INTEGRATED APPROACH TO CUMULATIVE EFFECTIVENESS ASSESSMENT

D.T2.5.3

Manual on how to assess the effectiveness of a system of measures in a river basin

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INTRODUCTION

Introduction to the FramWat project idea.

Fig. 1 Panoramatic picture of dry reservoir Klátova Nová Ves, Slovakia (Robert Slížik/SWME)

Natural inundation or water accumulation in landscape features has been a part of the hydrological cycle throughout history. Humans have strongly altered the natural landscape conditions over recent centuries. It resulted in significant changes in landscape behaviour. Particularly in the context of increasingly more frequent extreme events (floods, droughts), it is currently extremely important to focus on the renaturisation and revitalisation of landscape features. The alteration of natural land/landscapes by man contributes to increased risk of floods and droughts, and a decrease in water resources. It also leads to the loss of biodiversity within European river basins.

The objective of this document is to propose measures to mitigate negative impacts of flood and drought, and to improve the quality of water and ecosystems via increasing the water retention capacity of landscape.

In order to tackle these challenges, nine project partners and six associated partners came together in project FramWat. The partnership involved higher education institutions, water management authorities, international organisations, and policy representatives from six European countries.

The project focused on the following:

- Closing knowledge gaps
- Strengthening governance
- Strengthening integration into policy and encouraging better implementation

Project FramWat was co-funded by the European Regional Development Fund in the framework of the Interreg Central Europe Programme. Further information on the project, news on events, and project results are available at https://www.interreg-central.eu/Content.Node/FramWat.html.

The objectives of the project are:

- to help decision makers/authorities prepare background documents on natural small water retention measures for River basin management plans, Flood risk management plans, etc.; and
- to facilitate the argumentation and consultation process with different stakeholders.

1. OBJECTIVE AND BASIC ASSUMPTIONS

Objectives/scope of the Manual, main users and their experiences.

The primary goal of the Manual on how to assess the effectiveness of a system of measures in a river basin is to support the selection of the most hydrologically effective/appropriate natural small water retention measures (NSWRMs) at the local and catchment scale. The manual will help regional and national decision makers/authorities prepare relevant parts of the Program of Measures for their River basin management plans (RBMPs), Flood risk management plans (FRMPs), Wetlands management plans, or other "water-related national plans", and compile Action plans in the next planning cycles. Moreover, it will facilitate arguments for the consultation processes between different sectors or stakeholders in particular countries (agriculture, forestry, municipal authorities, etc.), aimed at the selection of NSWRMs to be used in strategic documents. If a system of several NSWRMs is adopted, decision makers/authorities need to evaluate the cumulative effectiveness of such a system in a synergic way.

The Manual is a generally applicable tool. The user is guided through the approach to be able to assess the effectiveness of the proposed system/combination of measures. It will facilitate the daily decision making process of water and other land management authorities and medium-size investments.

Once a system/combination of several NSWRMs is proposed/adopted for particular catchment, the manual should help water and other land management authorities evaluate the cumulative effectiveness of this system of NSWRMs (in a synergic way).

The Manual should help the authorities apply and adapt tools developed within the FramWat project to specific problems in their river catchments. The methodology of cumulative assessment of the effectiveness of measures is a flexible, hierarchical, and balanced approach using the existing data analyses and expert assessments. Unfortunately, the knowledge gap in quantitative assessment of the effectiveness of NSWRMs and their cumulative effects is still vast, and will probably remain so for years.

Who are users of the Manual?

The Manual on how to assess the effectiveness of a system of measures is dedicated to water and other land management authorities. They can be:

- a general authority with no expertise in the field of assessment of the effectiveness of NSWRMs, or
- authorities/experts with expertise in the field of assessment of the effectiveness of NSWRMs.

The Manual is dedicated for the following users:

- decision makers/water management authorities at the river basin level
- decision makers/water management authorities at the local level

who need to find a common ground in decision making with all parties involved in the river basin management planning process (water management, nature conservation, agriculture, forestry, recreation including spatial planning).

The required expertise and minimal knowledge of users covers:

- knowledge of particular outputs of the FramWat project (explained below);
- basic Ms Excel skills; and/or
- experience with modelling

The Manual assumes that the user has knowledge on the following:

- the scale of available input data
- the scale of a river basin for planning level.

Methodology on how to work with the Manual

The Manual provides users with a set of procedures to follow to reach the desired goal, namely the evaluation of the effectiveness of the proposed set of NSWRMs.

The document guides the user via targeted questions and responses through all four phases of the integrated approach to assessment of cumulative effectiveness of NSWRMs; from the first step of NSWRM effectiveness assessment process to the last step resulting in the design of the final Concept plan. The final Concept plan means the most effective/optimal scenario/variant of combination of NSWRMs for a particular river catchment.

The Manual also constitutes the main output/tool of workpackage 2 "*Effectiveness of Natural Small Water Retention Measures*" (O.T2.1 - TOOL: Manual on how to assess the effectiveness of a system of measures in a river basin). The Manual constitutes a supplement to the Guidelines developed within workpackage 3 "*Policy integration and economic instruments*" (O.T3.1 - TOOL Guidelines to improve water balance and nutrient mitigation by applying a system of N(S)WRMs). The results of a particular phase of the integrated approach to the assessment of cumulative effectiveness of NSWRMs (see chapter 3) were developed and tested in six pilot catchments (see Fig. 2) of partner countries of the project (see FramWat project website):

Austria	-	Aist catchment
Croatia	-	Bednja River catchment
Hungary	-	Nagykunsági River catchment
Poland	-	Kamienna River catchment

Slovakia – Blh River catchment

Slovenia - Kamniška Bistrica River catchment

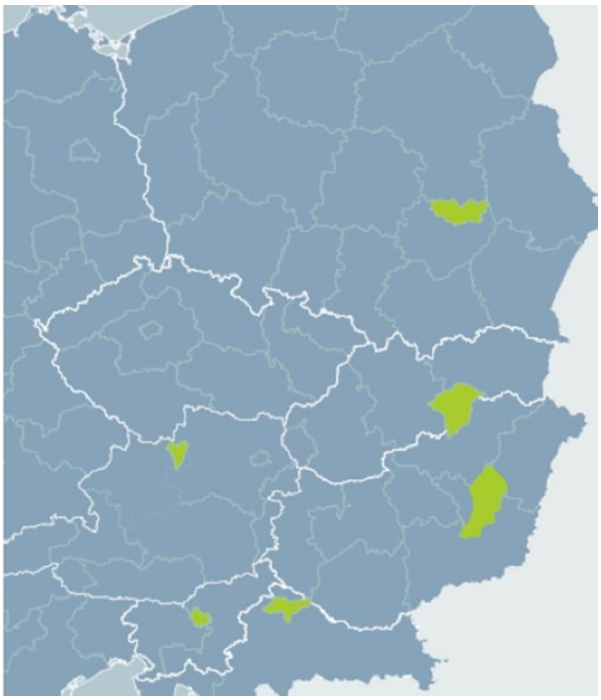


Fig. 2 Pilot catchments of partner countries of the project

2. INTEGRATED ASSESSMENT OF CUMULATIVE EFFECTIVENESS of NSWMRs

Description of the main idea and procedures/algorithms of the integrated assessment of cumulative effectiveness of NSWRMs

The Manual on how to assess the effectiveness of a system of measures in a river basin summarises and systematises all phases of assessment of the effectiveness of a system of natural small water retention measures (NSWRMs) in river basins/catchments. According to the FramWat project methodology, the assessment consists of the following phases:

Existing parameters for the evaluation of the effectiveness of NSWRMs

Proposal and selection of variants (combination of measures) for the effectiveness assessment

Static method of effectiveness assessment

Dynamic method of effectiveness assessment

The Manual summarises and systematises results of project activities A.T2.1 Review of the existing parameters for the evaluation of the effectiveness of NSWRMs; A.T2.2 Development of a GIS based method of assessment of the cumulative effect of NSWRMs at the river basin scale; A.T2.3 Development of a Concept plan for NSWRMs in river basins; and A.T2.4 Application of dynamic water quantity and/or quality models. The phases of the integrated approach to the assessment of cumulative effectiveness (IAACE) of NSWRMs and their relationships are demonstrated in Fig. 3 below. The existing knowledge about the used NSWRM features and IAACE results from the principle that the cumulative effectiveness of NSWRMs can be assessed:

- at the river basin (spatial planning unit) level
- at the local level

Before starting work with the Manual

Before the user (general authority or expert) starts work with the Manual, they need to become familiar with 50 types of NSWRMs listed in the "*Catalogue of measures*" and with measures behaviour/functioning described therein. The "*Catalogue of measures*" assigns relevancies of described NSWRMs to each of five defined goals:

- general[1]
- flood protection
- drought prevention
- water quality (nutrients) improvement

[1] The general goal represents the need for water retention based on environmental and economic requirements.

- sediments

The user of the Manual should be aware of the different behaviour of types of NSWRMs based on location in:

- highlands
- lowlands

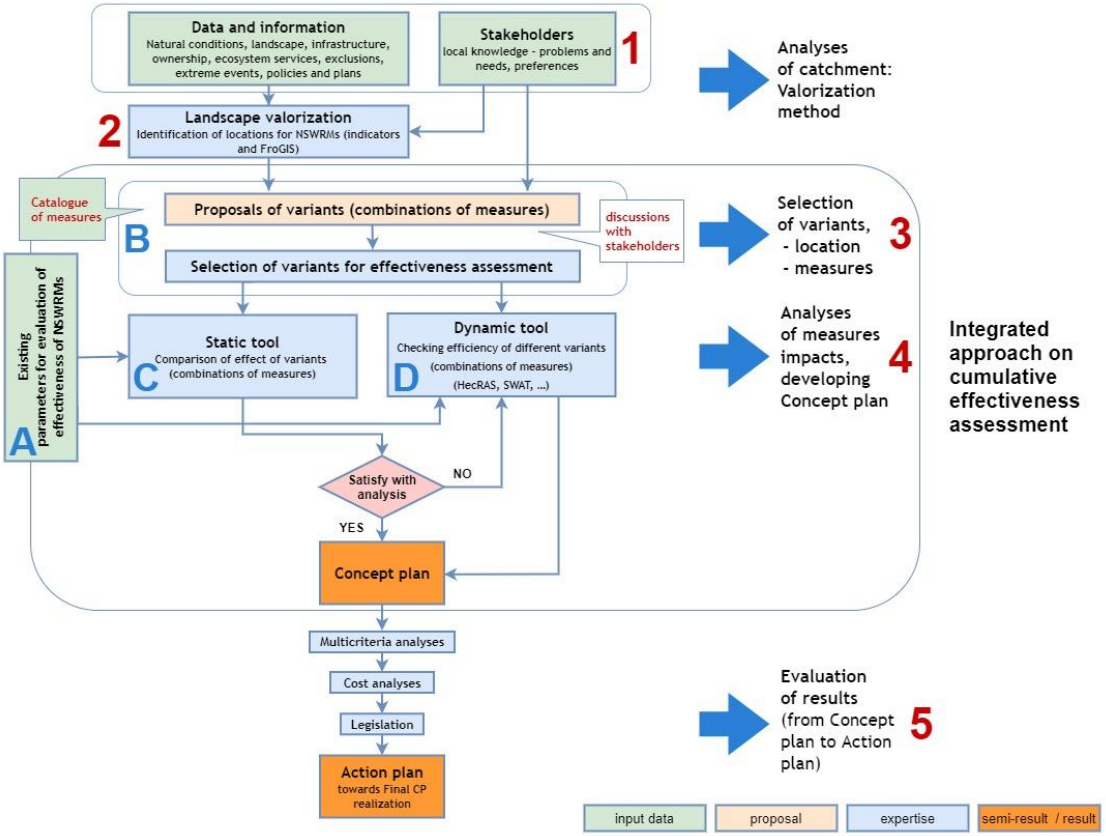
The user of the Manual should be aware of soil type in a given location:

- low permeable
- permeable
- any type

The FramWat project defines five sectors for which NSWRMs are relevant and may have positive or negative impact:

- agriculture (15 measures, codes A01-A15)
- forestry (12 measures, codes F01-F14)
- drainage areas (6 measures, codes D01-D06)
- hydromorphology (14 measures, codes N01-N14), and
- hydrotechnical structures (3 measures, codes T01-T03)

Furthermore, the user has to check which kind of data are available to them and which are missing. The user should know their role and level in the water management planning process, as well as the punctuality and scale of their goal, and have an overview of the situation and possible solutions for the targeted river catchment. It means that the locality needs and possibilities of the targeted river catchment are analysed (Landscape valorisation method – identification of locations for NSWRMs /Step 2 of "*Guidelines*"), and results of landscape valorisation (link to an example) are available.



Notes:
A, B, C, D - phases of IAACE
1, 2, 3, 4, 5 - steps of Guidelines

Fig. 3 Main phases of the integrated approach to the assessment of cumulative effectiveness of NSWRMs

Following the phases of IAACE (integrated approach to the assessment of effectiveness of NSWRMs) will help water and other land management authorities prepare relevant parts of the "*Program of Measures*" of their interest. It will also facilitate consultation processes regarding the proposed "*Program of Measures*" with other local stakeholders or authorities (forestry, agriculture, municipal authorities, NGOs, general public, etc.). In the final stage, the Manual will help them make optimal decisions concerning the mitigation of negative impacts of floods, droughts, or water pollution relevant for their river catchment in the form of so called "*Final Concept plan*" (CP) describing the most effective/optimal scenario/variant of a combination of NSWRMs (absolute Result of the Manual). Reports from CP compilations and experiences with CP preparation for pilot catchments are available at FramWat web.

The description of actions/particular procedures creating phases A to D are described in more detail in the chapters below.

The minimum knowledge of the user required for a particular step is described at the beginning of each chapter.

If you already have an idea which types of NSWRMs are necessary to be designed in your river basin to solve a particular problem or goal, or if you only know the problem or goal in your catchment, or you would like to identify the problem or goal in your catchment, please **ENTER**.

3. PHASES OF CUMULATIVE EFFECTIVENESS ASSESSMENT

Description of actions/procedures to be followed by the user within 4 phases of the integrated assessment of cumulative effectiveness to obtain the most effective system/combination of NSWRMs

The methodology of work with the Manual on how to assess the effectiveness of a system of measures in a river basin involves targeted questions and responses which will smoothly guide you through the process of assessment of the effectiveness of your proposed combination of measures.

Firstly, landscape valorisation should be performed to obtain a list of Spatial Planning Units (SPUs) of your catchment (sub-catchments, water bodies, hydrologic response units) with the greatest potential or need to improve water retention or quality, and/or goals for the SPUs.

As shown in Fig. 3, the second phase of IAACE is the proposal of several scenarios/variants of the combination of natural small water retention measures (set of measures). Variants of combinations of measures serve as input to Phase C and Phase D. The results of Phase D should be subject to Multicriteria analysis (MCA), described in more detail in Step 5 of the "*Guidelines*".

3.1. PHASE A: Existing parameters for the evaluation of the effectiveness of NSWRMs

The review of the existing parameters for the evaluation of the effectiveness of NSWRMs provides a look-up table including measure types listed in the "*Catalogue of measures*" and their values of effectiveness: high, medium, low, or none. The look-up table was compiled based on available up-to-date information, literature search, and past projects (REFORM, REFRESH, WETWIN, WARELLA, IDMP) within the project activity "*Review of the existing parameters for the evaluation of the effectiveness of NSWRMs*". The **result** of using the look-up table is a set of measures with specific maximum effectiveness values for particular benefits provided by selected measures.

General indication of requirements for the compilation of the effectiveness look-up table – standard PC, Ms Excel.

Time and work investment - it is expected to invest several days in the preparation of an effectiveness look-up table when using pre-defined values. It is expected to perform extensive research work when defining expert (own) effectiveness values.

User skills and knowledge

User preconditions to smoothly go through Phase A:

- no special technical skills are necessary
- basic knowledge of river catchment problems and goals is necessary
- familiarity with the "*Catalogue of measures*" and measures effect and behaviour

Are you already aware of individual measures necessary to be designed in your river catchment?

If yes == continue with the selection of effectiveness values for a particular measure in the look-up table in chapter 3.1

Are you unaware of individual measures necessary to be designed in your river catchment?

If yes == continue with setting variants of the combination of measures in chapter 3.2

Steps of searching for effectiveness values for individual measures and their further use (SWME)

- Find a specific code of your proposed NSWRMs in the "*Catalogue of measures*". Find your proposed NSWRM in a row (y scale bar) of the effectiveness look-up table, and use template 1 /A3/.
- Find the benefits (mechanism of water retention or biophysical impact) expected to be obtained/improved via the proposed measure in the columns (x scale bar) of the effectiveness look-up table, and use template 1 /A3/.

Did you find a value of effectiveness of a given measure in the look-up table?

If yes == continue with the compilation of the table of effectiveness values for a given measure in chapter 3.1

Steps of the compilation of the table of effectiveness values of particular measures (SWME)

- Delete all empty rows (y scale bar) and columns (x scale bar) from the effectiveness look-up table. You will obtain the final set of individual measures with specific values of effectiveness. Save the result in an Ms Excel document.

Did you compile a table of effectiveness values for a given measure?

If yes == continue according to the steps defined in chapter 3.3

Did you not find a value of effectiveness for a particular measure in the look-up table?

If yes == continue according to the steps defined in chapter 3.3

In the following text, Phase C and Phase D describe two ways of assessment of the effectiveness of a system/combination of natural small water retention measures.

3.2. PHASE B: Proposal and selection of variants (combination of measures) for effectiveness assessment

In this phase, the user will propose several variants of the combination of measures (developed Concept plan for NSWRMs in their river basin), i.e. different combinations of NSWRMs aimed at solving problems identified in particular SPUs in the river catchment. The **result** of this procedure is the "*Final Concept plan*", i.e. a proposal of the optimal combination of NSWRMs for a given river catchment.

The Concept plan provides information on the best locations and types of measures with a cumulative effect to mitigate problems (water quantity, nutrients, sediments) identified in your river basin/catchment. This phase helps create different variants of measure combinations, and is based either on sectoral expert knowledge and/or on field experience. It is strongly recommended to communicate your variants to local stakeholders with the following goals:

- to include their proposals
- to reach their understanding

The level of communication of the proposed variants also determines the details of your Final Concept plan and effectiveness assessment. Measures are divided into five groups of sectors or areas where their impact is obvious or defining the type of measures:

- agriculture
- forestry
- drainage areas

- hydromorphology, and
- hydrotechnical structures

The objective is for the proposed measures to mitigate the negative impacts of floods and droughts, and to improve the quality of water and ecosystems via increasing the water retention capacity of landscape.

The variants of combinations of measures should be prepared for river basins based on valorisation maps and goal maps resulting from Valorisation tool FroGIS. They should be further improved based on information obtained in the field or via consultations with local stakeholders.

The scope is to compile a final system/combination of measures (Final Concept plan, Final CP) for a given river catchment (after application of Phase C and/or Phase D) that can be further tuned through the application of Multicriteria analysis (MCA) according to Step 5 of the "*Guidelines*". After potential application of MCA you will obtain the final set of measures recommended for implementation, or at least for consideration to be implemented or discussed with other stakeholders.

General indication of requirement for Concept plan compilation – internet access, high-powered PC for GIS analyses, GIS software.

Time and work investment – it is expected to invest at least one month in the preparation of a combination of measures if the user would like to discuss proposals with sectoral experts, verify them in the field, and/or communicate them to local stakeholders. It also depends on the size of your river basin and number of SPUs or catchments.

User skills and knowledge

User preconditions to smoothly go through Phase B:

- special technical skills: the user should be able to work with an online application or any GIS software to propose different variants of combination of measures in particular SPUs
- basic knowledge of river catchment problems and goals is necessary
- familiarity with the "*Catalogue of measures*" and measures effect and behaviour

Are you already aware of problems/goals (landscape valorisation) identified in your river catchment?

If yes == continue with setting variants of the combination of measures in chapter 3.2

Are you unaware of problems/goals (landscape valorisation) identified in your river catchment?

If yes == continue with calculations of landscape valorisation via Valorisation tool FroGIS according to Step 2 of the "*Guidelines*".

Steps of setting variants of the combination of measures:

- Select the problem or goal you have identified in your river catchment for each Spatial Planning Unit (general, flood, drought, water quality, sediment) based on the Landscape valorisation method, and shown in valorisation maps for the identified goals calculated via Valorisation tool FroGIS. At least for SPUs identified as having "high" and/or "very high" there is a need for water retention.
- Select NSWMRs which can contribute to the mitigation of the problem identified in the SPUs (or to reaching the goal identified for the SPUs) in your river catchment based on template 3 /A5/ containing a list of 50 pre-defined measures and a pre-defined aggregation of individual measures. For example, individual measures A03-A09, A11, and A13-A15 (crop rotation, strip cropping along contours, etc.) are aggregated to measure WRAL – best practices for Water Retention in Agricultural Lands. If necessary, see more details about NSWRMs in the "*Catalogue of measures*". The user can also define new measures not listed in template 3 /A5/. A **maximum of 100 measures** can be defined.
- Create/compile variants of the combination of NSWRMs, and place each of the measures within SPUs (e.g. Local preferences variant: local stakeholders from local communities, authorities, agencies, etc.; Expert variant: experts from Water management, Forestry, Agriculture, etc.) using the online application for variant proposals accessible in DSS. Save each of your variants in a separate Ms Excel document, and use template 2 /A4/.
- Evaluate the proposed measures according to real/local conditions:
    - landscape conditions/characteristics, water availability, occurrence of extreme events and their impacts, soil characteristics, soil cultivation, land use and infrastructure, land ownership, development patterns, etc.
    - ecosystem services evaluation if available for the SPUs
    - exclusion areas, if any, in the SPUs (nature reserves, national parks, Natura 2000 areas, watercourses of key importance for fish migration, watercourses with poor water quality, etc.),
    - EU, national, regional, or local legislation.
- Check the location of the proposed measures in the field if necessary.
- Estimate the expected effects of the proposed measures:
    - based on the existing parameters for evaluation of the effectiveness of NSWRMs for the proposed measures included in the effectiveness look-up table (template 1 /A3/), or

- based on grading predefined for each measure from the "*Catalogue of measures*" in template 4 /A6/ according to the Static tool methodology, or
- based on your own estimation.

- Based on the expected effects of measures for each variant saved in separate Ms Excel documents created according to template 2 /A4/, select a set of variants of the combination of measures for your river catchment for further effectiveness assessment.
- Calculate the extent of measures (area, length) from a particular SPU for each measure of each variant. You will need this information further in Phase C and/or Phase D.

Do you have variants of the combination of measures defined for your river catchment?

If yes == continue with calculations of the effect of measures:

- in chapter 3.3 if you would like to "screen and compare" effects of the variants of the combination of measures at the SPUs or catchment level.

- and/or go to chapter 3.4 if you would like to "model" effects of the variants of the combination of measures in detail at the local level.

- save results of effectiveness calculated for each variant of the combination of measures to obtain the "*Final Concept plan*" after the application of Phase C in chapter 3.3 or Phase D in chapter 3.4

Are you definitely satisfied with measures included in the "*Final Concept plan*"?

If yes == Final CP is defined

If no == tune the Final CP based on Multicriteria analysis according to Step 5 of the "*Guidelines*" (see chapter 6.1 of the Guidelines) and via the Multicriteria analysis web application

In Phase D, you have the calculated expected effects of measures proposed in your variants of the Concept plan. Multicriteria analysis (MCA) will help you decide on more suitable measures from a point of view other than measures effectiveness. MCA works with the following parameters:

- ecological impact
- cost efficiency (comparing prices and potential savings)
- land requirements
- maintenance complexity
- potential conflicts (social, economic, financial) caused by the implementation of the measures

Based on the circumstances in your river basin, you can decide which parameter means more to you in general terms. See more about MCA scope and parameters in a brief description, and about the application of MCA in a short manual.

3.3. PHASE C: Static method to assess effectiveness

The scope of the project involved the development of so called Static method to assess the cumulative effect of NSWRMs in river basins. It is a GIS based Static tool within the activity "*Developing a GIS based method to assess the cumulative effect of NSWRMs at the river basin scale*". The Static tool works with measures, mainly from the European NWRM platform nwrm.eu. Particular indicators reflecting the effect of measures for particular intensities were developed. Effects are determined for individual measures and for aggregated[2] measures, grouped according to the similarity of their effect. In principle, the effect of same types of measures is different for highlands and lowlands.

The Static method serves to roughly assess and compare variants of measures and their potential effect to improve conditions of particular SPUs or catchments where single or combinations of NWRMs are planned. The **result** of the application of the Static method/Static tool is a recommended set of the most effective combination of natural small water retention measures in a given catchment.

General indication of Static method requirements – standard PC, Ms Excel with enabled Visual Basic Application macro

Input data requirements: To apply the Static method you need to know the scenario/variant of the combination of measures (maximum of 100 types of measures) you would like to test in your river catchment (chapter 3.2), and valorisation maps and goal maps resulting from the application of the Landscape valorisation method.

To apply the Static method, you do not need very detailed GIS or other very detailed hydrological or meteorological data available within the premises of particular national authorities. More information on **data preparation** can be found in chapter 2 of "*Static method to assess the cumulative effect of NSWRMs in river basins*" (see chapter 2 on data preparation requirements of the Methodology). If you are using the Static tool, you can either:

[2] Measures can be grouped/aggregated according to their affiliation with one sector of economic activity, and according to the similarity of their effect and magnitude of impact on water retention in the catchment determined based on sectoral expert knowledge.

- use already pre-defined values of intensities (T0 – no action, Tlow – between low and medium intensity, Thigh – between medium and high, Tmax - maximum possible intensity of measure), and expected effects of selected measures (grading, values included in template 4 /A6/: E0, Elow, Ehigh, Emax) relevant to your river catchment, or
- define your own values of intensities and expected effects of selected measures relevant to your river catchment. In this case you need to be an expert in the field of effectiveness assessment.

The user can even define their own intensity criteria and their values.

Time and work investment – it is expected to invest one week in the effectiveness assessment of variants when using pre-defined values from template 4 /A6/. It is expected to perform time-consuming research work when trying to define expert (own) values. It also depends also on the size of your river basin and number of SPUs or catchments.

User skills and knowledge

User preconditions to smoothly go through Phase C:

- special technical skills: the user should be able to work with Ms Excel workbook
- basic knowledge of the desired improvements of Landscape valorisation results within particular SPUs/catchments
- familiarity with the "*Catalogue of measures*" and measures effect and behaviour
- knowledge of the "*Static method to assess the cumulative effect of NSWRMs in river basins*" and "*Static tool methodology*"

Example experience with the application of the Static method and using the Static tool by project partners can be found on the FramWat website.

Are you unaware of measures necessary to be designed in your river catchment?

If yes == continue with setting variants of the combination of measures in chapter 3.2

Are you already aware of measures necessary to be designed in your river catchment?

If yes == continue with calculations of the effect of measures:

- in chapter 3.3 if you would like to "screen and compare" effects of the variants of the combination of measures at the SPU or catchment level, or

- go to chapter 3.4 if you would like to "model" effects of the variants of the combination of measures in detail at the local level

Steps of the calculation of the effect of measures based on the application of the Static method:

- import your variants of the combination of measures saved in separated Ms Excel documents into the Static tool according to chapter 3.2 of the "*Static tool methodology*"
  - fill-in Static tool sheet "*ProgramOfWRM*"
- assign the level of aggregation to each of the measures (keep as an individual measure or assign to a group of aggregated measures) according to chapter 3.3 of the "*Static tool methodology*"
  - fill-in Static tool sheet "*StaticAssessment*"
- define the intensity criteria of measures[3] (T) and propose threshold values of intensity levels for your proposed types of measures according to chapter 2.2 and 3.4 of the "*Static tool methodology*" for all of three boundaries - low/medium; medium/high, and maximum
  - adopt values pre-defined in Static tool sheet "*Intensity*", or
  - define own values:
    - based on values from the effectiveness look-up table to be used as maximum individual measures effectiveness in the Static tool, or
    - based on sectoral experts knowledge in Static tool sheet "*Intensity*"
- propose maximum grades, effect coefficients (E%), and calculate values of grades (E) of measures impact on water retention for the proposed types of measures according to chapter 2.3, 3.5, and 3.6 of "*Static tool methodology*" for all three types of conditions - low flows; high flows; quality and erosion"
  - adopt values pre-defined in Static tool sheet "*MaxIntensityImpact*" and sheet "*CheckParameters*", or
  - define own values:
    - based on values from the effectiveness look-up table to be used as maximum individual measures effectiveness in the Static tool, or
    - based on sectoral experts knowledge in Static tool sheet "*MaxIntensityImpact*" and sheet "*CheckParameters*"
- calculate effects of all your variants of the combination of measures for each SPU according to chapter 2.4 of "*Static tool methodology*"
  - run calculations in Static tool sheet "*ProgramOfWRM*" and sheet "*StaticAssessment*"
- save results calculated for each variant of the combination of measures in a separate Ms Excel file

[3] Intensity criteria of the proposed measures are defined as the share of the application area/length of the measures in the total area/length of the SPU or catchment.

A diagram of all steps of calculation of the effect of measures based on the application of the Static method is presented in Fig. 4.

Are you satisfied with water retention (WR) improvements in the SPUs for each of the variants of the combination of measures?

If yes == compare the catchment grades for the current variant and for all variants of the combination of measures, and choose the most efficient variant of the combination of measures based on values of "*Catchment grade for current variant*" in Static tool sheet "*StaticAssessment*" == Final CP variant is available; go back to Phase B.

If no == continue with Dynamic modelling and go to Phase D.

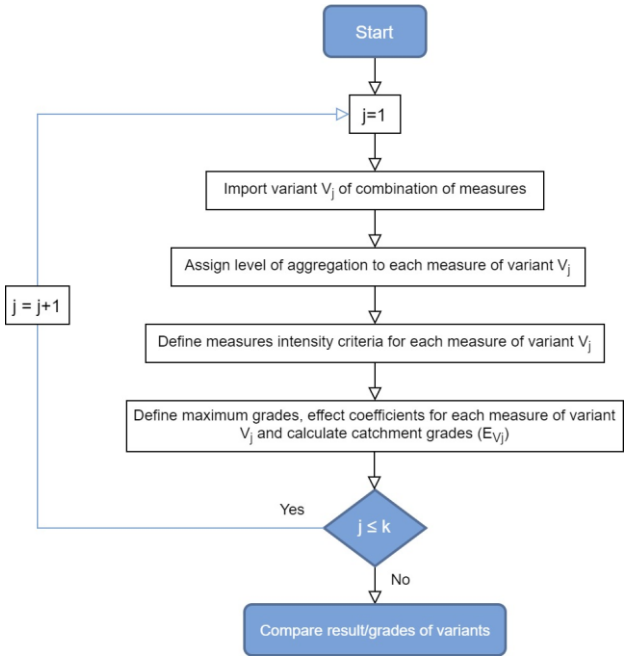


Fig. 4 Conceptual diagram of grades calculation to compare the effectiveness of variants within the Static method

3.4. PHASE D: Dynamic method to assess effectiveness

The objective of dynamic modelling is to demonstrate the application of different models (e.g. HECRAS, SWAT, …) to model site-specific problems (water quantity, nutrients, sediments)

in river basins/catchments. Models can help you evaluate the cumulative effects of particular types of measures. A possibility of running multiple model scenarios permits distinguishing factors influencing the efficiency of NWRMs. In principle, the effect of the same types of measures is different for highlands and lowlands.

Dynamic modelling serves precise calculations of the effect of single or combinations (of the same type or of different types) of NSWRMs planned in particular localities to improve conditions of SPUs or catchments. Due to the complex requirements of building a model, it is not possible to use the models to assess the effectiveness of measures at the river basin scale, but it is worth using smaller detailed models to analyse the impacts at a smaller, local scale. Models can help you tune/improve your variants of the "*Concept plan*" after Static method application.

The **objectives** of dynamic (hydraulic and/or hydrological) models are as follows:

- to test the feasibility of the implementation of measures in the framework of models
- to test the sensitivity of the framework of models to implementation of NSWRMs
- to test maximum potential improvement possible to be obtained from the implementation of some NSWRMs
- to test potential synergies of combined implementation of NSWRMs
- to rank measures based on their maximum potential benefit

Pilot actions (activity "*Application of dynamic water quantity and/or quality models*") involved testing **several models** by project partners for different modelled objectives.

For hydrological modelling:

SWAT[4] – model Soil and Water Assessment Tool (Arnold et al., 2012) is a processed-based, semi distributed, continuous-time model simulating the movement of water, sediment, and nutrients at the catchment scale with a daily time step).

- Basic unit – hydrological response unit (HRU)
- Model structure - channel routing modelled by the Muskingum method; surface runoff calculated by means of the modified USDA Soil Conservation Service (SCS) curve number method; Hargreaves method for estimating potential evapotranspiration (PET); runoff-infiltration split up simulated with the daily curve number method adjusted based on ICN method

HEC-HMS[5] - conceptual hydrological runoff model Hydraulic Engineering Center – Hydrological Modelling System (USACE 2012) is designed to simulate the complete hydrological processes of dendritic watershed systems. HEC-HMS 4.0 was applied.

[4] https://swat.tamu.edu
[5] https://www.hec.usace.army.mil/software/hec-hms/

TUW[6] - conceptual hydrological model (Parajka et al., 2007) developed by the Technical University Wien. It is a lumped conceptual rainfall-runoff model following the structure of the HBV model, running with a daily time step and consisting of a snow routine, soil moisture routine, and flow routing routine.

RiverFlow 2D[7] – two-dimensional combined hydraulic and hydrological flexible-mesh model (Hydronia LLC USA, 2020) offering a high-performance finite-volume engine for computations in all river and estuary projects. It tackles the most demanding flood modelling situations including dam-break and levee-break simulations over initially dry terrain.

For hydraulic modelling:

HEC-RAS[8] – model Hydraulic Engineering Center – River Analyses System (USACE 2012) is designed to perform one- and two-dimensional hydraulic calculations for a full network of natural and constructed channels. Partners have used the following models:

HEC-RAS 1D – one-dimensional model HEC-RAS 4.1 for steady flow data (static flow profiles)

HEC-RAS 2D – two-dimensional model HEC-RAS 5.1 for unsteady flow

HEC-RAS 1D/2D – combination of one-dimensional and two-dimensional model HEC-RAS 5.0.5 modelling system. 1D was used for river geometry data; 2D was used for floodplains.

MIKE21[9] – two-dimensional numerical model dedicated for coastal and marine areas modelling (DHI, 2020) capable of simulating physical, chemical, or biological processes.

For fine sediment accumulation (siltation) modelling:

RF – Random Forest Model (Breinman, 2001) provided by package "caret" in R[10] (Kuhn 2009; R Development Core Team, 2019), a free software environment for statistical computing and graphics.

For species distribution modelling:

SDM – Species Distribution Model as provided in package biomod2 in R[11] (Thuiller et al., 2013), a free software environment for statistical computing and graphics.

General indication of Model requirements: high-powered PC for modelling, software for hydrological and/or hydraulic modelling

Input data requirements: to apply the Dynamic method you need to know the scenario/variant of the combination of measures you would like to test in your river catchment (chapter 3.2). Unlike in the Static method, the number of proposed measures is not limited to 100.

[6] https://cran.r-project.org/web/packages/TUWmodel/index.html
[7] http://www.hydronia.com/riverflow2d
[8] https://www.hec.usace.army.mil/software/hec-ras/
[9] https://www.mikepoweredbydhi.com/products/mike-21
[10] https://www.r-project.org
[11] https://www.r-project.org

To apply the Dynamic tool you will need your own GIS data and other very detailed hydrological, meteorological data available within the premises of particular national authorities in the form of a digital elevation model and cross-sections of hydraulic structures, hydrographic map, land cover map, soil map, time series of meteorological forcing data (daily precipitation, temperature), reservoirs and lakes and rivers characteristics/technical parameters (geometry – cross-sections, surface area, volume, data on manipulation), water withdrawals, …. More information on data requirements can be found in deliverable "*Methodology on how a model can be used to assess effectiveness*" . Otherwise, the results of your modelling will not be useful.

Time and work investment - data acquisition and processing can take several months depending on the size of the catchment and desired level of detail in the model. The setup of the detailed hydrological and/or hydraulic model is very time consuming and costly, and depends on the size of your river basin and number of SPUs or catchments.

User skills and knowledge

User preconditions to smoothly go through Phase D:

- special technical skills: the user should be able to work with a specific hydrological and/or hydraulic model and have experience with interpretation of modelling results
- basic knowledge of desired improvements of Landscape valorisation results within particular SPUs/catchments
- familiarity with the "*Catalogue of measures*" and measures effect and behaviour
- knowledge of the detailed description on how to use the models for solving water management problems via NSWRMs in document "*Methodology on how a model can be used to assess effectiveness*".

Example experience with different Dynamic models used by project partners can be found on the FramWat website.

Measures tested by project partners through the application of the dynamic model have different effects depending on their location in highlands and lowlands. Project partners have tested the following circumstances:

- Bednja (upland to lowland) : …
- Kamniška (wooded subalpine hills to lowland):
    - dams (dam retention reservoirs)

      (peak flows lower in downstream locations close to dams; the impact weakens further downstream and becomes hardly evident at the end/outflow of the catchment)
    - river regulation – no water retention

  - erosion control measures – not modelled
  - flood diversion channels - no water retention
  - protected flood (natural) retention area – 3 % of rainfall of 100years rainfall retained
  - renaturisation of the existing or abandoned ponds, wetlands, … - greater flood water retention
  - earth fill removal - no water retention, but increasing flood retention
  - complex measures (levees, road heightening) – increased water retention, culverts – no water retention
  - other measures – periodical bed load removal – no water retention
  - combination of all measures – same effect as for dams
- Nagykunsági (lowland):
  - N02, N07, A01, D01, D02, D03, D04, D07 – not possible to analyse the effect via the applied model
  - A01, resp. A15 – calculated according to the researched value
  - D02, D03 – simulations of the retention potential of the existing system of drainage canals when water levels rise during floods and droughts, simulation of salinity dilution
- Kamienna (highland to lowland): …
- Aist (low mountain ranges with plateaus and gorges):
  - BRPC (stream hydromorphological improvements)
  - BPDA (small sediment retention ponds)
  - A02 (vegetated buffer strips)
- Blh (mountain-lowland type river):
  - T01 dry reservoirs with culverts
  - T01 dry reservoirs with lateral spillways and certain retention volume
  - D01 outflow from drainage systems in areas with hydro-melioration infrastructure – proposal of drainage system reconstruction
  - levees (e.g. at Dulovo)

  (TUW hydrological model - used for flow rate evaluation or for flood forecast)

Modelling exercises in pilot river basins show that it is not possible to generalise the effect of measures for certain conditions. It is necessary to run simulations for each occasion individually (e.g. transformation of each flood waves Q100, Q10, Q50, ….via dry reservoirs

develops in a different way). It is possible to assess the effect of a type of measure, but not in a specific manner!!!

Are you unaware of measures necessary to be designed in your river catchment?

If yes == continue with setting variants of the combination of measures in chapter 3.2

Are you already aware of measures necessary to be designed in your river catchment?

If yes == continue with calculations of the effect of measures :

- in chapter 3.4 if you would like to "model" effects of the variants of the combination of measures in detail at the local level, or

- go to chapter 3.3 if you would like to "screen and compare" effects of the variants of the combination of measures at the SPU or catchment level

Steps of calculations of the effect of measures based on the application of the Dynamic Method

- input data pre-processing
  - acquisition of data
  - pre-processing of numerous input data
- model set-up

Before starting the model calibration and validation process, the user has to define which aspects/inputs they will neglect/simplify (e.g. subsurface runoff, precipitation, …).

- model calibration (model parametrisation - calibration of standard parameters as Manning coefficient, CN, … and optimised numerical cell size, etc.)
  - The following boundary conditions (BC) for hydraulic models were defined:
    - recorded water waves and recorded flood events at gauging stations
    - downstream BC normal depth, upstream BC total precipitation
    - upstream BC flow time-series calculated from different correlations, downstream BC normal depth.

      As initial conditions – all constant water level values.
    - upstream BC historical discharge time series from gauging stations, downstream BC constant water level, or rating curve from the gauging station.

      Lateral boundary condition – outflow time series from hydrological model HRUs representing discharge of tributaries and runoff from sub-basins.

- upstream and downstream BC energy line gradient
- upstream BC precipitation as "area type" boundary condition set for every computation node (mm per time unit) and outflow boundary condition represents “flux boundary” where flow leaves the 2D flow area, downstream BC normal depth

- model validation (evaluation of simulations against observations/measured data values – e.g. measured discharges at gauging stations)

Model calibration and model validation are by standard done for different periods (see project partners reports on the FramWat website).

- baseline scenario definition (current state)
- simulation of NSWRMs scenarios (scenarios modelling)
  - parametrisation of measures (e.g. simulation of re-meandering reached by increasing riverbed roughness values)
- running models and calculating effects of all the proposed variants of the combination of measures for each SPU or catchment (compared to the effectiveness of the baseline scenario)
- saving results calculated for each variant of the combination of measures in a separate Ms Excel file

The diagram of all steps of calculation of the effect of measures based on the application of the Dynamic method is presented in Fig. 5.

Are you satisfied with WR improvements in the SPUs for each variant of the combination of measures?

If yes == Final CP variant with the most efficient combination of measures based on modelled values is available. Go back to Phase B

If no == continue with MCA application and go back to Phase B MCA section

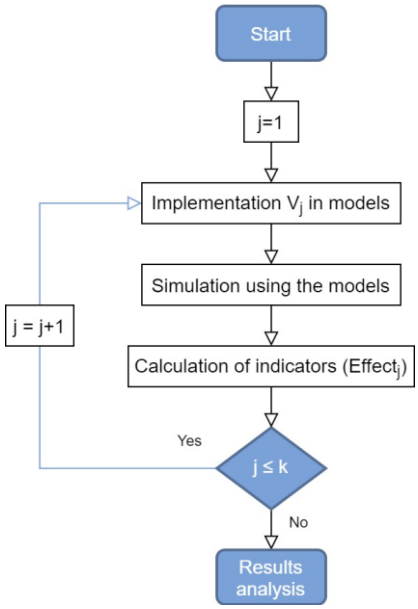


Fig. 5 Conceptual diagram of variant simulations for the assessment of the effectiveness of measures within the Dynamic method

REFERENCES

/1/ Report on the existing indicators and values for the assessment of effectiveness (Effectiveness report)

/2/ Methodology of Valorisation Water Retention Needs (Landscape valorisation method) https://docs.google.com/document/d/1iRxxHOCNuDdSB1tqBhnXtNLf14mr0S2Vl60tr8AGUc4/edit

/3/ Data preparation guidance for the Landscape valorisation method (Users input data preparation for FroGIS) https://docs.google.com/document/d/160XyXj2tB3OP3fNdvU7aKN3xBRWOb0VAGepk-qKOz1U/edit#heading=h.4ivs9lhtnip8

/4/ Valorisation tool FroGIS http://waterretention.sggw.pl/?id=b4647a8942025f639aaafdd707a676bc

FroGIS

/5/ Catalogue of measures – link to the application. XLSX format will also be effective as summary information

/6/ Online application to propose measures and Manual on how to work with the online application (in SK) http://planning.waterretention.sggw.pl/#/planner

N(S)WRM Planner

/7/ Reports on experience with preparation of the concept plan and Comprehensive report on Concpet plan preparation https://www.interreg-central.eu/Content.Node/Concept-Plans.html

/8/ Multicriteria analysis web application http://ahp.framwat.apps.vokas.si

AHP Method

/9/ Static method to assess the cumulative effect of N(S)WRM in river basins (Research study of Natural Small Water Retention Measures /NSWRM/ of project FRAMWAT Interreg CENTRAL EUROPE Programme, Static method)

/10/ StaticTool method and StaticTool_2020.xlsm application (Static tool methodology) https://www.interreg-central.eu/Content.Node/StaticTools-method-and-application.pdf

/11/ Static tool to assess effectiveness (Static tool web application)

https://www.interreg-central.eu/Content.Node/Stati-tool.html

StaticTool Method

/12/ Reports from testing of the Static tool to assess the effect of N(S)WRM

/13/ Methodology on how a model can be used to assess effectiveness (Methodology of model application)

/14/ Reports from testing of the dynamic model to assess the cumulative effect of N(S)WRM

/15/ Reports from national training and regional workshops

ANNEXES

/1/ AHP method as a supporting tool for optimal NSWRM selection "*AHP method_brief description_EN.pdf*"

/2/ AHP method web application – short manual "*AHP method_short manual_EN.pdf*".

/3/ template 1: refurbished effectiveness look-up table == Values of effectiveness look-up table for individual measures (effectiveness look-up table) (Manual_v201906_v3-5_t1_NWRMEffectivenessLookUpTable.xlsx)

/4/ template 2: empty template to help the user propose systems/variants of the combination of measures per SPU (max. 100 measures) (Manual_v201906_v3-5_t2_empty_CombinationOfMeasuresProposal.xlsx)

/5/ template 3: List of pre-defined individual and aggregated measures (Manual_v201906_v3-5_t3_ListOfPredefinedMeasures.xlsx)

/6/ template 4: List of pre-defined intensity criteria for individual and aggregated measures and their pre-defined values (grading) Tx, E%, Emax, E" (Manual_v201906_v3-5_t4_ListOfPredefinedIntensityCriteriaAndValues.xlsx)

ABBREVIATIONS

AP	Action plan
BC	Boundary condition
CP	Concept plan
DSS	Decision support system
E	calculated value of grade
E%	measures effect coefficient
FRMP	Flood risk management plan
IAACE	Integrated approach on assessment of cumulative effectiveness
MCA	Multicriteria analysis
NSWRMs	Natural small water retention measures
RBMP	River basin management plan
SW	software
T	measures intensity criteria for particular intensity level
WMP	Wetlands management plan (Wetlands action plan)
WR	Water retention