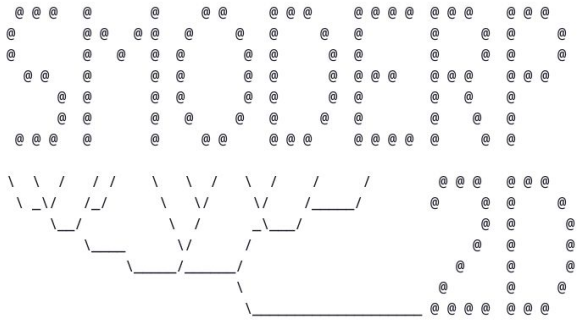

Connecting SMODERP with Living Landscape - QGIS Plugin

Petr Kavka[1], Ondřej Pešek[2], Martin Landa[2], Jakub Jeřábek[1], Jan Devatý[1]
[1]Department of Landscape Water Conservation
[2]Department of Geomatics
Faculty of Civil Engineering, Czech Technical University in Prague

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Content

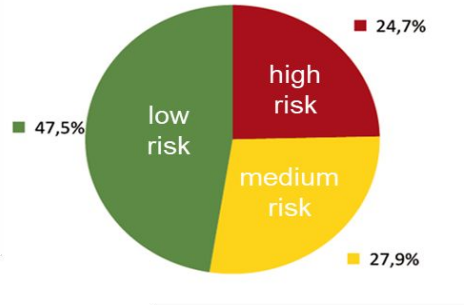
- Motivation
- What is Living Landscape project?
- What is SMODERP?
- How is SMODERP connected with Living Landscape?
- How is SMODERP implemented?

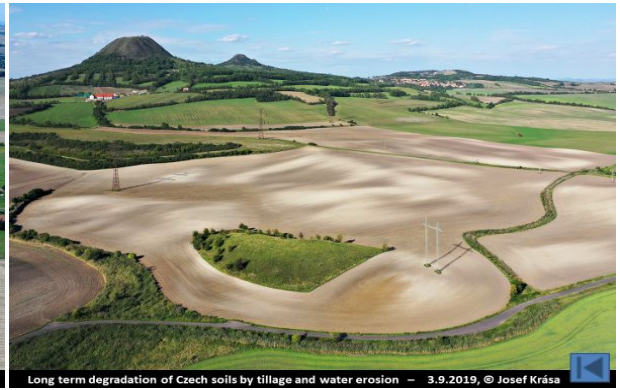
Motivation

- Soil erosion by water - major threat of soil degradation
- Processes in small (headwater) catchmets
- Supporting tool for landscape and water management

  ⟶ open source process-based model for control measure design

Soil erosion risk on arable land in Czechia (GAEC)

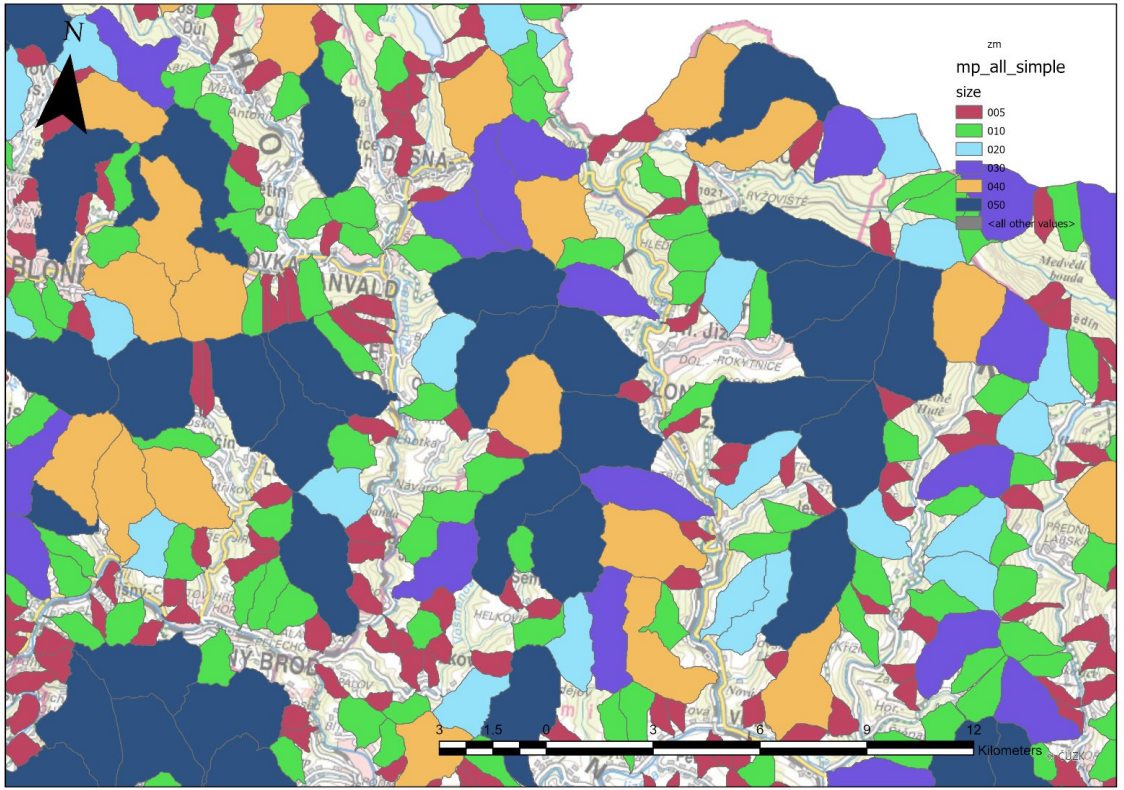




Soil erosion risk on arable land in Czechia (GAEC)

Small headwater catchment up to 5 km2

From [km²]	To [km²]	Class
0,3	0,7	05
0,7	1,3	10
1,3	1,7	15
1,7	2,3	20
2,3	2,7	25
2,7	3,3	30
3,3	3,5	35
3,5	4,5	40
4,5	5,5	50



80 % area of Czech Republic

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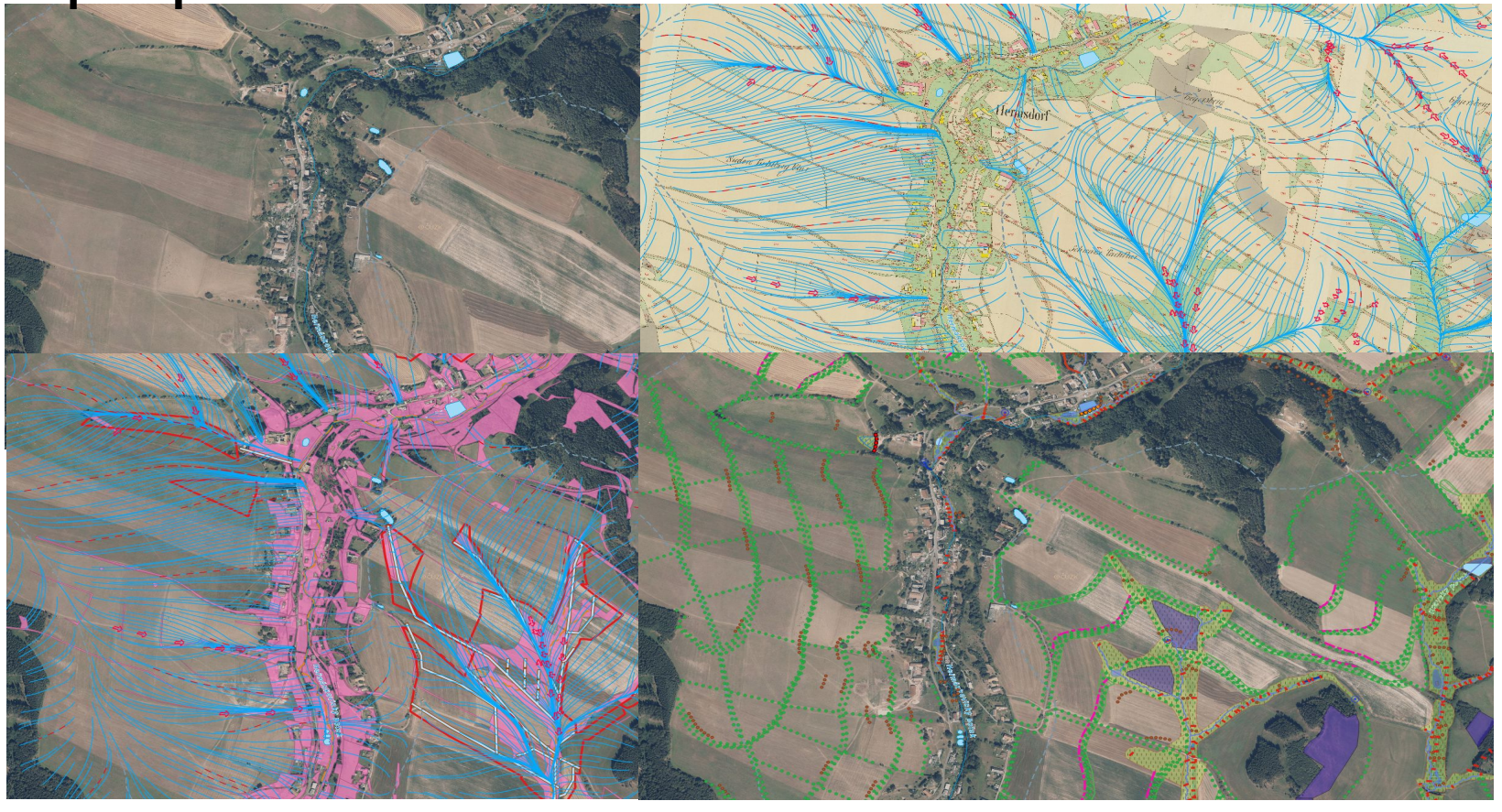
Kavka, Petr. 2021. "Spatial Delimitation of Small Headwater Catchments and Their Classification in Terms of Runoff Risks." Water (Switzerland) 13 (23). https://doi.org/10.3390/W13233458.

Living Landscape – volunteer activity for landscape protection



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Scientific motivation

Study of the origin and forms of surface runoff

- Causes, initial conditions
- Water balance and what affects it
- The randomness of precipitation
- Forms of surface runoff
  - Surface runoff → selective erosion
  - Concentrated runoff → erosion rills

Protection from potential impacts

- Reduction of substances transport watercourses and reservoirs)
- Design of technical measures in the
- Protection of earthworks slopes

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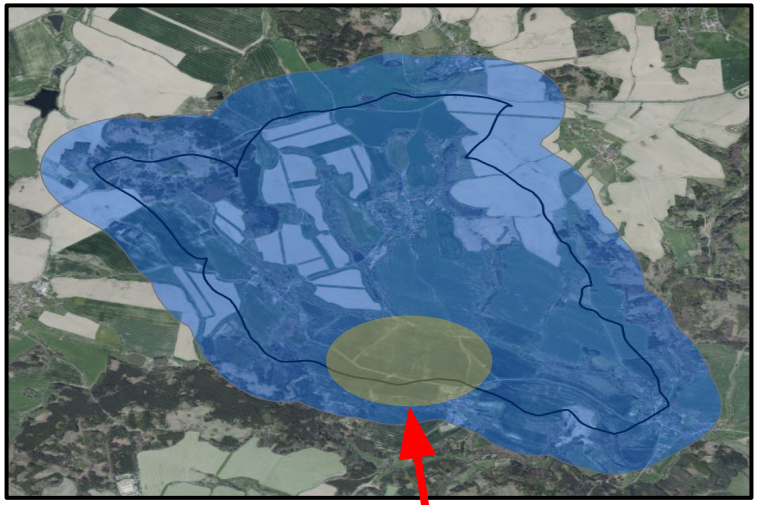
To catchments scale

- UAV rill monitoring
- Long term field plots

Báčová, M.; Krása, J.; Devátý, J.; Kavka, P. A GIS method for volumetric assessments of erosion rills from digital surface models. Eur. J. Remote Sens. 2018, *52, 96–107. https://doi.org/10.1080/22797254.2018.1543556*.

Kavka, P.; Devaty, J.; Vlacilova, M.; Krasa, J.; Dostal, T. Comparison of soil erosion rills identificatiaon by mathematical models and aerial photographs. In Proceedings of the 14th SGEM GeoConference on Informatics, Geoinformatics and Remote Sensing, Albena, Bulgaria, 19–25 June 2014; Volume 1, pp. 521–528.

Bauer, M.; Kavka, P.; et al. 2014 'Experimental research of soil erosion processes in the Czech Republic', International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 2(3), pp. 131–138. doi: 10.5593/sgem2014/b32/s13.018. 2014

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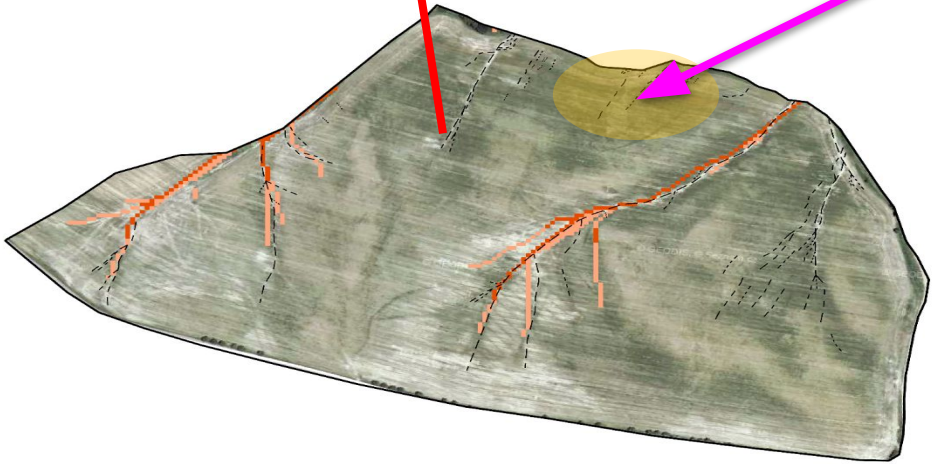
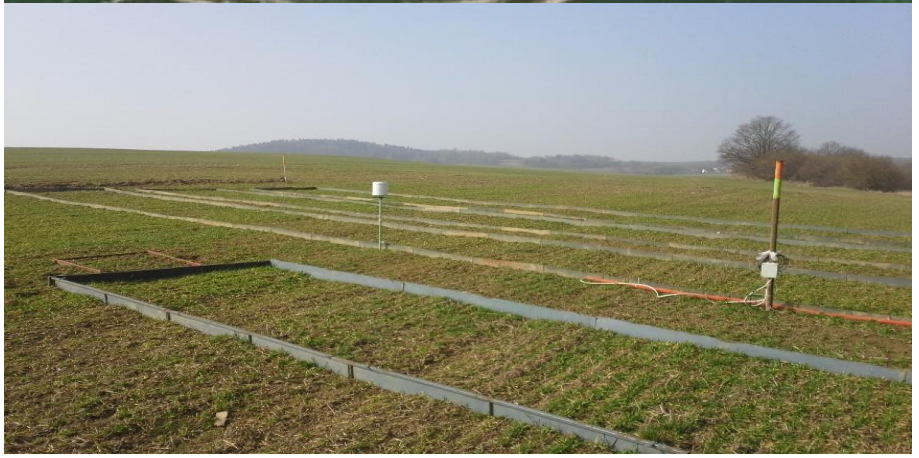
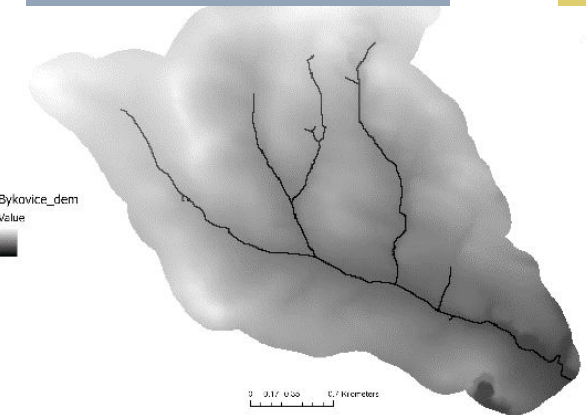
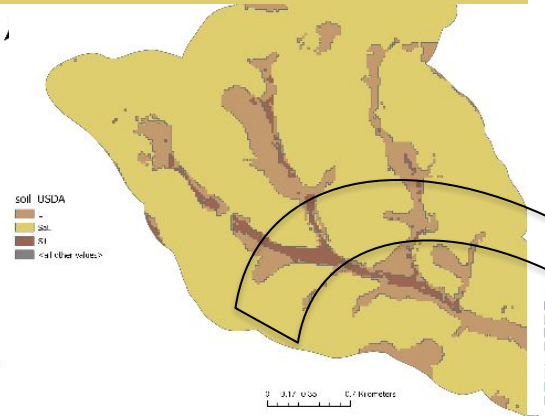




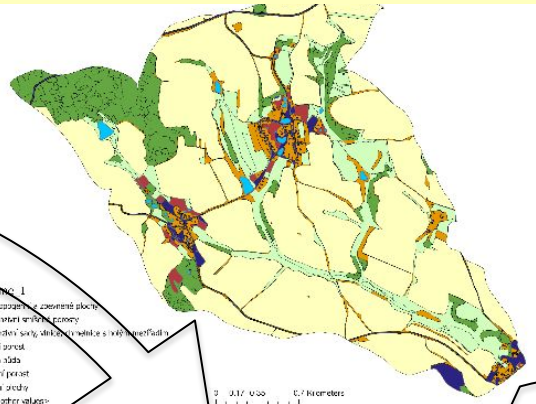
MORPHOLOGY



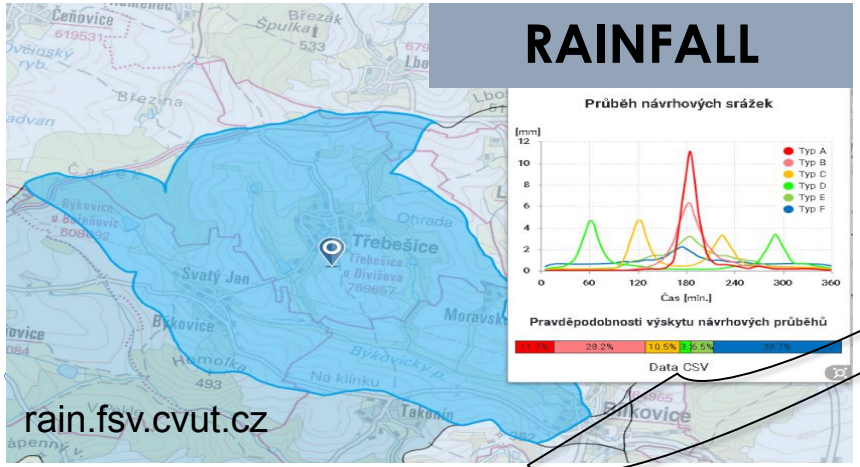
SOIL DATA



LAND USE



RAINFALL



MODEL
SMODERP2D

PREDICTION
&
CONSERVATION MEASURE

Processes

- Infiltration (Philip)
- Surface retention
- Interception
- Surface runoff
  - Sheet
  - Rill

Solution

$$\mathrm{inf} = \frac{1}{2}\mathrm{St}^{-1/2} + \mathrm{K}_{(s)}$$

$\rightarrow$ ep efective rainfall

$$q_{sheet} = \frac{\mathrm{X}}{n_{sheet}} \mathrm{s}^{\mathrm{Y}} \mathrm{h}^{\mathrm{b}}$$

$$q_{rill} = \frac{\mathrm{A}}{\mathrm{n_{rill}}} \mathrm{s}^{1/2} \mathrm{R}_{\mathrm{rill}}^{2/3}$$

$\mathrm{h_{crit}} \leftarrow v_{crit}, \tau_{crit}$

$$\frac{\mathrm{dh_i}}{\mathrm{dt}} = [\mathrm{q}_{\mathrm{in,i}}^{\mathrm{sheet}}(\mathrm{h_{sheet}}) + \mathrm{q}_{\mathrm{in,i}}^{\mathrm{rill}}(\mathrm{h_{rill}}) + \mathrm{ep}] - [(\mathrm{q}_{\mathrm{out,i}}^{\mathrm{sheet}}(\mathrm{h_{sheet}}) + \mathrm{q}_{\mathrm{out,i}}^{\mathrm{rill}}(\mathrm{h_{rill}}) + \mathrm{inf}]$$

Sheet flow calibration – rainfall simulator

$$q_{sheet} = \frac{X}{n_{sheet}} s^{Y} h^{b}$$

$$\inf = \frac{1}{2} S t^{-1/2} + K_{(s)}$$

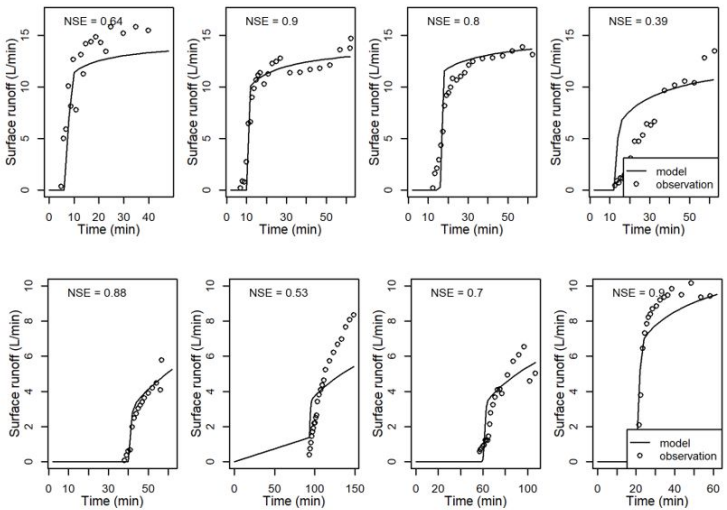
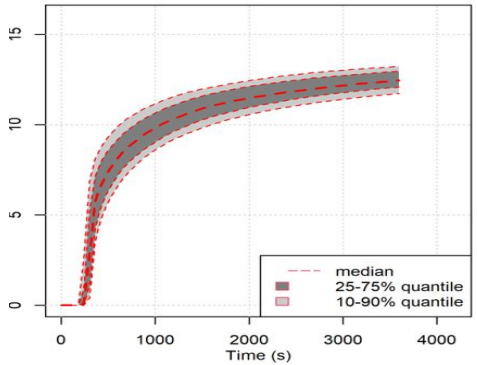
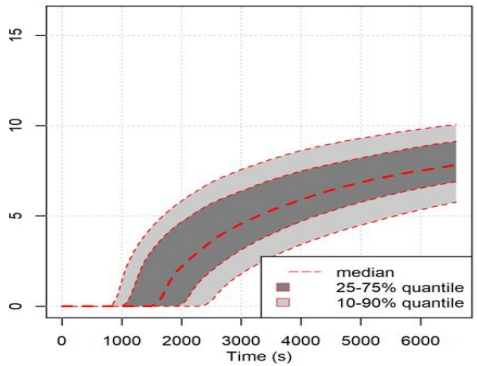


Figure 4. Results of the calibration procedure. The top row shows the bare soil results. The bottom row shows the results for plots with a vegetated soil surface.

Bare soil



Vegetation



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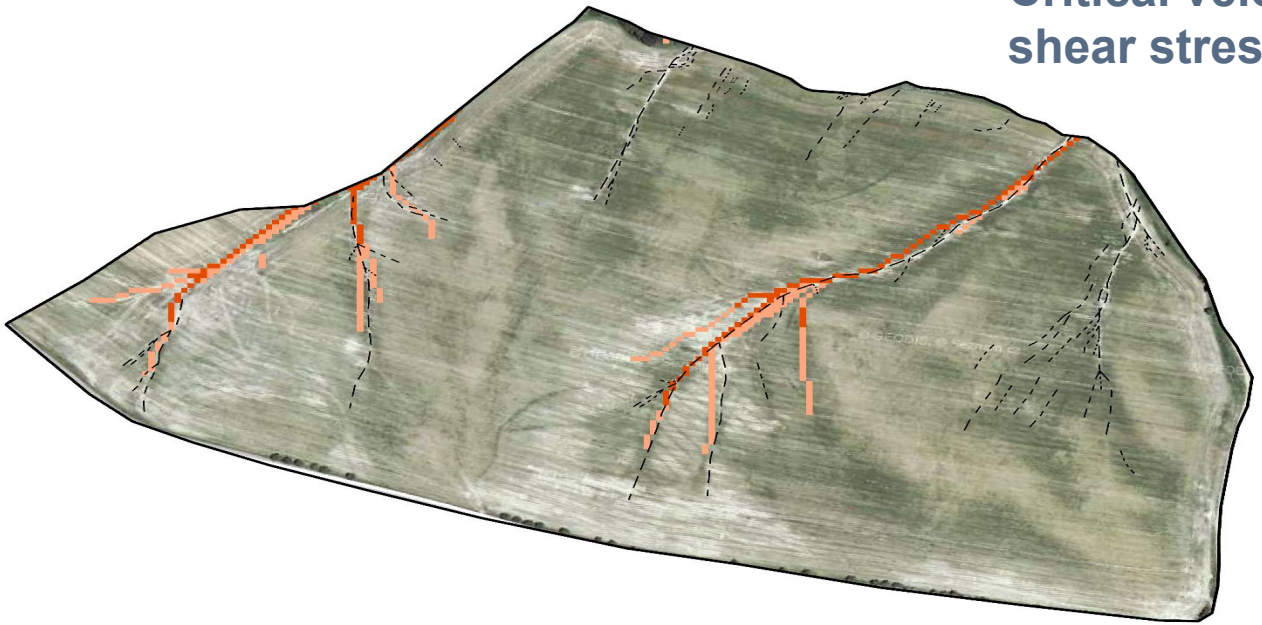
Kavka, P.; *Jeřábek, J.; Landa M.; 2022 "SMODERP2D-Sheet and Rill Runoff Routine Validation at Three Scale Levels." Water 2022, Vol. 14, Page 327 14 (3): 327. https://doi.org/10.3390/W14030327.*

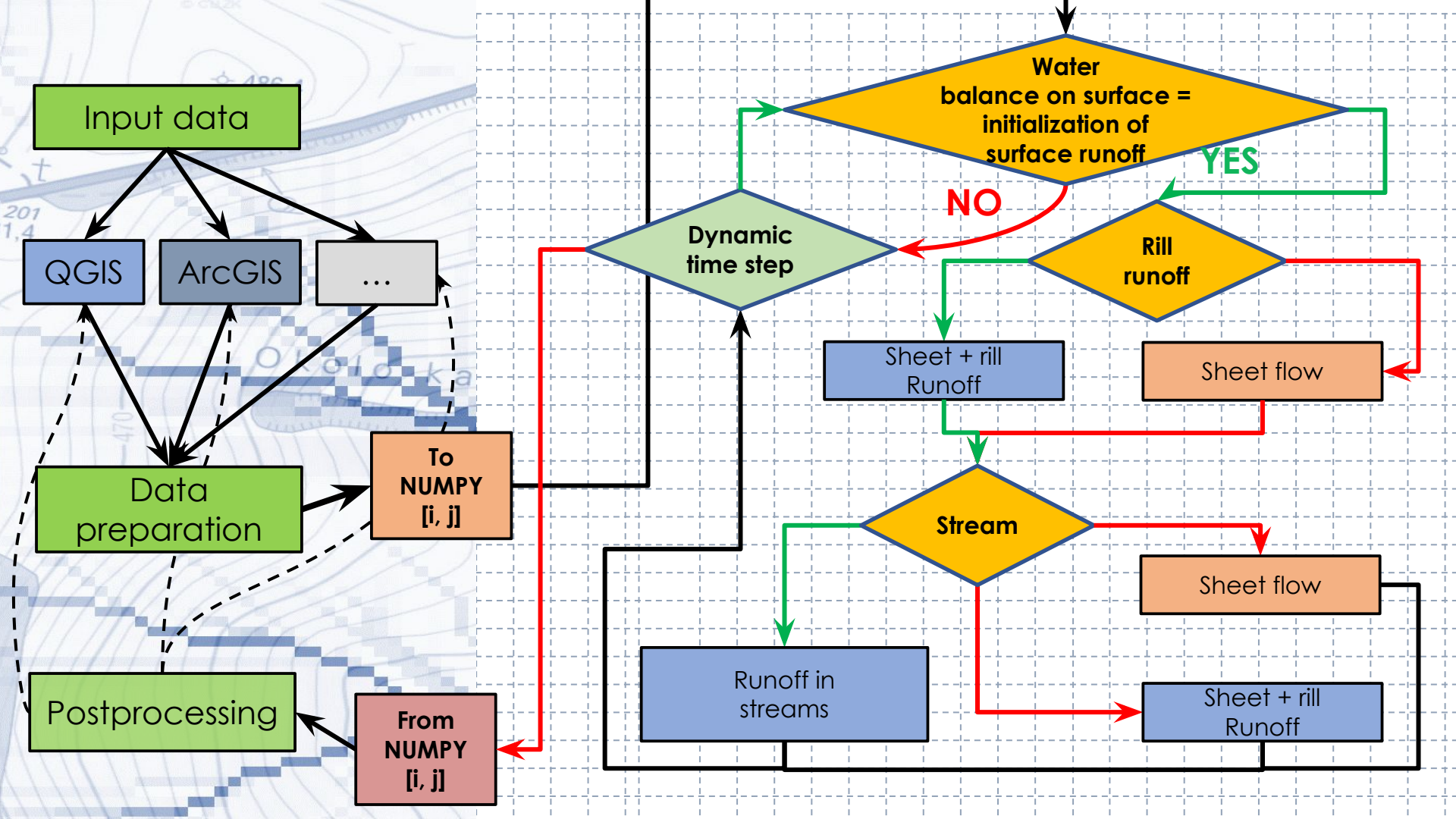
Rill flow calibration

Observed rills
Modeled rills

$h_{crit} \leftarrow v_{crit}, \tau_{crit}$

Critical velocity and/or shear stress



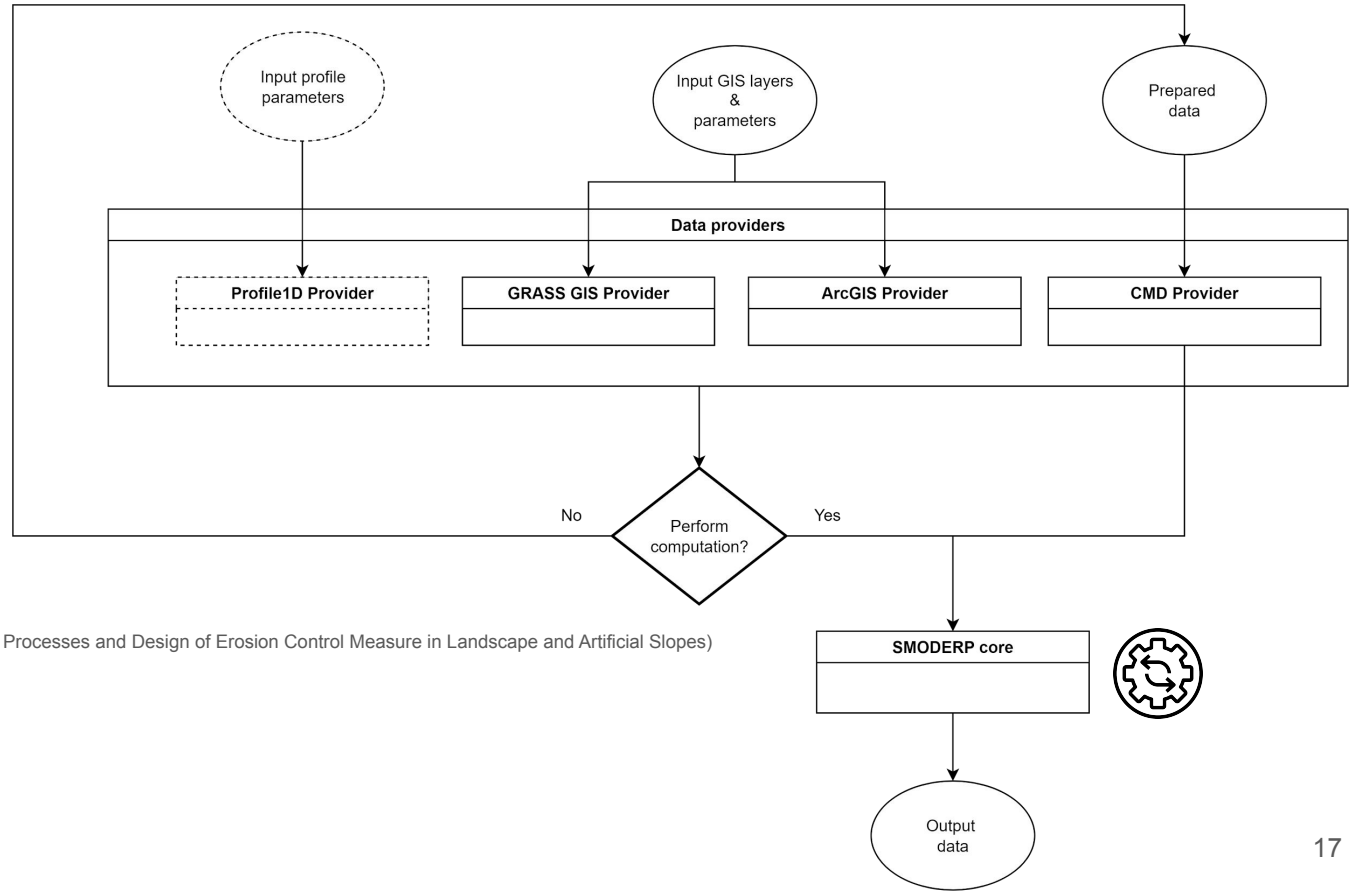

Input data
QGIS
ArcGIS
…
Data preparation
Postprocessing
To NUMPY [i, j]
From NUMPY [i, j]
Water balance on surface = initialization of surface runoff
YES
NO
Dynamic time step
Rill runoff
Sheet + rill Runoff
Sheet flow
Stream
Sheet flow
Runoff in streams
Sheet + rill Runoff

Connecting SMODERP with Living Landscape

- Current Living Landscape ⟶regular position of protection measure
- SMODERP additional information
  - Outputs ⟶position of the protection measure based on modelling
  - Discharge characteristics for design of protection measure
  - Assessment of the impact of the measures to runoff and erosion
  - Visualization of runoff path and discharge
- ⟶ Possibilities of irregular system of protection measure in Living Landscape activities
- ⟶ Visualization of effect planned measure to volunteers and stakeholders

Implementation

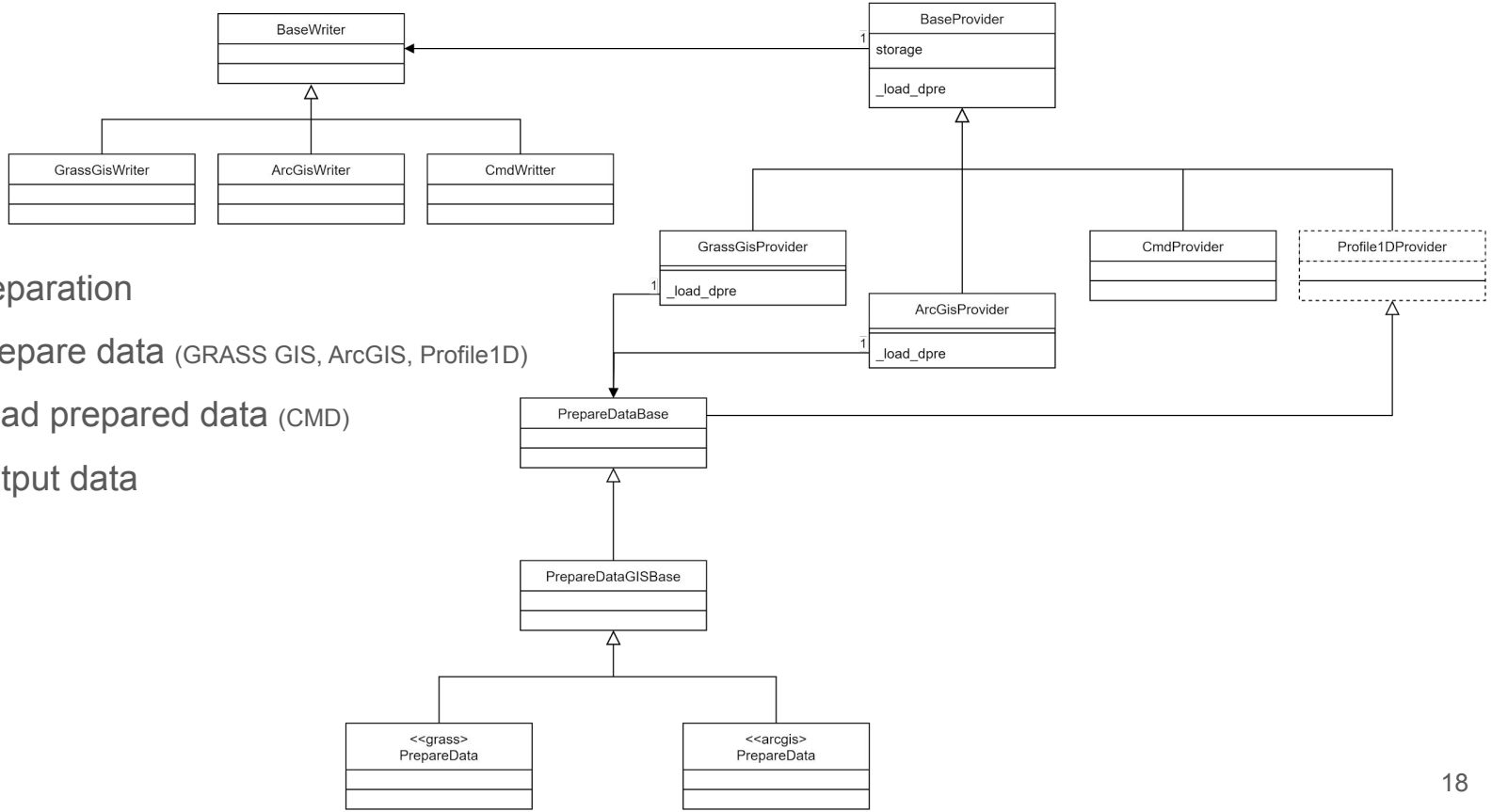
- Data providers:
  - GRASS GIS
  - ArcGIS
  - CMD
  - Profile1D (Talk: Surface Runoff Processes and Design of Erosion Control Measure in Landscape and Artificial Slopes)



Data providers

Functionality:

1. Data preparation
   a. Prepare data (GRASS GIS, ArcGIS, Profile1D)
   b. Load prepared data (CMD)
2. Write output data



SMODERP core

- Implemented in Python
- Only one dependency: NumPy

SMODERP core

- SMODERP 1.0: Computations run only for cells of interest
  - Data of 16 kB: 6s

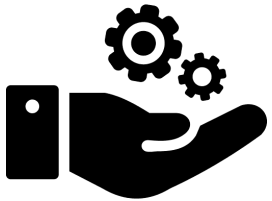
- SMODERP 2.0: Computations run for full areas in masked NumPy arrays
  - Data of 16 kB: 21s (**3.5 times slower**)

SMODERP core

- SMODERP 1.0: Computations run only for cells of interest
  - Data of 16 kB: 6s
  - Data of 660 kB: 31min
- SMODERP 2.0: Computations run for full areas in masked NumPy arrays
  - Data of 16 kB: 21s (**3.5 times slower**)
  - Data of 660 kB: 5min (**6.2 times faster**)

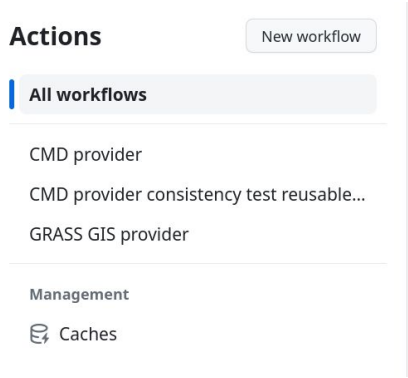
SMODERP core

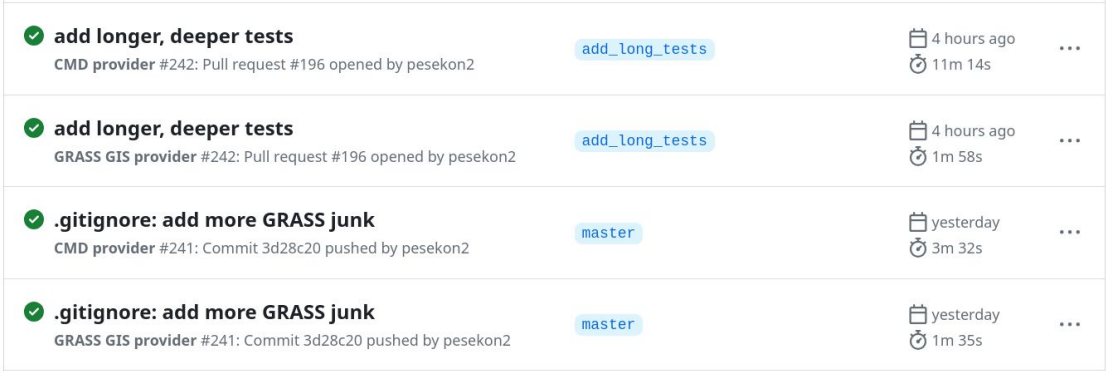
- SMODERP 1.0: Computations run only for cells of interest
  - Data of 16 kB: 6s
  - Data of 660 kB: 31min
- SMODERP 2.0: Computations run for full areas in masked NumPy arrays
  - Data of 16 kB: 21s (**3.5 times slower**)
  - Data of 660 kB: 5min (**6.2 times faster**)
- SMODERP WHOKNOWS
  - An implicit solution



Automated tests

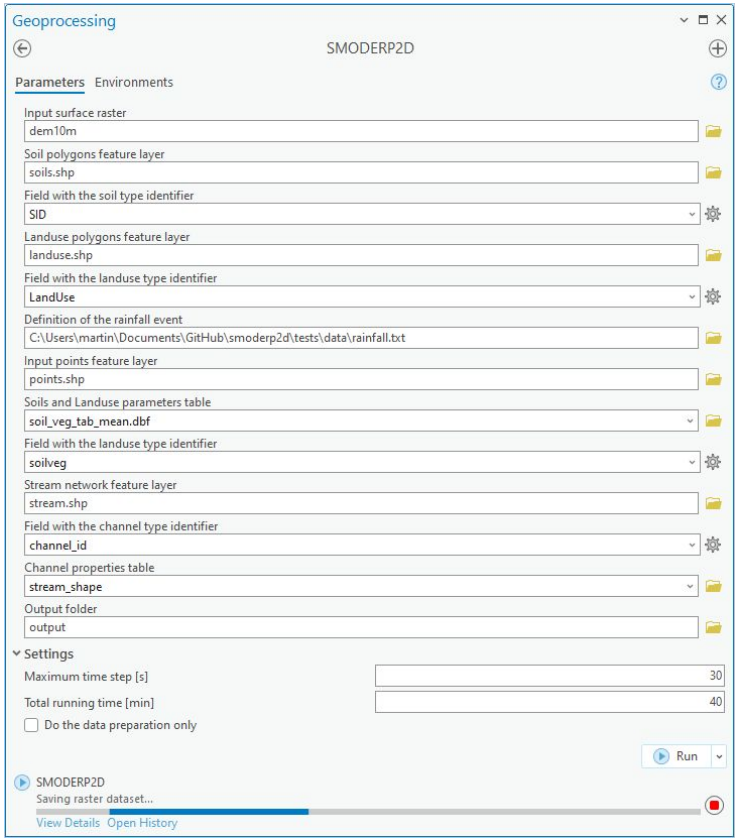
- Running in GitHub workflows
  - Profile1D data provider
  - CMD data provider
  - GRASS GIS data provider
  - ArcGIS data provider not integrated due to the Esri license limitation
- Implemented using pytest package
- Assuring the computation consistency





User Interfaces

1. **ArcGIS toolbox**
2. GRASS module
3. Command line
4. QGIS plugin



User Interfaces

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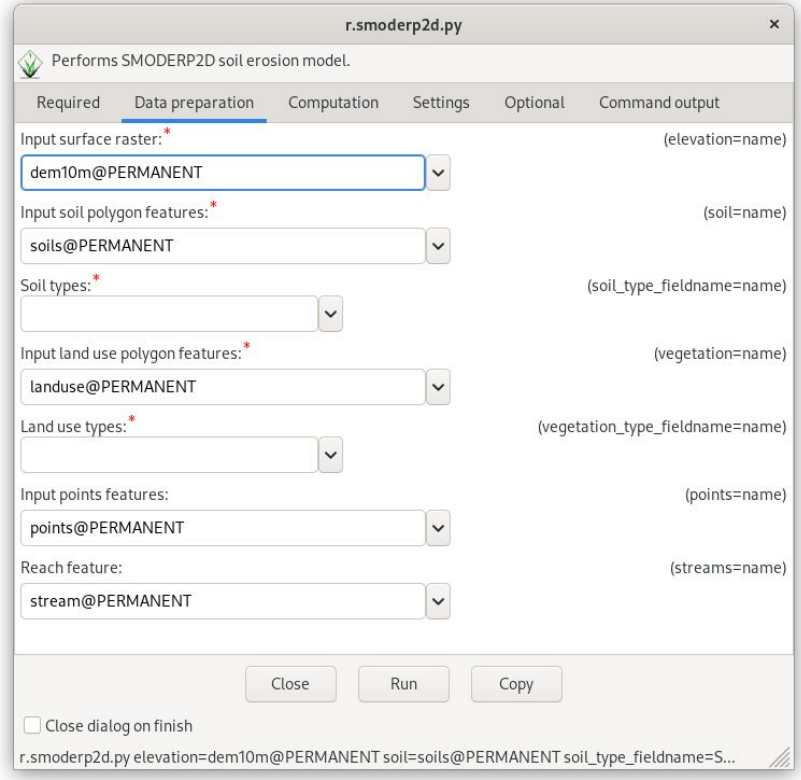


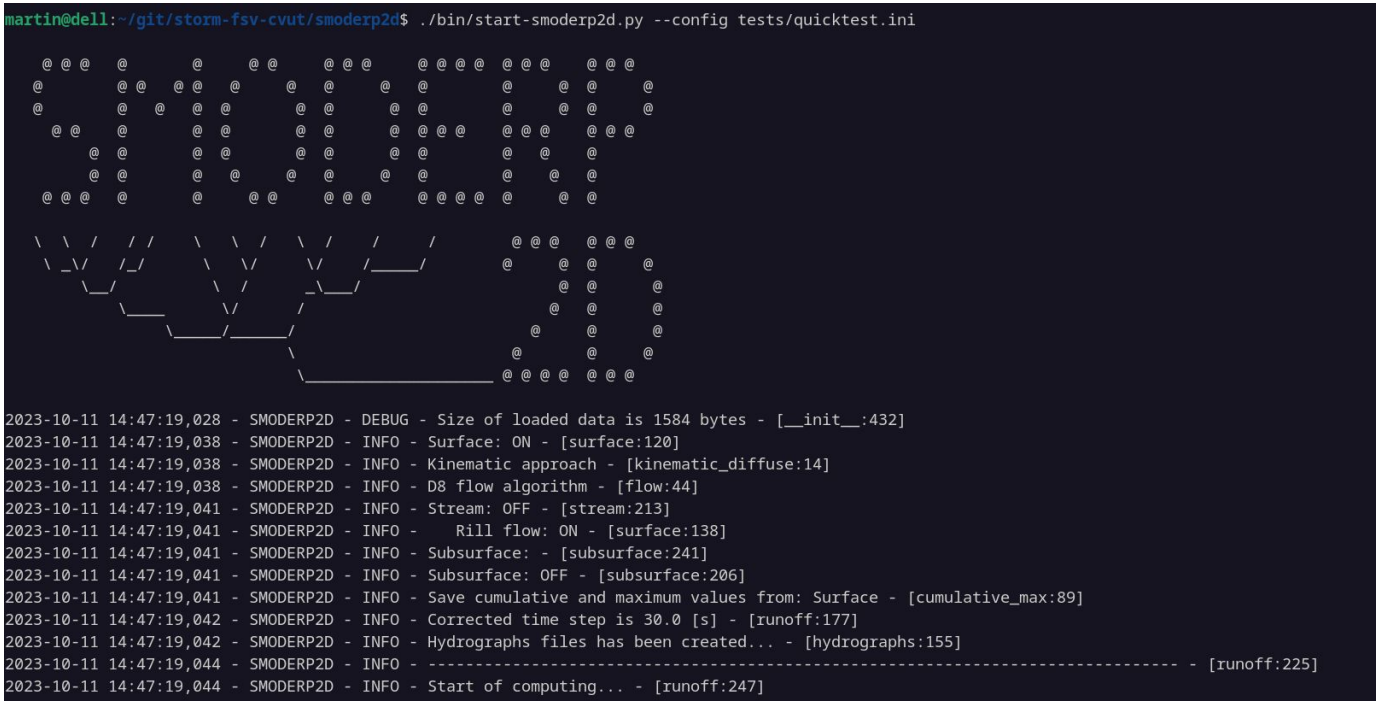
User Interfaces

1. ArcGIS toolbox
2. **GRASS module**
3. Command line
4. QGIS plugin

```
GRASS test_loc1/PERMANENT:smoderp2d > ./bin/grass/r.smoderp2d/r.smoderp2d.py
Performs SMODERP2D soil erosion model.

Usage:
 r.smoderp2d.py [-d] elevation=name soil=name soil_type_fieldname=name
   vegetation=name vegetation_type_fieldname=name rainfall_file=name
   maxdt=value end_time=value [points=name] [table_soil_vegetation=name]
   [table_soil_vegetation_fieldname=name] [streams=name]
   [channel_properties_table=name] [streams_channel_type_fieldname=name]
   output=name [--help] [--verbose] [--quiet] [--ui]

Flags:
  -d   Perform data preparation only and exit

Parameters:
                        elevation   Input surface raster
                             soil   Input soil polygon features
                 soil_type_fieldname   Soil types
                       vegetation   Input land use polygon features
          vegetation_type_fieldname   Land use types
                     rainfall_file   Rainfall file
                             maxdt   Max time step [sec]
                                     default: 30
                          end_time   Total running time [min]
                                     default: 5
                            points   Input points features
              table_soil_vegetation   Table of soil and land use information
    table_soil_vegetation_fieldname   Soil land use code
                           streams   Reach feature
          channel_properties_table   Reach shapes table
     streams_channel_type_fieldname   Reach shape table code
                            output   Name for output directory where to store results
```

User Interfaces

1. ArcGIS toolbox
2. GRASS module
3. **Command line**
4. QGIS plugin



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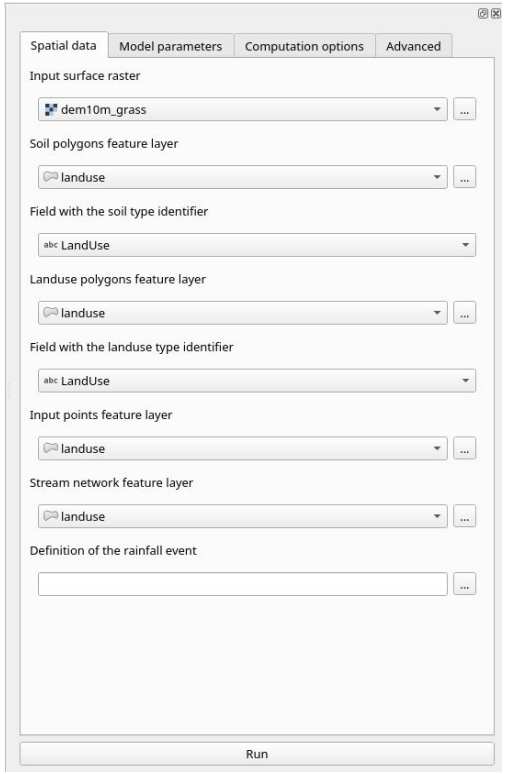
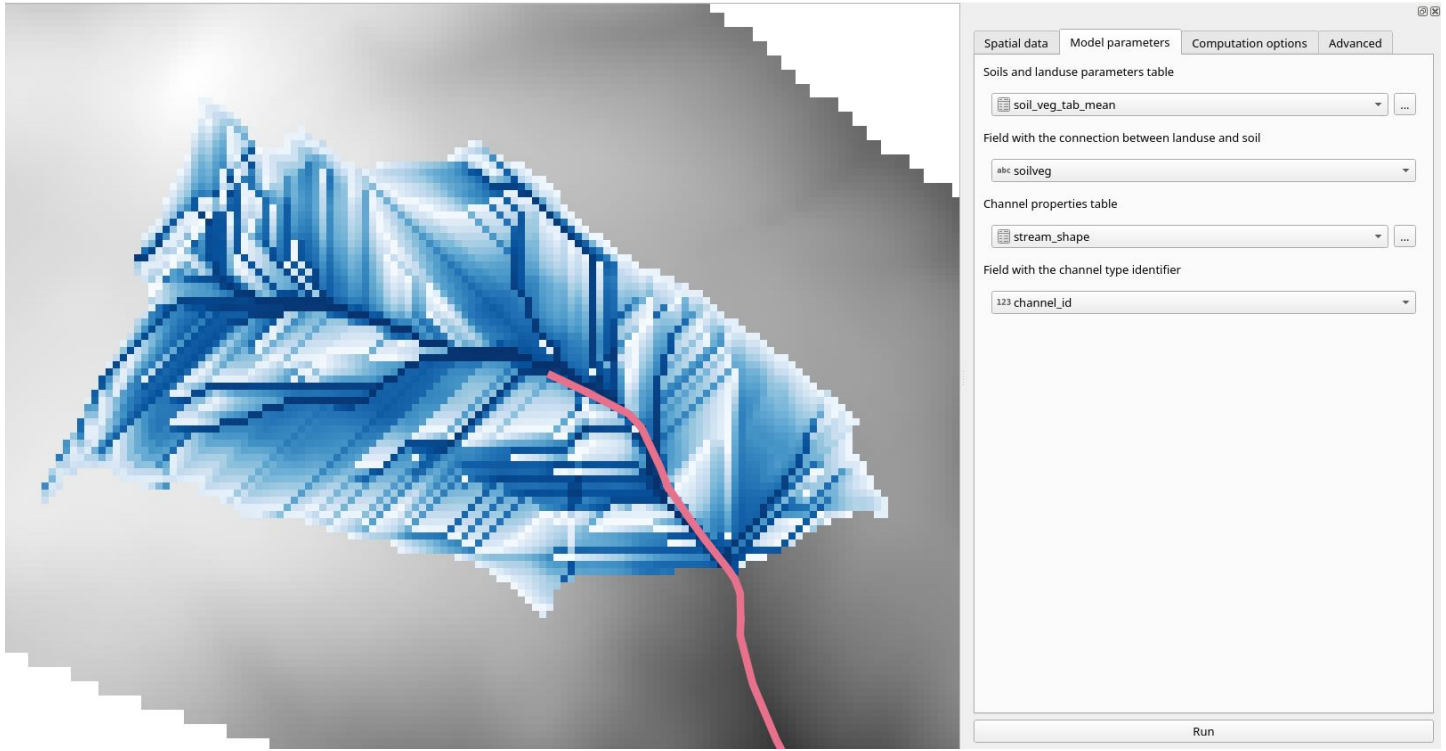
QGIS plugin

- A QGIS user interface for processes running in GRASS GIS
- Experimental prototype



QGIS plugin


Spatial data
Model parameters
Computation options
Advanced
Soils and landuse parameters table
soil_veg_tab_mean
Field with the connection between landuse and soil
soilveg
Channel properties table
stream_shape
Field with the channel type identifier
channel_id
Run

https://github.com/storm-fsv-cvut/smoderp2d/

smoderp.fsv.cvut.cz

rain.fsv.cvut.cz

Thank you for attention!

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