Patterns of Forming and Distribution of Maximum Flood water discharge in Prut and Siret River Systems

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Abstrakt: *Štúdium vzťahu medzi intenzívnymi dažďovými zrážkami a vysokým vodným stavom riek je v Zakarpatskom regióne aktuálnym problémom. Za predpokladu, že hustota meracích staníc vodného stavu a zrážok je dostatočná, možno získať veľmi presné údaje pre štúdium tohto vzťahu v povodí. Informácie o maximálnom prietoku vody v riekach v čase zvýšenej vodnej hladiny sú menej presné a menej podrobné. Takže na základe informácií o zrážkach a vodnom stave môžeme podrobnejšie analyzovať problémy súvisiace s vysokými vodnými hladinami tokov. Tento príspevok prezentuje výsledky systematického výskumu zrážok počas obdobia výskytu vysokých vodných hladín, ktoré sa objavujú v povodí horného Prutu a horného Siretu.*

Kľúčové slová: *povodie, vysoký úhrn zrážok, izohyeta, vodný prietok, korelačný koeficient*

Keywords*: drainage area, heavy rain precipitation, isohyets, water discharge, correlation coefficient*

Introduction

Maximum river water discharge is formed by corresponding processes in drainage area. Special category is compiled by floods and river overflows, caused by heavy rains. In Ukraine they are mostly typical for the rivers of Pre-Carpathians.

The relationship between precipitation and water discharge characteristics has long been studied. However, it is mostly applied to their average value for perennial term. The formation of river overflows caused by heavy rains has not been sufficiently studied and needs further investigation. The data on heavy rain precipitation is used in mathematical drain water models. At the same time, for considerably small reservoirs and similar in forming conditions drainage areas quite close and direct connections with maximum water discharge and other properties can be expected. With sufficient density of gauging centers, one may receive quite accurate data on heavy rain precipitation layers in river basins. Observation of maximum water drain in rivers is less accurate. Therefore, study of interrelation between them focuses at the problems of 1) clarification of information on maximum water discharge 2) peculiarities of basin system functioning analysis and estimation of water discharge distribution in river systems may be solved.

Regional publications review

In Ukraine heavy rains are regarded as dangerous meteorological phenomena when exceed 30 mm in less than 12 hours (Klimatologichni standartni normu 1961 – 1990, Stuhiŷni meteorologichni yavycsha na terytorii Ukrainu za ostannye dvadcyatyrichchya 1986 – 2005). It is also known from hydrological research (Vladimirov 1990, Chebotarev 1975) that minimum heavy rain intensity is about 22 mm/h. In such a way we get the evaluation of heavy rain precipitation layers that cause river overflows.

In the territorial conditions of Pre-Carpathians the length of the biggest rivers that carry the water from the mountains to the foothills are mostly up to 100 – 150 km. With the speed of flood wave spreading at 2 – 3 m/s we get the time lag of less than 24 hours (Opasnye gidrometeorologichiskie...

1973, Teplovoў i vodnyў rezhim... 1985). It allows us to use data on 24 hours' precipitation layers as an argument in studying maximum water discharge and drain modules.

In previous researches (Babichenko, Loyeva 1967, Vishnevskyў 1964, Gidrometeorologichni umovy… 2008, Kyrylyuk 2001, Lyutik, Kiptenko, Bedratenko 1972) the total of precipitation layers for periods of heavy rain falls, or current data on precipitation for realization of predictability mathematical models was mostly used (Kyrylyuk 2001, Sosedko 1980, Susidko 1998).

Aim, methods and specific subject of the study

The study is aimed at the elicitation and complex analysis of the relationship between daily amounts of heavy rain precipitation in the basins of Upper Prut and Siret river systems, maximum daily water discharge and drain modules of heavy rain overflows. Precipitation properties were calculated with the help of isohyet method and ArcGIS 9.3.1, Golden Surfer 9.0. software. Statistical characteristics of certain dependencies were obtained through Advanced Grapher 2.2, Graph 4.4.2. program. For drain water modules estimation in relation to unstudied folds recalculation the method of relationship establishment between precipitation amounts for different basins was used (based on stationary hydrological observation folds).

The specific subjects of the study are rivers that are investigated up to certain folds and their drainage areas in the Upper Prut and Siret rivers systems.

Major experimental findings and results

To analyze the correlation between daily precipitation amounts and maximum heavy rain overflows properties we have formed corresponding statistical rows. Basic principle of case selection was to grasp the range of maximum overflow water discharge change in gauging station. At the same time the quality and availability of outgoing information was essential. In most rain gauging centres and stations our research covers time-span from 1959 to 2010. Only in Putyla r. – Putyla t. station the data for the period of 1991-2010 is used. The length of the case rows is 11 – 19 cases.

The list of hydrological observation centres, for which the relationship between precipitation and water discharge characteristics is obtained, is given in tab 1.

Tab. 1. *Gauging station in Prut and Siret river basins*

№	River – Gauging station	Drainage areas, km^2	Time-span
1.	r. Siret – t. Storozhynets	672	1886 (1962) – 2013
2.	r. Prut – t. Vorokhta	48,3	1977 – 2013
3.	r. Prut – v. Tatariv	405	1909 – 2013
4.	r. Prut – c. Yaremche	597	1887 – 2013
5.	r. Prut – c. Chernivtsi	6890 (5200)*	1880 (1944) – 2013
6.	r. Cheremosh – v. Usteriky	1500	1890 (1957) – 2013
7.	r. Bilyi Cheremosh – v. Yablunytsia	555	1954 – 2013
8.	r. Chornyi Cheremosh – t. Verkhovyna	657	1910 (1963) – 2013
9.	r. Iltsia – t. Iltsi	86,1	1930 (1950) – 2013
10.	r. Putyla – t. Putyla	181	1950 (1963) – 2013
11.	r. Derelui – v. Molodiia	289	1953 – 1975

**part of reservoirs are located within the limits of Ukrainian Carpathians and Pre-Carpathians*
Region of research is depicted in fig. 1 and 2.
r. – river, t. – town, c. – city, v. – village

Fig. 1. *Location of region under study within the limits of Carpathian region*

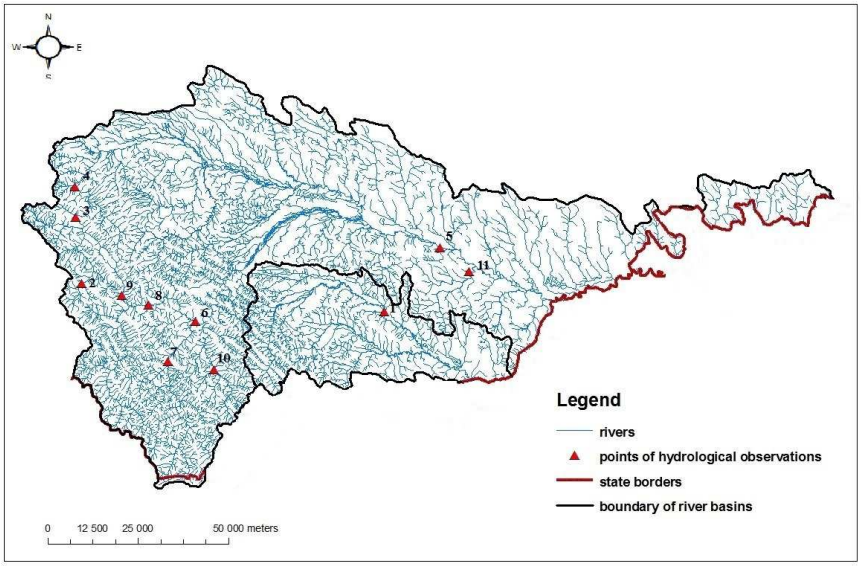

Fig. 2. *Hydrographic network and hydrological observation centers of river basins under study*

To build a skeleton map, Golden Software – Surfer 9.0. software was used. The number of precipitation observation centers in the basins of Upper Prut and Siret ranges from 25 to 50, which let us obtain satisfactory results within minimum flaw. Taking into account space division and precipitation amplitude change, which were 5, 10 mm, the intervals between isolines were established. Building precipitation distribution skeleton maps, the observation results of meteorological stations and hydrological posts situated in Zakarpatska, Ivano-Frankivska, Chernivetska oblasts (regions) were used. In the analysis of 2010 floods the results of meteorological stations observation of the Republic of Moldova and hydrological posts in the basins of r. Siret, r. Suchava located in Romania, were used. Isohyets are calculated and built in a way to make it possible to consider time of overflow wave peak reaching the given fold.

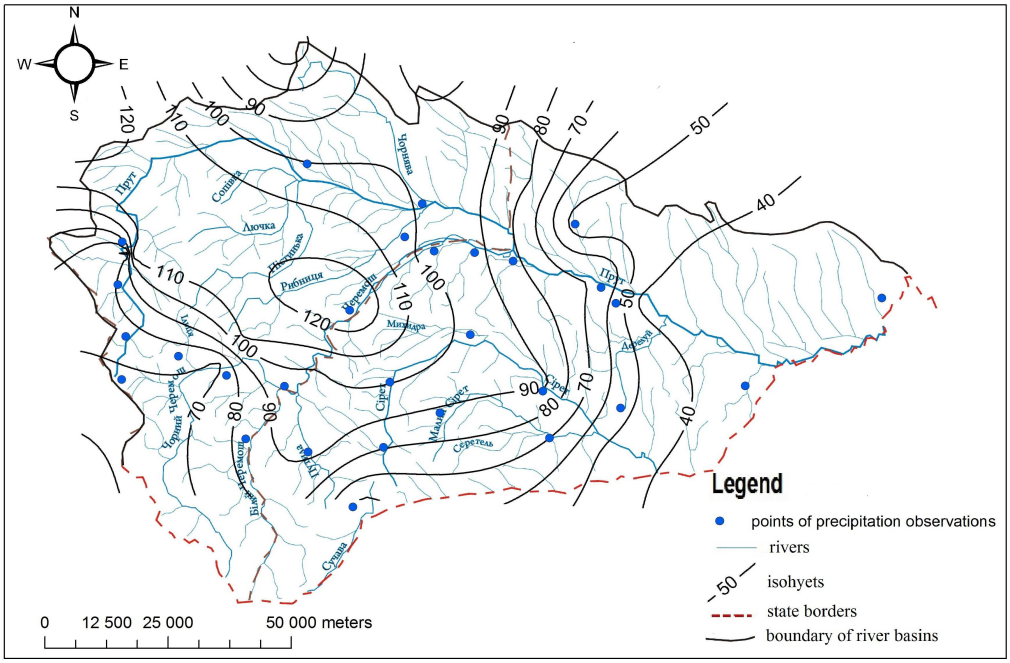

Fig. 3. *Precipitation distribution on the territory of Upper Prut and Siret, July 25, 2008.*

The analysis of received correlation and peculiarities of individual overflows course let us reveal some controversies and errors in maximum water discharge evaluations accepted by hydrological service. We introduced corresponding changes into outgoing statistical rows. In fig. 4, 5 the examples of linkage in the station of r. Bilyi Cheremosh – v. Yablunytsia (№7) and r. Siret – t. Storozhynets (№1) are presented.

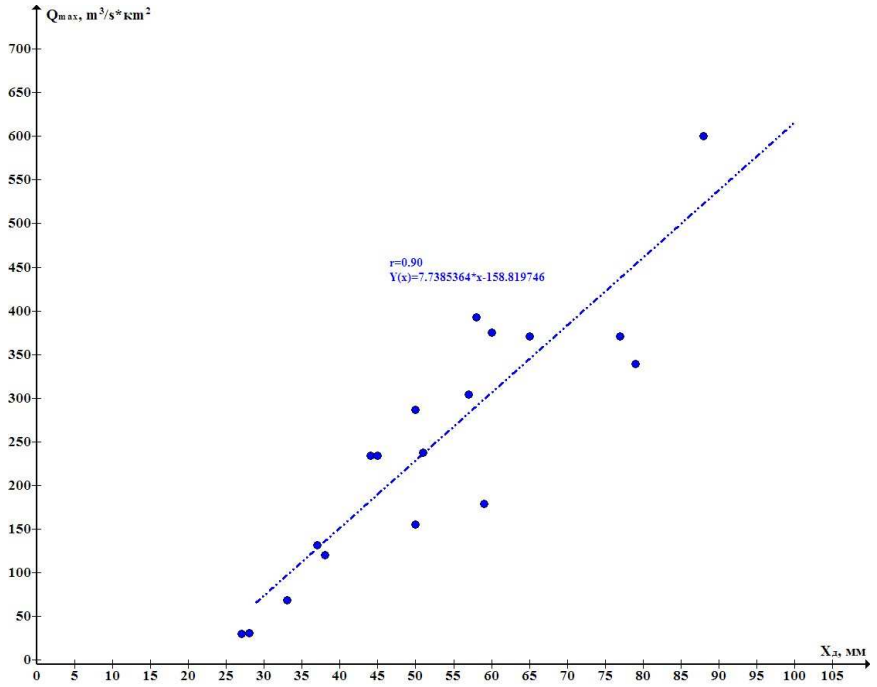

Fig. 4. *Graph Q_{max} - $f(X_o)$ relation, subbasin r.Bilyi Cheremosh – v. Yablunytsia*

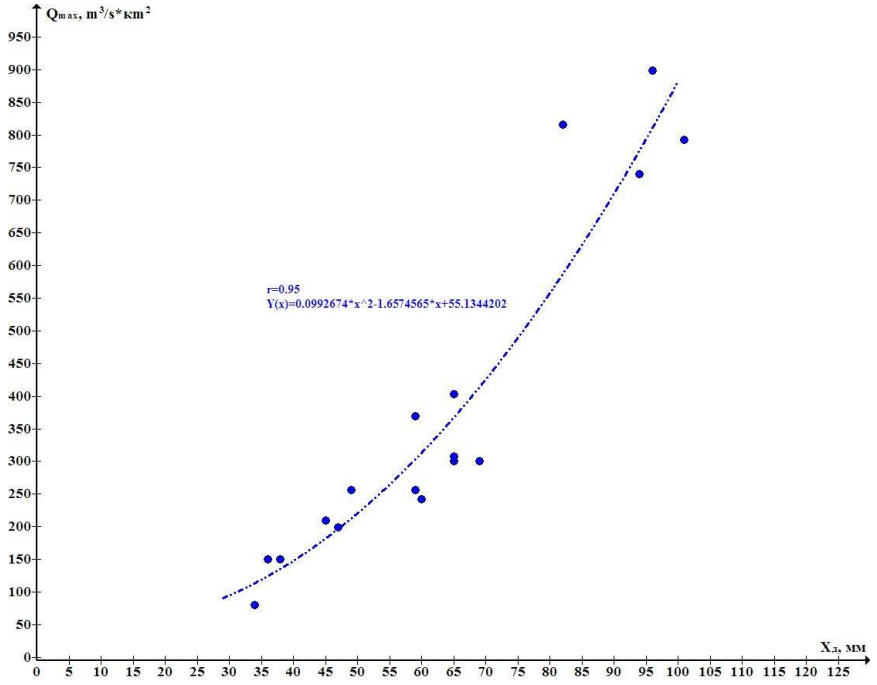

Fig. 5. *Graph Q_{max} - $f(X_o)$ relation, subbasin r. Siret – t. Storozhynets*

We have also built general graphs of Q_{max} - f($X_д$) relation, fig. 6, 7. They let us analyze general picture of basin systems functioning under study during heavy rain overflows in the Upper Prut and Siret rivers.

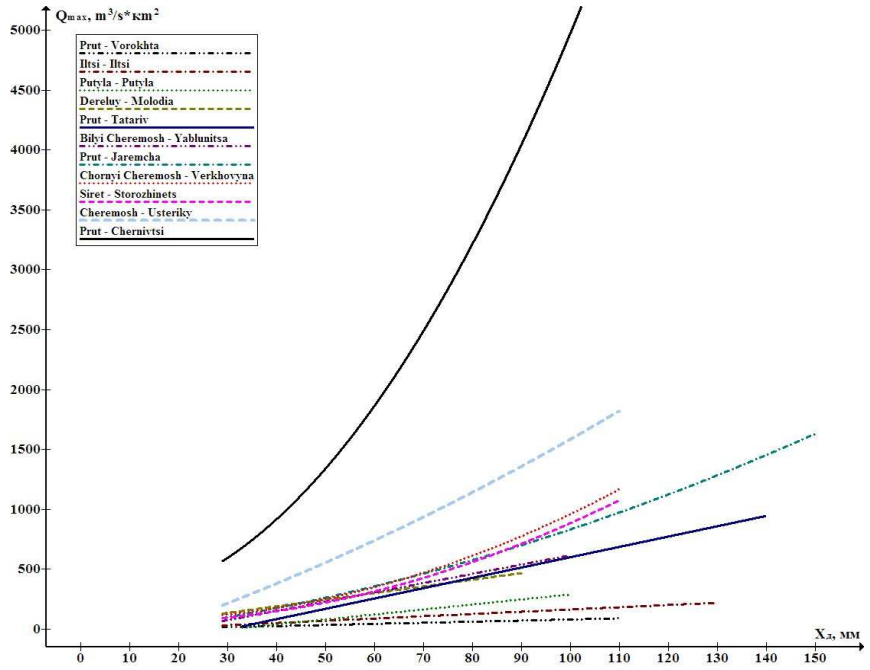

Fig. 6. *Dependencies Q_{max} - f($X_д$), basin of Upper Prut and Siret*

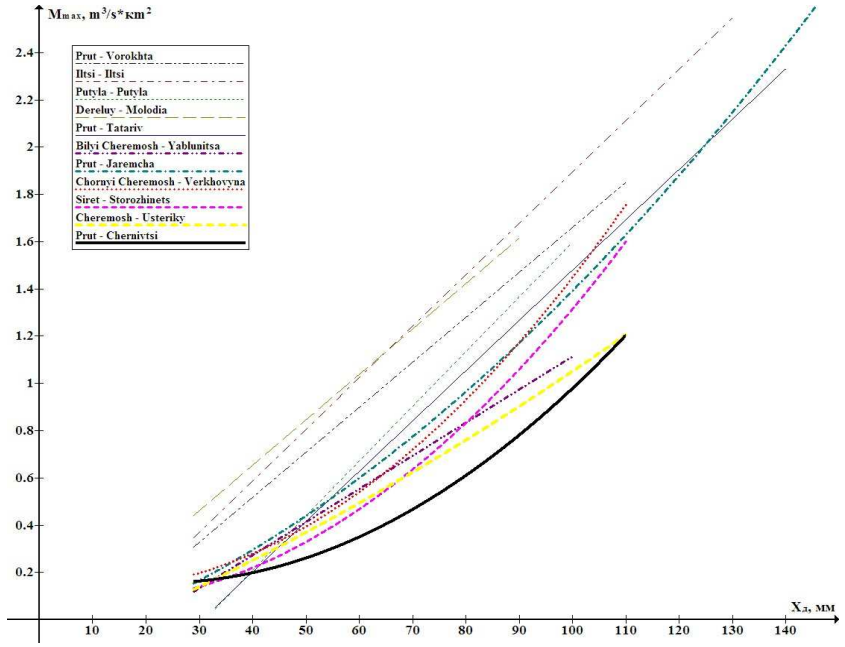

Fig. 7. *Dependencies M_{max} - f($X_д$), basin of Upper Prut and Siret*

Obviously, both water discharge and drain modules depend on the drainage areas. For the waste this dependency is direct, while for the modules – reversed. It is also worth mentioning, that the character of such dependency for drain modules is more complicated and ambiguous. We may single out three groups of drainage areas: a) < 300 km^2; b) 400 – 700 km^2; c) >1500 km^2. Corresponding groups of graphs are quite similar. Differences of drain module do not exceed 12 – 15 % (off the central lines). It allows us to recommend them for overflow properties evaluation based on data on daily rain layers.

Drainage area forming processes are also similar to basin systems formation occlusive folds of which are located not far along one river. Therefore we can make the hypothesis that relation between modules is similar to the relationship between precipitations. We use such hypothesis for evaluating modules of overflow drain in folds located relatively not far from hydrological observation centers (method of module evaluation through precipitation). The last ones are considered base folds, the others only their derivatives. Such consideration allows us to expand data coverage of different parts of river systems. It all is important in conditions of not sufficiently dense hydrological network. Eventually, using the method of consecutive data connecting and elimination of contradictions, with the help of general graph $M_{max} = f(X_д)$ we have estimated maximum water discharge for Upper Prut and Siret river systems at the times of overflows in 1969 and 2008. Such data allows us to conduct other researches: e.g. the study of river basins based on recorded high-water levels.

Conclusion

1. Quite tight relation between daily layers of precipitation and maximum water discharge in rivers and drain modules (r = 0,90 – 0,98) have been revealed. For the most of folds, average square flaws do not exceed 15-18%. It does not yield to modern forecasting methods accuracy.
2. General graphs of $Q_{max} = f(X_д)$, $M_{max} = f(X_д)$ relations show that maximum water discharge increases with the expansion of drainage areas, while corresponding modules tend to decrease. Basin systems and corresponding graphs may be joined into three basic groups.
3. The generalization of relationship between precipitation and overflows characteristics and also method of module through precipitation estimation allows us to describe maximum water discharge distribution in river systems during major heavy rain overflows and floods. It is important for conducting other hydrological studies and has some practical value.

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Zákonitosti formovania a rozdelenia maximálnych povodňových prietokov v systémoch riek Prut a Siret

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Zhrnutie: *Článok prezentuje výsledky systematického výskumu zrážok počas obdobia výskytu veľkých vôd, ktoré sa objavujú v povodí Horného Prutu a Horného Siretu. Použité hydrometeorologické údaje boli spracované pomocou softvéru Surfer 9.0 (Golden Software) a z nich boli odvodené mapy distribúcie zrážok v študovanej oblasti a iné analýzy. Použité boli údaje z 11 stacionárnych hydrologických pozorovaní. Je potrebné poznamenať, že rýchlosti toku riek neboli merané ale iba empiricky hodnotené. Na základe maximálnej výšky denných zrážok bol analyzovaný ich vplyv na prietok a odvodňovanie. Pomerne tesný vzťah medzi dennými úhrnmi zrážok a maximálneho prietoku vody v riekach a odvodňovacích modulov (r = 0,90 – 0,98), priemerné štvorcové chyby neprekročili 15 – 18 %. Táto analýza pomáha riešiť niektoré otázky ohľadom interpretácie hydrologických informácií a interpretácie maximálneho prietoku vody v riečnych systémoch počas trvania silných dažďov.*

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