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The development of flood zones

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Summary

As cities develop, more and more areas are occupied by buildings and transportation infrastructure. It is only natural that urban development requires the creation of recreational infrastructure for city residents. Recreational infrastructure is essential for the proper functioning of city dwellers. Providing land for such infrastructure falls under the responsibility of local authorities. However, acquiring such land in large cities is very expensive. Therefore, areas with development restrictions become a natural space for recreational facilities. For this reason, the use of river valleys has been studied. These areas are currently used as floodplains in case of floods.
The presented analyses were carried out for the city of Sandomierz. It is one of the oldest cities in Poland. The unique character of this city attracts many tourists each year. Most tourist attractions are located near the Old Town. The Old Town of Sandomierz is situated on the banks of the Vistula River. The Vistula River is the largest river in Poland. During floods it swells and the water overflows its bed. in order to protect residents from flooding, flood zones are designated, and flood embankments are constructed. Floodplains in this area occupy a significant part of the city. The research involved both geospatial and legal documentation analyses of this area. The paper proposes alternative ways of using these areas, taking into account the interests of city residents, municipal authorities, the natural environment, and institutions dealing with flood protection.

Keywords

GIS analysis • development • floodplains • spatial planning

1. Introduction

Human settlements were historically linked to direct access to rivers or bodies of water. Thus, many cities are located along rivers [Wolińska and Sławiński 2017, Zhang et al. 2021]. Rivers are characterized by significant fluctuations in water levels, and in

extreme cases, the water overflows from the riverbed, flooding adjacent areas. In order to mitigate the destructive activity of rivers, flood embankments are built. The areas between the flood embankment and the riverbed, called flood zones, are designated for water accumulation in case of flooding. The function of these zones is to accommodate excess water during floodings. Land use in flood zones is restricted due to the temporary flooding of these areas.

In modern times, we observe significant urban expansion. Urban infrastructure must satisfy the needs of residents. One of the natural human needs is relaxation and recreation [Sołowiej 1992, Soga and Gaston 2020]. Therefore, when planning urban development, city authorities must consider the creation of recreational infrastructure for residents. To ensure sustainable urban development, it is necessary to maintain spatial order and provide residents with good and healthy ways of living, including leisure conditions. Planning areas with natural and recreational values becomes an important element in urban spatial planning. Acquiring land for the development of such infrastructure is difficult due to existing development. A significant obstacle to the acquisition of such areas by local authorities is the high cost of such land in cities. A reasonable solution seems to be the use of flood zones. Such areas are attractive and can be used for tourism and recreation purposes. The development of these areas must take into account the needs of various social groups, such as property owners, business representatives, and local authorities [Gehl 2014, Bierwiaczonek 2016]. Environmental safety and flood protection institutions must also be considered. The implementation of this task should include the introduction of appropriate forms of development in areas adjacent to the river. This development should ensure easy public access to these areas without causing environmental damage. Spatial planning is particularly important in flood zones. Properly developed riverside promenades provide an attractive area for city residents and can also serve as a good showcase for tourists. The measures taken by engineers and architects in the development of the waterfront define the character of the city, create the city's perspective, and public space [May 2006].

2. Spatial policy – flood zones

The development of cities should take into account spatial policy, as well as social and economic policies. Spatial policy helps to achieve economic, social, and ecological objectives, and manages space as a basic element of an integrated development policy. This policy is multidimensional, combining conflicting interests and goals, seeking rational land management in line with the principles of sustainable development.

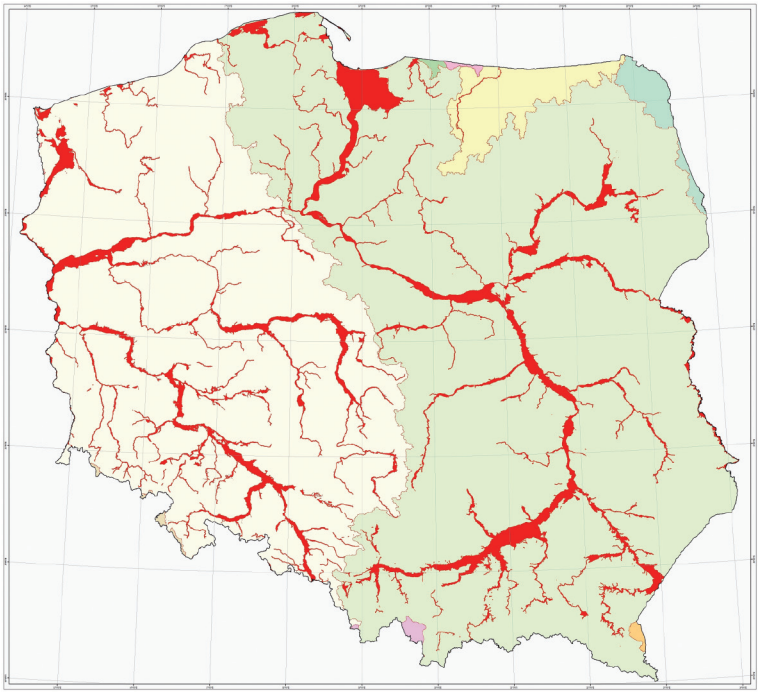
Poorly developed spatial policy in flood zones can have catastrophic consequences. Examples of poorly managed economy in this area are described in the Supreme Audit Office (NIK) report from 2013. The audit was conducted in 24 cities and municipal offices and 6 county offices in terms of legality, reliability, and efficiency, at the initiative of the NIK. The report states, 'In the opinion of the Supreme Audit Office, local government authorities did not take sufficient action to establish specific location conditions for investments, including limiting development in flood zones... In municipalities,

local spatial development plans were insufficiently used to shape the space in flood zones... Despite the preparation of these plans, in most of them, no prohibitions or conditions were introduced to limit development in flood zones. Also, in studies of spatial development conditions and directions for spatial development of municipalities, no spatial development directions were specified to limit development in these areas.' Failure to rational use of flood zones can lead to disasters, as evidenced by the flooding of Wrocław during the 1997 flooding (Fig. 1).

Source: NIK 2013

Fig. 1. Online report of the Supreme Audit Office

To prevent such disasters, appropriate legal provisions have been developed for this area. The most important are: Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (the Water Framework Directive – hereinafter referred to as the WFD) and Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (the Floods Directive). These provisions have been implemented into Polish law, including the Water Law Act 2017. Currently, the management of space in flood zones is regulated by many legal acts. These regulations are introduced at various levels. The EU directive was implemented in several stages. The first stage of adaptation was the preparation of an initial flood risk assessment. According to the information on the National Water Management Authority website, areas threatened by flood danger, which were marked in red on the map, were designated (Fig. 2).



Source: www.kzgw.gov.pl

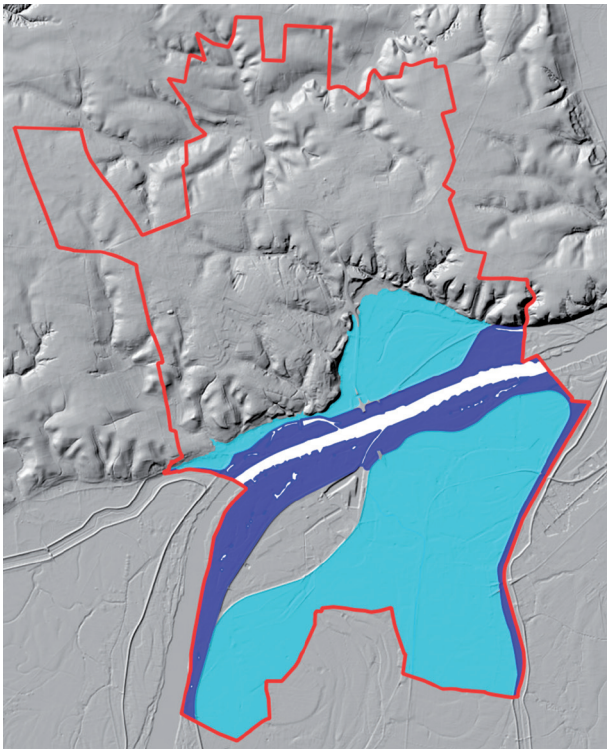
Fig. 2. Areas at risk of flooding

The next stage of implementing the directive was to prepare flood risk maps. These maps show areas with a specified probability of flooding. These areas are divided into 3 groups. The first group includes areas with a low probability of flooding once every 500 years (Q 0.2%). The second group consists of areas with a medium flood risk once every 100 years (Q 1%). The third group includes areas with a high probability of flooding once every 10 years (Q 10%).

Information on flood protection, such as flood hazard maps and flood risk maps, as well as meteorological hazard maps, is included in detailed flood risk management plans collected in the Integrated National Protection System (ISOK). The purpose of this system is to protect the society, economy, cultural heritage, and environment from floodings. This system is intended to support decision-making in the event of dangerous events. The ISOK system is a tool assisting local government authorities in the preparation of local spatial development plans. Data contained in the ISOK databases can be viewed online through a dedicated geoportal, and this data can also be accessed via the Web Map Service (WMS).

A shaded numerical terrain model with flood zones for the city of Sandomierz is shown in Figure 3. From the comparison presented in Table 1, it can be seen that the area of flood zones with possibility of a 1000-year flood (Q 0.1%) accounts for 32% of

the total area of Sandomierz. The area affected by the 0.1% flood is marked on the map in light blue. Meanwhile, areas most at risk of flooding (Q 10%) are marked in dark blue, and cover 13% of Sandomierz. Due to the high flooding probability in these areas, development restrictions have been introduced.



Source: Author's own study

Fig. 3. Shaded numerical terrain model with flood zones for the city of Sandomierz

Table 1. Areas at risk of flooding for the catchments of the Trześniówka, Koprzywianka, and Vistula rivers within the city of Sandomierz

Watershed names	Q 10% area	Q 1% area	Q 0.1% area
	[Ha]	[Ha]	[Ha]
Trześniówka River	32.0417	142.6236	907.4355
Koprzywianka River	1.6900	2.0197	
Vistula River	339.1563	518.9087	
Total	**372.8880**	**663.5520**	**907.4355**

3. Development of different types of area in Sandomierz

Sandomierz is one of the oldest cities in Poland and is a popular destination for tourists. The city boasts a rich history with numerous monuments and picturesque sites. Situated in southeastern Poland on the right bank of the Vistula River, Sandomierz lies in the Sandomierz Basin, which is known for its fertile soils of very high agricultural quality. As a result, the surrounding areas are utilized for agricultural and horticultural production. The agricultural character of these areas is evident based on data contained in the Topographic Objects Database (BDOT 10K), summarized in Table 2. According to this data, over 50% of the areas is made up of cultivated and agricultural vegetation, with almost 15% designated as permanent cropland. Meanwhile, urban infrastructure covers 23% of the built-up areas, 1.6% are transport areas, and 1.1% of the area is occupied by squares. The distribution of these areas is illustrated in Figure 4.

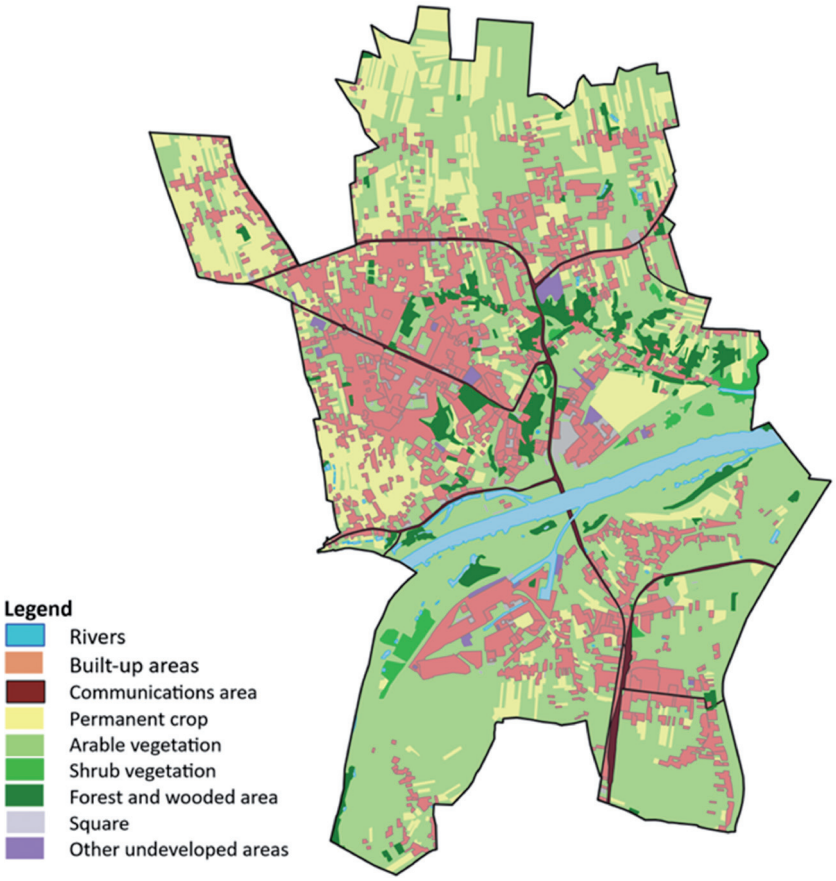
Table 2. Development of different types of area in Sandomierz based on the BDOT 10K database

Code	Class name of objects	Area [ha]	%
PT ZB	Built-up areas	657.2205	23.0
PT KM	Communications area	46.4966	1.6
PT PL	Square	32.9144	1.1
PT RK	Shrub vegetation	35.4701	1.2
PT UT	Permanent crop	428.9048	14.9
PT TR	Arable vegetation	1455.1278	50.8
PT LZ	Forest and wooded area	105.7464	3.7
PT WP	Surface water	86.0667	3.0
PT NZ	Other undeveloped areas	21.5089	0.7
Total		**2869.4562**	**100**

First settlements in the area of Sandomierz date back to the turn of the 10th and 11th centuries. Since its inception, Sandomierz had strong connection with the Vistula River that flows below the escarpment, serving as Poland's main trade route in the Middle Ages. The current architecture of Sandomierz contains many unique objects under the protection of monument conservators. The oldest part of the city, built on a high escarpment in close proximity to the Vistula River, is listed in the register of monuments and is under protection. This area is marked in Figure 5.

Thanks to its charming character and extensive promotion, the city attracts an increasing number of tourists every year. The influx of tourists necessitates the adaptation of recreational infrastructure for both tourists and residents. Recreational facilities are presented in Table 3, with a graphical representation shown in Figure 5 on the left

side. Sports facilities are marked in purple, while urban green areas are marked in light green. As part of recreational areas, the 'Pepper Mountains' reserve, which adjoins the city of Sandomierz, is also highlighted. Meanwhile, Figure 5 presents on the right side the areas at highest risk of flooding (Q10%) with development restrictions.



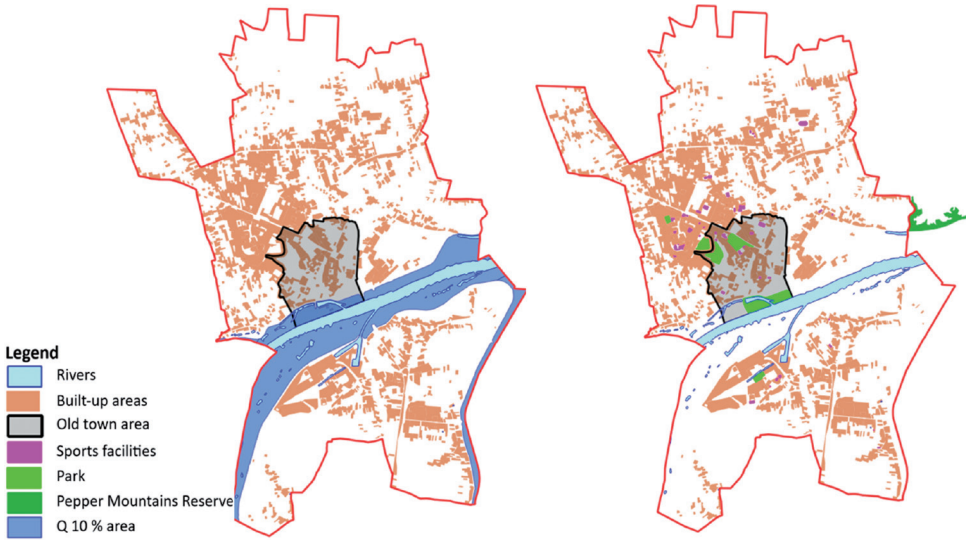
Source: Author's own study

Fig. 4. Development of different types of area in Sandomierz based on BDOT 10K

In Figure 5, the area of the old town in Sandomierz is presented in relation to the entire administrative area of Sandomierz, along with the designation of built-up areas. Built-up areas are marked in brown. The right side of Figure 5 presents recreational facilities such as sports facilities, parks, and reserves, while the left side shows areas within the Q10% flood risk zone. As can be seen from the comparison of these images, the possibilities of locating recreational facilities are limited by existing development. Areas located to the south of the Sandomierz old town are within the flood risk zone. These areas are very attractive both for tourism and for residents as recreational areas.

Table 3. Compilation of recreational facilities according to data from the BDOT 10K database

Type of facility	Designation according to BDOT 10K	Area	Number of objects
Public swimming pool	BUSP01	1134.42	1
Tennis court	BUSP04	1109.7	1
Playground	BUSP06	20603.32	31
Sports court	BUSP07	52955.24	30
Stadium	BUSP09	15829.93	1
Sports and recreational center	KUSK03	189847.2	4
Park	KUSK04	89124.49	2
Natura 2000 area	TCON01	3413471	1
Pepper Mountains Reserve	TCRZ01	416424	1

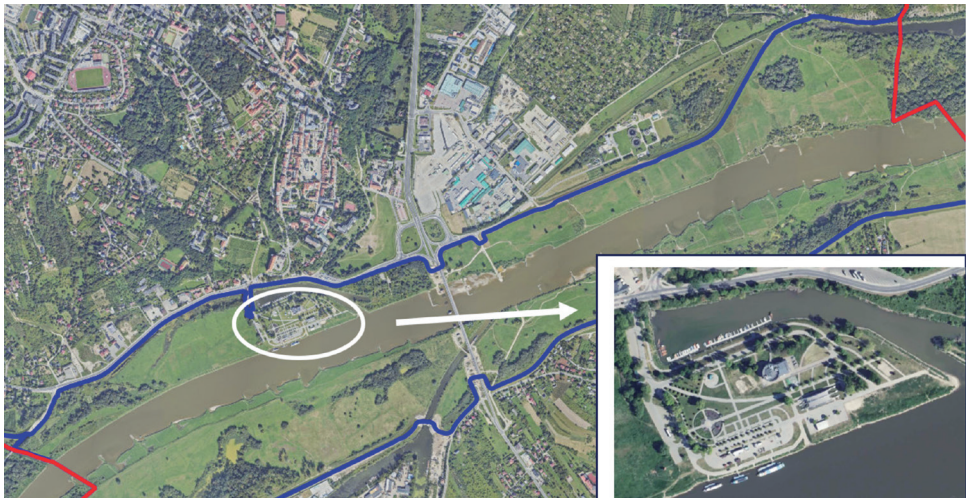


Source: Author's own study

Fig. 5. Location of recreational facilities and flood zones in Sandomierz

A significant portion of the areas within the flood risk zone are covered with grass vegetation, shrubs and riparian trees (Fig. 6). Only a part of these areas is developed by the Marshal Piłsudski Boulevard recreational complex. This complex is located on the Vistula River, and it stretches entirely within the floodplain. The main feature of this complex is the river port. Around the river port, appropriate infrastructure for recrea-

tion and water sports has been built. This facility was created as part of the project entitled 'Revitalization of the Old Town – Piłsudski Boulevard.'



Source: Author's own study

Fig. 6. Orthophoto map with marked areas of Q10% flood risk

4. Conclusions

Most cities in Europe are located along rivers. Flood risk areas are excluded from development by law. These regulations are dictated by many factors, including the need for a flood wave to pass through the city without harming people. However, this does not preclude the possibility of developing this area with facilities that do not obstruct the flood wave. Such facilities include pedestrian and cycle paths, green sports areas, sensory gardens, or facilities necessary for water tourism, such as beaches or boat launching ramps. An example of a skilful development of floodplains is the Marshal Piłsudski Boulevard recreational complex.

The analyses presented above indicate areas with the greatest potential for recreational development. This solution involves combining historical, natural, and sport values. The historical values are provided by the architecture of the old town in Sandomierz, the natural values are ensured by the proximity of parks and the Pepper Mountains reserve, while the sport values are provided by the MOSIR centre.

City authorities must strive to meet the expectations of residents and all types of tourists visiting Sandomierz. The planning of tourism development in this region should be closely linked to the river. Floodplains within cities pose a great challenge for local government authorities and at the same time an opportunity to create positive relations with the river.

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