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


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Pilot catchment Kamniska Bistrica

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## TABLE OF CONTENT




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# 1. PURPOSE AND SCOPE OF TEST

The purposes of the test were:

- To apply FroGIS to the Slovenian pilot catchment.
- To develop valorization maps for existing flooding issues in the pilot area.
- 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.

The result of testing in Kamniška Bistrica river basin is cartographic display of areas with low, medium and high need for N(S)WRM implementation. The scope of testing:

- Data preparation;
- Data validation;
- Testing;
- Results validation.

Also, purpose of testing the prototype of Frogis tool in Kamniska Bistrica river basin was to asses and validate the tool. The outcomes of the model will be used for its refinement and finalization. FroGis produces outputs that will be used by national stakeholders for the river basin management.

# 2. CHARACTERISTICS OF THE CATCHMENT

The Kamniska Bistrica River catchment was chosen as a pilot catchment because of its diverse character, ranging from wooded subalpine hills to lowland plains, which are highly urbanized. The main problem within the catchment are relatively frequent floods. As for water quality, Kamniska Bistrica River has moderate to very good ecological status. Although a large part of the settlements are connected to a sewage system and central WWTP, water in lower parts of the catchment is occasionally polluted, especially in summer months when the main channel is almost dry and the water temperature rises. Other sources of water pollution are sewage overflows during flood events. In its middle and lower part, Kamniska Bistrica River is highly regulated due to its hydropower potential and as protection against floods. This part of the catchment is covered with a dense network of artificial channels that used to supply water for the operation of water- and sawmills. Today, they are mainly used for supplying small hydropower plants.

*Table 1: Characteristics of the catchemnt*

| ***Characteristic*** | ***Unit*** | ***Value*** |
|---|---|---|
| *Character of catchment* | | *Upper part: highland; wooded, sparsely populated*<br><br>*Middle and lower part: lowland; highly urbanized* |
| *Catchment size:* | *km²* | *539* |
| *Average flow low/avg/high** | *m³/s* | *2.2/7.9/67.2* |
| *Extreme flow low/high** | *m³/s* | *0.9/282* |
| *Annual precipitation low/avg/high*** | *mm* | *998/1383/1851* |
| *Annual air temperature min/avg/max*** | *ºC* | *9/11/13* |
| *Agriculture area* | *%* | *34.5* |
| *Urban area* | *%* | *8.2* |
| *Forest area* | *%* | *54.1* |
| *Open Water area* | *%* | *2.8* |
| *Flooded area (1/100 years)* | *km²* | *0.4* |
| *Artificial drainage area* | *km²* | *12.7* |

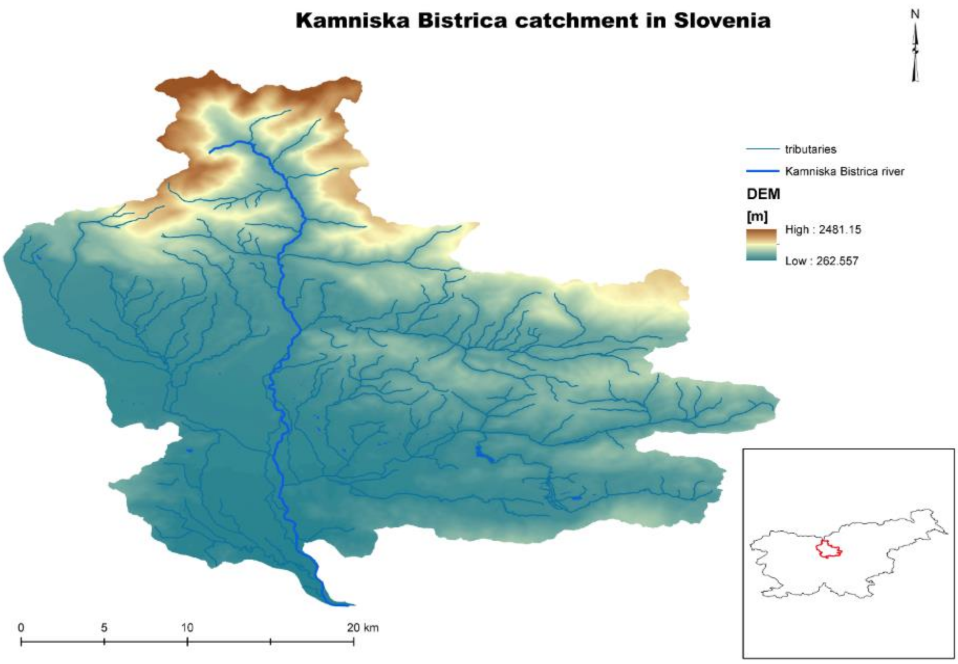


*Figure 1:Kamniska Bistrica morphology.*

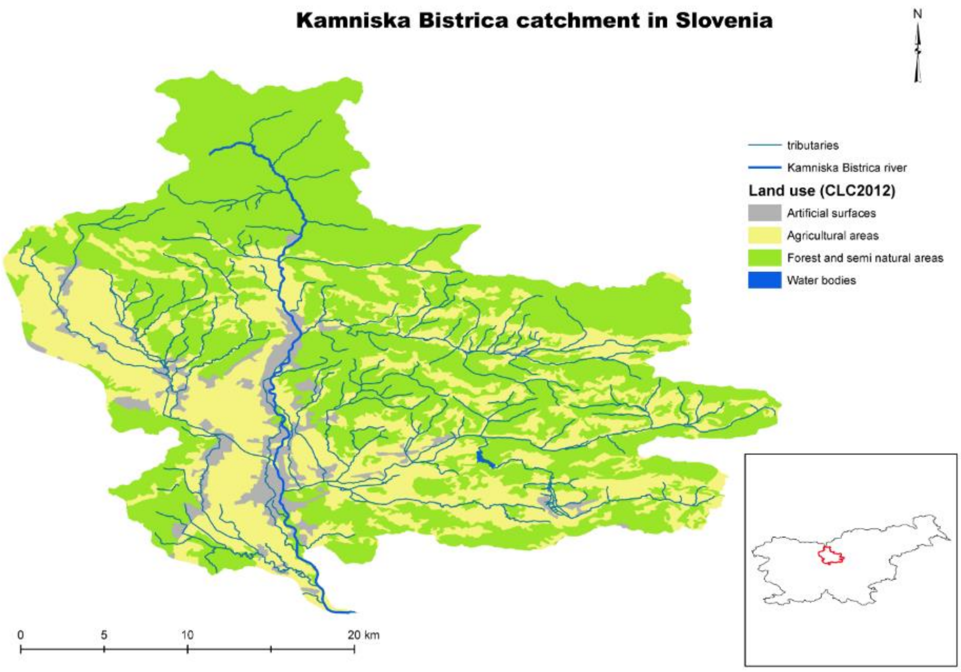


*Figure 2: Aist catchment land use.*

# 3. ISSUES IDENTIFIED IN THE CATCHMENT

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

Due to the development activities in catchment over the last decades and its characteristics (see chapter 1) the Kamniska Bistrica catchment shows the following main problems:

- Flooding of urban areas;
- Hydro-morphological alternations due to river regulation.
- There are no problems with the chemical status.

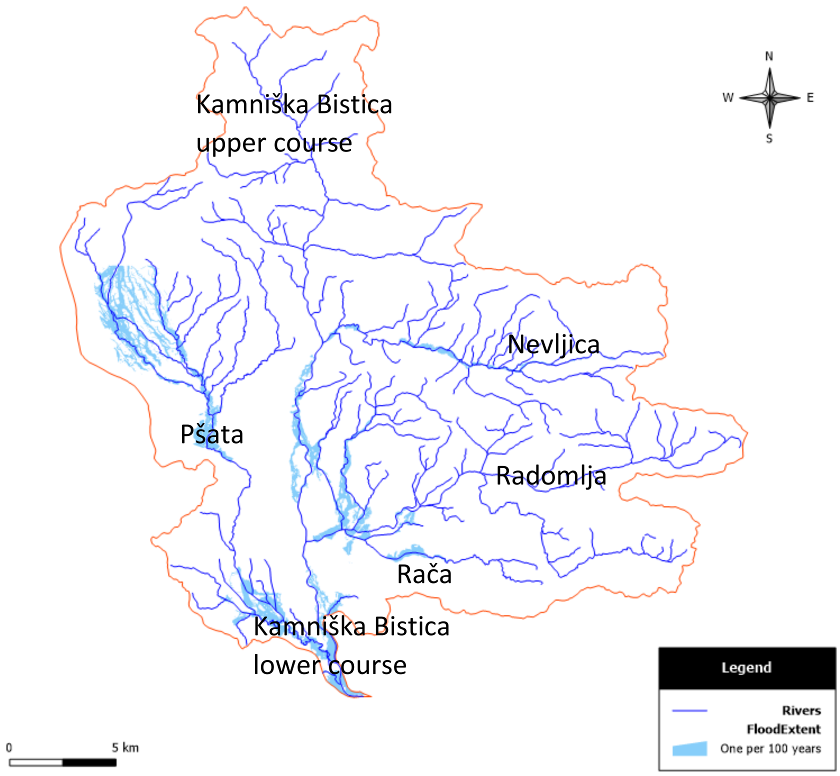


*Figure 3: Flood extent map with a return period of 1/100 years (Slovenian Water Agency[1], 2018).*

There are 5 water bodies within the catchment: Kamniska Bistrica, Psata, Radomlja, Raca and Nevljica. Figure 3 shows flood extent with a return period of 1/100 years which means that those areas are flooded in every 100 years.

[1] https://gisportal.gov.si/portal/apps/webappviewer/index.html?id=11785b60acdf4f599157f33aac8556a6

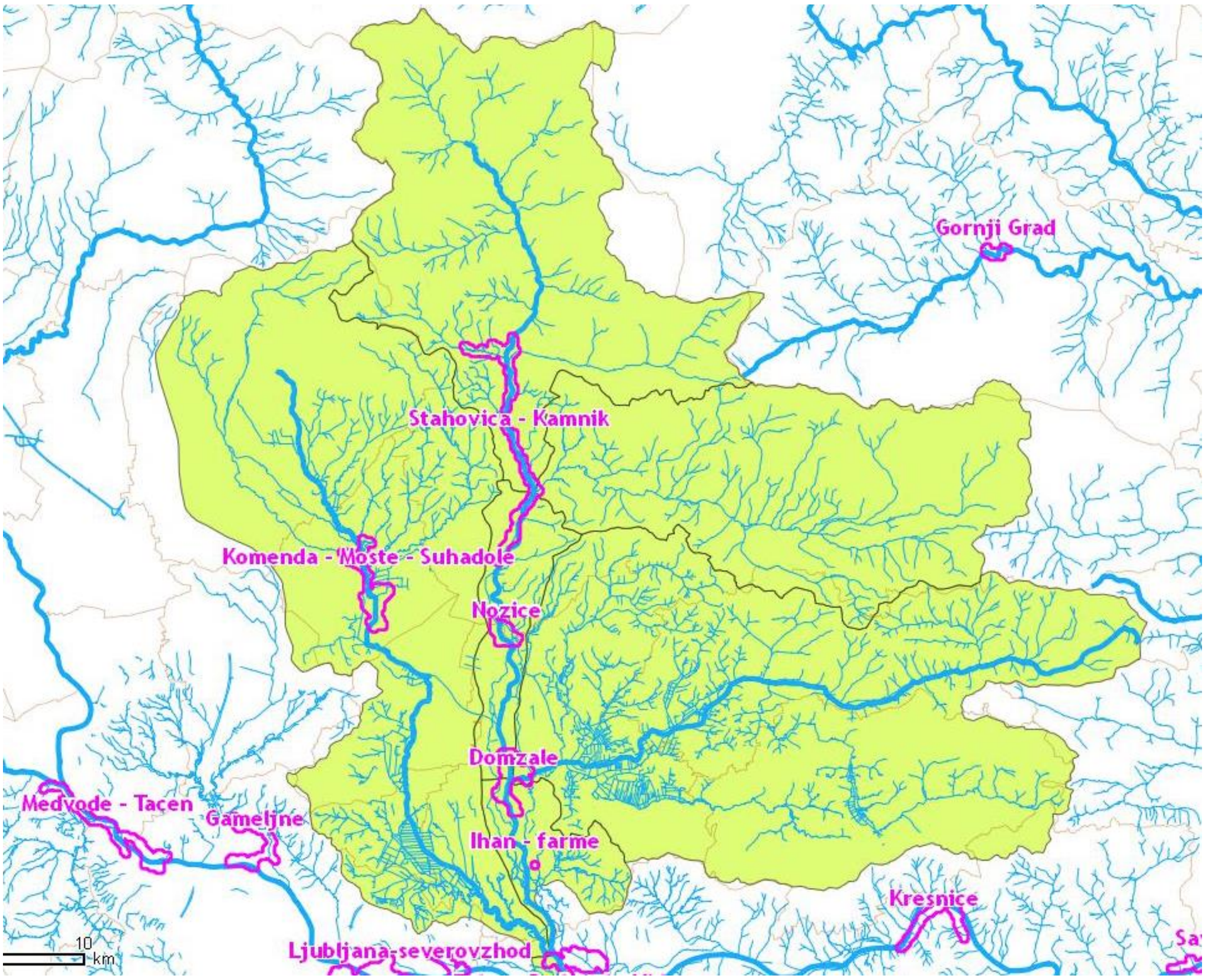


*Figure 4: Risk areas (Slovenian Water Agency[2], 2018).*

In Kamniska Bistrica catchment there are five areas of significant impact of floods: Stahovica-Kamnik, Komenda-Moste-Suhadole, Domžale, Nožice and Ihan- farms.

[2]http://www.mko.gov.si/fileadmin/mko.gov.si/pageuploads/podrocja/voda/opvp/09_Kamniska_Bistrica_OPVP.jpg

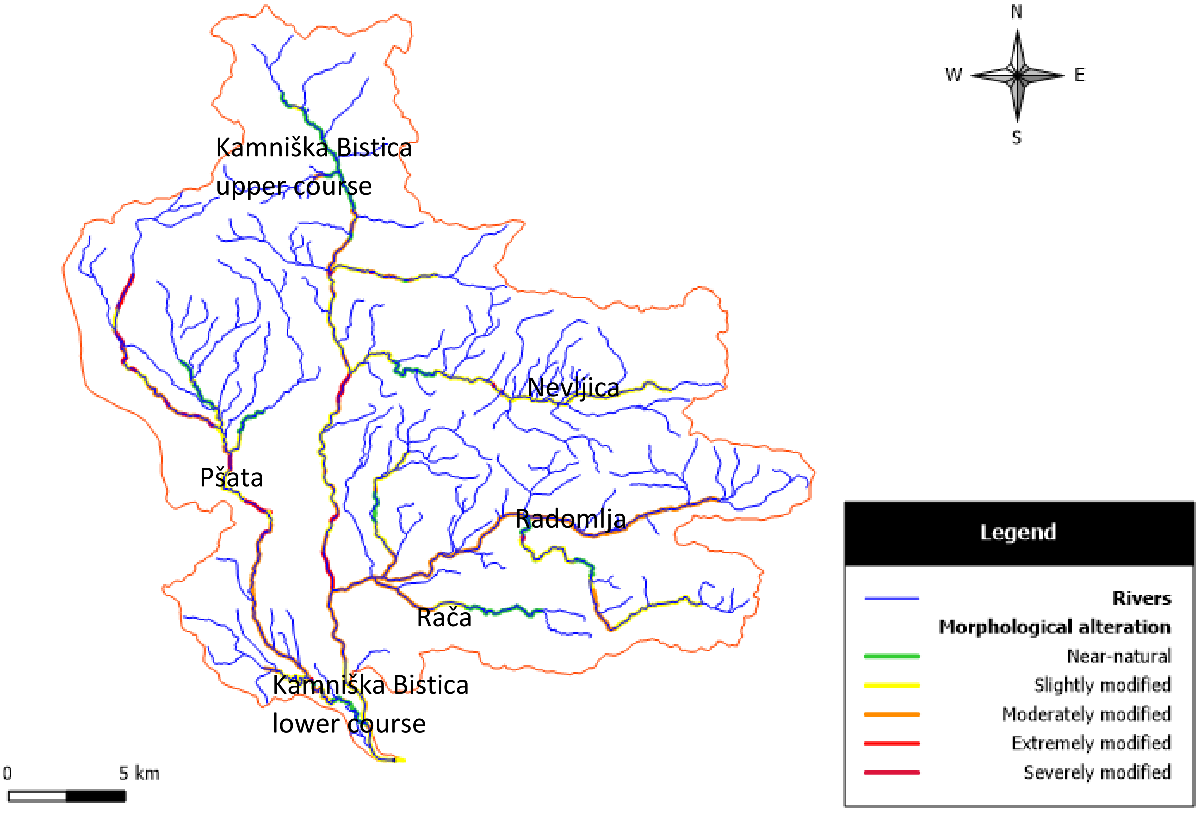


*Figure 5: Hydro-Morphological alteration of Kamniska Bistrica (Slovenian Water Agency, 2018).*

Upper course of Kamniška Bistrica has near-natural morphological alteration which changes downstream from slightly modified to severely modified on few points before Nevljica inflow. Nevljica has near-natural to slightly modified morphological alteration, similar Rača with moderately modified morphological alteration before confluence with Radomlja River. On the other hand Radomlja and Pšata have mostly moderately to severely modified morphological alteration. Middle and lowe course of Kamniška Bistrica has slightly to severely modified morphological alteration.

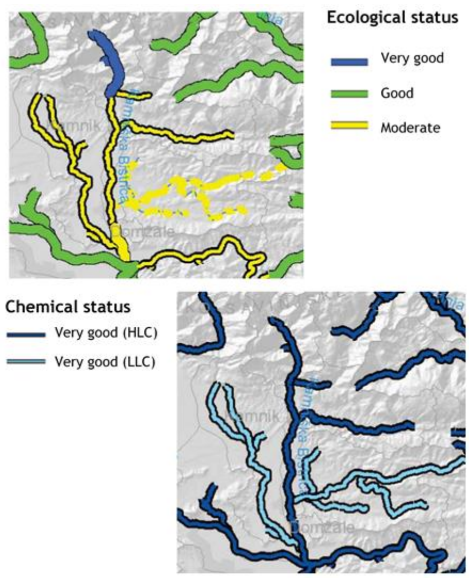


*Figure 6: Ecological and chemical status of Kamniska Bistrica (Slovenian Water Agency, 2018).*

All rivers in Kamniška Bistirca basin have moderate ecological status, except upper course of Kamniška Bistrica has a very good ecological status[3]. Chemical status of Kamniška Bistrica and Nevljica is very good while Pšata, Radolmlja and Rača have a good chemical status.The main problem to achieve a good ecological status is in hydro morphological alteration.

## 3.2 Review of existing and planned measures

Review of existing and planned measures was done by review of two strategic documents:

- River basin management plan for the Danube RBD (Danube RBMP 2016-2021)
- Flood risk managment plan (FRMP 2017-2021)

Implementation of measures may be in one of the following phases:

- P1: Preparation of professional bases,
- P2: Preparation of a spatial act,
- P3: Adopted spatial act,
- P4: Preparation of a project for obtaining a building permit,
- P5: Building permit obtained,
- P6: Construction,
- P7: Object in function.

Flood measures in implementation for Kamniška Bistrica (FRMP 2017–2021):

- Kamniška Bistrica regulation from the outfall to Domžale (P1 – in progress),
- Kamniška Bistrica regulation in Bišče (P1 – in progress),
- Kamniška Bistrica regulation from Volčji potok to Kamnik and (P4 – in progress),
- Retention reservoirs on Tunjščica (Komenda), Pšata (Komenda) and Knežji potok (Komenda) (P2 – in progress).

The priorities of flood protection measures for Kamniška Bistrica river basin are as follows:

- Determination and consideration of flood areas (U1),
- designing and constructing flood prevention measures (U7),
- implementing individual (self-protecting) flood protection measures (U8),
- regular maintenance of watercourses, water facilities as well as aquatic and coastal lands (U10) and
- documentation and analysis of flood events (U19).

Complementary measures relating to Kamniška Bistrica and its tributaries:

- implementation of measures to reduce the negative impact of land use in the riparian zone on water status (Pšata),
- implementation of measures to reduce the negative impact of regulation and other arrangements of watercourses, retentions, lakes and coastal waters on water status (Kamniška Bistrica, Pšata and Rača with Radomlja) and
- measures to reduce dispersed nutrient pollution in agriculture (Pšata).

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[3] http://www.mop.gov.si/fileadmin/mop.gov.si/pageuploads/podrocja/voda/nuv_II/13_4_OCENA_EKO_ST_REKE.pdf

## 3.3 Results of first consultations with stakeholders

First National event within FramWat project in Slovenia took place on 10th of May 2018. The main concern of stakeholders regarding NSWRM is their placement in environment due to geographical conditions and different interests. The identified concerns of stakeholders regarding SWRM implementation are:

- their requirements for constant maintenance,
- longevity and efficiency,
- different interests, partial communication and fragmented parcel ownerships.

The participants identified conditions for placing NSWRM in Kamniška Bistrica basin and discussed the already existing water retention measures. It is identified that:

- Steep parts of the watercourse do not allow small retention measures.
- Potential locations for NSWRM are at Knežji Potok, Pšata, Doblič, Tunjica.
- Space for water spillage should be included in municipal spatial plans.
- Flood Risk Managament Plan 2017-2021 includes potential spillage areas that often coincide with quality agricultural land.

The main conclusions:

- National legislation and related documents iclude very little about NSWRM and rarely specific measures.
- Cross-sectoral cooperation is needed (cooperation and coordination with agriculture sector and their actions on water surfaces).
- Greater awareness of the importance and effects of NSWRM public involvement in all steps; from planning to decision-making.
- More strengths and opportunities of NSWRM than weaknesses and threats (SWOT analysis).

## 3.4 Results of field recognition

Expert knowledge based identification of SWRM to reduce risk the risk of flooding:

- Retention reservoirs at Tunjščica, Vrtaški potok and Doblič
- River Pšata: flood bypass system and retention reservoir
- Suhadole: protection of flood plain areas
- River Motnica: retention basin to protect urbanization (Trzin)
- Dragomelj: retention reservoir and bypass
- Žabnica: 3 retention reservoirs
- Nožice: bypass system
- Šmarca: channel regulation (width)

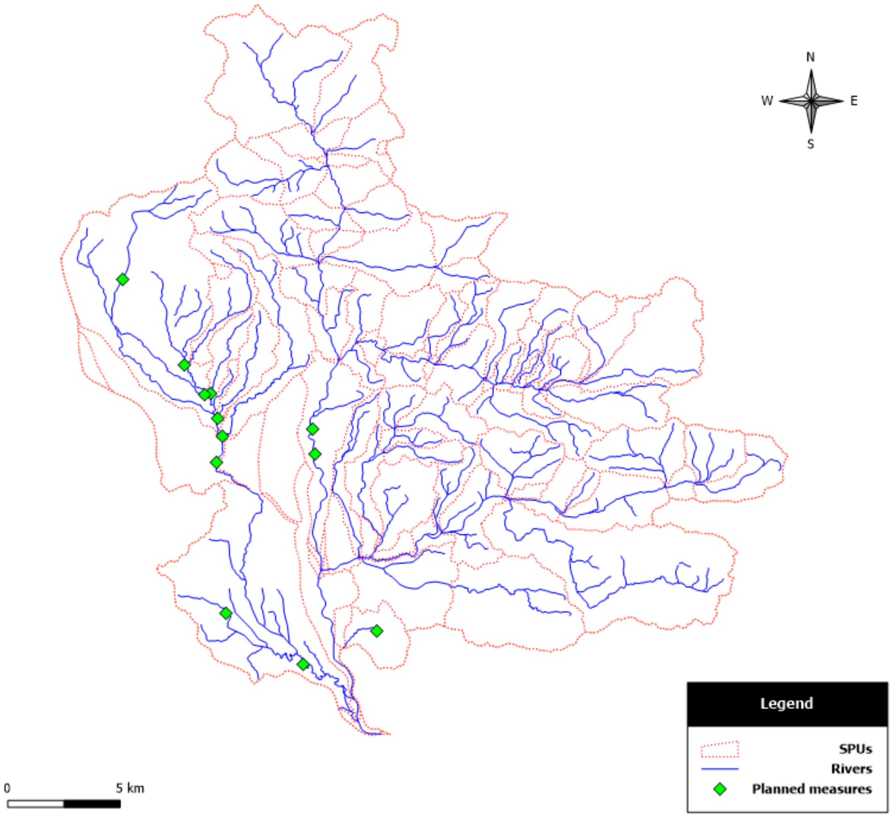


Figure 7: Planned SWRM in Kamniska Bistrica river basin.

# 4. DESCRIPTION OF WORKFLOW

## 4.1 Selected SPU

We tested SPUs from Slovenian Water Agency, which are being used for spatial planning of Kamniska Bistrica:

- total number of SPUs: 91.

The choice of the detail level of the SPUs can affect the subsequent analysis. We decided for SPUs from Slovenian Water Agency, which can be easily understandable by stakeholders and results can be easily incorporated into plans. However, probability of errors is higher in comparison to SPUs resulting from the watershed delineation.

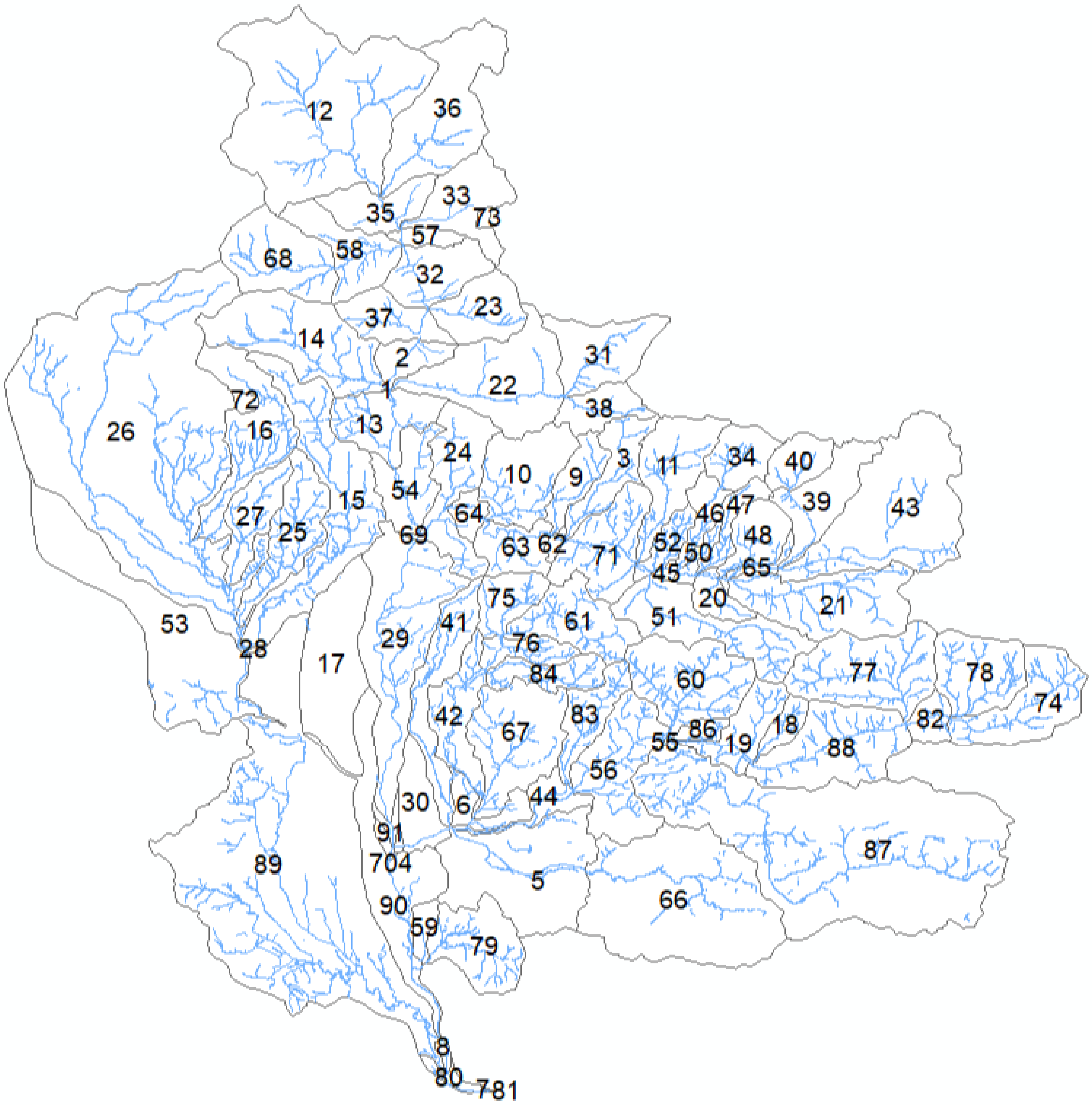


*Figure 8: SPUs of Kamniska Bistrica river basin (Slovenian Water Agency, 2018).*

## 4.2 Selected indicators

Indicators were selected among those present in the list provided within the FroGIS online tool. 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.**

*Table 2: Indicators stimulant/destimulant choice*

| Name | Stimulant/ Destimulant | Rationale |
|---|---|---|
| ArableRatio | S | The higher the share of arable land the higher the probability of flood. |
| BaseFlowIndex | D | The higher the base flow index higher the peak flow. |
| DrainageDensity | S | The higher the drainage density the lower the probability of flood. |
| FloodRiskAreaRatio | S | The higher the ratiot he higher probability of flood. |
| FlowMaxAvgRatio | S | The higher the ratio the higher the probability of flood. |
| FlowMinMaxRatio | D | The higher the ratio between low flow and high flow the higher the probability of flood. |
| ForestRatio | D | The higher the forest area share the lower the probability of flood. |
| LakeRatio | D | The higher the lake area share the lower the probability of flood. |
| LakeCatchRatio | D | The higher the lake catchment ratio share the lower the probability of flood. |
| LandSlope | S | The higher the land slope the higher the probability of flooding downstream. |
| MeanderRatio | S | The higher the number of meanders, the lower the probability of flood. |
| NonForestedRatio | S | The higher the non forest area share the higher the probability of flood. |
| OrchVegRatio | S | The higher the orchard area share the higher the probability of flood. |
| RainFallErodibility | S | The higher the rain falll erodibility the higher the probability of flood. |
| ReclaimedRatio | S | The higher the ratio the higher the probability of flood. |
| RiverSlope | S | The higher the river slope the higher the probability of flooding downstream. |
| Surface Runoff Index | S | The higher the SRI the higher probability of flood. |
| Topographic Wetness Index | D | The higher the water retained in soil, the higher the water that ends up in the river network during baseflow. |
| Urban Ratio | S | The higher the urban area share the higher the probability of flooding. |

## 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 uncompleted (land use map, soil map).

Global datasets used:

- LAND USE
  - Corine Land Cover 2012[4]
  - 25ha/100m resolution
- SOIL
  - European Soil Data Centre[5]

[4] https://land.copernicus.eu/pan-european/corine-land-cover

    - texture classes changed from shp file to raster

Local datasets used:

- SPU
    - 91 SPUs
    - Slovenian Water Agency
- CWB
    - 3 meteorological stations (Brnik, Lj Bežigrad, Celje)
    - Time period: 91-2016
    - Slovenian Environment Agency (public data)
- FLOW
    - 4 gauging stations (Nevlje, Kamnik, Topole, Podrečje)
    - 6 main points for flow calculation
    - Time period: 91-2016
    - Slovenian Environment Agency (public data)
- PRECIPITATION
    - 4 gauging stations (Nevlje, Kamnik, Topole, Podrečje)
    - 6 main points for flow calculation
    - Time period: 91-2016
    - Slovenian Environment Agency (public data)
- DIGITAL ELEVATION MODEL
    - Lidar
    - Ministry of the environment and spatial planning
- RIVER NETWORK
    - Slovenian Water Agency
- RIVER SLOPE
    - Lidar based, Slovenian Water Agency
- FLOOD EXTENT
    - Slovenian Water Agency (Water Atlas)
- RIVER HYDROMORPHOLOGY STATUS
    - RBMP2
    - Slovenian Water Agency
- GROUNDWATER RENEWABLE RESOURCES MODULE
    - Slovenian Environment Agency
- PHYSICOCHEMICAL QUALITY ASSESSMENT OF SURFACE WATERS
    - Time priod: 2007-2018
    - Slovenian Environment Agency (public data)
- DITCHES, EXISTING NATURAL SMALL WATER RETENTION MEASURES, LAKE, LAKE CATCHMENT
    - Slovenian Water Agency (Water Atlas)
- PROTECTED AREAS
    - RBMP2
    - Slovenian Water Agency

[5] https://esdac.jrc.ec.europa.eu/

## 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:

- Flow Min Max Ration and SRI removed because high correlation with with Flow Max Avg Ratio.
- LakeCatchRatio removed because high correlation with LakeRatio.
- Landslope removed due to high correlation with River Slope and TWI.

Correlation matric for flood mitigation is presented in the table below; highlighted cells in red are those corresponding to correlated couples of indicators. Highly correlated indicators were than removed from the use (see *Table 4*).

*Table 3: Correlation matrix*

| | Arable Ratio | BFI | Drainage D | Meander Ratio | Flood Risk Area Ratio | FlowMaxAvgRatio | FlowMinMaxRatio | Forest Ratio | Lake Ratio | LakeCatch Ratio | Land Slope | River Slope | TWI | Non Forested Ratio | Orch Veg Ratio | SRI | Rain Fall Erodibility | Reclaimed Ratio | Urban Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ArableRatio | - | 0.34 | -0.07 | -0.19 | 0.58 | -0.15 | 0.28 | -0.52 | 0 | -0.02 | -0.42 | -0.2 | 0.84 | -0.27 | -0.01 | -0.16 | -0.21 | 0.03 | 0.08 |
| BFI | 0.34 | - | -0.03 | -0.03 | 0.31 | 0.19 | 0.01 | -0.2 | -0.08 | -0.08 | -0.31 | -0.09 | 0.39 | -0.23 | 0.15 | -0.41 | -0.48 | 0.04 | 0.25 |
| DrainageD | -0.07 | -0.03 | - | 0.22 | 0.04 | 0.03 | 0.03 | -0.28 | -0.05 | -0.04 | -0.07 | -0.17 | -0.01 | 0.42 | -0.02 | 0.04 | -0.01 | -0.05 | 0.01 |
| MeanderRatio | -0.19 | -0.03 | 0.22 | - | 0.07 | -0.07 | 0.07 | -0.03 | -0.01 | -0.01 | 0.08 | 0.03 | -0.16 | 0.15 | 0.04 | 0.12 | -0.03 | 0.08 | 0.05 |
| FloodRiskAreaRatio | 0.58 | 0.31 | 0.04 | 0.07 | - | 0.02 | 0.11 | -0.49 | -0.05 | -0.05 | -0.49 | -0.28 | 0.67 | -0.32 | 0.07 | -0.29 | -0.33 | 0.15 | 0.18 |
| FlowMaxAvgRatio | -0.15 | 0.19 | 0.03 | -0.07 | 0.02 | - | -0.89 | 0.17 | -0.05 | -0.05 | -0.19 | -0.15 | -0.05 | -0.03 | -0.08 | -0.8 | -0.28 | 0.13 | -0.08 |
| FlowMinMaxRatio | 0.28 | 0.01 | 0.03 | 0.07 | 0.11 | -0.89 | - | -0.28 | 0.11 | 0.1 | -0.11 | -0.09 | 0.23 | -0.08 | 0.11 | 0.58 | -0.01 | -0.07 | 0.15 |
| ForestRatio | -0.52 | -0.2 | -0.28 | -0.03 | -0.49 | 0.17 | -0.28 | - | -0.01 | 0 | 0.57 | 0.33 | -0.61 | -0.18 | -0.08 | 0.07 | 0.29 | -0.12 | -0.53 |
| LakeRatio | 0 | -0.08 | -0.05 | -0.01 | -0.05 | -0.05 | 0.11 | -0.01 | - | 0.99 | -0.04 | -0.09 | -0.01 | 0.07 | -0.01 | 0.08 | 0.19 | 0.08 | -0.04 |
| LakeCatchRatio | -0.02 | -0.08 | -0.04 | -0.01 | -0.05 | -0.05 | 0.1 | 0 | 0.99 | - | -0.03 | -0.08 | -0.02 | 0.08 | -0.01 | 0.08 | 0.2 | 0.08 | -0.05 |
| LandSlope | -0.42 | -0.31 | -0.07 | 0.08 | -0.49 | -0.19 | -0.11 | 0.57 | -0.04 | -0.03 | - | 0.77 | -0.73 | 0.3 | -0.1 | 0.47 | 0.61 | -0.22 | -0.48 |
| RiverSlope | -0.2 | -0.09 | -0.17 | 0.03 | -0.28 | -0.15 | -0.09 | 0.33 | -0.09 | -0.08 | 0.77 | - | -0.48 | 0.25 | -0.09 | 0.33 | 0.43 | -0.12 | -0.31 |
| TWI | 0.84 | 0.39 | -0.01 | -0.16 | 0.67 | -0.05 | 0.23 | -0.61 | -0.01 | -0.02 | -0.73 | -0.48 | - | -0.47 | 0.08 | -0.35 | -0.4 | 0.16 | 0.4 |
| NonForestedRatio | -0.27 | -0.23 | 0.42 | 0.15 | -0.32 | -0.03 | -0.08 | -0.18 | 0.07 | 0.08 | 0.3 | 0.25 | -0.47 | - | -0.03 | 0.35 | 0.22 | -0.03 | -0.23 |
| OrchVegRatio | -0.01 | 0.15 | -0.02 | 0.04 | 0.07 | -0.08 | 0.11 | -0.08 | -0.01 | -0.01 | -0.1 | -0.09 | 0.08 | -0.03 | - | -0.07 | -0.1 | 0.08 | 0.18 |
| SRI | -0.16 | -0.41 | 0.04 | 0.12 | -0.29 | -0.8 | 0.58 | 0.07 | 0.08 | 0.08 | 0.47 | 0.33 | -0.35 | 0.35 | -0.07 | - | 0.41 | -0.15 | -0.14 |
| RainFallErodibility | -0.21 | -0.48 | -0.01 | -0.03 | -0.33 | -0.28 | -0.01 | 0.29 | 0.19 | 0.2 | 0.61 | 0.43 | -0.4 | 0.22 | -0.1 | 0.41 | - | -0.21 | -0.29 |
| ReclaimedRatio | 0.03 | 0.04 | -0.05 | 0.08 | 0.15 | 0.13 | -0.07 | -0.12 | 0.08 | 0.08 | -0.22 | -0.12 | 0.16 | -0.03 | 0.08 | -0.15 | -0.21 | - | -0.01 |
| UrbanRatio | 0.08 | 0.25 | 0.01 | 0.05 | 0.18 | -0.08 | 0.15 | -0.53 | -0.04 | -0.05 | -0.48 | -0.31 | 0.4 | -0.23 | 0.18 | -0.14 | -0.29 | -0.01 | - |

*Table 4: Correlation matrix (removed higly correlated indicators)*

| | ArableRatio | BFI | DrainageD | MeanderRatio | FlowMaxAvgRatio | ForestRatio | FloodRiskAreaRatio | NonForestedRatio | RiverSlope | TWI | ReclaimedRatio | UrbanRatio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ArableRatio | - | 0.34 | -0.07 | -0.19 | -0.15 | -0.52 | 0.56 | -0.27 | -0.2 | 0.64 | 0.03 | 0.08 |
| BFI | 0.34 | - | -0.03 | -0.03 | 0.19 | -0.2 | 0.31 | -0.23 | -0.09 | 0.39 | 0.04 | 0.25 |
| DrainageD | -0.07 | -0.03 | - | 0.22 | 0.03 | -0.26 | 0.04 | 0.42 | -0.17 | -0.01 | -0.05 | 0.01 |
| MeanderRatio | -0.19 | -0.03 | 0.22 | - | -0.08 | -0.03 | 0.07 | 0.15 | 0.03 | -0.16 | 0.06 | 0.05 |
| FlowMaxAvgRatio | -0.15 | 0.19 | 0.03 | -0.08 | - | 0.17 | 0.02 | -0.03 | -0.15 | -0.05 | 0.13 | -0.08 |
| ForestRatio | -0.52 | -0.2 | -0.26 | -0.03 | 0.17 | - | -0.49 | -0.18 | 0.33 | -0.61 | -0.12 | -0.53 |
| FloodRiskAreaRatio | 0.56 | 0.31 | 0.04 | 0.07 | 0.02 | -0.49 | - | -0.32 | -0.28 | 0.67 | 0.15 | 0.16 |
| NonForestedRatio | -0.27 | -0.23 | 0.42 | 0.15 | -0.03 | -0.18 | -0.32 | - | 0.25 | -0.47 | -0.03 | -0.23 |
| RiverSlope | -0.2 | -0.09 | -0.17 | 0.03 | -0.15 | 0.33 | -0.28 | 0.25 | - | -0.48 | -0.12 | -0.31 |
| TWI | 0.64 | 0.39 | -0.01 | -0.16 | -0.05 | -0.61 | 0.67 | -0.47 | -0.48 | - | 0.16 | 0.4 |
| ReclaimedRatio | 0.03 | 0.04 | -0.05 | 0.06 | 0.13 | -0.12 | 0.15 | -0.03 | -0.12 | 0.16 | - | -0.01 |
| UrbanRatio | 0.08 | 0.25 | 0.01 | 0.05 | -0.08 | -0.53 | 0.16 | -0.23 | -0.31 | 0.4 | -0.01 | - |

## 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 5: Indicators statistics*

| Indicator name | mean | min | max | std | units |
|---|---|---|---|---|---|
| ArableRatio | 5,209 | 0 | 83,967 | 15,315 | % |
| BFI | 0,054 | 0,003 | 0,101 | 0,032 | - |
| DrainageD | 1,474 | 0 | 19,122 | 2,097 | $km/km^2$ |
| MeanderRatio | 83,868 | 0 | 100 | 21,322 | % |
| FloodRiskAreaRatio | 5,588 | 0 | 76,455 | 11,806 | % |
| FlowMaxAvgRatio | 9,476 | 6,272 | 14,27 | 2,883 | - |
| ForestRatio | 52,235 | 0 | 100 | 27,406 | % |
| NonForestedRatio | 28,118 | 0 | 100 | 21,477 | % |
| RiverSlope | 7,866 | 0,30 | 39,10 | 6,894 | - |
| TWI | 8,904 | 6,43 | 18,365 | 2,149 | - |
| ReclaimedRatio | 0,64 | 0 | 14,886 | 1,964 | % |
| UrbanRatio | 8,268 | 0 | 92,582 | 19,414 | % |

The classification method can impact on the class that is assigned to every SPU.

*Table 6: Results of division of indicators values to five classes for flood protection goal (weight=1)*

| Indicator name | Classes | Equal witdth | Natural breaks | Quantiles |
|---|---|---|---|---|
| ArableRatio | 1 | 83 | 77 | 77 |
| | 2 | 3 | 5 | 5 |
| | 3 | 1 | 4 | 4 |
| | 4 | 2 | 2 | 2 |
| | 5 | 2 | 3 | 3 |
| BFI | 1 | 37 | 13 | 17 |
| | 2 | 0 | 2 | 20 |
| | 3 | 0 | 23 | 18 |
| | 4 | 46 | 46 | 18 |
| | 5 | 8 | 7 | 18 |
| DrainageD | 1 | 98 | 29 | 18 |
| | 2 | 1 | 43 | 18 |
| | 3 | 0 | 16 | 18 |
| | 4 | 0 | 1 | 18 |
| | 5 | 1 | 2 | 19 |
| MeanderRatio | 1 | 5 | 0 | 18 |
| | 2 | 0 | 10 | 18 |
| | 3 | 0 | 26 | 18 |
| | 4 | 6 | 34 | 18 |
| | 5 | 80 | 21 | 19 |
| FloodRiskAreaRatio | 1 | 82 | 64 | 64 |
| | 2 | 5 | 11 | 11 |
| | 3 | 2 | 11 | 11 |
| | 4 | 1 | 3 | 3 |
| | 5 | 1 | 2 | 2 |
| FlowMaxAvgRatio | 1 | 34 | 20 | 18 |
| | 2 | 26 | 13 | 18 |
| | 3 | 0 | 26 | 18 |
| | 4 | 0 | 24 | 18 |
| | 5 | 31 | 8 | 19 |
| ForestRatio | 1 | 13 | 10 | 18 |

| Indicator name | Classes | Equal witdth | Natural breaks | Quantiles |
|---|---|---|---|---|
| | 2 | 28 | 28 | 19 |
| | 3 | 21 | 24 | 18 |
| | 4 | 13 | 15 | 18 |
| | 5 | 16 | 14 | 18 |
| NonForestedRatio | 1 | 34 | 26 | 18 |
| | 2 | 34 | 34 | 18 |
| | 3 | 14 | 21 | 18 |
| | 4 | 7 | 7 | 18 |
| | 5 | 2 | 3 | 19 |
| RiverSlope | 1 | 60 | 31 | 18 |
| | 2 | 24 | 33 | 18 |
| | 3 | 3 | 21 | 15 |
| | 4 | 3 | 4 | 21 |
| | 5 | 1 | 2 | 19 |
| TWI | 1 | 2 | 3 | 18 |
| | 2 | 1 | 13 | 19 |
| | 3 | 10 | 22 | 18 |
| | 4 | 24 | 23 | 18 |
| | 5 | 54 | 30 | 18 |
| ReclaimedRatio | 1 | 86 | 72 | 72 |
| | 2 | 2 | 10 | 10 |
| | 3 | 2 | 3 | 3 |
| | 4 | 0 | 4 | 4 |
| | 5 | 1 | 2 | 2 |
| UrbanRatio | 1 | 79 | 65 | 65 |
| | 2 | 5 | 13 | 13 |
| | 3 | 2 | 6 | 6 |
| | 4 | 2 | 3 | 3 |
| | 5 | 3 | 4 | 4 |

## 4.6 Weights assignment

Weights were assigned by use of weight solver and expert based assessment.

*Table 7: Weights assigned to indicators*

| Indicator name | Needs/Possibility | Calculated by Weight Solver | | |
|---|---|---|---|---|
| | | Equal width | Natural breaks | Quantile |
| ArableRatio | Needs | 0,6 | 0,8 | 0,9 |
| BFI | Needs | 1,0 | 0,5 | 0,8 |
| DrainageD | *Possibility* | 0,7 | 0,6 | 1,0 |
| MeanderRatio | Needs | 0,7 | 0,9 | 0,5 |
| FloodRiskAreaRatio | *Possibility* | 0,5 | 1,0 | 0,7 |
| FlowMaxAvgRatio | *Possibility* | 1,0 | 1,0 | 0,9 |
| ForestRatio | Needs | 0,6 | 1,0 | 0,9 |
| NonForestedRatio | *Possibility* | 0,5 | 0,5 | 0,9 |
| RiverSlope | Needs *Possibility* | 0,5 | 0,5 | 0,5 |
| TWI | Needs | 0,6 | 0,5 | 0,5 |
| ReclaimedRatio | Needs *Possibility* | 0,8 | 1,0 | 1,0 |
| UrbanRatio | *Possibility* | 0,6 | 1,0 | 0,8 |

# 5. ANALYSIS OF VARIANTS

## 5.1 Valorization for flood mitigation purpose (5 classes)

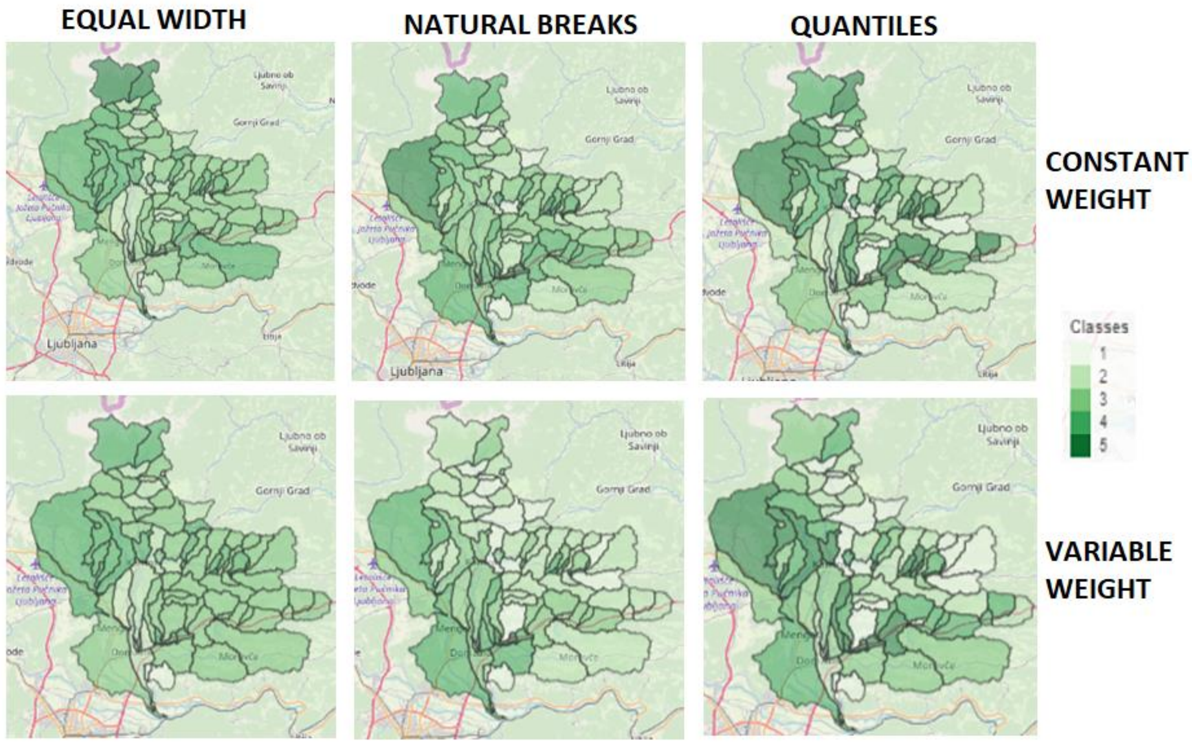


*Figure 9: Division into classes*

# 6. COMPARISON AND DESCRIPTION OF RESULTS

The map based on expert opinion and existing data has been compared with valorization results. The following statistics were computed by comparing the valorization needs identified 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 equal width.

*Table 8: Variant validation for flood mitigation goal*

| | **EQUAL WIDTH ERRORS** | | | **NATURAL BREAKS ERRORS** | | | **QUANTILES ERRORS** | | |
|---|---|---|---|---|---|---|---|---|---|
| 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 | 0,23 | 1,00 | 1,10 | 0,42 | 1,30 | 1,50 | 0,44 | 2,10 | 1,20 |
| MSE | 0,23 | 2,40 | 3,10 | 0,42 | 3,10 | 3,50 | 0,57 | 6,50 | 2,80 |
| RMSE | 0,48 | 1,55 | 1,76 | 0,65 | 1,76 | 1,87 | 0,76 | 2,55 | 1,67 |
| MAPE | 8,1 % | 20,0 % | 22,0 % | 19,1 % | 28,0 % | 32,5 % | 14,7 % | 45,0 % | 25,5 % |

# 7. SUMMARY

The valorization method has been tested for the Kamniska Bistrica catchment. Results are showing that:

- The best results were obtaind from equal width method of divison into classes. However, valorisation map indicates high need for water retention on steep upstream slopes (SPU 12 and 36) where measures are not feasible; map by division into claases by natural breaks eliminates SPU 12 from areas with high need for water retention;
- The introduction of weights changes the valorisation map for:
    - less than 10 % for division into classes by equal width metod;
    - around 20 % for division into classes by natural breaks;
    - 15 % for for division into classes by quantiles.
- The smallest errors were given by the division into classes by equal width method and the biggest by the quantile method;