REPORT FROM PILOT ACTION – TESTING THE PROTOTYPE OF THE FROGIS TOOL IN THE RIVER BASINS T1.3.1

Croatia /Croatian Waters
Pilot catchment Bednja

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1. PURPOSE AND SCOPE OF TEST

The purposes of the test were to:

- apply Frogis to the Bednja pilot catchment in Croatia
- develop valorization maps for flood issues
- test the sensitivity of the analysis to subjective choices, in order to provide suggestions for future application of the valorization tool. The investigated subjective choices were: the choice of SPUs used in the analysis, the choice of indicator classification methods, the choice of weights used for the final aggregation.
- validate the obtained map with expert opinion.

The scope of testing was data preparation, data validation, testing and results validation.

2. CHARACTERISTICS OF THE CATCHMENT

The Bednja river basin was chosen because of a serious problem caused by torrents forming after intensive rainfall, causing the movement and transport of significant sediment quantities into the lowland parts of the watercourse. It is common that torrents are accompanied by landslides. According to Natura 2000, in the Bednja basin there are 14 sites important for the conservation of endangered species and a total of 12 sites with different levels of protection. The most important road in the basin is a section of the motorway cutting the basin into two parts slightly further downstream of the natural borderline between the upland and lowland parts of the basin. Its major part was built on an embankment with several culverts causing obstacles for the flow of high waters of Bednja and its tributaries.

Bednja catchment has around 616 km2 catchment size and is composed of about 30% low hills with the rest 70% being lowland. Bednja river has an average flow of 7 m3/s with extreme flow going up to 179 with an annual precipitation averaging 931 mm/year and annual average air temperature of 10.4 ^{o}C.

The basin area is 30% covered with agriculture and around 49% is forest area.

Based on flood modelling scenarios a 100 year return period flood would cover around 37.7 km2.

From the River Basin Management Plan 2016.-2021. we have 6 water bodies with 2 having bad status, 3 moderate and 1 water body has good ecological status with Phytobenthos, Macrophytes, Macrozoobenthos, Total N and Total P being major problems in achieving good ecological status.

The Project activities should comply with the measures proposed by the River Basin Management Plan and the Flood Risk Management Plan (July 2016).

Table 1. Characteristics of the catchment

Characteristic	**Unit**	**Value**
Character of catchment		lowland 30%/low hills 70%
Catchment size:	km^2	616

Average flow low/avg/high*	m^3/s	0,8/7/77
Extreme flow low/high*	m^3/s	0,003/179
Annual precipitation low/avg/high**	mm	481/931/1312
Annual air temperature min/avg/max**	°C	10,4 (avg)
Agriculture area	%	30
Urban area	%	2
Forest area	%	49
Open Water area	%	0,1
Flooded area (1/100 years)	km^2	37,7
Artificial drainage area	km^2	
Ecological status no good/bad	water body	
Major problems to achieve good ecological status		

* From multiannual statistic 1949-2016

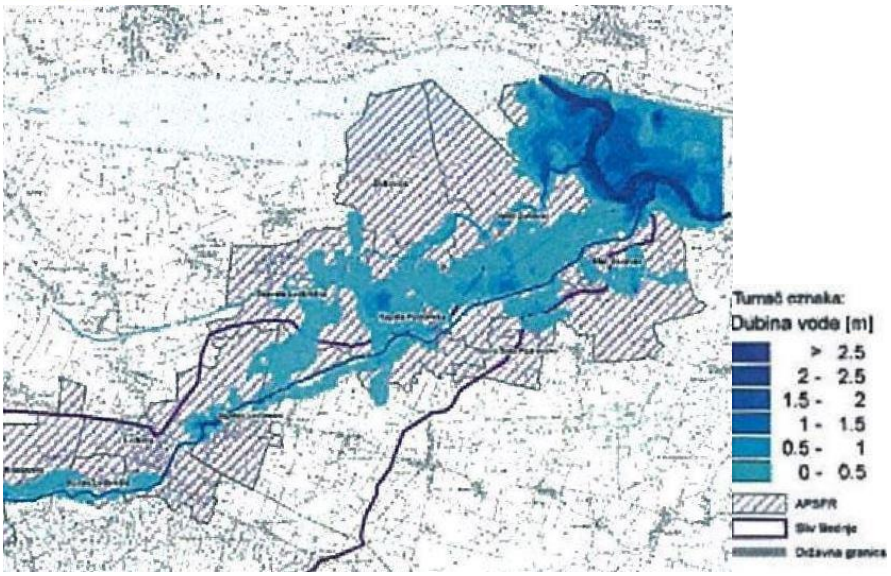
** From multiannual statistic 2007-2016

3. ISSUES IDENTIFIED IN THE CATCHMENT

3.1 Review of existing assessment of floods/drought/water quality/sediment transport

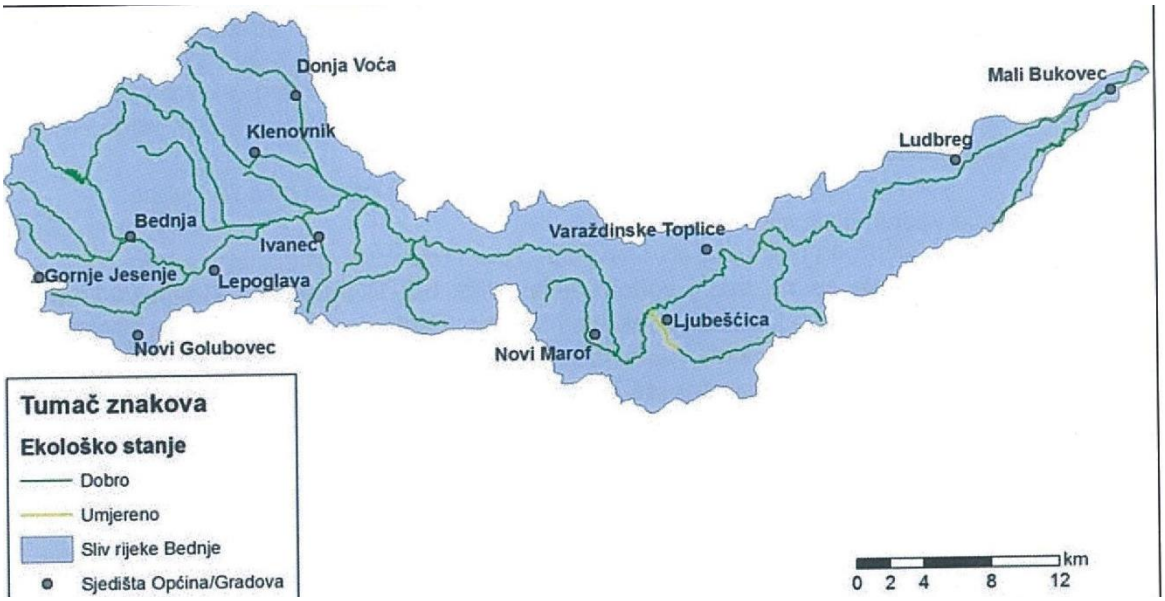
In Bednja catchment there are existing assessment and maps for flood extent and water body status. For flood extent we have maps for medium probability scenarios, and for water body's we have a map of ecological status.

Flood extent map for medium probability scenario.



On flood extent maps there are 6 water depth classes (0-0,5m; 0,5-1,0m; …;2-2,5m;>2,5m).

Ecological water body status from RBMP (green is good status, yellow is moderate status).

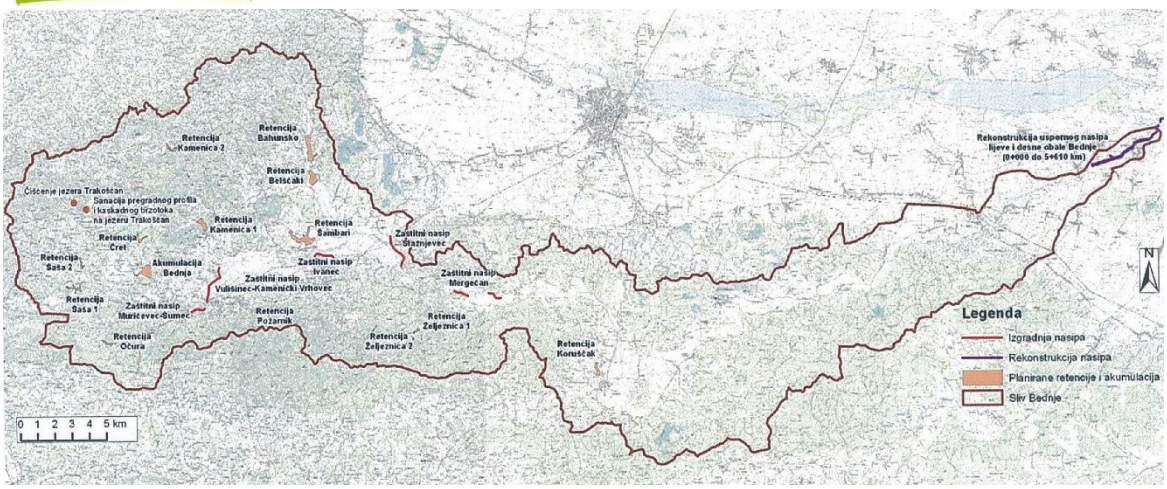


3.2 Review of existing and planned measures

Planned measures will be harmonized according to national planning documents:

- River Basin Management Plan for the Danube River Basin District (2016-2021)

- Flood Risk Management Plan (2017-2021)



Planned measures on Bednja catchment include 18 retention areas, 1 reservoir, around 7,2 km new dykes on 5 locations and reconstruction of 5 km of existing dykes with additional smaller measures.

3.3 Results of first consultations with stakeholders

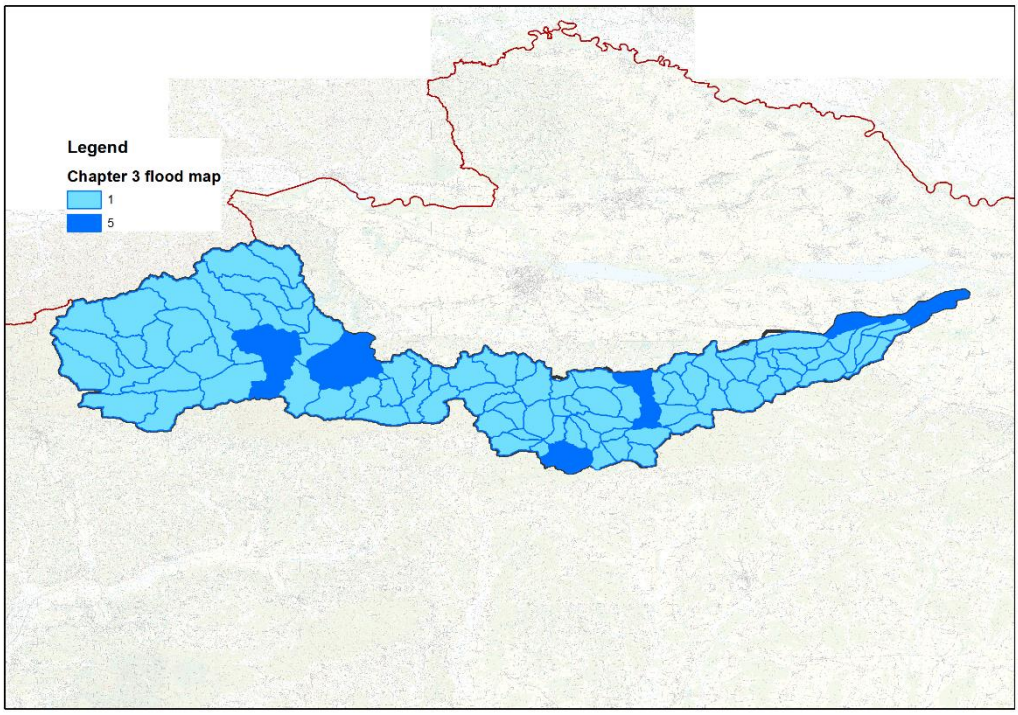
First National stakeholder meeting within FramWat project in Croatia took place on 10 May in Zagreb, Croatia. Organizer Croatian Waters presented to more than 30 participants from the Ministry of environment, national public authority, local public authority, NGOs, academia, international organization etc. Main topic in the meeting was on discussion with the participants about the Natural Water Retention Measures and where to locate them and possibilities for implementing them in the catchment. FramWat Project was presented in detail, both in general and per all work packages, as well as its objective, expected results and foreseen activities. Pilot area of the Bednja river basin was presented in detail and application of mathematical models in the Bednja river basin was presented. At the end of the workshop, a concluding discussion took place about all the topics covered. The stakeholders presented their opinions, comments and views about the presented topics.

3.4 Results of field recognition

During a field trip to the Bednja basin area a few locations were visited. Terrain review was carried out in October of 2018 by Croatian waters employees accompanied by external consultants.

Out of those locations one area seemed like a very good candidate for small water retention measure. It is on the right bank of the river and is a depression field which could be used as a small storage for water which would then be returned to the river over a wider area.

Map shows flood problems in Bednja basin based on available studies and expert judgement.



For other issues there is no data available prior to this Project.

4. DESCRIPTION OF WORKFLOW

4.1 Selected SPU

We tested SPU based on county data which proved to much coarse, then a SPU based on settlement spatial data was used but that also proved too coarse so a spatial analysis was done which resulted in finer distribution and that SPU was chosen which has 101 spatial planning units ranging from 0,5 km^2 to 18,5 km^2.

4.2 Selected indicators

Of all available data BadRHS indicator was rejected due to the fact that only 1 small part of a stream was in bad hydromorphological status and it was decided that it wouldn't have significant impact, next Climatic water balance was discussed and chosen to not be included as the basin is relatively small area with small precipitation and temperature gradient. Orchard and Wetland data from Corine Land Cover had none or one small area which again didn't have a significant impact.

Indicators which were used from the available data are ArableRatio and Semi-NaturalRatio from Corine Land Cover, Lakes and River shapefiles and swFlow hydrological characteristics file.

4.3 Input data

Input data were collected from local datasets.

Table 2. Input data.

Name	Source	Quality/scale	Time interval
Kljuc discharge	Hydrological database	daily	1987-2017
Lepoglava discharge	Hydrological database	daily	1987-2018
Ludbreg discharge	Hydrological database	daily	1987-2019
Tuhovec discharge	Hydrological database	daily	1987-2020
Zeljeznica discharge	Hydrological database	daily	1987-2021
Corine Land Cover	National database	1:25000	2012
Flood extent 100 years	Flood hazard maps	1:25000	2014
Lakes	Study	1:25000	2011
River network	Croatian waters database	1:25000	2015

4.4 Correlation matrix

Correlation matrices were computed based on indicator values obtained for each SPU.

Table 3. Correlation matrix with chosen indicators

	Arable Ratio	**DrainageD**	**MeanderRatio**	**EcoAreaRatio**	**FloodRiskAreaRatio**	**FlowMinMaxRatio**	**WaterYieldAvgFlow**	**Lake Ratio**
ArableRatio	-	0,31	0,07	-0,32	0,62	-0,04	-0,11	-0,03
DrainageD	0,31	-	0,23	-0,32	0,25	-0,08	-0,05	-0,02
MeanderRatio	0,07	0,23	-	-0,23	0,22	-0,08	0,04	0,07
EcoAreaRatio	-0,32	-0,32	-0,23	-	-0,44	0,02	0,3	0,03
FloodRiskAreaRatio	0,62	0,25	0,22	-0,44	-	0,02	-0,22	-0,02
FlowMinMaxRatio	-0,04	-0,08	-0,08	0,02	0,02	-	-0,7	-0,23
WaterYieldAvgFlow	-0,11	-0,05	0,04	0,3	-0,22	-0,7	-	0,18
LakeRatio	-0,03	-0,02	0,07	0,03	-0,02	-0,23	0,18	-

Indicators “FlowMaxAvgRatio”, “FlowMinAvgRatio”,”FlowVarRatio_m”, ForestRatio” were highly correlated (above 0,75) and so were removed.

4.5 Classification and aggregation method

Different classification methods have been used to split the indicators in to 5 classes and to test the sensivity of the tool to classification method.

Table 4. Statistics of indicators values Equal Width

	Statistics			
Short indicator name	Min	Max	Mean	Stdev
ArableRatio	0,00	13,22	0,22	1,45
DrainageD	0,00	2,56	0,49	0,48
EcoAreaRatio	5,71	100,00	66,56	23,91
FloodRiskAreaRatio	0,00	67,43	7,06	12,23
FlowMinMaxRatio	0,00	0,01	0,01	0,00
LakeRatio	0,00	1,74	0,04	0,22
MeanderRatio	0,00	100,00	80,92	29,34
WaterYieldAvgFlow	346,85	396,00	359,00	12,68

Table 5. Statistics of indicators values Natural Breaks

	Statistics			
Short indicator name	Min	Max	Mean	Stdev
ArableRatio	0,00	13,22	0,22	1,45
DrainageD	0,00	2,56	0,49	0,48
EcoAreaRatio	5,71	100,00	66,56	23,91
FloodRiskAreaRatio	0,00	67,43	7,06	12,23

FlowMinMaxRatio	0,00	0,01	0,01	0,00
LakeRatio	0,00	1,74	0,04	0,22
MeanderRatio	0,00	100,00	80,92	29,34
WaterYieldAvgFlow	346,85	396,00	359,00	12,68

Table 6. Statistics of indicators values Quantile

	Statistics			
Short indicator name	Min	Max	Mean	Stdev
ArableRatio	0,00	13,22	0,22	1,45
DrainageD	0,00	2,56	0,49	0,48
EcoAreaRatio	5,71	100,00	66,56	23,91
FloodRiskAreaRatio	0,00	67,43	7,06	12,23
FlowMinMaxRatio	0,00	0,01	0,01	0,00
LakeRatio	0,00	1,74	0,04	0,22
MeanderRatio	0,00	100,00	80,92	29,34
WaterYieldAvgFlow	346,85	396,00	359,00	12,68

Table 7. Results of division of indicators values to five classes

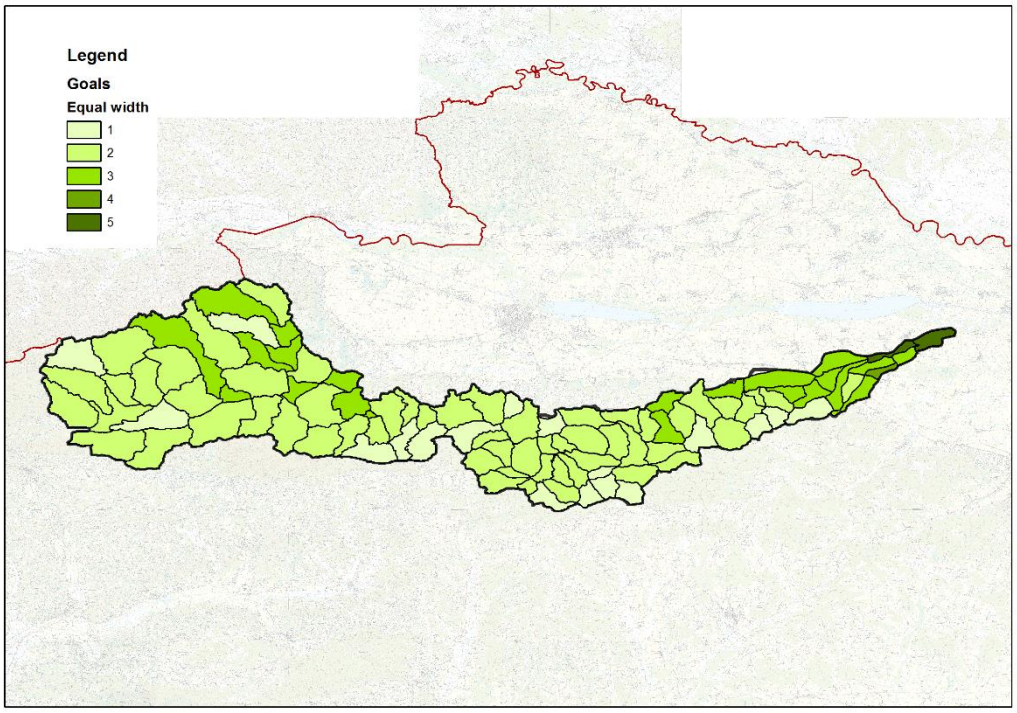
Short indicator name	**Classes**	Equal width			Natural breaks			Quantile		
		Count	**Min**	**Max**	**Count**	**Min**	**Max**	**Count**	**Min**	**Max**
ArableRatio	1	99	0,00	1,90	96	0,00	0,00			
	2	0			1	0,12	0,12			
	3	1	5,99	5,99	1	0,94	0,94			
	4	0			1	1,90	1,90			
	5	1	13,22	13,22	2	5,99	13,22			
DrainageD	1	61	0,00	0,50	34	0,00	0,23	20	0,00	0,05
	2	30	0,53	0,94	32	0,23	0,56	20	0,05	0,33
	3	6	1,10	1,40	24	0,58	0,90	21	0,37	0,50

	4	2	1,78	1,98	6	0,94	1,40	19	0,53	0,69
	5	2	2,22	2,56	5	1,47	2,56	21	0,71	2,56
EcoArea Ratio	1	34	82,25	100,00	29	85,63	100,00	20	90,32	100,00
	2	26	62,55	79,58	26	66,70	82,78	21	74,60	90,13
	3	26	44,16	61,92	25	49,88	66,19	20	61,92	74,57
	4	6	27,64	40,62	12	27,64	48,12	20	48,12	61,90
	5	9	5,71	22,17	9	5,71	22,17	20	5,71	47,34
FloodRiskAreaRatio	1	85	0,00	13,03	61	0,00	3,99	0		
	2	11	14,45	26,69	24	4,00	13,03	40	0,00	0,29
	3	1	31,94	31,94	11	14,45	26,69	20	0,35	3,91
	4	2	45,26	48,47	2	31,94	45,26	20	3,99	10,86
	5	2	62,17	67,43	3	48,47	67,43	21	11,10	67,43
FlowMinMaxRatio	1	39	0,01	0,01	0			0		
	2	51	0,01	0,01	40	0,01	0,01	40	0,01	0,01
	3	1	0,01	0,01	22	0,01	0,01	21	0,01	0,01
	4	0			30	0,01	0,01	20	0,01	0,01
	5	10	0,00	0,00	9	0,00	0,00	20	0,00	0,01
LakeRatio	1	1	1,74	1,74	1	1,74	1,74			
	2	1	1,11	1,11	2	0,86	1,11			
	3	1	0,86	0,86	1	0,49	0,49			
	4	1	0,49	0,49	1	0,16	0,16			
	5	97	0,00	0,16	96	0,00	0,01			
MeanderRatio	1	11	0,00	0,00	0			20	0,00	78,13
	2	0			20	0,00	78,13	20	79,70	88,34
	3	0			26	79,70	88,99	20	88,57	92,48
	4	10	66,06	79,70	23	89,26	94,79	20	92,87	97,83
	5	80	80,97	100,00	32	95,22	100,00	21	97,94	100,00
WaterYieldAvgFlow	1	10	394,41	396,00	10	394,41	396,00	20	359,96	396,00
	2	0			31	357,59	360,00	21	357,59	359,95
	3	0			19	353,97	357,05	20	353,42	357,05
	4	40	356,98	360,00	34	349,90	353,42	20	351,58	352,47
	5	51	346,85	356,40	7	346,85	349,67	20	346,85	351,49

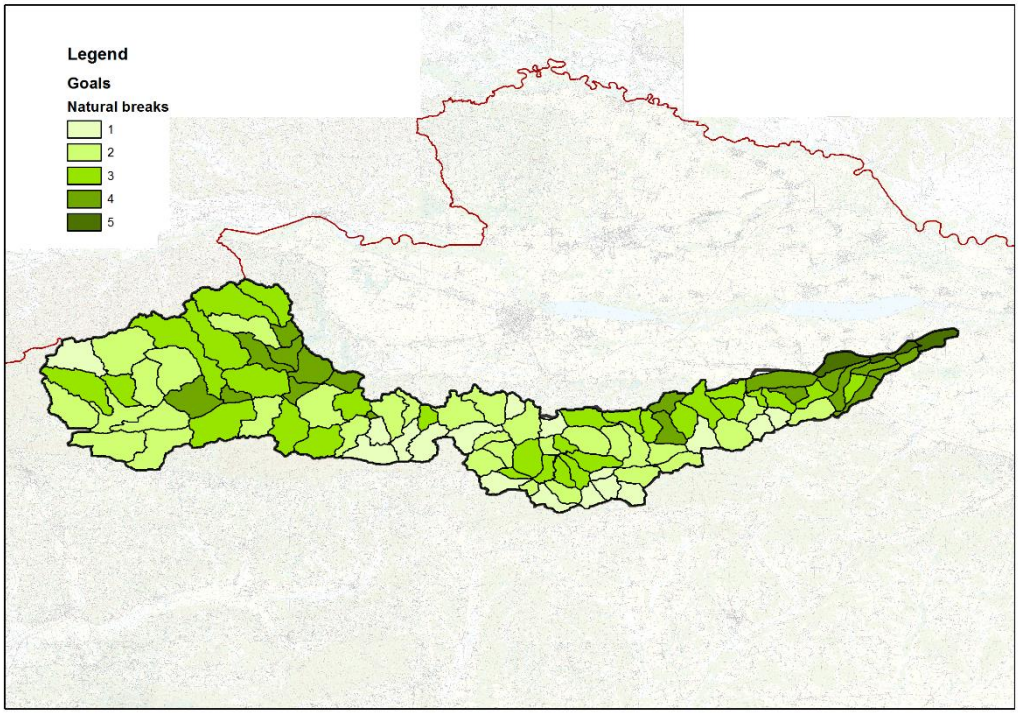
5. ANALYSIS OF VARIANTS

5.1 Valorization for general purpose (5 classes)

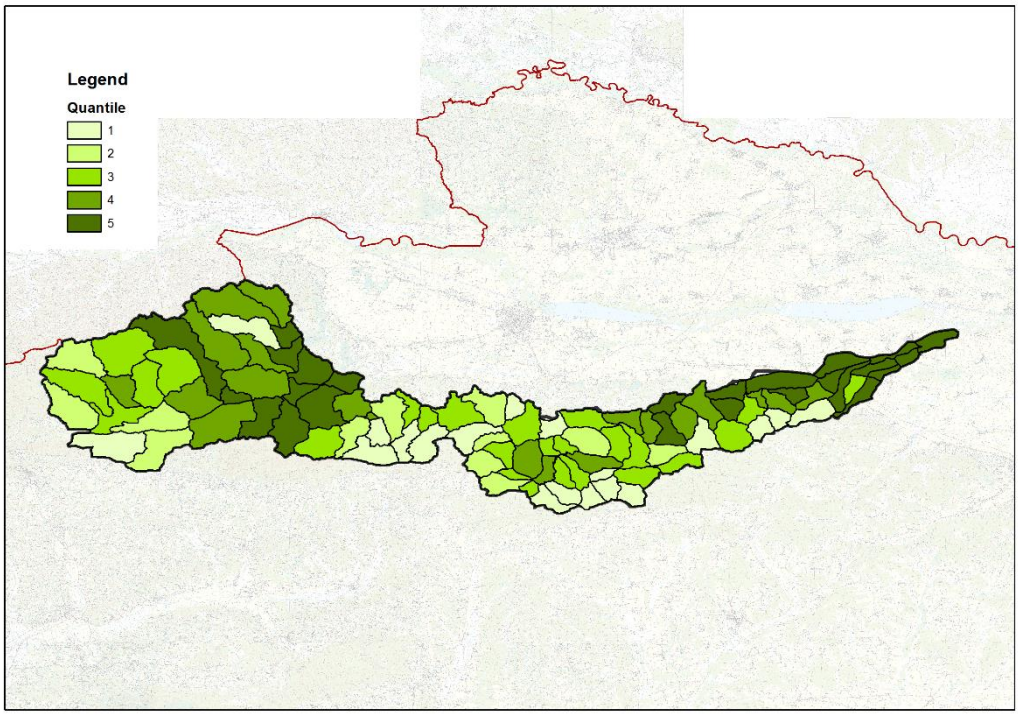
Variant G.EW.Wht1 division into classes by equal width for constant weight



Variant G.NB.Wht1 division into classes by natural breaks for constant weight

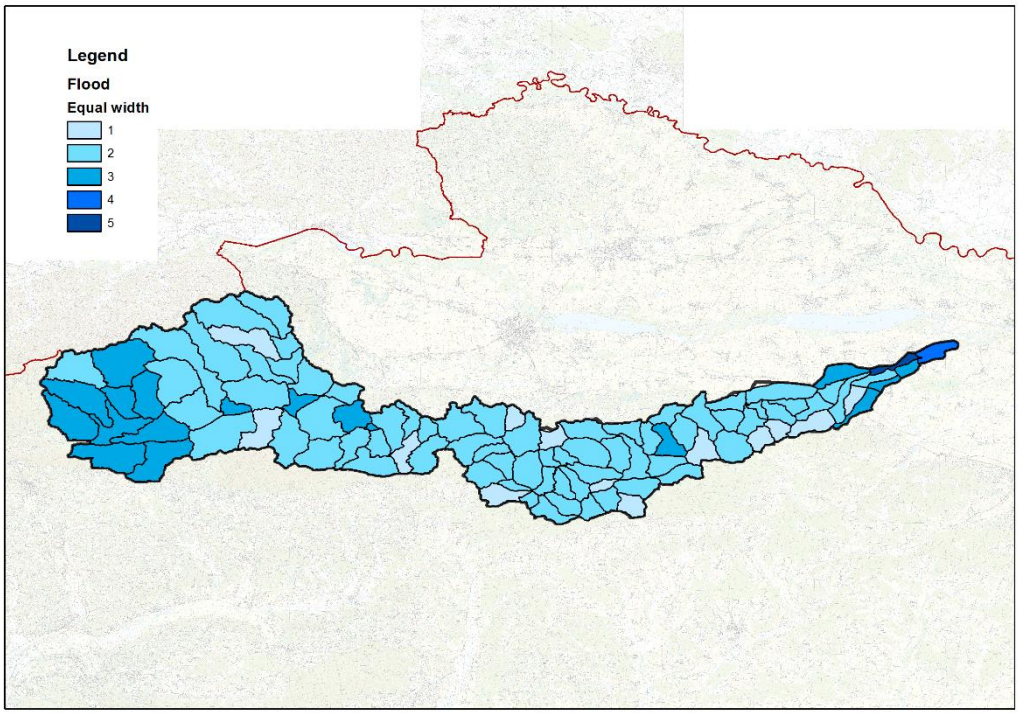


Variant G.Q.Wht1 division into classes by quantiles for constant weight

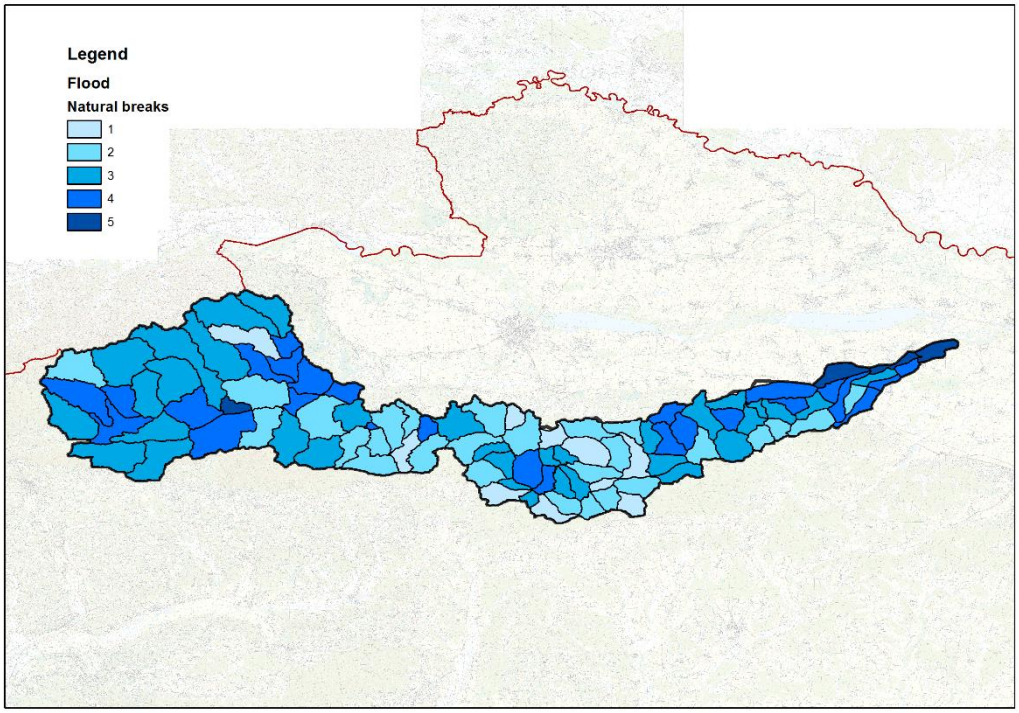


5.2 Valorization for flood mitigation purpose (5 classes)

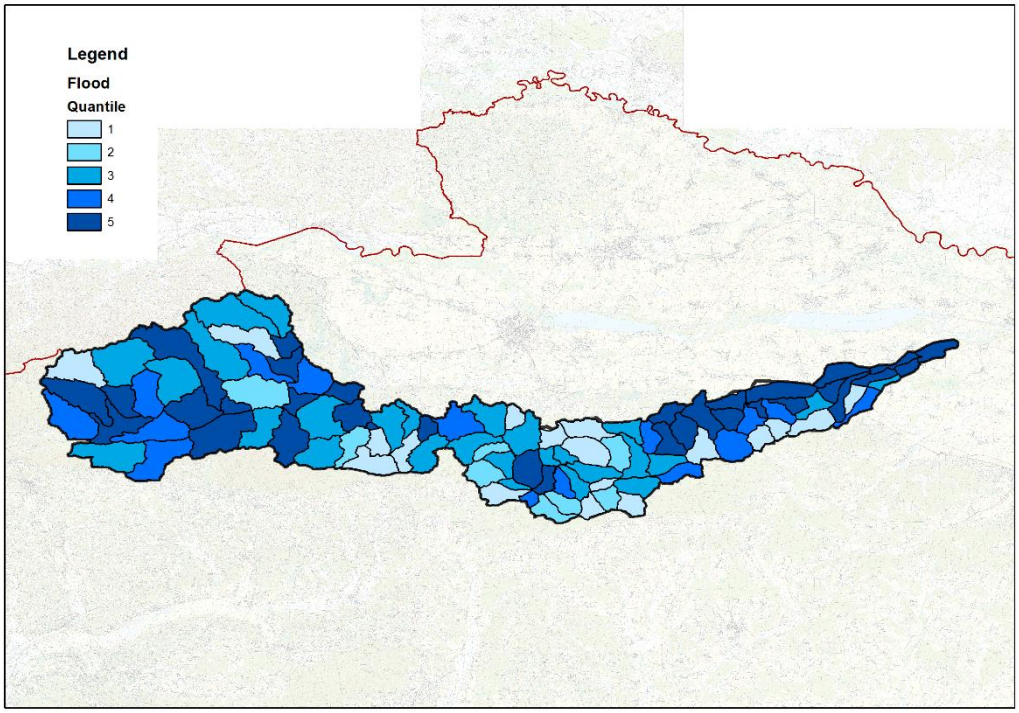
Variant F.EW.Wht1 division into classes by equal width for constant weight



Variant F.NB.Wht1 division into classes by natural breaks for constant weight

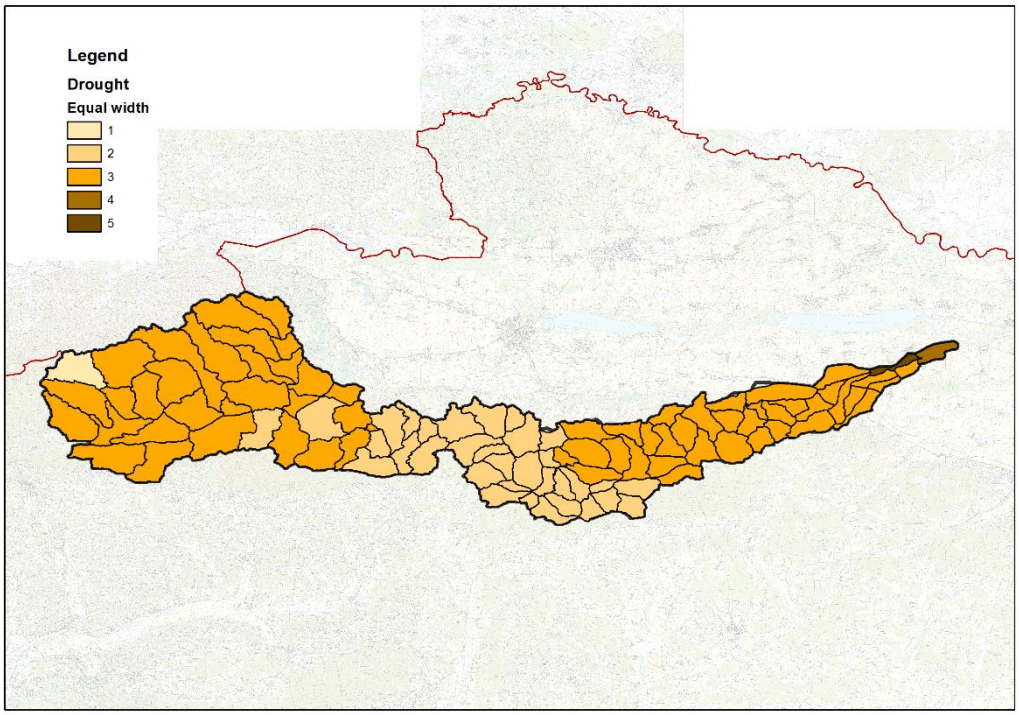


Variant F.Q.Wht1 division into classes by quantiles for constant weight

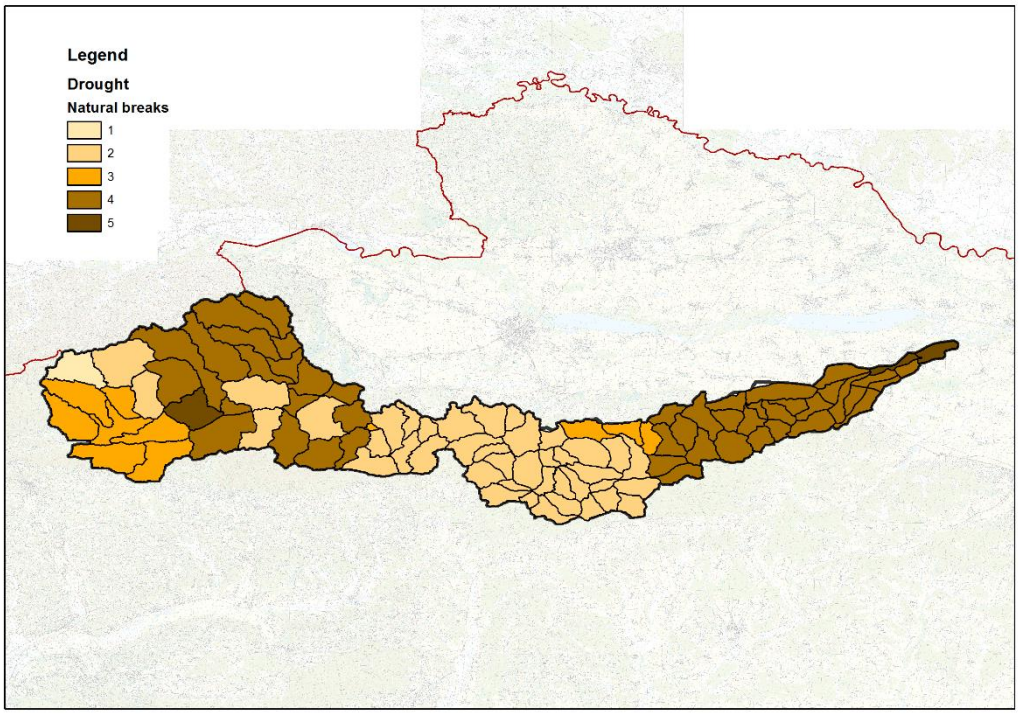


5.3 Valorization for drought mitigation purpose (5 classes)

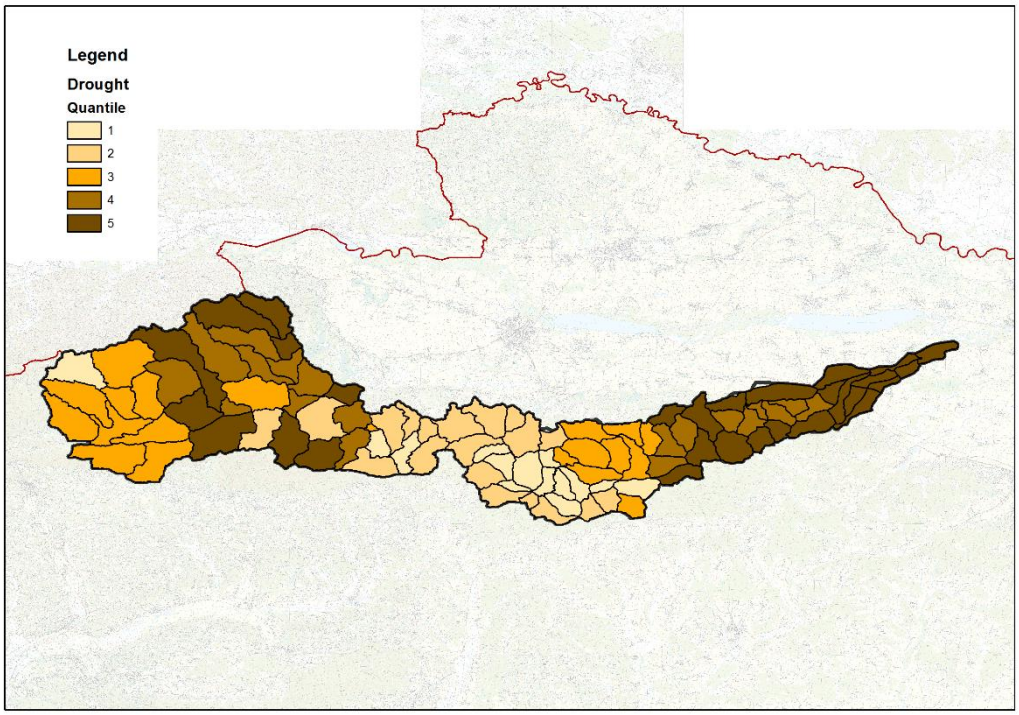
Variant D.EW.Wht1 division into classes by equal width for constant weight



Variant D.NB.Wht1 division into classes by natural breaks for constant weight

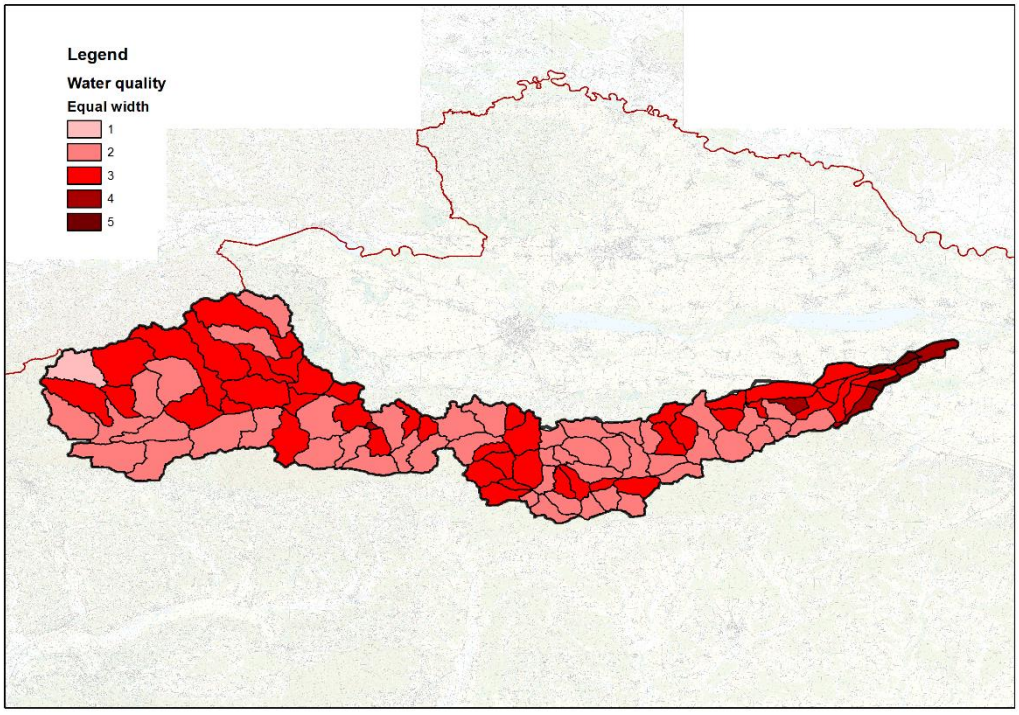


Variant D.Q.Wht1 division into classes by quantiles for constant weight

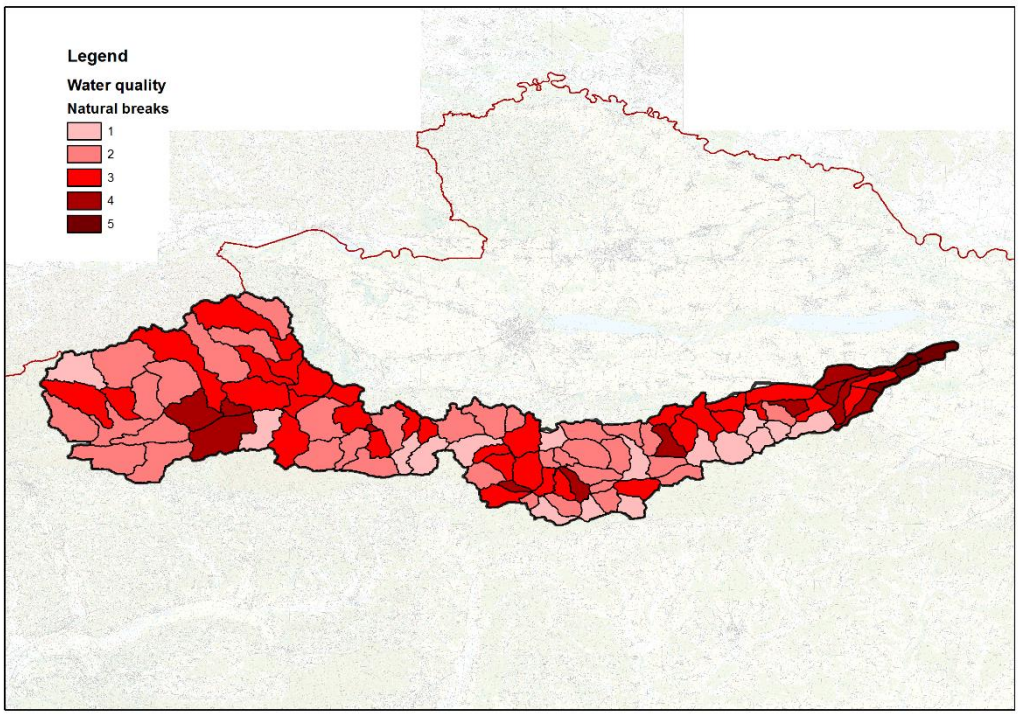


5.4 Valorization for water quality improvement purpose

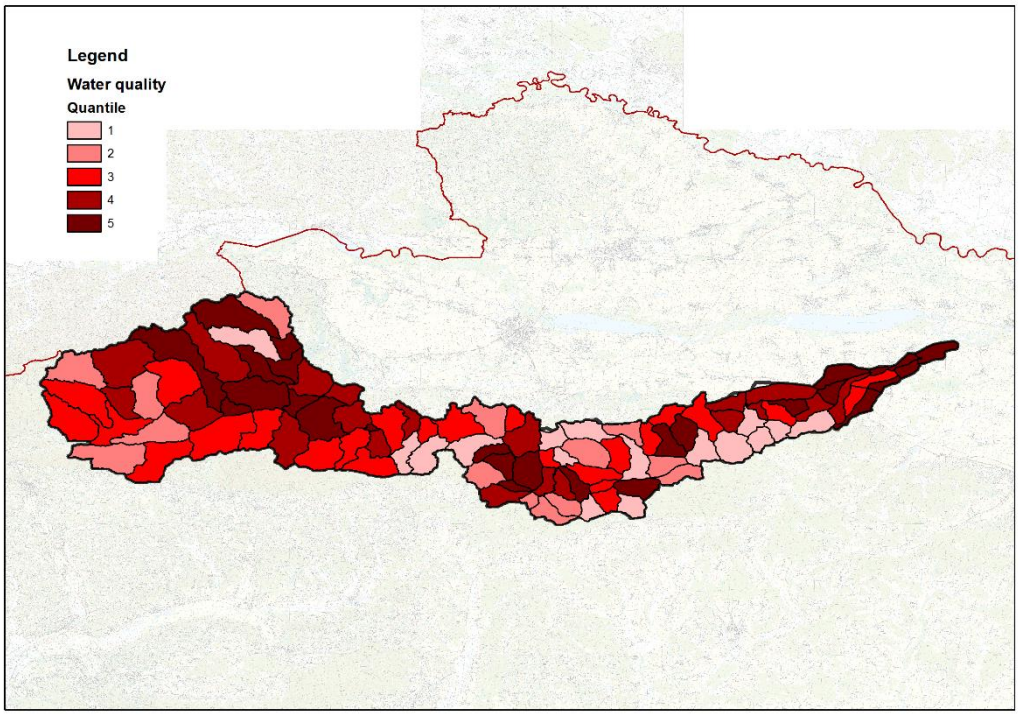
Variant WQ.EW.Wht1 division into classes by equal width for constant weight



Variant WQ.NB.Wht1 division into classes by natural breaks for constant weight



Variant WQ.Q.Wht1 division into classes by quantiles for constant weight



5.5 Valorization for reduction of sediment transport purpose

Not enough data is available for sediment transport analysis, and sediment is not a major problem in Bednja river basin.

6. COMPARISON AND DESCRIPTION OF RESULTS

Only flood data is available for comparison and that comparison is shown in the next table.

SPU	Flood_EW	Flood_NB	Flood_Q	Flood_previous	diffEW	diffNB	diffQ
7	2	1	2	5	3	4	3
8	2	2	2	5	3	3	3
22	2	1	3	5	3	4	2
41	5	5	5	5	0	0	0
42	3	4	5	5	2	1	0
43	4	5	5	5	1	0	0
46	2	2	3	5	3	3	2
54	3	5	5	5	2	0	0
68	2	2	2	5	3	3	3
77	2	4	5	5	2	1	0
78	1	2	3	5	1	3	2
81	2	2	3	5	2	3	2
84	3	3	5	5	3	2	0

Based on these differences the Quantile variant map is the most similar to the map based on previous analysis.

7. SUMMARY

Results of the FroGIS valorization method for Bednja catchment show that the best method depends on the usage of data. It looks like for general and flood mitigation purposes Natural breaks gives better results and on the other hand for drought and water quality better valorization results are obtained through Equal width method. Weighting has very little influence on the final results.

On the whole FroGIS is a good and valuable tool for planning of small water retention measures.