Methodology on how can model be used to assess the effectiveness – input for the Manual (DT2.4.2)

Poland/WULS

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1. INTRODUCTION

This document contains information how to assess 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.

1.1 Case studies

This document is based on experience gained during the FramWat project. The dynamic modelling within the FramWat project has been conducted in five catchments located in five countries listed in Table 1. Hydrological models were applied in three countries and hydraulic models in five countries. (Fig. 1)

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

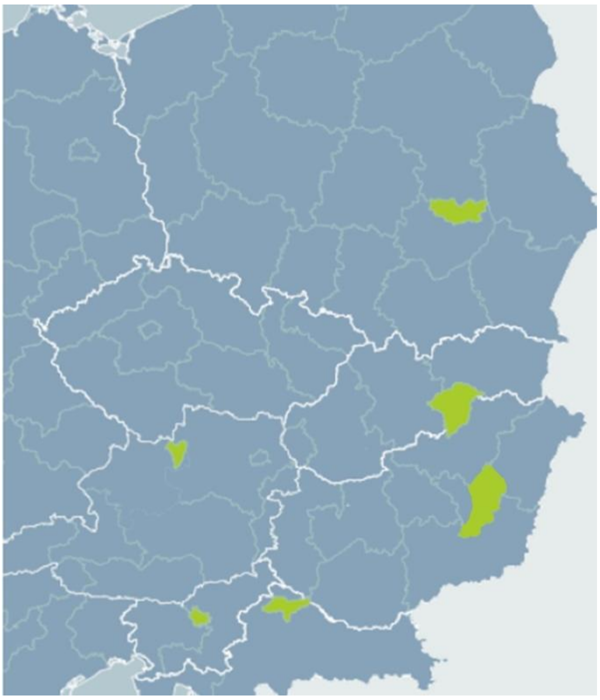

Figure 1 Location of catchments in which models have been applied (apart from Slovakia).

1.2 General approach for model-based assessment of measure effectiveness

Figure 2 presents a conceptual scheme of scenario simulations for assessing effectiveness of measures. In general, a set of *n* measures (M_1, M_2, ……, M_n) considered dor modelling have to be selected first. In the most simple case the model will be run n times for each individual measures, but what is of particular interest is 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 imporant factor is decision in which places (streams, sub-catchments, outlets) in the catchment the effectiveness will be assessed. After all indicators are quantified the results can be analysed and conculsions drawn. The calculated indicators can be also used as inputs to Decision Support Systems.

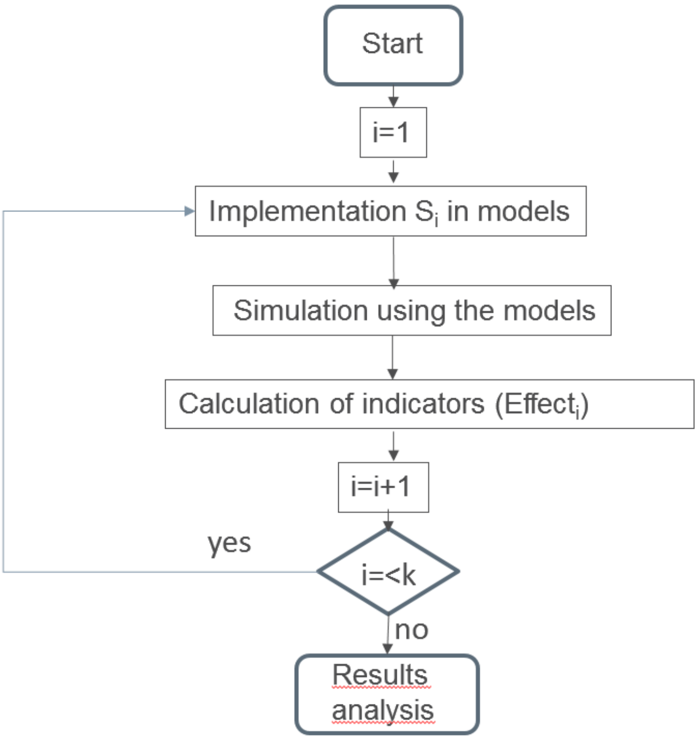

Figure 2 Conceptual scheme of scenario simulations for assessing effectiveness of measures.

2. HOW TO IMPLEMENT MEASURES IN THE MODELS

2.1 General approach

Figures 3-4 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 hydraulic model in more detail. The measures have been selected from the catalogue on the http://nwrm.eu website. Models SWAT and HecRAS are used as representative examples for each type of models.

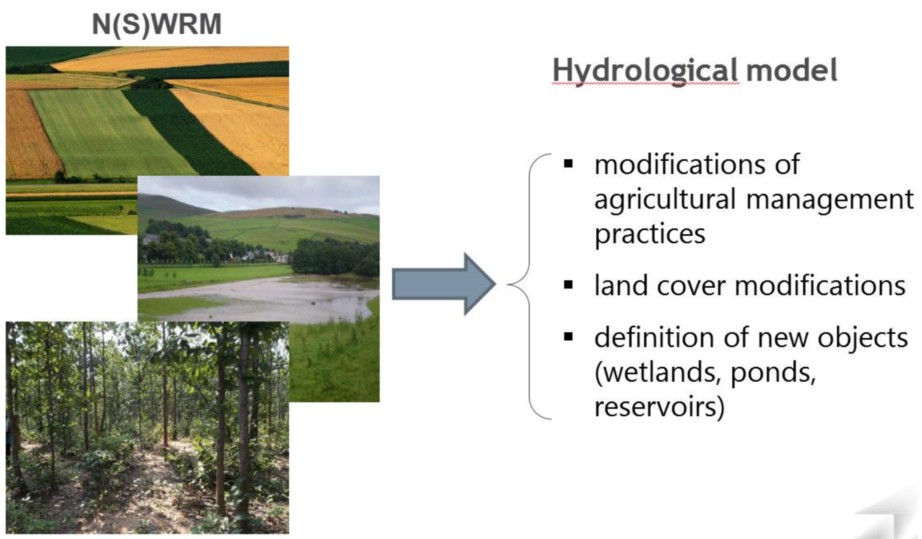

Figure 3 Implementation of measures in a hydrological model.

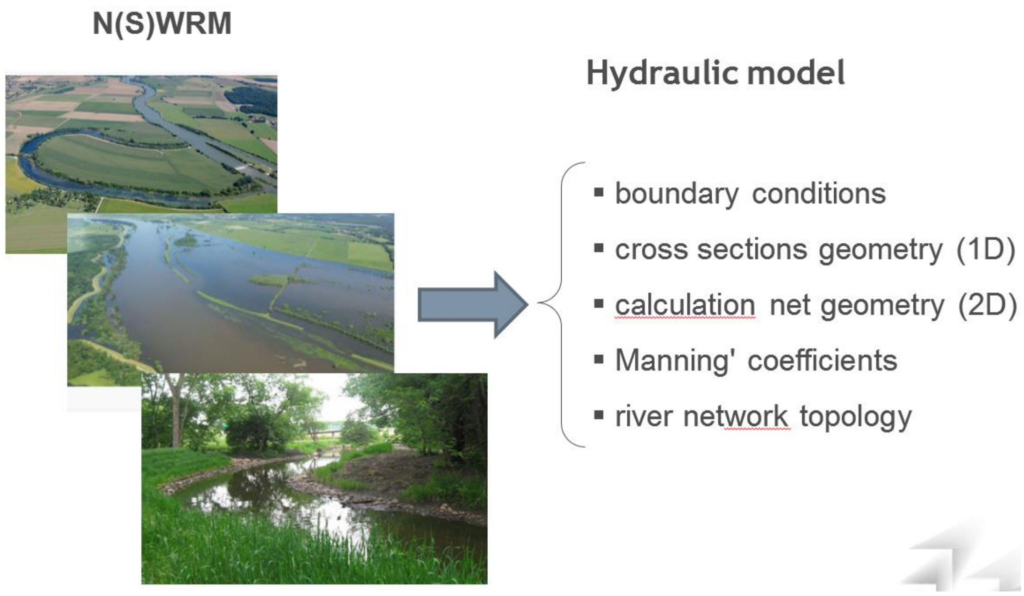

Figure 4 Implementation of measures in a hydraulic model.

2.2 Example measures in hydrological models

1. **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

2. **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 crp rotations)
- Expected effect in the model: depending on the type of rotation and the original (replaced) crop. Potentially: erosion reduction, supplementing nitrgoen to the soil, slower runoff

3. **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

4. 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

5. **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

6. **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

2.3 Example measures in hydraulic models

1. **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

2. **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.

3. **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

4. **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

5. **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

6. **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

7. **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

3. 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 subsections.

3.1 Flood hazard

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

- Reduction of a given flood index (e.g. 100-year flood, annual maximum flood, etc.) for a specific outlet (e.g. Fig. 5)
- Change in flood frequency for a given return period
- Reduction of flood extent or indundation depth (e.g. Fig. 6)

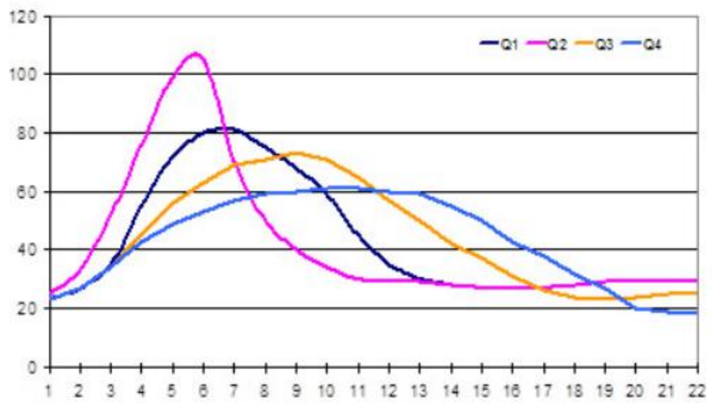

Figure 5 Example flood hazard indicator: reduction of peak flow for a specific outlet.

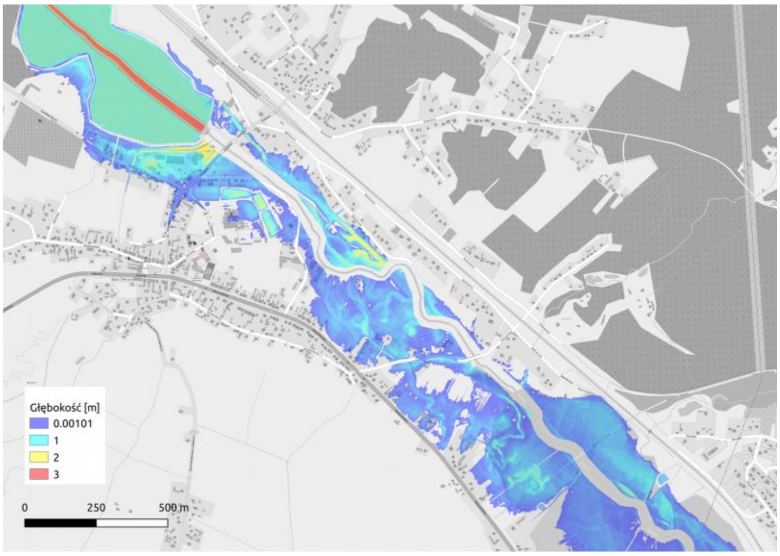

Figure 6 Example flood hazard indicator: reduction of flood extent / inundation depth.

3.2 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 (e.g. Fig. 7-8)
- Change in soil moisture deficit index (e.g. Fig. 9)

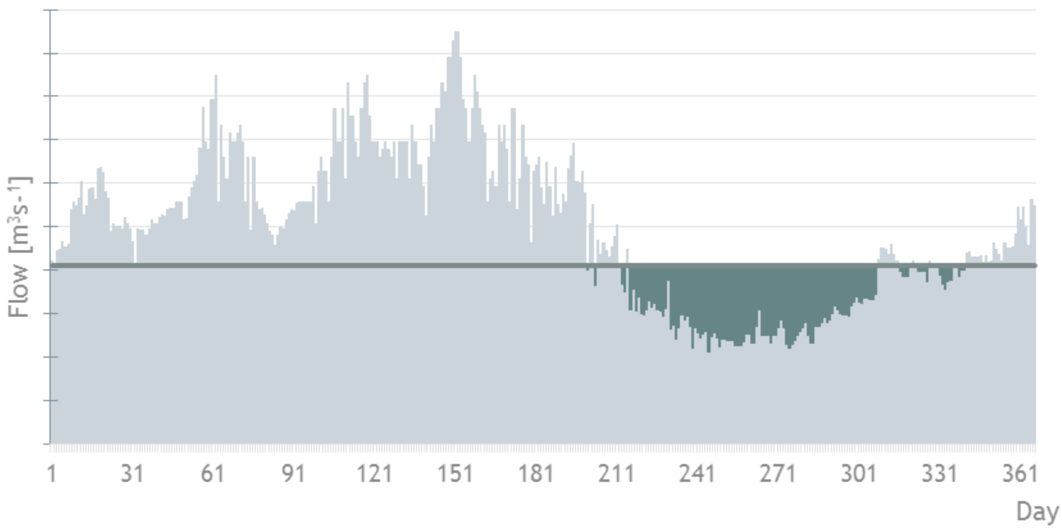

Figure 7 Example drought hazard indicator: reduction of low flow deficit volume for a specific outlet.

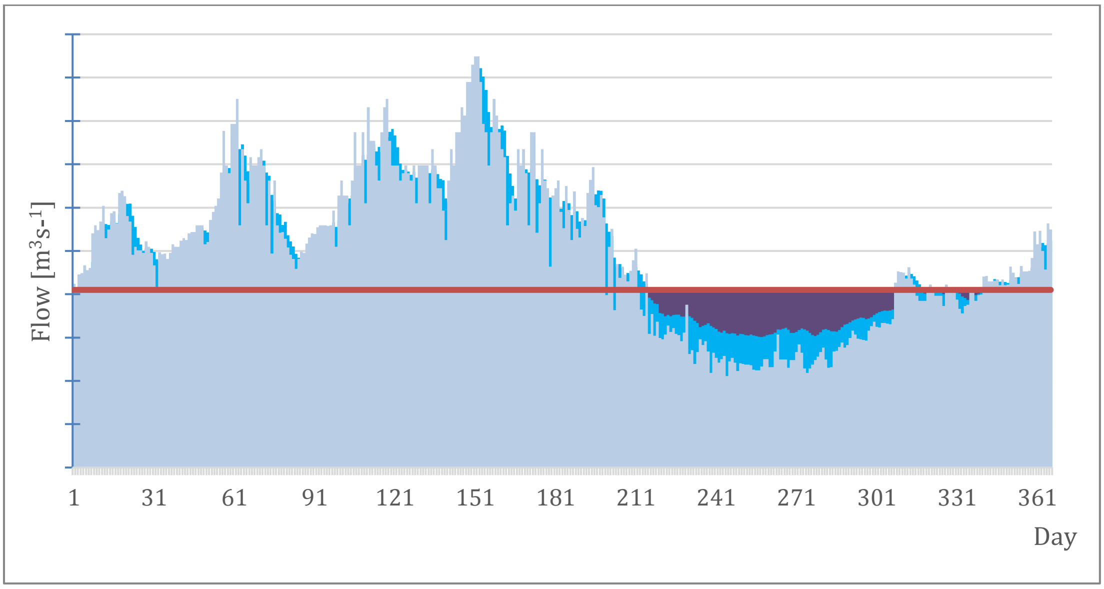

Figure 8 Example drought hazard indicator: reduction of hydrological drought duration for a specific outlet.

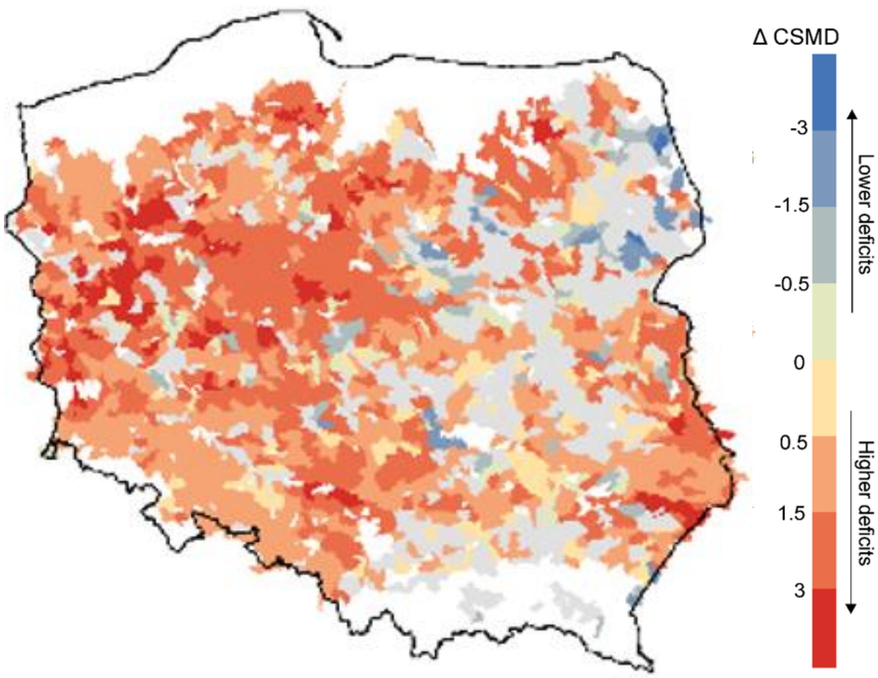

Figure 9 Example drought hazard indicator: reduction of soil moisture droughts.

3.3 Water quality problems

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) (e.g. Fig. 10)

- Reduction in mean constituent concentration in river reaches (e.g. Fig. 11)
- Reduction in mean constituent loadings for a specific outlet (e.g. Fig. 12)
- Reduction of constituent loading or concentration during peak events (e.g. Fig. 13)

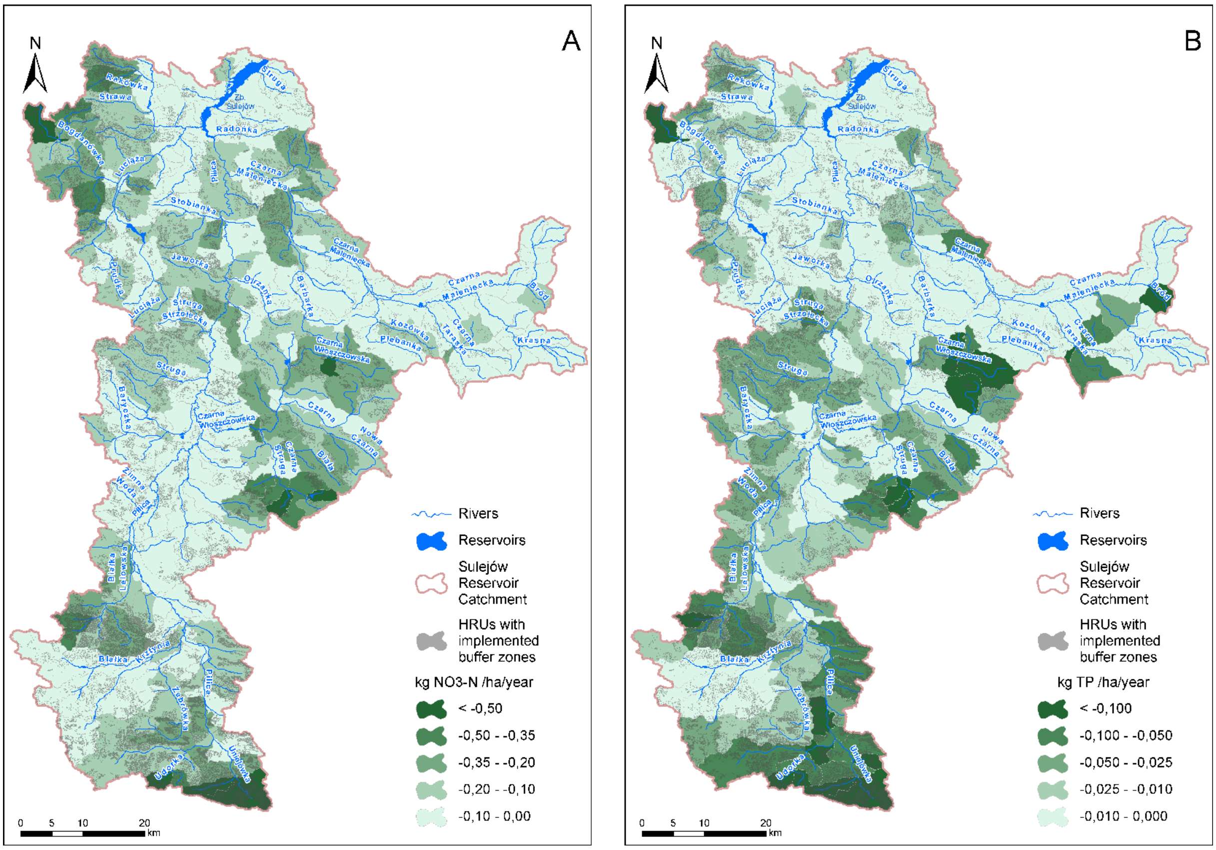

Figure 10 Example water quality indicator: reduction of mean constituent emission from sub-catchment areas.

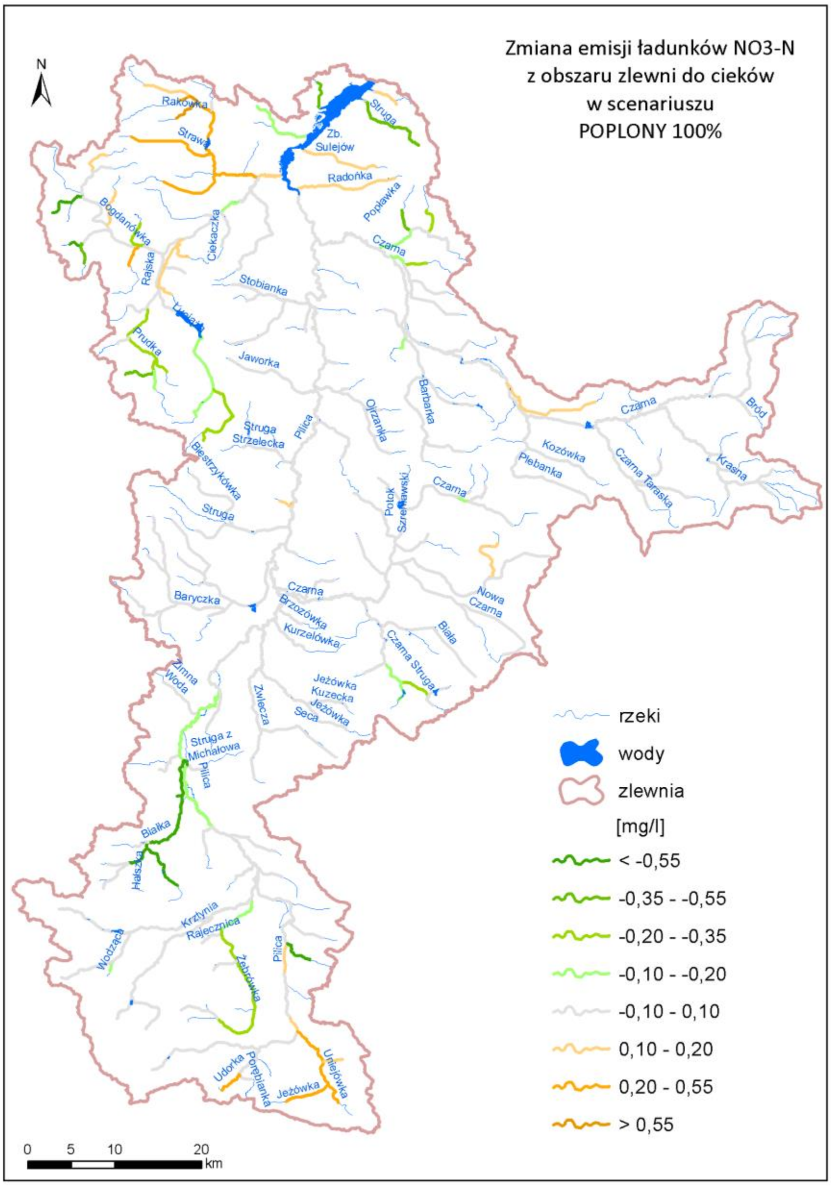

Figure 11 Example water quality indicator: reduction of constituent mean concentrations in river reaches.

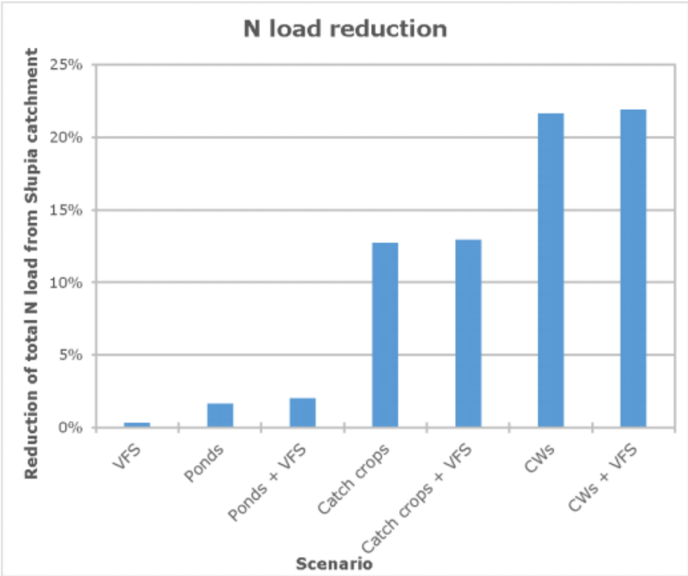

Figure 12 Example water quality indicator: reduction of mean constituent loading for a specific outlet (comparison of different measures, including combinations of measures).

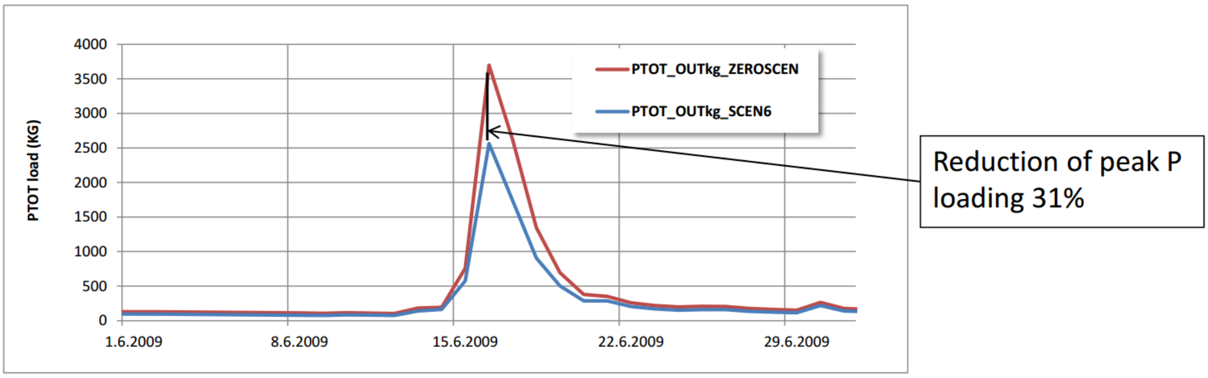

Figure 13 Example water quality indicator: reduction of constituent loading during a peak event for a selected outlet.