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FLOOD FREQUENCY ANALYSIS FOR UKRAINIAN AND AUSTRIAN DANUBE TRIBUTARIES

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The aim of this study is to determine and compare the design floods for the cold period (November-April) with 2-, 5-, 10-, 50-, and 100-year return periods for the selected catchments using flood frequency analysis.

STUDY AREA

small and medium size Ukrainian and Austrian, unaffected mountainous catchments of the Danube River Basin

ID	Gauge	Area, (km²)	Latitude	Longitude	Mean elevation (m.a.s.l.)	Forest cover (%)	Study period
Ukrainian catchments							
1	Rika River - Mizhhiria village	550	48° 32′ 20″	23° 29′ 47″	800	41	1958-2016
2	Rika River - Verkhnii Bystryi village	165	48° 37′ 36″	23° 30′ 50″	920	64	1958-2016
3	Holiatynka River - Maidan village	86	48° 36′ 54″	23° 27′ 17″	790	40	1958-2016
4	Pylypets River - Pylypets village	44	48° 40′ 15″	23° 20′ 29″	854	19	1958-2016
5	Lopushna River - Lopushne village (nyzhn.)	37	48° 39′ 13″	23° 34′ 46″	897	78	1958-2016
6	Studenyi River - Nyzhnii Studenyi village	25	48° 42′ 38″	23° 22′ 06″	800	18	1958-2016
7	Ploshanka Stream - Pylypets village (nyzhn.)	20	48° 40′ 14″	23° 20′ 27″	983	29	1958-2016
8	Lopushna River - Lopushne village (verkhn.)	13	48° 38′ 41″	23° 37′ 39″	925	93	1960-2016
9	Branyshche Stream - Lopushne village	10	48° 38′ 56″	23° 37′ 22″	916	72	1958-2016
10	Studenyi River - Verkhnii Studenyi village	8	48° 45′ 03″	23° 21′ 22″	809	20	1959-2016
11	Pylypets River - Podobovets village	7.4	48° 40′ 32″	23° 18′ 36″	747	12	1958-2016
12	Pylypetskyi Stream - Pylypets village	5.7	48° 39′ 43″	23° 19′ 00″	1000	37	1958-2016
13	Ziubrovets Stream - Lopushne village	3.2	48° 38′ 44″	23° 36′ 49″	871	91	1958-2016
14	Serednii Zvir Stream - Lopushne village	2.2	48° 38′ 48″	23° 36′ 28″	984	95	1958-2016
Austrian catchments							
1	Steyr River - Klaus an der Pyhrnbahn	545	47° 49' 51"	14° 09' 37"	1059	65	1952-2016
2	Teichl River - St. Pankraz	231	47° 45' 59"	14° 12' 35"	1009	63	1976-2016
3	Steyr River - Kniewas	190	47° 46' 04"	14° 10' 12"	1213	58	1952-2016
4	Teichl River - Teichlbrücke	147	47° 43' 37"	14° 17' 44"	1015	61	1952-2016
5	Steyr River - Hinterstoder	86	47° 41' 38"	14° 08' 27"	1358	46	1977-2016
6	Steyrling River - Steyrling	72	47° 48' 20"	14° 08' 17"	951	85	1957-2016
7	Dambach River - Windischgarsten	66	47° 43' 20"	14° 19' 57"	1016	63	1972-2016
8	Teichl River - Spital am Pyhrn	39	47° 40' 09"	14° 20' 05"	1205	71	1967-2016
9	Steyr River - Dietlgut	26	47° 40' 08"	14° 06' 33"	1375	46	1952-2016
10	Krumme Steyr River - Polsterlucke	18	47° 41' 34"	14° 06' 51"	1506	38	1977-2016

Table 1. Characteristics of the study catchments and the corresponding gauging station

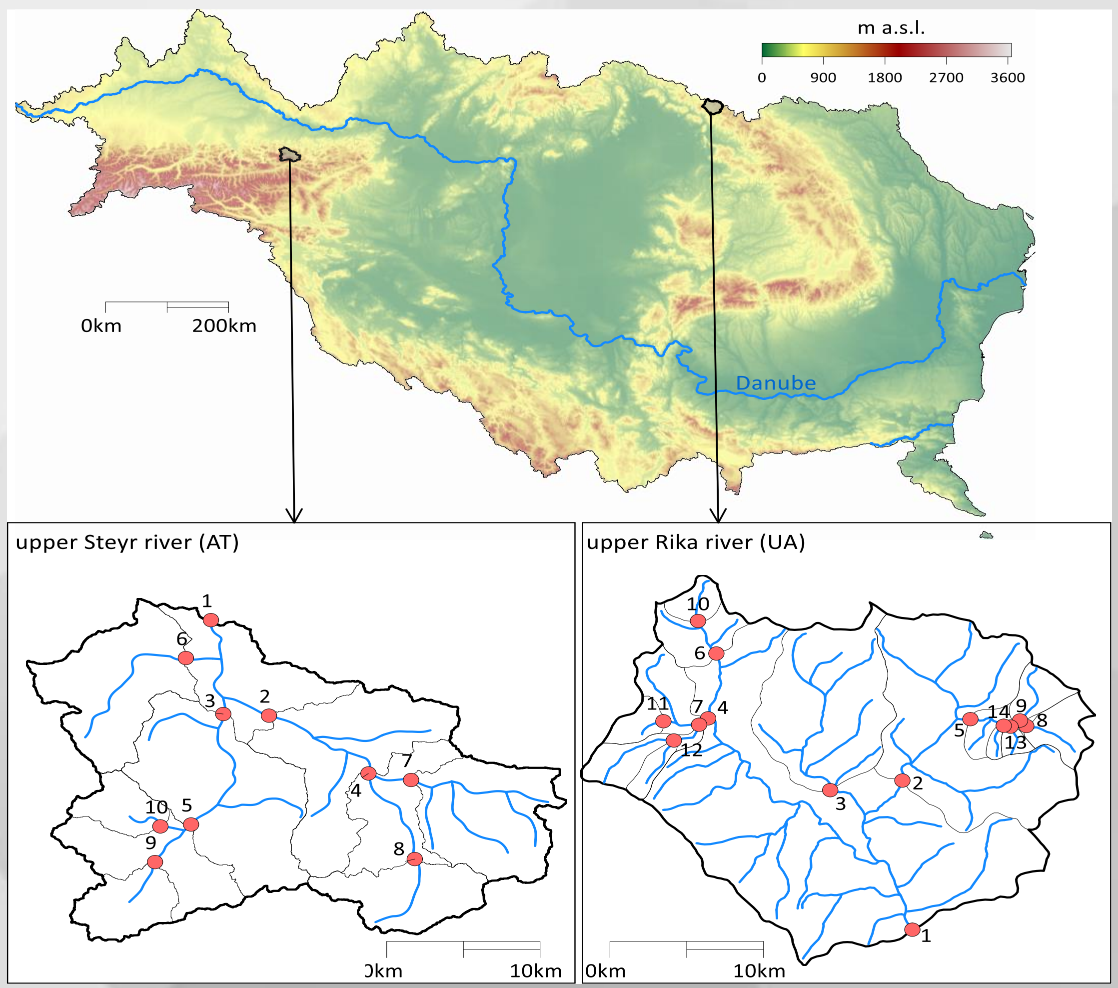

Fig. 1. Location of Ukrainian and Austrian study catchments in the Danube river basin. Labels of symbols refer to ID number in Table 1.

METHODOLOGY

Flood frequency analysis is carried out using Gumbel distribution. The density function of the Gumbel distribution is as follows

$$f(x) = \frac{1}{d}\exp\left(-\frac{x-c}{d}\right)\cdot\exp\left[-\exp\left(-\frac{x-c}{d}\right)\right]$$

where x – random variable, c – parameter of the distribution, d – parameter of the distribution.

The cumulative distribution function is $F(x) = \exp\left[-\exp\left(-\frac{x-c}{d}\right)\right]$

The quantile function can be calculated according to

$$x_T = c - d\cdot\ln\left[-\ln\left(1-\frac{1}{T}\right)\right]$$

where T – return period (in years) and the parameters can be estimated based on the method of moments according to

$$d = \frac{\sqrt{6}}{\pi}\cdot\sigma \text{ and } c = \mu - 0.5772\cdot d$$

where μ – mean, σ – standard deviation, 0.5772 – Euler-Mascheroni constant.

RESULTS

Gauge/$Q_{T\text{-}year}$	Q_2	Q_5	Q_{10}	Q_{50}	Q_{100}	Q_{min} (year)	Q_{max} (year)
Rika River - Mizhhiria village	196	296	362	508	569	55 (1961)	735 (1958)
Rika River - Verkhnii Bystryi village	43.4	63.1	76.1	105	117	10.4 (2015)	142 (1958)
Holiatynka River - Maidan village	30.9	48.8	60.6	86.6	97.5	7.87 (1961)	127 (1958)
Pylypets River - Pylypets village	21.2	33.5	41.7	59.7	67.3	4.74 (2003)	57.1 (1958)
Lopushna River - Lopushne village (nyzhn.)	10.6	16.7	20.8	29.9	33.6	1.65 (1961)	43.9 (1958)
Studenyi River - Nyzhnii Studenyi village	8.78	15.3	19.6	29.2	33.2	1.54 (1961)	52.6 (1986)
Ploshanka Stream - Pylypets village (nyzhn.)	10.9	17.3	21.5	30.7	34.6	1.18 (2015)	30.3 (1985)
Lopushna River - Lopushne village (verkhn.)	4.11	6.41	7.94	11.3	12.7	0.94 (1960)	13.4 (2001)
Branyshche Stream - Lopushne village	3.94	6.45	8.12	11.8	13.3	0.66 (2015)	16.7 (1958)
Studenyi River - Verkhnii Studenyi village	3.04	4.82	5.99	8.57	9.67	0.96 (1961)	12.3 (2001)
Pylypets River - Podobovets village	6.50	10.3	12.8	18.3	20.7	1.44 (1974)	17.6 (1986)
Pylypetskyi Stream - Pylypets village	2.96	4.62	5.72	8.14	9.17	0.65 (2014)	8.12 (2001)
Ziubrovets Stream - Lopushne village	1.23	2.10	2.68	3.95	4.49	0.27 (2003)	5.53 (1958)
Serednii Zvir Stream - Lopushne village	0.64	1.07	1.36	1.99	2.25	0.04 (1961)	2.97 (1958)

Table 2. Estimated design floods with 2, 5, 10, 50 and 100 years return periods (m³/s), largest (Q_{max}, m³/s) and lowest (Q_{min}, m³/s) observed winter and spring flood discharges for all Ukrainian study catchments.

Gauge/ $Q_{T\text{-}year}$	Q_2	Q_5	Q_{10}	Q_{50}	Q_{100}	Q_{min} (year)	Q_{max} (year)
Steyr River - Klaus an der Pyhrnbahn	141	205	246	338	377	59.4 (1963)	420 (1962)
Teichl River - St. Pankraz	60.9	88.3	106	146	163	24.5 (2010)	156 (1993)
Steyr River - Kniewas	38.9	56.9	68.8	95	106	10.1 (1960)	102 (1993)
Teichl River - Teichlbrücke	34.6	56.0	70.1	101	114	10.8 (1969)	129 (1992)
Steyr River - Hinterstoder	18.4	27.8	33.9	47.5	53.2	7.81 (1984)	56.0 (1993)
Steyrling River - Steyrling	23.2	35.7	44	62.3	70	5.65 (1963)	82.0 (1962)
Dambach River - Windischgarsten	15.1	24.8	31.2	45.3	51.2	4.60 (2001)	55.0 (1992)
Teichl River - Spital am Pyhrn	9.25	12.4	14.5	19.0	20.9	4.97 (1976)	22.9 (1993)
Steyr River - Dietlgut	5.27	7.91	9.65	13.5	15.1	2.02 (1960)	15.3 (1988)
Krumme Steyr River - Polsterlucke	8.31	12.2	14.7	20.3	22.7	3.56 (1985)	20.7 (1993)

Table 3. Estimated design floods with 2, 5, 10, 50 and 100 years return periods (m³/s), largest (Q_{max}, m³/s) and lowest (Q_{min}, m³/s) observed winter and spring flood discharges for all Austrian study catchments.

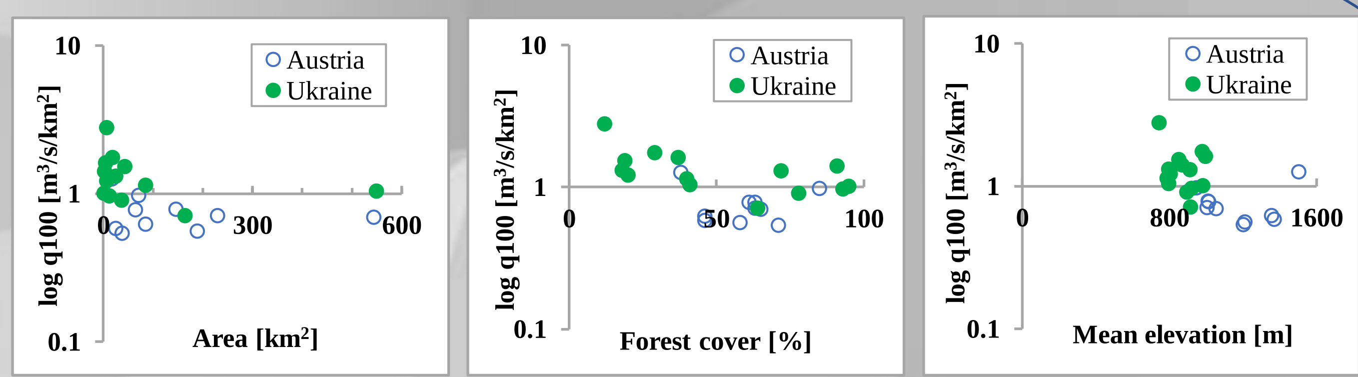

Fig. 2. 100-year floods scaled with catchments area as a function of catchment area, forest cover and mean elevation in the upper Rika and upper Steyr river basins.

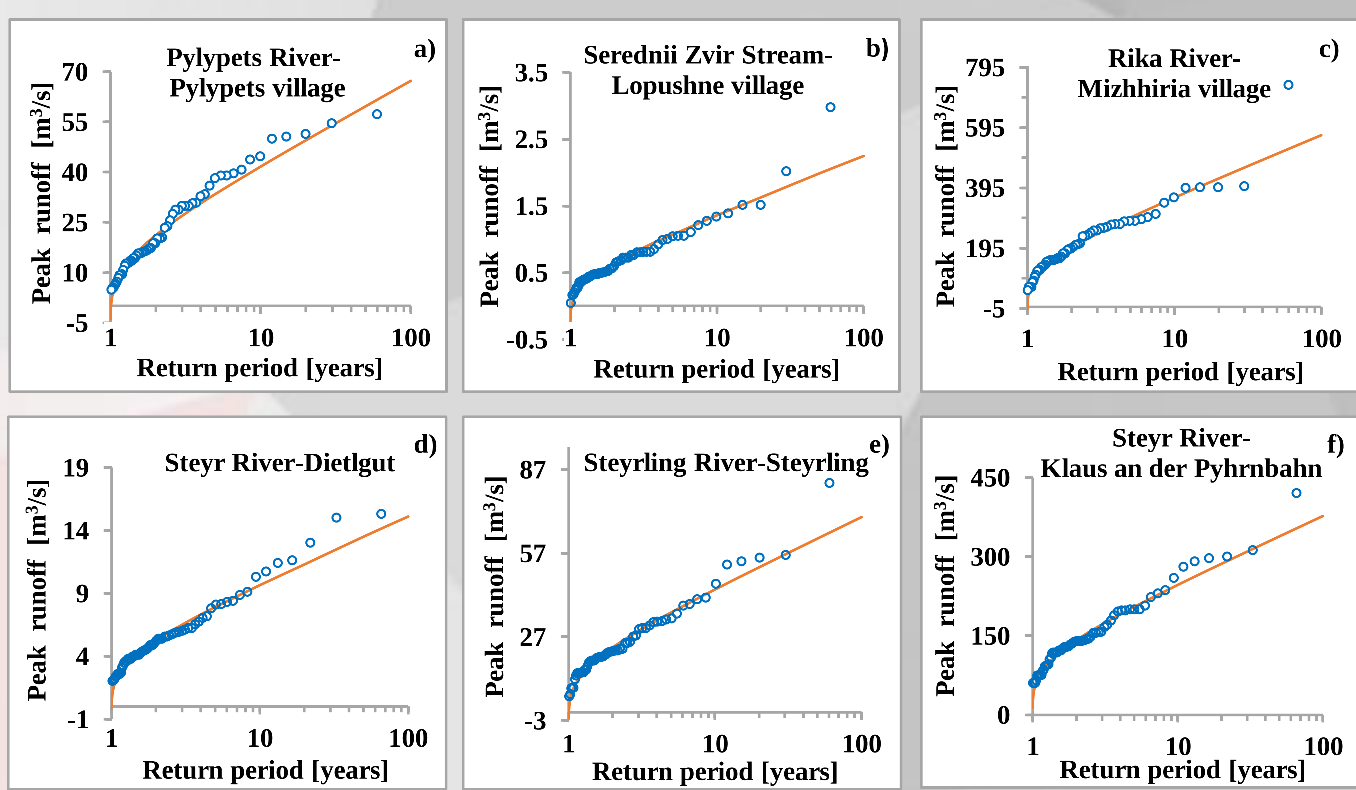

Fig. 3. Flood frequency curves (points – observed peaks vs empirical return period) for all study catchments in the upper Rika river basin (a, b, c) and Steyr river basin (d, e, f).

CONCLUSIONS

The main results of the present study can be summarised in the following points:

- Winter and spring floods with 2 yrs, 5 yrs, 10 yrs, 50 yrs and 100 yrs return periods were estimated for all the study catchments and will be useful for various management purposes (for designing dams, floodplain management etc.).
- For the majority of the Ukrainian and Austrian gauges, the flood frequency curves fit the observations very well for lower floods but the fit is not that good for higher floods.
- The results obtained using Gumbel's distribution shows better results for flood data series of Austrian catchments. It was found that the floods were larger in the upper Rika River Basin than in the upper Steyr River Basin.
- We have tested the relation between the 100-year flood and a set of the different physical-geographical characteristics of the catchments. It was observed that of the variations in flood magnitude could be explained by catchment area, forest cover and mean elevation. The forest cover of the catchment affects runoff, because for all of the study catchments both for Ukraine and for Austria, the smaller the forest cover, the highest values of specific discharge with the return period of 100 years occur in gauges.
- In future studies, it would be interesting to perform a more detailed study of the magnitude of floods from other characteristics of the catchment (rainfall, air temperature, soil, shape slope, length of river and other).