Floodplain Conference
June 08 2022, Baja, Hungary

The hydrological regime of the middle Danube reach and implications on the lateral connectivity of floodplains

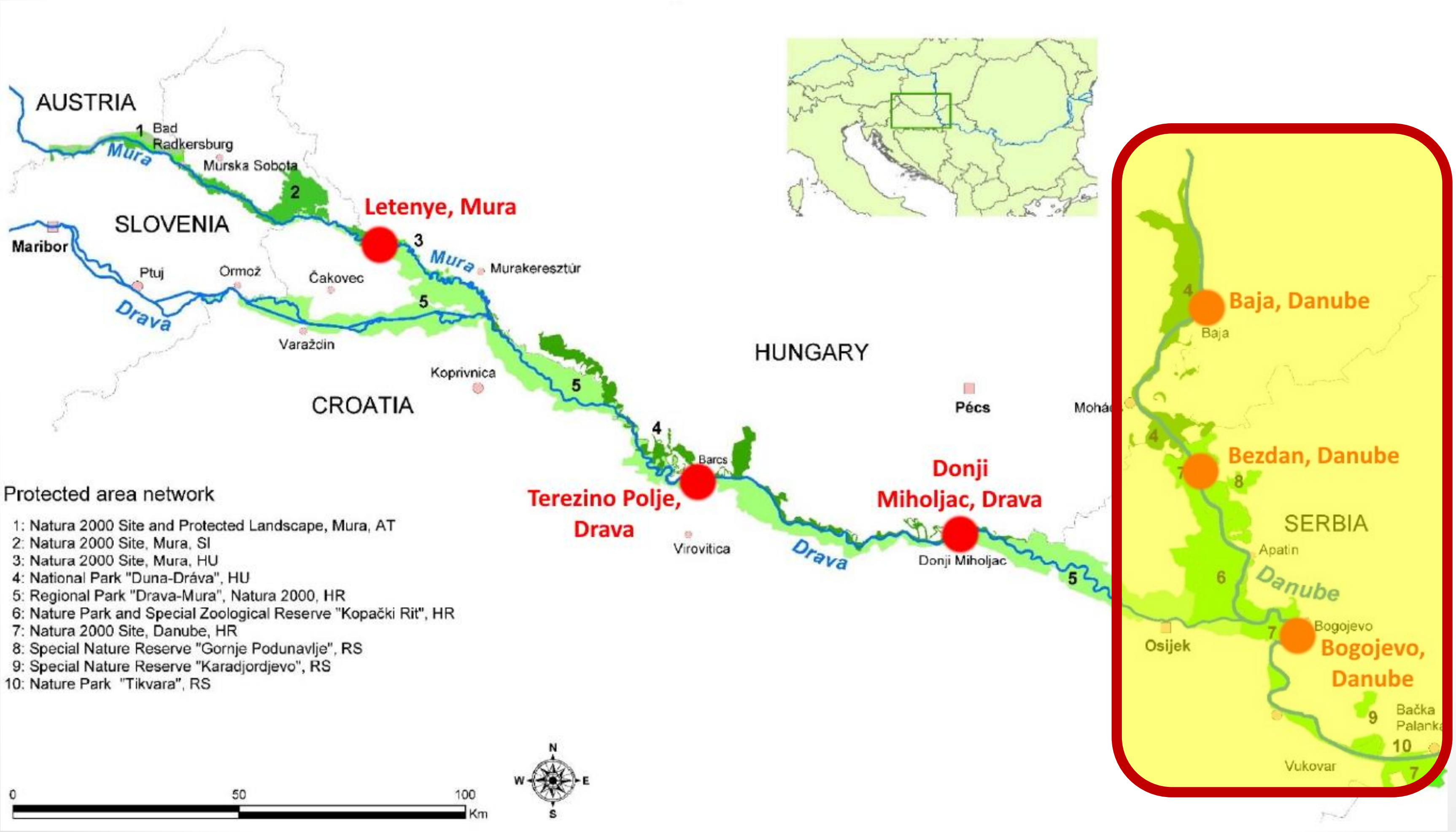
Tamás, *EA*

Faculty of Water Sciences, University of Public Service, Baja, Hungary

Introduction

- Hydrological regime plays a primary role in the sustainable management of floodplains
- Floodplain ecosystem dynamics and balance are largely dependent on the dynamics of the flow regime of rivers
- Drying of the floodplain forests along the Hungarian reach of the Danube River became evident in the late 1980s (*Zsuffa 1993*)
- Comprehensive hydrological statistical analyses (*Kalocsa 1992*)
- Lowering of water levels in the active channel of the Danube River in Hungary: river training and dredging (*Kalocsa & Zsuffa 1997)*
- Several works since the 1990s *(e.g. Goda et al, 2007)* for the Hungarian reach and other regulated rivers
- Extensive sediment deficit is proven *(e.g. Babić et al, 2003)*
- No comprehensive analysis for the alluvial middle Danube

Location: Danube – Drava – Mura TBR MDD (5 countries)

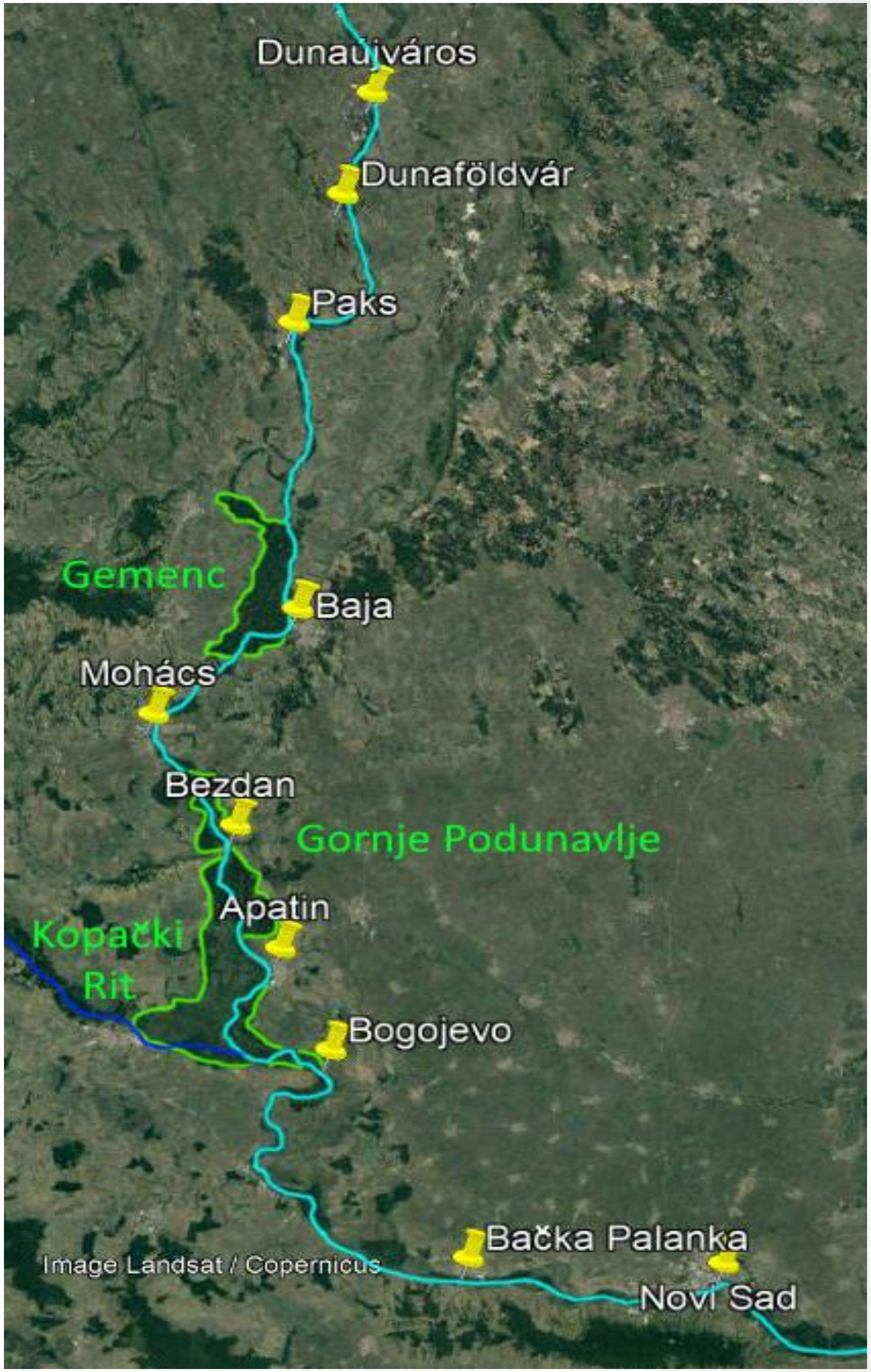


10/06/2022

Goals

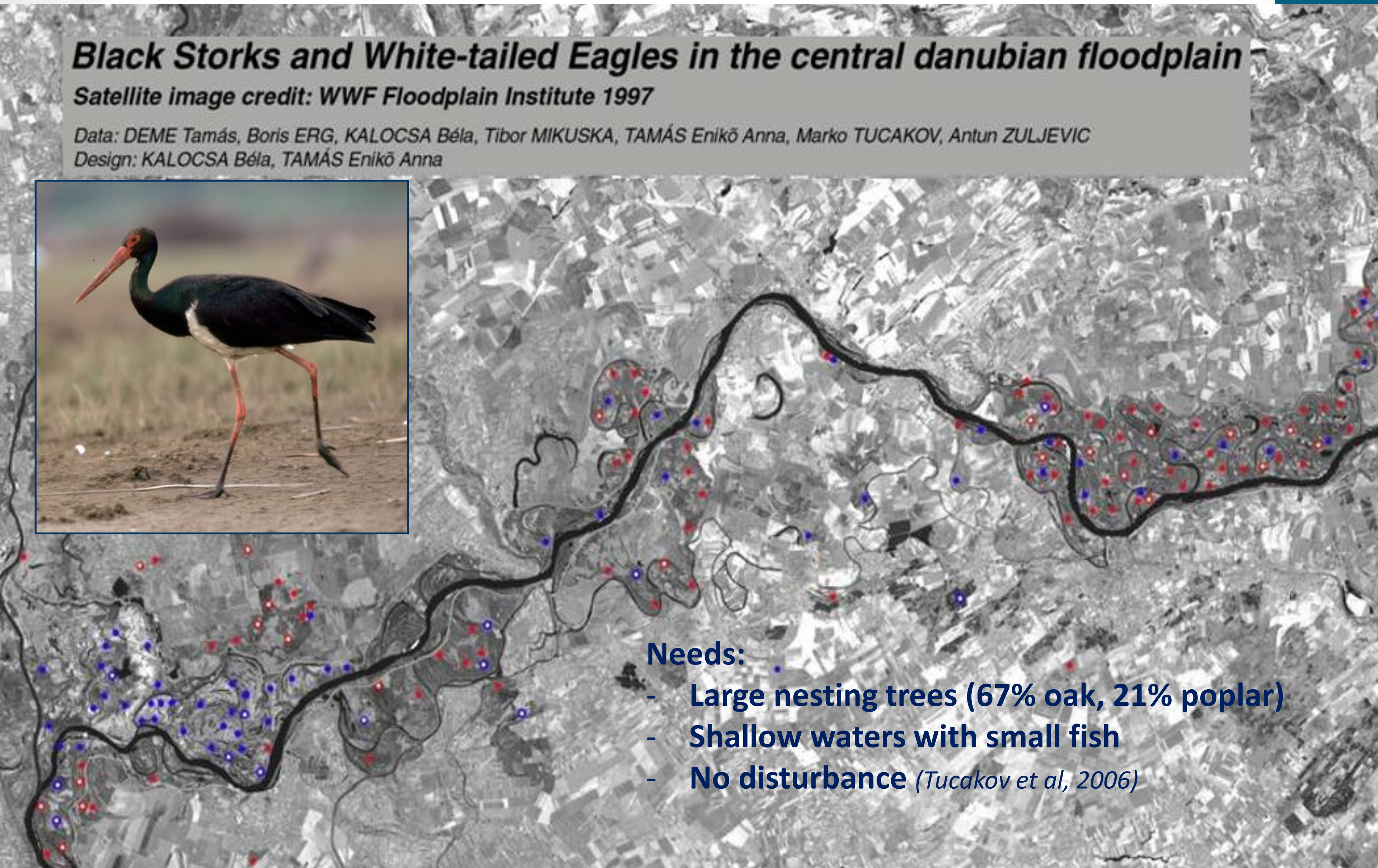
By analysing available time series of H (Z) and Q along the free-flowing middle reach

- To recognize hydrological indicators of the incision
- To estimate the rate of change
- To reveal the causes of the disruptions in lateral connectivity
- Investigated reach (~300 km):
  - rkm 1581 (Dunaújváros, Hungary)
  - rkm 1255 (Novi Sad, Serbia)
- **Focus on the 3 most important floodplain habitats along the reach**



10/06/2022

Connecting the floodplain habitats



Needs:

- **Large nesting trees (67% oak, 21% poplar)**
- **Shallow waters with small fish**
- **No disturbance** *(Tucakov et al, 2006)*

Data and software

- H and Q data series: 70 years between 1950 and 2019
  - official data of the Hungarian Hydrological Forecasting Service and the Republic Hydrometeorological Service of Serbia

Gauging stations (rkm):

- Dunaújváros (1581)
- Dunaföldvár (1560)
- Paks (1531)
- Baja (1479)
- Mohács (1447)
- Bezdan (1425)
- Apatin (1402)
- Bogojevo (1367)
- Bačka Palanka (1299)
- Novi Sad (1255)

→

- annual H minima, maxima and means
- daily H at Baja and Apatin
- annual Q at Baja, Bezdan and Bogojevo
- daily Q at Baja

Data and software

Threshold levels for inundation of the protected floodplain areas along the reach

- Gemenc floodplain, Hungary (*Tamás & Kalocsa 2020*)
- Gornje Podunavlje, Serbia (*the Official Gazette of Serbia*)
- Kopački rit, Croatia & Serbia (*Tadić et al. 2014*)

Software used

- data organization and trend analyses in MS Excel
- statistical analyses:
  - XLStat (*Addinsoft 2021*),
  - MHStat (Technical hydrology and statistics) 2.0.1.6. (2015),
  - U.S. Army Corps of Engineers Hydrologic Engineering Center's HEC-SSP

Statistical analyses

1. Testing of the homogeneity
    - annual time series of H (Z) minima, means and maxima for all stations
    - Kolmogorov-Smirnov test in XLStat (confidence level $\alpha = 0.05$)
2. Distribution fitting analysis in HEC-SSP
3. Trend analyses
    - annual time series of H (Z) minima, means and maxima for all stations
    - annual time series of Q minima, means and maxima for Baja, Bezdan and Bogojevo
    - linear regression with LSQ method in MSExcel
4. Analysis of average water level changes
    - 10-year average changes in H (Z) minima and means for all stations in MS Excel
5. Empirical probabilities of daily discharge values for 10-year periods grouped monthly in MHStat
6. Investigation of the exceeding frequencies of the inundation thresholds of the protected floodplain areas
    - daily H (Z) at Baja and Apatin

Results 1. Homogeneity

Gauging Station	Minima			Means			Maxima		
	D-value	*p*-value	can be considered homo geneous	*D*-value	*p*-value	can be considered homo geneous	*D*-value	*p*-value	can be considered homo geneous
Dunaújváros	1.000	< 0.0001	NO	0.943	< 0.0001	NO	0.343	0.033	NO
Dunaföldvár	0.971	< 0.0001	NO	0.857	< 0.0001	NO	0.257	0.197	YES
Paks	0.714	< 0.0001	NO	0.543	< 0.0001	NO	0.159	0.837	YES
Baja	0.457	0.001	NO	0.400	0.007	NO	0.114	0.976	YES
Mohács	0.457	0.001	NO	0.429	0.003	NO	0.086	1.000	YES
Bezdán	0.371	0.016	NO	0.371	0.016	NO	0.114	0.976	YES
Apatin	0.429	0.003	NO	0.371	0.016	NO	0.114	0.976	YES
Bogojevo	0.429	0.003	NO	0.429	0.003	NO	0.171	0.683	YES
Bačka Palanka	0.257	0.255	YES	0.357	0.038	NO	0.121	0.976	YES
Novi Sad	0.229	0,320	YES	0,171	0.683	YES	0.114	0.976	YES

- Homogeneity is seriously affected along the entire reach except at Novi Sad (backwater effect of Iron Gate I HPP during low water flow - *Babić-Mladenović et al. 2013*)

Discussion – inhomogeneity

- The causes of the inhomogeneity are:
  - river training works, cutoffs along the Hungarian stretch shortened the reach, changed energy balance and sediment transport capacities
  - extensive dredging activities in Hungary in the second half of the 20th century (*Tamás 2006*)
  - 69 upstream reservoirs, which were built between 1950 and 1980 (*Habersack et al. 2016*).
- All these activities led to a **significant sediment deficit** (cw eg. *Habersack et al. 2016*) and morphological changes of the riverbed that affected the homogeneity of water level time series (cw *Kalocsa & Zsuffa 1997*)

Results 2. Distribution fitting

- Pearson III distribution statistics for sample stations
- Kolmogorov-Smirnov Goodness-of-fit testing (α = 0.05)
- all annual data - minima, means and maxima fit Pearson III distribution the best

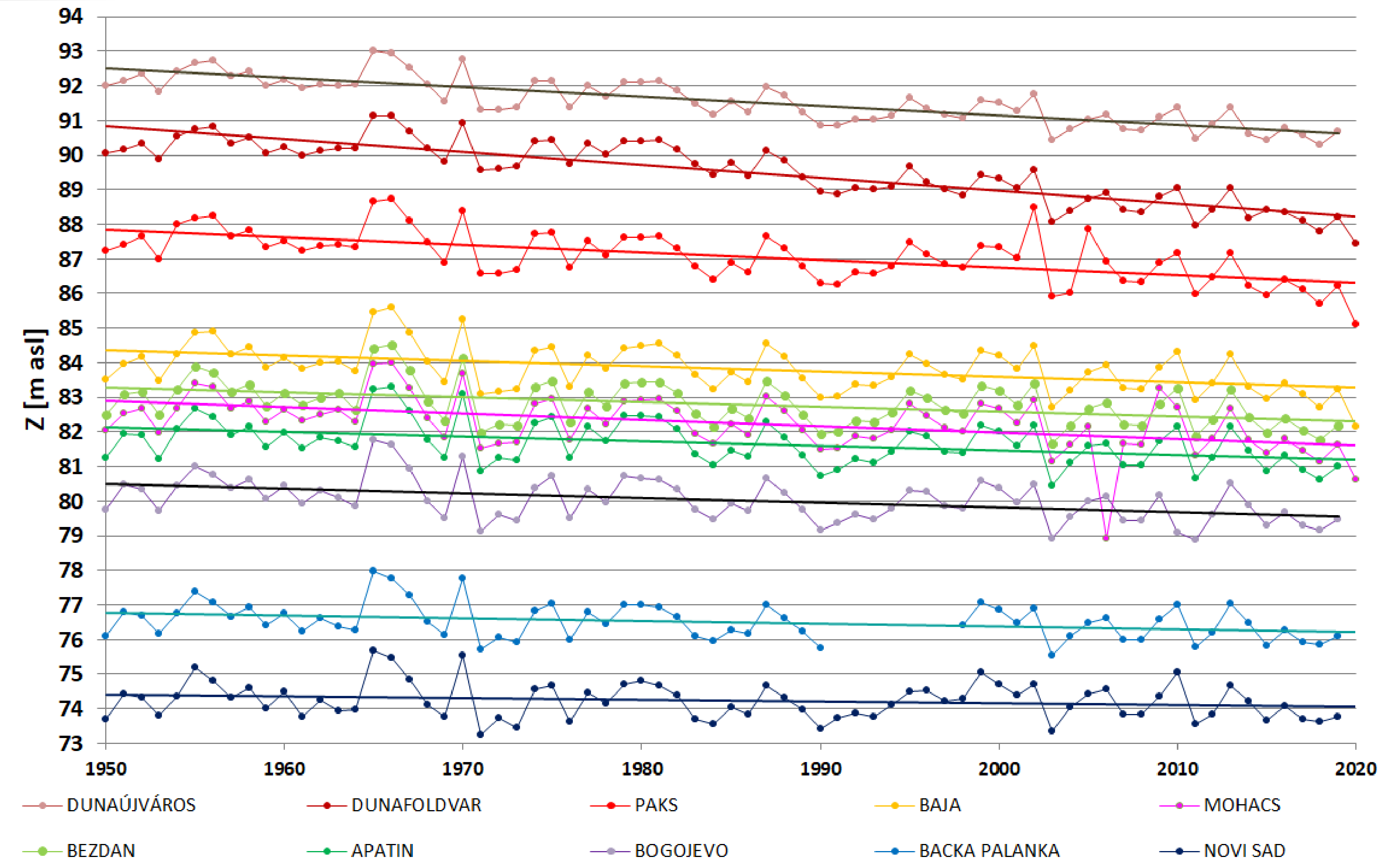
Gauging Station	Minima				Means				Maxima			
	Mean	StDv	Skew	K-S test stat.	Mean	StDv	Skew	K-S test stat.	Mean	StDv	Skew	K-S test stat.
Baja	81.70	0.52	0.26	0.078	83.85	0.64	0.51	0.074	87.64	1.17	0.45	0.058
Mohács	80.17	0.50	0.19	0.066	82.32	0.65	0.40	0.082	85.90	1.10	0.39	0.069
Apatin	79.46	0.50	0.32	0.054	81.67	0.62	0.43	0.059	84.89	0.97	0.43	0.056
Bogojevo	78.01	0.47	0.32	0.059	80.03	0.61	0.47	0.077	83.05	1.13	0.26	0.053

Results 3. Trend analyses

Gauging Station	Minima			Means			Maxima		
	a	b	R^2	a	b	R^2	a	b	R^2
Dunaújváros	-0.0254	140.42	0.77	-0.0270	145.13	0.68	-0.0105	115.42	0.03
Dunaföldvár	-0.0385	164.30	0.81	-0.0370	162.98	0.75	-0.0208	134.04	0.09
Paks	-0.0210	126.83	0.58	-0.0223	131.30	0.39	-0.0149	120.38	0.05
Baja	-0.0129	107.35	0.27	-0.0156	114.80	0.24	-0.0070	101.45	0.01
Mohács	-0.0110	102.02	0.21	-0.0183	118.54	0.23	-0.0112	107.98	0.03
Bezdán	-0.0105	101.56	0.20	-0.0139	110.45	0.21	-0.0020	90.39	0.00.
Apatin	-0.0101	99.56	0.17	-0.0131	107.58	0.18	-0.0006	86.11	0.00
Bogojevo	-0.0090	95.97	0.15	-0.0140	107.84	0.22	-0.0079	98.66	0.02
Bačka Palanka	-0.0026	79.83	0.02	-0.0082	92.80	0.11	-0.0016	82.27	0.00
Novi Sad	0.0051	62.06	0.06	-0.0049	83.98	0.04	-0.0009	78.73	0.00

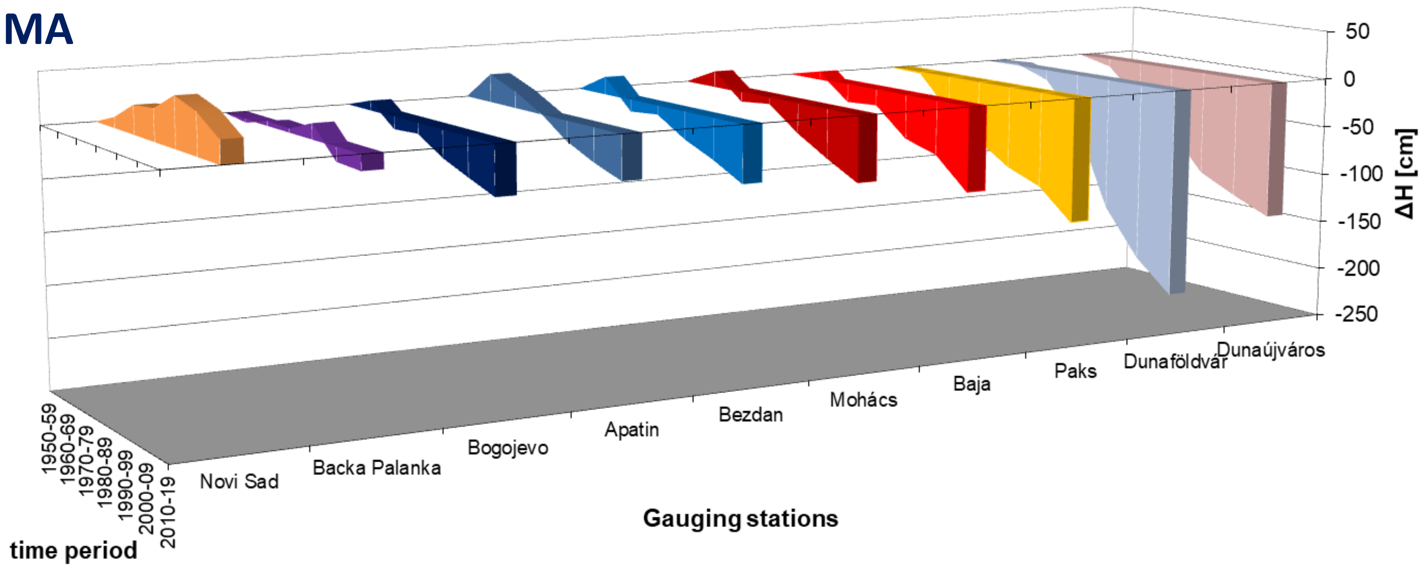
- A negative water level trend exists along the entire reach except for annual minima at Novi Sad (Iron Gate reservoir) – (as in e.g. *Kalocsa 1992, Kalocsa & Zsuffa, 1997, Goda et al., 2007, Savić and Bezdan 2009*)
- Annual mean water levels exhibit the fastest decrease

Annual mean Z and linear trends

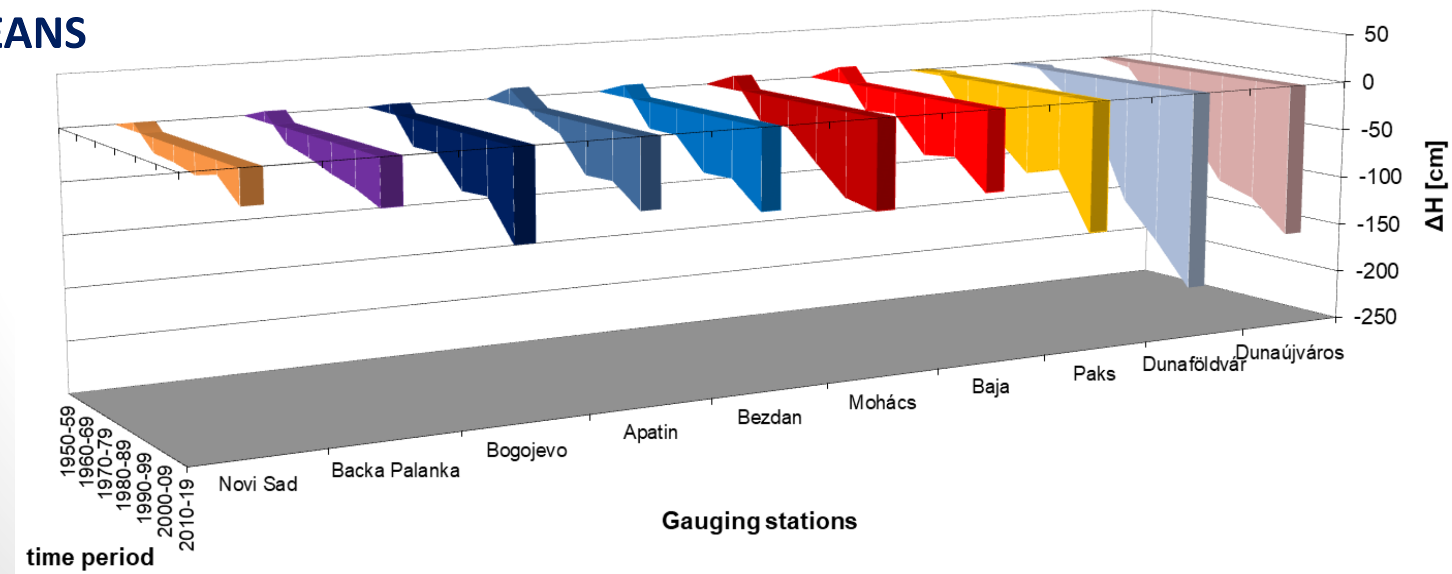


Results 4. Average level changes

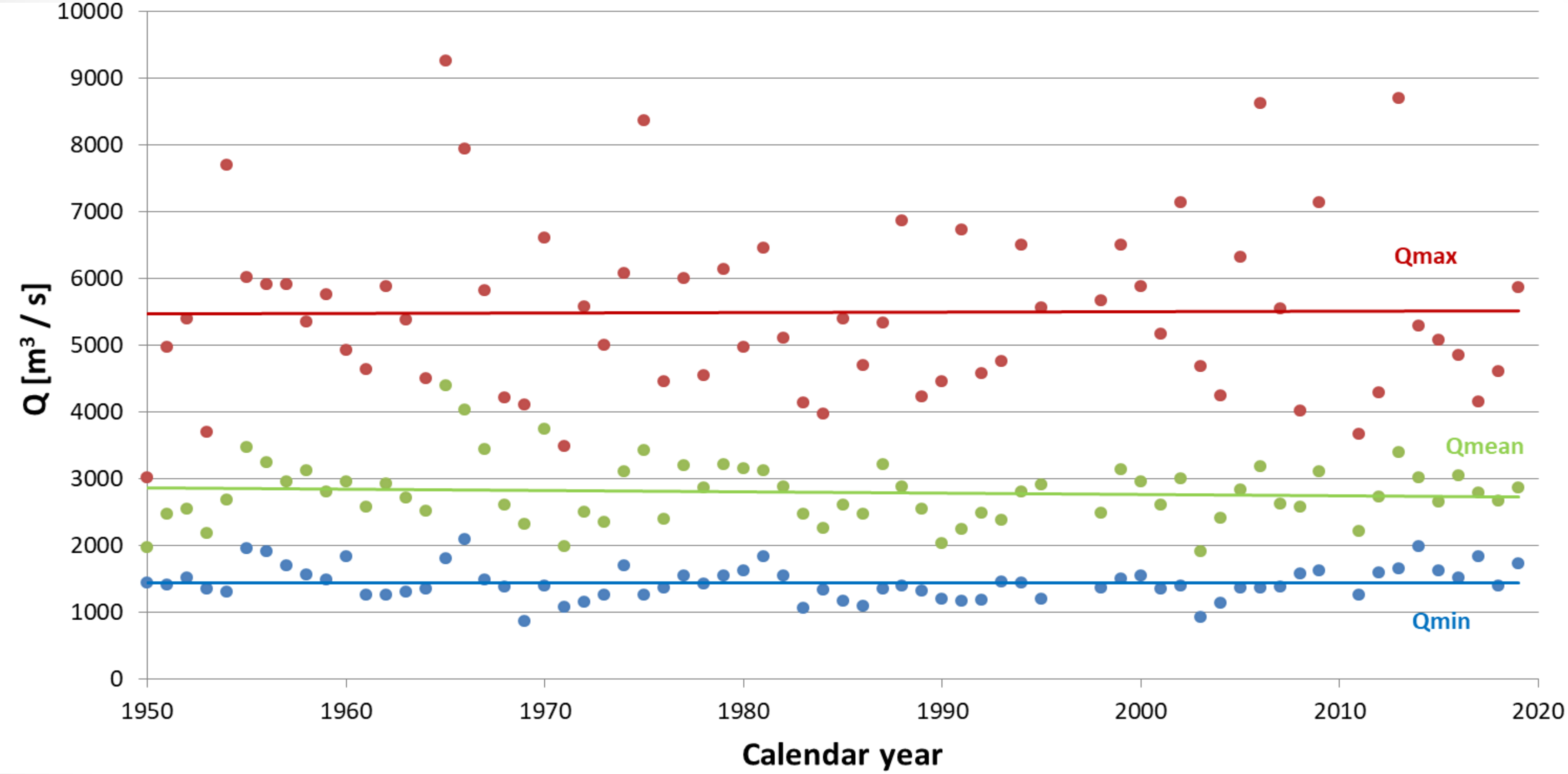
MINIMA



MEANS

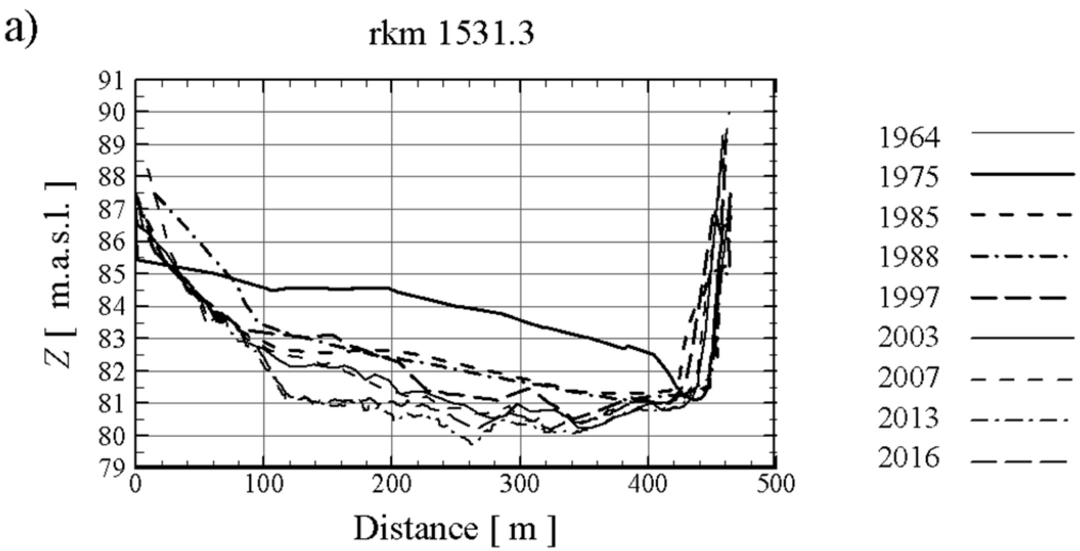


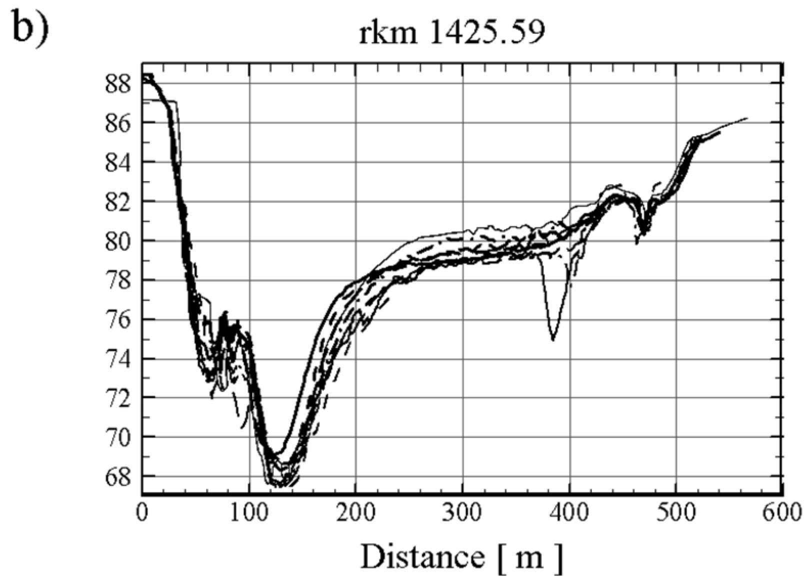
Discharge trends (Bogojevo)



- Annual minimum, mean and maximum discharges show no trend – they are constant, or almost constant
- Consequence: the continuous lowering of the annual water levels can (still) be explained by the incision of the riverbed (it seems…)

Changes in cross-sections

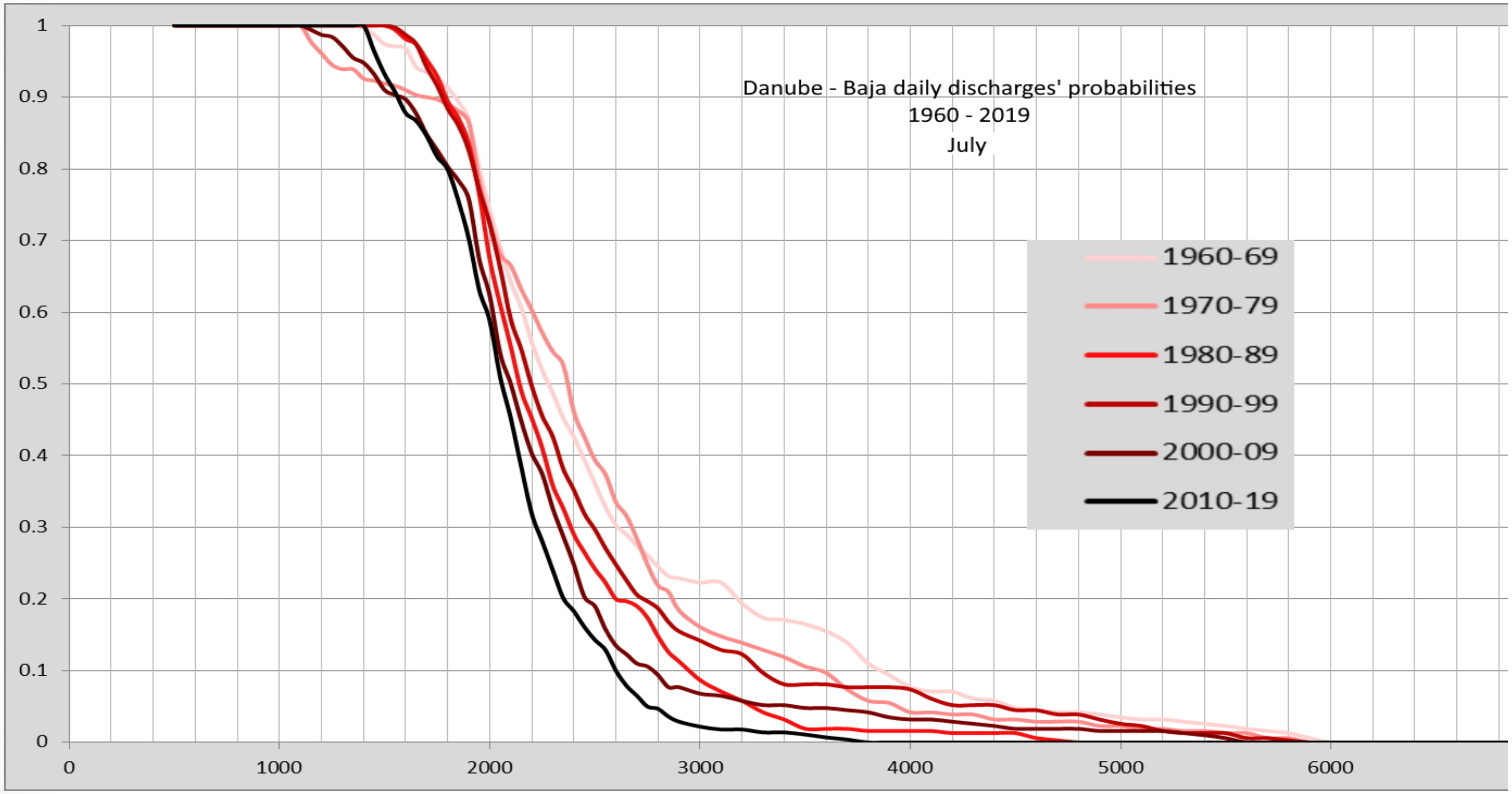




PAKS station BEZDAN station

- From the morphological point of view, the comparison of the cross-sections along the reach was done
- All cross-sections show a gradual increase during the period which corresponds and correlates to the waterlevel decrease

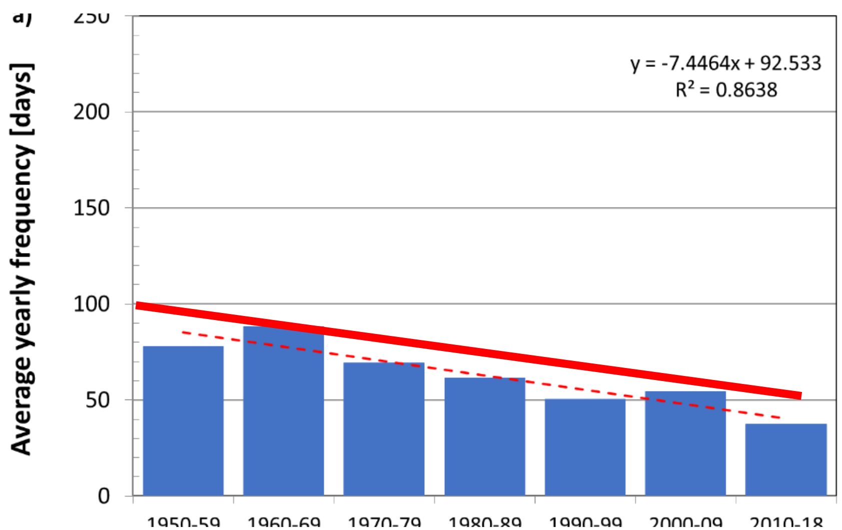
Changes in summer Q



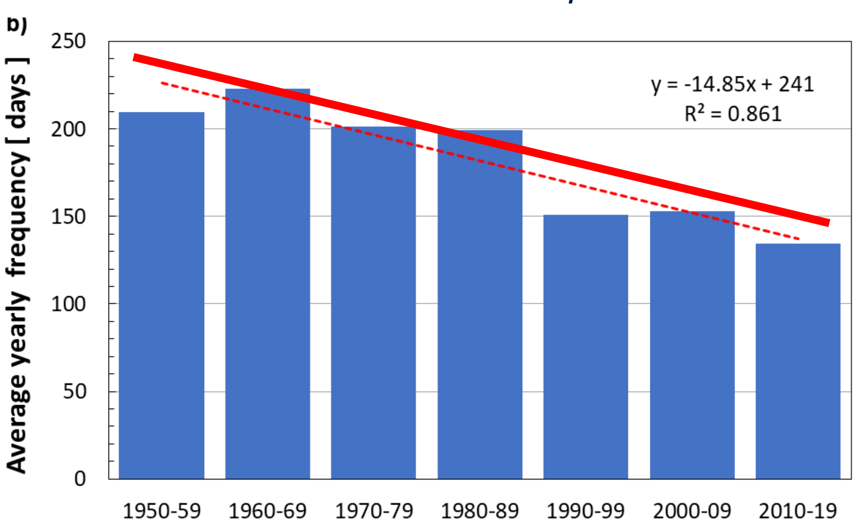
- Taking a closer look: discharges DO change! The annual values are not decreasing, however a shift in daily values towards negative can be observed in the summer months (best seen in July)

Results 5. Inundation frequency of important floodplain habitats

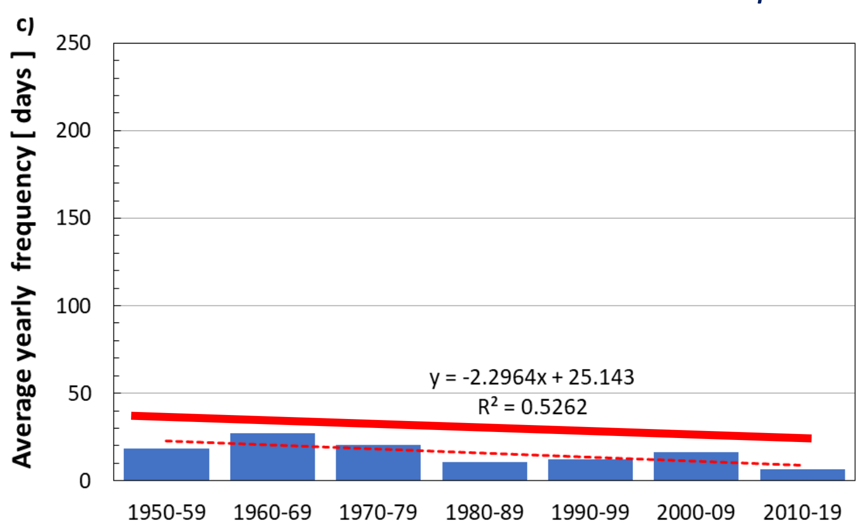
GEMENC *Z = 85.3 m a.s.l. at Baja*



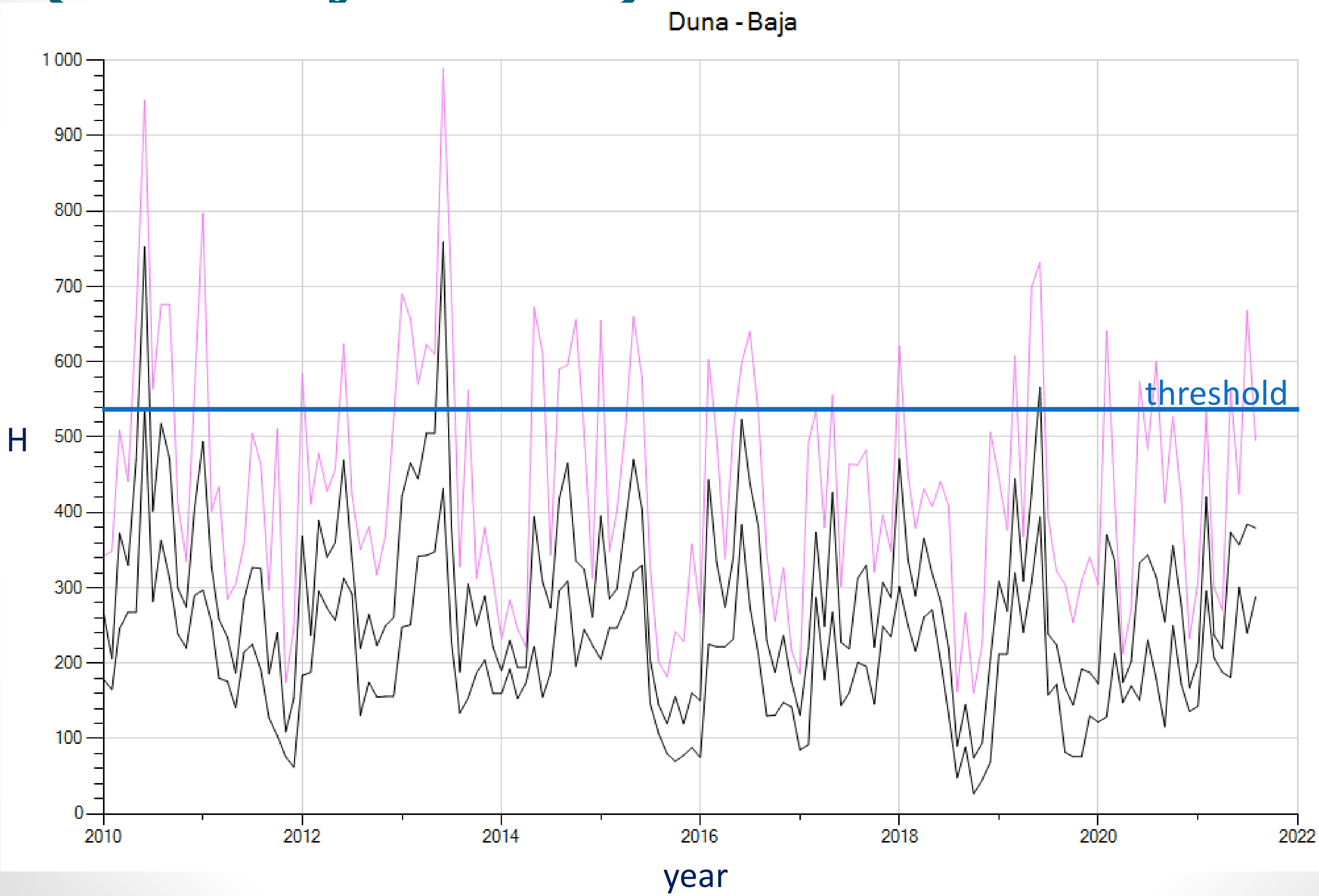
KOPAČKI RIT *Z = 81.5 m a.s.l. at Apatin*



GORNJE PODUNAVLJE *Z = 84.5 m a.s.l. at Apatin*



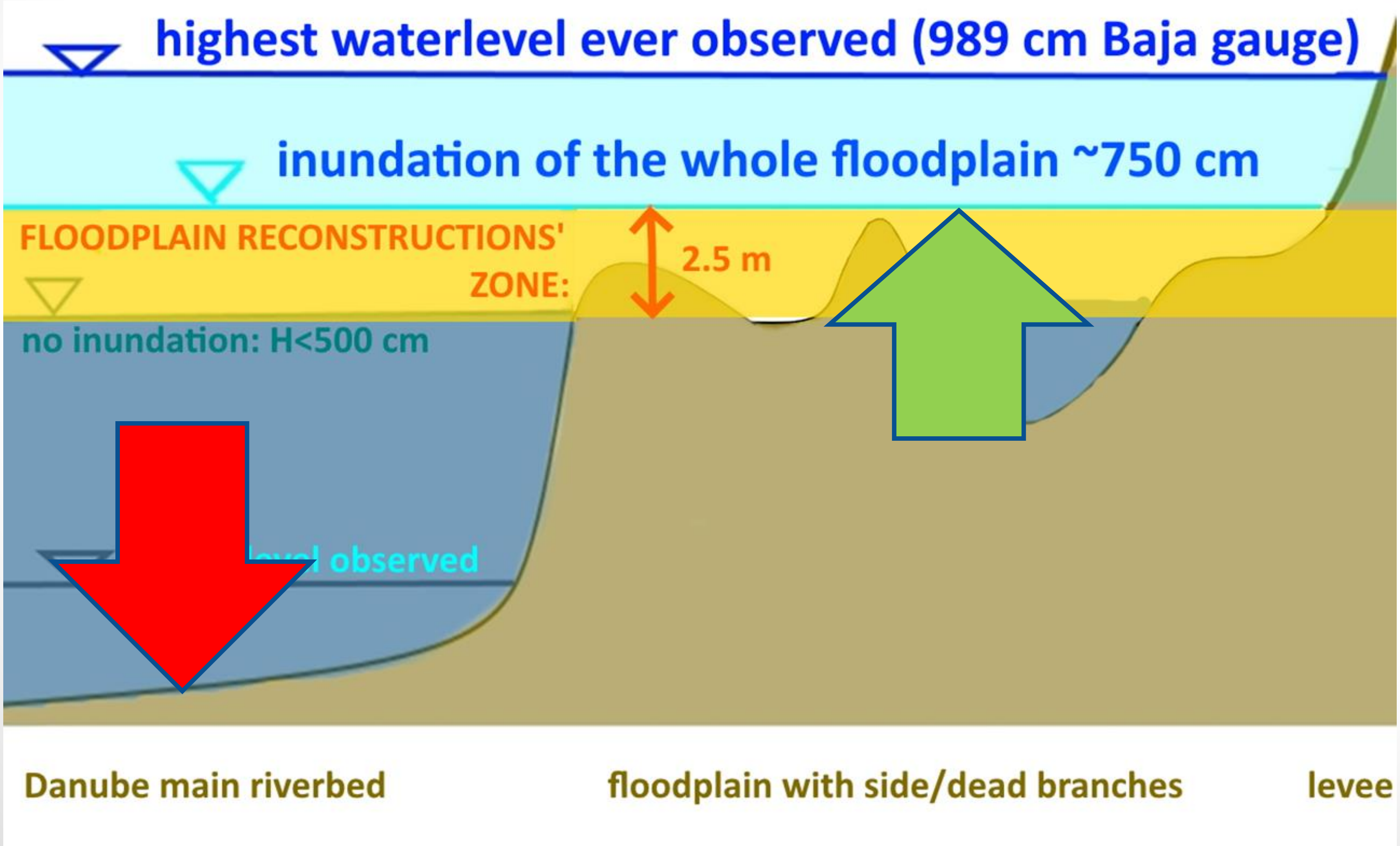
Inundations in the last 10 years (monthly values)



Discussion – lateral connectivity

- Inundation frequencies decrease most drastically in Kopački rit, which has the lowest inundation threshold elevation among the three investigated protected floodplain areas
  - inundation is 2 months shorter at the end of the 70-years period than in the beginning, decreasing from over 200 to a yearly average of 134,3 days
- In Gemenc, decrease is on average 1 month from 1950 to 2019, being now only 37 days
  - cw previous findings: 172 days in the beginning of the 20th century, decreasing at an alarming rate to 58 days at the end of the 20th century (*Kalocsa & Tamás 2003*).
- Because of much higher elevations, the inundation frequency of Gornje Podunavlje is considerably lower, not being so much affected by the recent changes, but still decreasing

Remark on traditional floodplain reconsructions (e.g. dredging, flood retention)



Conclusions

- If traditional river training activities continue, riverbed erosion will persist or increase in the future, resulting in slow, but continuous drying of floodplains – river management changes are needed
- During floods sediments will still fill up branches and aggrade
- Consequently, floodplain reconstruction works' effects might become negligible, while navigation problems will remain unsolved
- In the EU Floods Directive, natural flood management is important
- A focus is on increasing water retention capacities (e.g. re-connection of floodplains, restoration of wetlands to store flood water and slow the flow) – lateral connectivity is one of the most essential issues
- Floodplain lateral connectivity is already severed by the decreasing waterlevels and consequent frequency and extent of inundation – the shifts in discharges is alarming
- Hydrological regime and morphology determine the quality of floodplain habitats

Thank you
for your kind attention!

10/06/2022

Collaborating researchers:

- **Abonyi, Cs** (Lower Danube valley Water Authority, Baja, Hungary)
- **Dr. Đorđević, D** (Faculty of Civil Engineering, University of Belgrade, Belgrade, Serbia)
- **Kalocsa, B** (Palustris Co., Baja, Hungary)
- **Mihajlović, L** (Directorate for Inland Waterways, Ministry of Construction, Transport and Infrastructure, Belgrade, Serbia)
- **Dr. Tadić, L** (Faculty of Civil Engineering and Architecture, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia)
- **Vujanović, A** (Institute of transportation CIP Ltd, Belgrade, Serbia)

Dr. Enikő Anna ***Tamás***

tamas.eniko.anna@uni-nke.hu