DEVELOPING THE CONCEPT PLAN FOR N(S)WRM IN RIVER BASIN

D.T2.3.1

Version 7
03/2019

Pilot Catchment Aist
Austria/ WasserCluster Lunz

June 2019

CONTENT

Authors: WasserCluster Lunz/Austria
Damiano Baldan, Eva Feldbacher, Gabriele Weigelhofer, Thomas Hein

1. INTRODUCTION

The good ecological status of surface water in EU in 2015 has improved by 10 % since 2009. However, there is still a lot of work to be done in order to achieve a better status of fauna and flora, as well as favourable hydrological and chemical characteristics. Various types of measures listed under the name Natural (Small) Water Retention Measures (N(S)WRM) can have significant positive effects on solving environmental problems such as hydrological extremes, nutrients' transport and decreased biodiversity. The main objective of the FramWat project is to strengthen the regional common framework for floods, droughts and pollution mitigation by increasing the buffer capacity of the landscape using the N(S)WRM approach in a systematic way.

Limited integration of N(S)WRM in the river basin and flood risk management in CE is mainly a consequence of lack of knowledge base and tools on how to plan, assess and implement the multiple benefits of measures on the river basin scale. Until now, the projects were mainly focusing on one specific measure where effects on entire river basin scale are insignificant. Thus, it is important to strengthen the capacities and develop an innovative systematic approach to support the implementation of N(S)WRM.

The present Concept Plan was developed using the GIS Tool FroGIS developed for landscape valorization in the FramWat project and by building upon the first results of the static and dynamic modelling of the pilot catchment. The Concept plan gives information on best locations and suitable types of measures with cumulative effect.

<u>The main objectives of the present Concept Plan are</u>:

- to explain transparently the way how the analysis of information, data and context as well as the evaluation of experts knowledge and stakeholders preferences led to the chosen NSWRM design principles;
- to show how the design and location of the selected N(S)WRMs respond to the opportunities & constraints identified during the analyses;
- to explain and justify the way the N(S)WRMs are planned;
- to demonstrate a genuine response to context and not simply justify predetermined design solutions
- to provide a uniform guideline for the NSWRM planning process

2. ELABORATION METHOD OF THE CONCEPT PLAN

Figure 1 demonstrates the main steps of the concept plan elaboration, while details of the needed actions are discussed in the chapters below.

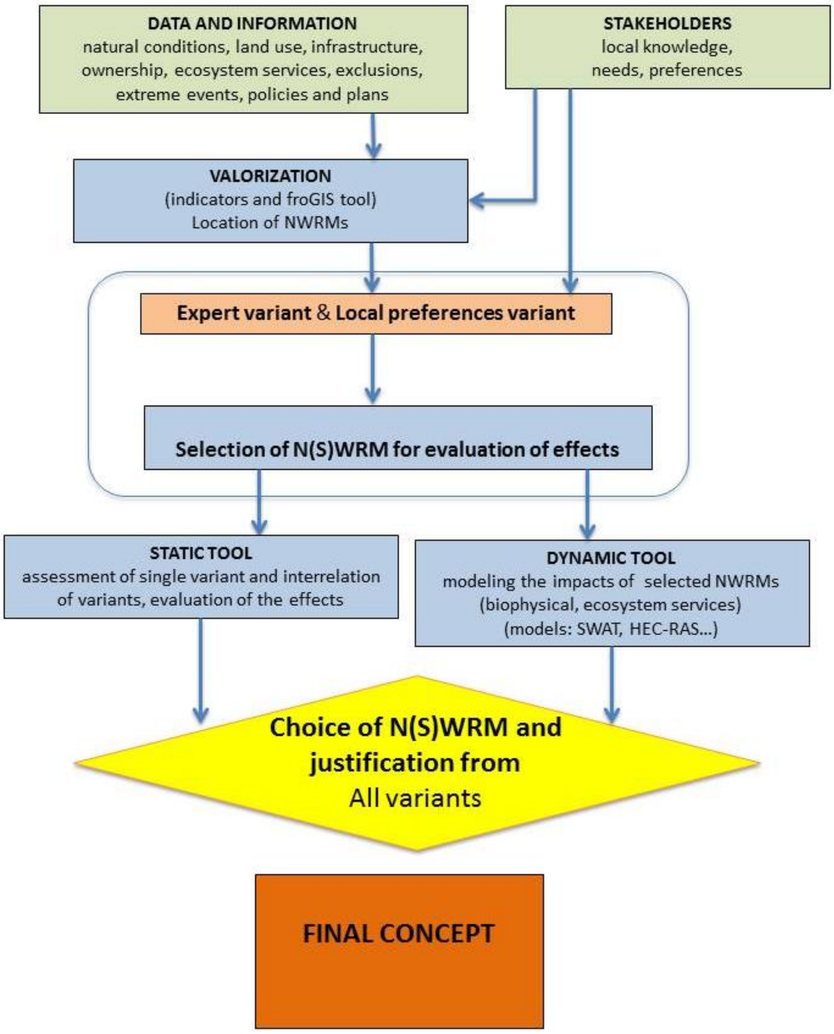


Figure 1: Main steps of the Concept Plan elaboration

3. CHARACTERISTICS OF THE PILOT AREA

3.1 Natural conditions 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 million 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.

In the Waldaist area forestry and extensive pastures are dominating, the Feldaist area is characterized by intensive agricultural practices. Summarizing there is a north to south and an east to west gradient regarding land use intensity and population density.

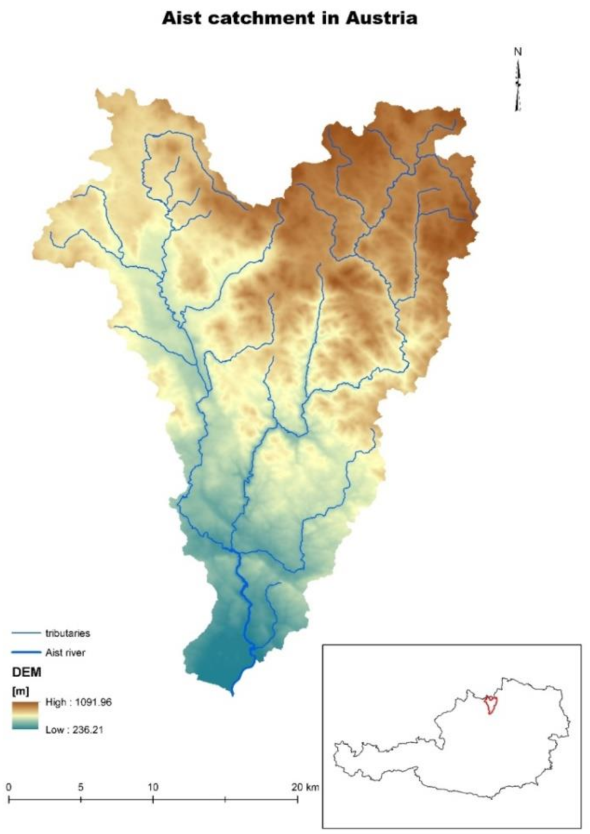


Figure 2: Aist catchment morphology

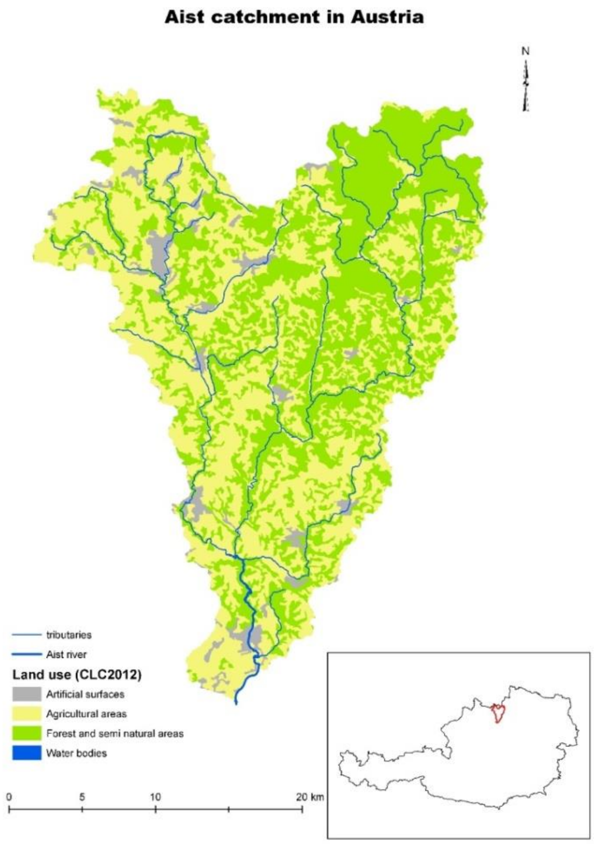


Figure 3: Aist catchment land use distribution

3.2 Land use, infrastructure and protected areas

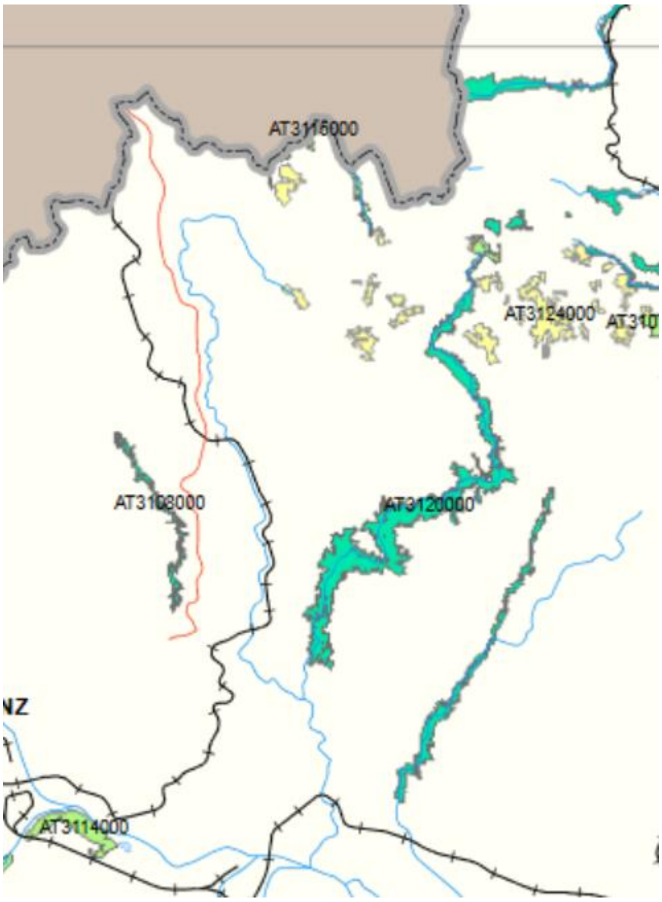
Land use (see figure 3) within the Aist catchment is dominated by agriculture (48,9%) and forestry (46,8%), urban areas are very limited (3,9%).

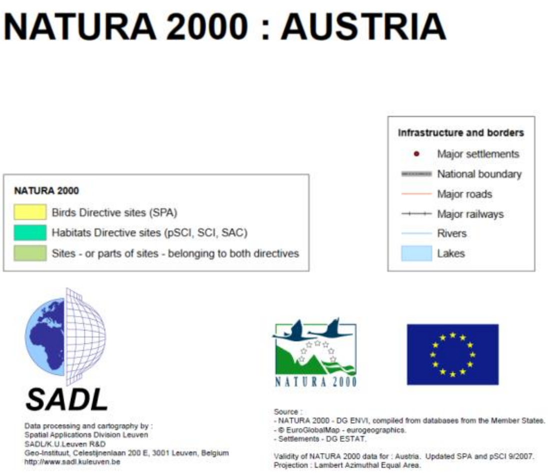
Regarding agricultural practices the catchment can be divided into three main areas - the southernmost part belonging to the Danube valley, the central midlands, and the northern highlands - following a gradient from intensive to extensive agriculture: In the southern part the amount of arable land is very high (77%, mainly winter wheat, barley and corn), whereas pastureland is limited (23 %). In the central midlands this ration gets more balanced, and it turns for the northern highlands where pastureland predominates (70%, arable land: 30%, mainly winter titricale).

Regarding forestry a differentiaion must be made between planted forests (mainly spruce monocultures) and natural forest (mixed conifer and broadleaf forest) as these thwo types have very different effects on the water and sediment balance in the catchment. A GIS estimation shows that that planted forests (mostly spruce monoculture) occupy 80% of the forested area, with the remaining 20% left to semi-natural, broad-leaves forest.

The biggest towns in the catchment are Freistadt in the northern part (ca. 8.000 inhabitants), Pregarten in the central part (ca. 5.500 inhabitants), and Schwertberg in the sourthern part (ca. 5.000 inhabitants). The population in total amounts to 56.000 inhabitants in the catchment, the population density varies between 31 (in the less populated north-eastern highlands) and 89 inhabitants (in the denser populated southern part) per km².

The most relevant protected area within the Aist catchment is the **Natura 2000 site "Waldaist, Naarn"** (protected area of the European network of nature protection areas based on the Habitats Directive, see figure 4). This FFH area is dominated by the valleys of the rivers Waldaist and Naarn, which are largely preserved in a natural condition, but locally also affected by small power plant constructions. In addition to man-initiated spruce cultures there are also numerous natural mixed forest types e.g. alluvial forests with alder and ash in the valley floors. In the widening sections, small-scale cultivated landscapes with extensive meadows have been preserved. Of particular importance is the occurrence of the freshwater pearl mussel.





Natura 2000 sites within the pilot catchment:

"Waldaist, Naarn", site ID: AT3120000; area: 3838,14 ha

„Meadows in the forest" (Wiesen im Freiwald) site ID: AT3124000, area: 2410 ha structured meadows, fallow land and brooks – important for breeding birds

Figure 4: Map of Natura 2000 sites in the catchment area

3.3 Ecosystem services

Based on Haines-Young, R. and M.B. Potschin (2018): Common International Classification ofEcosystem Services (CICES) V5.1and Guidance on the Application of the Revised Structure.

The Common International Classification of Ecosystem Services (CICES) has been designed to help measure, account for,and assess ecosystem services. CICES seeks to classify final ecosystem services, which are defined as the contributions that ecosystems (i.e living systems) make to human well-being. A fundamental characteristic of final services is that they retain a connection to the underlying ecosystem functions, processes and structures that generate them.

The catchment Aist provides many ecosystem services listed by CICES: Biotic and abiotic provisioning services in the divisions *Biomass* and *Water,* biotic and abiotic regulation and maintenance services in the divisions *Regulation of physical, chemical, biological condition* and *Transformation of biochemical or physical inputs to ecosystems*, as well as cultural ecosystem services in the divisions *Direct, in-situ and outdoor interactions with natural physical systems that depend on presence/do not require presence in the environmental setting.*

3.4 Catchment problems

Due to the catchment geographical, climatic, morphological and anthropogenic characteristics, (see chapter 3), 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.5)
- 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. 6)
- There are no recent problems with the chemical status (very good according to WFD status 2015)

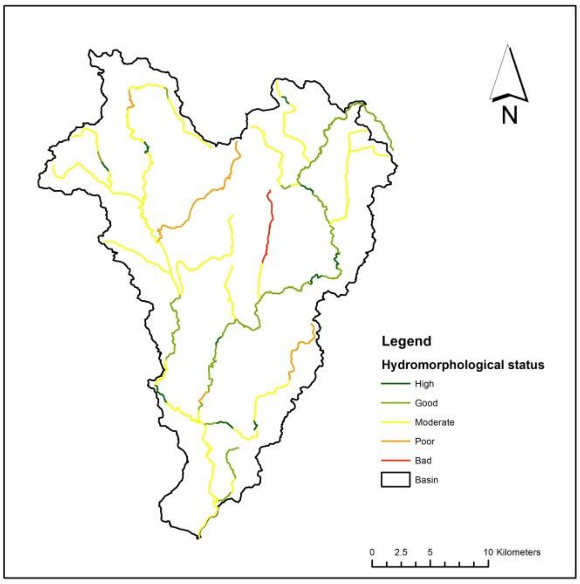


Figure 5: WFD hydromorphological status assessment for Aist river

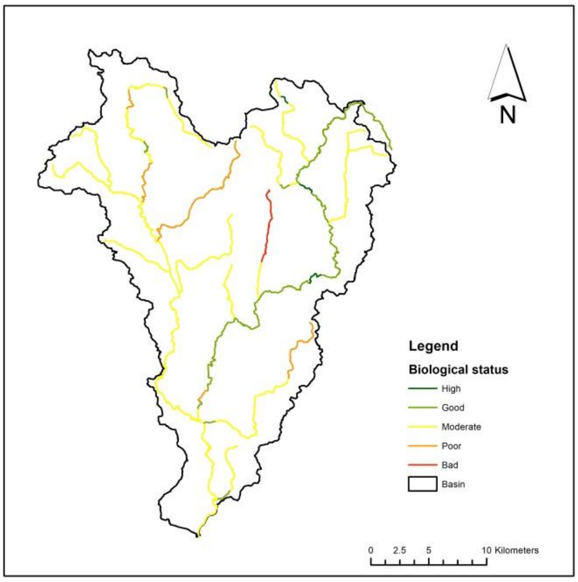


Figure 6:WFD biological status assessment for Aist river

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 prevalence 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 they show different characteristics regarding sediment generation and retention.

The siltation risk has been assessed by Hauer et al., 2015, and is reported in fig. 7. The extent of siltation at the mesohabitat scale was mapped in 2013 – 2014 with field surveys and is expressed in siltation classes ranging from class 0 (no fine sediment accumulation) to class 3+ (the fine sediment accumulations are completally clogging the mesohabitat). As expected, Feldaist and Aist have higher abundance of silted sites because of the higher extent of anthropogenic activities. However, also in the

Waldaist the siltation risk is present, even in the headwaters in the northern part, where the anthropogenic disturbance is supposed to be small.

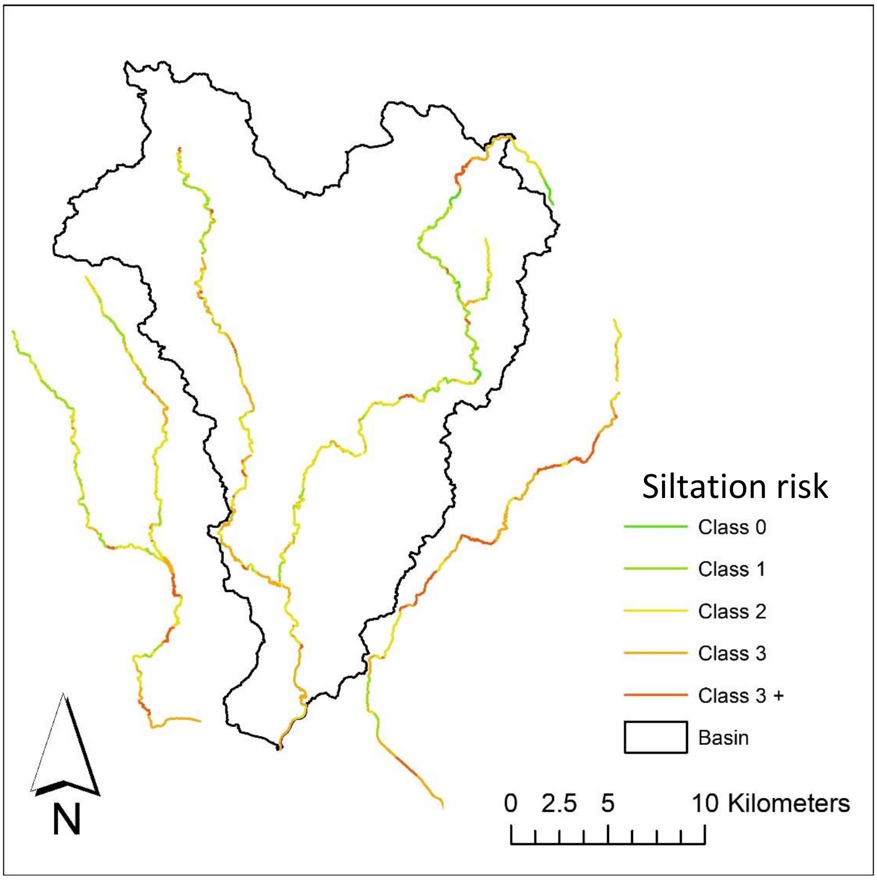


Figure 7: Mapped siltation risk for the main rivers in the Aist catchment (Hauer et al., 2015)

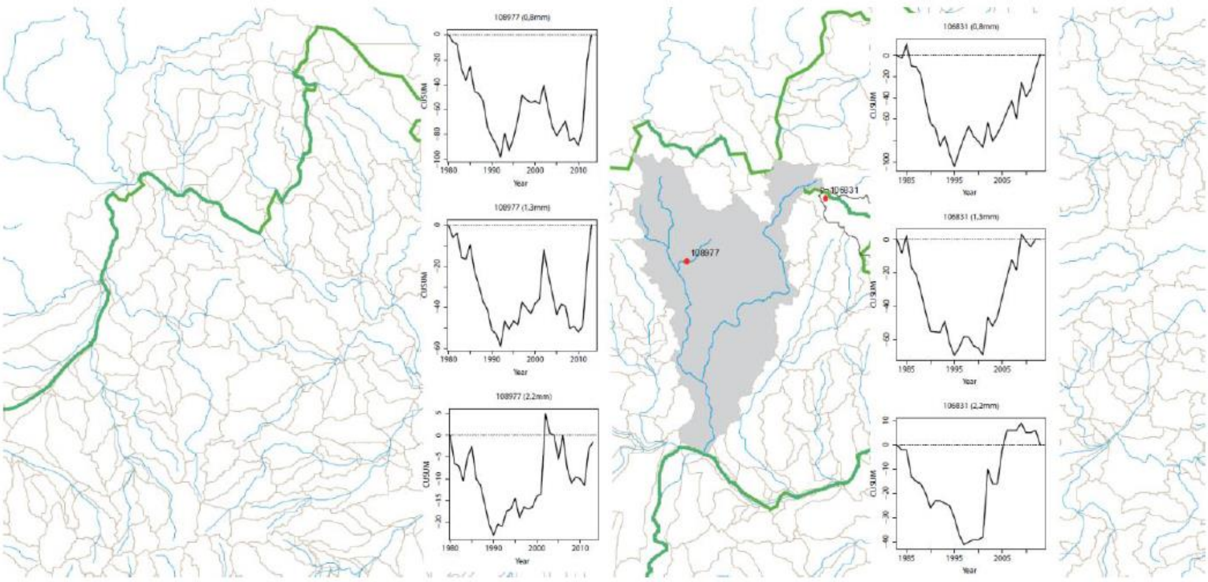


Figure 8: Changes in the precipitation patterns in the region

Previous projects running in the area have identified also climate change as one of the drivers of the fine sediment accumulation (fig. 8). In fact, changes in precipitation patterns (i.e. heavy rainfall events) have supposedly modified the energy that rainfall can develop to detach and mobilize fine sediments. This shows once again the possibility to employ NSWRM to mitigate water and sediment fluxes in this dynamic scenario.

4. VALORIZATION: A MULTI-CRITERIA ANALYSIS

4.1 The valorization method and tool

The aim of the landscape valorization was to identify areas with the highest need for NSWRM in the catchment for one of the overarching goals (1) drought mitigation, (2) flood control, (3) water quality improvement, or (4) sediment balance improvement. Valorization spatial scale (resolution) is based on the concept of spatial planning units (SPUs), which are homogeneous patches of the catchment that are assumed to have uniform response. Input data are processed and synthetized as indicators at the SPU scale. The valorization methodology allows incorporating different indicator classes such as land use, geological background, catchment morphology, climate and hydrology into a multi-criteria analysis. The valorization methodology is static, i.e. indicators are spatially explicit but time-independent. Statistics can be used to summarize multiannual time series of flow and climatic indicators into single values.

The GIS based tool FroGIS (Framework for Retention Optimization) was developed for the requested valorization purposes. Users are able to fill the online tool with their catchment data and get catchment maps and statistics as results showing areas with highest need for measures implementation.

The valorization for the Austrian pilot catchment Aist was performed for the goal "sediment balance", because fine sediments accumulation (siltation) in the rivers is a main problem in the catchment and also a major concern for the responsible regional water and nature protection authorities because it leads to both:

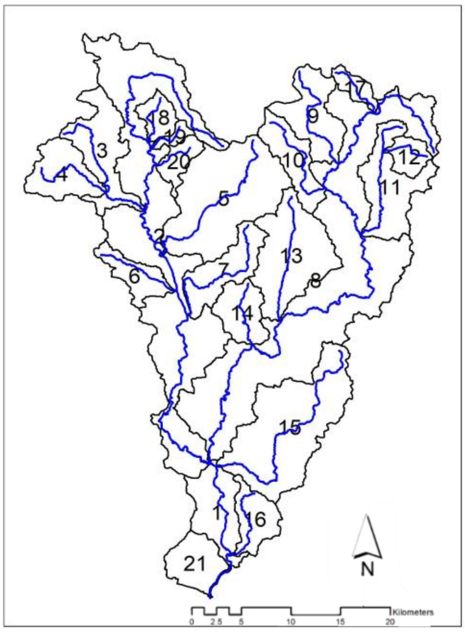
- ecological problems: habitat deterioration for river biota, key species: fresh water pearl mussel (Margaritifera margaritifera)
- hydraulic problems (flood control and protection): raising riverbeds causing decreased flow capacities within the river channels

The reasons for the siltation problem are diverse and a combination of multiple aspects. For a clearer understanding of the underlying processes the sediment aspect has therefore been studied separating the three fields (1) sediments generation, (2) sediment transport off stream, and (3) 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, and on 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 ending up in the river channels 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...).

4.1.1 Spatial planning units choice

Chosen SPUs are 21 sub-basins that are also used by regional water protection authorities, and are overlapping with the computational domain in the dynamic models (fig. 9). This allows the results from the valorization and the results from the dynamic models to be comparable and the choice of variants to be transparent



.

Figure 9: Spatial Planning Units

4.1.2 Input data

Global datasets:

- 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 datasets:

- 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

4.1.3 Indicators

Indicators from the list present in the FroGIS tool (levis-framwat.sggw.pl) were screened and only those related with sediment transport were selected. Additionally, some indicators have been added as user defined indicators:

- PlantedForestDensity
- NaturalForestDensity
- SandRatio

Valorization was performed for three aspects of the catchment sediment balance separately based on the following indicators:

Table 1: Classification of selected indicators

	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, ForestRatio, EcoAraBuf20m, PlantedForestRatio, NaturalForestRatio, ForestryRoadDensity*	EcoAraBuf20m,	
Climate	RainErodibility P_Avg_Ann, P_Avg_Weg	P_Var_a, P_Var_m	
Flow		WaterYieldAvgFlow, WaterYieldMinFlow (overland flow)	WaterYieldAvgFlow, WaterYieldMinFlow, FlowMinAvgRatio, FlowMinMaxRatio, FlowVarRatio_m
Outcome	Valorization map for sediment generation	Valorization map for sediment transport off-stream	Valorization map for sediment transport in stream

Examples of resulting maps for indicators for the pilot catchment:

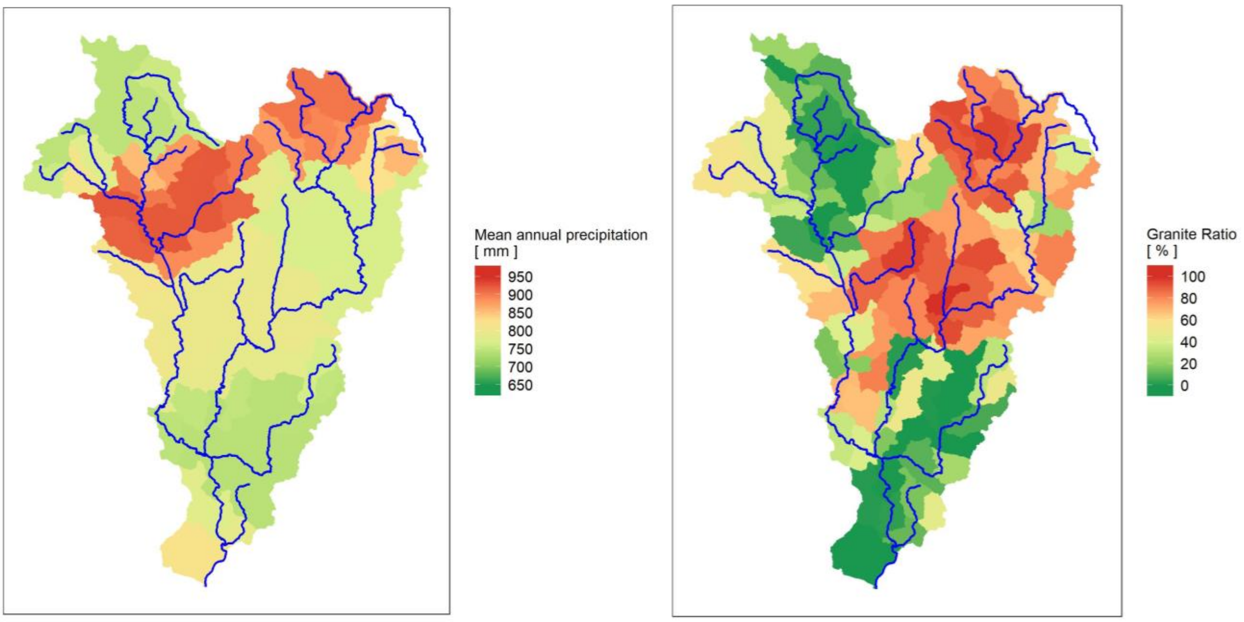
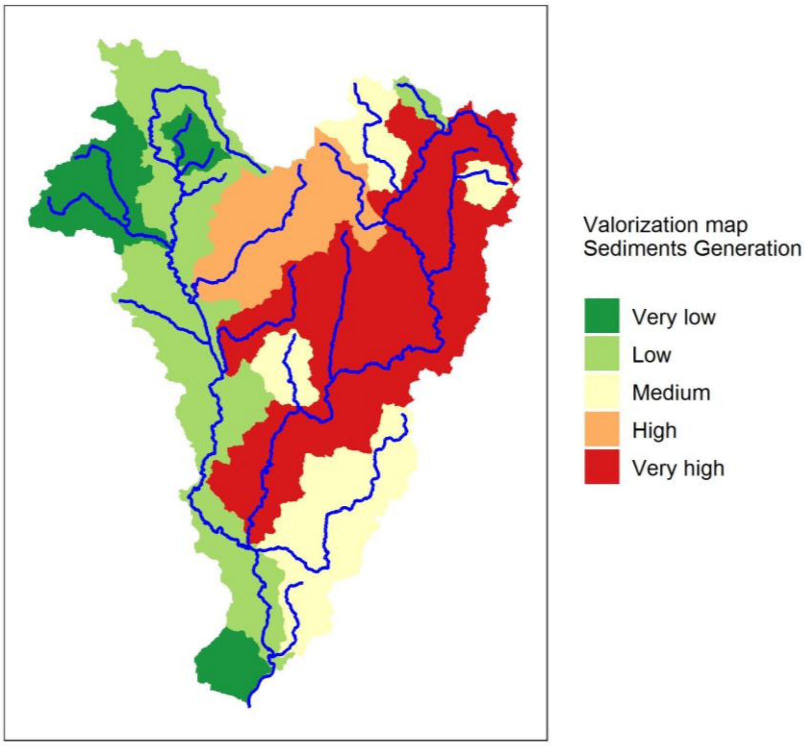


Figure 10: Example maps for selected catchment indicators

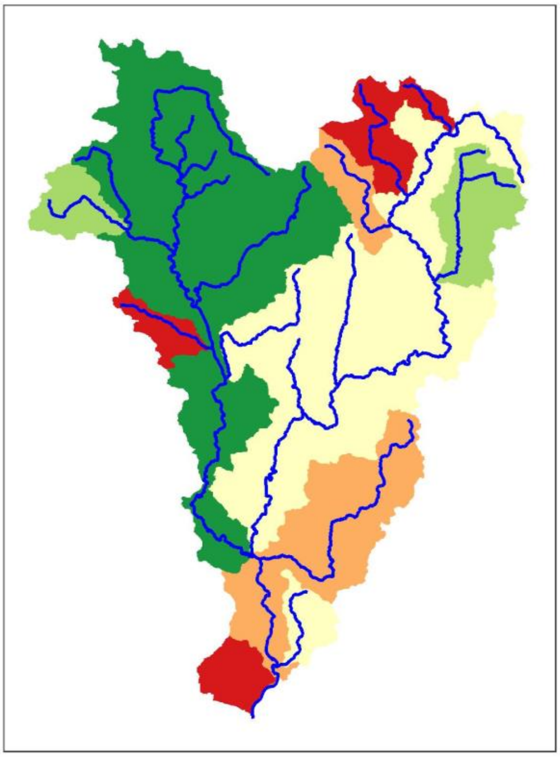
The GIS Tool analysis has been carried out using quantiles for indicators classification (3 classes) and for final aggregation (5 classes). Indicators have been aggregated without weights (all weights were set equal to 1, i.e. all indicators have the same relative importance).
Detailed information on the valorization, as well as user and pre-defined indicators were presented in Deliverable *DT1.3.1 Report from pilot action - testing the prototype of the frogis tool in the river basins.*

4.2 Results of the valorization:

Three different valorization maps were produced for three aspects of the catchment sediment balance separately (Fig. 11):



Valorization map for sediment in- stream transport



Valorization map for sediment off- stream transport

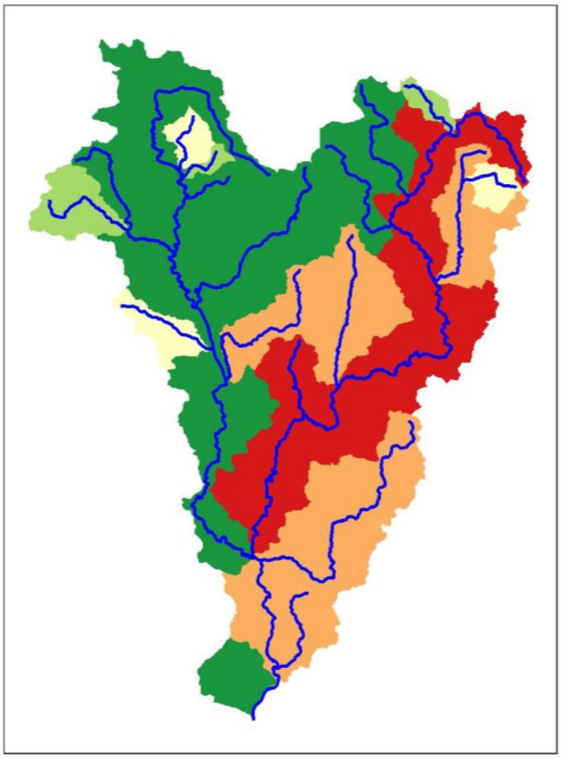


Figure 11: Resulting valorization maps for sediments

4.2.1 Valorization result from field recognition and consultation with regional stakeholders

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. 12 represents the areas in the catchment where water retention needs are higher and has been obtained using data from water framework directive assessment (Fig. 5 and Fig. 6) and expert opinions collected during the field excursion.

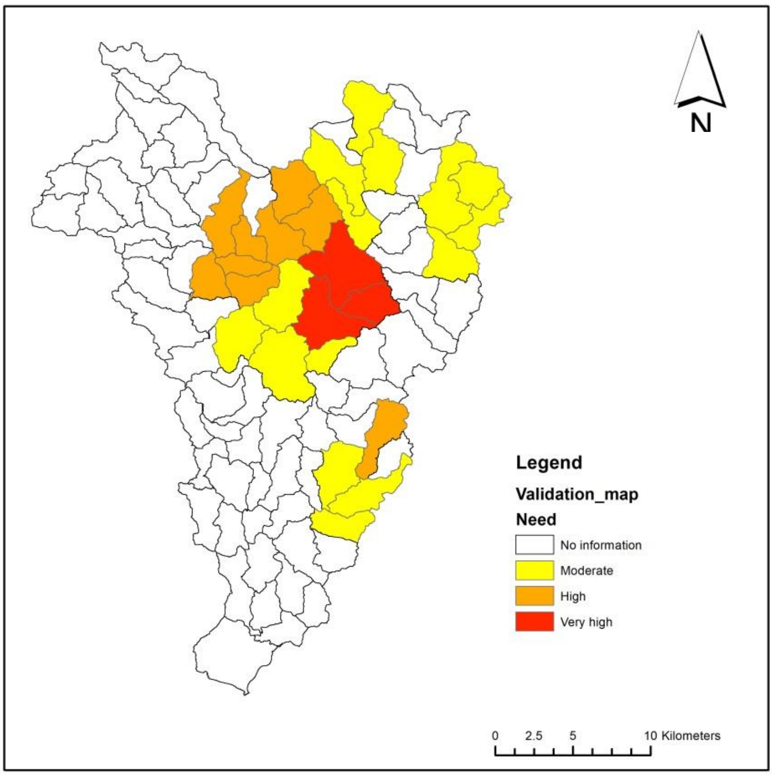


Figure 12: Water retention needs identification based on existing documents and expert opinion

5. DYNAMIC MODELING

5.1 Dynamic modeling methods and tools

Dynamic models are used in this project to :

- Assess the state of the system and the potential for NSWRMs implementation,
- Assess the effectiveness of NSWRMs in a process-based approach.

A brief introduction to the implemented models is reported here; more technical details on the implementation are available in the deliverable *DT2.4.1 REPORT FROM PILOT ACTION – Report from testing the dynamic model to assess cumulative effect of N(S)WRM*.

The following dynamic models have been set up (Fig. 14):

1. SWAT, calibrated at daily time step for hydrology and at monthly time step for hydrology and sediment;
2. Hec-RAS for the whole river network, calibrated for water level;
3. Siltation risk model;
4. Habitat model for Freshwater Pearl Mussel (FPM)

The SWAT model (Arnold et al., 2010) is a semidistributed hydrological model that allows for the simulation of streamflow and sediment loads. Input data to the SWAT model include a digital elevation model, a land use map, a soil map and a climatic dataset (daily rainfall and temperature range). The implemented SWATmodel was calibrated with the SWAT-CUP program and with daily discharge data (5 gauging stations) and monthly sediment loads (5 gauging stations), yielding acceptable results in the calibration (2005-2010, KGE = 0.65 – 0.80) and in the validation (2010-2015, KGE = 0.65 – 0.80) phase. The outputs from SWAT, i.e. the daily hydrograph for every subcatchment and the monthly sediment loads were used in the following modeling steps. Figure 13 shows a map of the SWAT implementation domain.

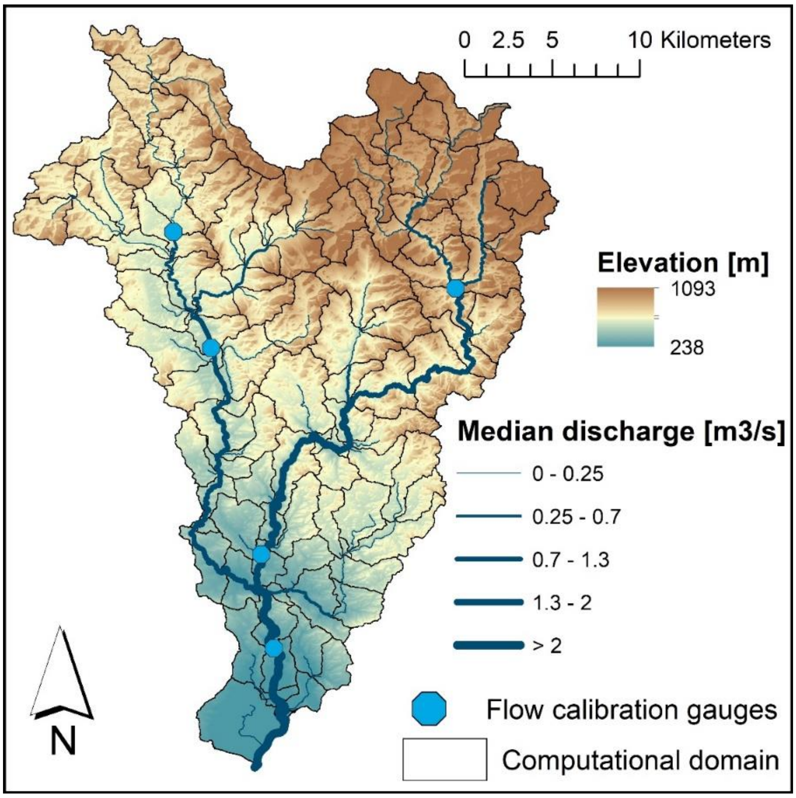


Figure 13: SWAT model computational domain and simulated river network

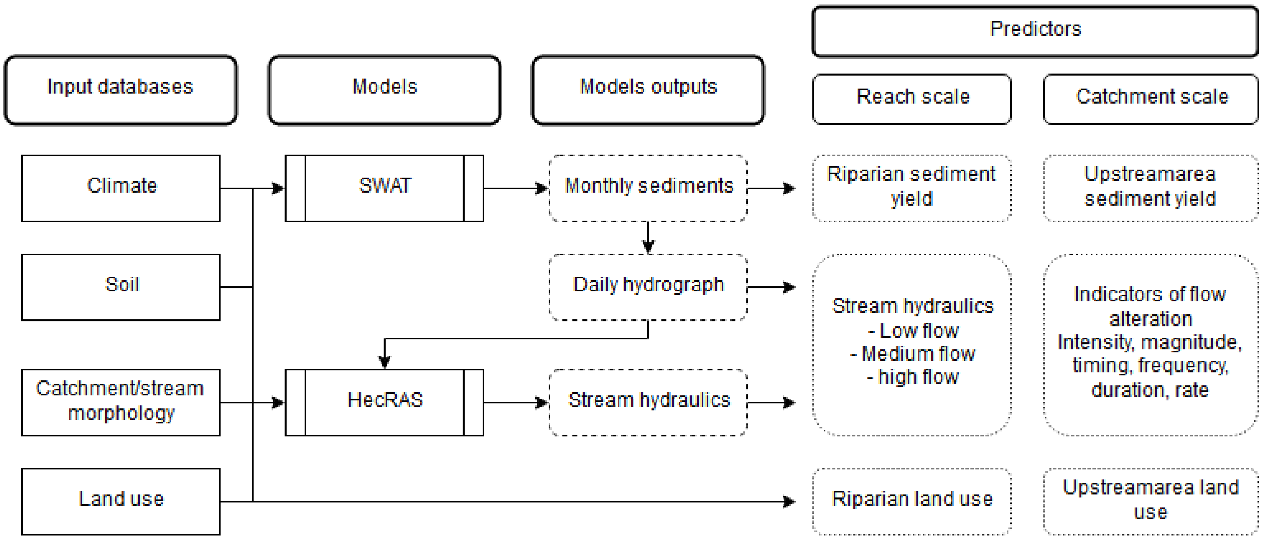


Figure 14: Models integration in the dynamic modeling

Indicators of flow alterations were also derived from SWAT daily hydrograph to assess the dynamic aspects of the hydrograph (Olden and Poff, 2003). The sediment yield out of SWAT was also used in the following modeling steps by computing the sediment input to the stream as the yield divided by the river length. Finally, 10th, 50th and 90th flow percentiles from SWAT daily hydrograph were computed and used as inputs to the HecRAS hydraulic model.

An Hec-RAS model developed by Hauer et al., 2015 was used to assess reach - scale hydraulics. One Hec model for each of the 21 SPUs was used. Flow percentiles obtained from the SWAT daily hydrograph were used to perform static flow profiles in order to assess local hydraulics.

The land use map was finally analyzed at two levels, computing the fraction of tilled, forested, pasture and urbanized land in a 100 m buffer from and in the area upstream every Hec cross section.

Because of the scale mismatch between the computed predictors classes (e.g. some predictors are available at the spatial scale of SWAT subcatchments, whereas others are available at the spatial scale of HecRAS cross section), only a subset of predictors was used in the subsequent models:

- HecRAS hydraulic outputs were used as predictors to assess the siltation risk;
- HecRAS hydraulic outputs and riparian land use were used to assess the habitat abvailability for FPM.

All the predictors were resampled to rasters (resolution 50 m) to allow the models to run on a uniform d ataset.

<u>Siltation risk</u> was assessed by using a generalized linear model (glm). Data collected in a survey con-ducted in the beginning of 2014 were used to calibrate the model (Hauer et al., 2015). The data, present ed in fig. 7 were reclassified to obtain a Boolean description of siltation. The purity of the data was assessed with 0.632 bootsrapping. Stepwise forward selection was used to build up a model with a parsimonous number of hydraulic predictors. The final model (fig. 15) is using the following predictors:

- Water depth (d_LF) and Froude (F_LF) number during low flow;
- Water depth (d_MF) during mean flow;
- Flow velocity (v_HF) and Froude number (F_HF) during high flow;
- High flow – low flow difference in shear stresses (SS_rng) and in water depth (d_rng).

The siltation model performs well (mean AUC = 0.75, bootstrapped range = 0.72 – 0.78) and is therefore suitable to predict siltation.

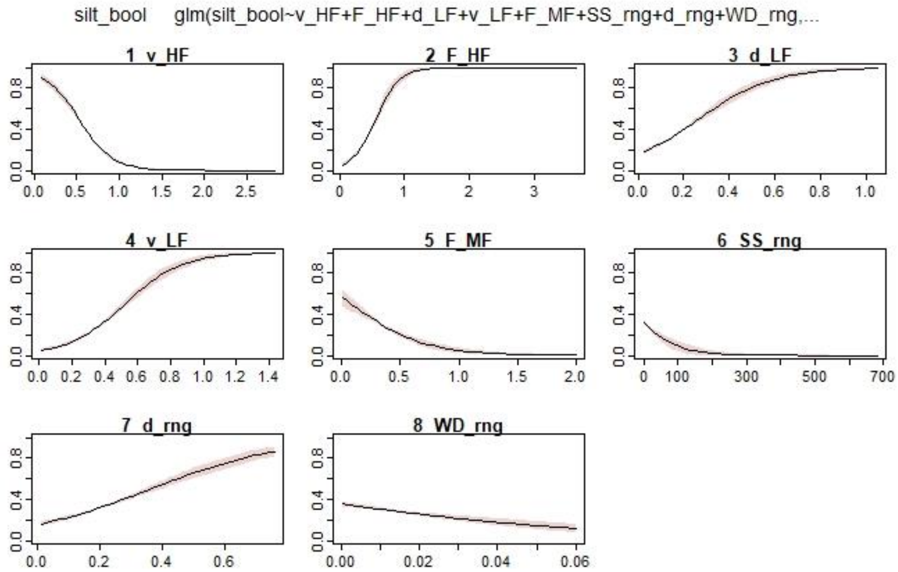


Figure 15: Influence of predictors on siltation risk (0 = no siltation, 1 = siltation).

<u>Habitat for freshwater pearl mussel</u> was assessed using a maximum entropy model (Philipps, 2003) (fig.15). Maxent is a suitable approach for modeling endangered species that do not occupy all the niches that would be available because they are highly disturbed by unmodeled factors.

69 presence points from Jung et al., 2012 were used to calibrate the model toghether with 10000 background values (unknown presence/absence). The stability of the model was assessed with repeated bootsrapping (10 repetitions with 10% of the data used for testing). Riparian land use and hydraulic predictors were used. The model performed well (mean AUC = 0.84, standard deviation = 0.014). Predictors were selected based on the ecological significance and the collinearity was checked before the implementation of the model, leading to a total amount of 9 predictors (fig. 16):

- Froude number for high flow (F_HF) and for low flow (F_LF);
- Specific stream power during low flow (SPs_LF):
- Shear stresses during high flow (SS_HF);
- Flow velocity during high flow (v_HF);
- Flow depth during low flow (d_LF);
- Agricultural, pasture and forestry riparian land use LU_AG_rip, LU_PA_rip, LU_FR_rip).

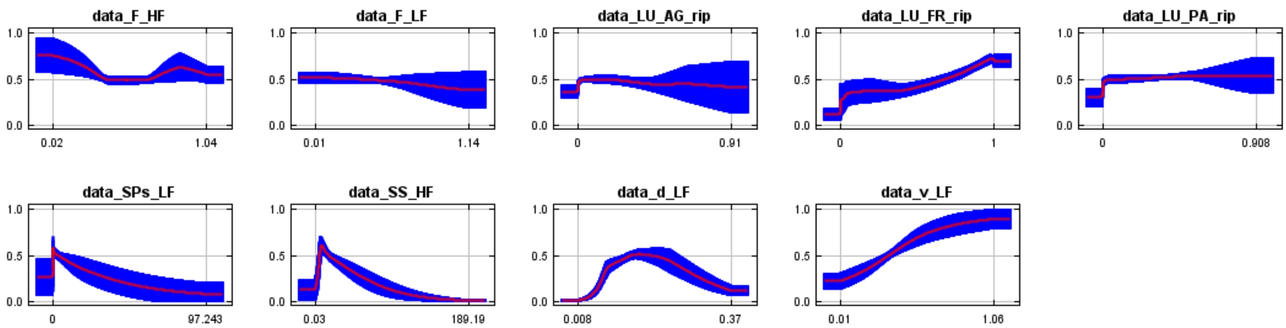


Figure 16: Response of the maxent model to the predictors.

The outputs of the siltation and habitat models are presented in fig. 17. It has to be noted that the habitat availability only represents potential habitat. Also, the results are to be interpreted in a probabilistic way, so that a value of 1 shows that a specific site has an high likelihood to be affected by siltation or to be a suitable site for the freshwater pearl mussel.

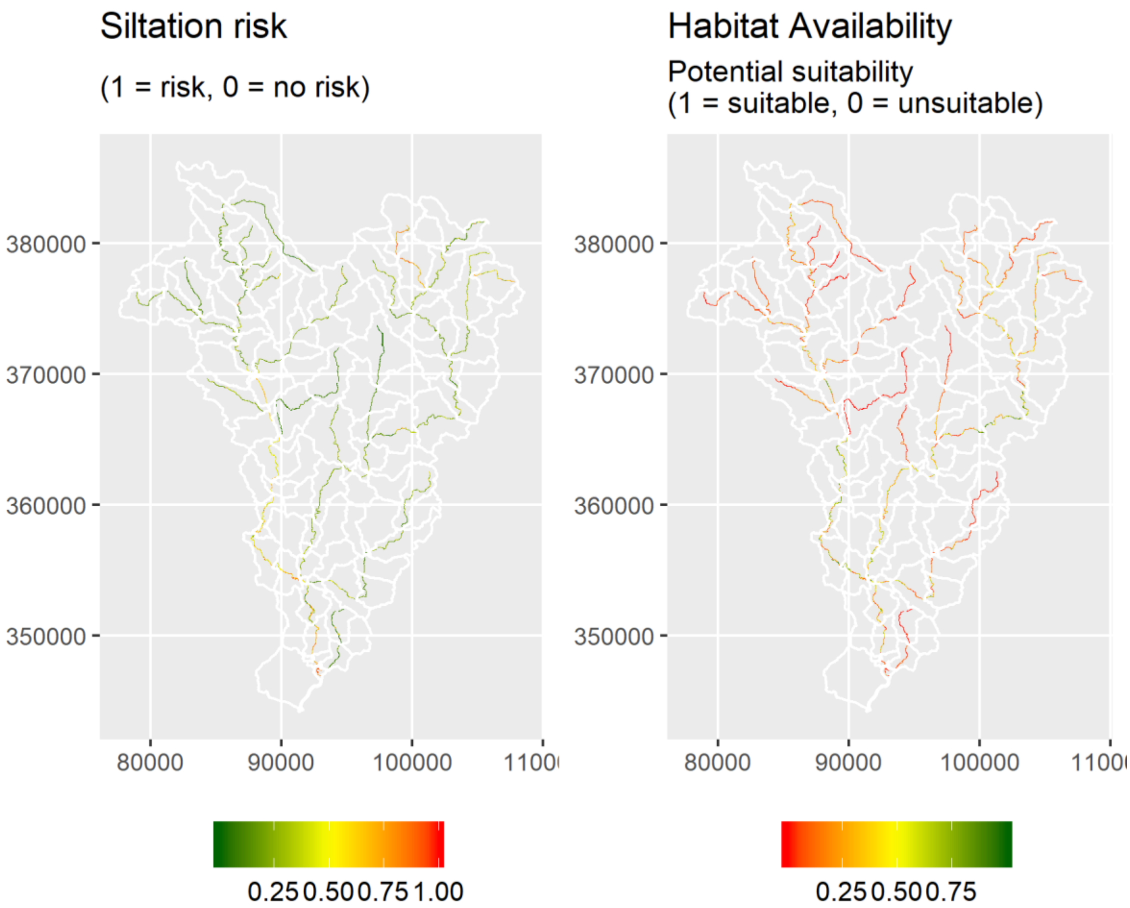


Figure 17: habitat and siltation model outputs for the river network raster.

5.2 Dynamic modeling outputs

The results of the dynamic models were aggregated with the same spatial resolution like the FroGIS outputs in order to allow for direct comparisons of the two methods.
Two descriptors were used for the aggregation:

- The mean value of the raster cells is an indication of the relative area of the river in the SPU that is under siltation risk or is potentially suitable for FPM;
- The sum of the raster cell values is an indicator of the absolute river length that is available for FPM or that is occupied by fine sediments.

Finally, the sensitivity of the habitat to siltation loadings was assessed by multiplying the potential habitat times the probability that a potential site is free from siltation:

$$HSI_{diff} = HSI_{mod} - HSI_{mod} * (1 - Silt)$$

Where HSI_{diff} is the difference between potential suitability and the suitability affected by siltation; HSI_{mod} is the modelled habitat suitability and $Silt$ is the probability of siltation risk. Results are presented in fig. 18 and 19.

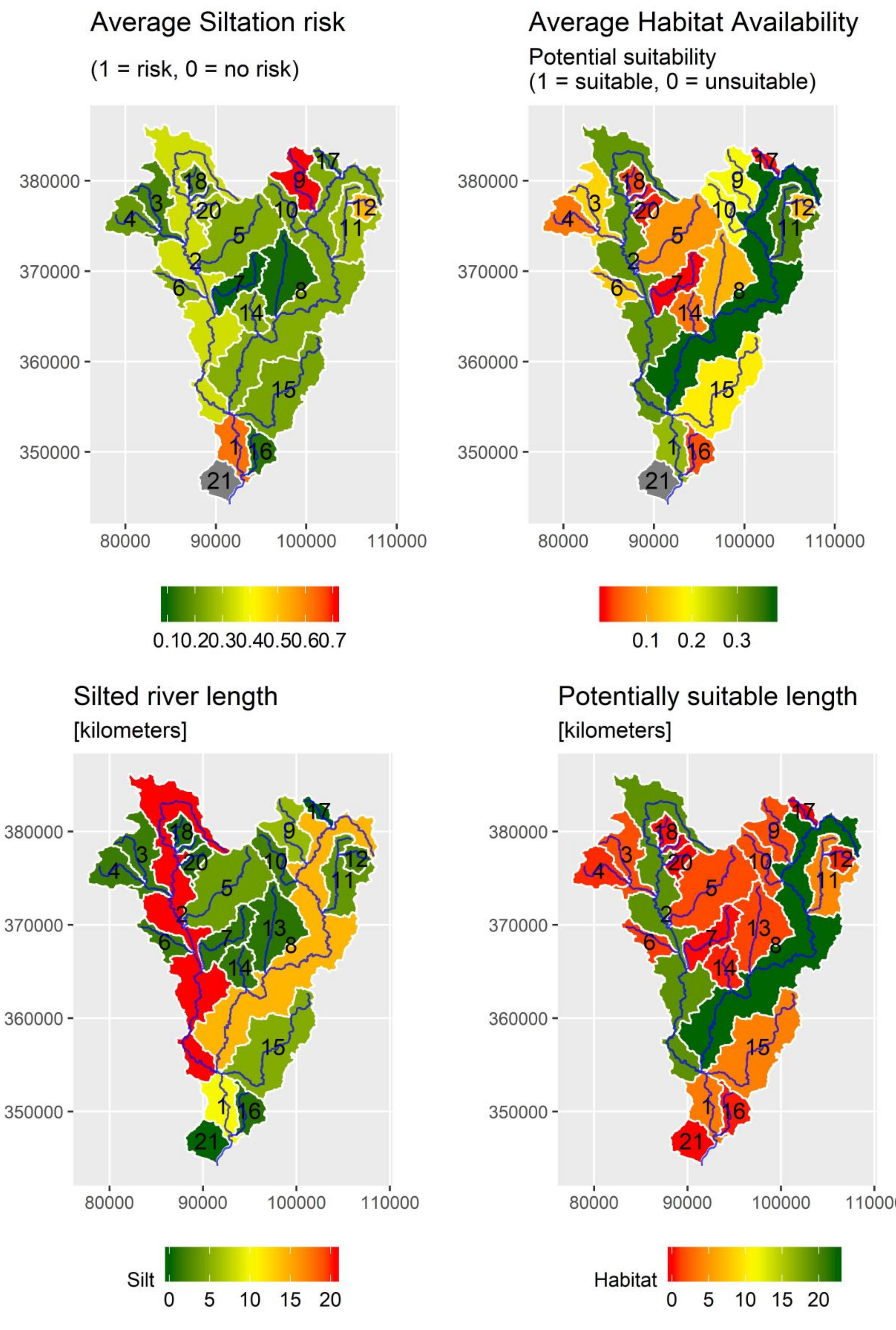


Figure 18: Resulting valorization maps for sediments. Numbers in the map refer to the SPUs' ID code.

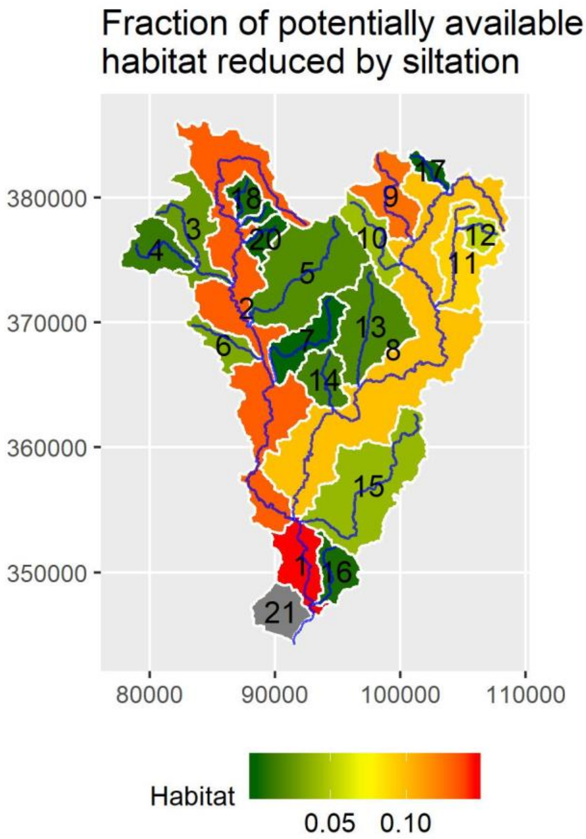


Figure 19: Fraction of the potential habitat that is lost due to siltation risk. Numbers in the map refer to the SPUs' ID code.

5.3 Uncertainties in the dynamic modelling procedure

The presented results allow for a model-based identification of the state of the system. However, uncertainties exist that are related with the correct selection of predictors from a broad set and with the up-scaling procedure. The description of siltation risk based on the glm can be improved by incorporating in the model also the hydrological indicators of flow alterations and the sediment loads out of SWAT.

6. DEFINING VARIANTS

Already existing measures as well as planned measures have to be taken into account in the future measures variant definitions. At the moment the following measures affect the sediment aspect in the catchment:

- cross sectional modifications to reduce sediment transport during periods with high flows (hudromorphological modifications);
- 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. These latter measures are small artificial floodplains that trap fine sediments during high flow periods.

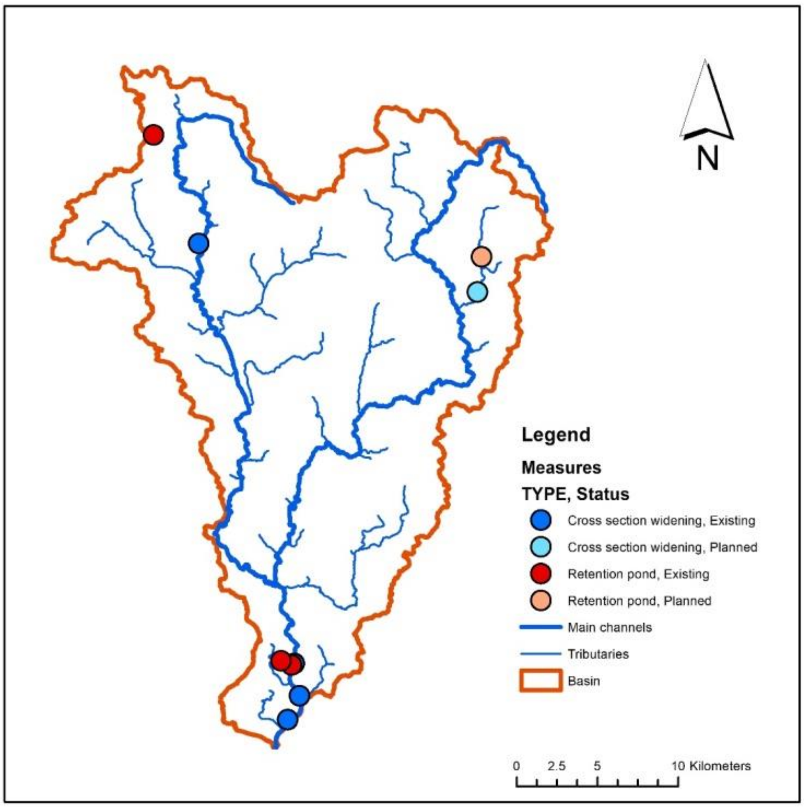


Figure 20: Existing and planned retention measures affecting the sediment issue in the Aist catchment

Further measures can be planned based on the above-mentioned valorization results and based on static and dynamic modelling results.

With the help of the above mentioned models three variants will be analyzed which will be described in more detail in the following sub-chapters:

1. Baseline Scenario
2. Threshold Varian
3. Expert Variant

These variants were chosen because there is no strategic plan yet on how to develop water retention with the help of NSWRM at catchment scale. Implementation and planning of NSWRM at the moment happens at local scale only. Potential effects of measure combinations at catchment scale on sediment input, transport, and on habitat availability are of special interest for regional water and nature protection authorities.

The scale of the analysis is the tributary level (21 stretches modeled with HecRAS). The tributaries subcatchments are overlapping with the 21 SPUs the valorization was carried out.

6.1 Baseline Scenario

The baseline scenario includes the following information: SWAT provides information on where sediment hotspots are located; Hec-RAS provides information on the siltation risk; Habitat model provides information on the potential sites available for FPM. It is important to notice that a hypothetical variant based on the stakeholders' planned measures in the area can still be considered as part of the baseline scenario because the planned measures are so small that a change at the catchment scale is not visible.

6.2 Variant 1: Threshold Variant

The aim is to assess threshold effects in the implementation of certain NSWRM.
The question is, if there is a critical threshold (volume, area coverage) that leads to a change in the river habitat when NSWRM are implemented. The measures that will be tested in SWAT are so-called sediment ponds. They simultaneously increase water retention and trap sediments.
This measure has been chosen to investigate threshold effects because it allows simulating any kind of increase in water retention in a transparent way. In fact, the parameters that are involved in the definition of the retention ponds in SWAT are the pond volume (amount of water retained), the pond area (amount of landscape that is affected by the implementation of the measure) and the bottom permeability (amount of water that is transferred from superficial to sub-superficial/groundwater flow)

6.3 Variant 2: Expert Variant

Based on habitat and sediment hotspots in the baseline scenario and on threshold effects determined in variant 1, a set of NSWRMs is proposed. The EU inventory will be filtered based on SWAT feasibility and on on-site feasibility. Single measure effects and combined effects are investigated.

7. MEASURES TESTING

The static tool and the dynamic models are two complementary approaches:

- The static tool relies on simple datasets and on expert opinion and is useful to assess the effectiveness of large sets of NSWRMs over broad spatial ranges;
- The implementation of NSWRMs on dynamic models requires more effort, therefore those models are more suited for a targeted approach.

Combining the information available on NSWRMs, expert opinions and local stakeholders knowledge, a set of measures is proposed and the potential spatial siting is discussed based on the results of the valorization and the baseline scenario from the dynamic models.
The selected measures were allocated to specific SPUs based on the results of the valorization method. The testing of such test of measures within the static tool would allow for a preliminary screening of potential applications for the dynamic models.

7.1 List of Measures to be tested

Various NSWRM were chosen from the EU catalogue of Natural Water Retention Measures for the three overarching goals addressing the sediment aspect in the catchment for the expert variant. The rationale for the choice of the below listed measures are:

1. These measures can be modelled both with the static method and the dynamic modelling cascade, allowing a comparison of the results and a better estimation of the effectiveness of the implemented measures.
2. The feasibility of the measures implementation due to catchment characteristics and restraints and due to stakeholders' expectations and restrictions.

<u>Measures for the goal "sediment generation":</u>

- WRAL - Water retention in agricultural lands through various best management practices, e.g. Crop rotation, strip cropping along contours, no/low till agriculture, green cover, early sowing...

<u>Measures for the goal "sediment in-stream transport":</u>

- BPRC - Natural channels and best practices of river channels maintenance/ improvements, e.g. riverbed material re-naturalization, stream bed re-naturalization, natural bank stabilization
- BPDA - Best practices on drained areas: small sediment retention ponds (located in-stream and off-stream)

<u>Measures for the goal "sediment off-stream transport":</u>

- BPDA - Best practices on drained areas, small sediment retention ponds (located in-stream and off-stream)
- A02 - buffer strips and hedges: mainly between (or across) fields, also along water courses

or

- F01 – Forest riparian buffers: tree covered areas alongside streams

7.2 Siting of measures to be tested with the static tool

The purpose of the Static Method is to enable the estimation of the effects of a set of NSWRM in a simplified way, which does not require a time-consuming and costly to set up, detailed hydrological model of the analyzed catchment. It is based on the results of the Valorization (see Chapter 4) and assumes that measures should be taken in those SPUs showing the highest need for action. The tool has a universal character due to the size of the analyzed area and regional climatic and geographical conditions but requires the involvement of experts with experience in planning and implementation of small water retention measures.

Workflow:

1. The SPUs showing class 5 and showing class 4 in the valorization process were chosen for the three different aspects of the sediment balance of the region (table 2, figure 24).
2. The areas of maximum implementation for the intended measures were calculated in GIS for each SPU.
3. Intensity classes (high, medium, low) for the various measures implementations were chosen based on expert judgement and recommendations, and applied to the affected SPUs.
4. With the help of the Static Tool (Excel spreadsheet) the improvement values were calculated for the selected measures.
5. Partial results are presented for each SPU and each activity, summary results for the SPU, results related to the implementation of a specific type of activities in the catchment and the total result for the whole catchment (all SPUs).

Table 2: List of SPUs, and SPUs showing valorization results of classes 5 and 4

SPU	Reach	Sediment generation	Off stream transport	In stream transport
1	Aist		4	4
2	Feldaist			
3	Jaunitzbach			
4	Kronbach			
5	Feistritzbach	4		
6	Lesterbach			5
7	Flanitzbach	5	4	
8	Waldaist	5	5	
9	Flammbach			5
10	Harbaist	4		4
11	Weisse Aist	5	4	
12	Fuchsreiterbach			
13	Stampfenbach	5	4	
14	Klammbach		5	
15	Kettenbach		4	4
16	Aisthofener Bach		4	
17	Grezenbach			5
18	Lichtenauenbach			
19	Gruenbach			
20	Schlager Bach			
21	Lowland catchment			5

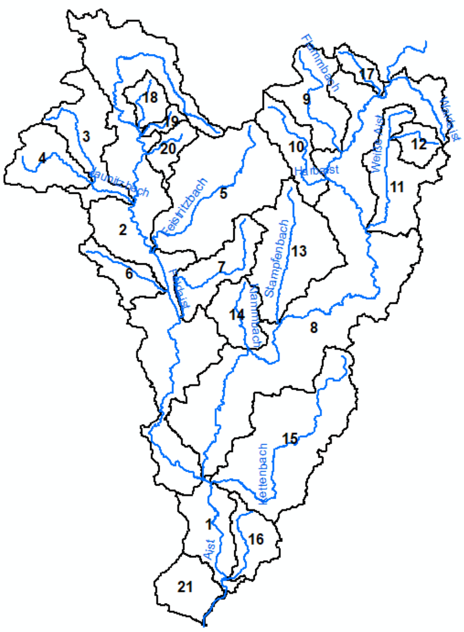


Figure 21: SPUs of the catchment

Detailed information on the Static Method are presented in Deliverable D.T2.2.1 Static method to assess cumulative effect of N(S)WRM in the river basins, detailed information on the Static Method Testing in the Pilot catchment are presented in Deliverable D.T2.2.2 Reports from testing the static method to assess cumulative effect of N(S)WRM.

7.3 Siting of measures to be tested with the dynamic models

The dynamic modeling results also allow for the SPU prioritization based on siltation risk, potential habitat availability and potential impacts of siltation on habitat (Table 3).

Table 3: Prioritization of SPUs for water retention measures based on the results of the dynamic models simulations.

SPU	Reach	Siltation risk	Potential habitat	Siltation affects habitat
1	Aist	X	X	X
2	Feldaist	X	X	X
3	Jaunitzbach			
4	Kronbach			
5	Feistritzbach			
6	Lesterbach			
7	Flanitzbach			
8	Waldaist		X	X
9	Flammbach	X		X
10	Harbaist			
11	Weisse Aist		X	X
12	Fuchsreiterbach	X		
13	Stampfenbach			
14	Klammbach			
15	Kettenbach			
16	Aisthofener Bach			
17	Grezenbach			
18	Lichtenauenbach			
19	Gruenbach			
20	Schlager Bach			
21	Lowland catchment			

The results from the dynamic modeling are matching with the results from the static method. The lower part of the Aist, Feldaist, Waldaist, Flammbach, Weisse Aist amd Fuchsreiterbach were identified by both the methods as reaches where the sediment budget is unbalanced and the habitat is compromized because of this.

Detailed information on the Application of the dynamic models are presented in Deliverable *D.T2.4.1 Reports from testing the dynamic model to assess cumulative effect of N(S)WRM (Pilot Action)*

8. FINAL CONCEPT FOR THE AIST PILOT AREA

Based on the results from the FroGIS and the dynamic models, the concept for measures testing in the pilot catchment area is presented.

The measures testing will be carried out with two steps.

- A broad screening with the static tool to identify areas/reaches with higher potential response to implementation (Table 4);
- A focused testing with the dynamic model (Table 5 and 6).

The implementation intensity is not reported in the dynamic models plans because it is itself an output of the modelling procedure with the help of the threshold variant.

The proposed concept plan builds on the results of the valorisation method and the dynamic modelling and presents independently the results from the two methodologies to build an evidence-based structured assessment of potential NSWRMs siting. The analyses highlighted that the planning process for NSWRMs in the pilot catchment area is still at an elementary stage therefore the concept has been developed to be a feasibility study.
However, there is a big potential for NSWRMs implementation in the catchment to solve the siltation issue and create new/re-create habitat for the endangered FPM.
The different sets of proposed measures will be evaluated on the basis of a unified modelling framework that will support a transparent choice of the best set of measures to address the pilot catchment issues.

Table 4: Position and typology of measures screened with the static tool

SPU	Tributary name	Measures addressing Sediment generation	Measures addressing Off stream transport	Measures addressing In stream transport
1	Aist		• Small sediment retention ponds (BPDA) • Buffer strips along water courses Implementation intensitiy: medium	• Small sediment retention ponds (BPDA) • River channel improvements (BPRC) Implementation intensitiy: medium
2	Feldaist			
3	Jaunitzbach			
4	Kronbach			
5	Feistritzbach	• Agricultural management practices fostering water retention (WRAL) Implementation intensitiy: medium		
6	Lesterbach			• Small sediment retention ponds (BPDA) • River channel improvements (BPRC) Implementation intensitiy: high
7	Flanitzbach	• Agricultural management practices fostering water retention (WRAL) Implementation intensitiy:	• Small sediment retention ponds (BPDA) • Buffer strips along water courses	

		high	Implementation intensitiy: medium	
8	Waldaist	• Agricultural management practices fostering water retention (WRAL) Implementation intensitiy: high	• Small sediment retention ponds (BPDA) • Buffer strips along water courses Implementation intensitiy: high	
9	Flammbach			• Small sediment retention ponds (BPDA) • River channel improvements (BPRC) Implementation intensitiy: high
10	Harbaist	• Agricultural management practices fostering water retention (WRAL) Implementation intensitiy: medium		• Small sediment retention ponds (BPDA) • River channel improvements (BPRC) Implementation intensitiy: medium
11	Weisse Aist	• Agricultural management practices fostering water retention (WRAL) Implementation intensitiy: high	• Small sediment retention ponds (BPDA) • Buffer strips along water courses Implementation intensitiy: medium	
12	Fuchsreiterbach			
13	Stampfenbach	• Agricultural management practices fostering water retention (WRAL) Implementation intensitiy: high	• Small sediment retention ponds (BPDA) • Buffer strips along water courses Implementation intensitiy: medium	
14	Klammbach		• Small sediment retention ponds (BPDA) • Buffer strips along water courses Implementation intensitiy: high	
15	Kettenbach		• Small sediment retention ponds (BPDA) • Buffer strips along water courses Implementation intensitiy: medium	• Small sediment retention ponds (BPDA) • River channel improvements (BPRC) Implementation intensitiy: medium
16	Aisthofener Bach		• Small sediment retention ponds (BPDA) • Buffer strips along water courses Implementation intensitiy:	

			medium	
17	Grezenbach			• Small sediment retention ponds (BPDA) • River channel improvements (BPRC) Implementation intensitiy: high
18	Lichtenauenbach			
19	Gruenbach			
20	Schlager Bach			
21	Lowland catchment			• Small sediment retention ponds (BPDA) • River channel improvements (BPRC) Implementation intensitiy: high

Table 5: Plans for measures implementation in the dynamic model

SPU	Tributary name	Siltation risk and habitat improvement
1	Aist	BPDA, WRAL, A02
2	Feldaist	BPDA, WRAL, A02
3	Jaunitzbach	
4	Kronbach	
5	Feistritzbach	
6	Lesterbach	
7	Flanitzbach	
8	Waldaist	BPDA, BPRC, F01
9	Flammbach	BPDA, BPRC, F01
10	Harbaist	
11	Weisse Aist	BPDA, F01
12	Fuchsreiterbach	BPDA, F01
13	Stampfenbach	
14	Klammbach	
15	Kettenbach	
16	Aisthofener Bach	
17	Grezenbach	
18	Lichtenauenbach	
19	Gruenbach	
20	Schlager Bach	
21	Lowland catchment	

Table 6: Concept of the tested measures with the dynamic models

VARIANTS	MEASURES TESTED	INFORMATION GAIN
BASELINE	NO	Position of sites prone to siltation risk; position of sites suitable for FPM
THRESHOLD APPROACH	Retention ponds	Existence of threshold effects for the implementation of water retention
EXPERT	WRAL BPRC BPDA BPDA A02 F01 (see section 7.1)	Effectiveness of the proposed set of measures, focused testing on local and catchment scale, effect on siltation and habitat

9. REFERENCES

Haines-Young, R. and M.B. Potschin (2018): Common International Classification of Ecosystem Services (CICES) V5.1and Guidance on the Application of the Revised Structure.

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.

Jung, M., Scheder, C., Gumpinger, C., & Waringer, J. (2013). Habitat traits, population structure and host specificity of the freshwater pearl mussel Margaritifera margaritifera in the Waldaist River (Upper Austria). Biologia, 68(5), 922-931.

Olden, J. D., & Poff, N. L. (2003). Redundancy and the choice of hydrologic indices for characterizing streamflow regimes. River Research and Applications, 19(2), 101-121.

Arnold, J. G., Moriasi, D. N., Gassman, P. W., Abbaspour, K. C., White, M. J., Srinivasan, R., ... & Kannan, N. (2012). SWAT: Model use, calibration, and validation. Transactions of the ASABE, 55(4), 1491-1508.