

Operating manual and source code of the DSS

D.T3.4.2

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1. Introduction

The application is created for people involved in planning water retention measures in order to mitigate the effects of drought, floods and surface contamination by biogenes. The application users will be, in particular, the management boards of the catchment areas, protected areas, communes, forest districts, non-governmental organizations and individual users. The goal of the application is to familiarize the user with the catalog of Natural Small Water Retention Measures (NSWRM) and the planning process as well as to survey their preferences for their area of interest. An additional function is to help the user in making a decision about the location and type of action and to develop a report, which will allow to develop the concept of operation and prepare the necessary permits for their implementation. The application administrator will be able to download a map of the proposed measures for the selected area and a report with the hierarchy of measures' validity. The application is dedicated for Central Europe, but in the demo and test version covers six pilot catchments located in Poland, Slovakia, Slovenia, Croatia, Austria and Hungary.

The web application consists of the start page and three groups of tabs:

- Education
- Catalog of measures
- Tools

The developers are responsible for software, installation and preparation of internet application documentation, placement of the application planner script and script on the Gitlab portal (<https://gitlab.com/framwat>). The user needs to provide the geodatabase with spatial data and substantive content to all tabs. The application is based on open source software, it supports seven languages and is able to analyze spatial data in a user-defined area.

2. How to start and install the application

The DSS app is available in its full version at <http://planning.waterretention.sggw.pl> or <http://planuj.retencjawod.sggw.pl> . This application was written in the open source portal <https://gitlab.com/FramWat> which will enable using it on any computer and allow for its further development. Using the application is very simple and does not require installation because everything is done through a web browser. It is possible to run it on the computer instead of through the browser and below is a description on how to do it.

The installation process should take place in the following steps:

Instal Docker software on your computer for appropriate operating system (LINUX or WINDOWS)

Download Docker CE from -> <https://www.docker.com/products/docker-desktop>

Install by instructions -> <https://docs.docker.com/install/>

Start Docker and open terminal like CMD, Power Shell

Check what is currently running in your Docker

All processes -> `docker ps -a`

Actual running processes -> `docker ps`

Stop or remove existing processes

`docker stop ActualRunningProcesName`

Remove from HD -> `docker rm ProcesName`

Download DSS software form GiTLab portal

`docker pull registry.gitlab.com/framwat/framwat/decision-support-system:latest`

Check what ports you have occupied

In OS Windows -> `ps-> netstat -o -n -a | findstr 0.0:8080`

Run this command (change port (80:8080····) and number of CPU)

```
docker run -dp 8080:8080 --cpus="4" --restart unless-stopped --name NewProcesName  
registry.gitlab.com/framwat/framwat/decision-support-system:latest
```

If an error occurs, you must stop and remove the NameProcess to restart this command

`docker stop NewProcesName`

`docker rm NewProcesName`

try using the corrected command -> `docker run····`

Start web browser and check DSS app at the address <http://localhost:8080> or other port

The source code of the app is available on the website <https://gitlab.com/framwat>.

3. Specification of structure and functionality

3.1 Home page

The home page contains a general introduction and also additional features discussed below. In the upper left corner of the page the logo of the FRAMWAT Project carried out within the Interreg Programme funded by the European Regional Development Fund (ERDF) is placed (Fig.1 mark 1). The upper panel (Fig.1 mark 2) consists of buttons with links to three groups of bookmarks (Education, Catalog of measures, Tools). It is possible to change the language of the website as there are 6 languages available (Fig.1 mark 3). An information about the viewed version of the website is

available (Fig.1 mark 4) and a login channel (Fig.1 mark 5). The footer has quick links to the above mentioned features (Fig. 1 mark 6).

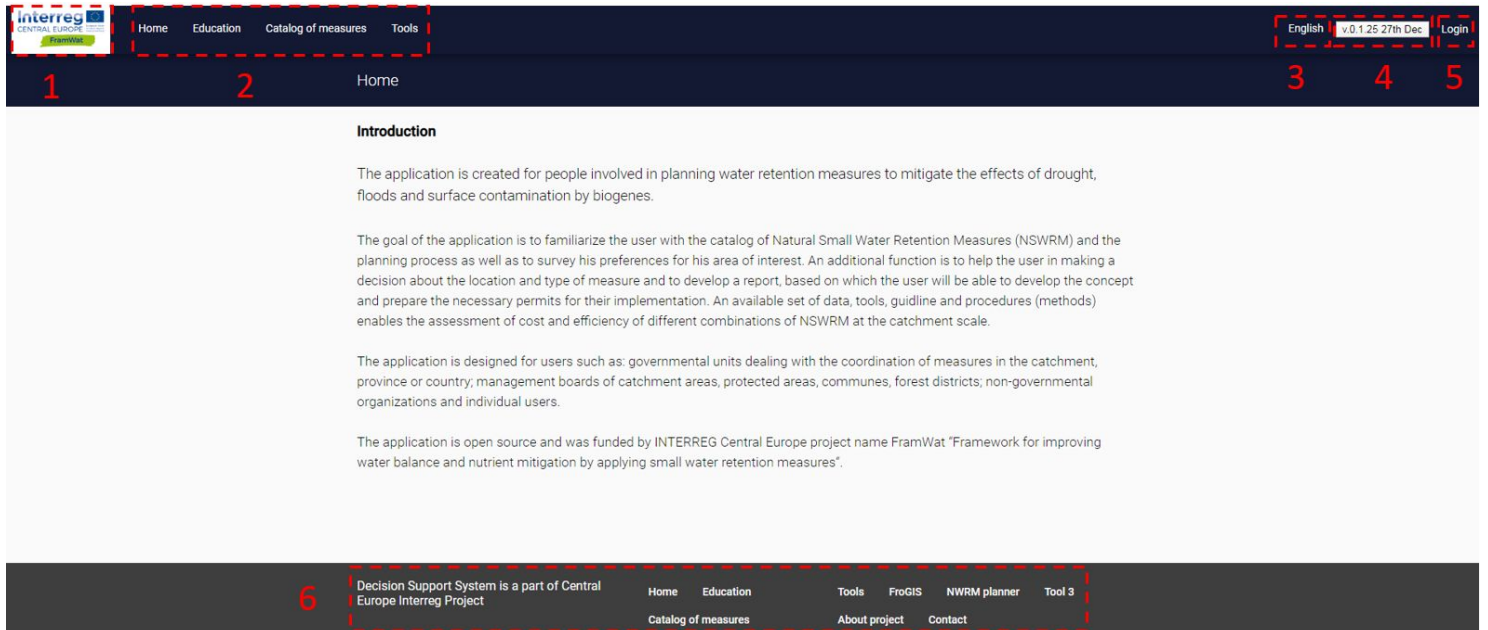


Figure 1. DSS home page.

3.1.1 Education

The main purpose of this page is to introduce the user to the topic of small water retention measures. The site has the following tabs: movies, programmes, science publications, databases, guidelines-case studies. The page includes information on small water retention planning, measures, estimating the needs for such measures, issues that might arise and benefits in mitigating the effects of drought and flood (Fig. 2).

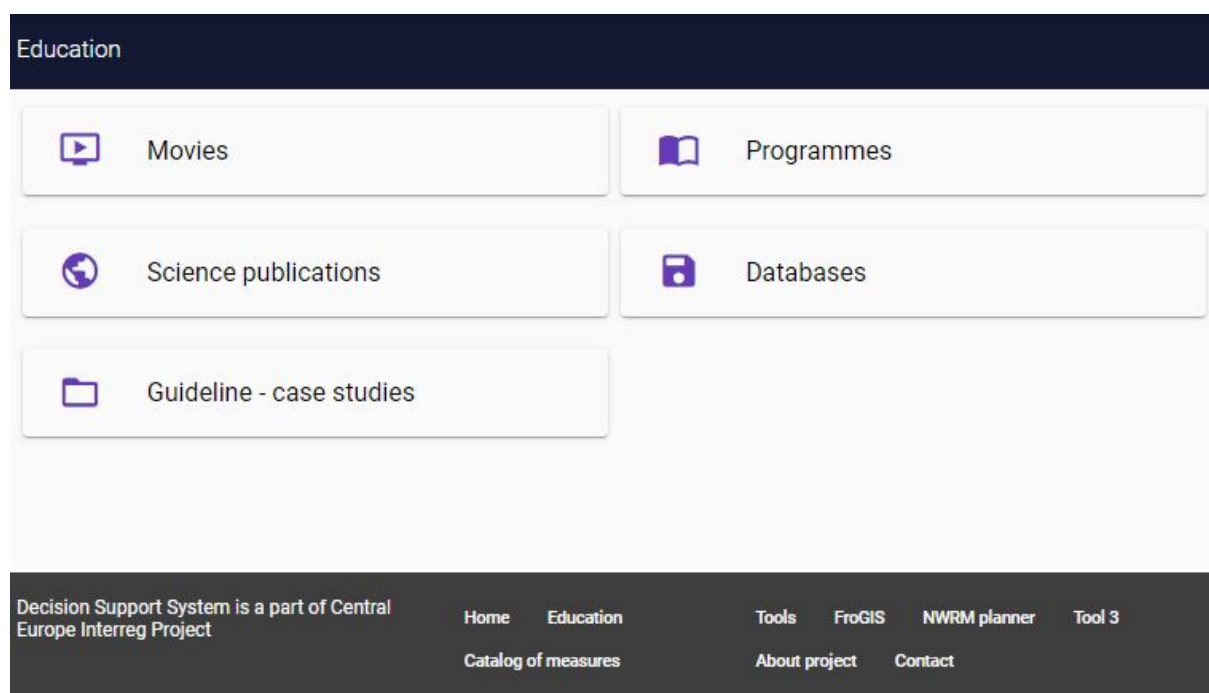


Figure 2. DSS education page.

3.1.2 Catalog of N(S)WRM

The catalog contains a list of 50 NSWRM divided into sectors (agriculture, drainage area, forestry, hydromorphology, hydrotechnical structures). The user can further filter the measures according to the goal they want to achieve (flood mitigation, drought mitigation, general, water quality improvement, sediment), scale of their project (catchment or field/farm), current land use (agricultural lands, arable lands, artificial surfaces, flowing water, forests, gardens, greenhouses, heterogen. agriculture, homogen. agriculture, meadows, orchards, pastures, roads, standing water, urban, wasteland, wetlands, vineyards), soil permeability (low permeable, permeable), type of landscape (lowland, highlands) and if it is located near a watercourse or drained area (yes/no). The catalogue provides resulting measures that fit the criteria (Fig. 3). After clicking on a selected criteria an information sheet opens up with a description of the measure and a photograph or figure (Fig. 4).

Catalog of measures

Search Criteria	Results
<p>Sector</p> <p><input checked="" type="checkbox"/> agriculture</p> <p><input type="checkbox"/> drainage area</p> <p><input type="checkbox"/> forestry</p> <p><input type="checkbox"/> hydromorphology</p> <p><input type="checkbox"/> hydrotechnical structures</p> <hr/> <p>Goal</p> <p><input type="checkbox"/> flood <input type="checkbox"/> drought</p> <p><input checked="" type="checkbox"/> general</p> <p><input type="checkbox"/> water quality</p> <p><input type="checkbox"/> sediment</p> <hr/> <p>Scale</p> <p><input type="checkbox"/> catchment</p> <p><input checked="" type="checkbox"/> field/farm</p> <hr/> <p>Land use</p> <p><input type="checkbox"/> agricultural lands</p> <p><input checked="" type="checkbox"/> arable lands</p> <p><input type="checkbox"/> artificial surfaces</p> <p><input type="checkbox"/> flowing water</p> <p><input type="checkbox"/> forests <input type="checkbox"/> gardens</p> <p><input type="checkbox"/> greenhouses</p> <p><input type="checkbox"/> heterogen. agriculture</p> <p><input type="checkbox"/> homogen. agriculture</p> <p><input type="checkbox"/> meadows <input type="checkbox"/> orchards</p> <p><input type="checkbox"/> pastures <input type="checkbox"/> roads</p> <p><input type="checkbox"/> standing water</p> <p><input type="checkbox"/> urban <input type="checkbox"/> wasteland</p> <p><input type="checkbox"/> wetlands <input type="checkbox"/> vineyards</p> <hr/> <p>Soil permeability</p> <p><input type="checkbox"/> low permeable</p> <p><input checked="" type="checkbox"/> permeable</p> <hr/> <p>Landscape</p> <p><input checked="" type="checkbox"/> lowlands <input type="checkbox"/> highlands</p> <hr/> <p>Near a watercourse or drained area</p> <p><input type="checkbox"/> yes <input checked="" type="checkbox"/> no</p>	<p>AGRICULTURE</p> <div style="border: 1px solid #ccc; padding: 5px; margin-bottom: 5px;">A03 Crop rotation ▼</div> <div style="border: 1px solid #ccc; padding: 5px; margin-bottom: 5px;">A05 Intercropping ▼</div> <div style="border: 1px solid #ccc; padding: 5px;">A11 Controlled traffic farming ▼</div>

Figure 3. DSS page with catalog of measurements with a selection of criteria

Results

AGRICULTURE

A03 Crop rotation ^



SECTOR: agriculture
GOAL: general, water quality,
SCALE: field/farm
LANDSCAPE: any type
LAND USE: arable lands,
SOIL PERMEABILITY: permeable
NEAR A WATERCOURSE OR DRAINED AREA: no

Crop rotation is the practice of growing a number of different types of crops in the same area in subsequent seasons. Rationally used (ie the selection of the right crop) crop rotation can improve soil structure and fertility by alternating the planting of deep-rooted and shallow-rooted plants. The traditional element of crop rotation is nitrogen supplementation through the use of green fertilizer in the order of cereals and other crops.

[Read more](#)

A05 Intercropping v

A11 Controlled traffic farming v

Figure 4 Pop-up window with information about selected measure in the catalogue of measures

3.1.3 Tools

This page has six tabs (Fig. 5):

- Valorisation of Water Retention Needs - FroGIS
- Static method of assessing the effectiveness
- Dynamic method of assessing the effectiveness
- N(S)WRM planner
- AHP method as a supporting tool for optimal NSWRM selection
- Legal procedures for implementing NSWRM (applicable in Poland)

Tools



FROGIS

A publicly available web application to analyze the needs and possibilities of water retention, the result of which is a valorization map supporting the N(S)WRM planning process.



N(S)WRM planner

The goal of the application is to: carry out a survey of local stakeholders in terms of ideas for planning measures in the field of water retention mitigating the effects of drought and floods; prepare the data necessary to develop the concept and estimate the investment risk.



Static method of assessing the effectiveness

Expert-knowledge-based system to support planning of small / natural water retention measures in rural landscapes. Its main goal is to enable the estimation of the effects of the planned (NSWRMP) in a simplified way, which does not require a time-consuming and costly setup of a detailed hydrological model.



Dynamic method of assessing the effectiveness

A set of data, tools and activities that enable the quantitative assessment of efficiency of different combinations of NSWRM at the catchment scale. Within FramWat project, mostly SWAT model setup is designed for evaluating scenarios of NSWRM application in the catchment area, whereas HEC-RAS model transforms the signal originating from SWAT.



AHP method as a supporting tool for optimal NSWRM selection

Analytic Hierarchy Process and is one of the multi criteria decision-making methods for dealing with complex decision problems. Based on experience 4-5 criteria is optimal for an effective AHP. AHP method used for needs of NSWRM selections is altered, for criteria values are non-existing (whether there is lack of data or criteria is not measurable). Hence each criteria has been assigned an expert value between 1-5 (with 1 being the least and 5 being the most important). By that the outcome of the AHP is not entirely based on end user (stakeholders) defined paired criteria comparisons, but is weighted by experts predefined criteria as well. This is arguably a way to get a more consistent outcome that considers both expert and stakeholders' opinion.



Legal procedures for implementing NSWRM

A query system that allows searching for legal procedures and documents necessary for the investment process for preparation of 50 different NSWRM after prior indication of the type of measure, description of the place of implementation (watercourse or outside, private area, protected area) and current land use. Developed for Polish conditions and valid for November 2019.

Figure 5 DSS page with tools.

4. FroGIS - Valorisation of Water Retention Needs

4.1 FroGIS methods

This tool has e-learning, methodology, manual example data and a changelog which is available at <http://waterretention.sggw.pl/>

The aim of the valorisation carried out within the FrGIS tool is to identify areas with varying degree of predisposition for implementation of small retention measures in non-urban areas.

As valorisation is meant to be universal, a number of statistical analyses are included and carried out for the selected area, which then allows the selection of appropriate indicators. The aim of this tool is to support the decision-making process. Fig. 6 presents the calculation algorithm. The following stages can be distinguished in the proposed method:

a) choosing a valorisation goal² (No. on fig.1)

Choosing from four objectives (problems to be solved): general (need for water retention due to environmental and economic requirements), flood protection, drought prevention, water quality improvement. Based on the user's response the indexes recommended for valorisation are selected.

b) choosing Spatial Planning Unit (SPU) and indicators dedicated to analysing the goal³⁻⁴

The choice of the basic valorisation field, SPU, depends mainly on the scale of the analysis (size of the valorisation area). The use of hydrographic units (eg. elementary basins, Water Framework Directive surface water bodies or aggregated water bodies) is recommended or modelling units (eg HRUs). Practically, this would involve introducing a shapefile layer with spatial units (SPU) for which the valorisation is performed.

After selecting the SPU, the user receives a list of recommended indicators to solve the problem and is able to view them through the catalogue of indicators. The user is able to remove some indexes and to add indexes from the catalogue, from outside the suggested list. The result is a set of valorisation indexes.

c) input of data necessary to calculate the indicators⁵⁻⁹

In the next stage, the user receives a list of data and their formats needed to calculate the selected indicators.

d) pre-processing of data using the selected method e.g. interpolation¹⁰⁻¹¹

Technical processing of data, eg. rasterization, possibly pre-processing, such as the distribution of indicators with a point value (precipitation, temperature) in the area as a result of interpolation.

e) calculating indicators and their statistics for SPU (correlation matrix)¹²⁻¹⁵

Calculation of index values in spatial units SPU, standardization of index values and calculation of a correlation matrix. When a correlation matrix is presented, the user decides which indicators are going to be removed from further analyzes due to strong correlation.

f) choosing the final set of indicators after analysing the correlation matrix¹⁶

g) choosing the conversion method of indicator to index¹⁷⁻¹⁸

Selection of systems for defining threshold values for indicators and calculation of valorisation indexes (classes). Transforming indicators values into indices is a partial

evaluation of the purpose of implementing small water retention measures depending on the analyzed indicator.

h) defining an aggregation method for indexes¹⁹⁻²⁰

Selecting the method for aggregating index values to determine the overall rating (eg, summing all indices for all spatial units, selecting the weights for individual indices). Aggregation of indices to assess the overall appropriateness of small retention measures implementation.

i) computing the aggregated values in SPU²¹⁻²³.

Computing the aggregated values in SPU. Presentation of analysis results - general valorisation and valorisation for selected objectives: flood protection, drought prevention, water quality improvement.

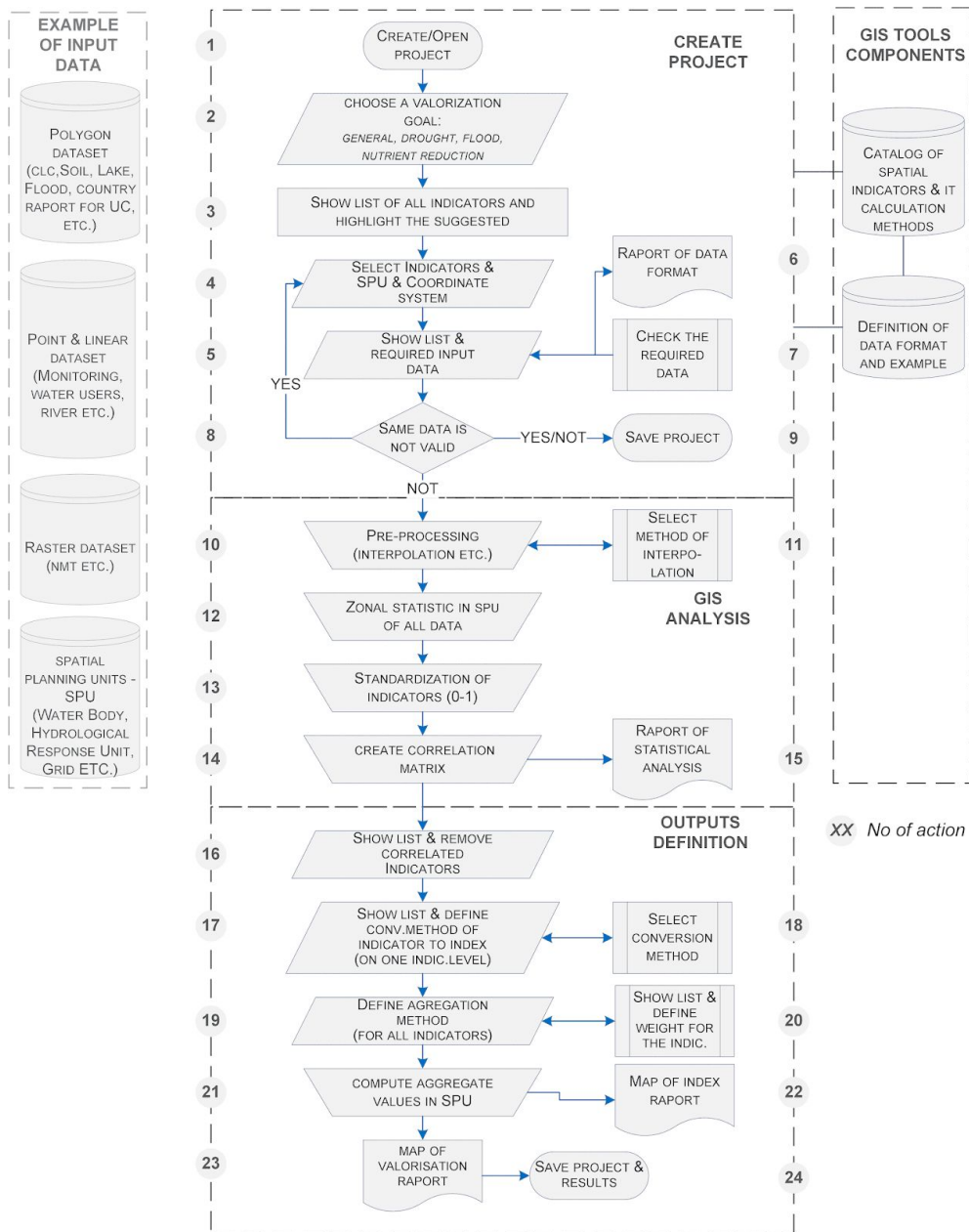


Figure 6 Algorithm GIS tools for valorization of water retention needs

4.2 FroGIS web application

The FroGIS home page has tabs with detail Methodology, dedicated Manual and Example Data to carry out exercises included in the e-learning platform (Fig 7).

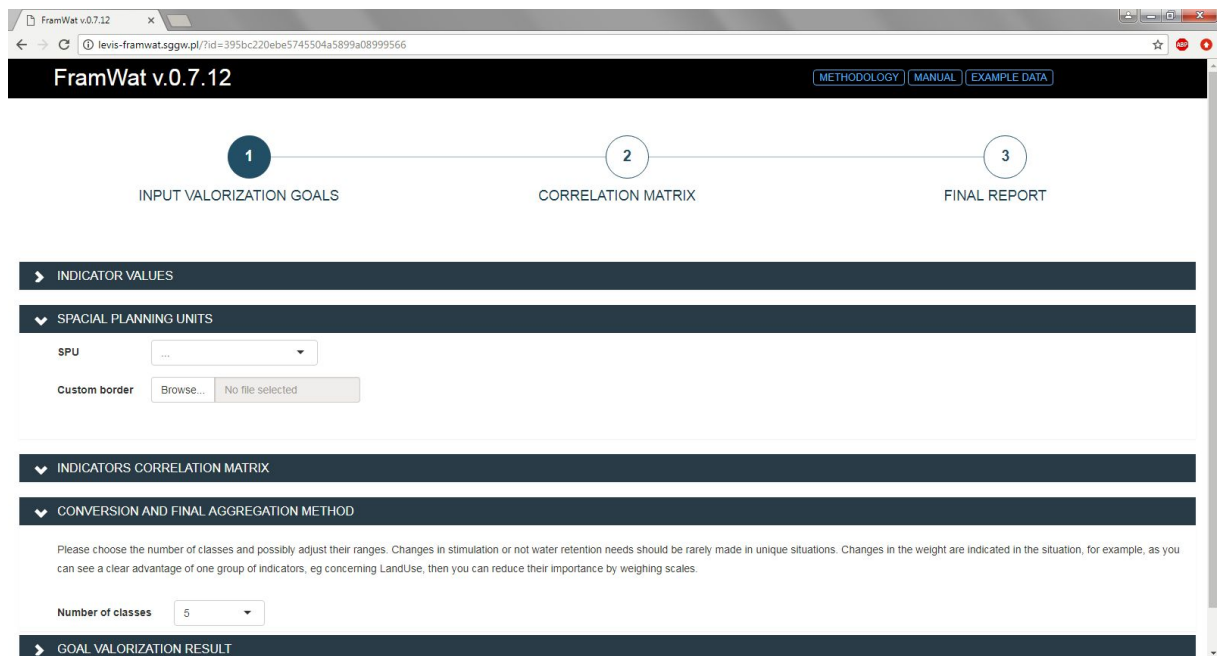


Figure 7 Home page of the FroGIS tool

First a choice of Spacial Planning Units (SPU) needs to be made and uploaded by the user (Fig. 8).

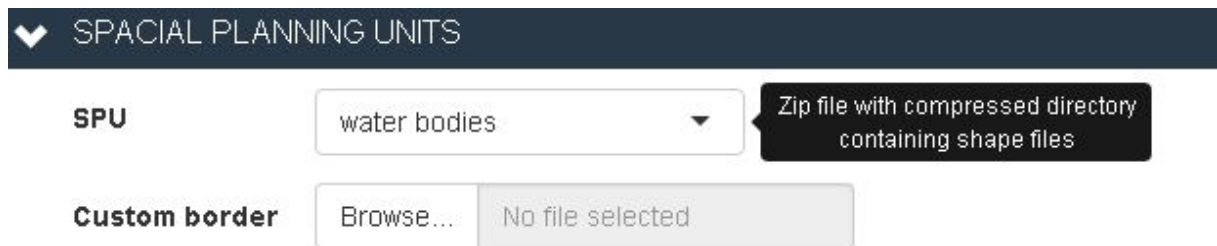


Figure 8 Selection of SPU in FroGIS

There are four main goals of the valorisation that the user can choose from: general, flood, drought and water quality. On the right the required input data names (separated by commas), indicator status (which changes with uploading data) and longer indicator description are given (Fig. 9).

GOALS AND INDICATORS

Choose goal: general

Indicator name	Required input data	Status
<input checked="" type="checkbox"/> ArableRatio Arable area in SPU area ratio	Arable layer;	Ready show description
<input type="checkbox"/> BFI Base Flow Index	BaseFlow Index; BaseFlow Index;	show description
<input checked="" type="checkbox"/> CWB Climatic Water Balance	Avarage Climatic Water Balance;	Ready show description
<input type="checkbox"/> CWB_Var_a Climatic Water Balance - average intra year variability (cwbMax-cwbMin)/cwb	Minimum Climatic Water Balance; Avarage Climatic Water Balance; Maximum Climatic Water Balance;	show description
<input type="checkbox"/> CWB_Var_m Climatic Water Balance - variability in the multiannual period cwbMin/cwb	Minimum Climatic Water Balance; Avarage Climatic Water Balance;	show description
<input type="checkbox"/> DrainageD Drainage Density	River;	show description
<input type="checkbox"/> EcoAraBur20mRatio Arable lands in 20-meters buffer around surface waters area to SPU area ratio	River; Lake; Arable layer;	show description
<input type="checkbox"/> EcoAreaRatio Semi-natural land cover types area to SPU area ratio	Semi-natural land;	show description
<input type="checkbox"/> EcoBadRHS Bad morphological elements length to total length of river in SPU	River Hydromorphology Status; River Hydromorphology Status;	show description
<input type="checkbox"/> EcoCombined Combination of number of semi-natural land cover patches and their area	Semi-natural land;	show description
<input type="checkbox"/> EcoNumRatio Number of semi-natural land cover patches to total number of land	Semi-natural land;	show description

Figure 9 List of required indicators

After clicking on an indicator a description will show underneath with the calculating method and equation (Fig. 10).

<input checked="" type="checkbox"/> ForestRatio Forested area to SPU area ratio	Forest layer;	Ready hide description
<p>CALCULATION METHOD</p> $ForestRatio = \frac{forested\ area}{SPU\ area} \cdot 100;$ <p>DESCRIPTION</p> <p>Forested area to SPU area ratio.</p> <p>GROUP</p> <p>general, drought, flood and quality</p>		

Figure 10 Description of an indicator

The next step is uploading required data in order to make the chosen indicators work (Fig. 11).

DATA INPUT

Input data	Custom data (input file)	Status
<input checked="" type="checkbox"/> Arable Arable layer	<input checked="" type="checkbox"/> <input type="text" value="Browse... Arable.zip"/> Upload complete	show description
<input checked="" type="checkbox"/> CWB Avarage Climatic Water Balance	<input checked="" type="checkbox"/> <input type="text" value="Browse... cwb.tif"/> Upload complete	show description
<input checked="" type="checkbox"/> swFlow Surface water multiannual flow characteristics [mm]	<input checked="" type="checkbox"/> <input type="text" value="Browse... swFlow.zip"/> Upload complete	show description
<input checked="" type="checkbox"/> Forest Forest layer	<input checked="" type="checkbox"/> <input type="text" value="Browse... Forest.zip"/> Upload complete	show description
<input checked="" type="checkbox"/> Lake Lake	<input checked="" type="checkbox"/> <input type="text" value="Browse... Lake.zip"/> Upload complete	show description
<input checked="" type="checkbox"/> NonForest NonForest layer	<input checked="" type="checkbox"/> <input type="text" value="Browse... NonForest.zip"/> Upload complete	show description
<input checked="" type="checkbox"/> DEM Digital Elevation Model [m a.s.l.]	<input checked="" type="checkbox"/> <input type="text" value="Browse... DEM.tif"/> Upload complete	show description

Figure 11 Uploading data

A list of Indicator values in the numbered SPUs appears as a result (Fig. 12).

INDICATOR VALUES									
	ArableRatioVal	CWBVal	FlowMinMaxRatioVal	ForestRatioVal	LakeRatioVal	NonForestedRatioVal	OrchVegRatioVal	UrbanRatioVal	WetlandRatioVal
1	80.38	-129.06	67.42	0	0.1	0	0	4.83	0
2	58.1	-126.91	67.68	0	0	0	0	0	0
3	85.51	-121.55	67.33	0	0	0	0	2.17	0
4	85.55	-128.89	67.54	0	0	0	0	0	0
5	75.79	-129.08	67.39	9.56	0.09	2.86	0	0	0
6	20.83	-191.38	0.01	56.29	0	18.72	0	4.4	6.02
7	14.23	-199.39	0.01	72.71	0	4.15	0	0.02	2.58
8	52.87	-199.34	0.01	0	0	0	0	0	39.57
9	22.12	-192	0.01	51.11	0	19.32	0	6.85	3.87
10	59.62	-134.86	67.43	21.51	0	1.47	0	0	0
11	51.4	-123.19	67.37	27.03	0	10.29	0	0	3.78
12	76.45	-127.28	67.68	0	0	4.11	0	0	0

Figure 12 Indicator values in SPUs

In order to remove strongly correlated indicators a correlation matrix can be viewed (Fig. 13).

	ArableRatio	CWB	FlowMinMaxRatio	ForestRatio	LakeRatio	NonForestedRatio	OrchVegRatio	UrbanRatio	WetlandRatio
<input checked="" type="checkbox"/> ArableRatio	-	0.35	0.28	-0.76	-0.01	0.27	0.17	-0.26	-0.3
<input checked="" type="checkbox"/> CWB	0.35	-	0.67	-0.34	-0.08	0.02	0.1	0.02	-0.17
<input checked="" type="checkbox"/> FlowMinMaxRatio	0.28	0.67	-	-0.34	-0.11	-0.06	0.13	0	-0.09
<input checked="" type="checkbox"/> ForestRatio	-0.76	-0.34	-0.34	-	-0.04	-0.4	-0.12	-0.25	0.38
<input checked="" type="checkbox"/> LakeRatio	-0.01	-0.08	-0.11	-0.04	-	0.13	-0.02	0.02	-0.05
<input checked="" type="checkbox"/> NonForestedRatio	0.27	0.02	-0.06	-0.4	0.13	-	-0.03	0.02	-0.11
<input checked="" type="checkbox"/> OrchVegRatio	0.17	0.1	0.13	-0.12	-0.02	-0.03	-	-0.06	-0.06
<input checked="" type="checkbox"/> UrbanRatio	-0.26	0.02	0	-0.25	0.02	0.02	-0.06	-	-0.19
<input checked="" type="checkbox"/> WetlandRatio	-0.3	-0.17	-0.09	0.38	-0.05	-0.11	-0.06	-0.19	-

Figure 13 Correlation matrix

CONVERSION AND FINAL AGGREGATION METHOD

Please choose the number of classes and if needed adjust their ranges. Changes in the direction of influence (stimulation or not-stimulation) of the indicator value on the need for water retention should be done only in exceptional situations. Changes in the weight are recommended if a clear dominance of one group of indicators, eg concerning LandUse was observed, then you can reduce their importance by changing the weight.

Number of classes: 5

Indicator name	Mean	Min	Max	Stdev	Unit	Stimulating	Aggregation weight
ArableRatio	33.49	0	86.95	30.1	%	non stimulating	1
Class ranges: 0, 17,3€, 34,7€, 52,17, 69,5€, 86,95							
CWB	-165.22	-263.01	-83.57	47.31	mm	non stimulating	1
Class ranges: -263.01, -227, -191, -155, -119, -83.57							
FlowMinMaxRatio	28.65	0.01	149.36	40.41	-	non stimulating	1
Class ranges: 0.01, 29,8€, 59,7€, 89,6€, 119,4, 149,36							
ForestRatio	34.52	0	100	33.08	%	non stimulating	1

Figure 14 Indices values, aggregation weights

The last step is visualizing the map. After choosing the number of classes the map will be presented with corresponding class numbers (Fig.15). It is possible to download the data by clicking "Download report file (.csv)".

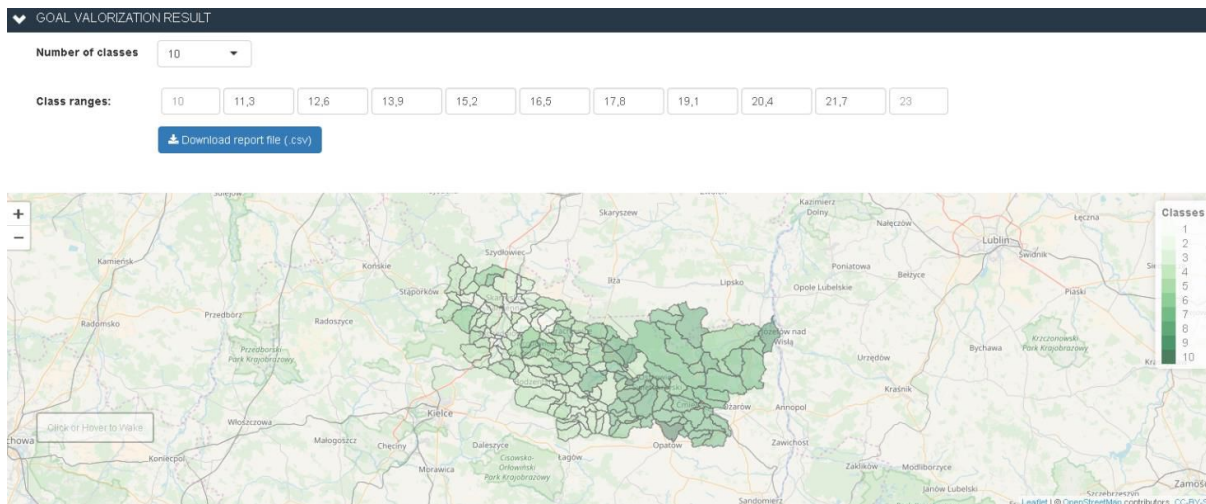


Figure 15 Final FroGIS output map

The entire process of FroGIS analysis in Kamienna catchment is presented in Fig. 16.

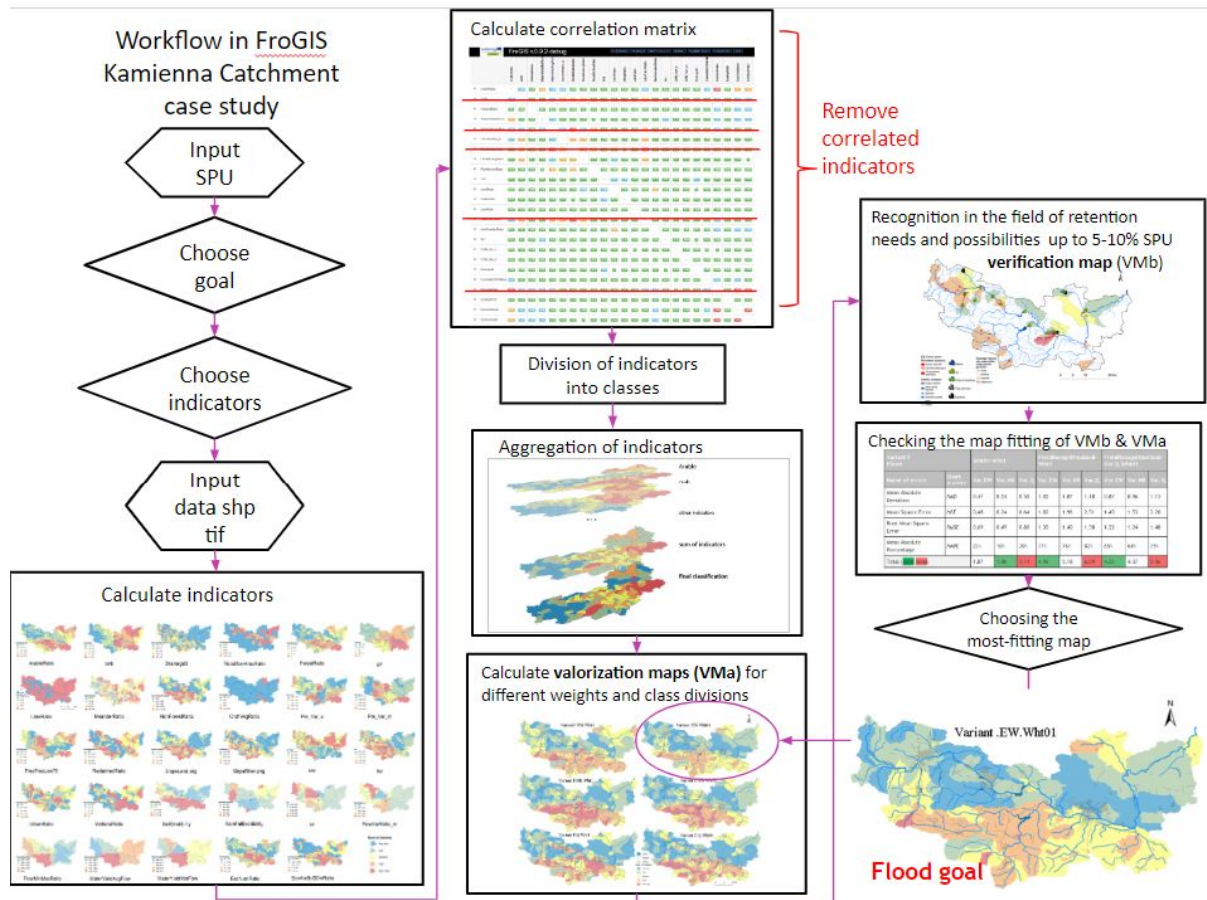


Figure 16 Graph describing the analysis process carried out in the Kamienna catchment in the FroGIS tool

5. Static method of assessing the effectiveness

5.1 Introduction

The purpose of developing the StaticTool method and the computer application StaticTool.xlsm is to enable the estimation of the effects of the implementation of a program of natural, small water retention measures (PoNSWRM) in a simplified way, which does not require the time-consuming and costly development of detailed models, hydrological or / and hydraulic, of the analysed area (catchment). This estimate is a grading system, based on expert knowledge and is used to compare variants of the NSWRM program.

The StaticTool method is universal in terms of the size of the analysed area and the types of climatic and geographical conditions, however the entire analysed area should have rather similar conditions. The choice of NSWRM and determination of parameter values require the participation of experts who know local conditions and have experience in the planning and implementation of small

retention measures, representing the fields of hydrology, hydrogeology, agriculture, drainage, hydrotechnics, forestry, ecology.

The computer application StaticTool.xlsm is dedicated for estimating the effects of the small retention program by the StaticTool method. The application is divided into two modules. The first module is designed to support the process of determining parameters of the StaticTool method for local conditions of the analysis area (**Parameters Module**). The second module assesses the effects of implementing a small retention program (**Grading Module**). The estimation of the effects of the program implementation is a grading and is primarily used to compare the proposed variants for the concept program.

The computer application StaticTool.xlsm includes small retention activities analysed in the FramWat project and parameter values developed based on experience from the Kamienna river catchment (pilot catchment in Poland). The parameter values correspond to the upland landscape in Poland.

5.2 The concept of the StaticTool method

The potential effects of individual NSW measures may be different, depending on the climatic and physiographic conditions (e.g. slopes, ground permeability) of the analysed area, so the method parameters should be adapted to local conditions (climate type, landscape type). The StaticTool method thus consists of two parts:

- i) developing method parameters for local conditions and
- ii) estimation of the effects of activities planned under the Natural Small Water Retention Program.

The StaticTool method assumes that the expected effect of the PoNSWRM is to improve catchment retention properties, which is understood as increasing low flows (LowQ), reducing high flows (HighQ) and / or limiting the load of pollutants yielded from the catchment area (Qual). This effect depends on the planned measures, in particular: i) their type and ii) the level of intensity. The measures included in the StaticTool method are summarized in the local catalogue of measures. For each measure, an intensity criterion is formulated, and threshold values are defined that correspond to the characteristic intensity levels (low, medium, high). Each measure is also assigned the expected improvement of retention properties of the SPU, expressed on a point scale (0-5 points). The greatest improvement that can be achieved (maximum points for a given measure) corresponds to the implementation of the measure with maximum intensity. For lower intensity levels, the assigned grades are proportional to the level of intensity of planned measure. Hence, developing parameters of the StaticTool method means defining a set of functions that make grade assessment dependent on the type of planned measures and their intensity for each measure from the local catalogue. Examples of such functions – the relationships of the expected improvement in the retention properties of the area, expressed on a grade scale, on the type and intensity of measures are shown in Figure 1.

The development of method parameters for the catchment area under study includes:

1. Preparation of the local catalogue of measures;

2. Defining measures intensity criteria and threshold values for characteristic intensity levels (low, medium, high);
3. Determining the grades of the impact of measures on the retention properties of the catchment.

After preparing the method parameters, the effects of programs of measures can be estimated. The method makes it possible to determine the global assessment, for the entire analysed catchment area, and assessments in individual planning units (SPU, differential catchments). The effect of implementing the variant of the PoNSWRM in the entire catchment is assessed by the weighted sum of grades obtained in the SPUs, where the weight is the share of the SPU area in the total area of the catchment. In addition to the method parameters representing local conditions, the necessary input data includes a list of SPUs area and a summary of the type and intensity of measures planned within the program.

5.3 StaticTool.xlsm Application

The **StaticTool.xlsm** application was developed for two tasks:

- i) supporting the process of determining StaticTool parameters for the local conditions of the area for which the small retention program is being developed; this task is carried out in the **Parameters Module**;
- ii) estimation of the effects of the implementation of the small retention program, expressed in grades, which can be obtained as a result of program implementation (**Evaluation Module**).

The application includes small retention measures analysed within the FramWat project. To determine the value of the StaticTool method parameters, experience from model analyses carried out in the Kamienna river basin (pilot basin in Poland) as well as expert assessments were used. The parameter values correspond to the upland landscape in Poland.

The **StaticTool.xlsm** application was developed in an MS Excel workbook with the Visual Basic Application macro support function enabled. The tool functions are implemented through MS Excel formulas and programs saved as VBA macros. Data entry and parameter values are determined in the MS Excel environment.

VBA macros refer to cell addresses in prepared sheets, so you must not change the structure of the sheets, i.e. add or remove rows or columns in the area used by the application or change the names of the sheets.

5.4 Organization of the StaticTool.xlsm application

There are 7 sheets in the **StaticTool.xlsm** application. To calculate the PoNSWRM grade on the catchment scale, parameters and data compiled in **CheckParameters** and **ProgramOfWRM** sheets are used. Assessment results for the entire catchment and individual SPUs are recorded in the

StaticAssessment sheet. The three sheets mentioned above form the **Evaluation Module**. The **Parameters Module** of the method contains 4 sheets. The parameters should be determined sequentially, in the following order, in sheets:

- i) **MeasuresFramWat**,
- ii) **SelectedMeasures**,
- iii) **Intensity**,
- iv) **MaxIntensityImpact**.

The following colour markings were used in the sheets compiling the input data, tool parameters and results:

green – user defined input values and parameters; contain values for the conditions of the Polish pilot catchment, considering the adopted assumptions;

blue – formulas in XLS or the use of VBA macros;

beige – calculation results for SPU;

yellow – highlighted or control values;

grey – headers (description of the contents of cells / columns / rows).

The sheets store three sets of application parameters:

- i) current parameters that the user views or changes on an ongoing basis; this set of parameters is used in the calculations;
- ii) parameters from the previous calculation session – parameters saved **before the current execution of VBA procedures**; the user can copy this set of parameters in place of the current parameters, thus facilitating editing; These parameters are saved in the right part of the sheets; the beginning of this part is marked with the comment ***A copy of the previous session***;
- iii) initial parameters developed for the Polish pilot catchment; saved on the right side of the sheet; the beginning of this part is marked with the commentary ***A copy of the Kamienna river parameters***.

5.5 MeasuresFramWat

The **MeasuresFramWat** sheet contains a list of small retention measures that can be used in agricultural and forestry areas. The table in this spreadsheet currently contains small water retention measures (WRM) taken from the NWRM.eu website or proposed by experts from the FramWat project. However, you can add your own measures not included in the original list. A maximum of 100 measures are foreseen (***MaxMeasuresN*** = 100).

In the **MeasuresFramWat** worksheet, you should select measures that are used in the analysed catchment area as individual or aggregate measures (see 3.3). The selection of the measures to be included in the next sheet is made by entering '1' in the **SELECT (0/1)** column in the row corresponding to the measure. You must select at least all activities that have been enabled in **PoNSWRM**. Entering "0" will remove the measure from further analyses. The number of measures contained in the table (**CurrentN**) and the number of measures selected (**SelectedN**) are displayed in the sheet header.

In the sheet, you can also choose an additional language (**Select language**) in which the names of WR measures and – after entering the relevant data – some descriptions will be displayed.

Saving selected measures and moving to the next sheet is done by pressing the **Accept selection and NEXT** key. At this time, the following activities are also implemented:

- i) saving the current version of the **MeasuresFramWat** sheet in the designated area on the right side of the sheet (**MeasuresFramWat** sheet, from column AA),
- ii) saving the previous version of the **SelectedMeasures** sheet in the designated area on the right side of the sheet (sheet **SelectedMeasures**, from column AA),
- iii) rewriting the currently selected measures from **MeasuresFramWat** to **SelectedMeasures**,
- iv) clearing the contents of columns intended for aggregating measures in **SelectedMeasures**.

5.6 SelectedMeasures

The sheet contains a list of measures selected from the **MeasuresFramWat** worksheet, relevant for the analysed catchment (after eliminating measures that will not be considered, e.g. naturalization of offshore polders in Poland) and allows aggregation of some of them.

Small retention measures can be defined as individual measures, such as conversion of arable land to meadows on a specific area, construction of a polder, small reservoir or ponds, or reclamation of a lake with a given area. At the same time, it is also possible to define aggregate measures, e.g. implementation of agricultural practices leading to water retention, which include, among others mulching, simultaneous cultivation, catch crops, permanent lead tracks; or restoration measures, e.g. wetland restoration, restoration of river and oxbow connections, revitalization of floodplains. Aggregated measures include a group of measures which implementation improves in a similar way the retention properties of a catchment, and assessment of the effects of individual measures, without detailed field and model studies at the current level of knowledge, is not possible.

A maximum of 100 measures (**MaxAggregN** = 100) can be distinguished, i.e. the same as for individual measures. This means that aggregation of measures may or may not be used.

Aggregation of measures is carried out by completing columns F-G and optionally column H: **Aggregated measure ID** and **Aggregated measure in English**. For single measures in the **Aggregated measure ID column**, enter the measure ID the same as the measure code in the **MeasuresFramWat** sheet. For measures that will form an aggregate measure, provide a unique identifier for the

aggregate measure (e.g. WRAL). The aggregate measure identifier should be repeated for each individual measure included in the aggregation. For the first measure that is included in aggregation, enter the name of the aggregate measure (the **Aggregated measure in English** column). Providing this name enables the introduction of this measure to the list of analyzed measures. The name should be entered only once. You can also enter the name of the aggregate measure in the selected secondary language (column H).

After pressing the key **Accept and create Aggregated Measures** follows:

- i) creating a list of individual and aggregated measures (J-M columns, **SelectedMeasures** sheet) that will be included in subsequent stages of analysis; they will hereinafter be referred to as aggregate measures;
- ii) displaying in the header of the spreadsheet the number of aggregates (**AggregN**) accepted for further analysis.

You can now check the list of aggregate measures to see if it contains all the measures you have planned. If necessary, you can modify the aggregation of measures (in columns F, G and optionally H) and recreate the list of aggregated measures (**Accept and create Aggregated Measures**).

Pressing the key **NEXT** causes:

- i) saving the version of the **Intensity** sheet from the previous session in the designated area on the right side of the sheet (**Intensity** sheet, from the column AA),
- ii) rewriting identifiers of aggregated measures from **SelectedMeasures** to **Intensity**,
- iii) clearing the contents of columns intended for defining intensity criteria for aggregate measures and threshold values of these criteria for low, medium and high intensity levels in the worksheet **Intensity**.

5.7 Intensity

The sheet **Intensity** is intended to define the criteria for the intensity of aggregate measures and to define threshold values that separate low, medium and high intensity. Four threshold values are used: **T0** – no action, **Tlow** – the boundary between low and medium intensity, **Thigh** – the limit between medium and high intensity and **Tmax**, which corresponds to the maximum (hypothetically) possible intensity of measure. For example, in the analyzes for Kamienna for measure A01 (meadows and pastures) the following intensity criterion was formulated: the ratio of arable land area transformed into permanent meadows or pastures and the total area of SPU. In this case, the value of **Tmax** corresponds to the situation when 100% of the SPU is occupied by arable land and all will be converted into meadows or pastures. This is a very rare situation in practice, although physically possible. The value of **T0** is 0.0 and corresponds to the lack of action A01.

Definitions of intensity criteria and intensity thresholds should be provided for each aggregate measure.

The formulated intensity criteria must be countable! To assess the Small Water Retention Program in the StaticTool method, the size of each of the planned measures will have to be expressed in the form corresponding to the adopted intensity criterion.

The next part of determining the StaticTool method parameters is followed by pressing the key **Accept definitions, Threshold values and NEXT**. At this time:

- i) the **MaxIntensityImpact** sheet version from the previous session is saved in the designated area on the right side of the sheet (the **MaxIntensityImpact** sheet, from the column BA);
- ii) the current list of the aggregated measures together with the definition of intensity criteria from the worksheet **Intensity** is copied to the **MaxIntensityImpact** sheet;
- iii) the columns for entering expert assessment of the impact of individual measures on three elements of the catchment retention properties (low flows, high flows and erosion) are cleared (the **MaxIntensityImpact** sheet);
- iv) the columns for subsequent operations on the worksheet **MaxIntensityImpact** are cleared.

5.8 MaxIntensityImpact

The **MaxIntensityImpact** sheet is intended for: i) determining expert assessments of the impact of aggregated measures on three elements of the catchment retention properties (low flows, high flows and erosion), with maximum intensity of measures' application, ii) formulating a general assessment of measures (3 above-mentioned elements together) and iii) defining effect coefficients for lower than maximum intensity of measures.

Various small retention measures can affect the retention properties of a catchment in different ways. Measures such as restoring floodplains affect primarily high flows. Measures supporting the infiltration of precipitation into groundwater have the strongest effect on low flows. Buffer zones around watercourses and some agricultural activities contribute to reducing the erosion of the catchment and the sediment load from the area. For this reason, the measures are assessed in terms of their impact on the three elements of the catchment retention properties: low flows, high flows and erosion. From these three component assessments, an average value is determined, which forms the basis for formulating the general grading proposal for each of the aggregated measures. For partial grading, on the elements of catchment properties as well as for general grading, a 6-grade scale was adopted, 0 - 5, where 0 means no positive impact on the retention of the catchment area, and 5 – very high positive impact.

The grading of measures is carried out by providing expert assessment of the impact of the measure on each component of the retention properties of the catchment. When specifying these grades, experts assume that the given activity is carried out with the maximum possible intensity. Therefore, they give 3 grades that correspond to the T_{max} intensity threshold, with the criterion of the intensity of the considered measure being defined in the previous stage (**Intensity** sheet).

After specifying the expert partial grades, pressing the **Save grades, compute average (AVG), sort and RIGHT** key will calculate the average value in these grades (AVG) and sort the measures by the determined mean values. The effects of this procedure will be saved in the **MaxIntensityImpact** worksheet, from the R column, under the heading **Sorted by AVG**.

It is now possible to check the assigned grades of individual aggregated measures and whether the relationship of measure ratings relative to each other is rational (whether the measure perceived as the stronger has a higher rating). If necessary, you can modify partial grades, recalculate the average, and sort measures.

After checking that the assigned grades are correct, you should create suggestions for the maximum general grade of each aggregated measure and proposals for effect coefficients for lower than the maximum intensity of the measures. Use the **Suggest GradeMax & Effect coefficients E%** key. The proposals are formulated on the basis of the average of partial expert gradings and threshold values of intensity levels for individual measure. Three assumed shapes of relationship between effects and intensity levels are used to formulate them. They are: linear relationship, steep and flat relationship. An example of the shape of such relationships is shown in the **Graph** sheet.

StaticTool parameter values proposed by the program and saved under the heading **Proposal of GradeMax & Effect coefficients E%** can be changed by experts according to their own judgment. Moving to the next sheet is done by pressing the **Save changes & NEXT** key. Then all the parameters of the tool are saved to the **CheckParameters** sheet. At this point the work in the **Parameter Module** ends.

5.9 CheckParameters

The **CheckParameters** worksheet is used to summarize the parameters of the StaticTool method with which the effects of the Small Water Retention Program will be evaluated. The parameters contained here are initially transferred from earlier stages of work with the application, in the **Parameters Module**. Parameter values can be changed by a user. Changes made to the **CheckParameters** sheet do not affect the values contained in the **Parameters Module** worksheets. The parameters are accepted for calculations by pressing the **Save Parameters & GO TO ProgramOfWRM** key. At this point, the previously analyzed variant of the small retention program is also saved in the **ProgramOfWRM** sheet (from column DD).

For the convenience of comparing variants, it is worth saving subsequent analyzed variants in a separate xls file.

5.10 ProgramOfWRM and StaticAssessment

The **ProgramOfWRM** worksheet contains a summary of planned measures in individual SPUs. The planned measures should be described by the appropriate value of the intensity criterion, in accordance with the adopted criteria definitions. The prepared program of measures must contain exactly the same number of measure types as the number of aggregate measures declared in the tool and in the same order as on the aggregate measures list. This does not mean that every measure

must have non-zero intensity values. There may be actions not yet planned in the current program but envisaged in the near future or in the neighboring catchment.

The table of planned measures has the following dimensions: number of **SPU** x number of aggregated measures + 3 (**AggregN** + 3). The three additional columns (B-D) contain the SPU identifiers, the SPU names and the area of individual SPUs (**F_SPU [km²]**) necessary for determining the grade for the entire analyzed catchment area.

In the **ProgramOfWRM** worksheet, you can check the correctness of preparation of data on planned measures in formal terms with the use of **Check number of measures & measures' IDs** key. The number of planned measures (**Number of measures – User**) and their identifiers will then be compared with the aggregated measures prepared in the StaticTool application (**AggregN - xls application**). In case of a lack of compliance, error messages will be displayed: **'ERROR !!! PoWWRM includes NN measure types, but it should be AggregN = MM measures'** or **'Wrong ID'**.

After verifying the formal correctness of the program and possible elimination of non-compliance, the evaluation of the given program variant may be calculated. The calculations will use the parameters listed in the **CheckParameters** sheet and the measures from the **ProgramOfWRM** sheet. After pressing the **Assess ProgramOfWRM & GO TO StaticAssessment** key, calculations are performed, the results of which are recorded in the **StaticAssessment** sheet:

- i) grading of each measure in each SPU where the measure is planned; written in the table area in the yellow cells;
- ii) the sum of the grades for each of the measures; recorded in the table header, in the row above the measure identifiers;
- iii) the sum of the grades obtained in each SPU; recorded in the last column of the table;
- iv) summary evaluation of the analyzed variant of the small retention program for the entire catchment, in the form of a weighted sum of grades of individual SPUs, where the weight is the share of the area of a given SPU in the total area of the analyzed catchment; saved in the table header, in the last column.

In addition to calculating the evaluation (grading) of the current variant of the program of water retention measures, the results obtained for the previously analyzed variant are recorded in the designated area, on the right side of the **StaticAssessment** sheet (from the DD column).

For the ease of comparing the results of grading variants, it is worth saving the results of successively analyzed variants in a separate xls file.

6. Dynamic method of assessing the effectiveness

6.1 Introduction

Dynamic method allows the assessment of the effectiveness of different N(S)WRMS (hereafter 'measures') with the help of mathematical models for solving typical water resources management problems such as flood hazard, drought hazard and water quality problems. The

dynamic modelling within the FramWat project has been conducted in five catchments located in five countries (Tab. 1). Hydrological models were applied in three countries and hydraulic models in five countries.

Table 1 List of models applied in FramWat case studies.

Partner	Pilot study catchment	Model name	
		Hydrological	Hydraulic
Austria -WCL	Aist	SWAT	HEC-RAS 1D
Croatia - HV	Bednja	HEC-HMS	MIKE21
Hungary - MTDWD	Nagykunsagi		HEC-RAS 1D
Poland - WULS	Kamienna	SWAT	HEC-RAS 1D/2D
Slovenia - UL	Kamniška Bistrica		RiverFlow 2D

6.2 General approach for model-based assessment of measure effectiveness

Figure 17 presents a conceptual scheme of scenario simulations for assessing effectiveness of measures. In general, a set of n measures (M_1, M_2, \dots, M_n) considered for modelling has to be selected first. In the most simple case the model will be run n times for each individual measure, but what is of particular interest is a combination of measures. In theory, there exists $k=2^n$ of different combinations of measures that could be tested, but this is rarely done in practice due to computational constraints.

Each measure has to be implemented (parametrized) in the model in an appropriate way. Then model runs can be executed. Model output is needed for calculating the values of indicators that measure effectiveness of measures. Another important factor is deciding in which areas (streams, sub-catchments, outlets) in the catchment the effectiveness will be assessed. After all indicators are quantified the results can be analysed and conclusions drawn. The calculated indicators can be also used as inputs for the Decision Support Systems.

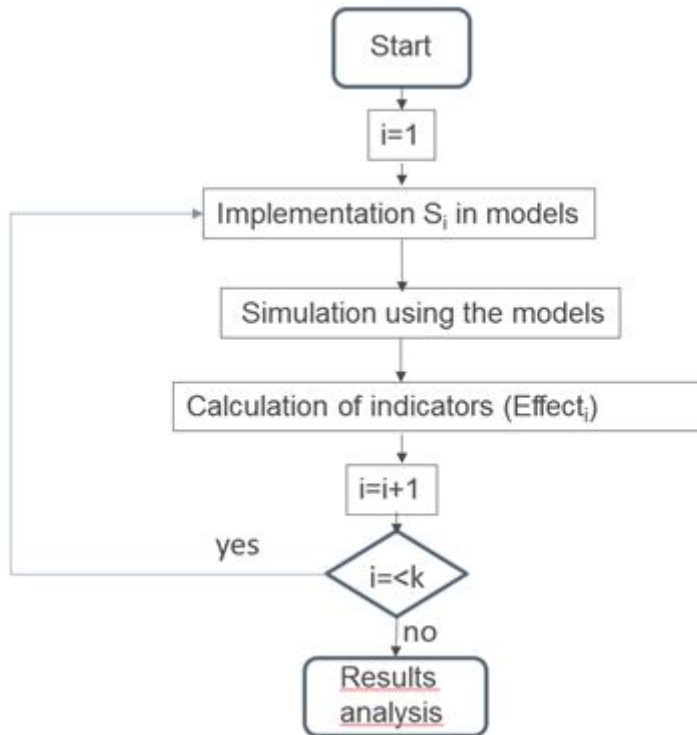


Figure 17 Conceptual scheme of scenario simulations for assessing effectiveness of measures.

6.3 General approach for implementing measures in the models

Figures 18 and 19 illustrate how different measures can be implemented in hydrological and hydraulic models. The following section describes 6 example measures for hydrological models and 7 measures for the hydraulic model in more detail. The measures have been selected from the catalogue on the <http://nwrn.eu> website. Models SWAT and HecRAS are used as representative examples for each type of models.

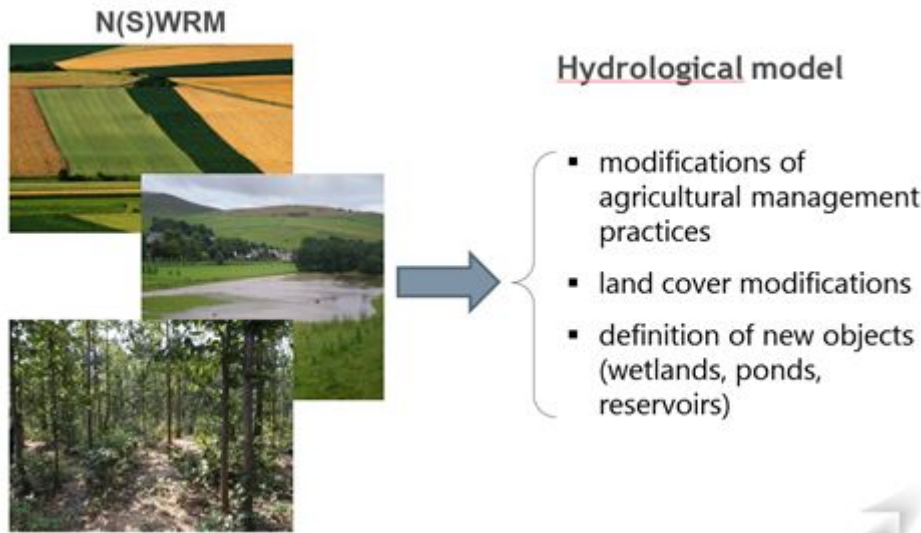


Figure 18 Implementation of measures in a hydrological model.

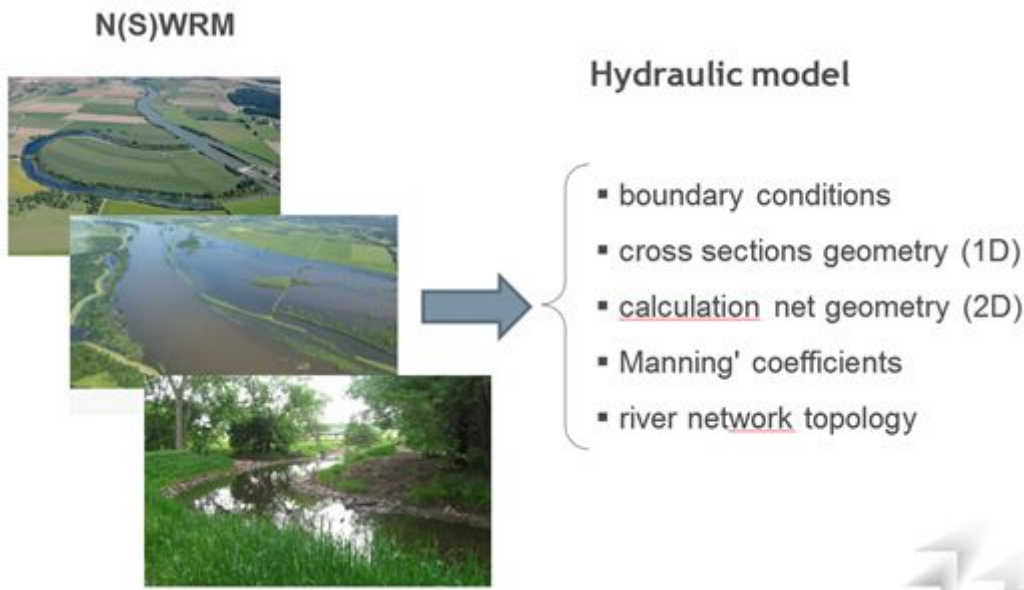


Figure 19 Implementation of measures in a hydraulic model.

6.3.1 Examples of measures in hydrological models

A01: MEADOWS AND PASTURES

- Description: conversion of other land cover types (e.g. arable land) into meadows and pastures

- Implementation in SWAT: applying the *Land Use Update* option (need to indicate: 1) which land cover types, 2) in which sub-basins, 3) in which year are supposed to change into meadows/pastures)
- Expected effect in the model: slower runoff, erosion reduction, nutrient assimilation

A03: CROP ROTATIONS

- Description: replacement of crop monocultures by 2-5 year rotations
- Implementation in SWAT: modification of management practices schedules in selected HRUs (replacement of single crops by crop rotations)
- Expected effect in the model: depending on the type of rotation and the original (replaced) crop. Potentially: erosion reduction, supplementing nitrogen to the soil, slower runoff

A06: NO-TILL AGRICULTURE

- Description: growing crops or pasture from year to year without disturbing the soil through tillage
- Implementation in SWAT: modification of management practices schedules in selected HRUs (removal of tillage operation)
- Expected effect in the model: reducing erosion, increase of soil water retention

A08: GREEN COVER (CATCH CROPS / COVER CROPS)

- Description: planting crops in late summer or autumn, usually on arable land, to protect the soil, which would otherwise lie bare during the winter, against wind and water erosion
- Implementation in SWAT: modification of management practices schedules in selected HRUs (adding *plant* operation for a cover crop)
- Expected effect in the model: slower runoff, erosion reduction, mitigation of the loss of soluble nutrients

F03: AFFORESTATION OF RESERVOIR CATCHMENTS

- Description: planting trees on abandoned land in reservoir catchments
- Implementation in SWAT: applying the *Land Use Update* option (need to indicate: 1) which land cover types, 2) in which sub-basins, 3) in which year are supposed to change into forest)
- Effect in the model: slower runoff, erosion reduction, increase of interception and ET

F09: SEDIMENT CAPTURE PONDS

- Description: engineered ponds placed in networks of forest ditches to slow the velocity of water and cause the deposition of suspended materials
- Implementation in SWAT: adding and parametrising (e.g. geometry) of *Reservoirs* (for ponds placed on the main river network) or *Ponds* (for higher order tributaries)
- Effect in the model: slower runoff, erosion reduction

6.3.2 Examples of measures in hydraulic models

A01: MEADOWS AND PASTURES

- Description: conversion of other land cover types (e.g. arable land) into meadows and pastures
- Implementation in SWAT: applying the *Land Use Update* option (need to indicate: 1) which land cover types, 2) in which sub-basins, 3) in which year are supposed to change into meadows/pastures)
- Expected effect in the model: slower runoff, erosion reduction, nutrient assimilation

N04: RE-MEANDERING

- Description: River re-meandering consists in creating a new meandering course or reconnecting cut-off meanders.
- Implementation in HECRAS: modification of geometry of cross-sections and distances between them, modification of river network topology.
- Expected effect in the model: slowing down the river flow, reduction of the flood wave peak, increasing travel time along the river.

N05: STREAM BED RE-NATURALIZATION

- Description: Streambed re-naturalization consists in removing some concrete or inert constructions in the riverbed and on riverbanks, then replacing them with vegetation structures
- Implementation in HECRAS: modification of geometry of cross-sections, modification of Manning's coefficients
- Expected effect in the model: slow river water, reduction of the flood wave peak, increasing travel time along the river

N11: ELIMINATION OF RIVERBANK PROTECTION

- Description: Eliminating a riverbank protection consists in removing some parts of the bank protection

- Implementation in HECRAS: modification of geometry of cross-sections, modification of Manning's coefficients

- Expected effect in the model: diversify flows (depth and speed) , reduction of the flood wave peak

N10: NATURAL BANK STABILISATION

- Description: River bank renaturalisation consists in recovering its ecological components

- Implementation in HECRAS: modification of geometry of cross-sections, modification of Manning's coefficients

- Expected effect in the model: slow river water, reduction of the flood wave peak

N07: RECONNECTION OF OXBOW LAKES AND SIMILAR FEATURES

- Description: Reconnecting oxbow with the river consists in removing terrestrial lands between both water bodies

- Implementation in HECRAS: add a river reach (cross-sections), modification of river network topology

- Expected effect in the model: diversify flows (depth and speed) , reduction of the flood wave peak, slow river water

N03: FLOODPLAIN RESTORATION AND MANAGEMENT

- Description: Restoring the floodplain roles requires measures such as: modification of the channel, floodplain, vegetation, removing of the legacy sediment

- Implementation in HECRAS: modification of cross-sections, modification of river network topology, change of Manning's coefficients, change 1D to 2D flow domain

- Expected effect in the model: diversify flows, reduction of the flood wave peak, slow river water, increasing travel time along the river

6.4 indicators of measure effectiveness

Indicators that measure effectiveness of individual measures or of collections of measures are typically developed separately for different water management problems: flood hazard, drought hazard and water quality problems. Example indicators for each of these aspects are illustrated in consecutive sub-sections.

6.4.1 Flood hazard

The following indicators for quantifying effectiveness of measures reducing flood hazard can be distinguished:

- Reduction of a given flood index (e.g. 100-year flood, annual maximum flood, etc.) for a specific outlet
- Change in flood frequency for a given return period
- Reduction of flooding extent or inundation depth

6.4.2 Drought hazard

N(S)WRMs are able to cope with two types of droughts: hydrological droughts and soil moisture (agricultural) droughts. The following indicators for quantifying effectiveness of measures against hydrological and agricultural drought hazard can be distinguished:

- Increase in a given low flow index (e.g. annual minimum low flow, environmental flow) for a specific outlet
- Change in hydrological drought severity frequency / duration
- Change in soil moisture deficit index

6.4.3 Water quality issues

Hydrological water quality models are typically used for simulating sediment, nitrogen (N) and phosphorus (P) loadings. The following indicators for quantifying effectiveness of measures against water quality problems can be distinguished:

- Reduction of mean constituent (e.g. sediment, N, P) emission from the sub-catchment areas (loading that enters the stream network)
- Reduction in mean constituent concentration in river reaches
- Reduction in mean constituent loadings for a specific outlet
- Reduction of constituent loading or concentration during peak events

7. NSWRM planner

7.1 NSWRM planner methods

The goal of the application is to carry out a survey of local stakeholders in terms of ideas for planning measures in the field of water retention mitigating the effects of drought and floods and prepare the data necessary to develop the concept and estimate the investment risk.

The user can draw and modify polygons, generate reports in the form of tables and maps (rtf, pdf), save the polygon layer and attributes to the session file (eg GeoJson, shp), enable or disable the following layers: OpenStreet Map, Validation maps (vector), Drop map (raster), TWI map (raster). Another functionality is the ability to identify individual objects, i.e. on the valorization map and from the connected WMS map, connect a layer from any WMS site (OpenGIS® Web Map Service Interface Standard). A report can be generated with a map and table with the following attributes calculated on the basis of the shapes of the polygons introduced by the user:

- area of a single polygon [ha],
- the area of land use (according to CLC 2016),
- name, identifier and area of protected areas (according to GDOŚ data),
- parameters obtained from the terrain elevation model (ordinate of the area Min, Average, Max, slope of the area),
- the name and area of the sub-basin (according to MPHP),
- distance to the nearest river,
- distance from the nearest ditch,
- class of valorisation of water retention needs,
- monthly temperature and precipitation characteristics,
- climatic water balance
- flow characteristics in the nearest river,
- parcel numbers (if WFS will be available)
- administrative affiliation, district, commune, county, voivodeship
- information from the development plan (if available)

7.2 NSWRM planner web application

After selecting the NSWRM planner the mapping application will open. Currently the application contains six pilot catchments developed in the FramWat project. Examples below are presented for Kamienna catchment (Fig. 20). On the basis of data provided within the system the user can create, select and edit an area and propose a measure. The application has a side panel

which contains the main tools such as managing layers (legend), viewing and adding measures (Fig. 20 and 21).

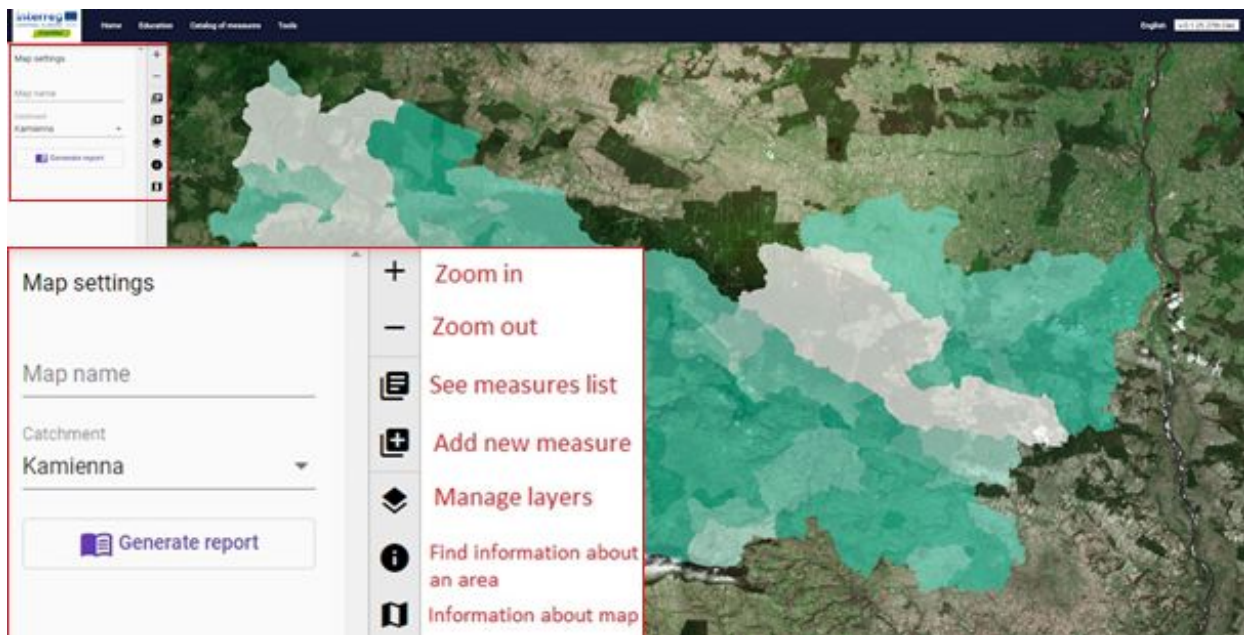


Figure 20 Opening screen with Kamienna catchment and enlarged side panel

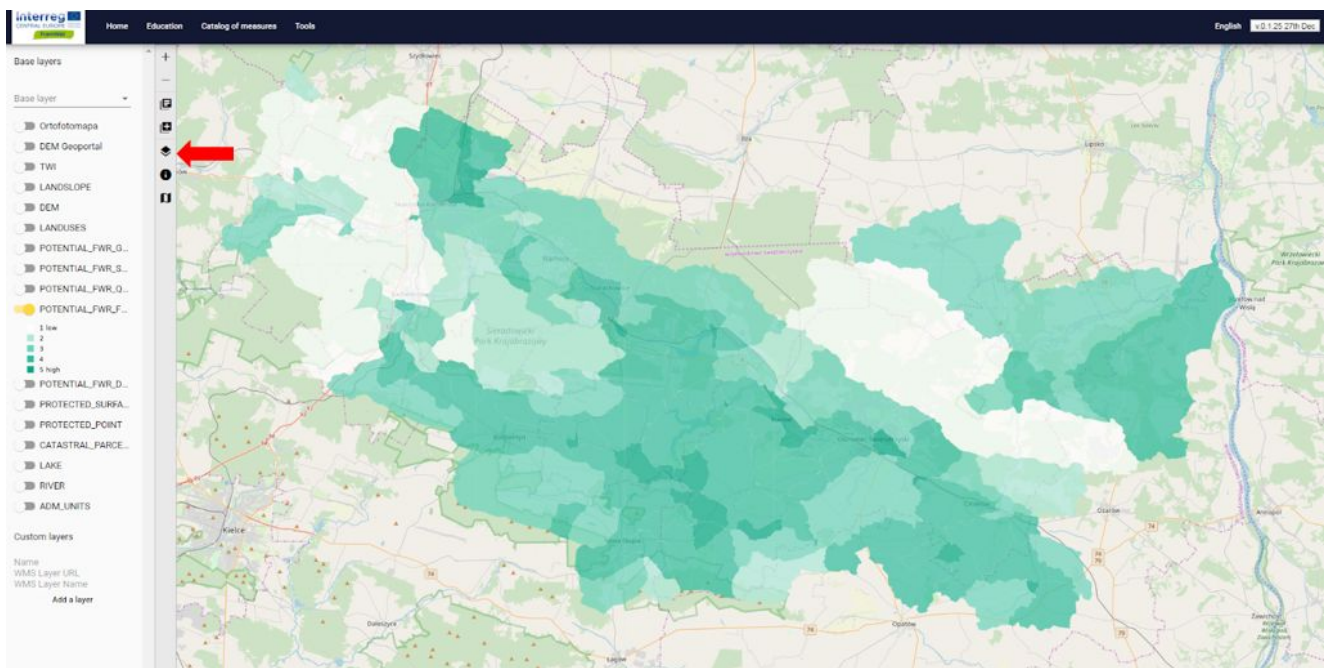


Figure 21 Kamienna catchment with the legend and the appropriate button **manage layers** marked with a red arrow

Users can propose the location of measures by using the “Add new measure” button. First the user is requested to draw with points the shape on the map (Fig.22). In order to finish drawing

the shape the user has to click the first point again (Fig. 23). The next step includes inputting data about the measure such as its type, surface area, name by clicking the edit button (Fig. 24).

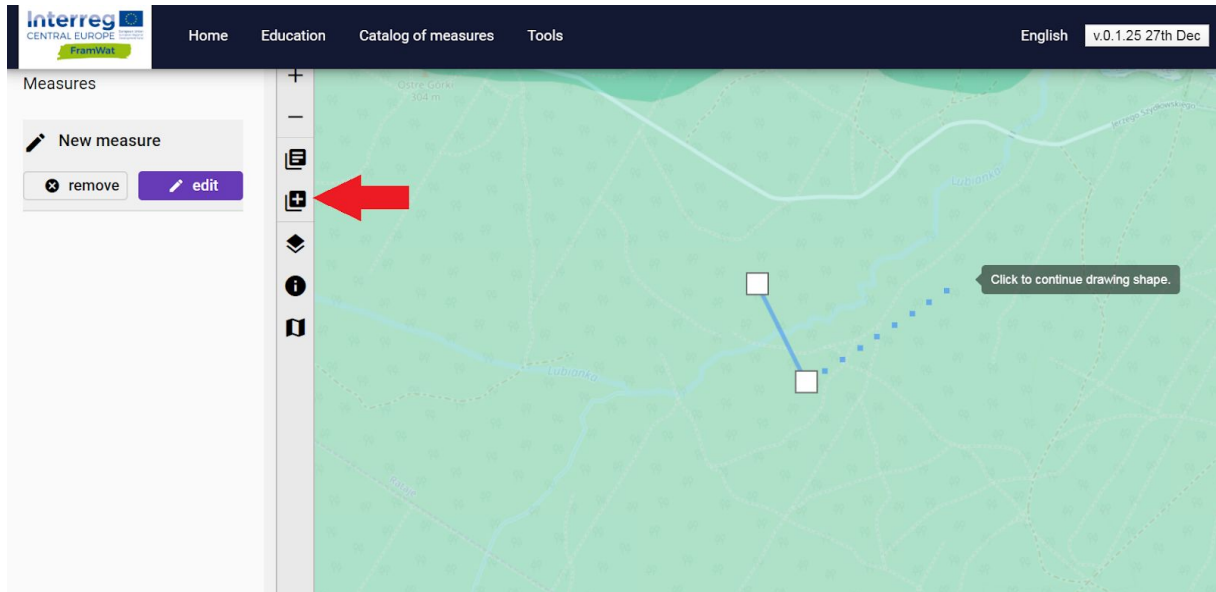


Figure 22 Adding a new measure (red arrow pointing towards the button)

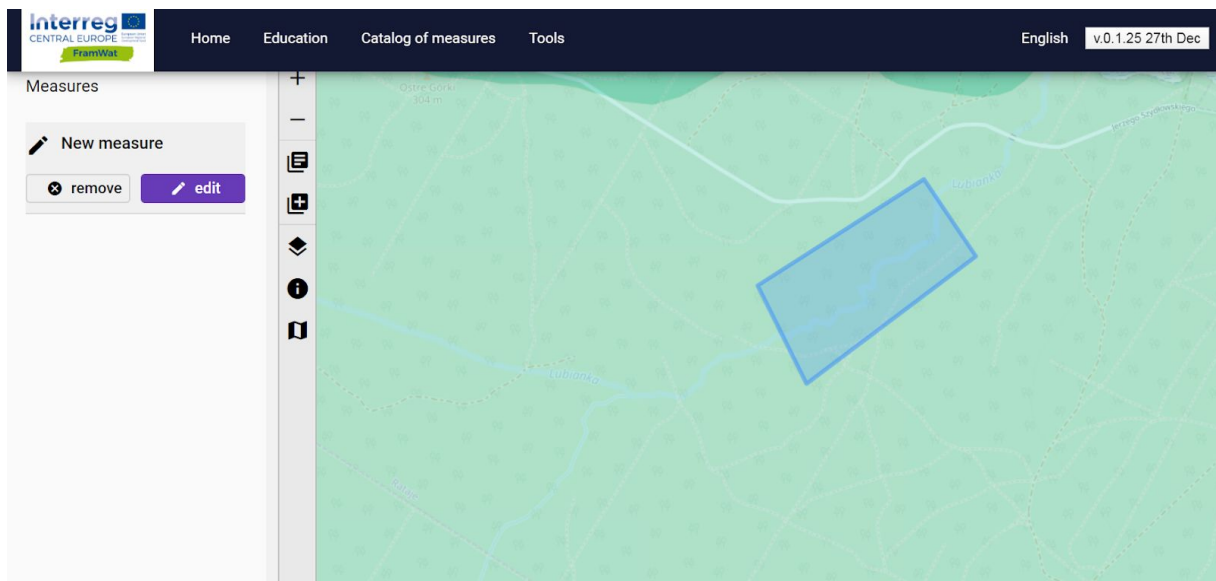


Figure 23 Adding a new measure -finishing drawing the shape

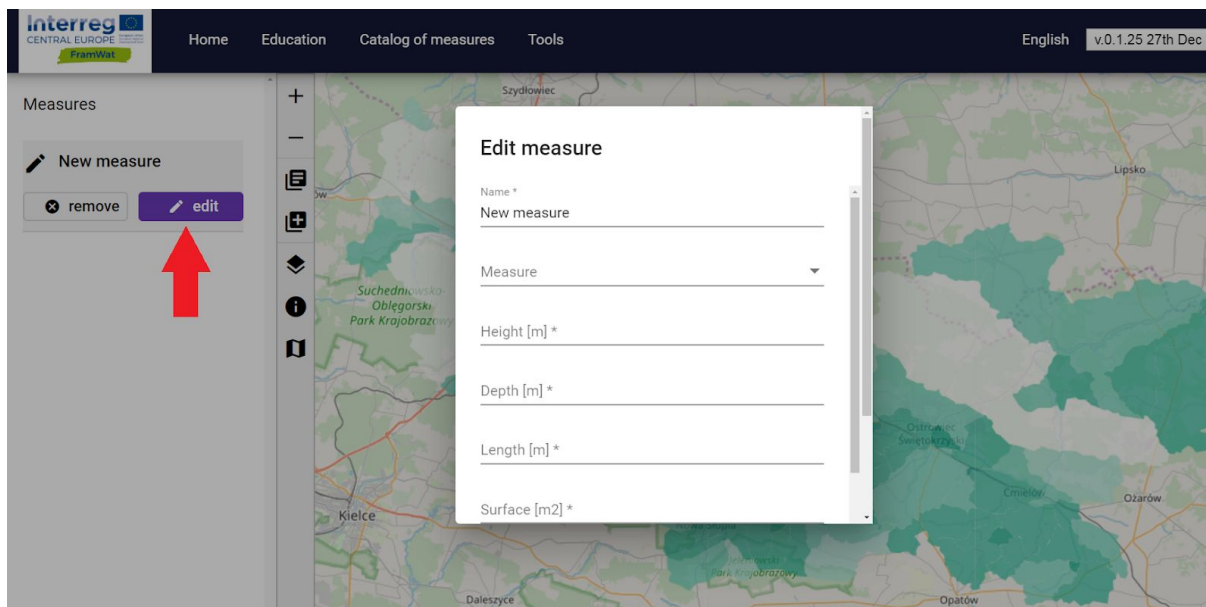


Figure 24 Editing the newly created measure (red arrow pointing towards the button)

7.3 Administration panel

Switching on the administration panel (Fig. 25) allows the admin to view the users details such as their id, name, email address, when the user created their account and the last time they logged in (Fig. 26). It is also possible to download or view measures added by the users (Fig. 27).

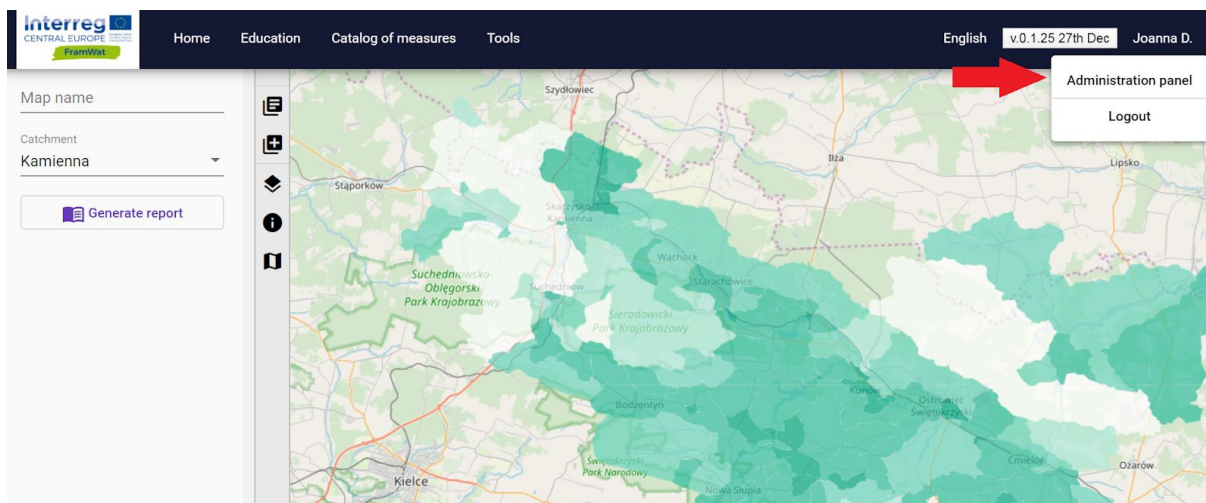
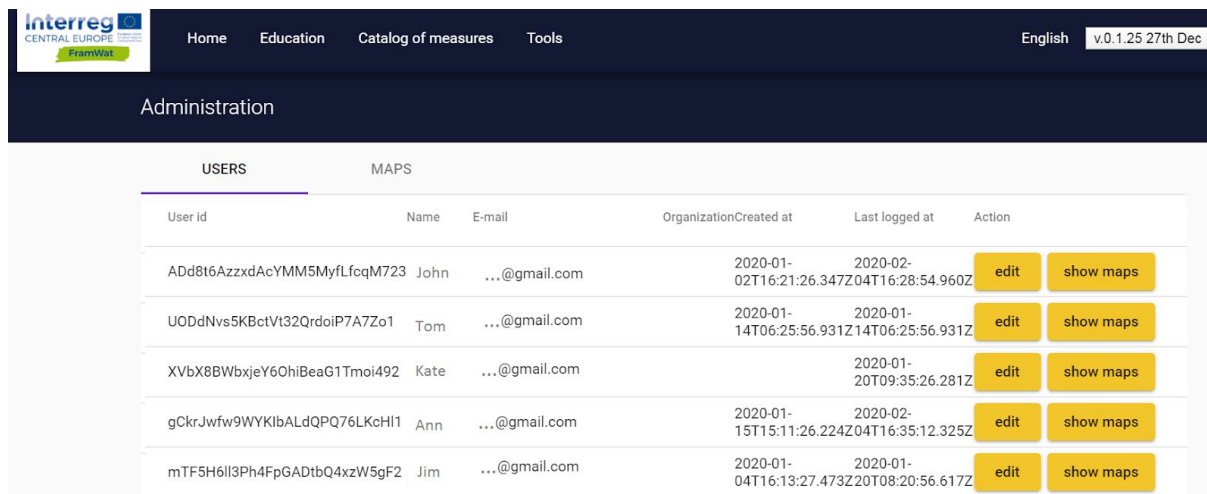


Figure 25 Switching on the administration panel



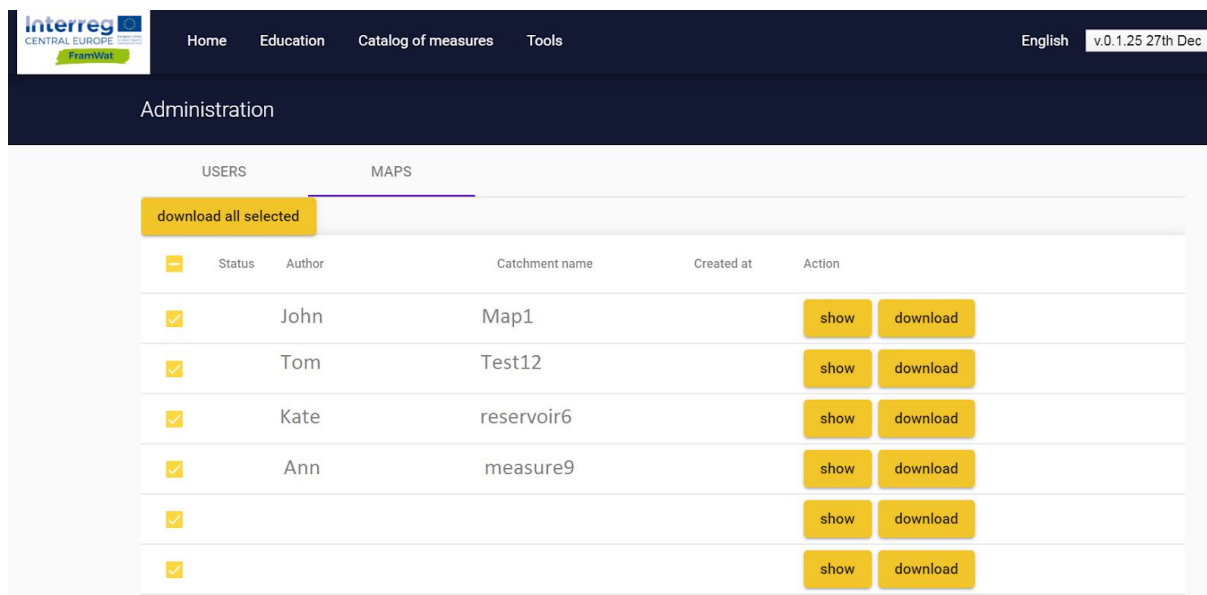
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Administration

USERS MAPS

User id	Name	E-mail	Organization	Created at	Last logged at	Action
ADd8t6AzzxdAcYMM5MyfLfcqM723	John	...@gmail.com		2020-01-02T16:21:26.347Z	2020-02-04T16:28:54.960Z	edit show maps
UODdNvs5KBctVt32QrdoIP7A7Zo1	Tom	...@gmail.com		2020-01-14T06:25:56.931Z	2020-01-14T06:25:56.931Z	edit show maps
XVbX8BWbxjeY6HiBeaG1Tmoi492	Kate	...@gmail.com			2020-01-20T09:35:26.281Z	edit show maps
gCkrJwfw9WYKibALdQPQ76LkChI1	Ann	...@gmail.com		2020-01-15T15:11:26.224Z	2020-02-04T16:35:12.325Z	edit show maps
mTF5H6ll3Ph4FpGADtbQ4xzW5gF2	Jim	...@gmail.com		2020-01-04T16:13:27.473Z	2020-01-20T08:20:56.617Z	edit show maps

Figure 26 Viewing the users of the planner



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Administration

USERS MAPS

download all selected

<input type="checkbox"/>	Status	Author	Catchment name	Created at	Action
<input checked="" type="checkbox"/>		John	Map1		show download
<input checked="" type="checkbox"/>		Tom	Test12		show download
<input checked="" type="checkbox"/>		Kate	reservoir6		show download
<input checked="" type="checkbox"/>		Ann	measure9		show download
<input checked="" type="checkbox"/>					show download
<input checked="" type="checkbox"/>					show download

Figure 27 Switching on the administration panel

8. AHP method as a supporting tool for optimal NSWRM selection

8.1 AHP method

AHP stands for Analytic Hierarchy Process and is one of the multi criteria decision-making methods for dealing with complex decision problems. It was developed by Saaty in 1977 and has since evolved depending on the needs of a variety of disciplines in which it is used.

Saaty (2009) describes decision making as a cognitive and mental process in which the most adequate selection is made based on different tangible (e.g. price, weight, etc) or intangible

(e.g. satisfaction, feelings, etc.) criteria. In AHP a person performing the task defines pair-wise comparisons of criteria, and by doing that the importance of criteria in a decision are determined. This can usually be achieved by simply selecting a weight on a predefined symmetric scale, that defines which of the two compared criteria is preferable, any by a what margin. It is important that pairwise comparisons are done with respect to all criteria (Saaty,Tran, 2007).

AHP method used for needs of NSWRM selections is altered, for criteria values are non-existing (whether there is a lack of data or criteria is not measurable). Hence each criteria has been assigned an expert value between 1-5 (with 1 being the least and 5 being the most important). By that the outcome of the AHP is not entirely based on end user (stakeholders) defined paired criteria comparisons, but is weighted by experts predefined criteria as well. This is arguably a way to get a more consistent outcome that considers both expert and stakeholders' opinion.

Detailed mathematical background of the method is extensively written in the article *On the invalidity of fuzzifying numerical judgements in the Analytic Hierarch Process*, Thomas L. Saaty, Liem T. Tran, Science direct – Mathematical and Computer modelling 46 (2007) 962-975.

8.2 AHP web application

AHP method (Analytic Hierarchy Process) has been implemented into the DSS tool (DSS stands for Decision Support System) as an optional supporting tool for NSWRM selection. It is designed as an interactive web application freely available for all interested parties, accessible both from DSS tool or directly through a web address <http://ahp.framwat.apps.vokas.si>.

AHP web application is translated to six (6) languages, that is to all official languages of FramWat project partners.

Whether using DSS link or web link, user is transferred directly to AHP web application's main window. It is designed as a single window application with sliders, selection boards and tables, but a separate window with additional data opens when a NSWRM is selected. App window is divided into major topics (Tab.2).

Table 2: Application design information

Nr	Topic:	Input or output	Mandatory input (Yes/No)	Comment
1	Filter by	Input	No	Optional filter
2	Choose which parameter values more		Yes	Mandatory input
3	Selected weights	Output	/	Only for informative purpose

4	Suggested measures	/	Output of the tool
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The upper part of the tool window is reserved for the input topics (Nr. 1 and 2), followed by Nr. 3 which is only informative and cannot be directly altered, and Nr. 4 which is the outcome of the tool. Application's main window is shown in Fig. 28.

The only topic that is mandatory to use is Nr. 2 (Choose which parameter values more).

Catalogue of measures is listed at the bottom of the tool (Nr. 4).

After user alters the mandatory parameters/weights (Nr. 2), measures in the catalogue (Nr. 4) are assigned the calculated scores and listed in descending order based on the score. The topmost measure in the list has the biggest score meaning, it is the best fit regarding user input and is as such suggested by the tool more than measures listed further below.

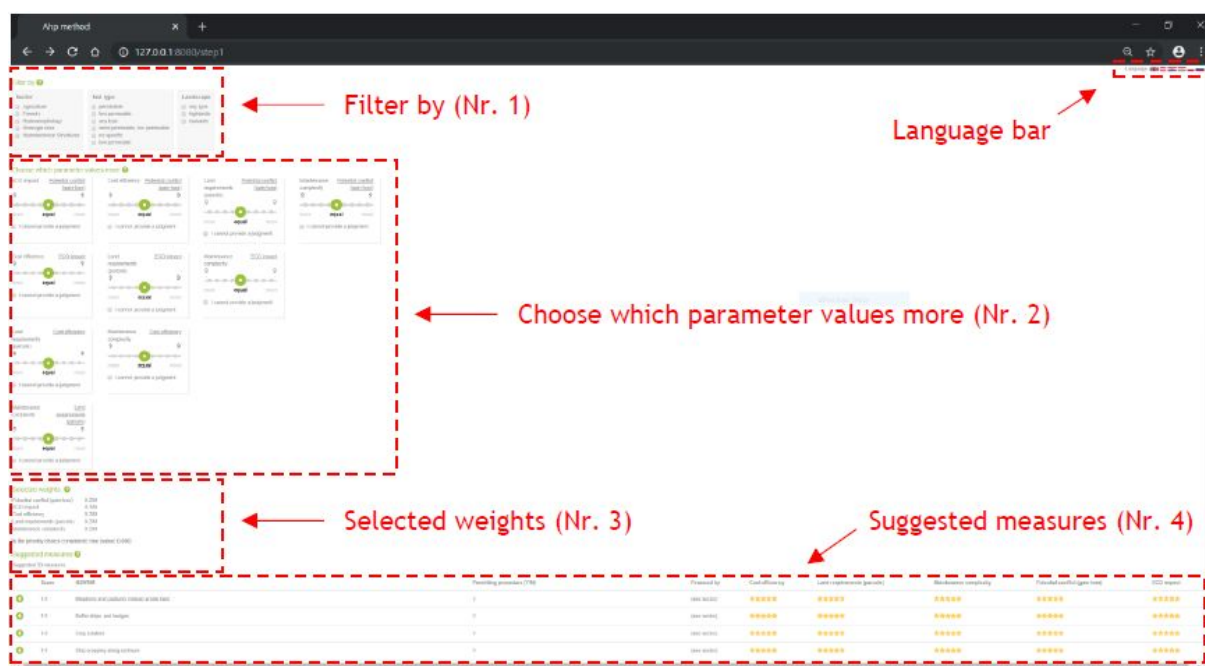


Figure 28: Application's main window. Red text, arrows and dashed frames are used for illustration purposes and are not included in the application itself.

User can filter results by selecting several options (Fig. 29). Selection is not mandatory. In case nothing is selected, all measures under Suggested measures (Nr. 4) will be shown in descending order based on calculated score. If some filters are selected, only measures that fit the filter selection will be shown.

Filter by ?

Sector	Soil type	Landscape
<input type="checkbox"/> Agriculture <input type="checkbox"/> Forestry <input type="checkbox"/> Hydromorphology <input type="checkbox"/> Drainage Area <input type="checkbox"/> Hydrotechnical Structures	<input type="checkbox"/> permeable <input type="checkbox"/> low permeable <input type="checkbox"/> any type <input type="checkbox"/> semi permeable, low permeable <input type="checkbox"/> no specific <input type="checkbox"/> low permeable	<input type="checkbox"/> any type <input type="checkbox"/> highlands <input type="checkbox"/> lowlands

Figure 29 Example of a selection board under the Filter by (Nr. 1) topic. Actual content in the application may vary, depending on the application.

Number of pairwise comparison depends on number of parameters, which is not something individual user could choose or alter (Fig. 30). User should move the slider towards the parameter of the two, which per his/her opinion values more and this conceptual selection directly influences the calculated weights and prioritization of measures. It is important, that weights of the chosen parameters are consistent.

Choose which parameter values more ?

<p>ECO impact <u>Potential conflict</u> (gain-loss)</p> <p>9 ← → 9</p> <p>more equal more</p> <p><input type="checkbox"/> I cannot provide a judgment</p>	<p>Cost efficiency <u>Potential conflict</u> (gain-loss)</p> <p>9 ← → 9</p> <p>more equal more</p> <p><input type="checkbox"/> I cannot provide a judgment</p>	<p>Land requirements <u>Potential conflict</u> (parcels) (gain-loss)</p> <p>9 ← → 9</p> <p>more equal more</p> <p><input type="checkbox"/> I cannot provide a judgment</p>
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Figure 30 Example of sliders under the Choose which parameter values more (Nr. 2) topic. Actual content and number of sliders in the application may vary, depending on the application. Red arrows and frames are used for illustration purposes and are not included in the application itself.

Listed parameters:

- ECO impact (stands for ecological impact)
- Cost efficiency (e.g. price vs. potential savings)
- Land requirements (parcels)
- Maintenance complexity
- Potential conflicts caused by implementation (social, economic, financial)

Choice between parameter weights is conceptual, hence users should select them accordingly - which parameter in terms of general meaning means more to them.

Consistency index is calculated based on users' input (weights) in previous step (Choose which parameter values more (Nr.2)). Here, user can not alter anything, it is meant for informative purpose only. "True" means that user selected weights are consistent in relation to each other and results in the next step are calculated correctly, "False" means the contrary (Fig. 31). Output of the tool relies heavily on consistency index, hence in case of "False" index, user

should inspect and correct inconsistently selected weights (Under Nr. 2, Choose which parameter values more).

Selected weights: ?

Potential conflict (gain-loss)	0.200
ECO impact	0.200
Cost efficiency	0.200
Land requirements (parcels)	0.200
Maintenance complexity	0.200

Consistency index:
-True
-False

Is the priority choice consistent: **true** (value: 0.000)




Figure 31 Example of consistency index under the Selected weights (Nr. 3) topic. Actual content in the application may vary, depending on the application. Red arrows and frames are used for illustration purposes and are not included in the application itself.

As a result the measures are listed in descending order based on calculated score (Fig. 32). The topmost measure in the list has the biggest score meaning, it is the best fit regarding user input and is as such suggested by the tool more than measures listed further below. By clicking on the measure, a new window opens with some additional data and a sample photograph to give a user a better understanding what the measure is about.

Score	NSWRM	Permitting procedure (Y/N)	Financed by	Cost efficiency	Land requirements (parcels)	Maintenance complexity	Potential conflict (gain-loss)	ECO impact
+ 1.0	Active water management on a drainage system (river valleys)	Y	(see sector)	★★★★★ ★	★★★★★★	★★★★★★	★★★★ ★★	★★ ★★ ★
+ 1.0	Widening or removing of flood protection dikes	Y	(see sector)	★★★★★ ★	★★★★★★	★★★★★★	★★★★ ★★	★★ ★★ ★
+ 0.96	Removal of dams and other longitudinal barriers	Y	(see sector)	★★★★★ ★	★★★★★	★★★★★★	★★★★ ★★	★★ ★★ ★
+ 0.96	Construction of small reservoirs on rivers (dammed reservoirs)	Y	(see sector)	★★★★★ ★	★★★★★	★★★★★★	★★★★ ★★	★★ ★★ ★
+ 0.96	Meadows and pastures instead arable land	Y	(see sector)	★★★★★ ★	★★★★★★	★★★★★	★★★★ ★★	★★ ★★ ★

Figure 32 Example of suggested measures and additional data window

9. Legal procedures for implementing NSWRM (applicable in Poland)

This tool is a query system in Microsoft Excel that allows searching for legal procedures and documents necessary for the investment process for preparation of 50 different NSWRM after prior indication of the type of measure, description of the place of implementation (watercourse or outside, private area, protected area) and current land use. Developed for Polish conditions and valid for November 2019.