based on the method created by Thomas Balstrøm (Balstrøm, 2015), using the Cloudburst extension of ArcGIS10. The Bluespots Map was applied first by the Danish government to assess flood risk areas due to Cloudburst phenomena in Copenhagen and then by Indiana University Richard M. Fairbanks School of Public Health to create a bluespots map for the Near West Neighborhood in Indianapolis. The method uses DEM data and the buildings map of the city and results in the identification of low areas with the potential for storm water overflow in case of heavy rains and the identification of buildings in or adjacent to the flood affected areas.

The ModelBuilder created by T. Balstrøm is detailed below and visually represented in Figure 2, where dark rectangles represent INPUTS, light rectangles OUTPUTS and ovals represent PROCESSES executed by ArcGIS. The DEM used is processed by running “Fill”for sinks less than 0.02 m, considered potential errors, accordingly the vertical accuracy of DEM used for Craiova, with result “Small sinks filled” and then “Fill” again for pour points, having result “All sinks filled”.

The result of “Minus” process is the raster data “Bluespot Depths Cell by Cell”, “Small sinks filled” being subtracted from “All sinks filled”, and shows the location and depths of valid sinks, considered bluespots. In “Con” process, representing conditional evaluation, valid cells were considered with value > 0, and they were arbitrary assigned to value 1. For the rest of the cells were assigned value NoData.

“Region Group” process groups the bluespot cells that have already been identified into uniquely numbered regions on the basis of continuity. In the next step, the “Bluespots with ID” are converted to polygons. In a separate process of Modelbuilder, the polygons of buildings are first converted to raster and then back to polygons, in this way, bluespots and buildings will receive a similar shape.

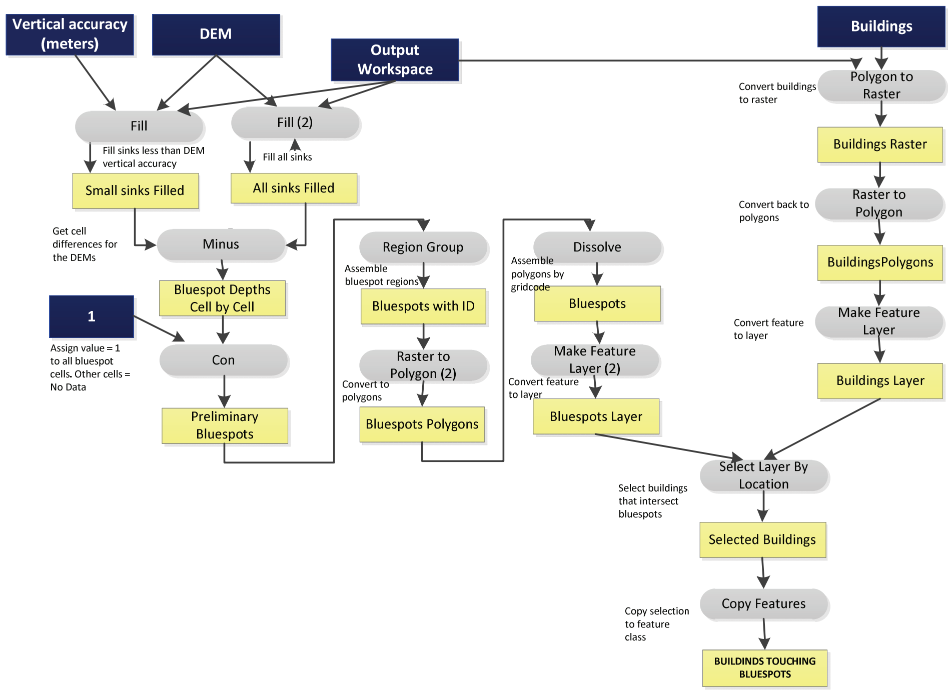

Figure 2: Flow chart representing ModelBuilder used to achieve the Building Touching Bluespots (Source: C. D. Albă, after the ModelBuilder created in ArcGIS by T. Balstrøm, 2018)

“Dissolve” will merge the diagonally connected cells to a bluespot, in the bluespots that they belong to. “Make feature layer” creates a layer from existing data. In “Select data by location” the buildings are spatially compared to the bluespots by the intersection and will be selected if they are adjacent or partly or completely within bluespots. In the last step “Copy feature”, a new layer with feature class is made including the selected buildings.

Results and discussion

The Dynamics of the Hydrography and the Hydrotechnical Works Achieved in Craiova

In Craiova, a city developed on the left bank of the Jiu River, at the end of 19th century, the floodplain was occupied in proportion of about 30% by swamps, which constituted an impediment in the development of the city. The city's hydrography was completed by natural streams with NE-SW flow direction, originating in the upper terraces and discharging into the swamps. The current territory occupied by Craiova has been affected by strong floods, caused either by the overflowing of the Jiu, or by the inability of the internal courses and lakes in retaining the rainfall. Written records about exceptional floods on the river Jiu throughout the 19th century, in 1864, 1879, 1881, 1893, were elaborated by Engineer Chiru (Savin, 1990) and the lakes and swamps in the floodplain were the result of the Jiu's flooding, being subsequently maintained from the springs that originated from the terrace contact with the floodplain and meteoric water. Before the city's first systematization, conceived in 1855, some streams had their channels on the current large boulevards of the city: Valea Vlăicii — on the current Brestei street, having two tributary streams whose subsequent sewerage allowed the construction of the streets Stefan cel Mare and Calea Bucuresti; Valea Tabacilor — the current Ghe Chitu Street. Some of the streams have been arranged and are also preserved in the current hydrographic area: Valea Jianului inside the Botanical Garden, Valea Fetii, on which were built recreational lakes in the Romanescu Park, Valea Preajba in the southern extremity of Craiova, Hanul Doctorului Valley and the rest were captured in the sewage system or transformed into Collecting Canals: Elca Valley, Corniţoiu Valley, Craiovița stream and Şarpelui Valley (Figure 3).

Swamps from the floodplain restricted the construction expansion and maintained epidemics and insalubrity, for which reason, no later than 1887 it became a priority for the authorities to drain, collect and channel the resulting water as well as waste water and rainwater. The landscaping works began with small steps around 1889 and in 1914 the ponds were partially drained and there were also partial works at the canal system (Avram et al., 1998). The urban hydrography renewal had continued in the interwar period and also after the Second World War. But swamps drainage did not offer any protection against Jiu flooding or when the new constituted hydrographic bodies were overflowed. The first protection dikes on the left side of Jiu were built, but their inefficiency was proved on the occasions of exceptional hydrological events produced in 1940, 1948, 1953, 1956, 1970, 1972 and 1975 when more city neighborhoods were flooded. As a result, more dikes were built: in the period 1981–1983 the dike at the confluence Jiu – Amaradia area, in the north of the city, in the period 1978–1980 the right bank of Jiu River underwent a dike construction and in the period 1981–1984 the left bank (Avram et al., 1998). The Collecting Canal settled on the former course of the Craiovița stream, based on the Lindley Project from 1914, had proved to be overwhelmed by the continuous urban expansion and a permanent covering of surfaces with impermeable materials in the second part of the 20th century and this imposed the arrangement of the Craiovița Lake to take over the rainwater and also the flooding protection for this water bodies (Figure 4).

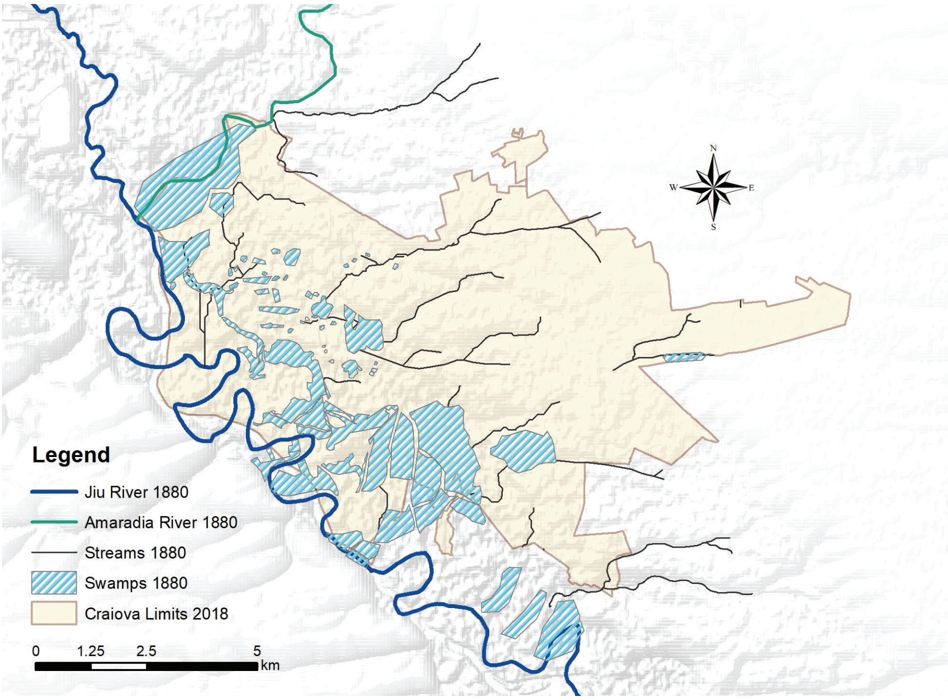

Figure 3: The city hydrography in 1880 (Source: C. D. Albă, 2018)

Nowadays the Collecting Canal is culverted in most of its course and protected with dikes on surface areas. So, in the present, the main streams that could produce flooding in normal weather conditions are regularized and diked, but most of the dikes were achieved or elaborated in the 1970–80 years, not considering then the global climate change that caused extreme events such as heavy rainfall. In plus, in the past, in Romania and also in Craiova, the construction of dikes was the most important strategy for flood protection, but the actual strategies should be more comprehensive and include prevention, protection and preparedness measures (Vinke-de Kruijf, Kuks, & Augustijn, 2015), such as: hazard and risk maps, streamlining of information systems for forecast, citizens` education, forestation, restricting construction in areas exposed to a flood risk. Besides the relative protection offered by actual embankments, there remains the second type of hydrological urban risk: the low-lying areas without natural outflows.

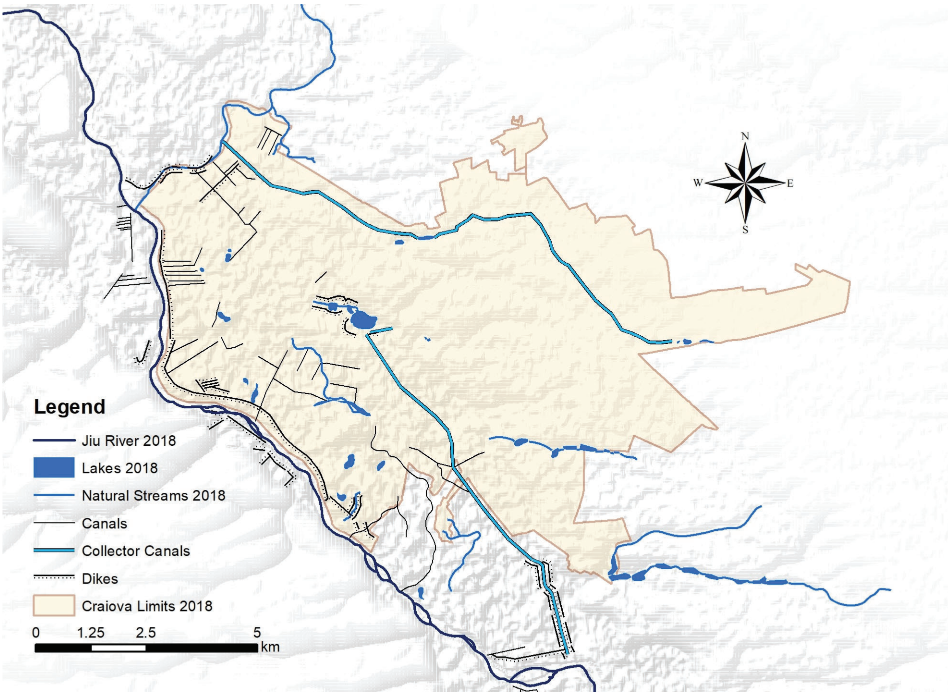

Figure 4: The hydrography and the hydrotechnical works realized in 2018 (Source: C. D. Albă, 2018)

BluespotsMap and the Affected Buildings

At Weather Station Craiova, values of rainfall quantities dropped in 24 hours relatively close to the maximum recorded in July 1972 — 84.8 l/m², they have also been recorded in the last years: April 2003 — 77.6 l/m², July 2009 — 74.2 l/m², July 2008 — 67.4 l/m² and the climate changes could lead to a greater frequency of rainfall days and to large amounts of rainfall. To identify the areas that could be affected in a cloudburst, we achieved the Bluespot map for a part of the city (Figure 5).

For obtaining the Blusepot map, the most important inputs are DEM data. Thereby we used a DEM based on high precision measurements made in the central part of the city, the most populated area of Craiova. We collected the 2,200 points used for DEM with the help of GPS GNSS South S82T. The result was a DEM with a vertical accuracy of 0.02 m. Besides DEM, we used an extract of the cadastral map of Craiova and we applied the ModelBuilder, developed by T. Balstrøm in the extension Cloudburst of ArcGIS.

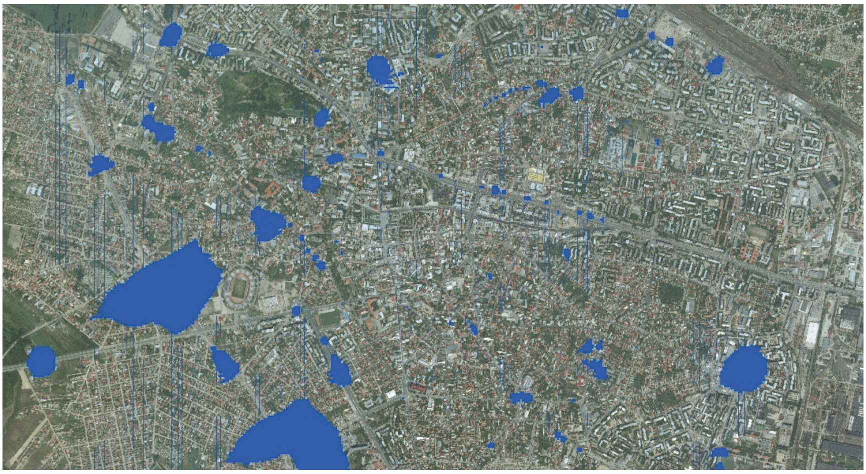

Figure 5: Bluespots map for the central part of Craiova (Source: C. D. Albă, 2018)

The results of the Bluespots maps are polygons representing low lying areas that could fill up and overflow in heavy rains. The second process line of the ModelBuilder processes the buildings map in such a way that buildings intersected or situated within the bluespots are selected and these buildings are considered to be exposed to the risk of flooding in a cloudburst (Figure 6).

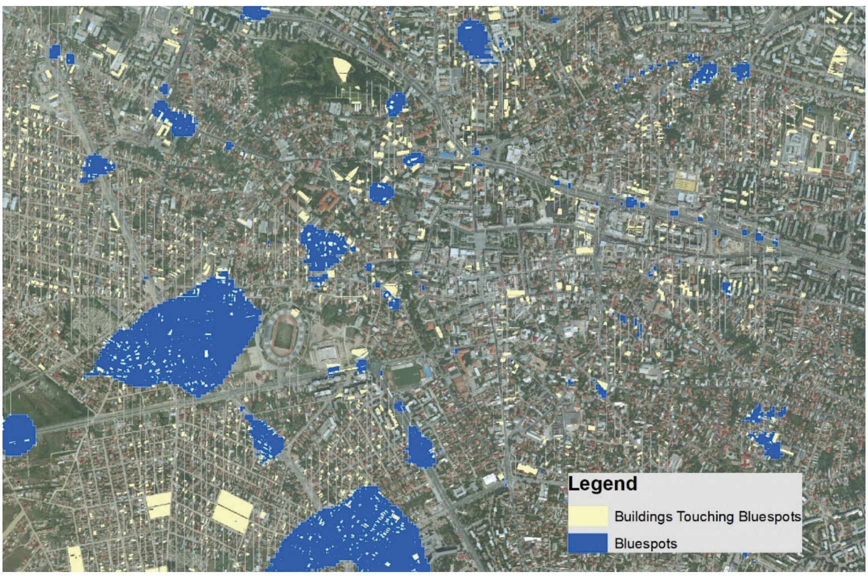

Figure 6: Buildings Touching Bluespots map in central part of the Craiova city (Source: C. D. Albă, 2018)

On field validation and limitations

After obtaining the bluespots map, we followed up in the period of April–September 2018 with the comparison between the areas and buildings automatically identified in ArcGIS with the flooding produced on the field. In many bluespots indicated on the map or around them flooding had occurred in the spring and summer of 2018. Two areas affected by flooding in Craiova in the summer 2018 are exposed in Figure 7.

Regarding the selected buildings, part of them were or could be touched by a moderate flooding, but the maps should be enhanced with ways of communications, as more frequently the most affected are the roads. Also, in correct determination of areas and buildings affected by flooding, more data should be used: capacity of sewage system and quantity of precipitation.

The limit in application of the method for the entire city was determined by the lack of high precision data for an extended area. We tried to also use a lower resolution DEM, available for the entire city, but the results were significantly influenced by the accuracy of the data.

Figure 7: Affected areas by flooding in Craiova in summer 2018 (Photo: C. D. Albă, 2018)

Conclusion

The hydrotechnical works performed on the current territory of the city of Craiova have included the drainage and channeling of swamps, the construction of dikes on the main streams and on the Craiovita Lake, the discharge regulation and the adjustment of the Jiu River flow, the creation and enlargement of the collecting canals. The most important hydrotechnical works were performed before the year 1990 and have not kept up with permanent urban expansion from the last decades. Moreover, the climatic changes to which we need to adapt must direct our thinking towards permanently finding new prevention and protection methods, in accordance with the current urban necessities.

The areas from the Bluespots map must be considered by estate developers, these surfaces not being suitable for designing construction works. But the Bluespots map, in order to be a real useful tool, should be enhanced with the city's sewage system, its absorption capacity and water (amount of precipitation and discharge of waterflows) as input data.

In order to avoid the negative consequences on the population health, economic activities, the goods or the environment, in case when exceptional discharges occur on the water courses or in case of heavy rain occurrence, a new strategy should be applied to improve the capacity of retention, prevention and protection against the effects of flooding.

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