Evidence and Solutions for improving **SPONGE** Functioning at Land**SCAPE** Scale in European Catchments for increased Resilience of Communities against Hydrometeorological Extreme Events

# How to model floods and droughts?

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**MINISTRSTVO ZA OKOLJE, PODNEBJE IN ENERGIJO**
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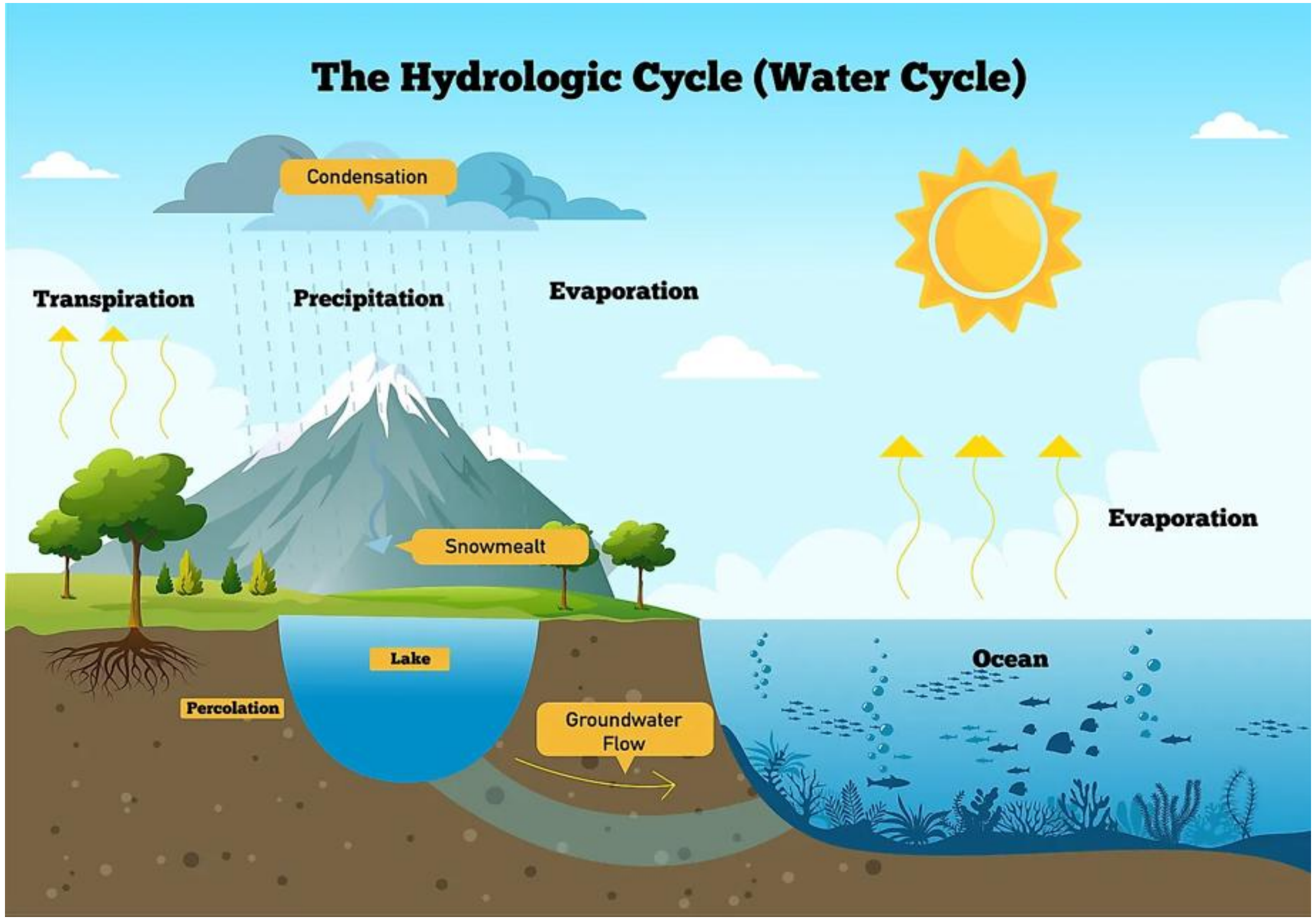
# Content

- Modelling of water cycle
- Hydrological modelling
- Wflow, HydroMT-Wflow
- Hydrometeorological events selection
- Model setup
- Model calibration and validation
- Model simulation

# Water cycle modelling: What is it all about?




## Why do we want to model water cycle?

- to understand how much water is available
- to predict, monitor and manage extreme weather events (floods and droughts)
- to manage water resources sustainably
- to understand the impact of human activities and climate change on water resources

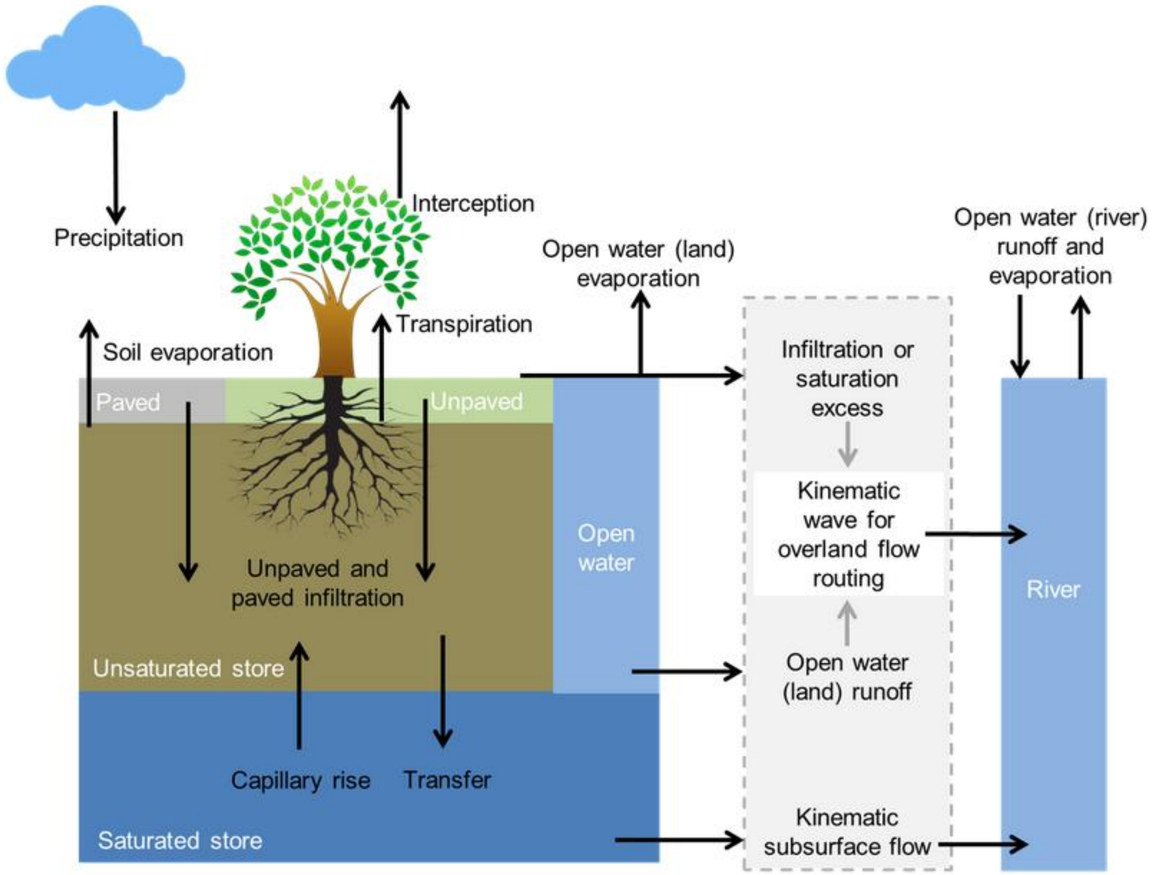
**SpongeScapes**: using the models to evaluate the efficiency of sponge measures

$$P = ET + Q + dS$$

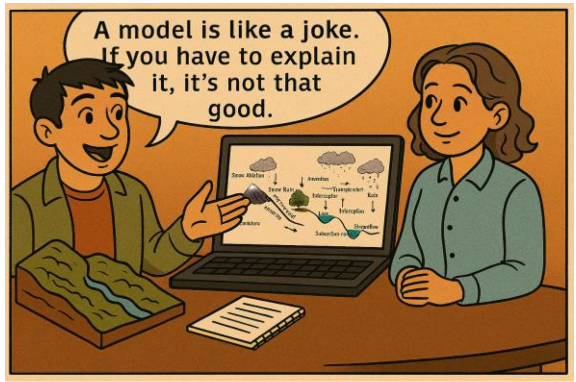
# Water cycle modelling: model types

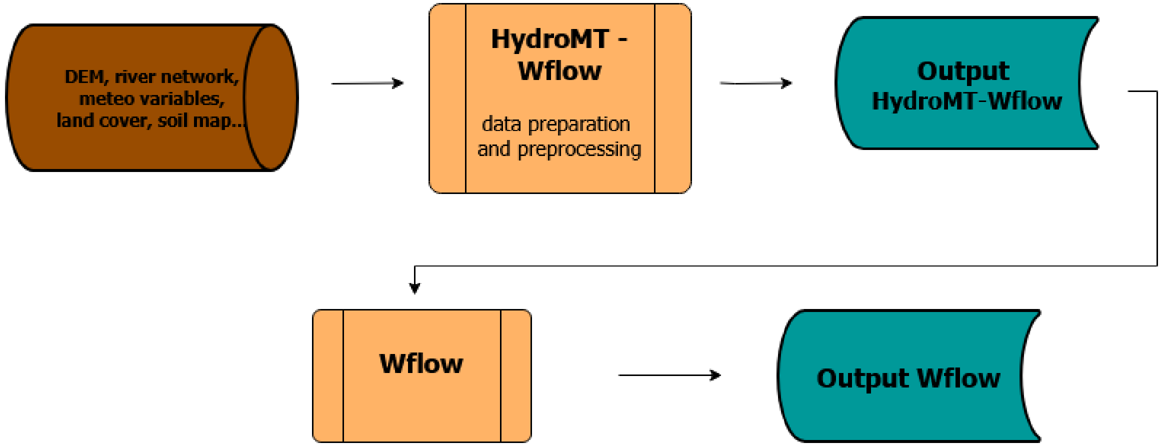
- hydrological models (water flow over the surface and through the soil; from rainfall to runoff)
- hydrodynamic models (river flow)
- groundwater models (water flow through aquifers)

- **Hydrological models**
  - **Wflow:**
    - sbm
      - spatially distributed: each cell has its own state (e.g. moisture, runoff)
      - simple concept: water enters (precipitation), leaves (evaporation, runoff) and is stored (in the soil)



# HydroMT-Wflow and Wflow




**Modelling process:**

Hydrometeorological events selection

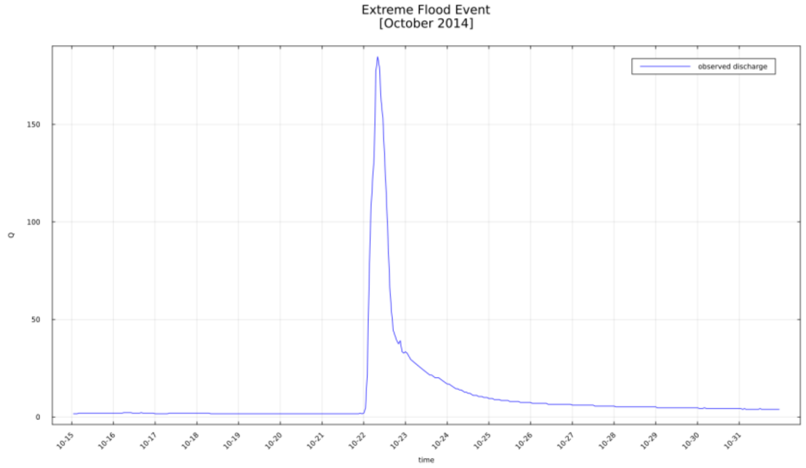
Model setup

Model calibration and validation

Model simulation

# Hydrometeorological events on Gradaščica catchment: floods

| Flood event category | General consequences | Flood event ecological effect | Required Flood risk management level | Gradaščica |
|---|---|---|---|---|
| | | | | |
| **Extraordinary** | Agricultural areas are flooded, local flooding of roads and less important facilities. Potential of significant damage to crops. Minor soil erosion/loss. Beneficial fine sediments delivered to floodplains. | Presence of beneficial and harmful effects on ecological functioning | 1 … Low (the event should be easily managed, damage on flood risk measures not expected) | 25.07.2023 (consequences: the second high water level was exceeded, which caused flooding; flooded local roads) |
| **Extreme** | Extensive flooding including exposed settlements and industrial zones. Significant damage to crops, infrastructure and buildings. Considerable soil erosion/loss. Presence of bank erosion and debris flow. | Temporary harmful effects on ecological functioning, especially due to excessive risk for increased pollution loads, but recovery is feasible. | 2 … Medium (the event should be managed with sufficient measures, damage on flood risk measures expected) | 22.10.2014 (consequences: flooded main roads, residential and commercial buildings) |




**Other event categories**:

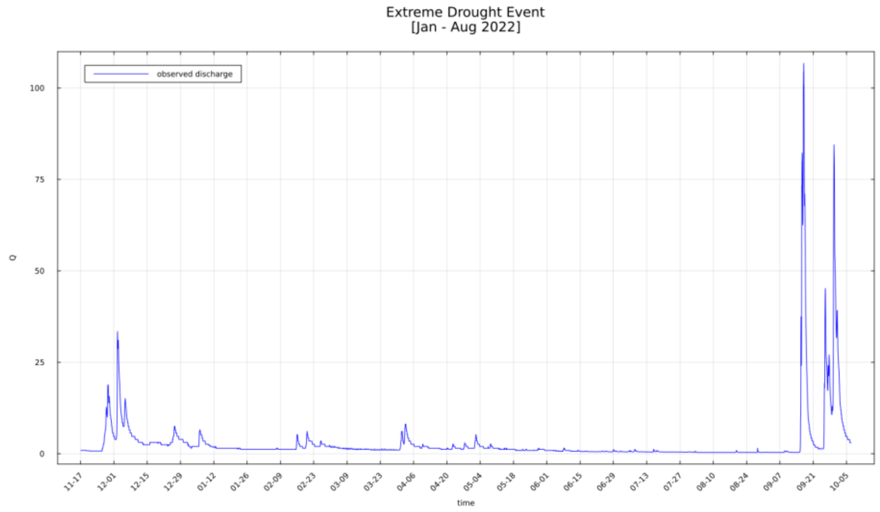
- ordinary
- exceptional



SpongeScapes

# Hydrometeorological events on Gradaščica catchment: droughts

| Drought event category | General (economic) consequences | Drought event ecological effect | Required drought management measures | Gradaščica |
|---|---|---|---|---|
| | | | | |
| **Extraordinary** | Substantial economic losses across multiple sectors, including agriculture, tourism, and energy production | Moderate harmful effects on ecological functioning | 1 … Moderate measures (mandatory water use restrictions) | 3 months with SDI≪0 (July – Sept. 2012) |
| **Extreme** | Severe economic losses across all sectors | Severe harmful effects on ecological functioning | 2 … Emergency measures (crisis management, emergency water distribution centres) | 8 months with SDI≪0 (Jan.-Aug. 2022, June-Aug. SDI = -2) (consequences: indirect - fish mortality along with probable water pollution) |



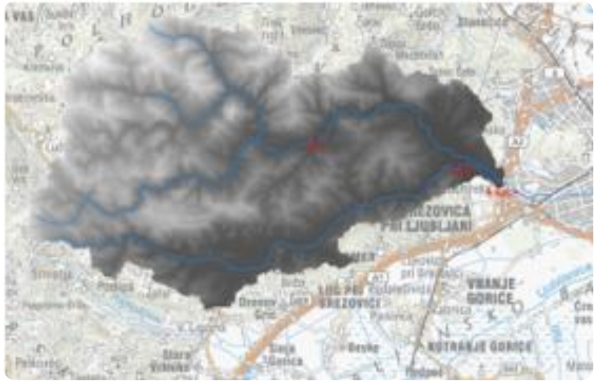
# HydroMT-Wflow: Model setup

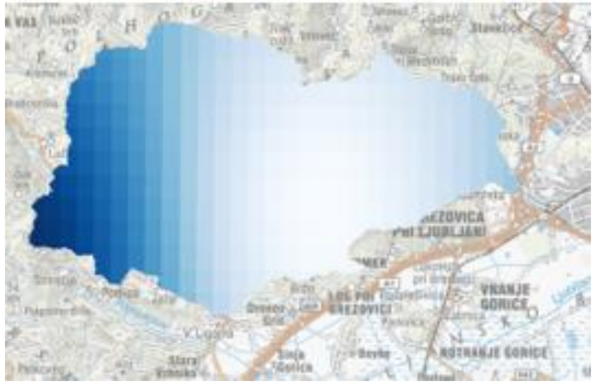
event: 15.10.2014 - 31.10.2014, but: longer period to provide the warm state of the model (2012 – 2014)

## Data preparation and preprocessing

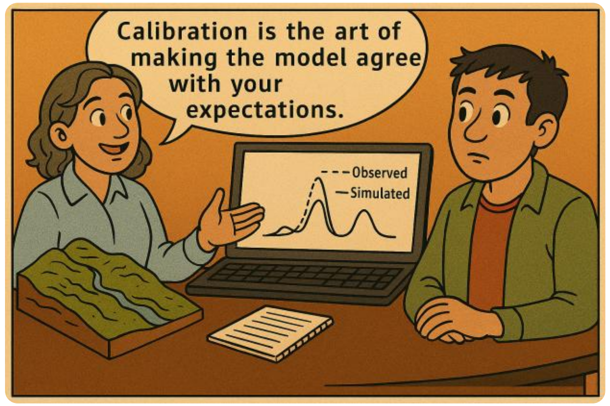
- decisions about:
  - resolution (50m → 250m),
  - observation period,
  - time-step (daily, hourly),
  - modelling subcatchments
- input data: DEM, river network, precipitation, temperature, pressure, sun radiation, land cover, soil map, LAI…

- HydroMT-Wflow creates:
  - **staticmaps**: land cover, soil map, soil infiltration capacity, vertical saturated conductivity, leaf area index, crop coefficient…( around 90 parameters)
  - **forcing file:** precipitation, temperature, pet

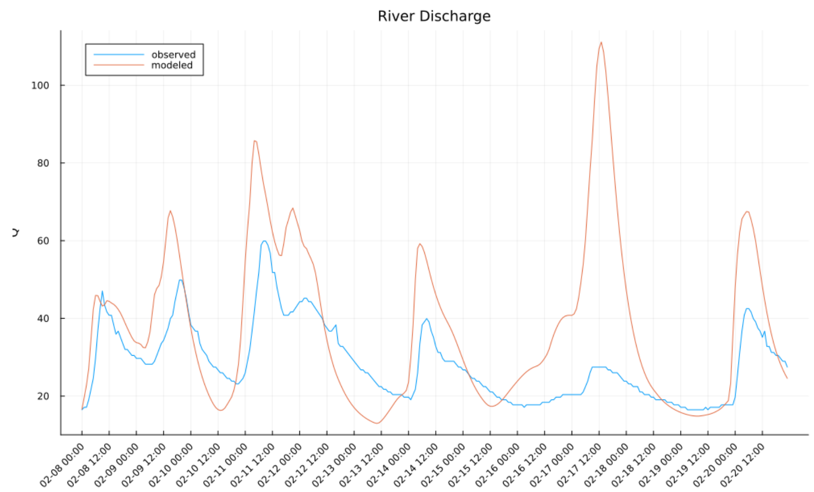




# Wflow: Model calibration




- **Wflow output: discharge at the outlet**, also possible to obtain discharge on other gauges
- comparison of observed and modeled discharges
- **calibration goal:** modeled discharge are as close as possible to observed discharge values
- **calibration period:** longer time period including different hydrological conditions
- **calibration method:** setting different values of selected parameters
  - vertical and horizontal saturated conductivity
  - snow parameters

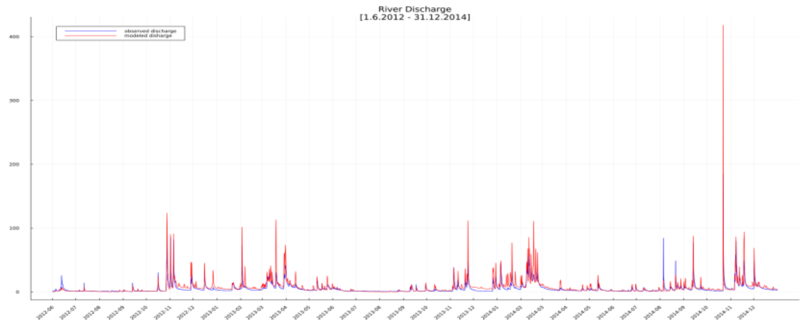


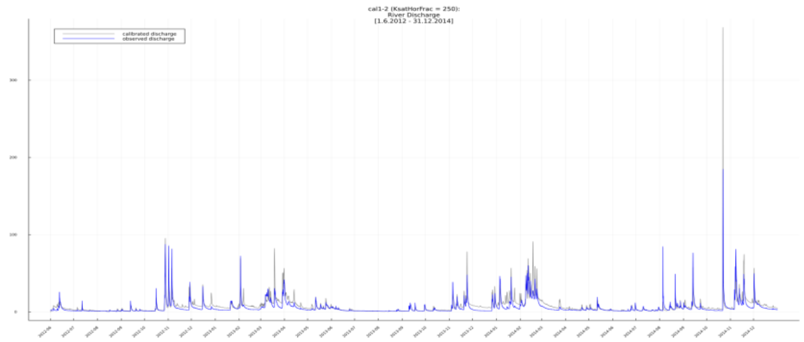

- 3 options for setting parameter values:
  - uniform value
  - different values per subcatchments
  - values related to other spatial units (land cover, soil map)

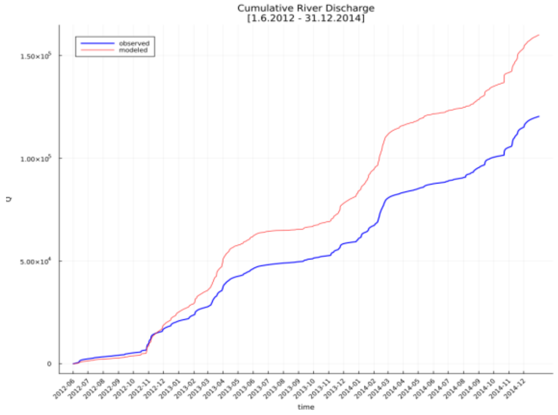
- model performance quantification:
  - Nash-Sutcliffe Efficiency (NSE)
  - **Normalized NSE: NNSE (easier interpretation)**
  - Kling-Gupta efficiency (KGE)
  - RMSE

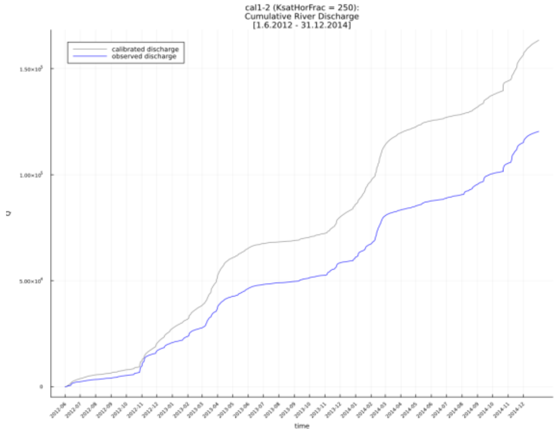
# Wflow: Model calibration and validation

## Model calibration




NNSE base: 0,553
NNSE calibrated: 0,647

## Model validation

- **goal: to ensure the model is robust, reliable and suitable for future use**
- the process of evaluating a model's ability to accurately simulate real-world hydrological conditions, using independent data (not used during calibration)
- efficiency criteria

# Wflow: Model simulation

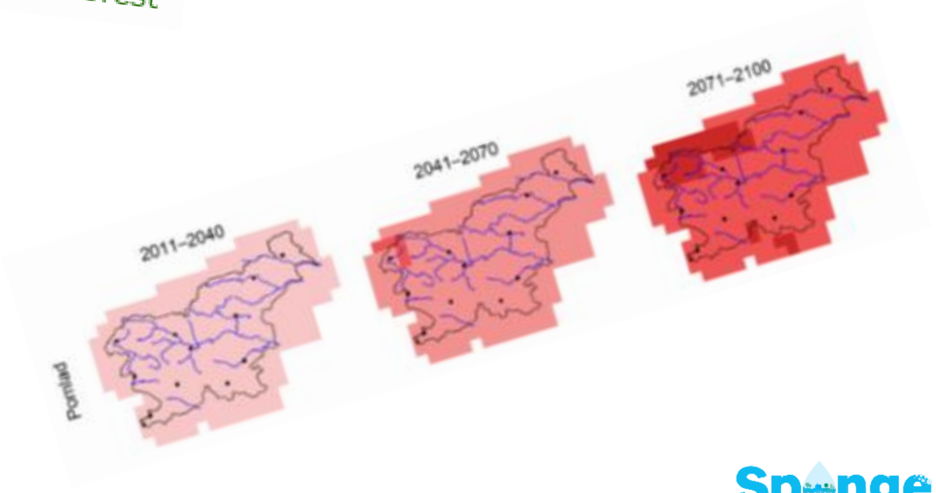
- identification of the key model parameters representing the sponge measure
- preparation of the simulation matrix
- running the model simulations with different "level" of sponge measures in the catchment for current climate state
- running the model simulation for future scenarios
- evaluation of the simulation results through the technical indicators

**land cover change**
→ key model parameters:
change of leaf storage,
crop coefficient..

**simulation matrix:**
events x
key parameter settings x
various initial
states of the model
(dry, normal, wet)

**land cover change:**
forest: 0% - 100%
coniferous forest ↔ mixed forest

technical indicators:
change in storage,
change in peak flow,
change in baseflow,
...



# Model simulation: Land cover scenarios

**Testing the impact of different share, types and locations of forest in the catchment**

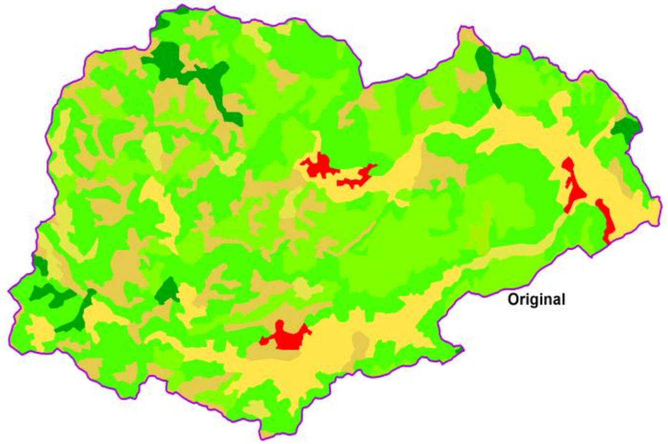
## Associated parameters:

- extinction coefficient (to calculate canopy gap fraction)
- fraction of compacted area
- root depth
- leaf storage
- wood storage
- fraction of open water (excluding rivers)
- crop coefficient…

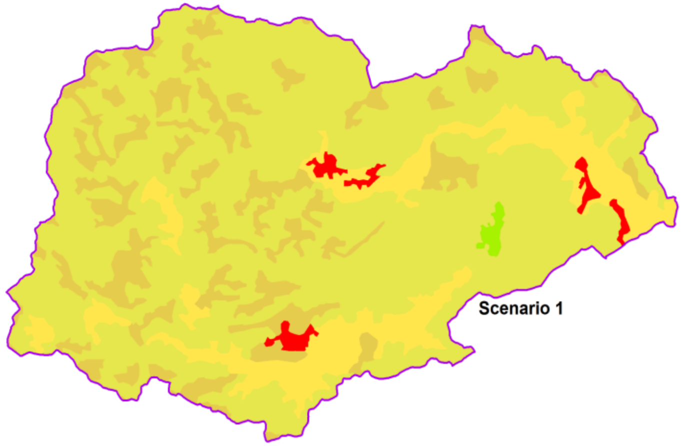
## Pilot catchment (Gradaščica):

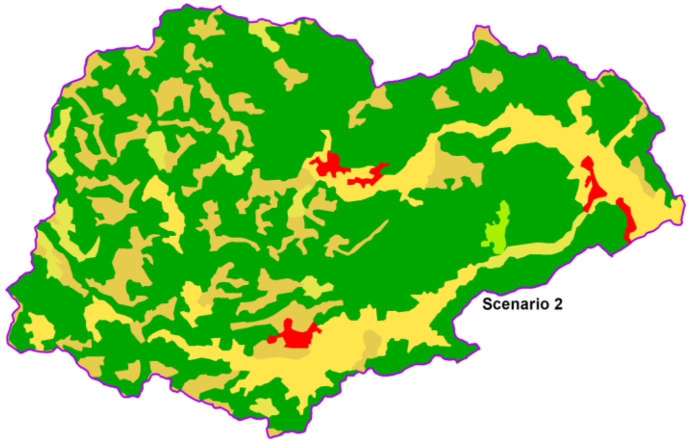
- 160 $km^2$
- almost 70% forest

**Original**




**Scenarios**




**CLC Code**

- 112: Discontinuous urban fabric
- 122: Road and rail networks and associated land
- 231: Pastures
- 242: Complex cultivation patterns
- 243: Land principally occupied by agriculture
- 311: Broad-leaved forest
- 312: Coniferous forest
- 313: Mixed forest
- 324: Transitional woodland-shrub

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