FLOODS IN TUTOVA BASIN.
GENESIS, PROPAGATION AND IMPACT

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ABSTRACT. – Viiturile din bazinul Tutovei. Geneză, propagare şi impact. Prezentul articol abordează şi interpretează factorii de geneză, condițiile de propagare şi impactul viiturilor în principalul bazin hidrografic al Colinelor Tutovei. În acest scop, au fost analizate 279 de viituri produse între 1969-2005, urmărindu-se mai multe aspecte legate de elementele climatice (temperatură, salt termic, precipitații, strat de zăpadă, presiune atmosferică, condiții sinoptice etc.), hidrologice (hidrograful debitelor pentru trei posturi hidrometrice: Rădeni, Puieşti, Pogoneşti) sau morfologice (pe baza Modelului Numeric al Terenului).

Keywords: Tutova, flood, genesis, propagation, impact simulation.

1. INTRODUCTION

The studied basin (68594 hectares) represents the backbone of Tutova Hills, from the south-central part of the Moldavian Plateau. The lithology of the region is represented by Upper Miocene and Pliocene layers mainly consisting in sands, sandy clays and clays. The dominantly sculptural relief, with higher fragmentation in the middle and upper basin, sustains the runoff through declivity, fragmentation, relief energy etc.

The temperate continental climate, sometimes excessive, is important mainly through a distinct aspect: the the heavy rainfall in the warm season. From a bio-pedologic viewpoint, two aspects are important: the reduced percentage of forested surfaces of 20.5%, in comparison to the normal bioclimatic equilibrium conditions, in which forests would occupy 65-70%, and the high percentage of eroded or high erodible soils.

Tutova's mean annual discharge is of 0.277 mc/s at Rădeni in the upper basin, reaching 0.455 mc/s at Puieşti in the middle basin and 0.449 mc/s at Ciocani, downstream Cuibul Vulturilor reservoir. River alimentation is made dominantly from surface sources (67.7% at Rădeni and 71.3 at Puieşti), fact that explains the very high variations in discharge rates.

The mean multi-annual discharge regime is characterized by the presence of two maximums, a main one in March and a secondary one in June. From year to year, this regime is extremely irregular. In the extremely droughty years, the river may totally run dry, while in the periods of excess rainfall the discharge may

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overpass 200-300 times the mean multi-annual value. These record values are specific to the highest floods, responsible for flood occurrence in the floodplain.

2. MATERIALS AND METHODS

For the analysis of the floods from Tutova basin have been interpreted 279 floods occurred between 1969 and 2005 for the hydrological control point Rădeni, Puieşti and Pogoneşti. The hydrologic database (mean, maximum, minimum, hourly discharge rates etc.) has been constructed with the help of Iaşi-Prut Water Directorate. For the interpretation of the genesis conditions has been created a climatic database (temperature, thermal jump, rainfall, snow stratum, atmospheric pressure etc.), with the amiability of Iaşi-Moldova Regional Center. In the interpretation of the synoptic conditions that have generated rainfalls of hydrologic effect we used the Wetterzentrale cartographic database (available online). The spatial data processing (1:25000) has been conducted in TNTmips7.3 (license obtained through CEEX 756/2006 grant). The statistical analyses have been conducted in Microsoft Office Excel 2003.

The determination of the impact (floods and induced consequences) was related to the direct observations, reports of the local public authorities, media information and less from domain literature. More, we have conducted interpolations and simulations in GIS, with the help of dedicated software and aerial images (obtained through CEEX 756/2006 and CNCSIS 476/2007 grants).

3. FLOODS GENESIS AND PROPAGATION

Studying the 279 floods registered in Tutova basin between 1969 and 2005, we may see that their largest part have a rainfall-related genesis (85.2%), followed by those with mixed rainfall-snow melting origin (13.4%). Only 1.4% of the floods are generated by snow melting, most of them thus having modest discharge rates that do not exceed 5-10 m^3/s. The rainfall-related genesis of the floods is expressed by a satisfactory correlation between the rainfall generating floods and the discharge rates generated by them, correlation as representative as basin dimensions are more reduced. Thus, for the flood registered on Tutova between 17-28 June 1985 (figure 1) have been overimposed the rainfall pluviograms (Plopana and Bârlad) and the flood hydrograph (Rădeni, respectively Puieşti).

The analyzed period is characterized by an intense cyclonal activity, responsible for the high rainfall quantities and reflected by baric parameters. Thus, on June 19th was registered the barometric minimum of the month, respectively 968.1 mb at Plopana, 972.8 mb at Onceşti and 974.5 mb at Bârlad. In these conditions, rainfall quantities exceeded 40 l/m^2 in 24 hours at almost all stations and pluviometric posts, higher values being measured in the northern part, where during 18-19 June have fallen even over 100 l/m^2. The rainfall torrential character represents an extremely important element in the formation and propagation of the flood wave. In these conditions, Tutova registers exceptional discharge rates of 80 m^3/s at Rădeni and 85.1 m^3/s at Puieşti.

The correlation between rainfall and discharge is very expressive in the upper basin (Rădeni), but decreases downstream (Puieşti). This situation is explained by the differentiation in the progressively received water stratum in the floodplain, in relation with the increase in reception basin surface; the differentiated interception of rainfall according to the characteristics of topographic surface; the different time of water concentration at the slope level and the differentiated propagation of the flood wave in the floodplain.

Extremely suggestive in illustrating the way flood waves propagate in the basin are the correlated analyses of hydrographs. In this purpose are given two examples of the floods from July 1974 and August 1997.

July 1974 was characterized by a high rainfall quantity, summing up 251.8 l/mp at Plopana, more than three times the multi-annual mean, which in fact has been equaled in only one day (74.4 mm on July 20th). This situation was determined by an intense cyclonal activity, explained inclusively by the baric parameters (970 mb minimum atmospheric pressure on July 22nd).

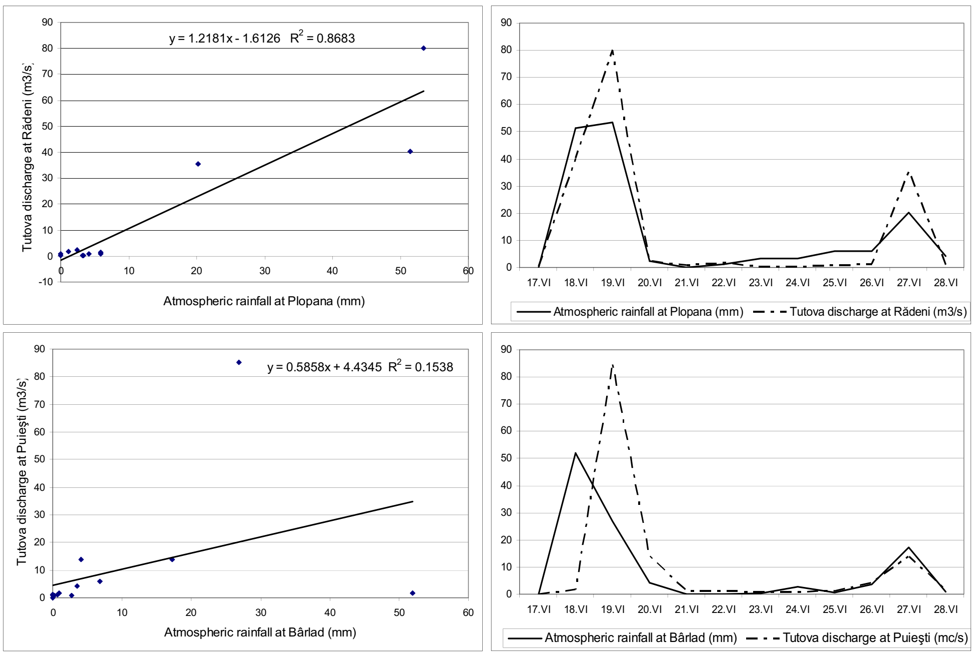

Fig. 1. ***Relations between atmospheric rainfall and flood discharge rate during 17-28 June 1985***

The high rainfall values are remarked and in river discharge rates. Tutova exceeded 40 m^3/s at all pluviometric posts, with gap between the maximum flood moments: Rădeni – July 22nd, 4^{00} hours, Puieşti – July 22nd, 15^{00} hours, Pogoneşti – July 23, 17^{00} hours. This situation indicates a progressive decrease in the flood wave speed from the upper basin to the lower one, accordingly to the decrease in slope, floodplain enlargement and the increase in its buffering capacity (table 1, fig. 2).

Table 1. ***Parameters of the flood from July 21-31, 1974 from Tutova basin***

STATION	QMAX. (M^3/S)	DATE	SPEED OF FLOOD WAVE	TCR. (HOURES)
Rădeni	41,2	July 22, 4^{00}	-	44
Puieşti	46,0	July 22, 15^{00}	1,96 km/hour	32
Pogoneşti	43,6	July 23, 17^{00}	1,43 km/hour	48

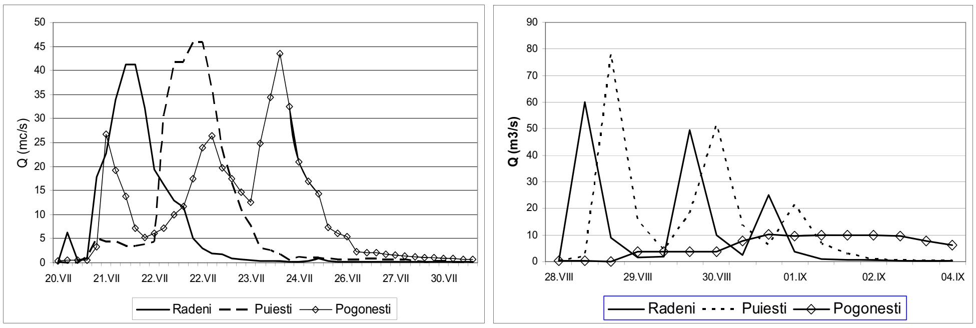

Fig. 2. ***Flood wave hydrograph on Tutova River during July 21-31, 1974 (left) and 28.08. – 04.09.1997 (right)***

At the end of August 1997, the eastern part of the country was under the influence of a cyclonal area (the barometric minimum being measured on August 26th), that generated important quantities of rainfall. Thus, at Ghergheşti accumulated 136.6 mm. The existence of two torrential nuclei (August 25-26th and 30th) may be easily seen on the flood wave hydrograph from Tutova at Rădeni, where the discharge exceeded 60 m^3/s.

This time we must remark the role played by Cuibul Vulturilor reservoir (functioning since 1978) in attenuating flood waves. If at Rădeni and Puieşti the flood is clearly characterized by two main peaks (of over 50 m^3/s) and a secondary third (20 m^3/s), at Pogoneşti, downstream the mentioned reservoir, the controlled discharge is characterized by a progressive increase in two stages (3-4 m^3/s and 9-10 m^3/s), conditioned by the water evacuation from the lake.

4. FREQUENCY, PROBABILITATY AND IMPACT

The dominant rainfall-related genesis of the floods also explains their annual regime. Thus, a special frequency of floods is registered in the warm season of the year (79.93%), while during October-March interval, corresponding to the cold season, are registered only 20.07% of the floods. On seasons, dominant are the summer floods (42.29%), followed closely by the spring ones (39.07%), while autumn floods sum up 11.83% and the winter ones, occurred in the first part of December or mainly in the last decade of February, represent only 6.81% of the cases.

In the monthly distribution of the floods attention is caught by the two maximums (April and June), as well as by their total absence in January, due to the influence of the eastern European climatic conditions generated by the Siberian cyclone. The first maximum, from April, is determined mainly by the existence of a supersaturated soil that facilitates accentuated runoff even at not quite significant rainfall quantities. The second maximum corresponds to the rainfall one, frequently being associated to torrential precipitations.

The largest part of the floods has reduced discharge rates, their hydrological and risk signification thus being modest. To appreciate the importance of floods may be used a synthetic indicator proposed by Chiriac et al. 1980, of the type: $I = Qmax/\sqrt{F}$, where I – importance of flood; Q max represents the maximum flood discharge rate (m^3/s); F – basin surface in square kilometers.

Analyzing the floods registered at Rădeni, Puieşti, Pogoneşti and Lipova, we may see that the largest part has a reduced importance factor $I \leq 1,0$ (44.6%), 38.8% of the floods have medium importance (I between 1,1-2,0) and only 16.6% may be considered important floods ($I > 2,0$), that imply a high risk for inundations, but also an accentuated dynamics of river banks.

At the same time, the frequency of exceptional discharge rates is much reduced. Thus, the maximum flood discharges do not exceed 10 m^3/s in about 30% of the cases, thus not having a significant importance from the viewpoint of the induced risks. In fact, through progressive summing we see that the values up to 20 mc/s have a percentage of about 54%, while values over 80 mc/s have only 3.64%. We see that, as in the case of other hydro-climatic parameters, there is a increase tendency of the percentage of the extremes, specific in the conditions of the continental temperate climate (table 2).

Table 2. ***Frequency of maximum discharge rates of different amplitude***

Q (M^3/S) STATION	≤ 10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	≥80
	1	2	3	4	5	6	7	8	9
Rădeni (%)	35,71	18,57	14,29	10,00	7,15	1,43	1,43	5,71	5,71
Puieşti (%)	28,81	23,73	18,64	10,17	6,78	3,39	1,69	5,09	1,70
Total (%)	32,85	21,17	16,79	9,49	7,30	2,19	1,46	5,11	3,64

Correlating flood waves with characteristic levels, we see that only 5.79% of the floods have exceeded the danger level (table 3), these being in fact the hydrologic phenomena to which are related the highest inundations from Tutova basin, mainly those from 1969-1975. The mentioned floods have imposed both river regularization as well as the systematization of villages in the floodable area (Rădeni, Iana etc.)

Table 3. ***Discharge rates corresponding to characteristic levels (Tutova at Rădeni)***

STATION	CHARACTERISTIC LEVEL (CM)	EQUIVALENT Q (M^3/S)	FREQUENCY
Rădeni	Attention level	14	57,65%
	Flood level	53	12,49%
	Danger level	80	5,79%

For the analyzed cases, we computed the flood risk index, that is directly proportional to the flood maximum discharge, with reflex in the exceeding of attention, flooding or danger levels and opposite to the flood increase time, with impact in the society's capacity on intervening in useful time (goods' salvation, evacuation etc.). The risk index (Qmax/Tc) was computed and grouped on different levels. Yet, having in mind the multitude of factors needed for the complete evaluation of the risk induced by a certain flood, we preferred a simplification of the classification, considering that it responds, for the studied area, both to the necessities of the study and to the scientific criteria.

Thus, a flood presents a very reduced and/or reduced risk if the value of the index is lower than one ($Ir \leq 1.0$), a medium risk if it enters the 1.1-2.0 interval, and a high or very high risk if it exceeds the value of $Ir \geq 2.0$. Thus 59% of the floods do not present a real risk for anthropic structures, 23% present a medium risk and about 18% present a high and very high risk (table 4).

Table 4. ***The risk index and the correlation with the main parameters in Tutova basin***

Category	Ir	Frequency %	Q max	Qmax/√F
Very reduced and reduced risk	≤ 1,00	59,03	47,7	0,68
Medium risk	1,01-2,00	22,91	70,7	2,15
High and very high risk	≥ 2,00	18,06	97,5	3,80

Based on the data presented previously, for the determination of the flood risk in needed the determination of exceeding probabilities for different characteristic discharge rates. In this purpose, we used the empiric correlation curve and the Pearson III theoretical correlation curve, the last one being considered the most adequate for the hydrologic conditions of Romania (Giurmă et al., 2003). The results of the probabilistic analysis are synthesized in table 5, and the relevance of the numbers is defined by their reference to three characteristic levels (implicitly discharge rates): attention, flooding and danger.

Table 5. ***Characteristic discharge rates (mc/s) for different occurrence probabilities***

Probability (%)	0,01	0,1	1	10	20	50	80
Rădeni (mc/s)	280,3	197,6	127,0	68,1	51,7	29,8	14,6
Puieşti (mc/s)	242,5	159,7	99,8	54,2	42,21	26,8	17,3

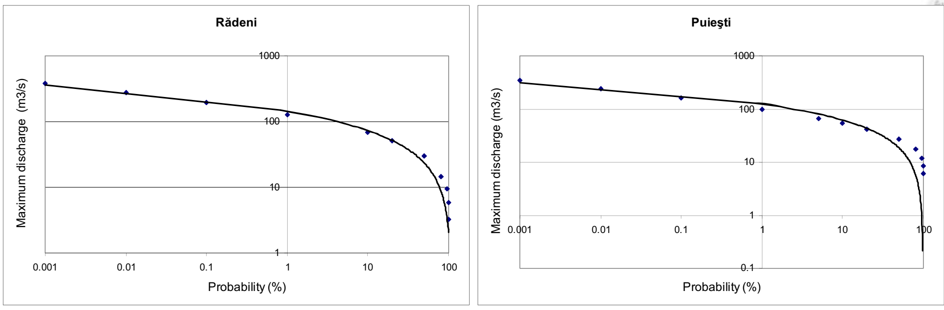

Fig. 3. ***Pearson III theoretical probability curve of maximum discharge rates for Tutova at Rădeni and Puieşti***

With the help of TNTmips software, we simulated some theoretical floods, characterized by levels of up to one-meter amplitude in the area of Iveşti, situated in the river's lower basin. The analysis was conducted by reference to strictly local conditions, without taking into consideration the flood genesis and propagation conditions. Obviously, between water level on one side and the flooded area, respectively specific water volume on the other, are established significant correlations, that allow rapid approximations according to one of the parameters.

Knowing the surface of the active section and taking into consideration an average water speed of 0.8-1.2 m/s (according to Diaconu, 1995 and Giurmă, 2003, on the basis of local conditions) we attempted the approximation of the liquid discharge for each level. In this way were obtained the parameters of theoretical simulated floods. In table 6 are included the water levels (above the river level) considered flooding levels, measured after the exceeding of the minor floodplain banks (1,5 m), the mean computed discharge, the probabilistic insurance for the respective discharge rates, the flooded surface and the instantaneous (static) volume.

Table 6. ***Parameters of theoretical simulated floods in Iveşti section***

H (m)	Qmed (m^3/s)	Prob. (%)	S (ha)	Vi (m^3)
0.25	47.8	10.00	50.49	74139
0.50	104.7	1.00	61.04	176149
0.75	170.1	0.10	66.54	328543
1.00	248.6	0.01	74.07	498994

Due to the reduced possibilities of recording, the typologic analysis of flooded surfaces has been conducted up to a maximum water level in the floodplain of 0.5 m, the equivalent of a flood with a occurrence probability of once to 100 years (1%). At this level are flooded 123 houses and a surface of about 61 ha of terrains of different uses: houses and additional buildings (24.21 ha), arable terrains (17.57 ha), pastures (5.29 ha), roads and access networks (4.03 ha), gardens and complex use terrains (3.96 ha) etc.

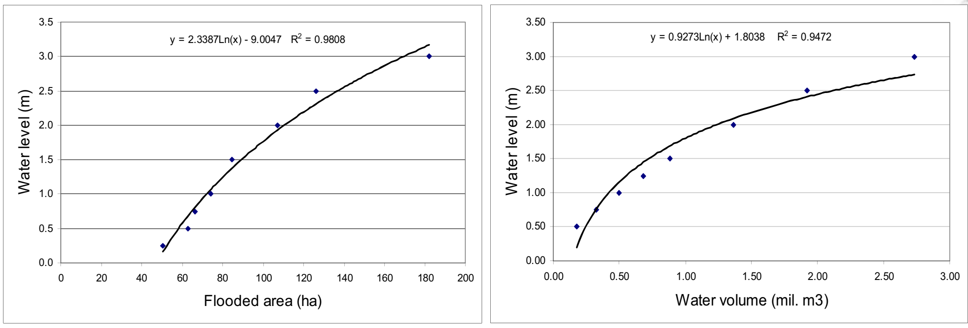

Fig. 4. ***Relation between water level and flooded surface (a), respectively specific volume (b) of a theoretic simulated flood in Iveşti section***

4. CONCLUSIONS

In Tutova basin, the dominant rainfall alimentation explains the irregular regime of river runoff, with very high variations, from total depletion up to values that during the highest floods exceed 200-300 times the mean multi-annual discharge rates. The propagation of flood waves is done differently due both to the spindle-shaped basin and to the way floodplain runoff is realized. The differentiated impact of floods may be adequately evidenced through GIS modeling in different sections of the floodplains.

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