UNIVERSITY OF LATVIA

Spring watershed modeling

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Assessment of common groundwater resources in Gauja/Koiva and Salaca/Salatsi river basins meeting
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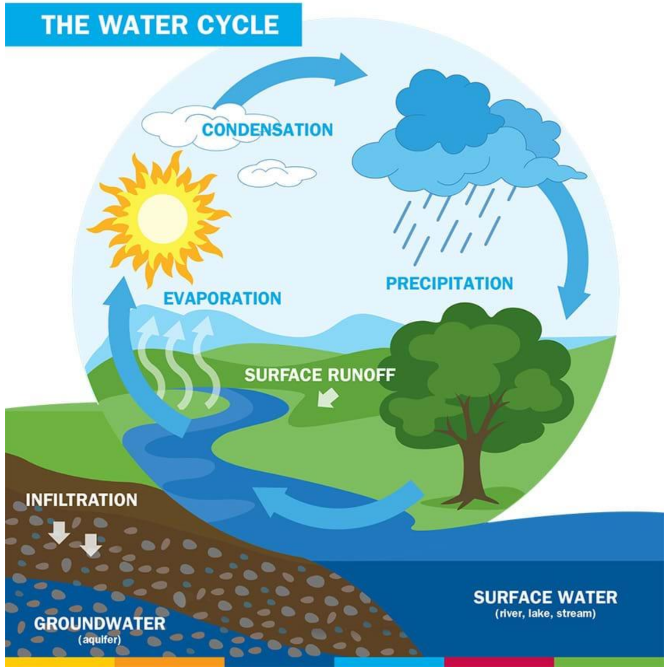
Interreg Estonia-Latvia
European Regional Development Fund
EUROPEAN UNION

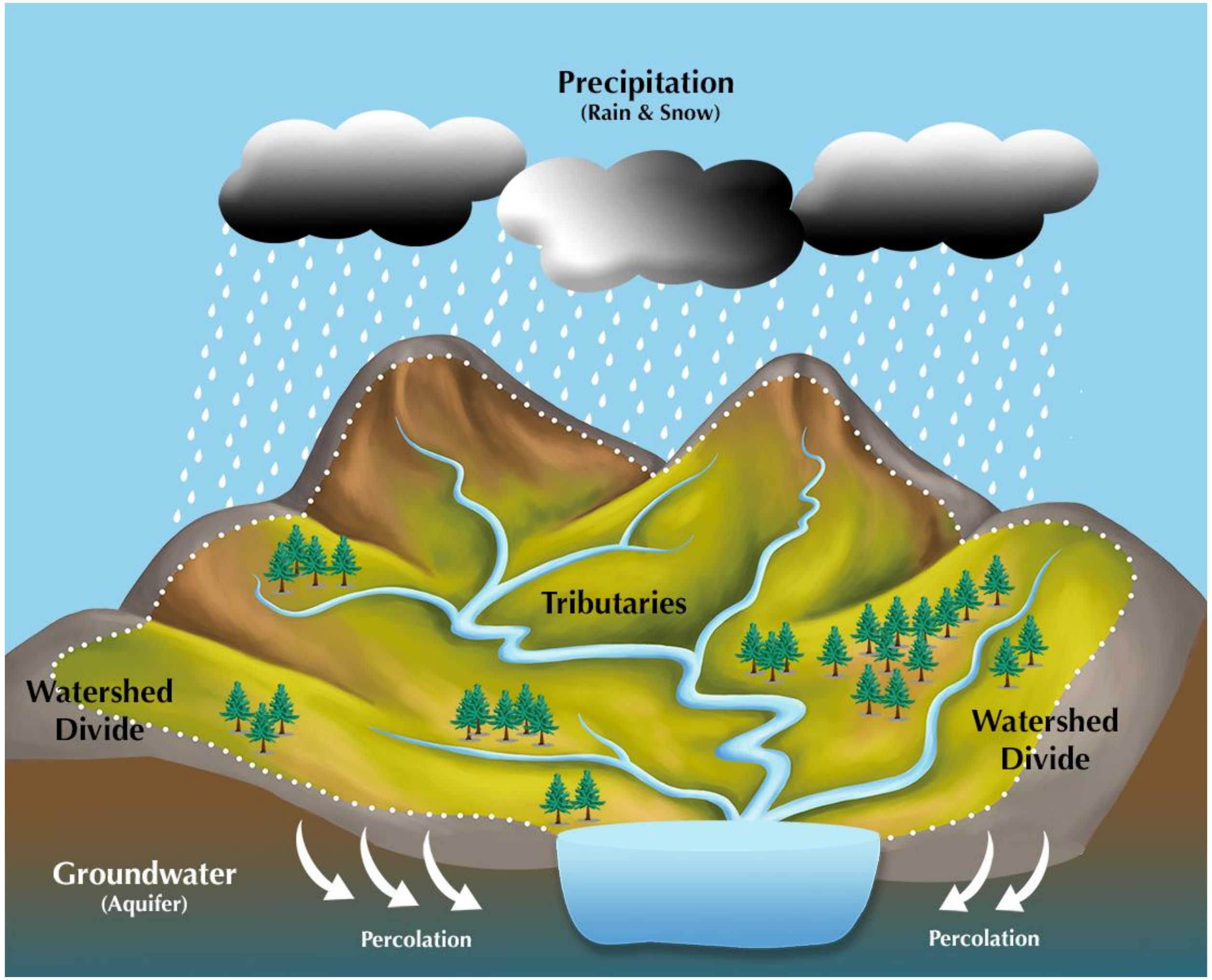
WaterAct
Joint actions for more efficient management of common groundwater resources

What is watershed?

Drainage basin – Catchment – Watershed

Area from which all precipitation flows to a single stream or set of streams.

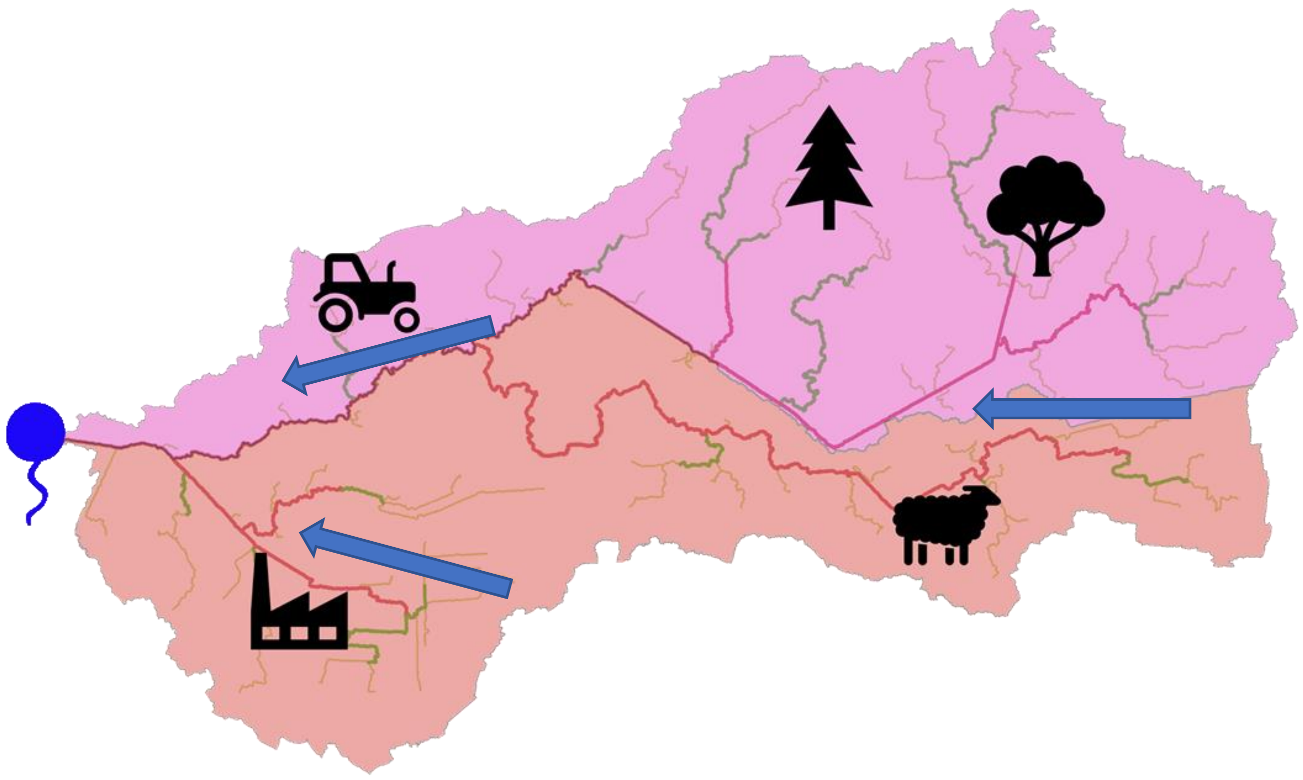




https://www.cwp.org/watershed101/

Why watersheds?

- Representative catchment areas
- Understanding groundwater origin:
  - Geology, rock types
  - Land use
  - Interaction with surface water
- Identify pressures/impacts:
  - Agricultural load
  - Point source pollution



The role of watersheds in WaterAct project

- To improve representativity of spring monitoring network
- To select new appropriate springs for monitoring (spring sampling campaigns)
- To build conceptual understanding of springs – assessment of pressures within watershed

Spiģu spring

Spring campaigns

In total, ~50 springs have been visited, samples collected and analyzed in the EE-LV transboundary area

Several springs have been visited more than once to account for seasonal variability

Chemical analysis and field measurements

Provide information that can be used to identify the origin of groundwater that can be:

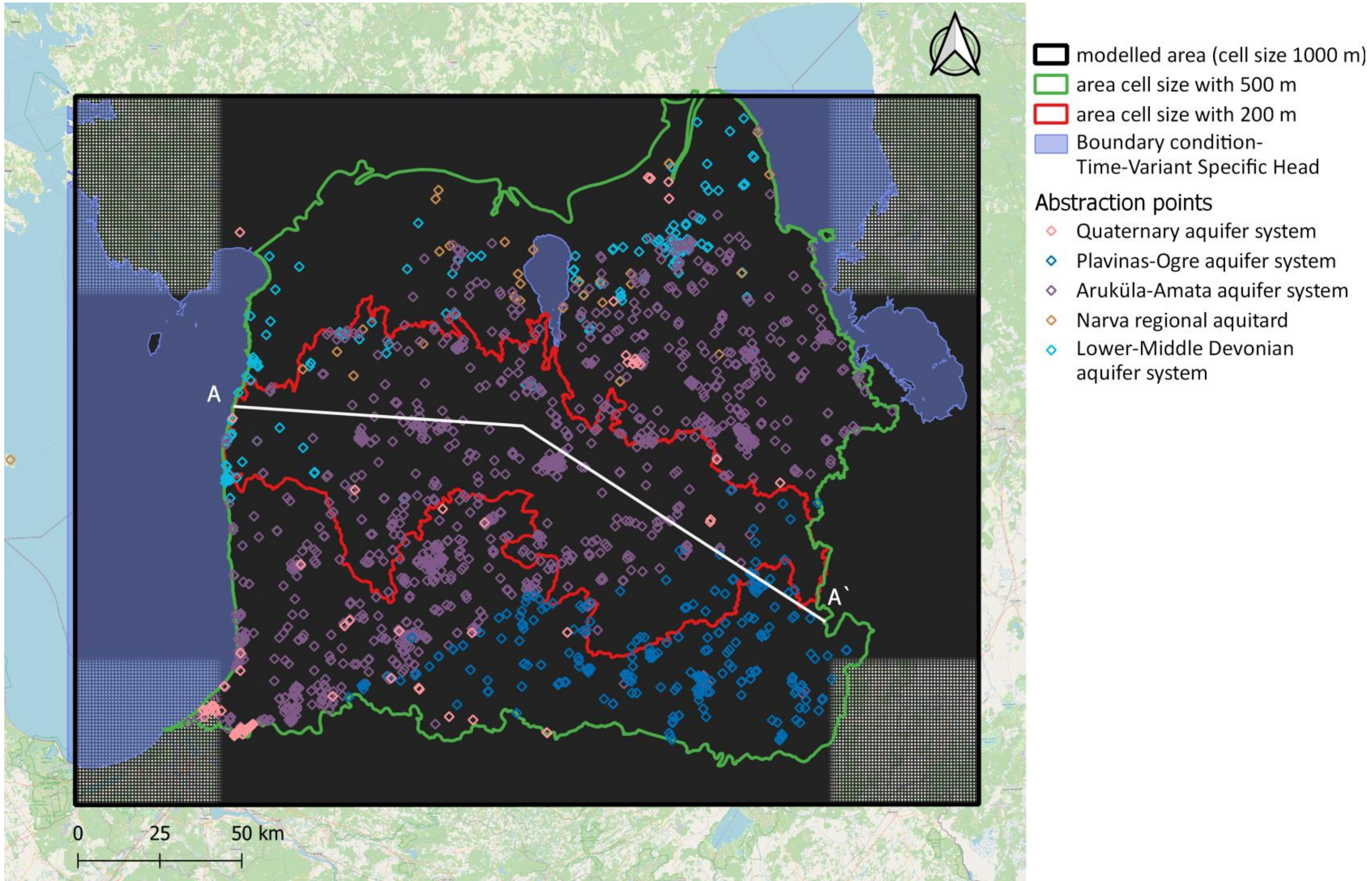
1) Bedrock aquifers (typically deeper, confined)
2) Quaternary aquifer (typically shallower, unconfined)
3) Mixture of both

Discharge measurements

- Spring discharge measurements provide invaluable data that can improve conceptual understanding of groundwater origin and evolution
- Validation of developed watersheds
- The most common approach is using bucket and stopwatch method to calculate spring discharge

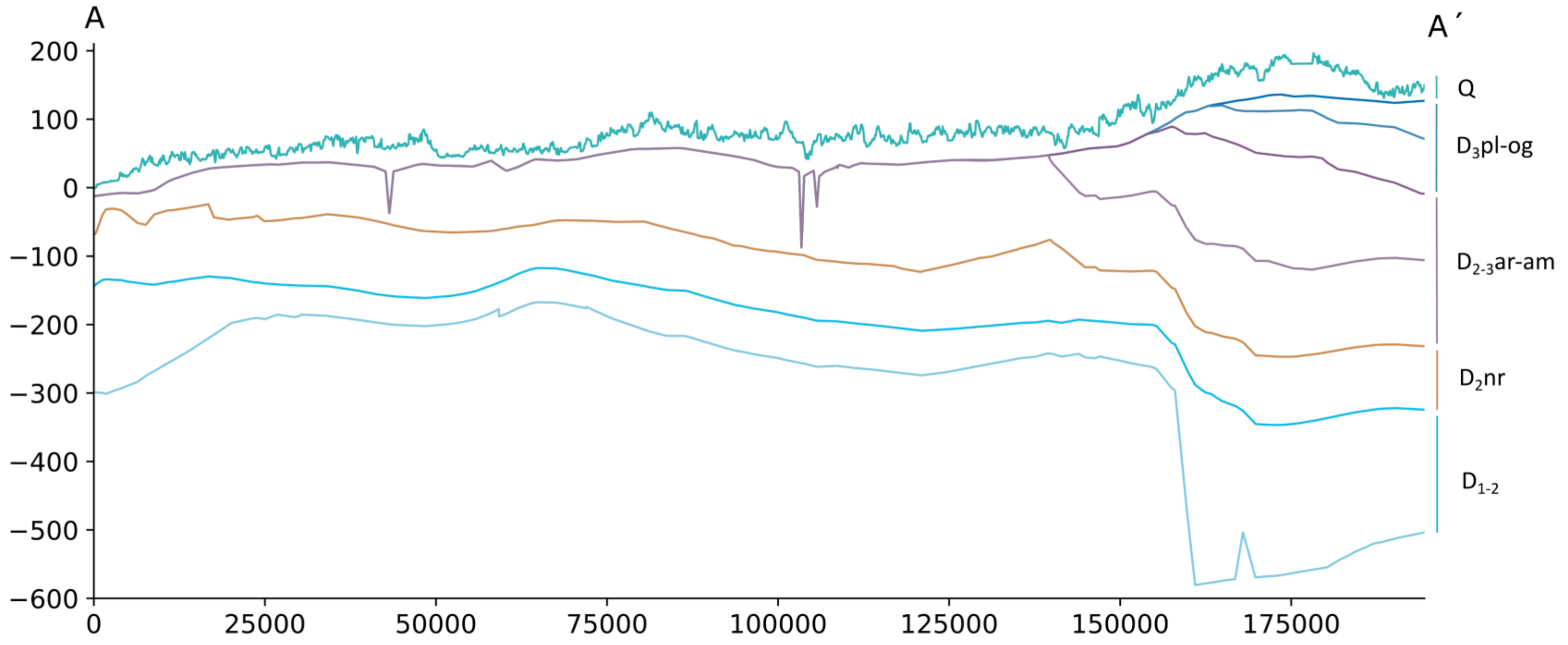
Bedrock watersheds - methodology

- Based on groundwater flow model created in MODFLOW 6 (Langevin et al., 2022) using ModelMuse open-source interface;



Bedrock watersheds - methodology

- The model consists of 7 layers that discretize three main aquifers and represents an area of 45 000 km^2. PUMA model (Virbulis et al., 2013) geological surfaces were used to describe the model hydrogeological interfaces
- Included groundwater abstraction points
- Steady-state simulation for the year 2010 was used to conduct first calibration



Bedrock watersheds - methodology

- For each spring accordingly the first bedrock aquifer piezometric level data was used for watershed calculation
- The actual watershed was calculated with the SAGA GIS tool Upslope area in QGIS.

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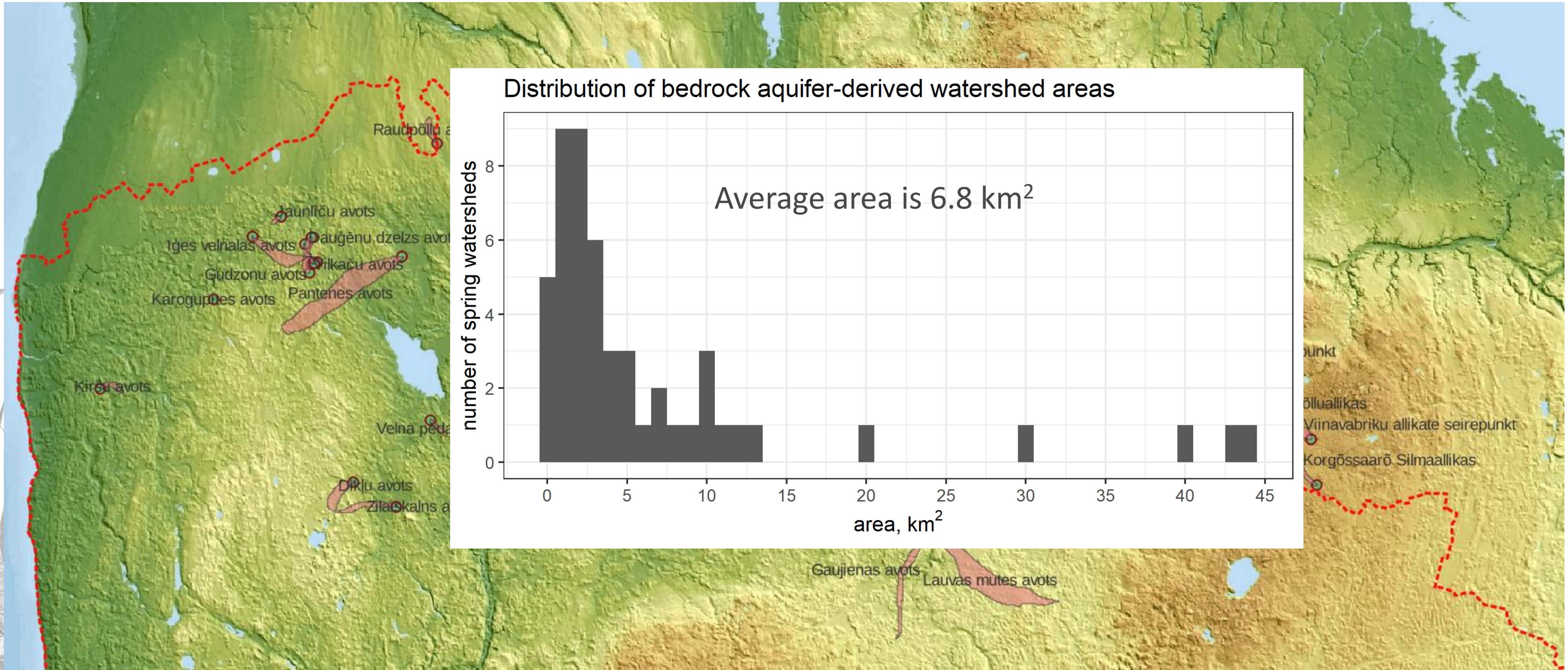


Bedrock watersheds – representing geology

- Most bedrock watersheds represent outcrops of Upper/Middle Devonian Gauja and Middle Devonian Burtnieku terrigenous formations.
- Fractured rocks are represented in lesser extent – i.e. Pļaviņas formation accounting for 18.4% of all bedrock variety.

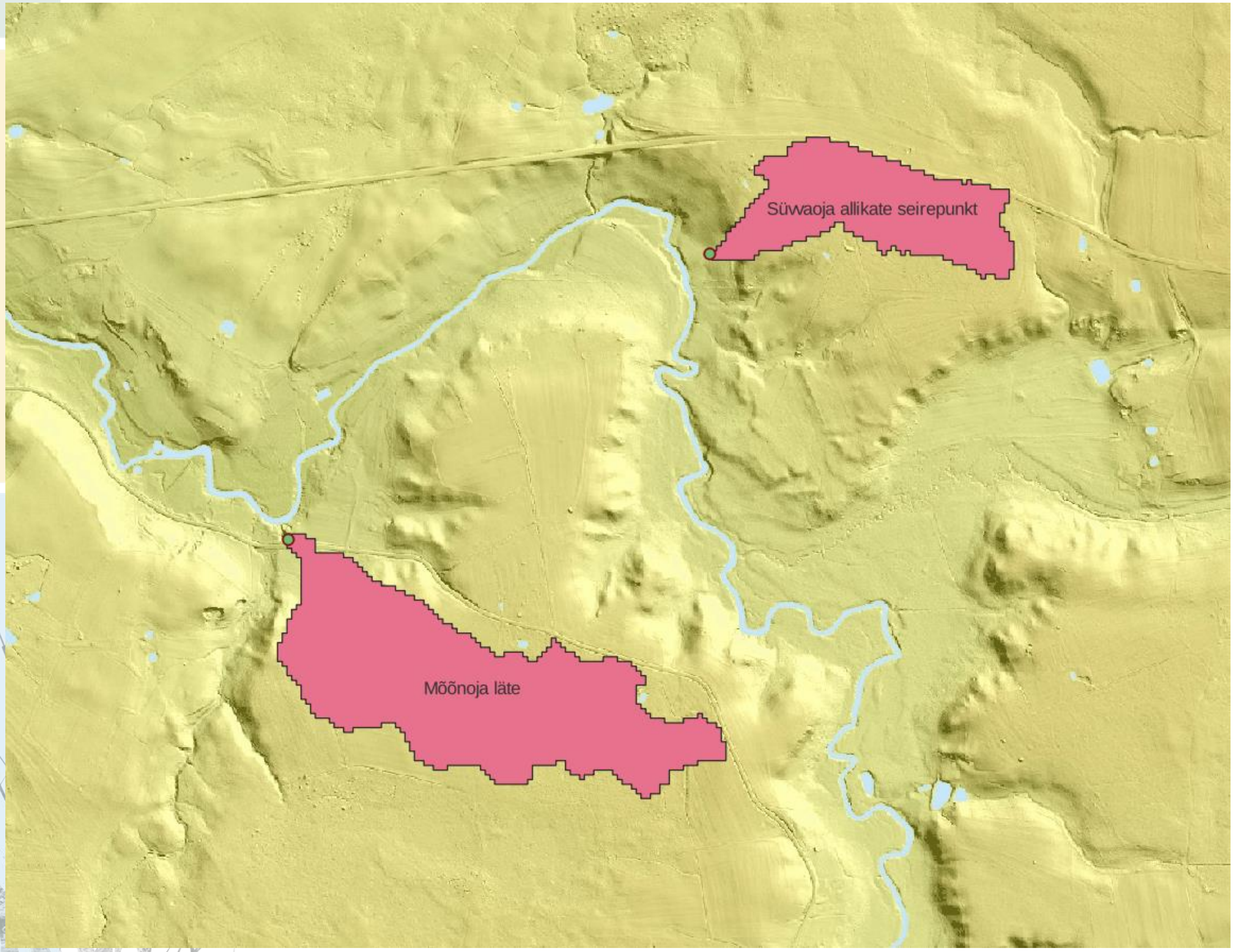
geology at outcrop	Fraction, %
D2gj	27.7
D2br	27.1
D3pl	18.4
D3am	14.2
D3kt	4.4
D3slp	4.3
D3dg	3.2
Dslp	0.6
D2ar	0.2

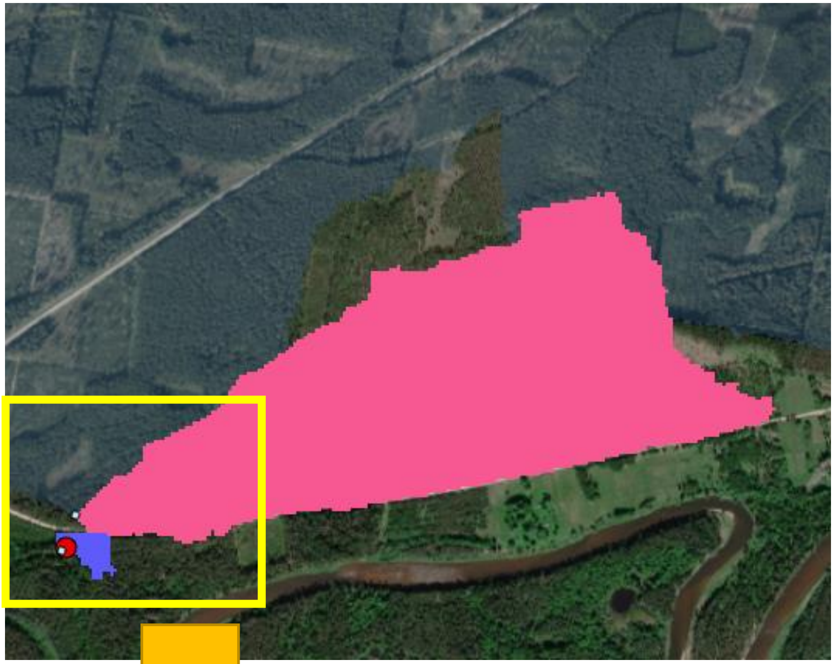
Dauģēnu cirka spring

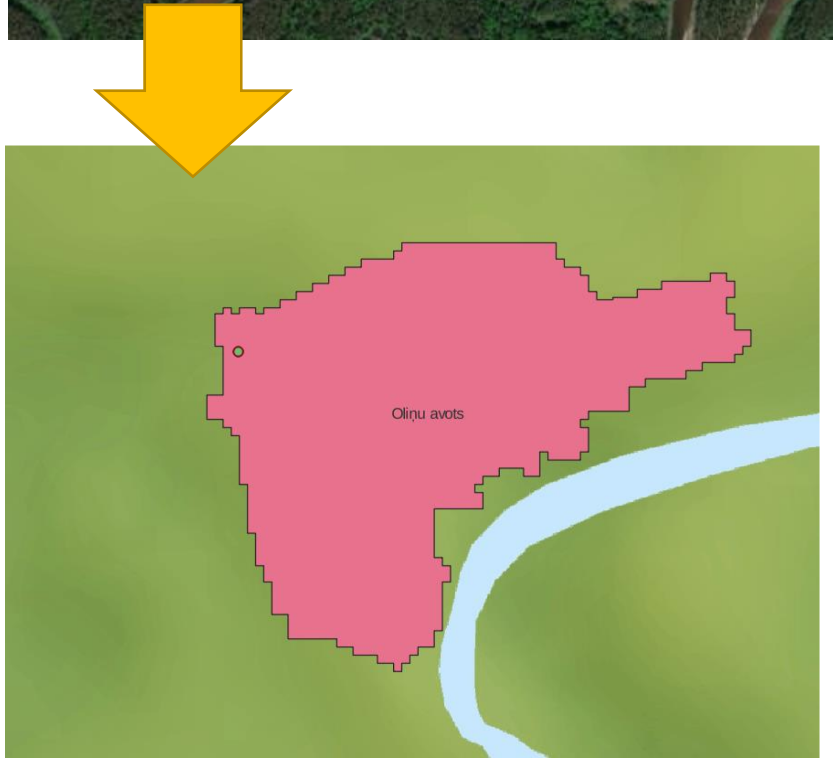
Watersheds based on topography - methodology

- Based on digital elevation model (DEM) created by combining Estonian (5 m resolution) and Latvian (10 m resolution) national DEMs (developed from Lidar data)
- The calculation of watershed based on topography was done by performing following steps in ArcGIS:
    1. Local depressions filled with Fill tool
    2. flow direction calculated with Flow direction tool
    3. The final watershed was calculated by Flow accumulation tool
- However, some springs required few more steps, for example, to “remove” a road ☺

Few examples

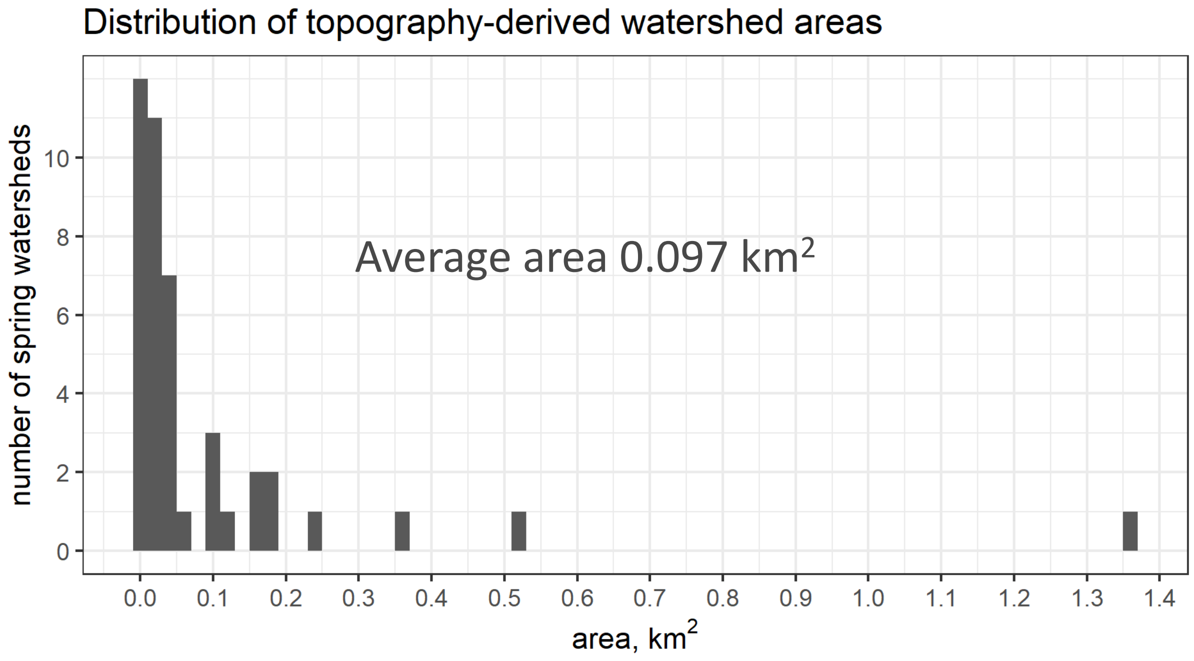






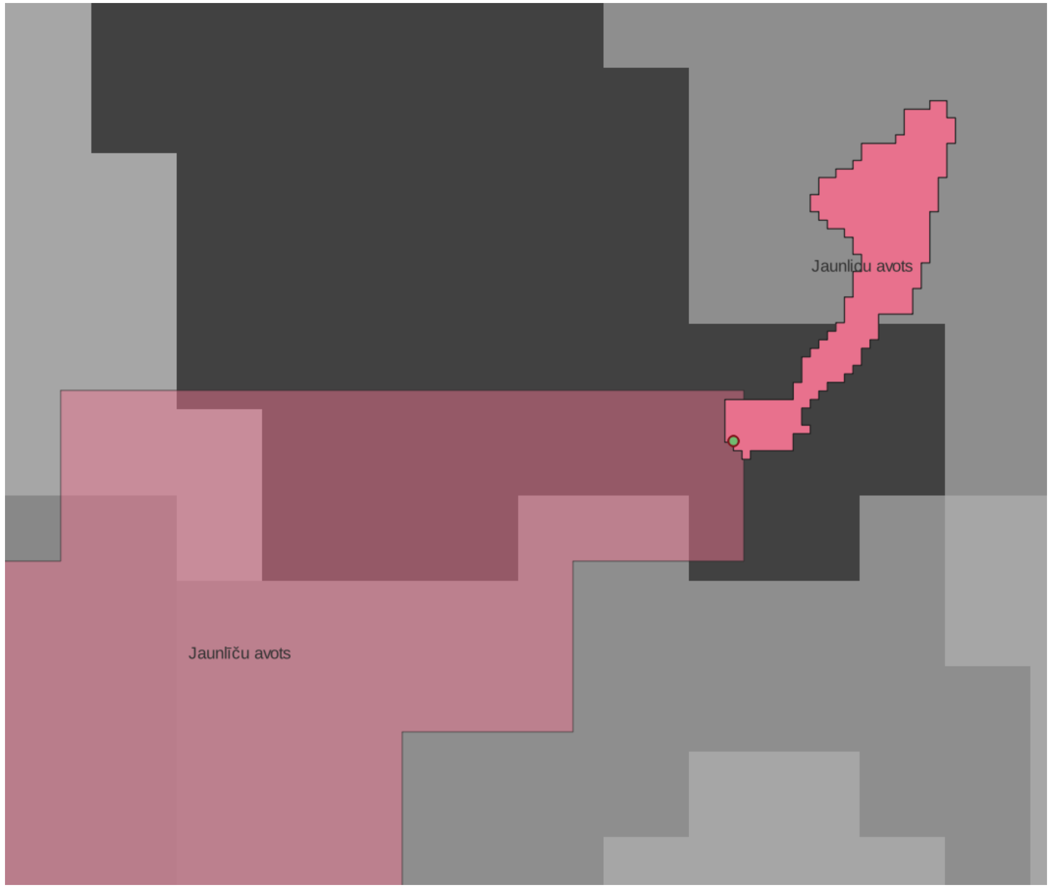
Watersheds based on topography

- Mostly small watersheds, especially compared to watersheds derived from hydrogeological model (bedrock aquifer representatives)
- They cover local vicinity around the spring due to having sole impact from the local topography



Land cover in watersheds

According to Corine Land Cover (2012) data following land uses dominate within watersheds



For topography derived watersheds:

- 25 – agricultural areas
- 20 – Forest and semi natural areas
- 2 – Artificial surfaces

For bedrock aquifer derived watersheds:

- 9 - agricultural areas
- 37 – Forest and semi natural areas
- 1 - Wetlands

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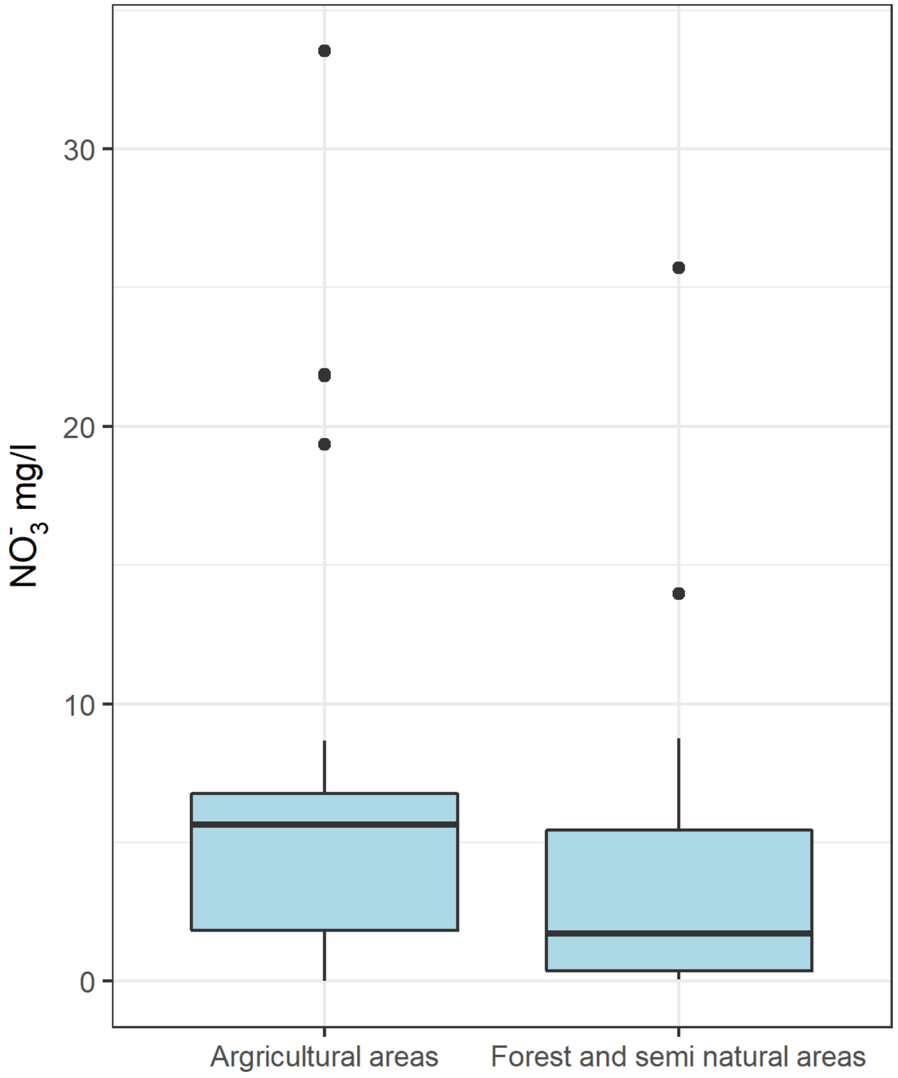
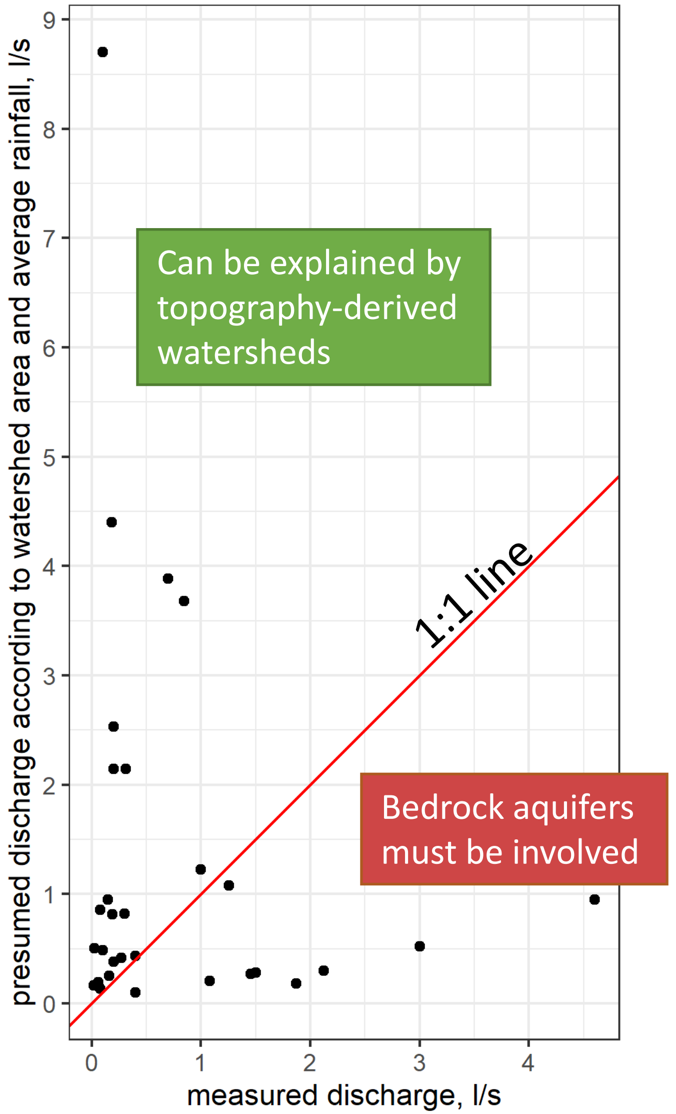


Watershed validation using discharge measurements

- Calculation of presumed discharge i.e. the maximum possible discharge that can be viable according to calculated watershed area and measured discharge rate.
- The validation can test if topography-derived watershed can be the only source of groundwater or (also) bedrock aquifers must have contribution to the spring water
- If the presumed discharge is larger than measured discharge, then it is possible that the spring is recharge solely in the topography-derived watershed and contains relatively new/fresh groundwater



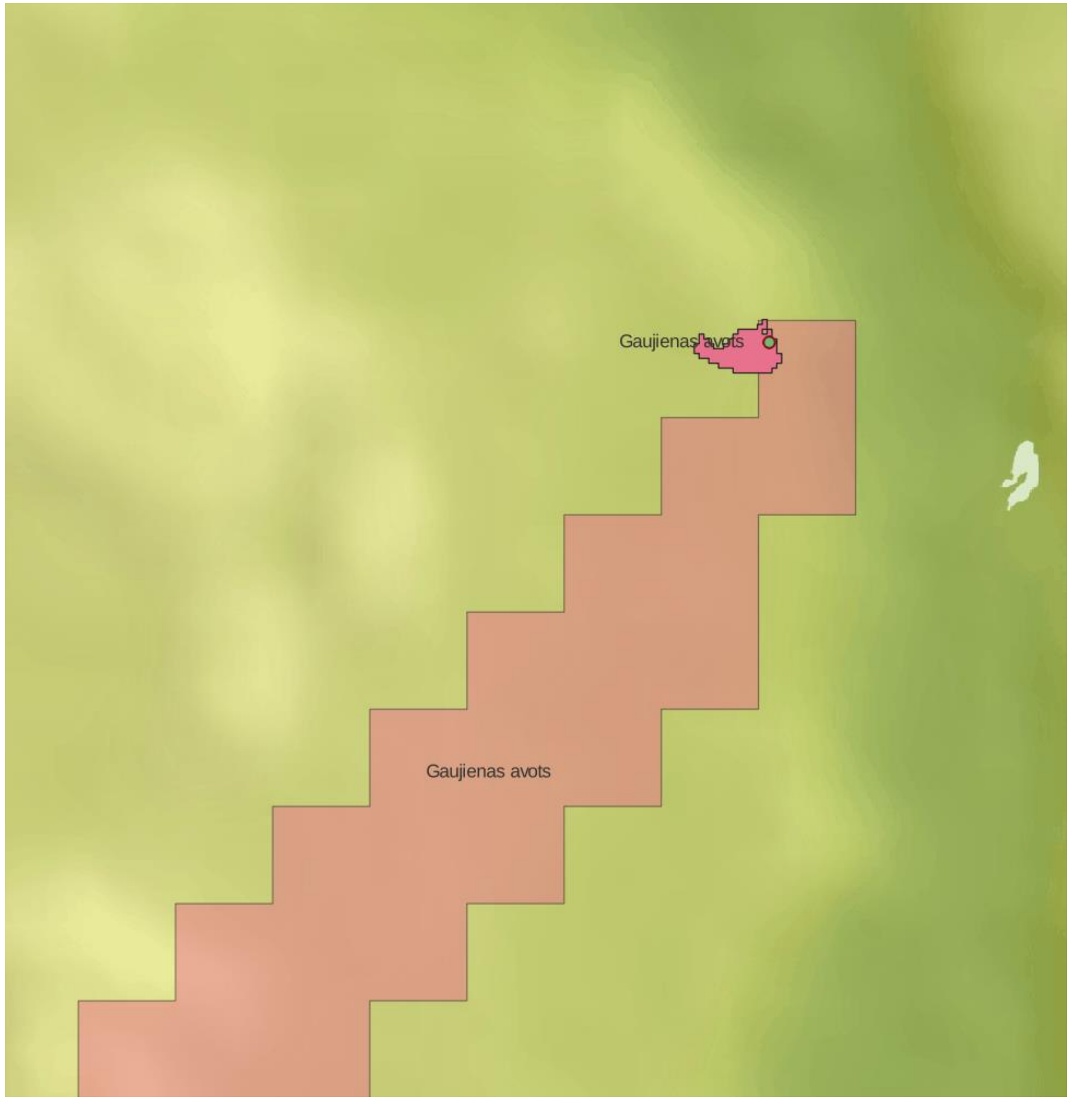
Watershed validation using discharge measurements

Example:

Gaujienas spring has topography derived watershed area of 11400 m^2 and precipitation rate in a range 650-750 mm/year, while the minimal contribution to groundwater is presumed to be ~35%.

This translates in presumed discharge rate in a range from 0.095 l/s up to 0.27 l/s, while the actual measured discharge was 1.46 l/s, indicating that for this spring **topography-derived watershed alone can't explain** the measured discharge and bedrock aquifers are most likely involved.

The maximum possible discharge for Gaujienas spring according to bedrock watershed (9 km^2) is up to 219 l/s thus bedrock aquifer contribution is very likely (in this case D_3*am* aquifer)



Concluding remarks

- Topography-based and bedrock aquifer-based watersheds have been calculated for all springs that have been visited in spring campaigns: new springs as well as springs already included in Latvian national monitoring program
- Watersheds are validated against actual discharge rates and discharges for 9 to 16 springs (depending on presumed groundwater contribution fraction) indicate significant bedrock aquifer contribution
- Watersheds are useful to identify pressures within the catchment areas and provide knowledge to conceptual understanding

Acu spring (in Ape)

- Thank you for the attention!

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bit.ly/WaterAct-project

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