DELINEATION OF SMALL BASINS PRONE TO FLASH FLOODS OCCURRENCE AS A METHOD SUPPORTING LOCAL FLOODS PREDICTION – ON THE EXAMPLE OF SOUTHERN PART OF THE NIDA BASIN (POLAND)

T. Bryndal

Pedagogical University, Institute of Geography, Kraków, Poland
tbryndal@ap.krakow.pl

Introduction

Flash floods in small basins have been the subject of research for many years. Results of investigations devoted to mechanisms of runoff generation, hydro-chemical analyses of water during flood event, delineation of stream water contribution areas, have been described in literature abundantly. Flash floods in small basins are a result of intense, short duration, convective rainfall. During a storm an overland flow as well as a flood wave can be a reason of considerable soil erosion (e.g. Bielders *et al.*, 2003; Verstraeten, Poesen, 1999). The floods can also cause human lives lost (Gutiérres et al., 1998). If any economic damage appears, then the flood is considered as a local flood. Predictions of flash floods rely on the weather forecast predominantly. Therefore, the prediction is limited mainly, due to the fact, that the time and the place where heavy rain may occur are still impossible to accurate prediction. Meteorological forecast gives the overall information that the given region can be affected by heavy rainfall events causing flash floods in small rivers. Such information is not sufficient for decision-makers and rescue workers. Admittedly, meteorological radars allow the real-time observation of heavy rainfall zone (e.g. the website); such information is too general for preventing or reducing flood hazard. Therefore, there is a need to make the solution that may improve prediction of flash floods in small basins. One of the ways, which may support prediction of such events, is delineation of basins especially prone to flash floods occurrence. The article presents results of the investigations, where an attempt to create the method supporting prediction of flash floods in small basins was made. Created method was applied in southern part of the Nida Basin.

Study area

Southern part of the Nida Basin constitutes rolling terrain where elevations range from 200 to 400 m. a.s.l. The bedrocks consist of Cretaceous Age marls, limestone and gaize as well as Miocene Age clays and sands. Various types of Quaternary Age deposits cover more than three-quarters of the region. Loess deposits, 1-10 m thickness cover about 60% of the region (Cabaj, Nowak, 1986). Average annual precipitations range form 550-650 mm., whereas average annual temperature excess 7°C (Paszyński, Klunge, 1986). Cambisols and Chernozems form a soil cover predominantly. Southern part of the Nida Basin is the agriculture region where arable lands dominate. Forest areas covers valleys bottoms predominantly.

Assumption and description of the method

The flood wave parameters depend on rain (intensity, time duration and depth) as well as basins parameters. The basin is treated as an element, which transforms rainfall into outflow. It can be assumed, that basin in which most of the rainfall is transformed into outflow is more prone to flash flood creation. Even thought, parameters of basins influence on flood wave formation, the studies on physiographic parameters of small basins where flash flood occurred have not been undertaken widely. This was the reason to take up the investigations. Eighty-three basins were characterized by fourteen parameters describing: dimension, relief, hydrological and geological features as well as structure of land use. The parameters were selected on the basis of results of the investigation pertained to mechanisms of outflow formation during intensive short duration downpour. Detail analysis of physiographic parameters (Bryndal, 2006), indicated that such basins: 1) have physiographic parameters which make them prone to flash floods formation. If such a basin is affected by heavy rain, there is a high probability that flash flood appears. 2) the basins are similar to each other and moreover 3) transformation from rainfall into outflow in such basins is comparable what was confirmed by specific runoff value (Bryndal, 2006, 2007). The parameters of basins are similar in spite of the fact that the basins came from different physiographical regions (upland, foothills, mid-mountain region or basin). Therefore, an attempt to create the models of small basins in which small flash floods occur was undertaken. Cluster analysis was used to create the models. At the beginning, correlation analysis was applied and the features that had high correlation were eliminated. In this way, ten physiographic parameters were selected, and basins were divided into five groups. These groups (except two of them – D,F, which are not numerical) can be considered as the models of small basins, where flash floods occur. Table nr 1 presents descriptive characteristics of delineated models.

The method relies on the result of these investigations and constitutes an attempt to their practical utilization to support prediction of flash floods in small basins. Geographic Information System enables

Table 1. Descriptive characteristics of models of basins prone to flash floods occurrences

	A (km^2)	Ck	ř (ş)	V_D ($km{\cdot}km^{-1}$)	Rb	FA (%)	BA (%)	AA (%)	RD ($km{\cdot}km^{-1}$)	ö
Type A										
x	7.7	0.7	11	3.2	3.5	64	3	33	5.5	0.74
min	1.0	0.4	6.0	2.3	2.2	29.0	0.4	4.7	1.5	0.5
max	19.0	1.0	17.0	4.4	5.1	93.3	9.8	65.2	9.3	0.8
Type B										
x	6.5	0.6	8	3.3	5.3	39	5	56	4.9	0.83
min	3.6	0.3	6.0	2.7	4.2	0.0	0.9	22.4	3.0	0.8
max	9.3	0.9	12.0	4.0	6.2	76.7	8.4	92.3	7.9	0.9
Type C										
x	15.9	0.7	7	3.0	4.0	26	5	70	4.8	0.76
min	4.1	0.5	3.0	2.1	3.3	0.0	0.6	45.9	1.4	0.5
max	38.7	1.0	11.0	5.8	4.9	50.0	9.4	96.2	8.7	09
Type D										
x	3.1	0.8	6	3.8	3.6	7	19	74	10.8	0.64
min	1.4	0.7	4.0	2.3	3.5	1.5	10.5	52.2	5.9	0.6
max	4.8	0.9	8.0	5.0	3.7	17.0	30.8	88.0	14.3	0.8
Type E										
x	9.0	0.7	7	3.7	4.1	17	7	76	7.2	0.56
min	2.7	0.5	3.0	2.7	3.4	0.5	2.7	56.6	5.6	0.4
max	18.7	0.8	9.0	4.4	4.8	37.0	16.2	92.2	10.3	0.7
Type F										
x	4.0	0.5	7	6.1	4.6	33	5	62	6.0	0.57
min	2.9	0.3	3.0	5.2	3.6	6.9	1.7	16.5	5.5	0.5
max	5.5	0.7	10.0	7.3	5.3	81.8	8.9	90.1	6.5	0.7
Type G										
x	5.6	0.7	3	2.7	4.1	1	7	92	3.3	0.52
min	2.5	0.6	1.0	1.5	2.6	0.0	3.3	87.3	2.2	0.4
max	11.3	0.9	6.0	3.5	6.0	5.0	11.0	96.7	4.1	0.6

A – area of basin, Ck – shape ratio, ψ – average slope gradient, V_D – valley network density, Rb – bifurcation ratio, FA – forest areas, BA – build-up areas, AA – arable land areas, RD – road network density. φ – outflow ratio computed on the basis of soils map 1:300 000 according to method suggested by H. Czarnecka (1976), x – mean value of parameter, Source: Statistica 7.0.

delineation of basins, on the ground of given set of physiographic parameters. Given that, each model of flood basin is accurately characterized by given values of parameters, comparing the parameters of model with parameters of investigated basins, is possible to delineate basins similar to the model. Given that, models of basins have the parameters predisposing them to flash flood occurrence, it can be assumed that delineated basins have the same properties.

Delineation of basins

Using GIS tools delineation of such basins was performed. At first, the geodatabase of southern part of the Nida Basin was created. Then, the geodatabase was "searched" using the minimum and maximum values of each physiographic parameter. In this way, the basins the most similar to the models were selected. Figure nr 1 presents spatial distribution of these basins. Types A and B are not represent. The most numerical is type C (36 basins). This type groups the largest basins ($x_A \approx 16$ km^2) with a steep slope gradient ($x_\psi \approx 7°$), the most forested ($x_{FA} = 26\%$) and dense and well-developed valley and road network ($x_{VD} \approx 3$km·km^{-1}; $x_{Rb} \approx 4$; $x_{RD} \approx$ 4.8 km·km^{-1}). The second most numerical is type E (13 basins). Type E groups the basins smaller in area ($x_A \approx$ 9 km^2). Slope gradient is similar to type C. The basins have denser (than type C) road and valley network (x_{VD} $\approx$ 3.7 km·km^{-1}; $x_{Rb} \approx 4.1$; $x_{RD} \approx 7.2$ km·km^{-1}) and they are more deforested ($x_{FA} = 17\%$). Type G is represented by one basin. This type groups basins of smallest in area ($x_A = 5.6$ km^2), with a gentle slope ($x_\psi = 3°$), the least density of valley and road network ($x_{VD} \approx 2.7$km·km^{-1}; $x_{Rb} = 4.1$; $x_{RD} \approx 3.3$ km·km^{-1}). They are almost completely deforested ($x_{FA} = 1\%$). Eighteen basins were delineated as a type E, inside the largest basins, which were included to type C. Information about flash floods described in literature confirm that delineated basins were affected by flash floods (Figure 1). This high accordance may indicate usefulness of the created method.

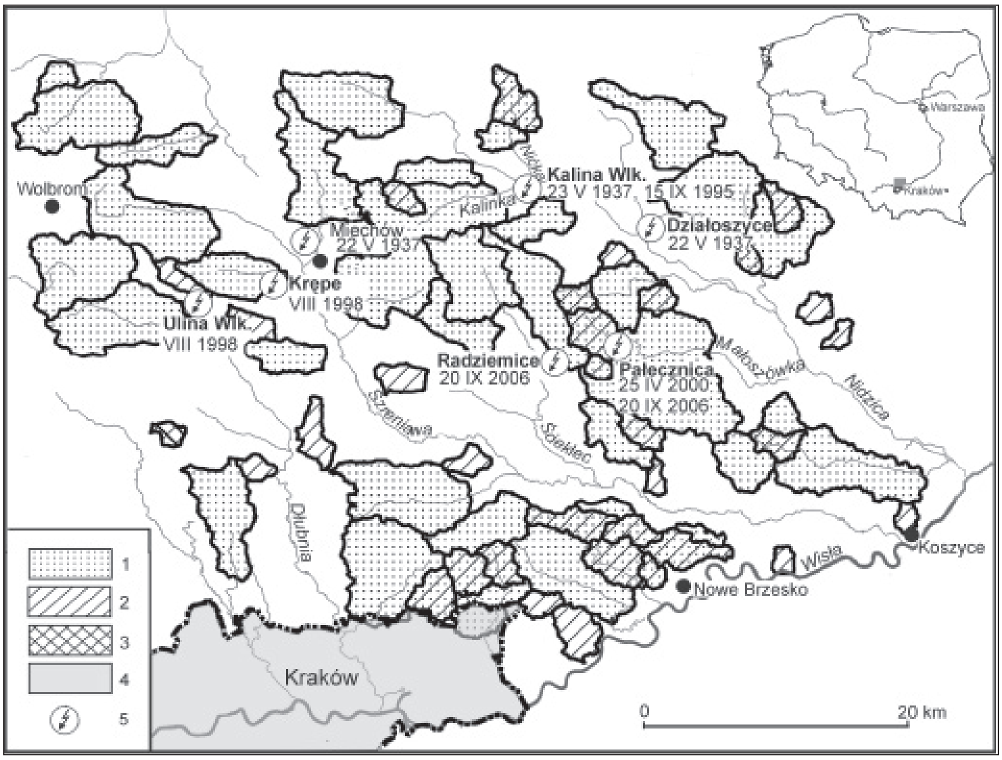

Figure 1. Spatial distribution of small basins prone to flash flood occurrence in southern part of the Nida Basin. 1–3 – types of basins A,C,F, 4- city of Kraków, 5 – places where downpour causing flash flood in small basins occurred.

Conclusion

Prediction of flash floods in small basins is one of most difficult aspects of hydrological forecast, due to the fact that it relies mainly on the weather forecast. Described method can improve prediction of flash flood in small basins by delineating the basins prone to flash flood occurrence. In such basins efforts in order to prevent and reduce damage should be undertaken.

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