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

Austria/ WasserCluster Lunz Pilot catchment Aist	Version 2 December 2018

TABLE OF CONTENT

Authors: WasserCluster Lunz/Austria

Damiano Baldan, Eva Feldbacher, Gabriele Weigelhofer, Thomas Hein

1. PURPOSE AND SCOPE OF TEST

The purposes of the test were:

- To apply FroGIS to the Austrian pilot catchment (Aist catchment in Upper Austria).
- To develop valorization maps for existing fine sediment issues in the pilot area.
- To develop maps for three separate aspects of sediment balance in the studied systems: sediment generation, sediment transport off-stream, sediment transport in-stream (in the main channels).
- To test the sensitivity of the analysis to the subjective choices involved in order to provide indications to future application of the valorization tool. Subjective choices investigated were: the choice of SPUs used in the analysis, the choice of indicators classification method, the choice of the weights used in the final aggregation.
- To validate the obtained map with expert opinions.

2. CHARACTERISTICS OF THE CATCHMENT

The Aist Basin was chosen as a pilot catchment in Austria because the existing topographical characteristics as well as the prevailing problems, pressures and water management measures make it an appropriate case study region for a NSWRM approach. It is a representative catchment for the Austrian part of the ecoregion Central Uplands (low mountain ranges with plateaus and gorges), a region that geologically belongs to the Bohemian Massif (Variscan orogeny, 370-290 mil. years) with the prevailing bedrocks granite and gneiss. Within this region all river catchments share one common problem: siltation from granite weathering and erosion, causing ecological problems in rivers (habitat degradation) as well as problems for water and flood management (riverbed rising). Further issues in the Aist catchment are: (a) hydromorphological deficits due to river regulations and flood protection measures, and (b) poor ecological status in several river stretches (assessment for WFD, Austrian Water Management Plan). NSWRM can help mitigate the existing problems in the catchment and improve conditions related to the aspects of water quality, sediment balance, nutrient cycle and habitat diversity.
Activities to improve the situation in the catchment are already included in various strategic national planning documents, based on the Water Framework Directive, e.g. action plans within the National Water Management Plan (NGP, 1st 2009, 2nd 2015) and the National Flood Risk Management Plan (HRMP 2015).

Characteristic	***Unit***	***Value***
Character of catchment		*Central Uplands*
Catchment size:	*km^2*	*647*
*Average flow low/avg/high**	*m^3/s*	*5.1/6.4/7.8*
*Extreme flow low/high**	*m^3/s*	*0.44/336.6*
*Annual precipitation low/avg/high***	*mm*	*726/835/993*
*Annual air temperature min/avg/max***	*°C*	*5.4/7.1/9.5*
*Agriculture area****	*%*	*48.9*
*Urban area****	*%*	*3.9*
*Forest area****	*%*	*46.8*
*Open Water area****	*%*	*0.01*
Flooded area (1/100 years)	*km^2*	*1.9*
Artificial drainage area	*km^2*	*0*

** From multiannual statistic 1984-2016*
*** From multiannual statistic 1981-2010*
**** From CORINE LandCover 2012*

The main tributaries in the Aist catchment are the Feldaist, draining the northwestern area, and the Waldaist, draining the northeastern area. After the confluence of Feldaist and Waldaist at the municipality Hohensteg, the Aist has 14 more kilometers until it joins the Danube south of Schwertberg.
On the contrary, in the Waldaist area forestry and extensive pastures are dominating, the Feldaist area is dominated by more intensive agricultural practices. Summarizing there is a north to south and an east to west gradient regarding land use intensity and population density.

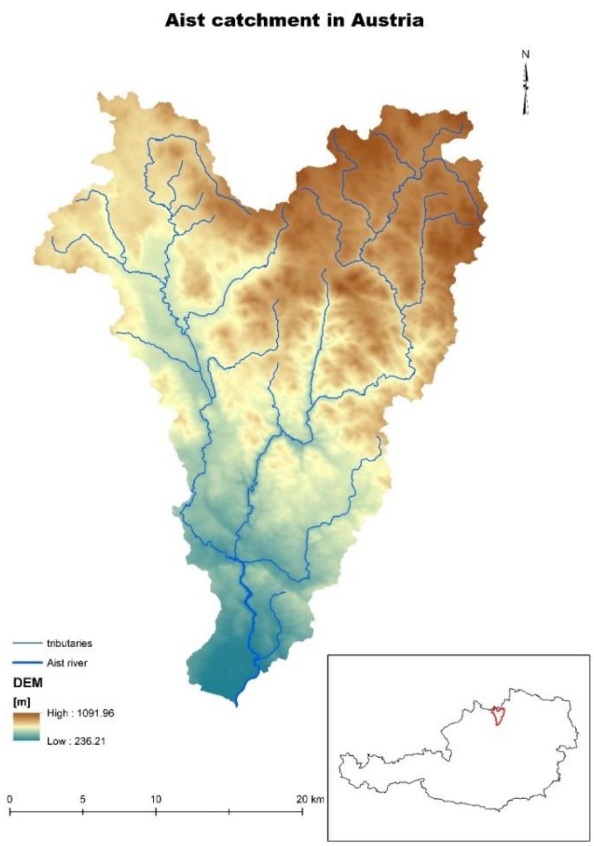

Figure 1 – Aist catchment morphology

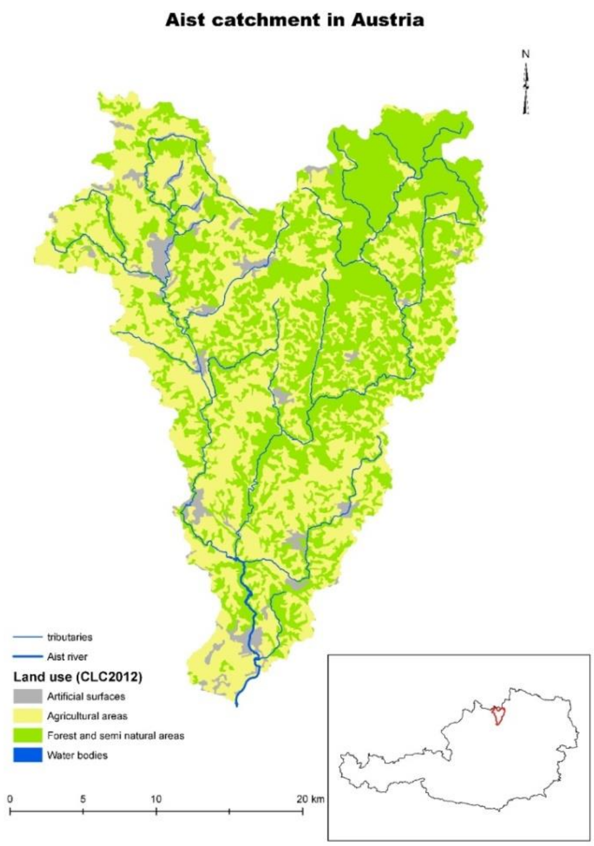

Figure 2 - Aist catchment land use

3. ISSUES IDENTIFIED IN THE CATCHMENT

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

Due to the catchment characteristics (see chapter 1) the Aist catchment shows the following main problems:

- Area with peculiar geological background – high erosion rates of granite/gneiss and their weathering products
- Accumulation of fine sediments (granite weathering products) in river beds (siltation)
- Hydromorphological conditions of rivers are mostly "moderate" (WFD status 2015, see Fig. 3)
- Conditions of riverbed habitats are deteriorating due to fine sediment accumulation - degradation and disappearance of suitable habitat, target species: freshwater pearl mussel (WFD status 2015, see Fig. 4)
- There are no problems with the chemical status (very good according to WFD status 2015)

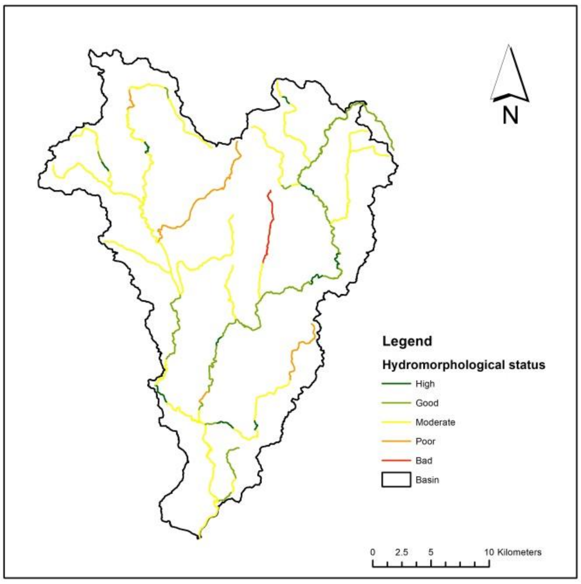

Figure 3 - WFD hydromorphological status assessment for Aist river

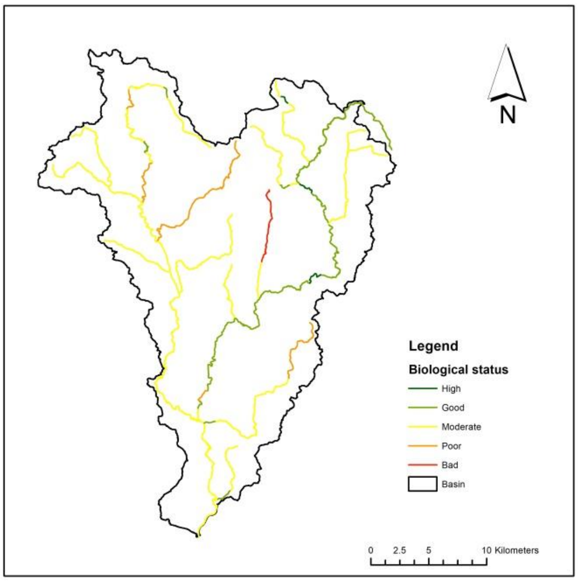

Figure 4 - WFD biological status assessment for Aist river

3.2 Review of existing and planned measures

At the moment several measures are planned within the catchment. Those affecting the sediment aspect are:

- cross sectional modifications to reduce sediment transport during periods with high flows
- sediment retention ponds off stream

Measures have been already implemented in the western and southern part of the catchment, where most of the settlements are. Recently, some measures have been planned in the forested, north-eastern part of the catchment because of the raising awareness that the fine sediment accumulation issue exists also in this area and constitutes a risk for river habitat conditions.

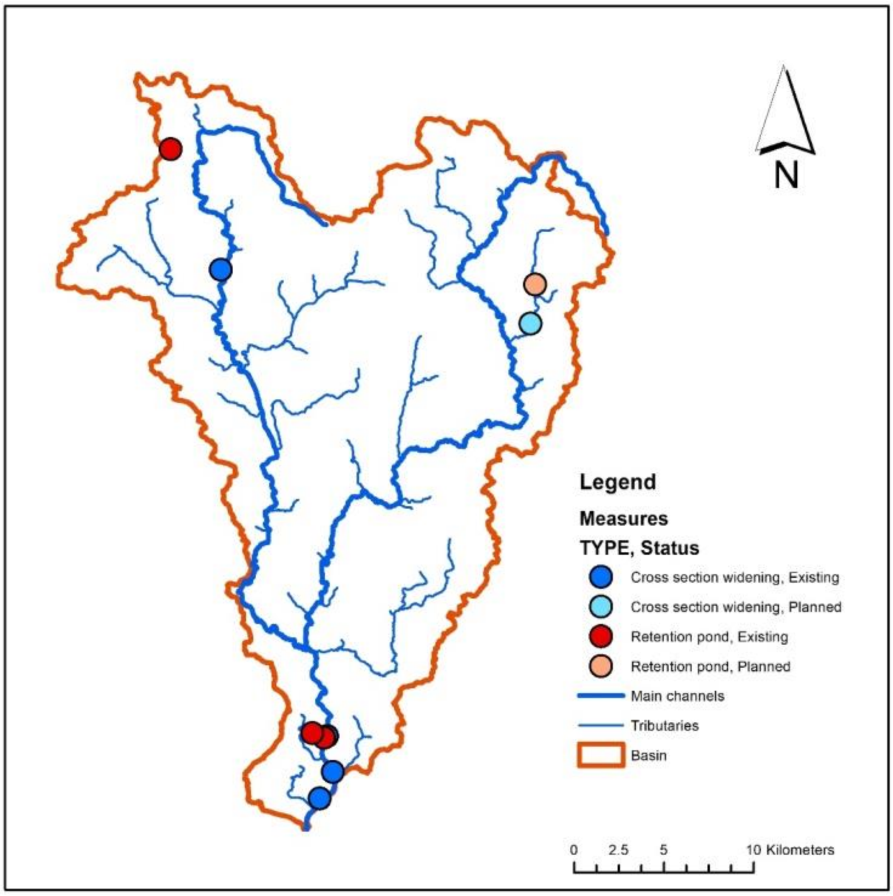

Figure 5 - Existing and planned retention measures affecting the sediment issue in the Aist catchment

3.3 Results of first consultations with stakeholders

Fine sediments accumulation (siltation) is a main concern for the regional stakeholders, because of the resulting:

- ecological problems (habitat deterioration for the target species fresh water pearl mussel – Margaritifera margaritifera)
- problems for flood control/protection (riverbed rising)

The sediment aspect has been then studied in the Aist catchment separating the three aspects sediments generation, sediment transport off stream and sediment transport in stream based on the evidence that:

- Retention need is higher for those areas in the catchment where sediment is easily produced (high erosion). This depends on the geological background, on soil properties, on land use, on climatic conditions, morphological conditions.
- Sediment retention need is higher for those areas where off-stream transport of sediment is higher and where the probability of detached sediment of ending up in the river network is higher.
- Regarding in-stream sediment transport, the need for onward sediment transport is higher for those reaches with higher tendencies for sediment accumulation and siltation due to their morphologic condition (lower slope, widening of cross-section...) and flow characteristics (less flow, less depth, less shear stress...).

Three different valorization maps are produced for each aspect separately.

3.4 Results of field recognition

During several field trips (with and without regional stakeholder involvement) the catchment was specifically visited and investigated.

It can be concluded that the sediment problem is quite strong in the Waldaist sub-catchment despite generally being the 'more natural/forested' part of the Aist catchment. High erosion rates at banks of forest roads and banks of small brooks could be identified. The manifold reasons include the existing forestry practices, such as the prevailance of planted spruce monocultures and a high density of forest roads. The consequence is high accumulation rates of fine sediments in rivers, especially in reaches with low slope.

As forests should be considered in the catchment valorization for the Aist catchment, there is the need to differentiate between monoculture forest and natural mixed forest (coniferous and deciduous trees) within the Aist catchment as show different characteristics regarding sediment retention.

3.5 Summary

More sensitive areas resulting from in field investigation are in the Waldaist reach, where a small freshwater pearl mussel (FPM) population is left.

Fine sediment accumulation has been noticed to occur also on the tributaries. The map in fig. 6 represents the areas in the catchment where water retention needs are higher and has been obtained using data from water framework directive assessment (fig. 3 and fig. 4) and expert opinions collected during the field excursion.

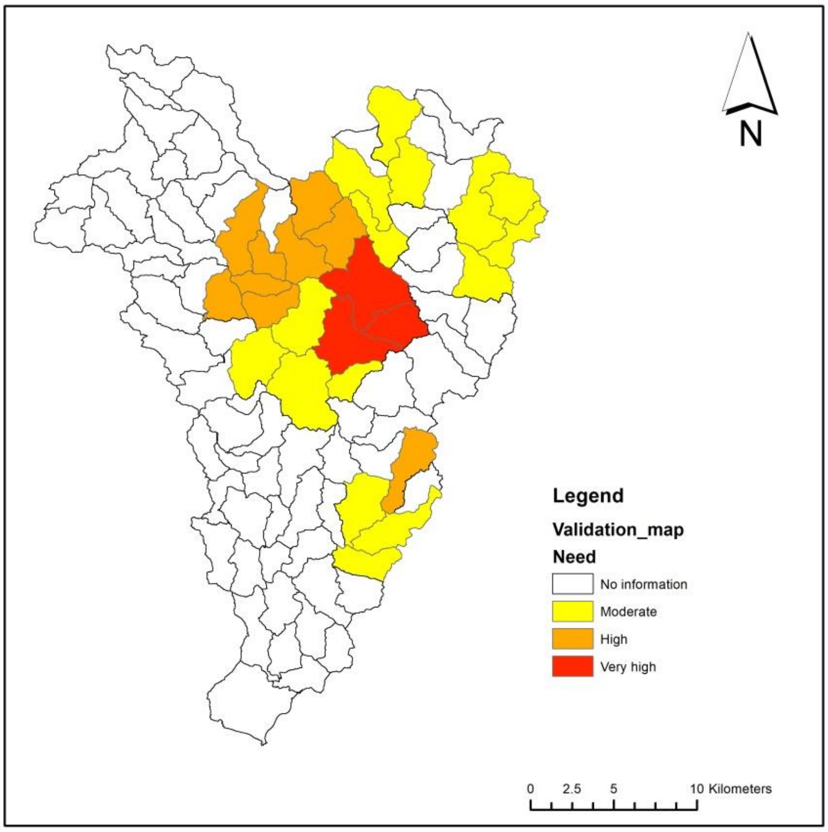

Figure 6 - Water retention needs identification based on existing documents and expert opinion

4. DESCRIPTION OF WORKFLOW

The valorization method has been developed for three separate aspects of the catchment's sediment balance:

- Sediment generation
- Sediment transport from the generation place to the river (sediment transport off-stream)
- Sediment transport in-stream

4.1 Selected SPU

Two different types of spatial planning units (SPUs) were tested:

- SPUs resulting from the watershed delineation step in the implementation of dynamic modeling in the test catchment (SWAT): total number 92, average area 6 km^2 (actual number resulting from SWAT implementation is 103, but small SPUs with an area smaller than 50 ha were merged with adjacent ones to avoid errors in the computation of indicators)
- SPUs from official Austrian spatial planning regulations: total number: 21, average area 30 km^2 (this shape correspond to the layer "*Routenteileinzugsgebiet*" of the local DORIS dataset and represents all the sub-catchments in the basin whose area is greater than 10 km^2)

The choice of the detail level of the SPUs can affect the subsequent analysis. Fine SPUs (Fig. 7) can provide a higher detail level in the spatial representation of indicators, but may also have some drawbacks. In fact, the smaller the SPUs, the higher the probability of errors in the computation of indicator and the noisier the results. Coarse SPUs (Fig. 8) on the other side can provide a less detailed output, but they are easily understandable by stakeholders and results can be easily incorporated into plans.

The final valorization maps have been implemented with coarse SPUs, the sensitivity of weight assignment and classification method has been tested with fine SPUs. In fact, four variants were considered:

- Variant 1 computes valorization for sediment generation
- Variant 2 computes valorization for sediment transport off stream
- Variant 3 computes valorization for sediment transport in stream
- Variant 4 assesses the impact of SPUs detail level choice on the final result

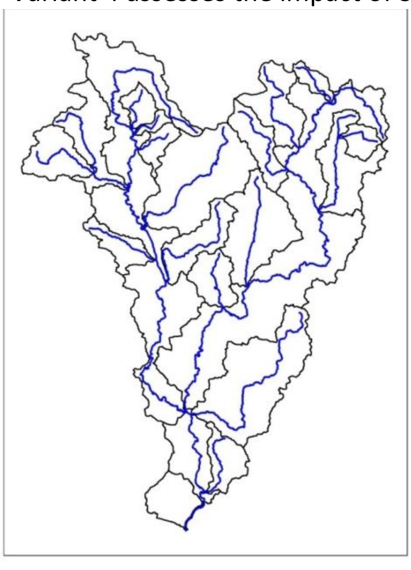

Figure 7 – Coarse SPUs

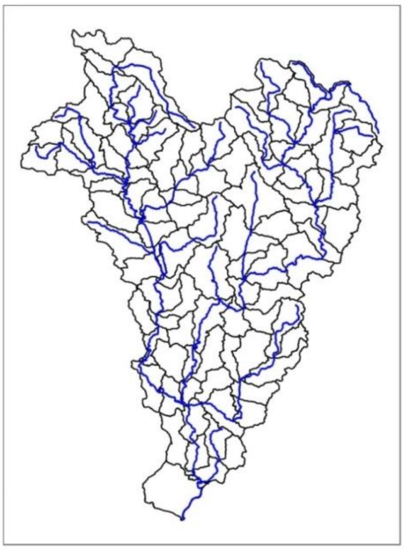

Figure 8 - Fine SPUs

4.2 Selected indicators

Indicators were selected among those present in the list provided within the FroGIS online tool. Indicators have been grouped into different categories according to the described phenomenon: Geological background, Soil properties, Morphology (land/river), Land use, Climate, Flow (Table 1).

Table 1 - Selected indicators classification

	Sediments generation	**Sediments transport off-stream**	**Sediment transport in- stream**
Geological background	GraniteRatio	-	-
Soil properties	SoilErodibility, SandRatio	-	-
Morphology	LandSlope,	LandSlope, DrainageDensity	RiverSlope, MeanderRatio,
Land use	ArableRatio, PlantedForestRatio, NaturalForestRatio,	EcoAraBuf20m,	-
Climate	RainErodibility	P_Var_m	-
Flow	-	WaterYieldAvgFlow, WaterYieldMinFlow	WaterYieldAvgFlow, WaterYieldMinFlow, FlowMinAvgRatio, FlowMinMaxRatio, FlowVarRatio_m

Indicators that are not present at the moment in FroGIS have been inserted as user defined indicators. Calculations were developed in R environment and resulting rasters imported in FroGIS as user defined indicators. Such indicators are:

- NaturalForestRatio
- PlantedForestRatio
- SandRatio
- GraniteRatio

Table 2 - Indicators stimulant/destimulant choice

Name	**Stimulant/ Destimulant**	**Rationale**
ArableRatio	S	The higher the share of arable land the higher the probability of sediment generation
ForestRatio	D	The higher the share of forest land the higher the trapping capacity
EcoAraBuf20m	S	The higher the share of arable land close to a water body the higher the probability that sediments are ending up in the river
SoilErodibility	S	The higher the soil erodibility the more prone is the soil to erosion
GraniteRatio	S	The higher the granite and gneiss substrate the higher the probability of generating sandy sediments
RiverSlope	D	The higher the river slope the lower the probability of in stream sediment accumulation
MeanderRatio	S	The higher the number of meanders, the higher the probability of sediments accumulation
LandSlope	S	The higher the SPU slope the higher the risk for soil erosion
DrainageDensity	S	The higher the drainage density the higher the probability that sediments are ending up in the main river network
RainErodibility	S	The higher the rainfall energy the higher the probability of sediment generation
TWI	D *	The higher the water retained in soil, the higher the water that ends up in the river network during baseflow, the lower the depositional patterns
CWB	D *	The higher the difference between precipitation and evapotranspiration

		the higher the water that ends up in the river network, the higher the average stream power, the lower the depositional patterns
P_Avg_Ann	S	The higher the annual precipitation the higher the rainfall energy to mobilize off-stream sediments
P_Avg_Weg	S	The higher the annual precipitation in the vegetation period the higher the rainfall energy to mobilize off-streamsediments
Pre_Var_a	S	The higher the intra-year variability, the higher the probability of peaks in precipitation the higher the probability of off-stream sediment detachment.
Pre_Var_m	S	The higher the precipitation inter annual probability, the higher the probability of peaks in precipitation the higher the probability of off-stream sediment detachment.
WaterYieldAvgFlow	D §	The higher the water yield, the higher the discharge that ends up in the stream the higher the stream power
WaterYieldMinFlow	D §	The higher the water yield, the higher the discharge that ends up in the stream the higher the stream power
FlowMinAvgRatio	S*	The lower the minimum flow the higher the probability of sediment accumulation
FlowMaxAvgRatio	D	The higher the maximum flow the higher the probability of sediment transport in stream
FlowMinMaxRatio	S *	The lower the ratio between low flow and high flow the higher the probability of sediments deposition in river
FlowVarRatio_m	S *	The higher the multiannual flow variability the higher the probability of erosion/deposition patterns, the less the sediment accumulation is stable
SandRatio	S	The higher the share of sand in the SPU area the higher the probability of sediments generation
PlantedForestRatio	S	The higher the planted forest area share the higher the sediment generation
NaturalForestRatio	D	The higher the natural forest area share the lower the sediment generation

* Indicators whose classification as stimulant/destimulant is uncertain, therefore have been removed from the analysis
§ Stimulant when used for off stream transport, Destimulant when used for in stream transport

Indicators implemented were classified as stimulant or destimulant. Stimulant indicators are those that are showing a high need for water retention when the indicator values are high; destimulant indicators are those that are showing high needs for water retention when the indicator values are low.

4.3 Input data

Input data were collected from local and global datasets. Local datasets were preferred because of the higher resolution; global datasets were used when local datasets were not existing or were un-completed (land use map, soil map).

Global datasets used:
- Corine Land Cover 2012, 25ha/100m resolution (https://land.copernicus.eu/pan-european/corine-land-cover)
- Soil grid raster, 250m resolution (https://soilgrids.org/)

Local datasetsused:
- River network (1, 10, 100 km2 resolution) DORIS Hauptgewaesser, Berichtsgewaessernetz und Detailgewaessernetz
- Subcatchments (1, 10, 100 km2) DORIS Haupteinzugsgebiete, Routenteileinzugsgebiet und Detaileinzugsgebiete

- Daily Precipitation data from 13 rain stations, 1999-2016, provided by Government of Upper Austria
- Daily Discharge data from 5 gauging stations, 1999-2016, provided by Government of Upper Austria
- DEM (100m, 20m) DORIS based on DGM10m
- Geologic map (granite gneiss) DORIS Geologie1:20.000

4.4 Correlation matrices

Correlation matrices were computed based on indicator values obtained for each SPU. To avoid double counting effect, correlated indicators were removed:

- Sediment generation: NaturalForestRatio removed because correlated with PlantedForestRatio; LandErodibility removed because correlated with SandRatio
- Sediment transport off stream: WaterYeldMinFlow removed because correlated with WaterYeldAvgFlow
- Sediment transport in stream: WaterYieldMinFlow, FlowMinMaxRatio removed because correlated with other indicators

Correlation matrices are reported in tables 3, 4 and 5; highlited cells are those corresponding to correlated couples of indicators.

Table 3 - Correlation matrix for Sediment Generation goal. NOTE: highlighted cells are showing correlated indicators.

Correlation matrix Sediment Generation	GraniteRatio	ArableRatio	NaturalForestRatio	PlantedForestRatio	RainErodibility	SandRatio	LandErodibility	LandSlope
GraniteRatio	1							
ArableRatio	-0.36	1						
NaturalForestRatio	0.24	-0.04	1					
PlantedForestRatio	0.52	-0.56	**0.61**	1				
RainErodibility	-0.59	0.14	-0.26	-0.51	1			
SandRatio	0.59	**-0.65**	0.27	**0.82**	-0.50	1		
LandErodibility	0.50	-0.33	0.47	**0.73**	-0.55	**0.60**	1	
LandSlope	0.25	-0.49	-0.14	0.23	-0.16	0.32	-0.14	1

Table 4 - Correlation matrix for Sediment Off-stream Transport goal. NOTE: highlighted cells are showing correlated indicators.

Correlation matrix Off-stream Transport	Drainage-Density	E-coAraBuf20mRatio	LandSlope	pVar_m	Wa-terYeldA-vgFlow	WaterYeld terYeld-MinFlow
DrainageDensity	1					
EcoAraBuf20mRatio	-0.25	1				
LandSlope	0.46	-0.32	1			
pVar_m	-0.07	0.05	0.19	1		
WaterYeldAvgFlow	0.13	-0.33	-0.11	0.12	1	
WaterYeldMinFlow	0.36	-0.31	0.31	0.34	**0.79**	1

Table 5 - Correlation matrix for Sediment In-stream Transport goal. NOTE: highlighted cells are showing correlated indicators.

Correlation matrix In-stream Transport	RiverSlope	MeandersRatio	WaterYeldAvgFlow	WaterYeldMinFlow	FlowMinAvgRatio	FlowMinMaxRatio	FlowVarRatio
RiverSlope	1						
MeandersRatio	0.32	1					
WaterYeldAvgFlow	-0.11	-0.08	1				
WaterYeldMinFlow	0.30	0.02	**0.79**	1			
FlowMinAvgRatio	0.54	0.10	0.34	**0.85**	1		
FlowMinMaxRatio	0.54	0.13	0.15	**0.63**	**0.84**	1	
FlowVarRatio	-0.29	-0.07	-0.09	-0.33	-0.38	0.04	1

4.5 Classification and aggregation method

Three different classification methods have been used to split the indicators into 5 classes and to test the sensitivity of the tool to classification method:

- Classes of equal width
- Quantiles (breaks at 0.20, 0.40, 0.60 and 0.80 percentiles)
- Natural breaks (Jenks)

Final classification was obtained by aggregating the indicators with weighted sums. Two possibilities were tested to assess the impact of weights assignment on final result:

- Wht1: all weights set equal to 1
- Wht01: weights chosen in the interval 0-1

In total, for each variant 6 possibilities were tested (combination of 3 classification methods and 2 weight choices).

Table 6 - Indicators statistics for Sediment Generation goal

Sediment generation – Indicators statistics					
Indicator name	**min**	**max**	**mean**	**std**	**Units**
GraniteRatio	0.00	99.94	43.82	33.31	%
ArableRatio	0.00	69.53	15.52	15.68	%
NaturalForestRatio	0.00	55.30	6.20	10.84	%
PlantedForestRatio	0.00	99.72	37.45	23.43	%
LandErodibility	8298.70	10147.64	9291.86	702.57	$0.013\ \frac{t\ m^2 h}{m^3\ t\ cm}$
SandRatio	30.10	52.77	44.92	3.70	%
RainErodibility	0.17	0.18	0.18	0.00	$\frac{MJ\ mm}{ha\ h\ y}$
LandSlope	4.79	37.12	18.47	7.14	%

Table 7 - indicators statistics for Sediment Off-stream Transport goal

Sediments Off-stream Transport – Indicators statistics					
Indicator name	**min**	**max**	**mean**	**std**	**Units**
DrainageDensity	0.38	2.92	1.63	0.49	km / km^2
EcoAraBuf20mRatio	0.59	0.75	0.66	0.04	%
LandSlope	4.79	37.12	18.47	7.14	%
WaterYeldAvgFlow	272.83	444.17	323.12	48.64	mm
WaterYeldMinFlow	50.06	114.82	79.09	21.40	mm
pVar_m	0.00	2.39	0.43	0.57	-

Table 8 - Indicators statistics for Sediment In-stream Transport goal

Sedimetns In-stream Transport – Indicators statistics					
Indicator name	**min**	**max**	**mean**	**std**	**Units**
RiverSlope	0.20	13.79	5.09	2.64	%
MeandersRatio	76.10	95.94	90.04	3.26	%
WaterYeldAvgFlow	272.83	444.17	323.12	48.64	mm
WaterYeldMinFlow	50.06	114.82	79.09	21.40	mm
FlowMinAvgRatio	0.18	0.32	0.24	0.05	-
FlowMinMaxRatio	0.02	0.04	0.03	0.01	-
FlowVarRatio	0.20	0.44	0.32	0.09	-

The classification method can impact on the class that is assigned to every SPU, since the histograms (fig. 9, 10, 11) are split in different ways.

Table 9 - Results of division of indicators values to five classes for sediment generation goal

Indicator name	Classes	Classes of equal witdth	Natural breaks	Quantiles
GraniteRatio	5	31	23	19
	4	13	16	18
	3	15	18	18
	2	13	14	18
	1	20	21	19
SoilErodibility	5	8	7	19
	4	34	32	18
	3	37	24	18
	2	7	21	18
	1	6	8	19
SandRatio	5	1	0	19
	4	3	13	18
	3	32	28	18
	2	39	31	18
	1	17	20	19
LandSlope	5	12	12	19
	4	42	26	18
	3	23	28	18
	2	11	15	18
	1	4	11	19
ArableRatio	5	49	33	19
	4	22	18	18
	3	15	21	18
	2	4	15	18
	1	2	5	19
NaturalForestRatio	5	71	59	19
	4	12	12	18
	3	5	13	18
	2	3	6	18
	1	1	2	19
PlantedForestRatio	5	26	22	19
	4	22	23	18
	3	29	25	18
	2	11	17	18
	1	4	5	19
RainErodibility	5	50	0	19
	4	21	28	18
	3	5	22	18
	2	0	22	18
	1	16	20	19

Table 10- Results of division of indicators values to five classes for sediment transport off stream

Indicator name	Classes	Classes of equal witdth	Natural breaks	Quantiles
LandSlope	5	12	12	19
	4	42	26	18
	3	23	28	18
	2	11	15	18
	1	4	11	19
DrainageDensity	5	4	7	19
	4	29	25	18
	3	34	25	18
	2	16	22	18
	1	9	13	19
EcoAraBuf20m	5	57	46	0
	4	17	18	37
	3	10	11	18
	2	3	8	18
	1	5	9	19
ArableRatio	5	49	33	0
	4	22	18	37
	3	15	21	18
	2	4	15	18
	1	2	5	19
WaterYieldAvgFlow	5	11	11	19
	4	0	24	18
	3	0	8	18
	2	50	20	17
	1	31	29	20
WaterYieldMinFlow	5	41	28	19
	4	0	14	18
	3	1	20	18
	2	19	9	18
	1	31	21	19
PreVar_m *	5	1	4	19
	4	20	43	18
	3	25	5	18
	2	30	27	18
	1	16	13	19

Table 11 - Results of division of indicators values to five classes for sediment transport in stream

Indicator name	**Classes**	**Classes of equal witdth**	**Natural breaks**	**Quantiles**
FloMinAvgRatio	5	52	52	19
	4	0	13	21
	3	11	8	15
	2	9	1	18
	1	20	18	19
FlowMinMaxRatio	5	42	21	19
	4	41	20	18
	3	0	10	18
	2	0	31	18
	1	9	10	19
FlowVarRatio	5	22	22	0
	4	27	31	37
	3	14	11	18
	2	20	20	18
	1	9	8	19
WaterYieldAvgFlow	5	11	11	19
	4	0	24	18
	3	0	8	18
	2	50	20	17
	1	31	29	20
WaterYieldMinFlow	5	41	28	19
	4	0	14	18
	3	1	20	18
	2	19	9	18
	1	31	21	19
MeanderRatio	5	17	0	19
	4	0	20	18
	3	0	26	18
	2	9	35	18
	1	66	11	19
RiverSlope	5	30	28	18
	4	51	45	19
	3	7	12	4
	2	3	5	32
	1	1	2	19

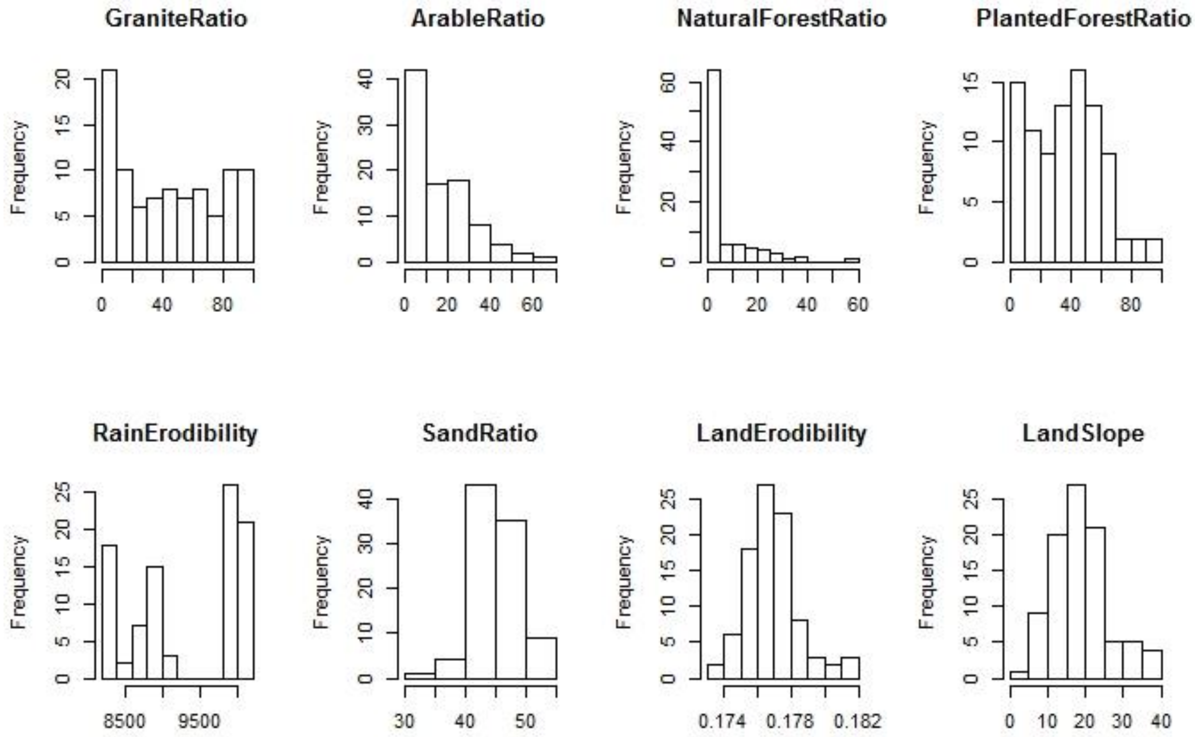

Figure 9 – Indicators distribution hystograms for sediment generation goal

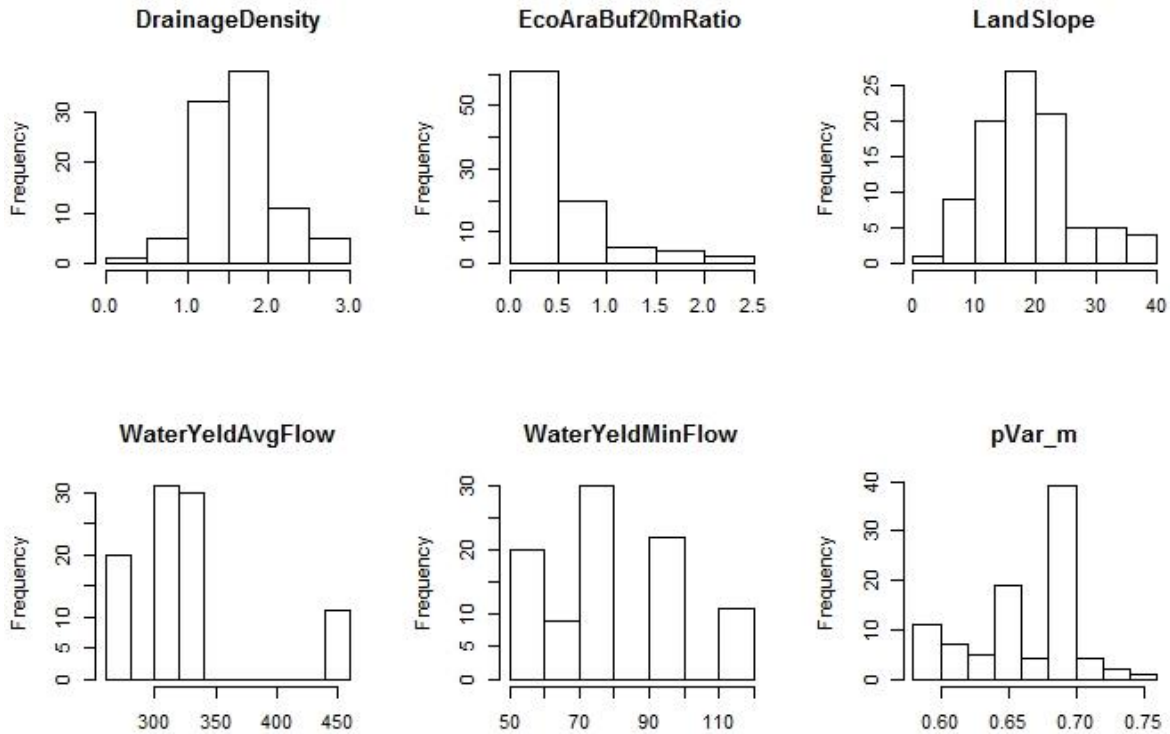

Figure 10 - – Indicators distribution hystograms for sediment off stream transport goal

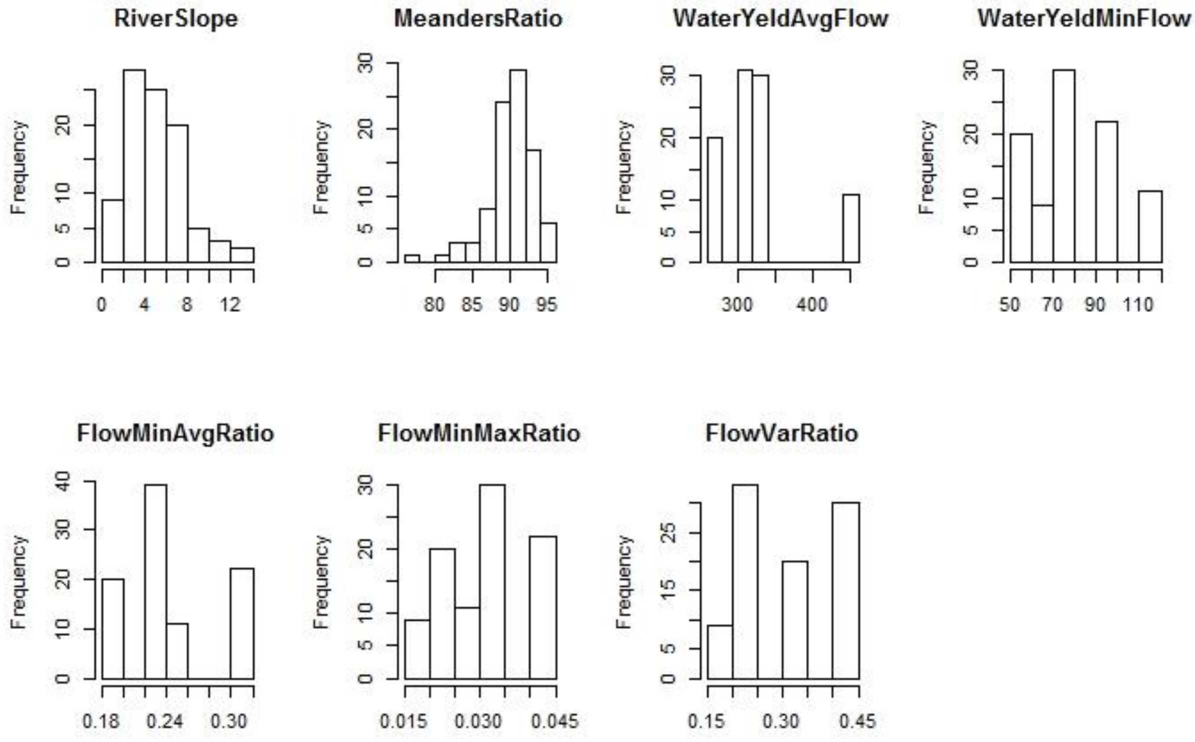

Figure 11 - Indicators distribution hystograms for sediment in stream transport goal

4.6 Weights assignment

Weights were assigned by reducing the relative importance of indicators that are the result of management practices (including choice of the land use) or that are highly uncertain (Table). Therefore, weights were assigned as follows:

- indicators whose evaluation has low uncertainty and are not related with management practices: weight = 1
- indicators whose evaluation has low uncertainty and are related with management practices: weight = 0.5
- indicators whose evaluation has high uncertainty: weight = 0.3

Table 12 – Weights assigned to indicators

Sediments generation		Sediments off stream transport		Sediments in stream transport	
Indicator	**Weight**	**Indicator**	**Weight**	**Indicator**	**Weight**
GraniteRatio	1	DrainageDensity	1	RiverSlope	1
ArableRatio	1	EcoAraBuf20mRatio	0.5	MeandersRatio	1
NaturalForestRatio	0.5	LandSlope	0.5	WaterYeldAvgFlow	0.3
PlantedForestRatio	0.5	WaterYeldAvgFlow	1	WaterYeldMinFlow	0.3
RainErodibility	0.5	WaterYeldMinFlow	1	FlowMinAvgRatio	0.5
SandRatio	0.5	pVar_m	1	FlowMinMaxRatio	0.5
LandErodibility	0.3			FlowVarRatio	0.5
LandSlope	1				

5. ANALYSIS OF VARIANTS

5.1 Variant 1 - Valorization for sediment generation

Variant 1.C5: Five classes of indicators

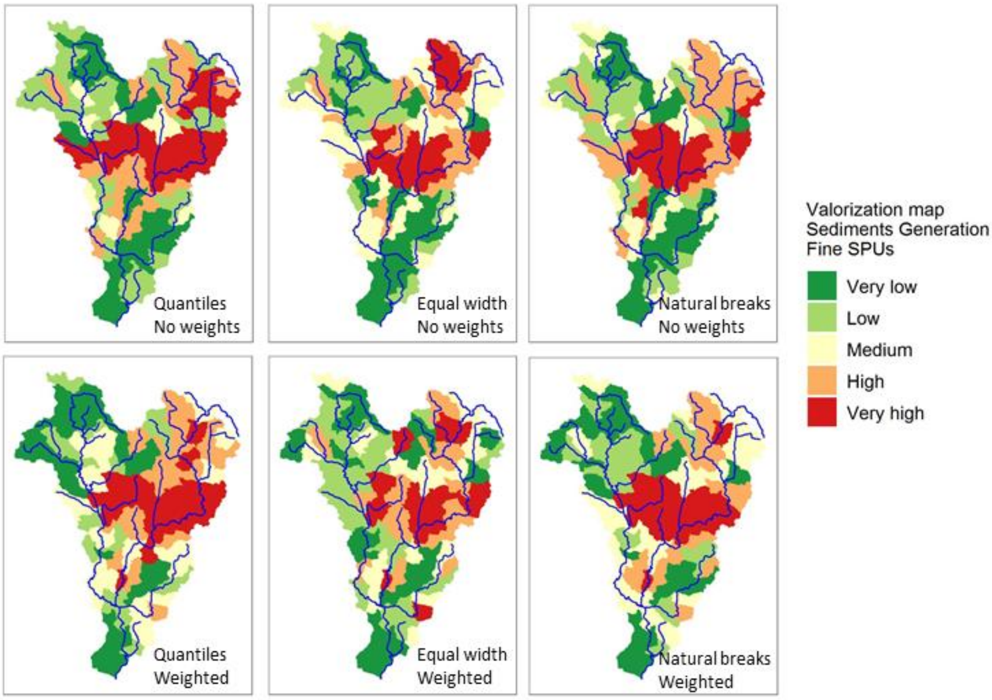

Figure 12 - Sensitivity analysis for sediments generation goal

5.2 Variant 2 - Valorization for sediment transport off stream

Variant 2.C5: Five classes of indicators

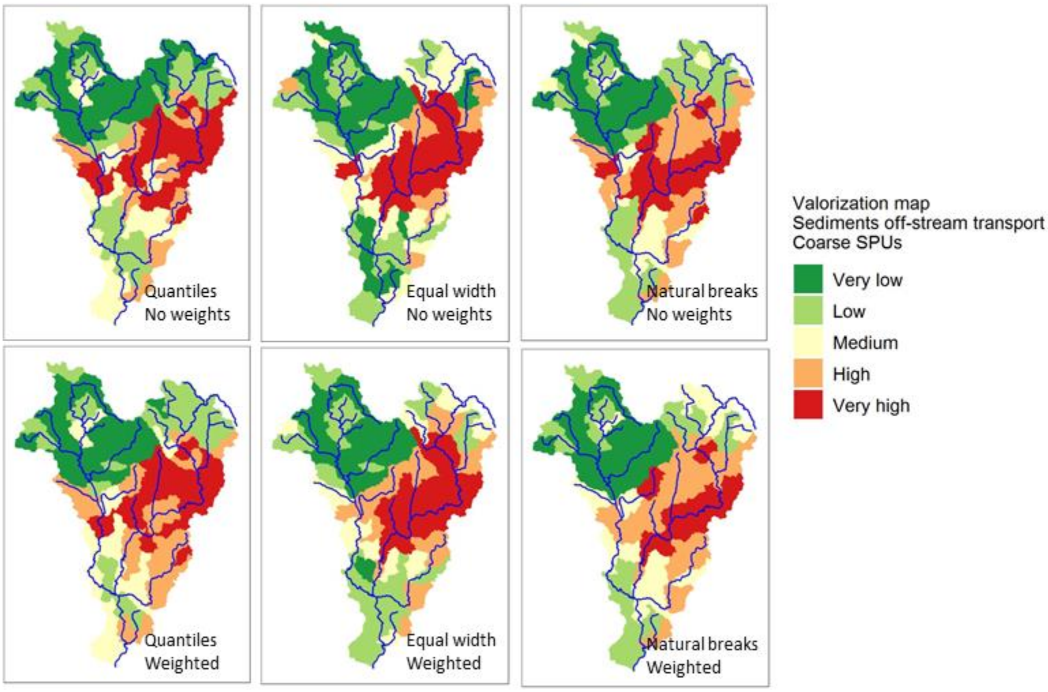

Figure 13 - Sensitivity analysis for off-stream sediment transport goal

5.3 Variant 3 - Valorization for sediment transport in stream

Variant 3.C5: Five classes of indicators

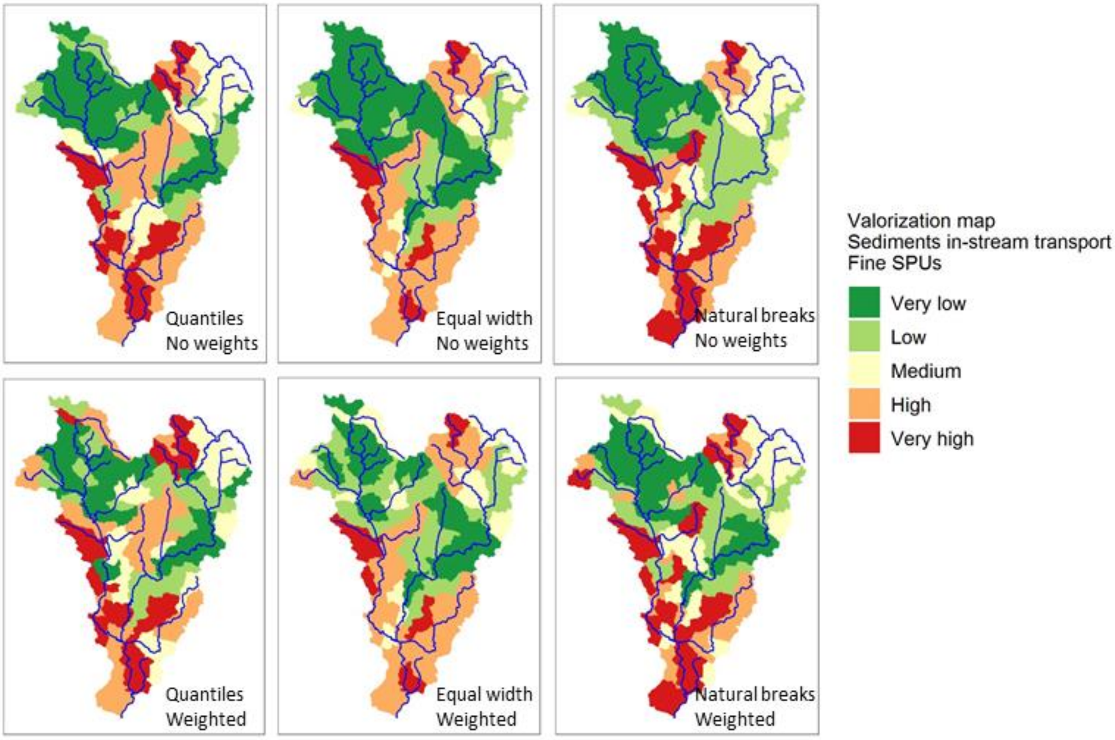

Figure 14 - Sensitivity analysis for in-stream sediment transport goal

5.4 Variant 4 SPUs choice comparison

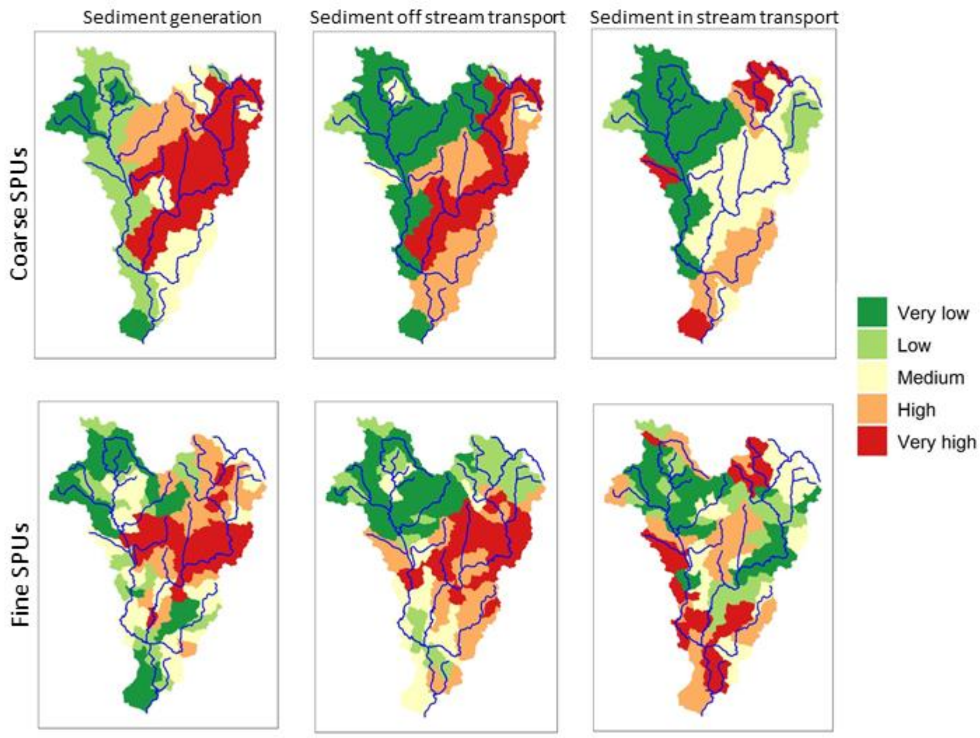

Figure 15 - Sensitivity analysis on the choice of SPUs detail level for all the valorization goals. Classification methiod: quantiles.

The valorization maps obtained using coarse SPUs are coherent with the maps obtained using refined SPUs and the same input data. Therefore, the choice of the detail level is then not affecting the indications that are possible to get out of the analysis.
Furthermore the use of elementary basins used allows to avoid the misleading interpretation of neasted SPUs (when it may not be clear if the upstream contributions are prevailing on the SPUs contribution to some indices – infact, this issue is not addressed in the GIS tool and should be avoided with a careful choice of SPUs).
Finally, during the analysis it has been noticed that the refined map is more “noisy” when using imput data with low resolution. Therefore the use of small sized SPUs is suggested only in case the input data have a high quality.

6. COMPARISON AND DESCRIPTION OF RESULTS

The map based on expert opinion and existing data has been compared with valorization results (Tables 10, 11, 12). The following statistics were computed by comparing the valorization needs identified on the field excursion and discussed with stakeholders presented in Fig. 6 with the results of the valorization method. The following statistics were used:

- Mean absolute deviation (MAE)
- Mean square error (MSE)
- Root mean square error (RMSE)
- Mean absolute percentage (MAPE)

The sum of these quantities was computed and the impact of the classification method on the valorization results assessed. The best classification methods (minimizing the sum of the error statistics) resulted to be classes of equal width for all the valorization goals. However, it is suggested to repeat this analysis when the valorization goal is changed or when valorization is performed with different input datasets.
The classification method that minimizes the influence of weighting process (difference between Goal-VarX.Wht1 and Goal-VarX.Wht01 is minimum) is quantiles.
Finally, it has to be noticed that the map used for validation is reporting SPUs where unbalanced sediments conditions are noticed based on existing documents and expert opinion on the field. Therefore it has to be used carefully when the analysis disaggregates different aspects of the same problem to treat them separately.

Table 13 - Variant validation for sediment generation goal

	Classes of equal width errors for the SPU population			Natural breaks errors for the SPU population			Quantiles errors for the SPU population		
Errors	VarA.Wht01-VarA.Wht1	Goal-VarA.Wht1	Goal-VarA.Wht01	VarB.Wht01-VarB.Wht1	Goal-VarB.Wht1	Goal-VarB.Wht01	VarC.Wht01-VarC.Wht1	Goal-VarC.Wht1	Goal-VarC.Wht01
MAD	0.53	2.24	2.18	0.58	2.36	2.30	0.46	2.23	2.16
MSE	0.66	6.76	6.51	0.75	7.08	7.20	0.52	7.14	6.66
RMSE	0.81	2.60	2.55	0.87	2.66	2.68	0.72	2.67	2.58
MAPE	27.5%	11.1%	11.5%	25.5%	13.5%	11.3%	23.6%	9.5%	10.0%
TOT	**1.04**	**13.28**	**13.66**	**1.50**	**14.26**	**14.59**	**1.89**	**13.72**	**14.01**

Table 14 - Variant validation for off-stream sediment transport goal

	Classes of equal width errors for the SPU population			Natural breaks errors for the SPU population			Quantiles errors for the SPU population		
Errors	VarA.Wht01-VarA.Wht1	Goal-VarA.Wht1	Goal-VarA.Wht01	VarB.Wht01-VarB.Wht1	Goal-VarB.Wht1	Goal-VarB.Wht01	VarC.Wht01-VarC.Wht1	Goal-VarC.Wht1	Goal-VarC.Wht01
MAD	0.22	2.27	2.34	0.16	2.48	2.42	0.23	2.39	2.42
MSE	0.22	7.55	7.71	0.16	8.24	7.95	0.23	7.80	7.97
RMSE	0.47	2.75	2.78	0.40	2.87	2.82	0.48	2.79	2.82
MAPE	7.8%	15.3%	15.3%	6.2%	17.1%	16.1%	8.8%	17.1%	16.5%
TOT	**0.98**	**12.73**	**12.97**	**0.79**	**13.76**	**13.35**	**1.02**	**13.16**	**13.38**

Table 15 - Variant validation for in-stream sediment transport goal

	Classes of equal width errors for the SPU population			Natural breaks errors for the SPU population			Quantiles errors for the SPU population		
Errors	VarA.Wht01-VarA.Wht1	Goal-VarA.Wht1	Goal-VarA.Wht01	VarB.Wht01-VarB.Wht1	Goal-VarB.Wht1	Goal-VarB.Wht01	VarC.Wht01-VarC.Wht1	Goal-VarC.Wht1	Goal-VarC.Wht01
MAD	0.21	2.41	2.49	0.29	2.54	2.55	0.42	2.46	2.49
MSE	0.25	7.91	8.18	0.42	8.65	8.92	0.55	8.26	8.49
RMSE	0.50	2.81	2.86	0.65	2.94	2.99	0.74	2.87	2.91
MAPE	8.6%	13.8%	12.2%	13.6%	12.7%	12.4%	16.5%	12.9%	12.0%
TOT	**1.96**	**11.77**	**12.27**	**1.24**	**11.81**	**12.52**	**1.18**	**11.86**	**12.04**

7. SUMMARY

The valorization method has been tested for the Aist catchment. Four variants were developed to assess the sensitivity of weights, classification method and SPUs detail subjective choices. Results are showing that:

- the SPUs detail level is not influencing the results of the analysis in terms of spatial distribution of identified valorization needs;
- the best method for the used input data is the classes of equal weights; however, the method that minimizes the influence of weight assignment is subdivision with quantiles;
- the obtained valorization map can be validated with data on selected SPUs from expert opinions or existing documents, making the decision more robust; however, when analysis disaggregates the selected goal the use of validation maps is less straightforward

8. OTHER COMMENTS

On October 22nd 2018 a workshop was held for the regional stakeholders of the pilot catchment area at WasserCLuster Lunz to present the FroGIS Tool and first testing results for the catchment.

Summarizing, the stakeholders are very interested in the tool and the idea of catchment valorization. But the FroGIS Tool in the current form seems not to meet their expectations: On the one hand it is not detailed enough to be a proper planning instrument, on the other hand it's too complicated to serve just a screening instrument (for rough assessment of a catchment and its characteristics).

If authorities should be frequent users of the tool, it has to become user-friendlier by simplifying the tool's working steps (going „one step back").
One suggestion was to make a two-step approach for the tool:

- Version „light"– fixes datasets with lower resolution for screening purposes of catchments
- Version „pro"– restricted access for trained experts only; possible to make „regionalisation" by input of catchment specific data and indicators with higher resolution

Further topics addressed by the stakeholders were:

- Uncertainties and ambiguities concerning the terminology of data and indicators exist – the meaning and the data base of various indicators is unclear:
  e.g. ArableRatio – it's not clear, which agricultural areas fall under this term
  (plough land with tillage farming only, no pastures/meadows)
  DrainageDensity – the term is connected to agricultural draining practices (at least in Austria) but only includes the river network for catchments >1 km² (no ditches or other artificial drainage systems)
- Indicator „Forest": For the Austrian catchment it is necessary to distinguish between spruce monocultures and natural/semi-natural mixed forests (conifers and broadleaf forests) because these two have different effects on water and sediment retention: In the spruce monocultures there are high erosion rates and sediment inputs into surface waters (due to fissures at banks of rivers and forest roads), whereas natural mixed forests show less erosion rates and support water and sediment retention.
- The possibility of one indicator to be stimulant and non-stimulant for different retention goals seems can lead to problems in understanding. It would be easier if certain indicators always act into the same direction.

- The possibility to include expert judgement (e.g.in the selection of the indicators, in the weighting process…) is seen very critically. Generally speaking, the more expert judgement is included, the more difficult the application of the tool gets because comprehensibility, reproducibility, and transparency get lost.
- SPUs (Standard Planning Units): it's unclear what level of detail should be used; the use of SPUs exported out of SWAT is not feasible for water authorities as these are normally not available; as a fast & simple application is wanted, existing catchment divisions should also lead to meaningful results.
- The resulting maps need proper legends and meaningful descriptions! At the moment the coloring is a bit unclear.
- It's necessary to properly describe what "high need for retention" means for all resulting maps, as otherwise even experts can jump to wrong conclusions. Deficit analyses and implications have to be described precisely.
- It has to be made clear that the GIS Tool is a static tool and not applicable for assessments of extreme events. Results cannot be used to deduce necessary flood retention measures.

Finally, it was necessary to write a report on FroGIS with explanations on the methodology, the input data and the used indicators also in the national language German. This was needed by the stakeholders in order to be able to understand the FroGIS testing results.

8.1 Comments on user's experience

Some critical issues have been experimented during the application of FroGIS to the pilot catchment and the interpretation of results:

- It is difficult to disaggregate "river network" contributions from "SPUs" contributions to the some indicator values. A weighting system that considers the river network geometry could solve this issue, at the cost of adding more complexity to the model.
- Guidelines for weighting process are missing.
- Documentation is still partial and hard to understand for users with limited hydrological engineering background
- Guidelines on the presentation of results may be useful when it comes to interpret the results

9. REFERENCES

Hauer, C., Höfler, S., Dossi, F., Flödl, P., Graf, G., Graf, W., Gstöttenmayr, D., Gumpinger, C., Holzinger, J., Huber, T., Janecek, B., Kloibmüller, A., Leitner, P., Lichtneger, P., Mayer, T., Ottner, F., Riechl, D., Sporka, F., Wagner, B., Habersack, H. (2015): Feststoffmanagement im Mühlviertel und im Bayerischen Wald. Endbericht. Studie im Auftrag des Amtes der Oberösterreichischen Landesregierung, gefördert durch das BMLFUW und das Interreg Programm Bayern – Österreich 2007 - 2013. Wien, 391 S.

Kapfer, S., Steiner, A., Abel, R., Schauer, G., Sieber G. AIM Jahresbericht 2016 - Inspektionsbericht zur Zustandsbewertung der Fließgewässer in Oberösterreich 2015-180026/4