O.T1.1 - TOOL: Landscape Valorisation Method (VM) and GIS Tool for identifying locations where N(S)WRM are needed

Version 1

01.2019

Contents

1. Introduction

This report contains the final version of the valorisation methodology and a description of the structure and functionality of the GIS Tools called FroGIS. Work was carried out as part of WP T.1 "Identification of the potential locations of the Natural Small Water Retention measures" in the period from July 2017 until Dec. 2018. This task was divided into three activities and six deliverables presented in Tab. 1. WULS was the leader and main contractor of the WP and was responsible for all activities related to the development of the methodology and FroGIS prototype, training and updates. Partners along with stakeholders helped in the development of the valorisation method by:
(1) reviewing literature in English and in their native languages, (2)developing a list of publicly available datasets and datasets available on request for their country area, (3) analysis of global datasets to determine the extent (statistics) of the spatial variability of climatic and physico-geographical indicators for a given country, (4) obtaining detailed data for the pilot catchment or larger region in order to prepare an analysis, (5) selection of objectives for mapping and indicators relevant at the national level and depending on global and regional variations,
(6) recommending changes to the proposed valorisation method. In terms of the FroGIS app development partners and stakeholders helped with: (1) testing the app in their pilot catchments, (2) consulting testing results with stakeholders, (3) reporting bugs and ideas, (4) submitting proposals for new indicators and helping to develop them in the R language.

Tab. 1 Structure of the activities and outputs in WPT.1

No	Name activities	Duration	Deliverable	Outputs
1.1	Developing landscape valorisation method for Natural Small Water Retention Measures	July 2017 - Dec. 2017	D.T1.1.1 - First version of the method ready for national feedbacks and inputs	
1.2	The prototype of the GIS tool and training	Sept. 2017 - May 2018	D.T1.2.1 - Prototype of the GIS tool D.T1.2.2 - Training course for the GIS Tool	O.T1.2 - TRAINING: Training course on how to use the GIS tool
1.3	Testing the prototype of the GIS tool in the river basins together with stakeholders	April 2018 - Dec. 2018	D.T1.3.1 - Reports from Pilot Action - testing the prototype in the river basins (all 6 river basins) D.T1.3.2 - Feedback workshop D.T1.3.3 - Updated version of valorisation method and GIS Tool	O.T1.3 - PILOT ACTION: testing GIS tool in the pilot catchments

2. Valorisation method

The aim of valorisation is to identify areas with a varying degree of predisposition for development (implementation) of small water retention measures and with different needs for the development of those measures in non-urban areas (rural areas, including rural housing, open spaces and forests).

As valorisation is meant to be universal, a set of statistical analyses is included and carried out for the selected areas, which then allows choosing suitable indicators. Therefore, in this method, an emphasis is placed on supporting the decision-making process. Fig. 1 presents the calculation algorithm. To make the figure more comprehensive, numbers were placed next to the individual actions. The following stages can be distinguished in the proposed method:

a) choosing a valorisation goal[2 (No. on fig.1)]

b) choosing Spatial Planning Units (SPU) and indicators dedicated to analysing the goal [3-4]

c) input of data necessary to calculate the indicators[5-9]

d) pre-processing of data using the selected method e.g. interpolation[10-11]

e) calculating indicators and their statistics for SPU (correlation matrix)[12-15]

f) choosing a final set of indicators after analysing the correlation matrix[16]

g) choosing the conversion method of indicator to index[17-18]

h) defining an aggregation method for indexes [19-20]

i) computing the aggregated values in SPU[21-23].

The detailed description of specific stages

a) (no. 2)

This step allows to choose from five available objectives (problems to be solved): general (need for water retention due to environmental and economic requirements), flood protection, drought prevention, water quality improvement and sediment (suspended and riverbed). A list of recommended indicators based on the user's response will appear. A lookup table with goals of assessment and indicators in two input variants is presented in Tab. 2. In the first variant, the user provides input from existing risk assessments (drought prevention plan, flooding, Nitrate Vulnerable Zones, groundwater pollution risk). In the second variant, the user can choose several indicators of needs or possibilities for water retention, which are summarised in Tab. 3.

b) (no. 3-4)

The choice of the basic valorisation unit depends mainly on the scale of the analysis (size of the valorisation area). We recommend using hydrographic units (eg. elementary basins, Water Framework Directive surface water bodies or aggregated water bodies) or modelling units (eg HRUs). Practically, it involves 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. In the catalogue, the indicators are described by the following attributes: name, label, definition (equations, if needed), indicator unit, and data necessary for calculating the indicators.

Additionally, they are assigned with names of the groups that derive from their type (eg. climatic, physico-geographical, hydrological, hydrogeological, economic, environmental and threat status from biogenic substances) and the purpose of the analysis for which they are recommended.

The user is able to remove some indicators or add another from the catalogue, from outside the suggested list. The result is a list of valorisation indicators (v.1).

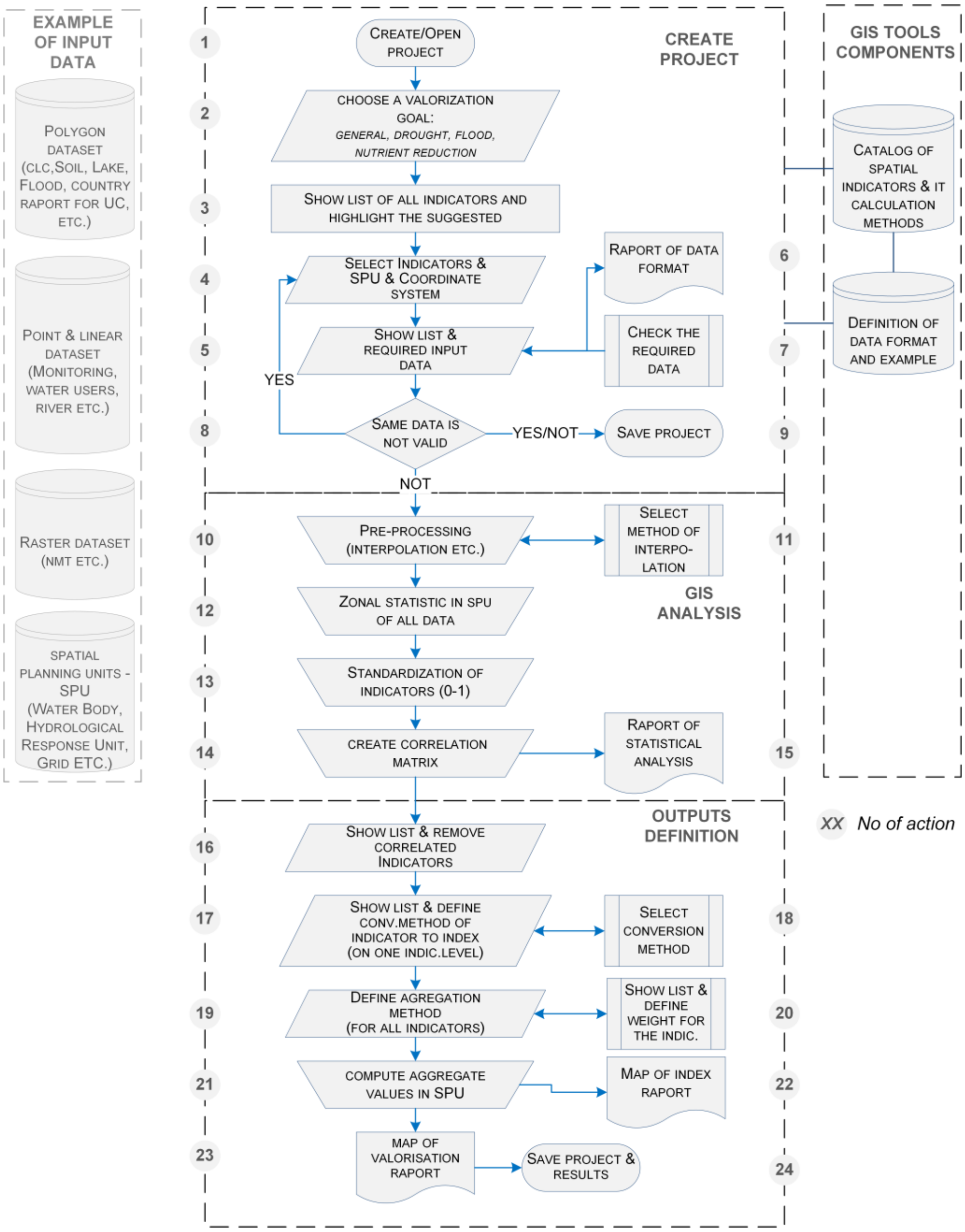

Fig 1 GIS tools algorithm for NWRM valorisation

c) (no. 5-9)

In the next stage, the user receives a list of data and their formats needed to calculate the selected indicators. Input must be prepared in the same coordinate system and should have a specified raster or vector format with the appropriate attributes. After providing the input data or during the validation of the data (data format, attribute names, coordinates, etc.), if it does not work correctly, the user will be allowed to resign from calculating that particular indicator.

d) (no. 10-11)

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

e) (no. 12-15)

Calculation of indicator values in spatial units SPU (Zonal Statistic function). Standardization of indicator values to scale <0, 1> ((x-AVGx) / σ) and calculation of a correlation matrix which finds and allows eliminating indicators with a strong correlation. Simplest linear standardization is sufficient. For each Xj indicator (eg share of forests, share of urbanized areas), which for SPU has a value of Xij, i = 1, ..., the number of SPU in the analysed area and MINj and MAXj denote the minimum and maximum values of the j-th indicator in the set of SPU's, the standardization conversion is carried out as:

$$XST_{ij} = (X_{ij} - MIN_j) / (MAX_j - MIN_j)$$

XSTij values are the basis for the correlation matrix calculations.

When a correlation matrix is presented, the user decides which indicators are going to be removed from further analyses. It is important to present/distinguish groups (pairs) of indicators that are highly correlated.

f) (no. 16)

Final determination of a set of valorisation indexes (v.2).

g) (no. 17-18)

In this section, the following must be carried out:

g1) Determination of stimulants and destimulants (or verification)

g2) Selection of the number of ranges

g3) Selection of methods for defining threshold values for indicators and calculation of indexes (classes)

g1) Determination of stimulants and destimulants (or verification)

The user will obtain a list for approval (with the possibility of editing), with the indicators identified as having characteristics of a stimulant or destimulant. Stimulant (S) is a variable for which the increasing value means an increasing need of developing small water retention (eg percent of urbanized areas), and destimulant (D) is a variable whose high values correspond to decreasing need for small water retention measures (eg. percentage of forests). Classification of stimulants / destimulants is a part of the "database of indicators".

g2) Selection of the number of ranges

The number of ranges should be consistent for all Xj indicators. It is suggested to choose between three, four or five classes, with numerical values, always starting with 1 and being integers {1, 2, 3} {1, 2, 3, 4} and 5.

g3) Selection of methods for determining threshold values for indicators and calculation of indexes (classes).

The following ways of determining the class thresholds (transforming functions) are available:

- ranges of equal width: the range of variation of the indicator divided by the number of classes selected by the user;
- natural breaks: thresholds of the ranges are chosen in such a way that the sum of the distance of the individual values of the indicator from the average in the range is the smallest (the calculation algorithm may be created, it is similar to cluster analysis with the given number of resulting clusters);
- percentile division (quantile): the thresholds for 3 classes are: 0, 20, 80, and 100% of the range of variation of the indicator; for 4 classes: 0, 15, 50, 85, 100%; for 5 classes:- 0, 10, 25, 75, 90, 100% (This is an example but it is advised not to use ranges of equal width);
- user division: the choice of setting the upper thresholds of the ranges (ranges closed from the top, <=) or the percentage of the variation range.

For all indicators, it is possible to choose one of the methods for determining the thresholds of the ranges, which (eg quantile) should also be defined by the default method.

In the case of destimulants, it should be ensured that the class 1 (the smallest) is assigned to the maximum value of the indicator (in stimulants, it should be the opposite). Displaying the statistic of the value of the indicator can be useful during decision making on how to set the thresholds of the ranges.

Conversion of indicators values into classes is carried out for non-standardized indicators.

h) (no. 19-20)

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

The default value of the weight is 1; the user has the ability to change the weight for the indicators (between 0 and 1).

Selection of weights can be carried out through the use oamif optimization methods:

h1) preparation of two input data sets:

a) lookup table SPU IDs and indicators classes (computed in No. 17-18)

b) collection of SPU IDs created as a result of field studies of up to 10% of all SPUs that have very low or very high needs and retention capabilities

h2) calculation of the weighted average of the indicator classes for individual SPUs (***WightAvg***)

h3) grouping of above-mentioned calculations into two sets (recognized - ***RecoWightAvg*** and unrecognized - ***NotRecoWightAvg***) and searching for each of their median value

h5) using, for example, the Nonlinear GRG method to find the maximum or minimum for the ***Median equation (RecoWightAvg) -Median (NotRecoWightAvg)*** with the assumption that the weights are chosen in the range 0-1. The maximum when it concerns an SPU with a recognized high water retention potential and the minimum in the opposite case. An example of calculations is available in the application's manual.

i) (no. 21-23)

Compute aggregated classes into SPU. Then, again the number of classes and ways of determining the limits of the intervals transforming aggregated classes should be defined. The choice may be different than in the previous case.

Presentation of analysis results - general valorisation and valorisation for selected objectives: flood protection, drought prevention, water quality improvement.

Tab. 2 Lookup table goals of assessment and indicators in two variants

Goal of assessment/ actions	Input variant 1	Input variant 2
	The user provides input from existing risk assessment (drought protection plan, flood, Nitrate Vulnerable Zone, groundwater pollution risk)	The user provides indicators of needs and possibilities of water retention
Drought	Map of atmospheric drought hazard	**cwb**- Climatic Water Balance
		Pre_Var_a- Growing season monthly Precipitation Variability - Annual
		Pre_Var_m- Growing season Precipitation Variability -Multiannual
		PrecFreqLow75- Frequency of precipitation lower than 75% of the multiannual average (in the growing season)
	Map of soil (agricultural) drought hazard	**swr**- Maximum soil water retention
	Map of hydrogeological drought hazard	**grr**- Groundwater Renewable Resources Module
	Map of hydrological drought hazard	**sri**- Surface Runoff Index
		bfi- Base Flow Index
		FlowMinMaxRatio- Mean low flow to mean high flow ratio
		FlowMinAvgRatio- Mean low flow to mean flow ratio
		FlowVarRatio_m- Low mean flow to hight mean flow ratio
		WaterYieldMinFlow- Water yield (specific runoff) for low flow in the multiannual period
		WaterYieldAvgFlow- Water yield (specific runoff) for mean flow n the multiannual period
Flood/Drought	Flood Risk Management Plans	**sri**- Surface Runoff Index
		bfi- Base Flow Index
		FlowMinMaxRatio- Mean low flow to mean high flow ratio
Flood		**FlowMaxAvgRatio**- Ratio of high low flow to mean flow in the multiannual period
		RiverSlope- Slope of river
		LandSlope- Slope of land area
		MeanderRatio- Ratio of artificially straight main stream length to natural length of main stream
		FloodRiskAreaRatio- Flood hazard zone area ratio
		NonForestedRatio- Non-forested area with a slope above 5% to SPU area ratio
		LakeCatchRatio- Lake catchment area to SPU area ratio
Flood/ Drought (the land use and topography group)		**DrainageD**- Drainage Density
		twi- Topographic Wetness Index
		ForestRatio- Forested area to SPU area ratio
		LakeRatio- Lakes and reservoirs area to SPU area ratio

Goal	Input variant 1	Input variant 2
		WetladRatio- Wetland area to SPU area ratio
		OrchVegRatio- Orchards & vegetable farming area to SPU area ratio
		UrbanRatio- Urban area to SPU area ratio
		ArableRatio- Arable area in SPU area ratio
		ReclaimedRatio- Reclaimed meadows and pastures area to SPU area ratio
Quality (High values indicate the need to develop NSWRM)		**NonForestedRatio**- Non-forested areas with a slope above 5% to SPU area ratio
		EcoAraBuf20mRatio- Arable lands in 20-meters buffer around surface waters area to SPU area ratio
		EcoAreaRatio- Semi-natural land cover types area to SPU area ratio
		EcoNumRatio- Number of semi-natural land cover patches to a total number of land cover patches in SPU
		EcoCombined- Combination of number of semi-natural land cover patches and their area
		EcoBadRHS- Bad morphological elements length to total length of the river in SPU
Sediment		**GraniteRatio**- Granitic bedrock area in SPU area ratio
		RainFallErodibility- Rainfall erodibility factor
		SoilErodibility- Universal soil loss equation factor
		NonForestedRatio- Non-forested areas with a slope above 5% to SPU area ratio
		ForestRatio- Forested area to SPU area ratio
		RiverSlope- Slope of river
		LandSlope- Slope of land area
		MeanderRatio- Ratio of simplify main stream length to natural length of main stream
Additional to make a decision (Information which is not used for indexing)	Map of groundwater contamination hazard from the land/terrain surface	
	Nitrate Vulnerable Zones Maps	
	Protected Areas Map	
	Physicochemical quality assessment of surface waters	
	Existing hydro-technical constructions - towering water	

Tab. 3 Characteristics of indicators for assessing the needs and possibilities of water retention

Thematic group	Description of indicators	Unit	Type: N-needs, P-possibilities	Type of stimulation: St-stimulant, Dstt-destimulator	Aim: D-drought, F-flood, Q-quality, S-sediment	Relevance where 1-important, 2 less
Climat	**cwb**- Climatic Water Balance; cwb = 1/NYears * sum(Pi-ETpi), i=1,NYears, [mm]; climatic water balance, calculated as accumulated for the growing season, averaged for the multiannual period	mm	N	Dst	D	1
	Pre_Var_a- Growing Season Monthly Precipitation Variability; Pre_Var_a = 1/NYears*{sum(([pMaxMth_i]-[pMinMth_i])/[pAvgMth_i])}, i=1,NYears, [-];Precipitation sum - average intra year variability- amplitude of monthly sum of (pMax_i - pMin_i) divided by mean monthly precipitation, averaged for the multiannual period	-	P	st	D	1
	Pre_Var_m- Growing Season Precipitation Variability for the multiannual period - the ratio of the lowest (min) growing season sum of precipitation to average growing season sum of precipitation; Pre_Var_m= [pMin]/[P], [-]	-	N	Dst	D	2
	PrecFreqLow75 [-]; Frequency of precipitation lower than 75% of the multiannual average (in the growing season)	-	N	st	D	1
	RainfallErodibility - Rainfall erosivity factor from universal soil loss equation. This factor depends on average annual precipitation for mediterranean climates and on average annual precipitation during vegetative season for temperate climates. The implemented formulation uses fuzzy logic to choose the correct formulation according to latitude., as described by van der Knijff et al (2000). [(MJ mm) / (ha hr y)]	(MJ mm) / (ha hr y)	N	st	S	1
Ecological status	**AraBuf20mRatio** - Arable lands in 20-meters buffer around surface waters (streams, rivers and lakes) area to SPU area ratio [%]	%	N	st	Q	1
	EcoAreaRatio - Semi-natural land cover types area to SPU area ratio [%]	%	N	Dst	Q	2
	EcoBadRHS - Total length with poor or bad morphological elements assessment and the total length of watercourses in SPU [%]	%	N	st	Q	1
	EcoCombined - the combination of a number of semi-natural land cover patches and their area (combination use EcoAreaRatio and EcoNumRatio and look-up table) [-]	-	N	Dst	Q	2
	EcoNumRatio- Number of semi-natural land cover patches to a total number of land cover patches in SPU [%]	%	N	Dst	Q	2
	NonForestedRatio- Non forested areas with a slope above 5% (2,86°; 0.05radian) to SPU area ratio [%]	%	NP	st	FQS	
Hydrogeology	**grr** [mm] - Groundwater Renewable Resources Module. Get a ready map from the hydrogeological institute or from the hydrogeological map	mm	N	Dst	D	1
	DrainageD- Drainage Density - river network density [km/km2]	km/km2	P	st	DF	1
	LakeCatchRatio - Lake catchment area to SPU area ratio - Immediate lake's catchment area in SPU ratio [%]	%	N	Dst	F	2
	LakeRatio- Lakes and reservoirs area to SPU area ratio [%]	%	N	Dst	DF	1
	MeanderRatio - Ratio of artificially straight main stream length to natural length of main stream [%]	%	N	st	FS	1
Hydrology	**bfi**- Base Flow Index - groundwater contribution to river flow; bfi= Median (LQij) /Average(MQij), i=1,NYears, j=1,12 months, LQij-the lowest of daily flows within a month, MQij-mean of daily flows within a month; [-];	-	N	Dst	DF	1
	FloodRiskArea - Flood hazard zone area to SPU area ratio [%]	%	P	st	F	1
	FlowMaxAvgRatio- ratio of high flow (swMHQ) to mean flow (swMMQ), [-]; high flows assessment	-	P	st	F	2

Thematic group	Description of indicators	Unit	Type: N-needs, P-possibilities	Type of stimulation: St-stimulant, Dstt-destimulator	Aim: D-drought, F-flood, Q-quality, S-sediment	Relevance where 1-important, 2 less
	FlowMinAvgRatio- ratio of mean low flow [swMLQ] to mean flow [swMMQ], [-] low flows assessment; Calculated for internal runoff from sub-basins.	-	N	Dst	D	2
	FlowMinMaxRatio- the ratio of mean low flow [swMLQ] to mean high flow [swMHQ] [-]; Variability of river flows in the multiannual period; Calculated for internal runoff from sub-basins.	-	P	Dst	DF	1
	FlowVarRatio_m= ratio of low mean flow [swLMQ] to hight mean flow [swHMQ] [-] Flow Variability multiannual: the ratio of the lowest and the highest of yearly mean flows; Flow variability in dry and wet years in the multiannual period	-	N	Dst	D	2
	sri = swMMQ / P [-]Surface Runoff Index- the ratio of multiannual mean flow (swMMQ, expressed in mm) and the average sum of precipitation [mm]; calculated for internal runoff from sub-basins, without imported (flowing from upstream) water	-	P	st	DF	1
	WaterYieldAvgFlow [mm] - water yield (specific runoff) for mean flow [swMMQ]	mm	N	Dst	D	1
	WaterYieldMinFlow [mm] - water yield (specific runoff) for low flow [swMLQ]	mm	N	Dst	D	2
Landuse	**ArableRatio**- Arable area in SPU area ratio [%]	%	N	st	DF	1
	ForestRatio - Forested area to SPU area ratio [%]	%	N	Dst	DFQS	1
	OrchVegRatio- Orchards & vegetable farming area to SPU area ratio [%]	%	N	st	DF	1
	ReclaimedRatio - Reclaimed meadows and pastures area to SPU area ratio [%]; Intersect meadows and pastures (CLC code: 231) with ditches (buffer 100m)	%	NP	st	DF	1
	UrbanRatio- Urban area to SPU area ratio [%]	%	P	st	DF	1
	WetlandRatio - Wetland area to SPU area ratio [%]	%	N	Dst	DF	1
Soil	**GraniteRatio** - granitic bedrock area in SPU area ratio [-]	%	P	st	S	1
	SoilErodibility - Soil erodibility factor in universal soil loss equation (USLE). Formulation proposed by Williams (1995): K erodibility factor depends on soil grain size distribution (silt, clay, sand) and organic matter content. [(t ha hr) / (MJ ha mm)]	(t ha hr) / (MJ ha mm)	N	st	S	1
	swr [mm] - soil water retention maximum soil water retention based on the type of soil (general)	mm	N	Dst	D	1
Landform	**LandSlope** - Slope of the land area calculated from DEM	deg	P	st	FS	1
	RiverSlope - Slope of main stream in SPU [%]	%	NP	st	FS	2
	twi - Topographic Wetness Index - a steady state wetness index based on DEM [-] (SAGA TWI)	-	N	Dst	DF	1

3. GIS Tools (FroGIS)

In the initial assumptions, the GIS tools (FroGIS) was to development of a widely available and intuitive application that can be used in the first stage of planning actions and in the future become a part of a larger decision support system enabling communication between stakeholders (local authorities) and catchment management authorities. In addition, this application should be written in Open Source software and published in a portal which would enable its further development. In addition, it should have a universal character, which would allow using it in Central Europe.

Finally, after testing and upgrade, the above mentioned assumptions were made and the FroGIS application was development. The app is available at http://WaterRetenion.sggw.pl along with manual, online course, sample and global data, FAQ and a public forum guaranteeing its development.

The application architecture (Fig. 1) is based on open source software and can be installed on another computer after installing the free Docker software from https://www.docker.com. Details of the installation are described in the manual. The user can use the application without installation by going to the website http://WaterRetenion.sggw.pl and downloading input data from his computer. The communicating with the user takes place through an Internet browser and GUI divided into seven handbands, which develop in accordance with the required work steps described in the methodology (Fig.2). The last handband presents the results in the form of an interactive map and allows download results of calculations in the form of * .csv and * .shp. Initial users can practice working on the application using test data. User's advancements can prepare own data using the global dataset and manual or develop app on GitLab forum https://gitlab.com/framwat.

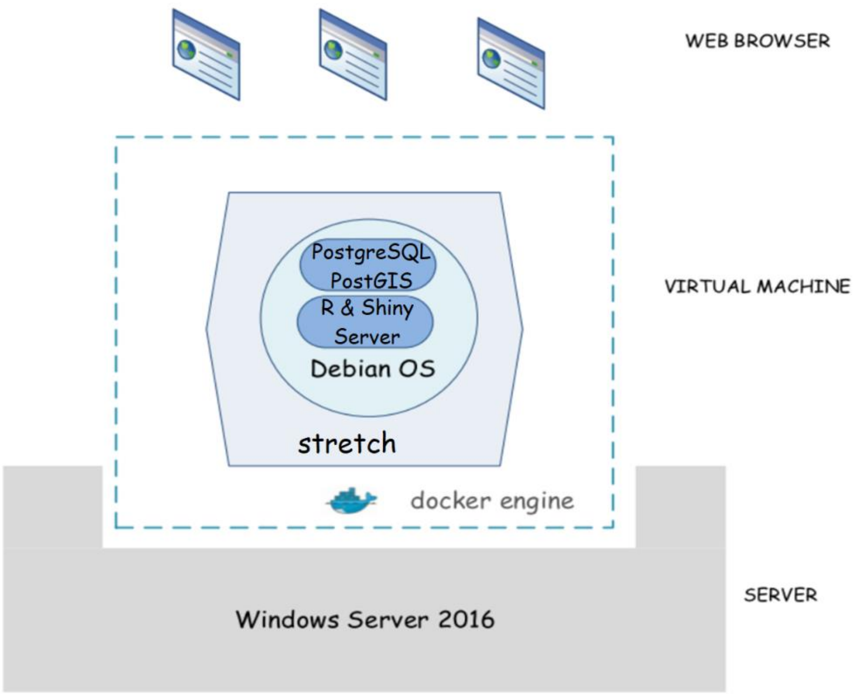

Fig. 1 FroGIS architecture

The FroGIS software has the following functionality:

- Downloading *.shp and *.geotiff files
- The ability to maintain a calculation session until the application is closed
- Possibility of stepping back and correcting input data and paramters
- Presentation of the correlation matrix and removal of unnecessary indicators

- Presentation of statistics for indicators
- Option to choose different classification methods and to manually adjust intervals
- Presentation of interactive result map with the ability to identify values
- Downloading the report in csv and shp format
- Support 20 Geographic Coordinate Systems
- Handy links to methods, instructions, sample data, FAQ

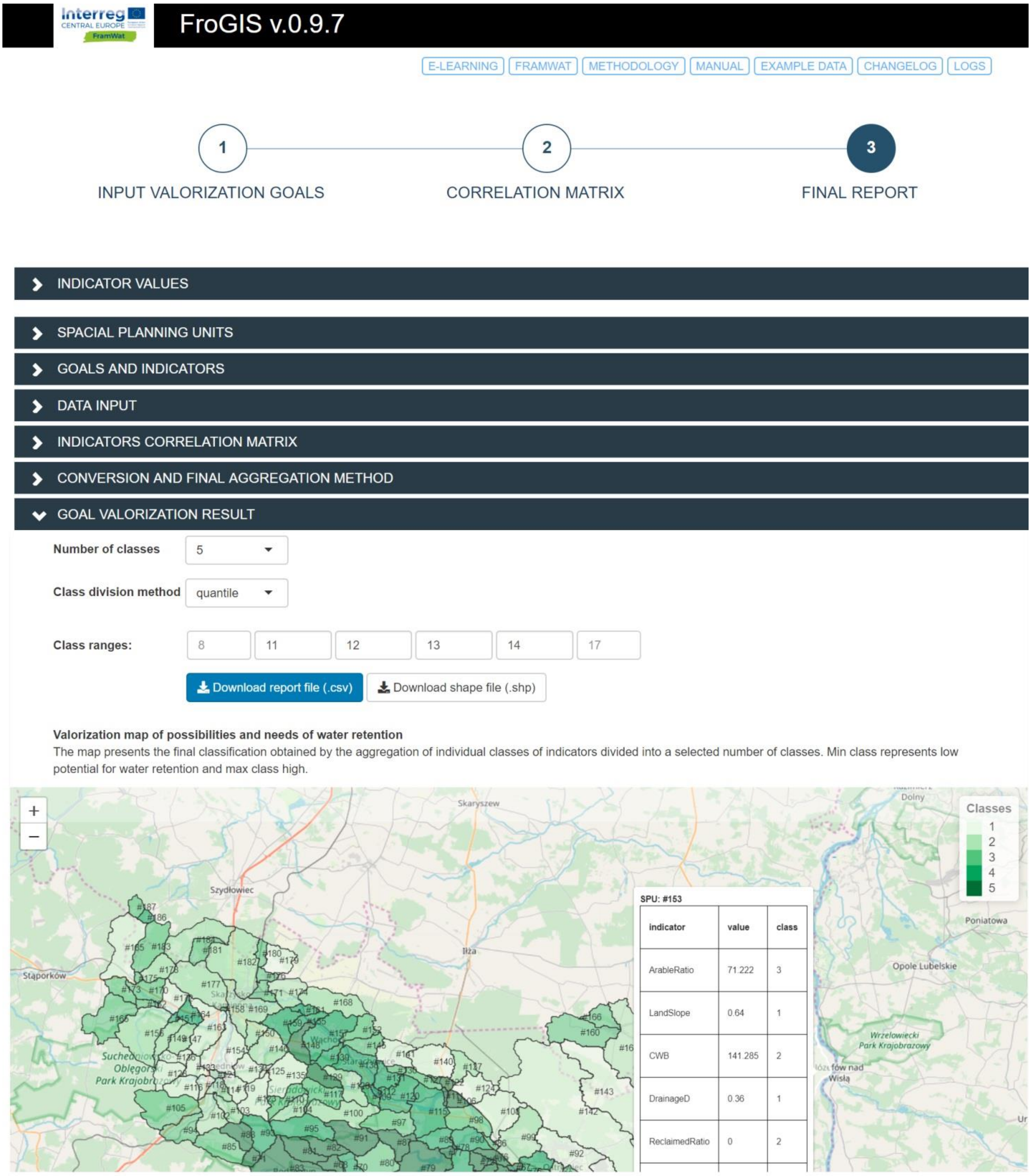

Fig. 2 Graphic user interface of FroGIS app