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Elżbieta Bielecka
Andrzej Ciołkosz

FLOOD SUSCEPTIBILITY OF THE ODRA VALLEY; ITS RELATION TO LAND USE CHANGES

Abstract

As a result of torrential rains during 1997 in Poland, the worst disaster in the country in the written history, six voivodships in the Odra River Basin were partly flooded. Damage to urban, rural and hydrotechnical infrastructures were extensive. To asses the extent of flood and evaluate damage a great number of aerial photographs have been taken. Due to unfavourable weather condition they covered only a part of the Odra catchment. Landsat, Spot and IRS satellites took a few images. Only microwave images acquired by ERS-2 satellite were available for the whole flooded area. The interpretation of images taken by ERS satellite resulted in delimitation of maximum extents of water in the Odra River Basin. This information created a new thematic layer in the GIS database. Analytical GIS tools enabled determination of the area affected with flood in particular administration division, as well as computing the area of each land use category covered with water.

1. Introduction

A great number of floods occurred in Poland since the origin of its statehood. In the written history the first mention about this disaster came from 10-th century. Destructive floods occurred some score of times in each century. There were at least six serious floods in most of the regions of Poland and many others in particular regions in the last hundred of years. Floods threaten 7% of the total area of Poland each year, most of the risk territories are located in river valleys. It is estimated that the losses caused by floods in years 1958-1970 were some 140 million US dollars and more than 210 million US dollars in years 1970-1980. In the Odra Basin only, there were devastating floods in 1902-1903, 1938-1941, 1965-1966, 1972, 1974, 1977, 1985 and the last one in 1997. According to the experts the Odra valley belongs to the most flood-prone regions of Europe.

In the recent period, together with fast economic development, one can observe serious civilisation catastrophes caused by natural disaster. There are several reasons for civilisation catastrophes ***/Maciejewski., 1998/***:

- High density of population in urban areas;
- Unfavourable location of technical and communal infrastructure (water intakes, sewage works, dumping sites);

- Poor quality of river and canal embankments;
- Location of industrial investments and build-up areas in zones designated to be covered with water during flood.

Floods are one of the most important reasons for civilisation catastrophes. In the last 70 years Poland experienced four catastrophes of that type. The flood that occurred in the Odra river catchment in July 1997 was the most devastating one in the history of Poland (table 1). It caused the biggest damage to the technical infrastructure of south-western Poland, thousands of people had to be evacuated, 52 lost their lives.

Table 1. Devastating floods in Poland in the last 70 years

	1934	1960	1970	1997
Arable land cover by water (ha)	250 000	352 720	156 000	502 703
Damaged buildings (number)	22 000	27 000	23 000	70 000
Destroyed bridges (number)	102	1 207	1 400	3 879
Damaged roads (km)	100	596	751	14 371

2. Geographical characteristics of the Odra catchment

The Odra river catchment is located in the Sudety Mountains and on the Great European Plain. Total area of the Odra catchment is 118 861 km2 (without the catchment of its largest tributary, Warta). About 89% of this area belong to Poland, 9% to the Czech Republic and 2% to Germany.

The upper, mountainous stretch of Odra flows mostly on the territory of the Czech Republic. Total length of Odra River in the Czech Republic territory is 120,1 km. The size of the adjoining catchment area located inside the Czech Republic is about 10 288 sq. km. Three separate parts belongs to the Odra catchment inside the country. The largest area covers 85 % area of the catchment and is situated in Northern Moravia. It includes the sources of Odra River in Oderske Vrchy at the elevation 652 m a.s.l. Two mountain ranges, Jeseníky in the west and Beskydy (Karpatian Mountains) in the east are covered by coniferous and mixed forests. The river flows between both ranges through the valley of Moravská Brana into Ostrava basin, where Odra takes its largest Czech tributaries: Opava from the left side, Ostravice and Olse from the right side. The land of the Moravská Brana is mostly used for agriculture. Ostrava basin is a typical black coal mining and industrial region.

The middle reach of Odra from the town of Koźle till Brzeg Dolny (30 km downstream of Wrocław) has been regulated and canalised in the years 1888-95, 1905-17 and 1950-58. Odra takes here tributaries from the southwest and from the east. This is an area comprising two parts with quite different natural features, namely, the Sudety Mts., which are a part of the Bohemian Massif, and the Silesian Lowland, a part of the Central European Plain.

In its middle stretch Odra changes its course several times from north to west and to the north again. This configuration of the river course has been shaped during the successive recession stages of the last glaciation, when a system of *pradolines* (wide, east-west valleys) was formed.

Land use in this part of the Odra catchment is dominated by agriculture. Forests prevail in the south-west (Sudety Mts.) and in the north. Industry and mining are concentrated in the south-east (part of the Silesia Industrial District), near the town of Legnica (copper mining) and in large towns along the river (Opole, Wrocław, Zielona Góra, Frankfurt an der Oder).

In its lower reach Odra flows through forested lowlands with considerable large areas of agricultural land, taking in small tributaries, mainly from the east. Industry is concentrated in and around Szczecin.

The German part of the Odra catchment comprises only narrow strip of land (approximately 10 - 20 km wide) stretching along the western bank of the Odra River. Agriculture and forests dominate land-use in the area. The settlements are mostly small; there are a few larger industrial towns and four lignite-mining areas. It also includes the "Oderbruch" stretching to the northwest of the town Kostrzyn/Küstrin, which was heavily flooded during the floods of 1997.

The geographical location and surface features are the two most important factors determining the climate of southwestern Poland. Due to the location of this part of the country in the temperate latitudes, arctic air masses dominate. The share of maritime air is greater than continental air, because of the more common, western (oceanic) circulation of air. The pattern of terrain forms along the parallels of latitude also aids to the flow of humid air masses from the ocean to Poland.

The features of the maritime climate are more prevalent in southwestern Poland i.e. in the Odra River catchment area. The year average amount of precipitation is above 1000 mm in the Sudety Mts. and less then 700 mm in lowland part of the Odra Basin. The amount of rainfall in spring and summer is about 60-70% of the total precipitation. In spring, the average precipitation does not exceed 80 mm in most of rain gauge stations located in the lowland part of the Odra Basin. In late summer the amount of rainfall is even lower, but in July it is usually much higher reaching in some stations more than 150 mm. The 30 years' average precipitation in lowland part of the upper Odra river catchment in 6 mounts (April through September) is about 400 mm. In July 1997 the rainfall in this region exceeded 200 mm (some rain gauge stations recorded more than 250 mm) and was concentrated mostly in the first decade of that month (table 2). Such torrential rains during July 1997 were the main cause of the devastating flood that occurred in the Odra River Basin.

Table 2. Precipitation in southwestern Poland in 1997.

Town (rain gauge stations)	**March**	**April**	**May**	**June**	**July**	**August**	**September**
	mm						
Legnica	22	24	71	59	237	67	26
Leszno	23	36	48	48	205	140	27
Poznan	21	44	66	87	192	40	33
Wrocław	14	50	67	39	239	42	37
Zielona Góra	23	57	69	92	139	59	36

3. Recording of flood extent by remote sensing

To control the situation during a flood event and to evaluate damage to urban, rural and hydrotechnical infrastructures, as well as to plan and introduce preventive measures, the local and regional decision makers required timely information about the water level and extension of flood. A great number of aerial photographs have been taken. Low or medium clouds restricted flying altitude of reconnaissance aircrafts and only large-scale photographs as well as video images had been taken. They covered only small part of the Odra River Basin. Due to unfavourable weather conditions satellite working in optical part of electromagnetic spectrum were unable to image the whole area covered by water. Only the satellites carrying synthetic aperture radar (SAR) instrument could collect data independently on weather and light condition ***[Barbieri, Basutti, Calabresi, 1997]***. Images taken by European Space Agency (ESA) satellite ERS-2 have been used in the study.

The flood started in the Upper Odra River Basin on 8 July 1997. Four days later, on 12 July 1997, when flood wave reached Opole and Wroclaw, the ERS-2 satellite passed over this area taking the first of the series of several images of the Odra River Basin. In the next three days, when flood water moved down the river, ERS-2 passed again on the next orbit, acquired the image over the area situated to the West of the previous one. The situation happens again on 18 and 21 July 1997. Last image of the Odra River Basin was taken on 28 July 1997. It covered the upper part of the Basin. The microwave images taken by ERS-2 SAR covered the whole Odra River Basin from the border between Poland and Czech Republic up till the mouth of the river to Baltic Sea. (Fig.1).

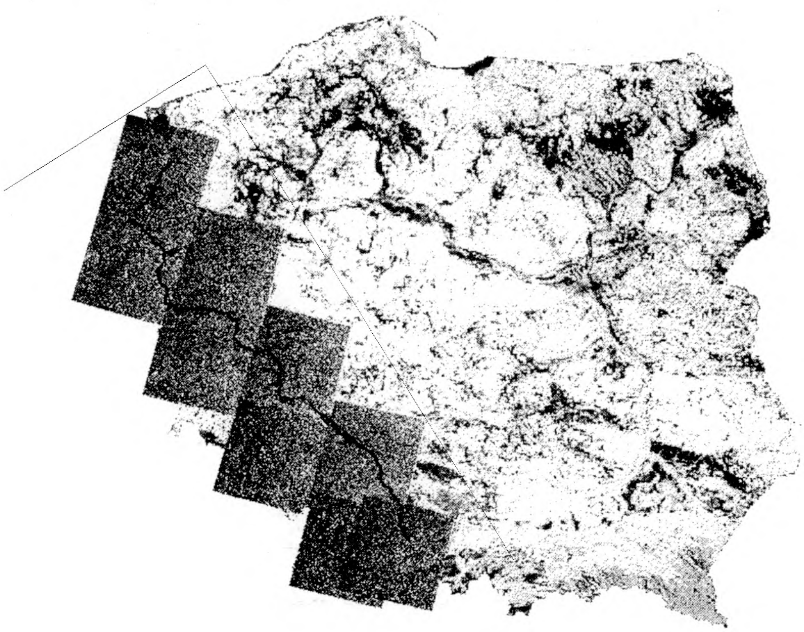

Figure 1. ERS-2 SAR images taken in July 1997 during the flood in the Odra River Valley.

Thanks to generosity of the European Space Agency (ESA) the Remote Sensing and Spatial Information Centre of the Institute of Geodesy and Cartography in Warsaw obtained several images taken by ERS-2 covering the Odra River Basin during the flood event. The images have been geometrically processed with the reference to topographic maps at the scale 1:100 000 in Gauss-Krüger projection.

Visual interpretation of microwave satellite data has been used to distinguish the water recorded in these images. The satellite images were enhanced and filtered to facilitate the interpretation. There was a problem in assessment of the extent of water since in many places water partially flooded forests and radar echo was reflected from the top of trees. In such cases archived Landsat TM images, aerial photographs and topographic maps were used as auxiliary materials to simplify interpretation of SAR images.

The interpretation of microwave satellite images resulted in delimitation of maximum extent of water in the whole Odra River Basin. This information has been loaded into database of the Geographical Information System located in the Institute of Geodesy and Cartography (IGC) in Warsaw (fig. 2) for further processing and analysis.

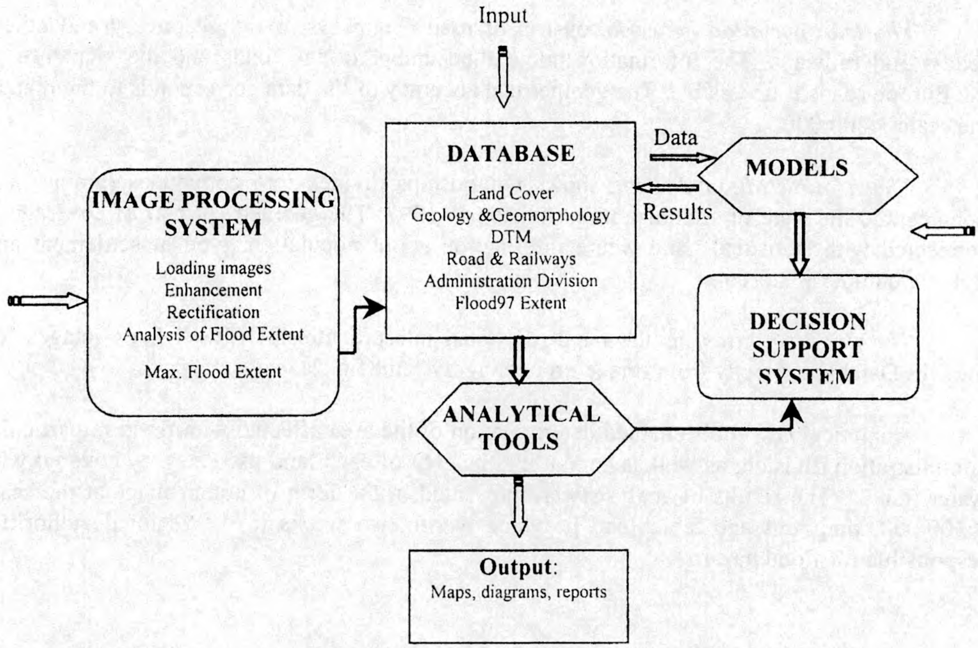

Figure 2. Schema of flood risk geographical information system supported with remote sensing data.

4. IGC Geographical Information System

The spatial database covering the whole Poland is maintained in the ARC/INFO, so all structural solution come from ARC/INFO system. The database comprises several thematic layers and the accuracy of stored data oscillates from the scale 1:50 000 to 1:200 000. To assess the flood damage in the Odra River Basin only six layers has been used: land cover, geology and geomorphology, digital terrain model, transportation network, administration division and flood 97 extent.

The Land Cover layer is the result of CORINE Land Cover project. The nomenclature includes 44-land cover types grouped in the hierarchical way (three levels), but 11 cover types do not exit in Poland ***[Baranowski., Ciolkosz]***. The smallest mapped area, due to accepted technology, is 25 ha, so the detailness of this layer is smaller than used in elaborating of topographic maps at the scale 1:100 000.

The geology and geomorphology cover stores information about origin and age of forms of terrain relief and about the material they are build from. The more important is localisation of landforms due to fluvial accumulations such as terrace flat, and flood plains.

The digital terrain model has a form of point coverage with spatial resolution 250 m, the accuracy of delimitation highs is 20 m.

The transportation network consists of road (highways, main, secondary and others roads) and railways. The information about the number of the roads and the signature of the Europe roads is accessible. The geometrical accuracy of the data corresponds to the map at the scale 1:200 000.

The administration division shows voivodships divided into communes (gmina) and documented the state of administration division in 1997. The geometrical part of coverage is connected with statistical table where information about population, type of settlement and statistic number is stored.

The flood 97 extent as the result of visual interpretation of ERS 2 SAR images fed the GIS Database directly from Image Processing System (fig. 2).

Analytical GIS tools enabled determination of the area affected with flood in particular administration division, as well as computing the area of each land use category covered with water (tab.3). The results of analysis were presented in the form of colour maps at the scale 1:300 000, diagrams and tables and provided within two weeks to the regional authorities responsible for flood hazard.

Table 3. Area covered with water in the Odra River Basin

Land cover nomenclature	**Flooded area (km^2)**
Urban fabric	52,0
Industrial, commercial and transport units	5,1
Mine, dump and construction sites	1,9
Artificial, non-agricultural vegetated areas	15,6
Agricultural areas	379,7
Permanent crops	2,2
Pastures	365,8
Heterogeneous agricultural areas	79,1
Broad leaved forest	167,1
Coniferous forest	42,0
Mixed forest	24,9
Inland wetlands	7,0
Total	**1142,4**

5. Assessment of the flood damage

Six voivodships (Gorzów, Katowice, Legnica, Leszno, Opole, Wroclaw and Zielona Góra) located in the Odra River Basin had been affected by flood. Water submerged the most extensive areas in Opole and Wroclaw voivodships (358,3 and 325,1 sq. km). There was also the biggest damage to urban fabrics. More than 23 sq. km of densely built-up areas and almost 3 sq. km of heavily industrialised area was flooded. The specification of land use classes covered by water has been presented in table 3.

Investigating of the extent of flood on the background of geomorphologic map one can come to conclusion, that the water did not overflow floodplains. The investment in the area of floodplain was the main reason of such vast damage caused by flood.

Modern information technology fully facilitates setting up an operational flood management information system containing data on stable and dynamic parameters of the catchment area. Such a system would be used for forecasting flood events and assessing the extent of flooding. The extensive damage caused by 1997 flood could have been partially avoided, had a sufficient information been available to decision-makers.

In 1997, the Government of Poland requested the World Bank to develop a project to provide financing and technical assistance for flood recovery and protection. The project encompasses three main Systems one of the most important is the Early Warning and Flood Reduction System.

References

1. Baranowski M. Ciolkosz A.: *Opracowanie bazy danych Pokrycie Terenu Polski.* Prace IGiK, tom 44, zeszyt. 95 str. 7-25.

2. Barbieri M., Basutti M., Calabresi G., 1997, *Monitoring of summer 1997 Floods in North-Eastern Europe through "Earth Wathing".* ESA. EOQ. No. 56-57.

3. Maciejewski M., 1998, *Klęski żywiołowe w Polsce – stopień zagrożenia i aspekty prawne.* Materiały konferencji naukowo-technicznej "Zagrożenia klęskami żywiołowymi". Bielsko-Biała, 14-16-10.1998 str.5-13.

Recenzował: dr inż. Stanisław Mularz