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Prírodovedecká fakulta UPJŠ v Košiciach

International Remote Sensing Summer School 2026 (IRSSS 2026)

Application of high-resolution DEMs in GRASS GIS/QGIS
Surface runoff and river-dynamics simulation using r.sim.water

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Learning objectives

After this session, participants will be able to:

- understand the role of Digital Elevation Models (DEMs) in hydrological modelling;
- distinguish between regional Copernicus DEMs and high-resolution UAV-derived DEMs;
- understand the physical principles behind the **r.sim.water** model;
- run a simple hydrological simulation in GRASS GIS;
- interpret simulation results.

Introduction

Why do we need hydrological modelling?

- Where will water flow after an intense rainfall event?
  Why does runoff follow different pathways?
- How does terrain control water movement?
- How can remote sensing support hydrological modelling?

This is the concept of integrating remote sensing with physically-based environmental modelling.

Terrain Analysis in GRASS GIS

Basic terrain parameters derived from a DEM:

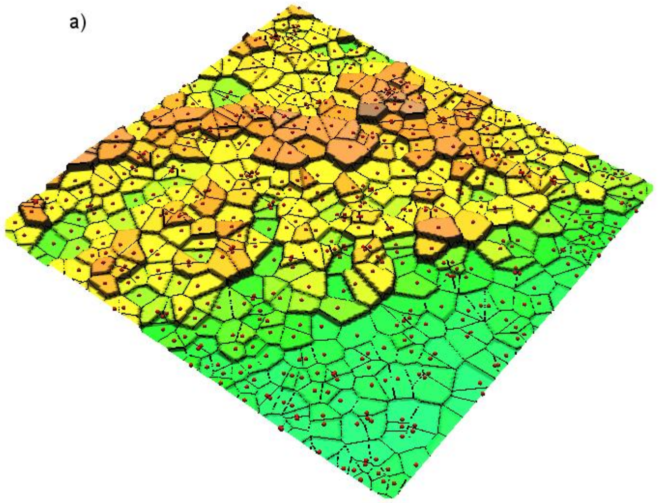
- elevation
- slope
- aspect
- curvatures
- drainage pathways

This includes several GRASS modules such as v.surf.rst, r.slope.aspect, r.flow and others.

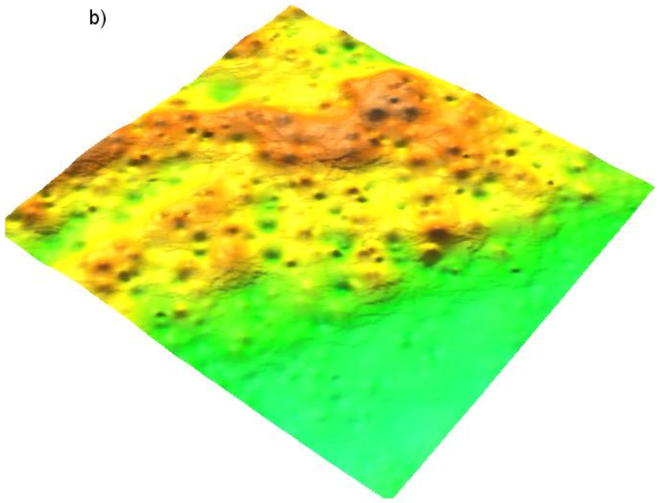
GRASS GIS

DEM - interpolation

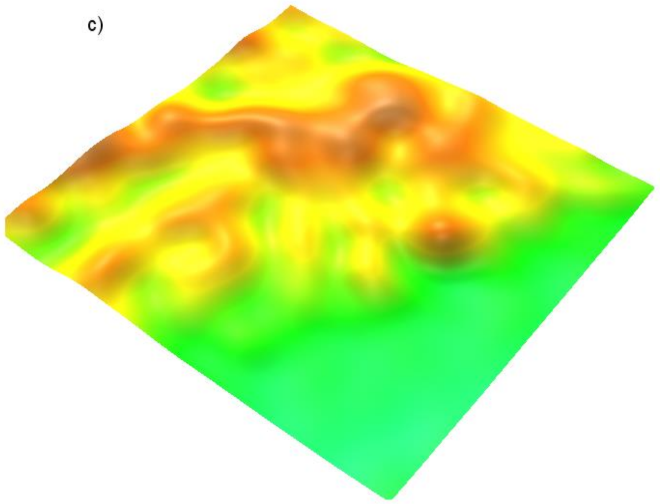
a)



b)



c)

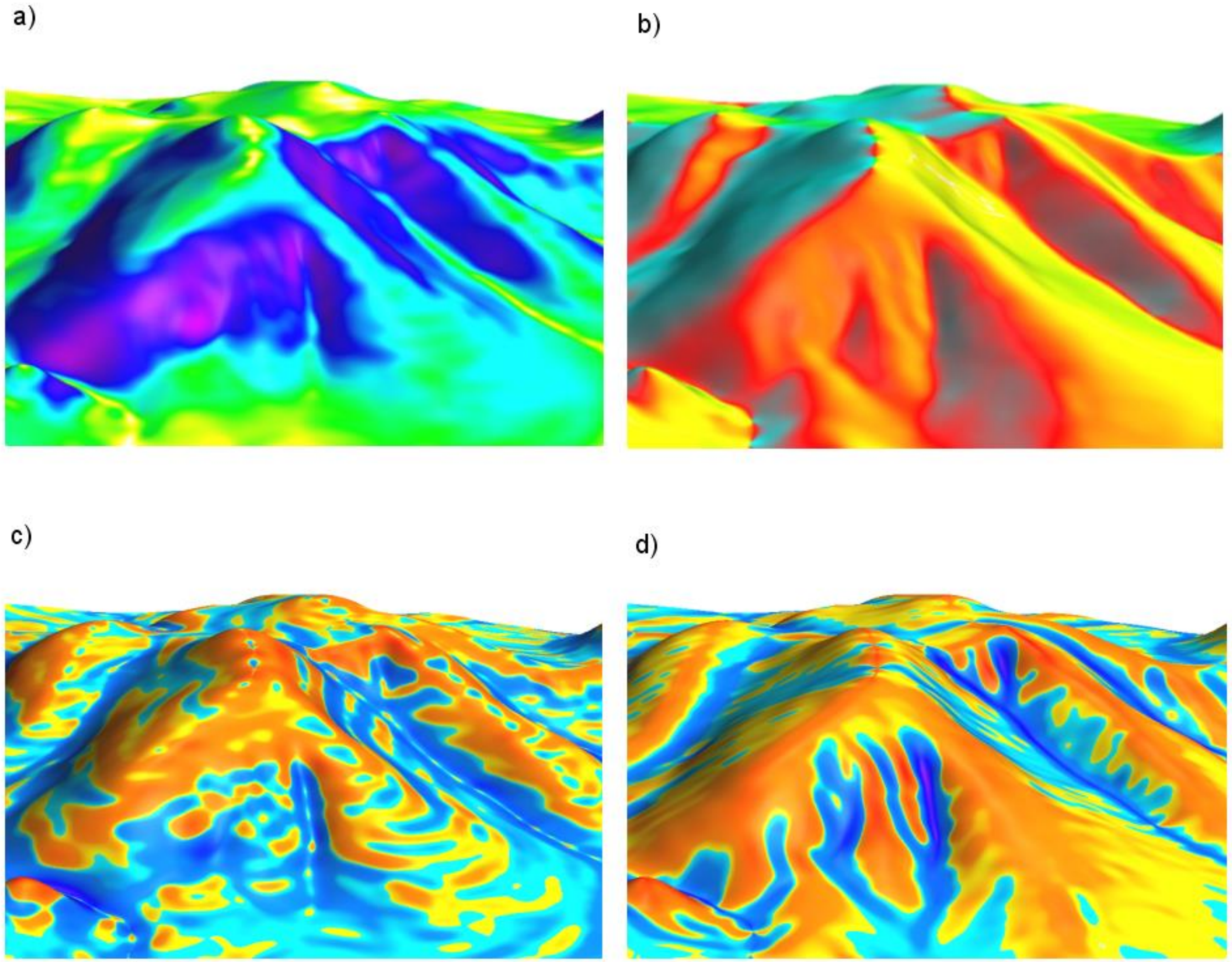


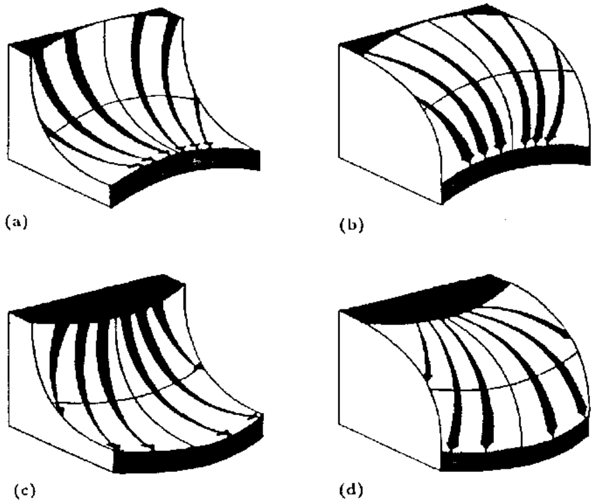
a) Voronoi polygons + input data
b) inverse distance weighted IDW
c) regularized spline with tension RST

Terrain Parameters

Basic terrain parameters derived from a DEM (v.surf.rst):

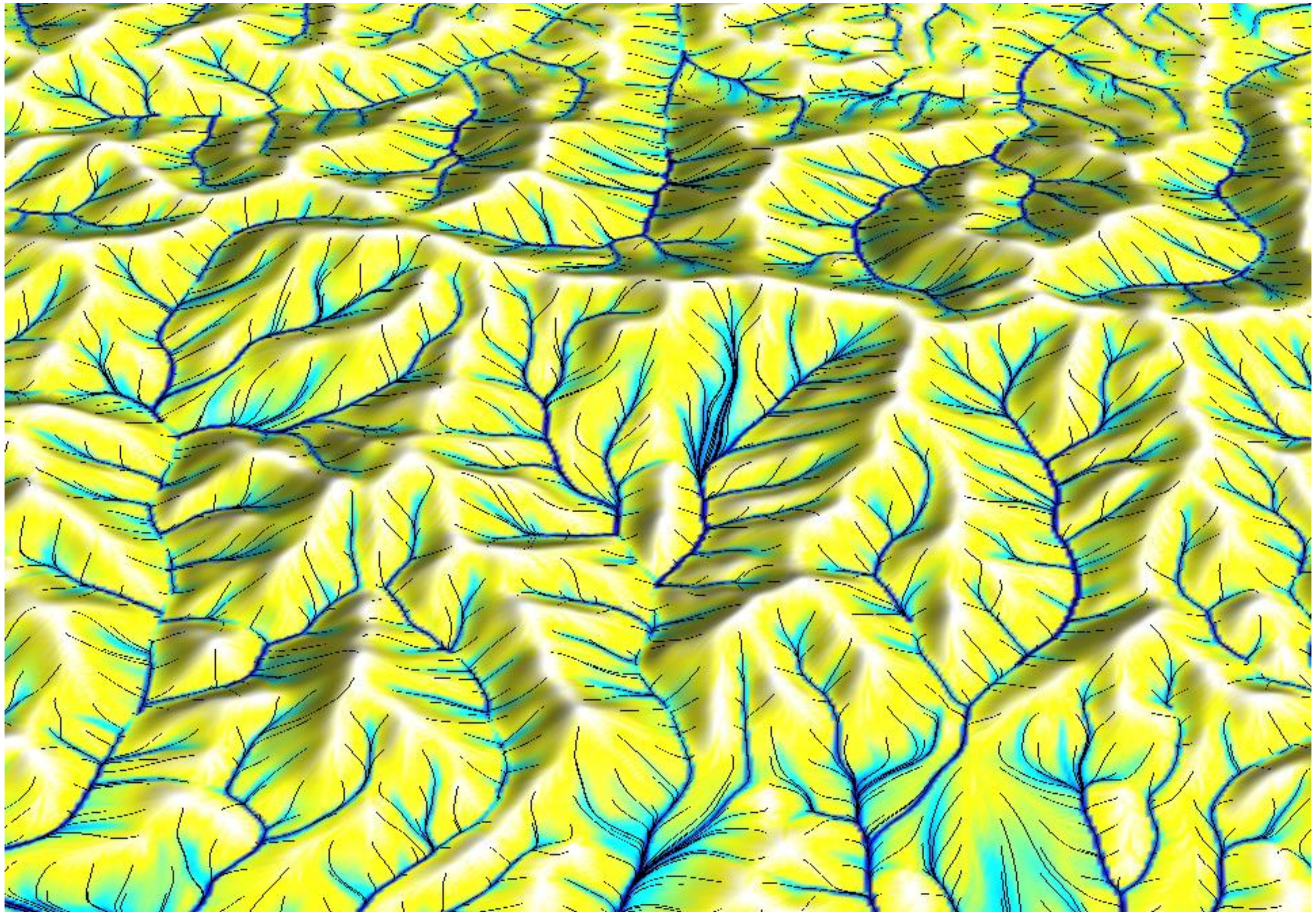
- elevation
- slope (a)
- aspect (b)
- curvatures (c, d)
- drainage pathways





Terrain Parameters

drainage pathways:
slope lines + upslope
contributing area (r.flow)



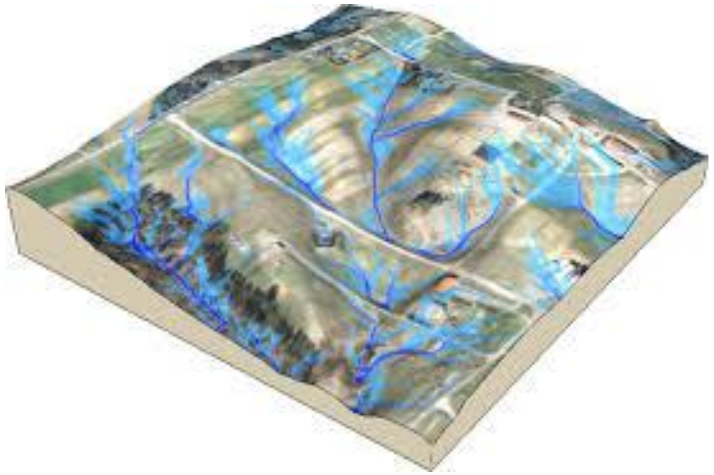
Introduction to the r.sim.water model

Model concept:

shallow overland flow
rainfall excess=rainfall-infiltration
Manning roughness coefficient
Monte Carlo numerical simulation of water movement

Modelling workflow:

Digital Elevation Model
↓
Terrain analysis
↓
Hydrological parameters
(Manning’s n, flow control,..)
↓
r.sim.water
↓
Water depth
Water discharge



Water Erosion Modeling Using SIMWE

- Simulation of water erosion processes using Monte Carlo path sampling method
- The method is based on duality between physical field and particles
- Topography plays an important role (direction and size of elevation gradient)

MITAS, L., MITASOVA, H. (1998). Distributed soil erosion simulation for effective erosion prevention. Water Resources Research, 34(3):505–516.

Path sampling method

based on duality between particles and fields

fields - continuous distribution (scalar, vector, tensor)
particles - discrete distribution

Duality - density of particles in space defines a field and vice versa

Landscape processes are represented by evolution of fields or spatially distributed particles

Method properties

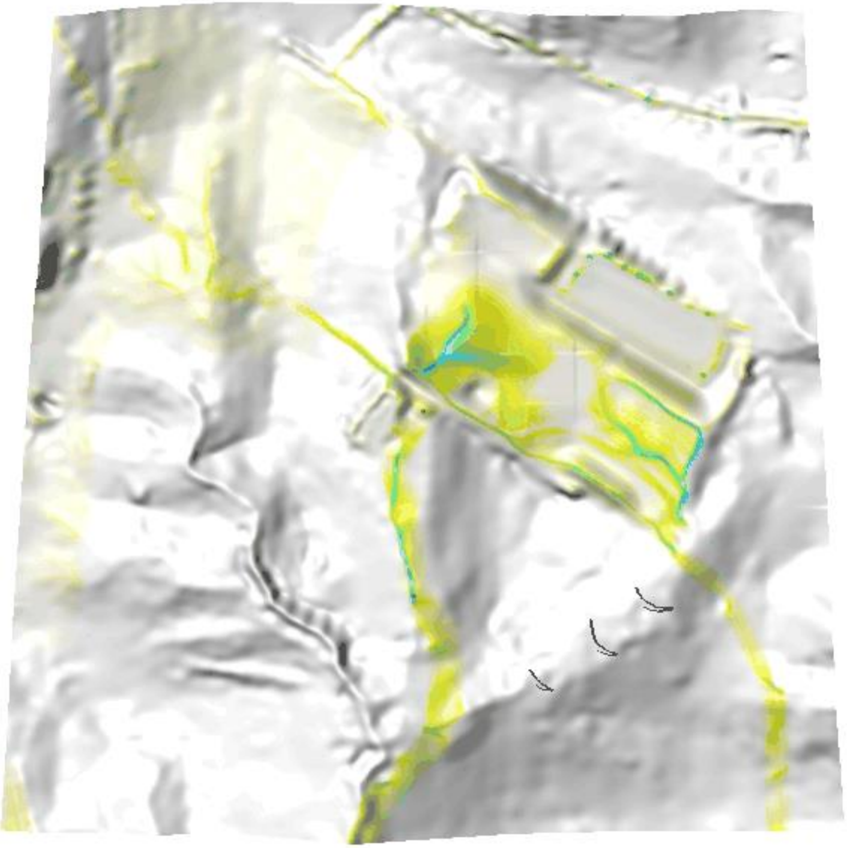
- ✓ mesh-free (can be used with standard GIS formats)
- ✓ robust
- ✓ flexible
- ✓ multidimensional
- ✓ multiscale
- ✓ computationally demanding - well suited for parallel processing

SIMWE in GRASS GIS

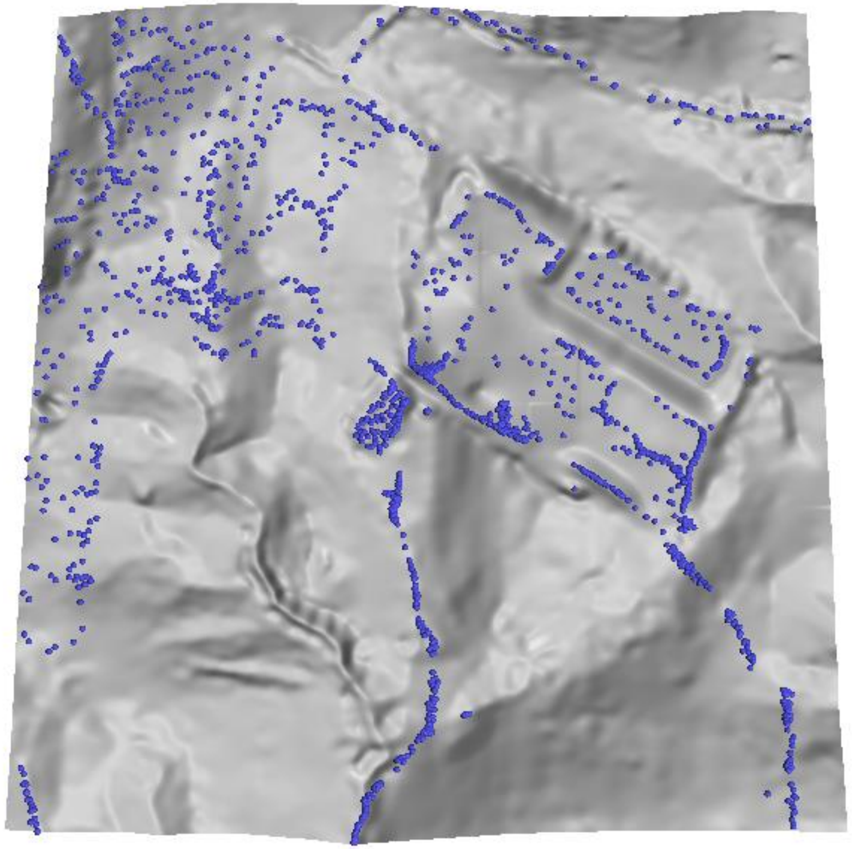
- 2D continuity equation of water overland flow (*r.sim.water*)
- 2D water erosion model based on the WEPP model

  (*r.sim.sediment*)

Overland water flow simulated by r.sim.water in GRASS GIS

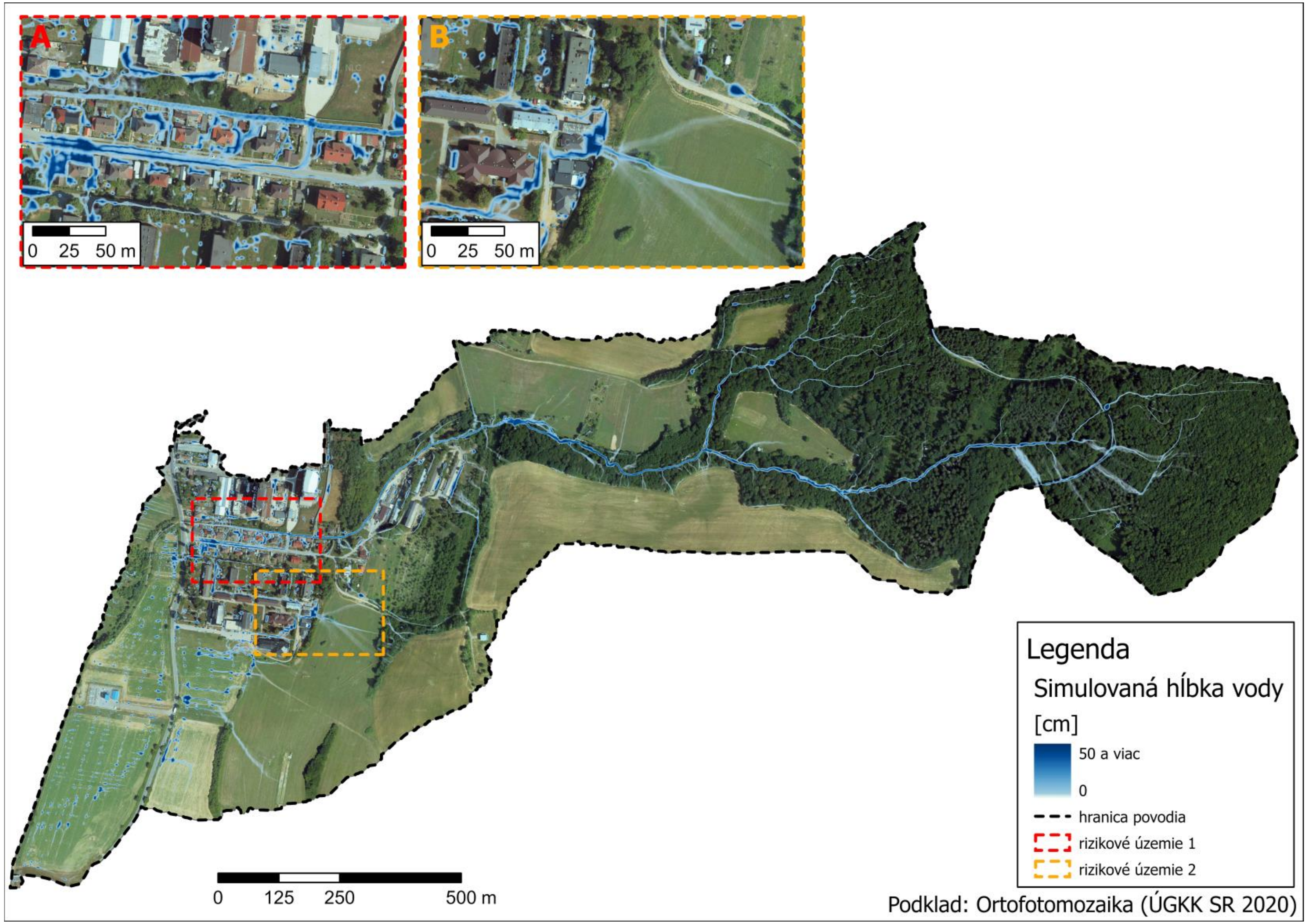


field representation



particles representation (only 1% shown)

Water flow simulation



Flooding in a built-up area near city of Púchov, SK

Ondrej Tokarčík, 2024

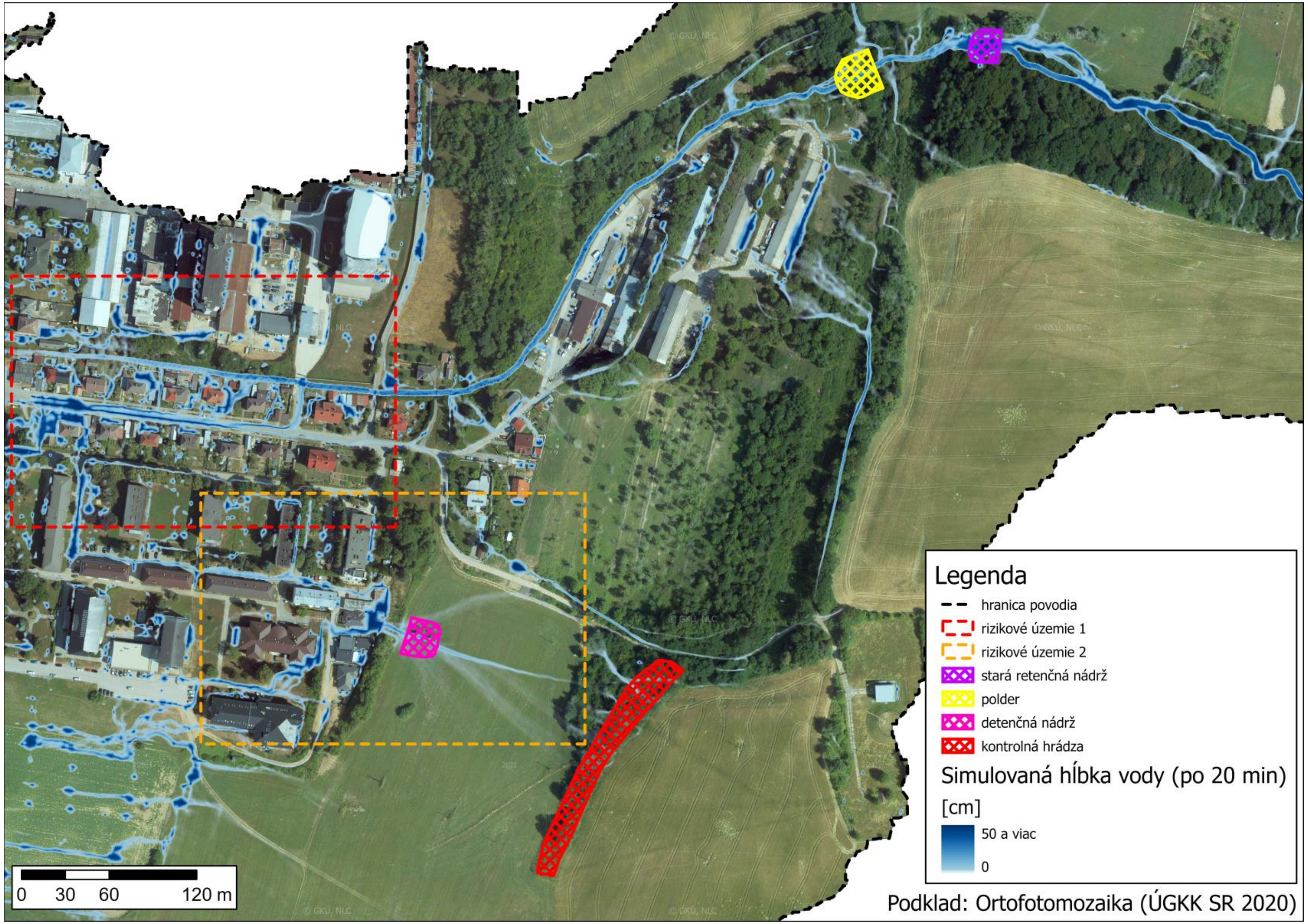
Water flow simulation

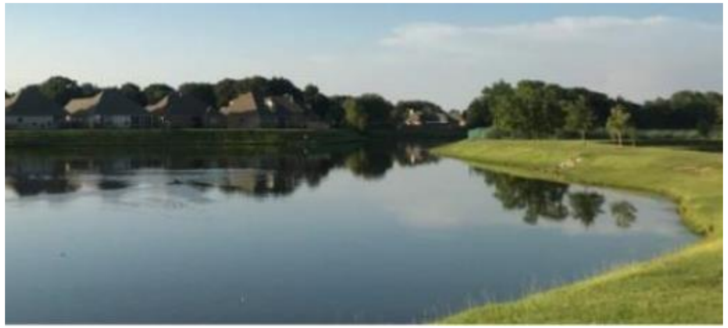
Ondrej Tokarčík, 2024

Water flow simulation

Ondrej Tokarčík, 2024

Flood controls based on the simulation





Ondrej Tokarčík, 2024

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Road rain drainage case study for the City council of Košice

Drainage inputs

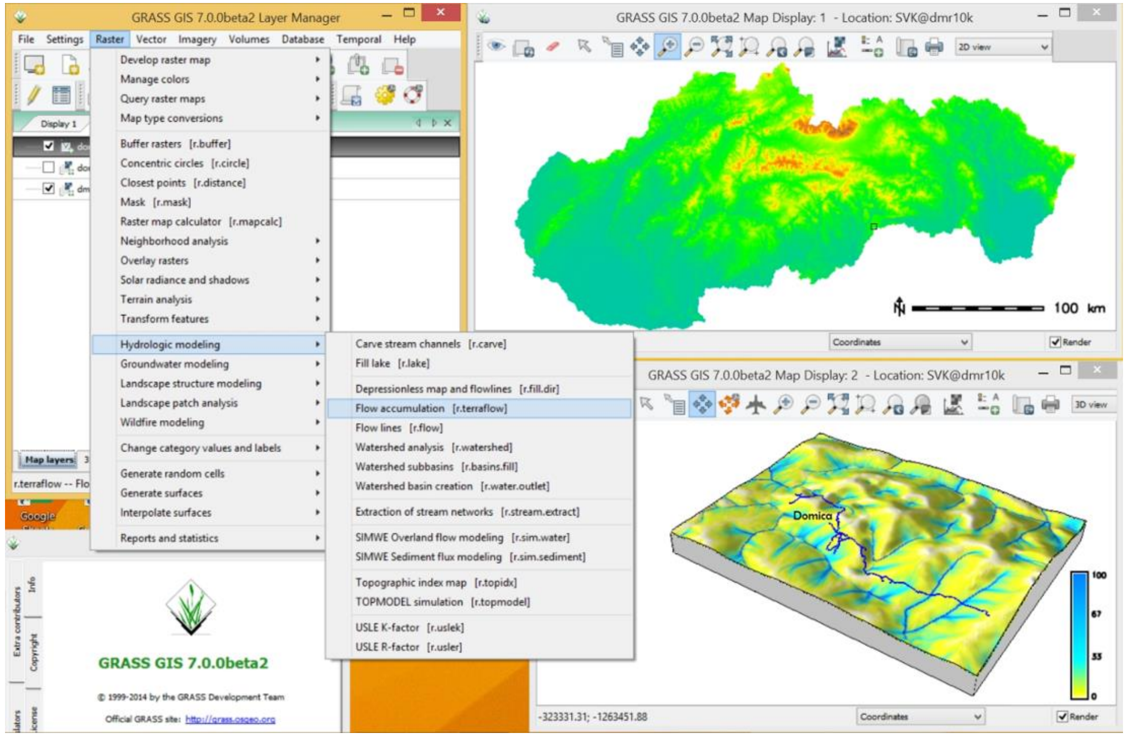
Current road drainage effect

Impovements of drainage

GRASS GIS

GRASS – Geographical Resources Analysis Support System

1982 – 1995 – U.S. Army Corps of Engineers
Construction Engineering Laboratory (CERL), Unix-based



GRASS GIS

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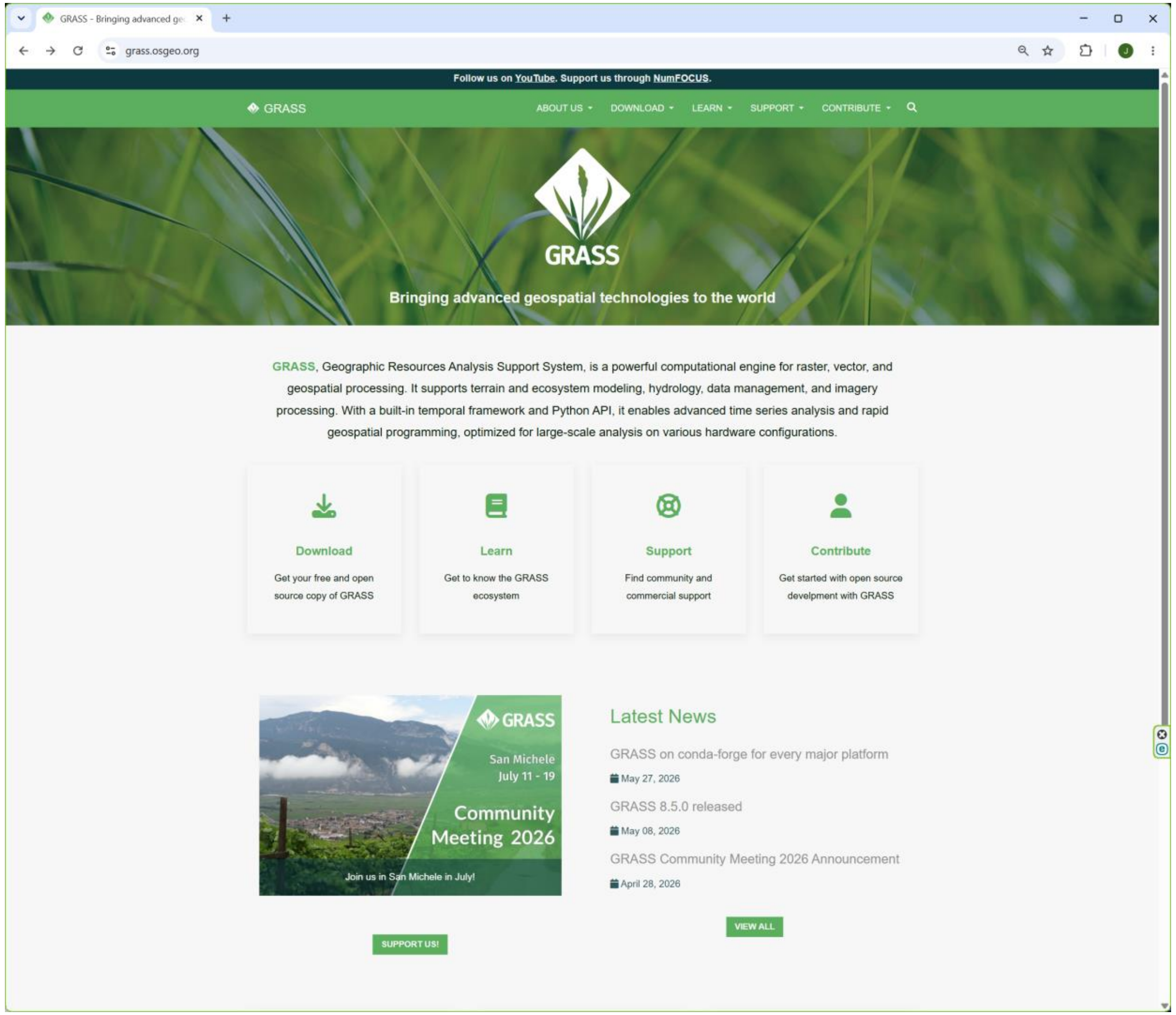
GRASS GIS, OSGEO



GRASS GIS – basic facts

- modular architecture, more than 350 modules
- ca. 670,000 code lines
- C, Python, shellscript
- strong users and develoment community
- GNU GPL licence

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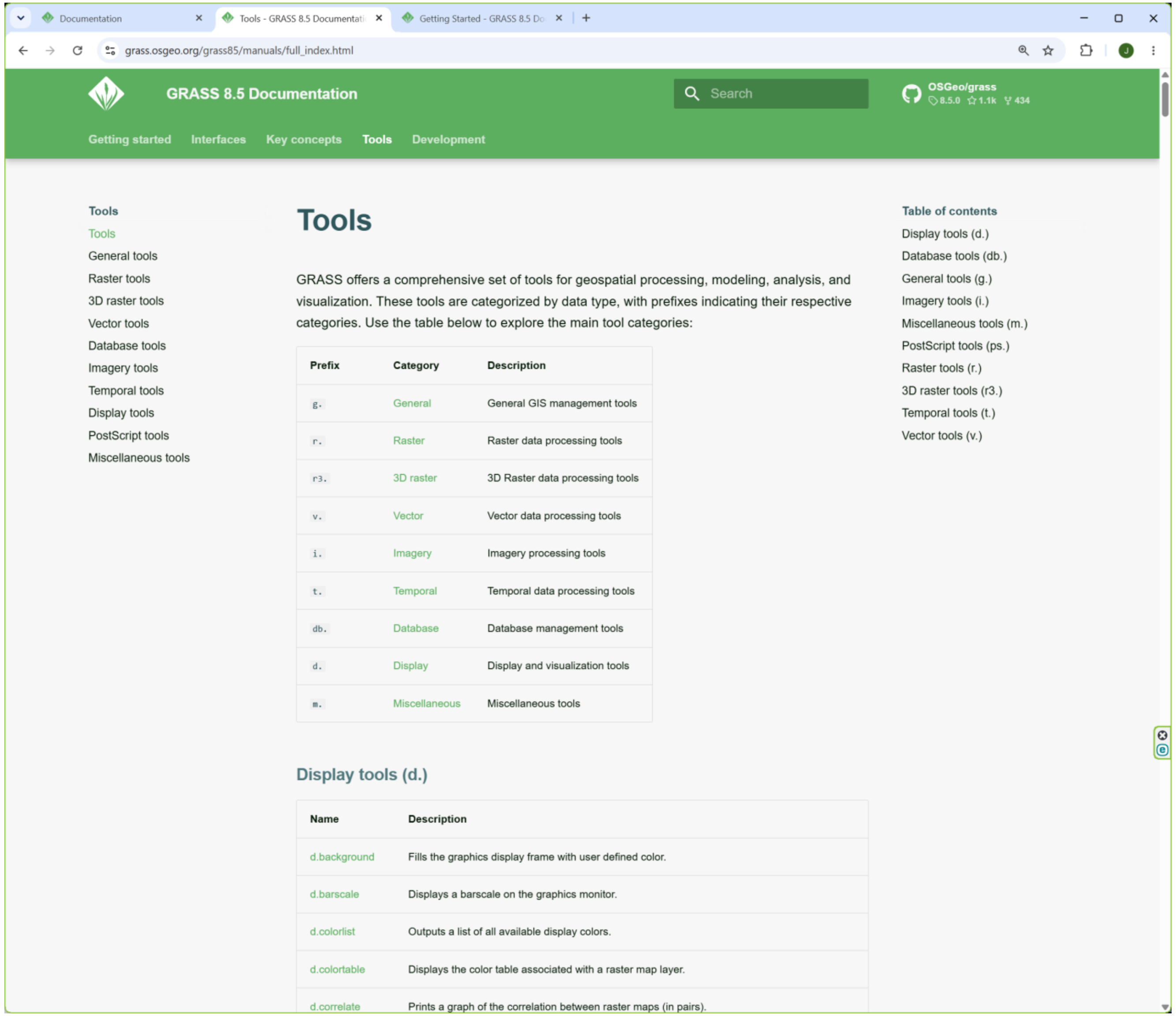
GRASS GIS Documentation



Documentation | Tools - GRASS 8.5 Documentati | Getting Started - GRASS 8.5 Do

grass.osgeo.org/grass85/manuals/full_index.html

GRASS 8.5 Documentation

Search

OSGeo/grass 8.5.0 1.1k 434

Getting started | Interfaces | Key concepts | Tools | Development

Tools
- Tools
- General tools
- Raster tools
- 3D raster tools
- Vector tools
- Database tools
- Imagery tools
- Temporal tools
- Display tools
- PostScript tools
- Miscellaneous tools

Tools

GRASS offers a comprehensive set of tools for geospatial processing, modeling, analysis, and visualization. These tools are categorized by data type, with prefixes indicating their respective categories. Use the table below to explore the main tool categories:

Prefix	Category	Description
g.	General	General GIS management tools
r.	Raster	Raster data processing tools
r3.	3D raster	3D Raster data processing tools
v.	Vector	Vector data processing tools
i.	Imagery	Imagery processing tools
t.	Temporal	Temporal data processing tools
db.	Database	Database management tools
d.	Display	Display and visualization tools
m.	Miscellaneous	Miscellaneous tools

Display tools (d.)

Name	Description
d.background	Fills the graphics display frame with user defined color.
d.barscale	Displays a barscale on the graphics monitor.
d.colorlist	Outputs a list of all available display colors.
d.colortable	Displays the color table associated with a raster map layer.
d.correlate	Prints a graph of the correlation between raster maps (in pairs).

https://grass.osgeo.org/

Zambelli, Gebbert, Ciolli (2013): Pygrass: An Object Oriented Python Application Programming Interface (API) for Geographic Resources Analysis Support System (GRASS) Geographic Information System (GIS). ISPRS Int. J. Geo-Inf. 2013, 2, 201-219; doi:10.3390/ijgi2010201

https://grasswiki.osgeo.org/wiki/GRASS_and_Python
https://grasswiki.osgeo.org/wiki/GRASS_Python_Scripting_Library
https://grass.osgeo.org/grass78/manuals/libpython/index.html

Neteler, M., Mitasova, H. (2008): Open Source GIS: A GRASS GIS Approach. Third Edition. 420 pages, Springer, New York (ISBN-10: 038735767X; ISBN-13: 978-0387357676). www.grassbook.org

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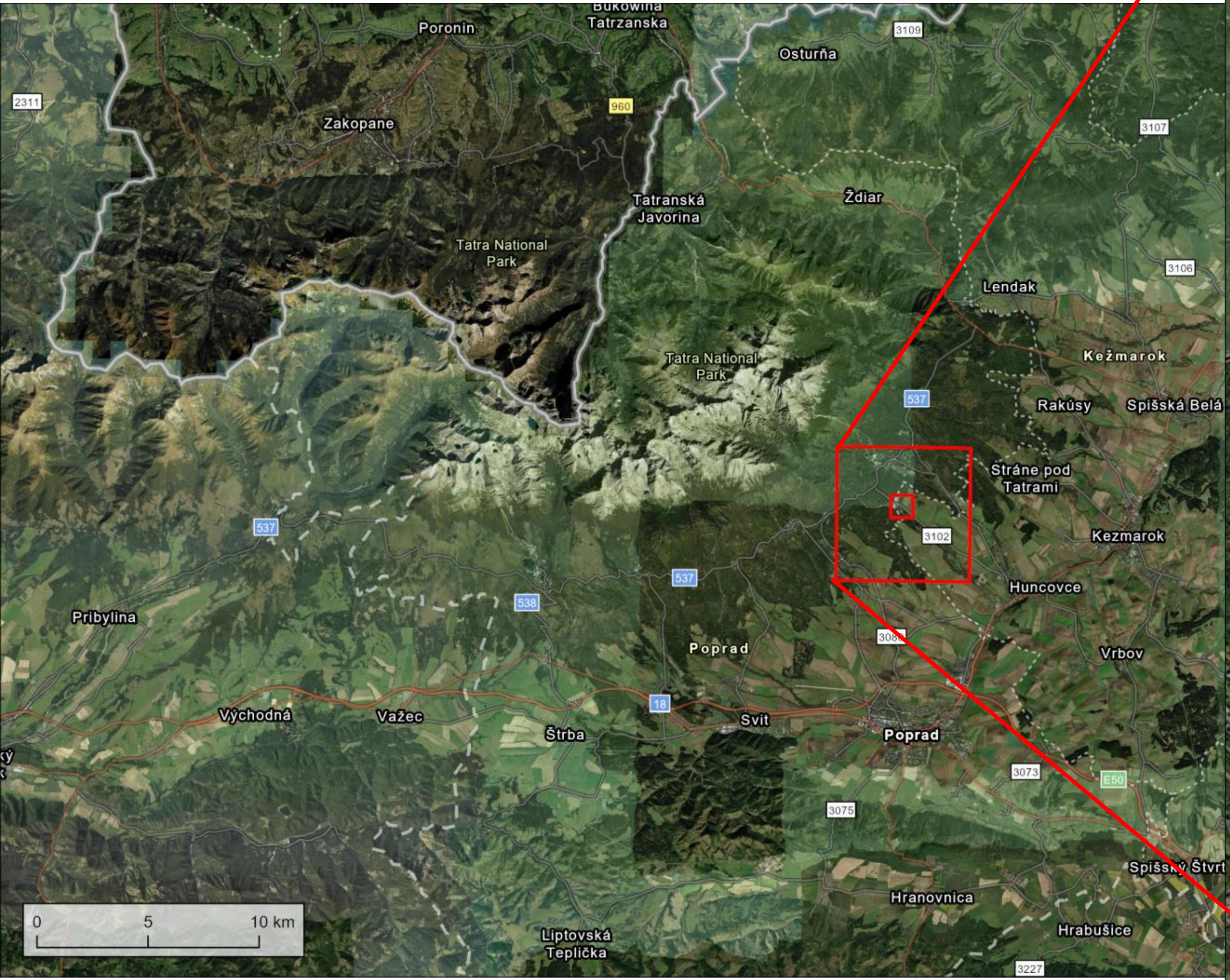
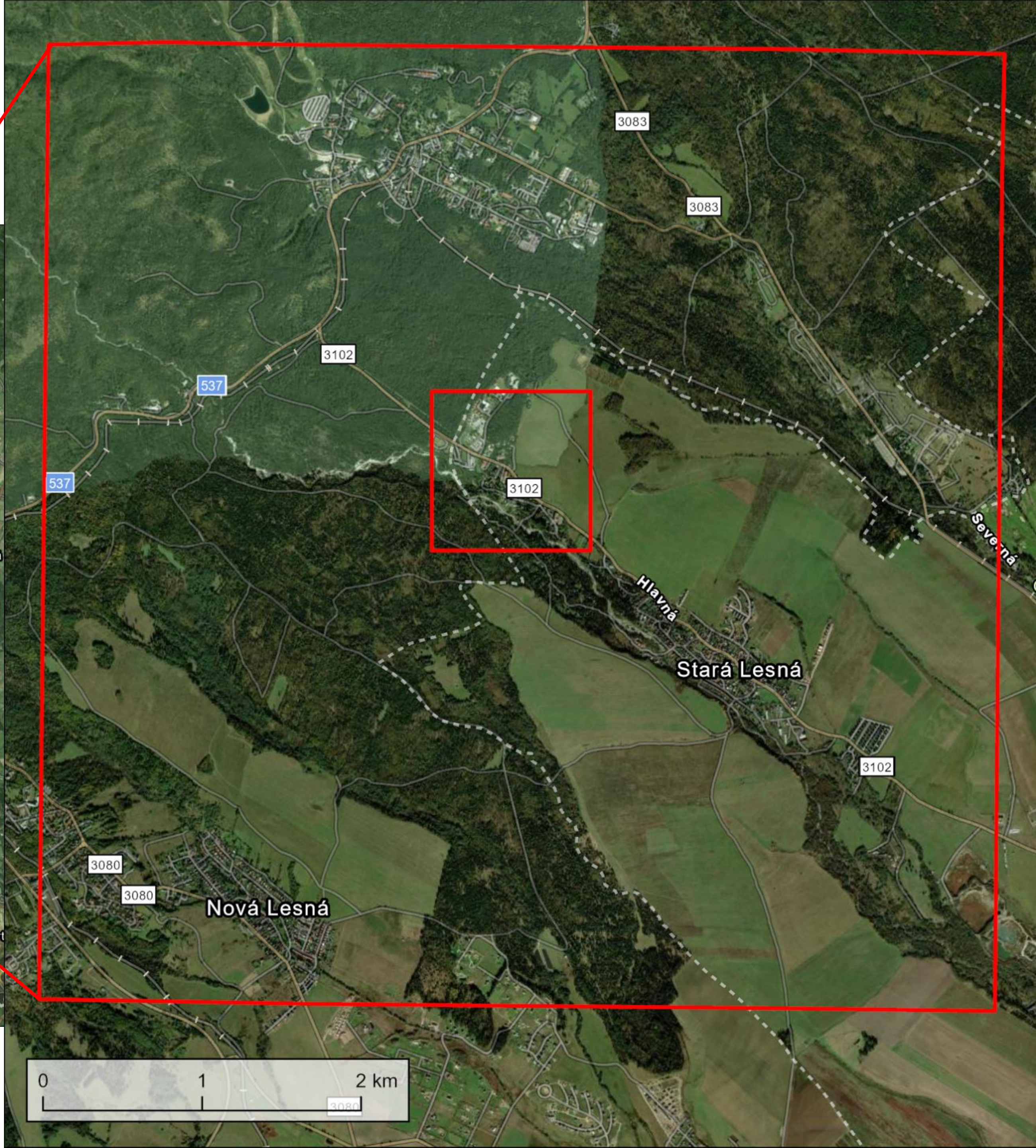
Study area





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Study area – Land cover

Sentinel RGB (10 m)

ZBGIS Orthophoto (0.20 m)

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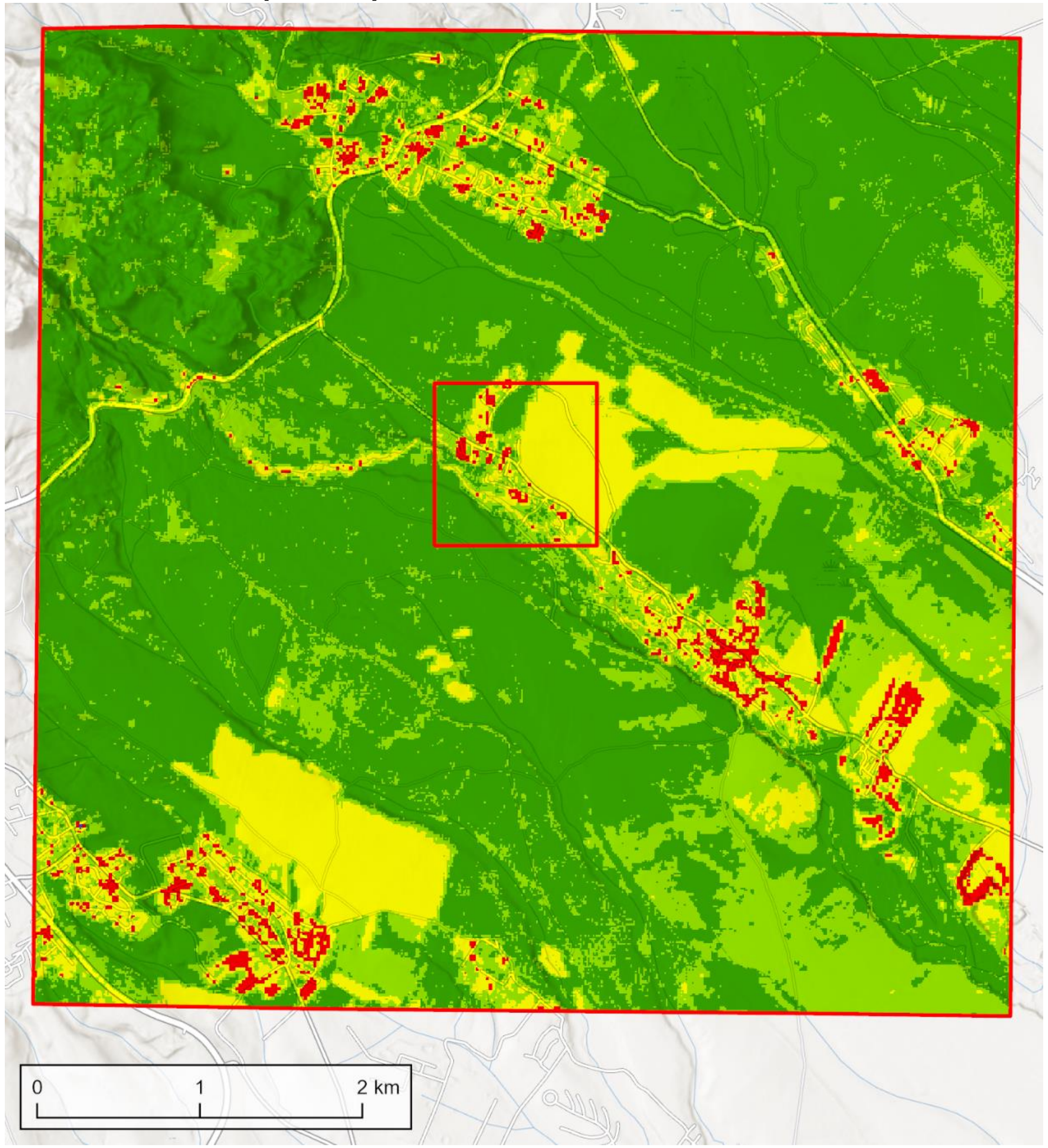
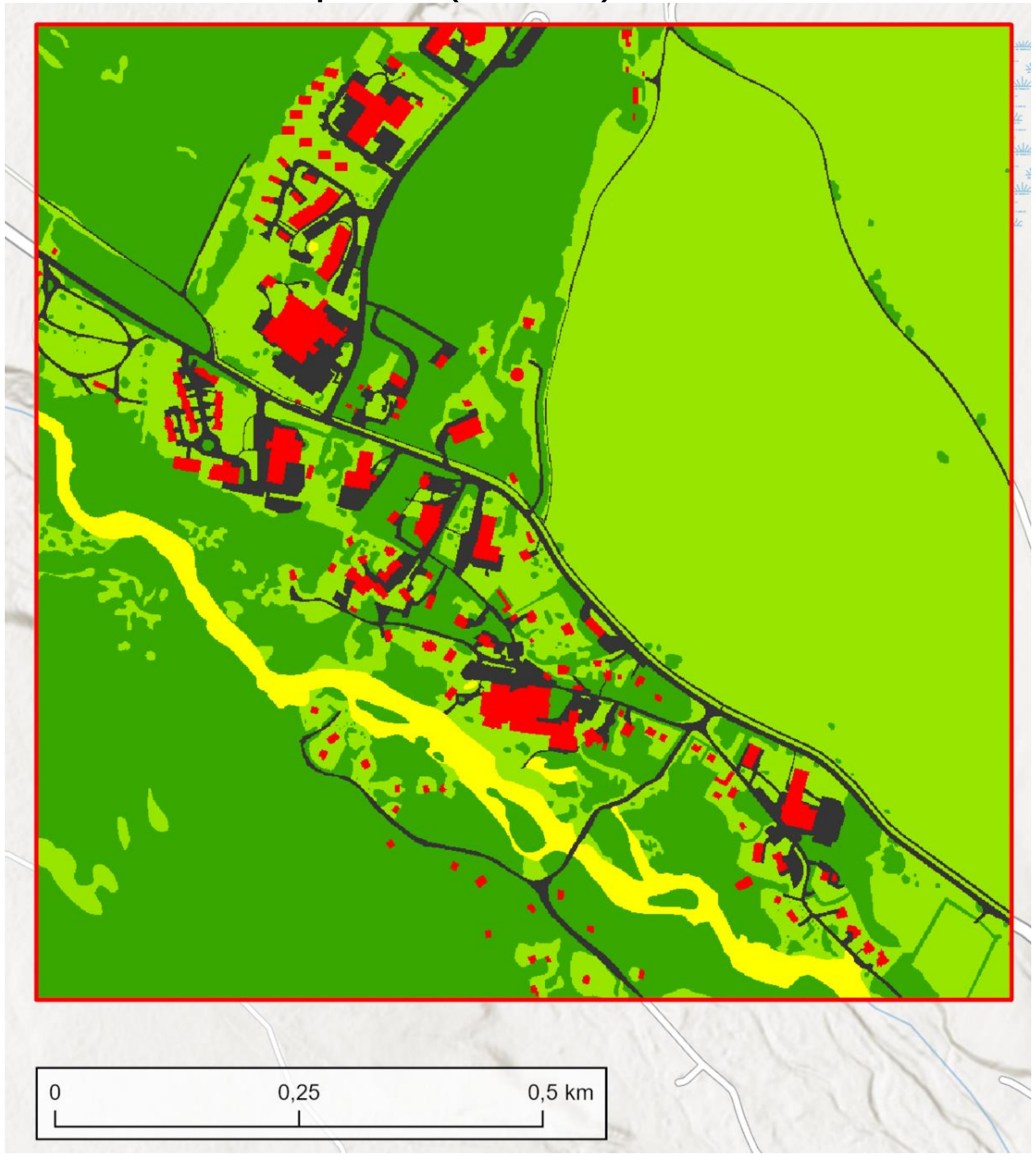
Study area – Land cover

Sentinel 2 (10 m)



High vegetation
Low vegetation
Bare soil
Built up area
Paved surface

ZBGIS Orthophoto (0.20 m)



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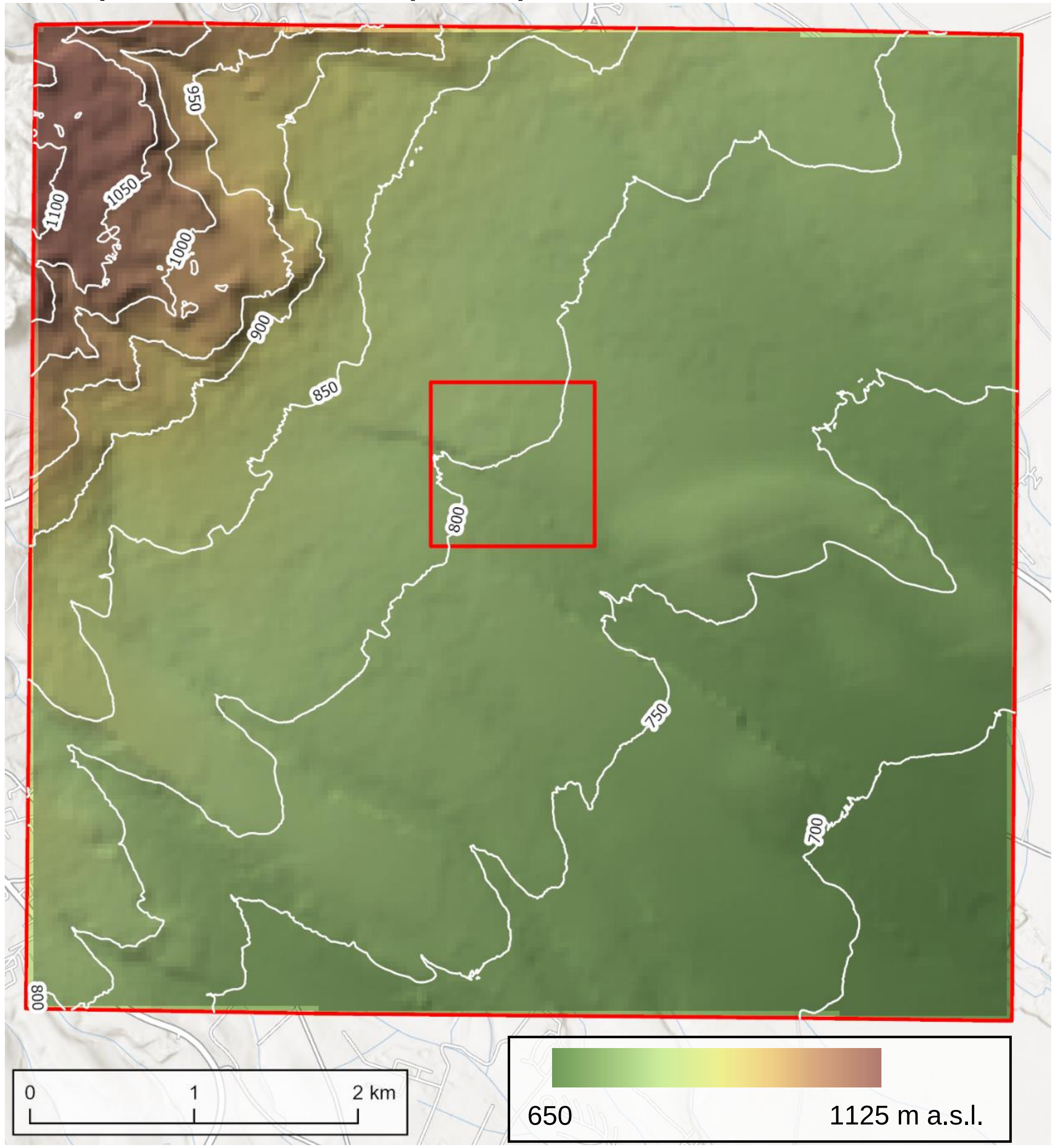
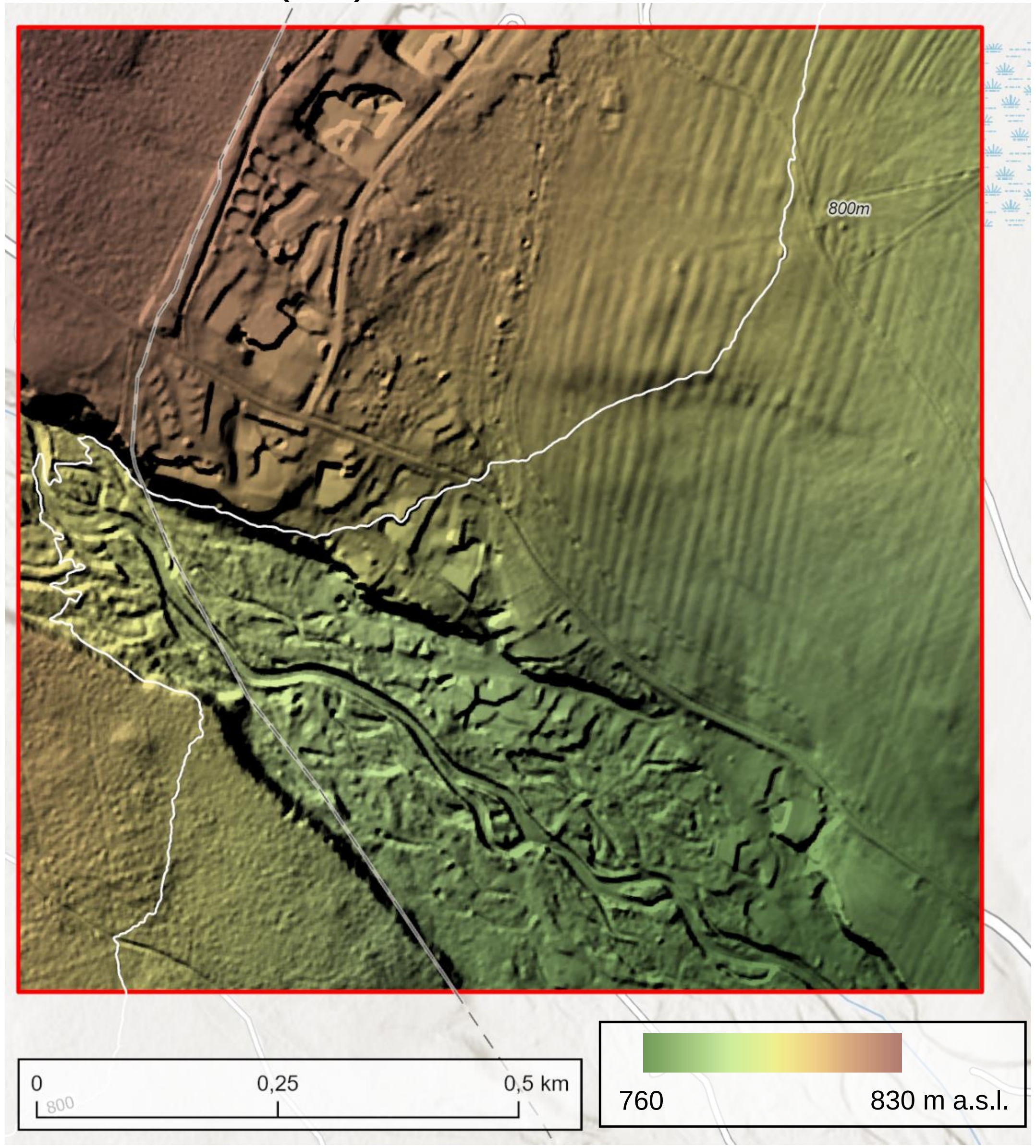
Study area – Elevation

Copernicus DEM (30 m)



ZBGIS DEM (1m)



Input Data for Practical Excersise

Copernicus DEM – a global DEM created by EEA, combination of multiple global datasets incl. SRTM, ASTER GDEM, TanDEM-X and others, approx. 30 m resolution, RMSE~5-10m
Sentinel2 RGB - Sentinel-2 Level-2A surface reflectance image acquired on 27 June 2026 (Bands 4, 3, and 2)
Sentinel2 Land Cover - rule-based classification approach based on spectral indices (MNDWI, EVI, NDBI, NDBal, NBR)

ZBIS DEM – a high-resolution Digital Terrain Model (1 m spatial resolution) produced by the Geodesy, Cartography and Cadastre Authority of the Slovak Republic (ÚGKK SR) from airborne LiDAR data.
ZBGIS Orthophoto – 4 channels (RGB + NIR), 15-20 cm
ZBGIS LandCover – derived from ZBGIS Orthophoto

Practical Exercise: running r.sim.water

Software: GRASS 8.4.2, e.g., included in QGIS 4.0.3 standalone installation

IRSSS2026_GRASS_Handout.docx

Thank you!

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https://www.facebook.com/ustavgeografie/

https://www.instagram.com/geography_kosice/

https://www.youtube.com/channel/UCZa7Izih81o0582_0KpXV2w