



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

Jaroslav Hofierka, Jozef Šupinský

Address: Jesenná 5, 040 01 Košice, Slovakia
<http://uge.science.upjs.sk>



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?

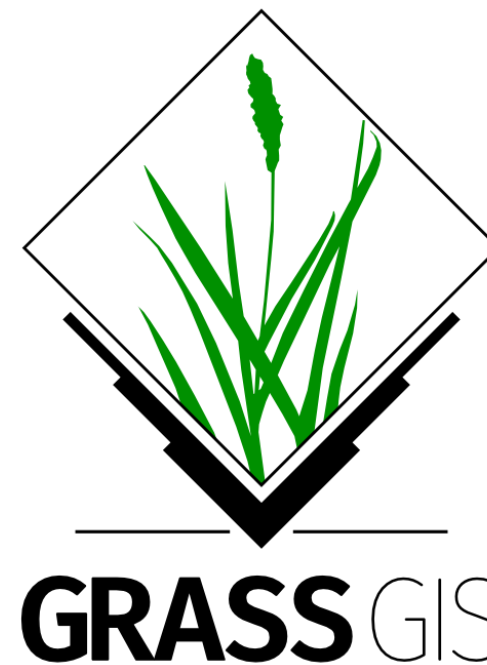
This is the concept of integrating remote sensing with physically-based environmental modelling.

Terrain Analysis in GRASS GIS

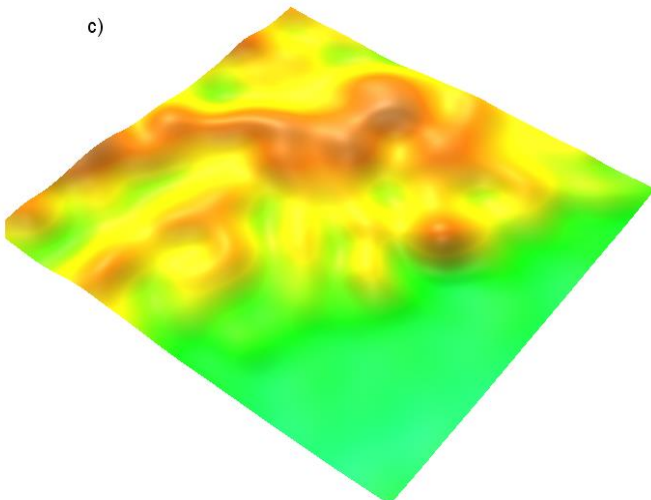
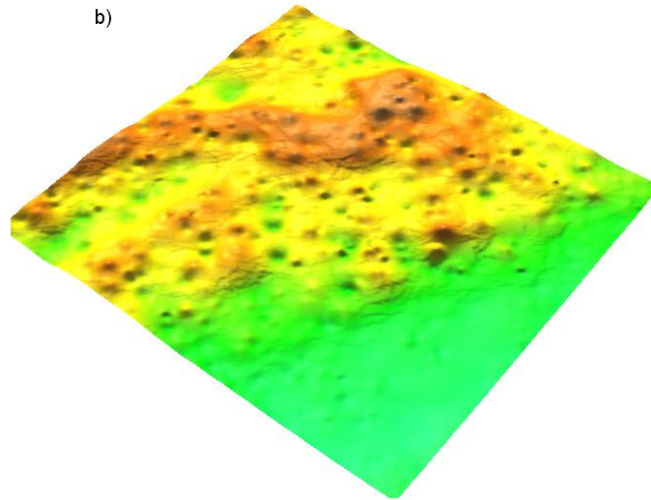
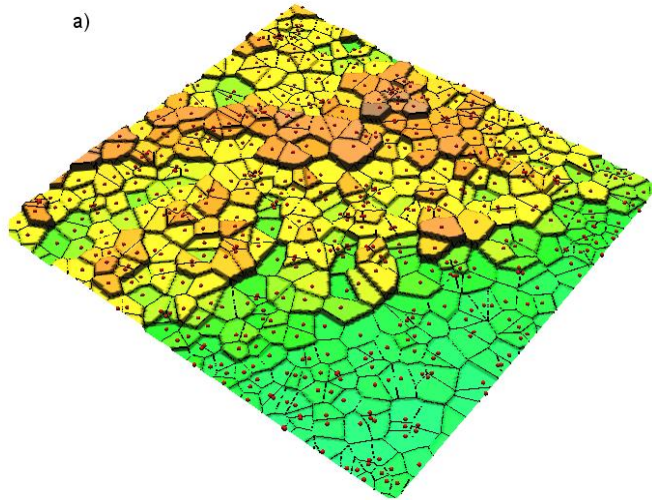
Basic terrain parameters derived from a DEM:

- elevation
- slope
- aspect
- curvatures
- drainage pathways

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



DEM - interpolation

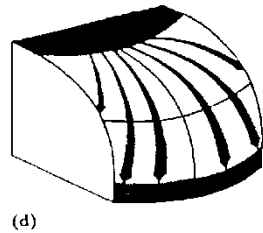
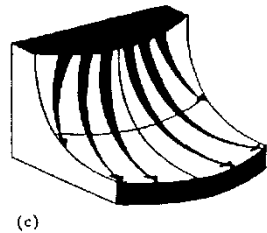
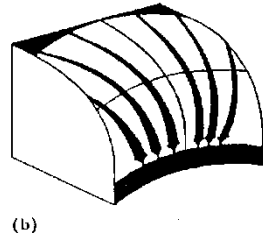
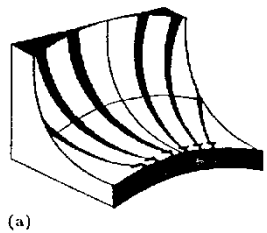


- a) Voronoi polygons + input data
- b) inverse distance weighted IDW
- c) regularized spline with tension RST

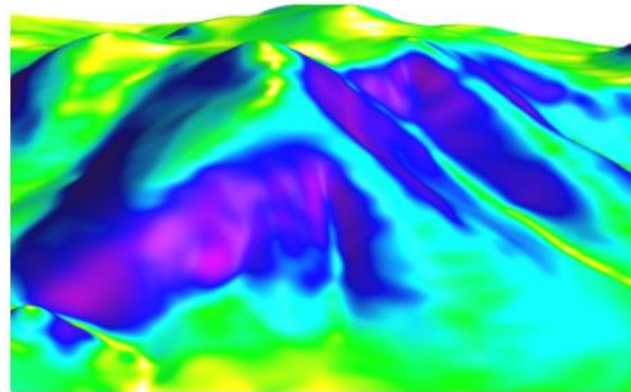
Terrain Parameters

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

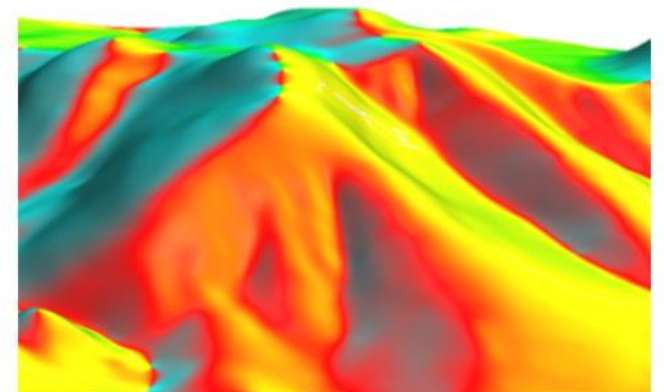
- elevation
- slope (a)
- aspect (b)
- curvatures (c, d)
- drainage pathways



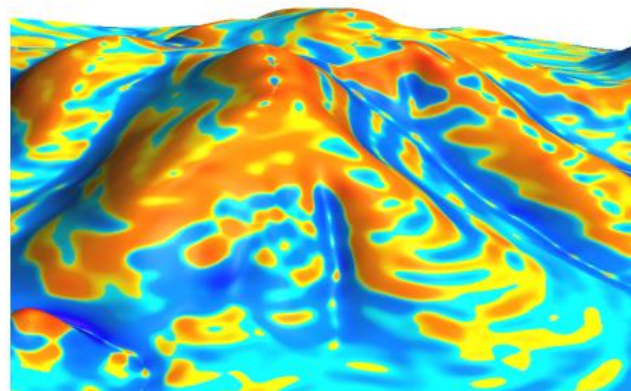
a)



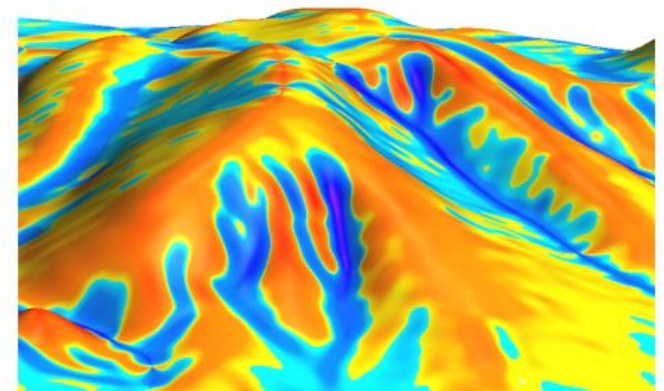
b)



c)

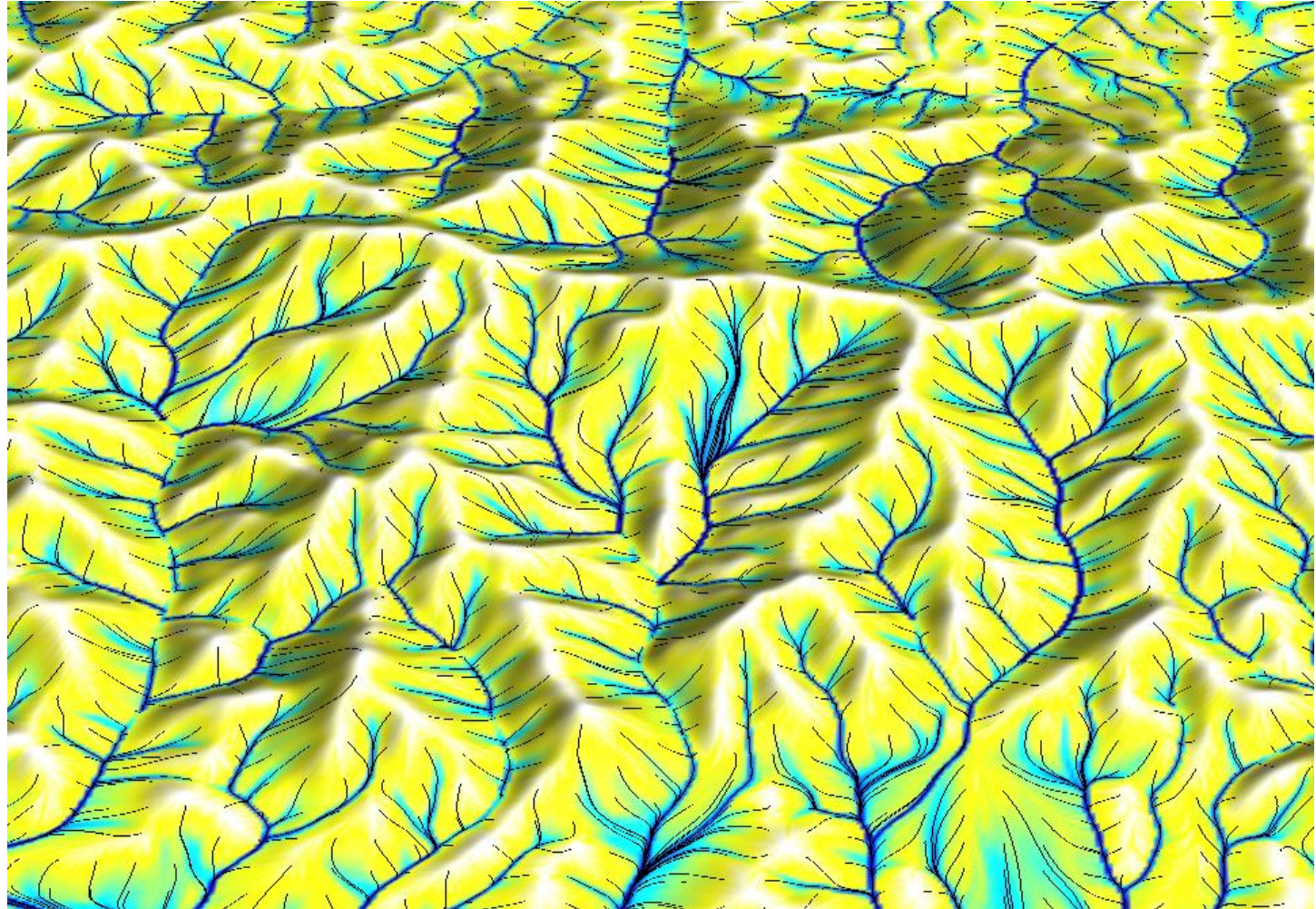


d)



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



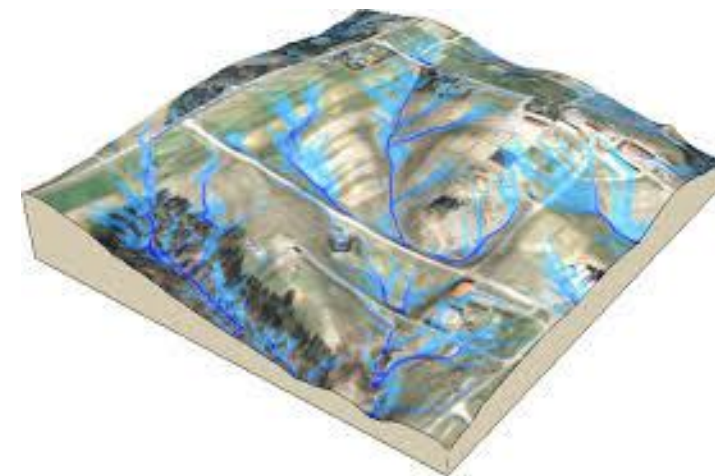
Hydrological parameters
(Manning's n, flow control,...)



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

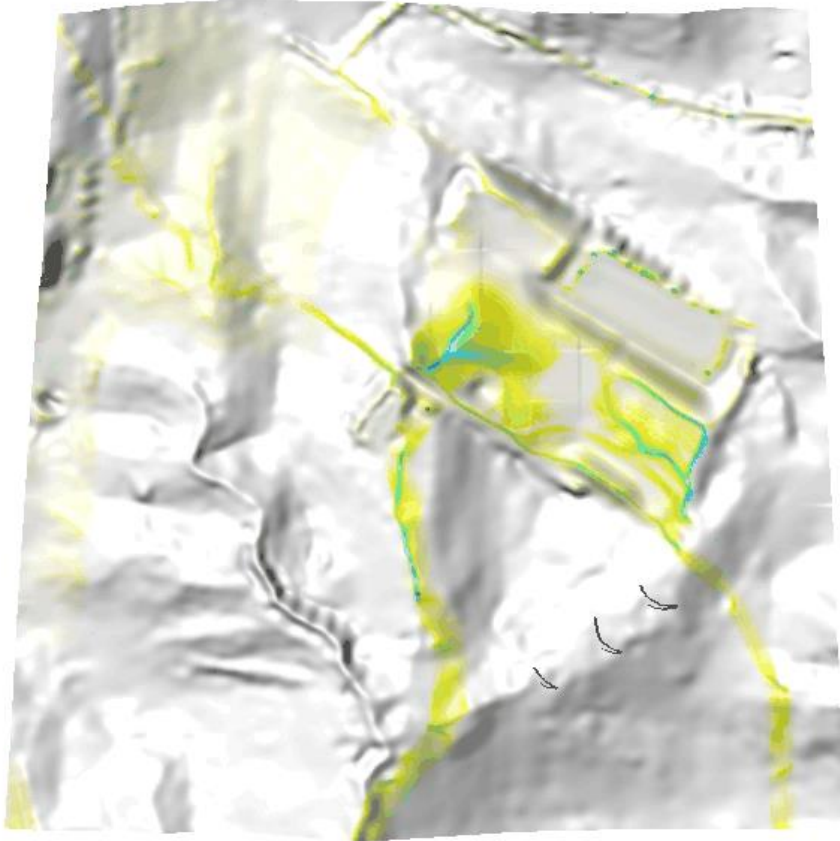
Method properties

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

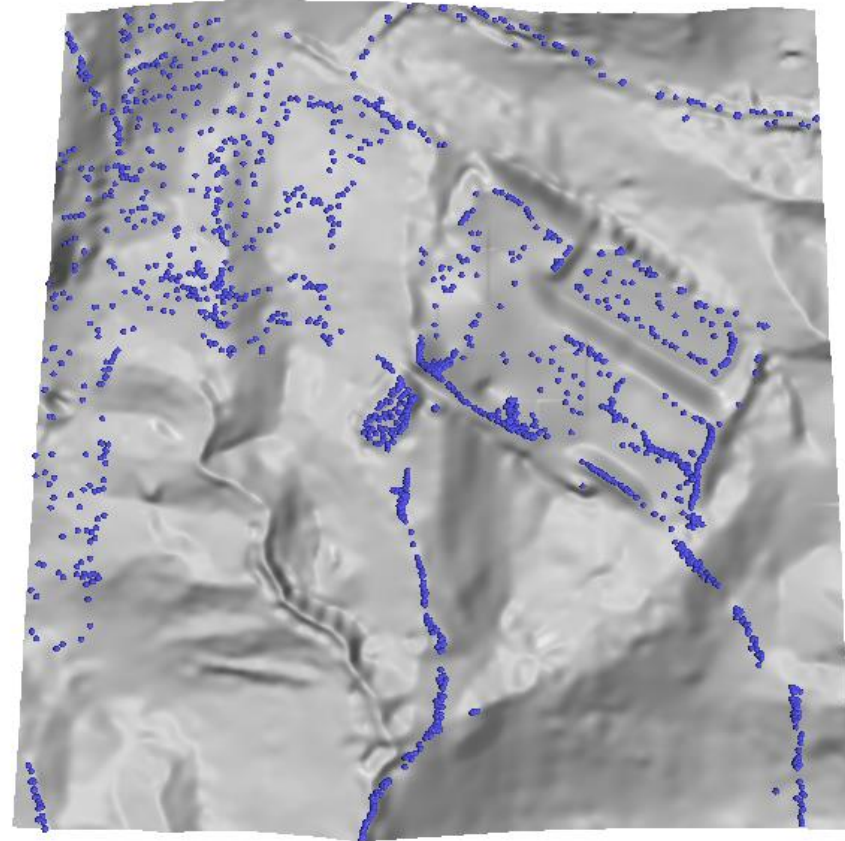
SIMWE in GRASS GIS

- 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

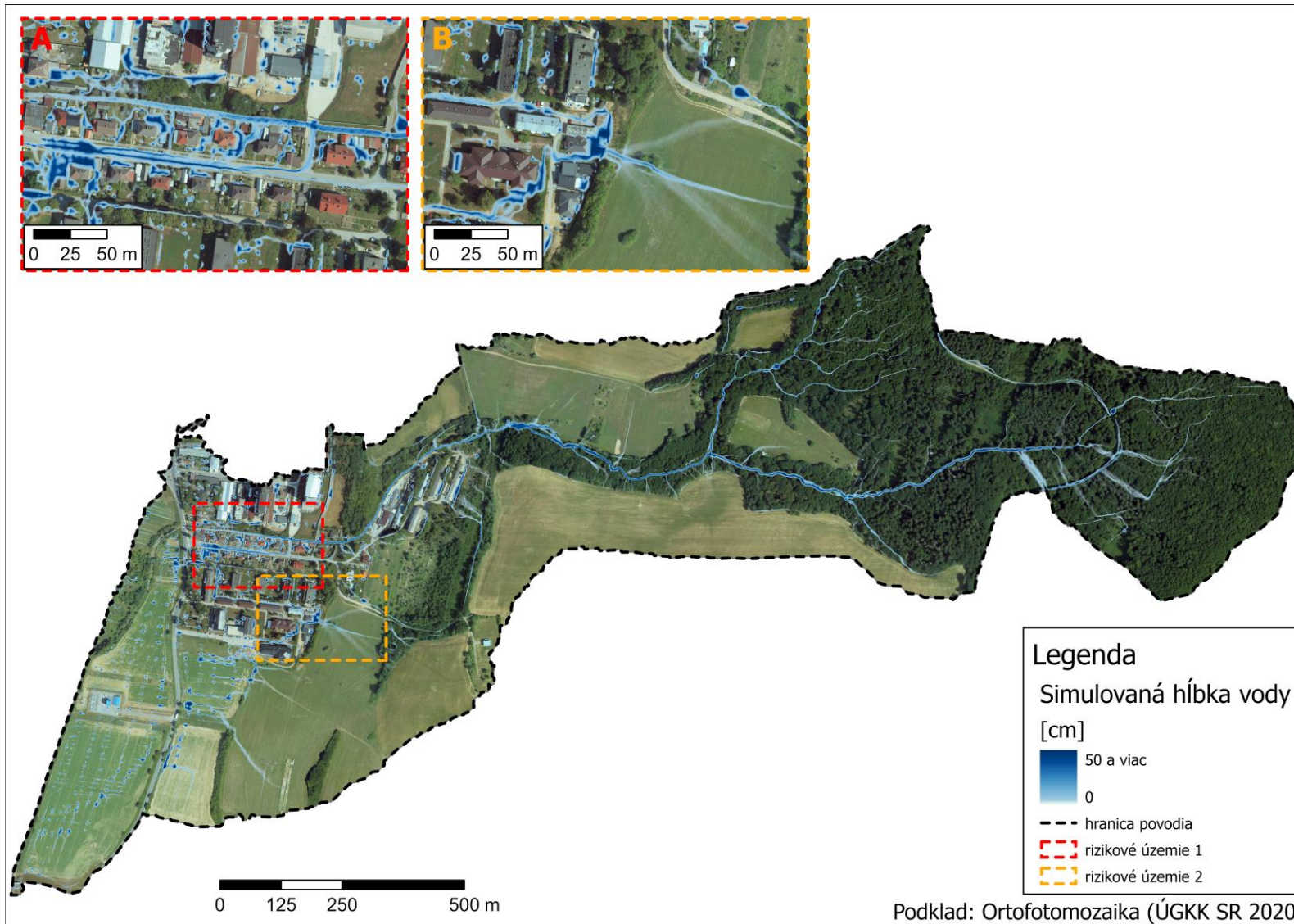


field representation



particles representation (only 1%
shown)

Water flow simulation



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

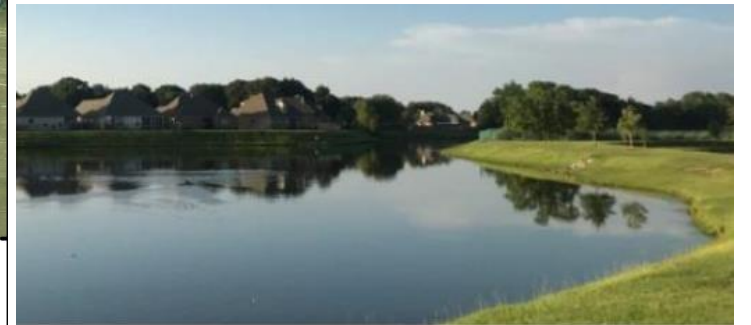
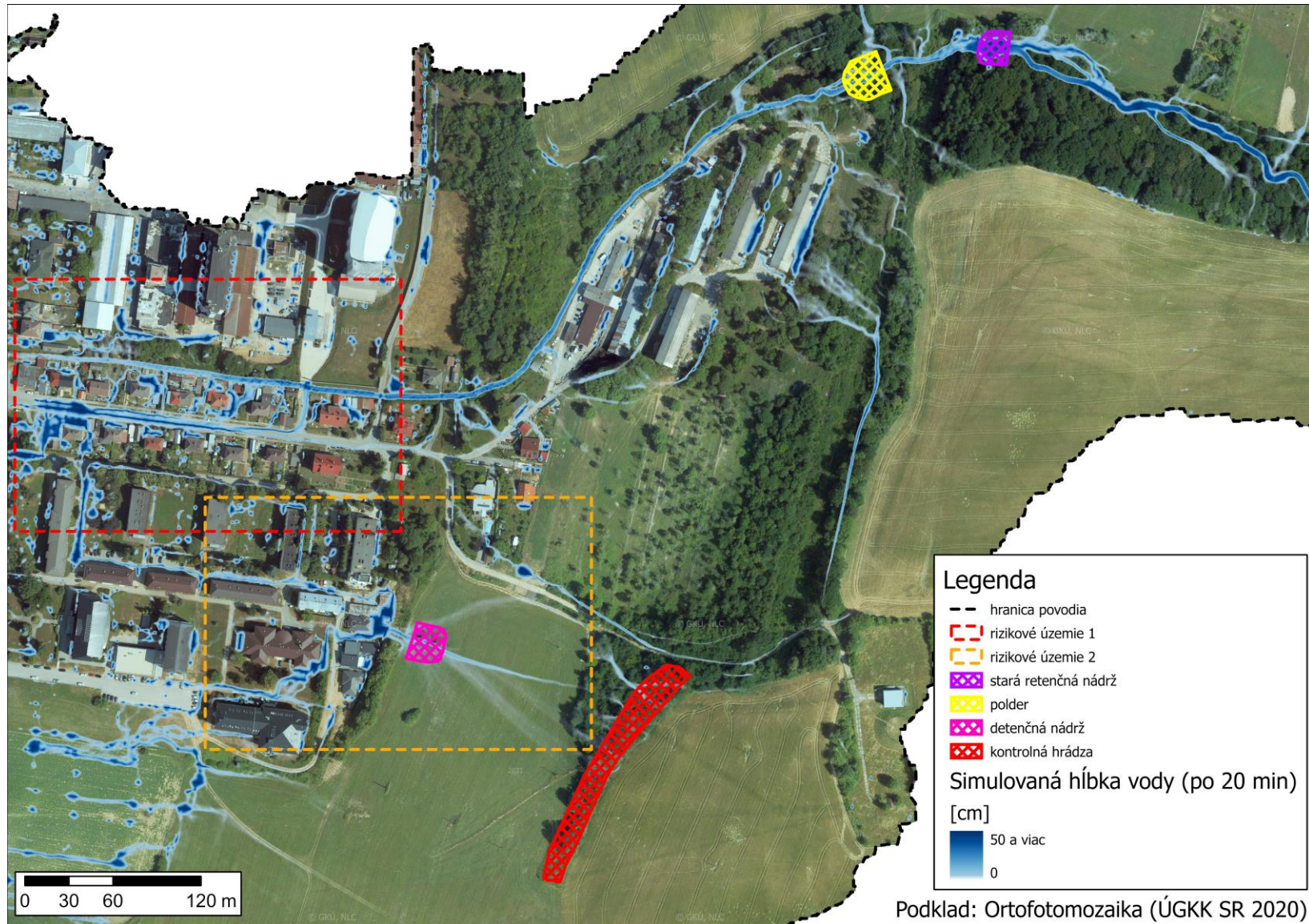
Water flow simulation



Water flow simulation

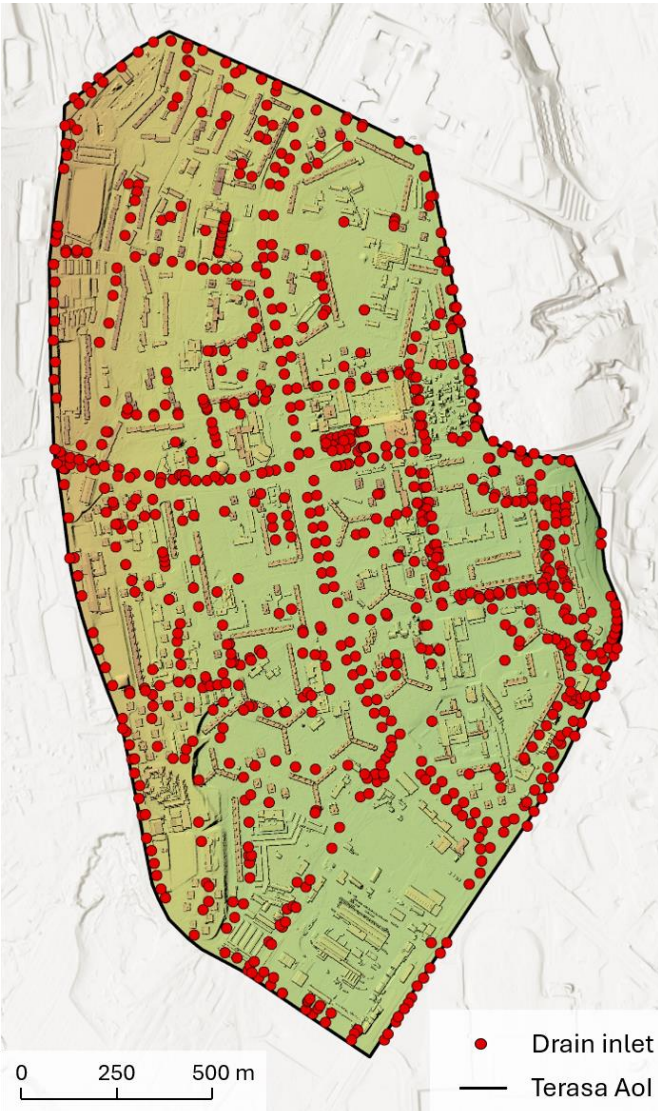


Flood controls based on the simulation

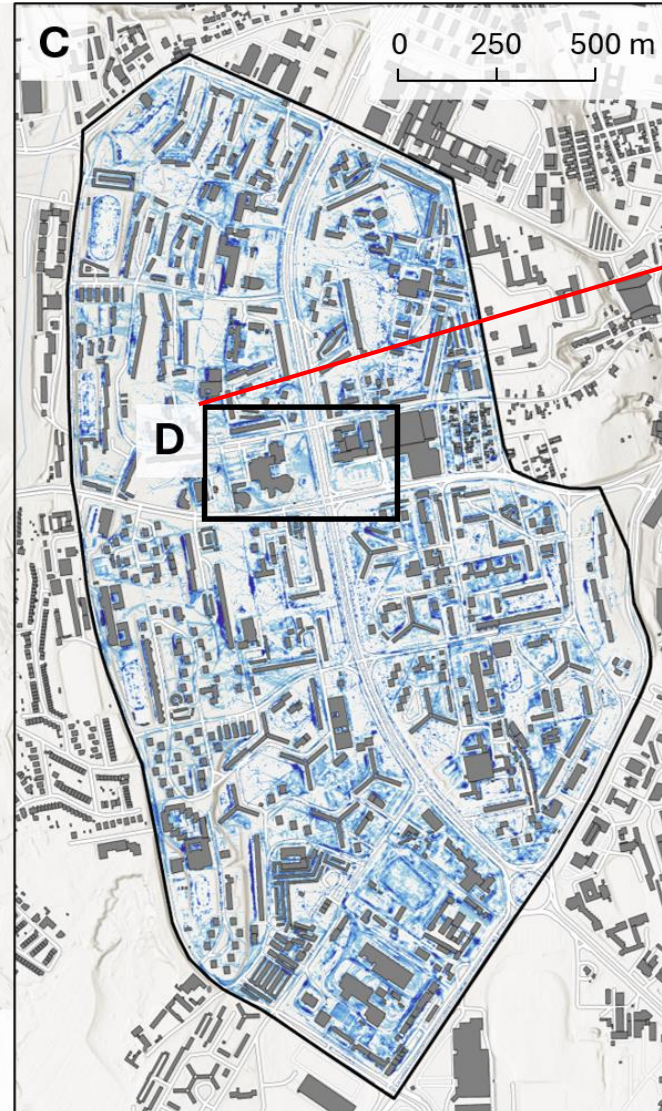


Road rain drainage case study for the City council of Košice

Drainage inputs



Current road drainage effect



Improvements of drainage



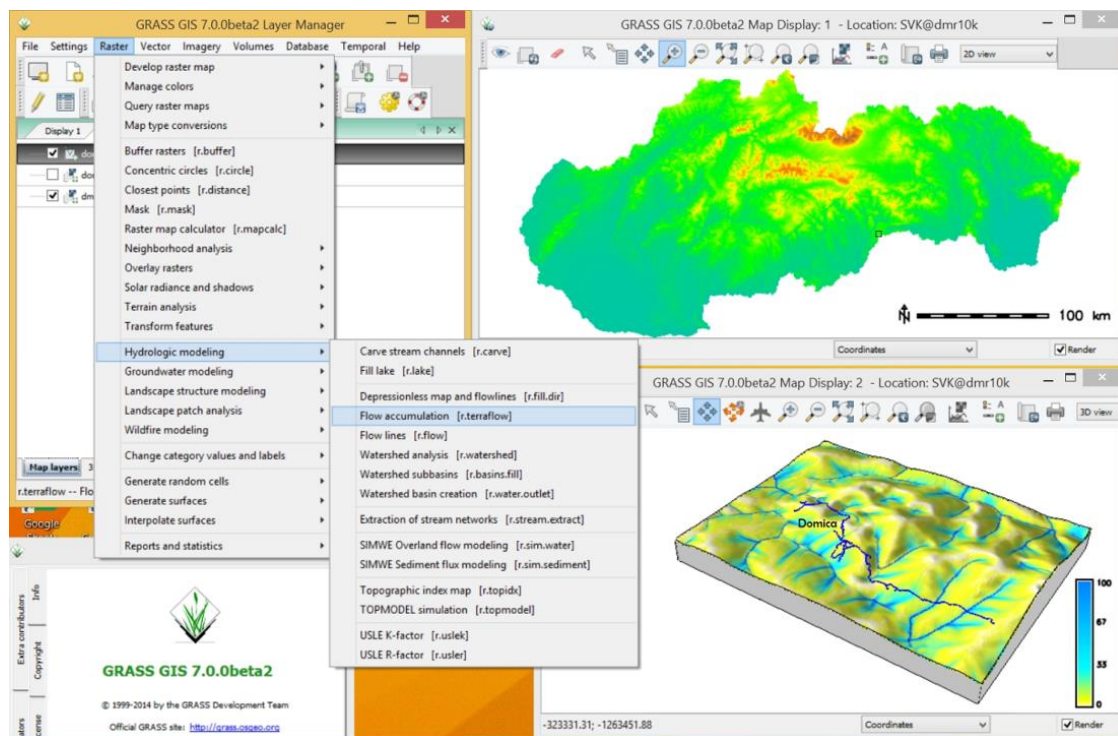
○ Proposed new inlets

GRASS GIS

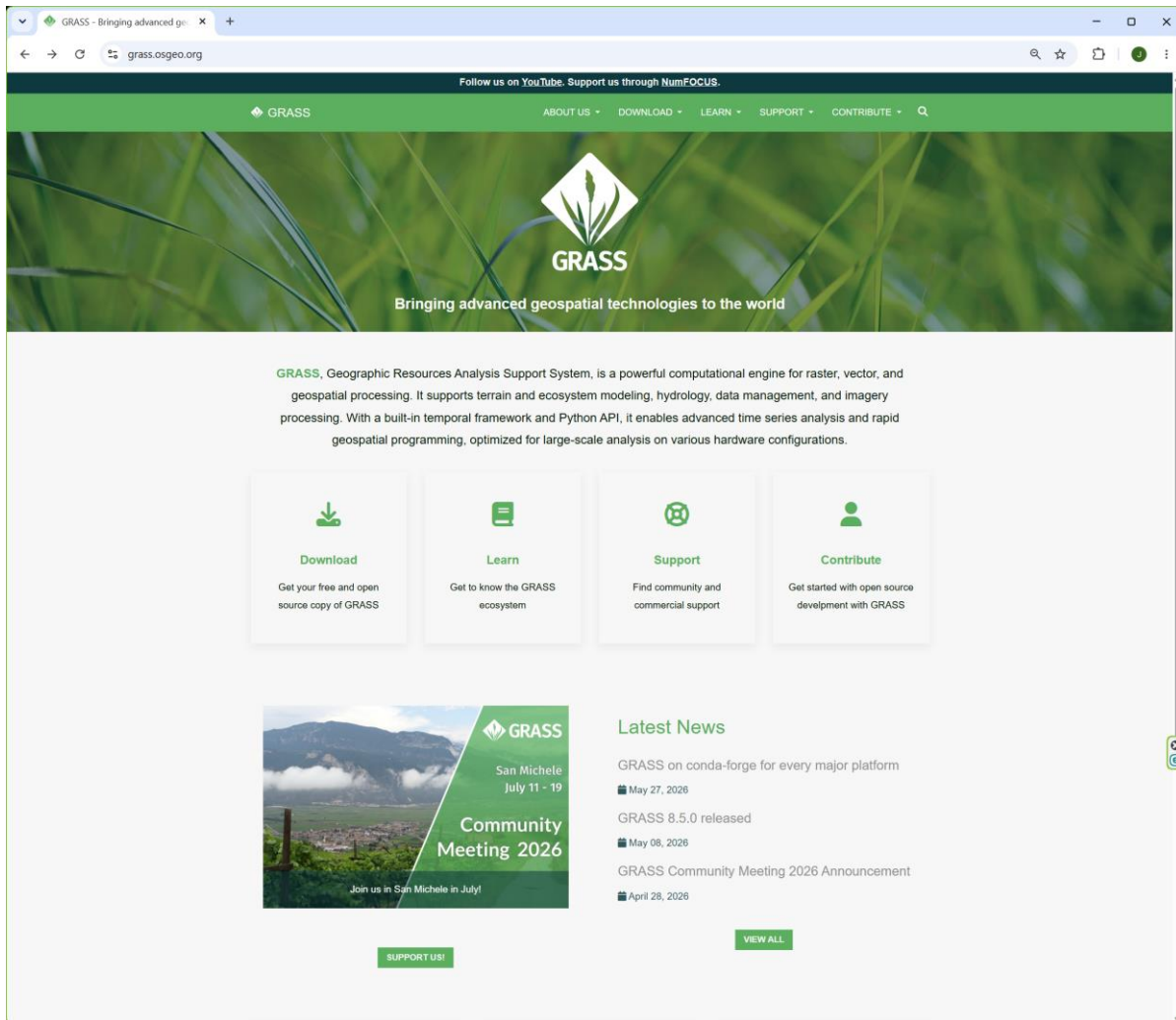
GRASS – Geographical Resources Analysis Support System

1982 – 1995 – U.S. Army Corps of Engineers

Construction Engineering Laboratory (CERL), Unix-based



GRASS GIS, OSGEO



The screenshot shows the GRASS GIS website. The header includes the GRASS logo and navigation links: ABOUT US, DOWNLOAD, LEARN, SUPPORT, and CONTRIBUTE. The main banner features the GRASS logo and the tagline "Bringing advanced geospatial technologies to the world". Below the banner, a paragraph describes GRASS as a powerful computational engine for raster, vector, and geospatial processing. A grid of four cards provides links to Download, Learn, Support, and Contribute. The bottom section includes a "Latest News" area with a "VIEW ALL" button and a "Community Meeting 2026" announcement.

Follow us on YouTube. Support us through NumFOCUS.

GRASS

ABOUT US · DOWNLOAD · LEARN · SUPPORT · CONTRIBUTE

GRASS

Bringing advanced geospatial technologies to the world

GRASS, Geographic Resources Analysis Support System, is a powerful computational engine for raster, vector, and geospatial processing. It supports terrain and ecosystem modeling, hydrology, data management, and imagery processing. With a built-in temporal framework and Python API, it enables advanced time series analysis and rapid geospatial programming, optimized for large-scale analysis on various hardware configurations.

Download
Get your free and open source copy of GRASS

Learn
Get to know the GRASS ecosystem

Support
Find community and commercial support

Contribute
Get started with open source development with GRASS

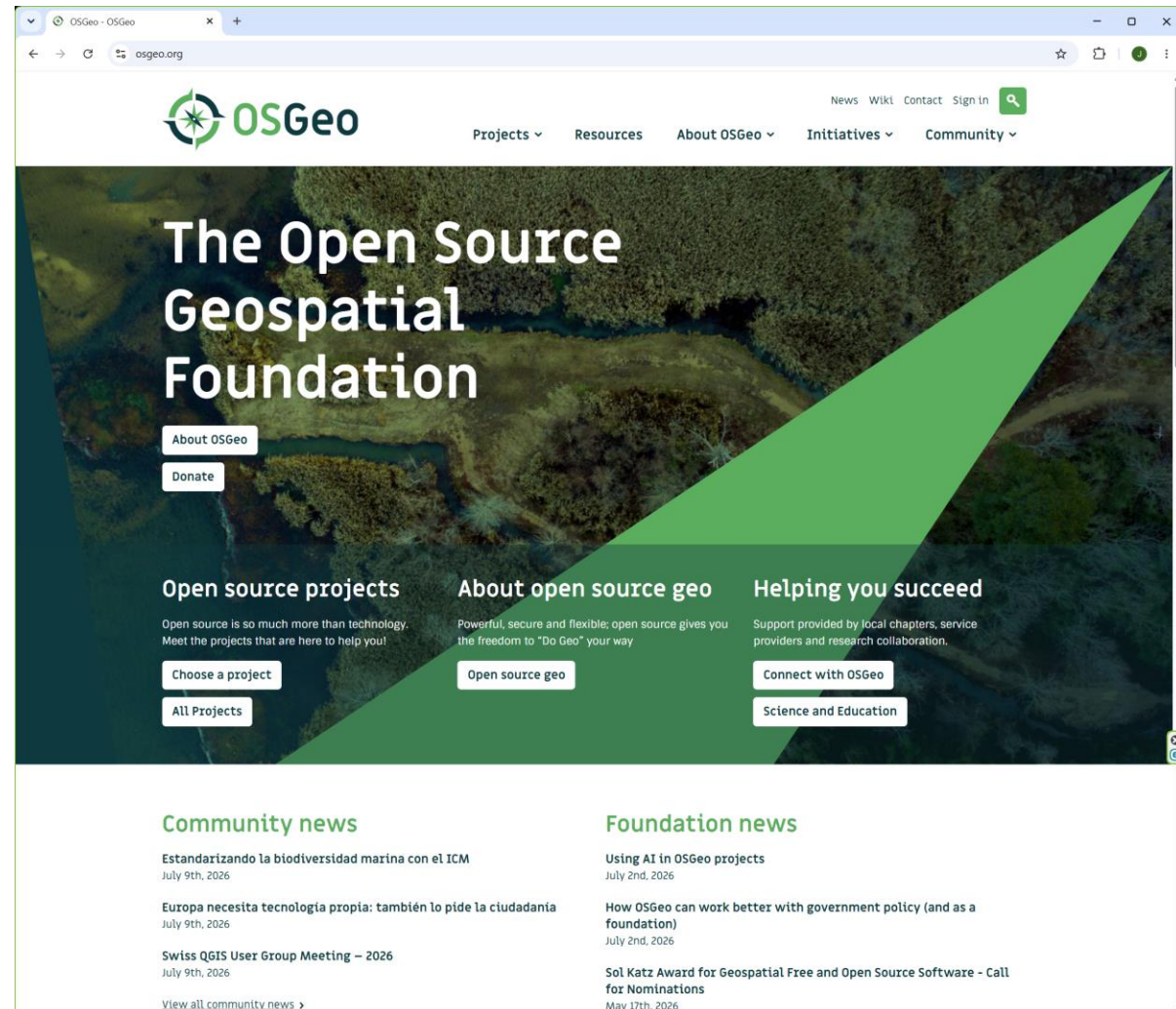
Community Meeting 2026
Join us in San Michele in July!

Latest News

- GRASS on conda-forge for every major platform
May 27, 2026
- GRASS 8.5.0 released
May 08, 2026
- GRASS Community Meeting 2026 Announcement
April 28, 2026

[VIEW ALL](#)

[SUPPORT US!](#)



The screenshot shows the OSGeo website. The header includes the OSGeo logo and navigation links: Projects, Resources, About OSGeo, Initiatives, and Community. The main banner features the OSGeo logo and the tagline "The Open Source Geospatial Foundation". Below the banner, a paragraph describes OSGeo as a powerful, secure, and flexible foundation for open source geospatial projects. A grid of three cards provides links to Open source projects, About open source geo, and Helping you succeed. The bottom section includes "Community news" and "Foundation news" sections.

OSGeo

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Open source projects
Open source is so much more than technology. Meet the projects that are here to help you!
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About open source geo
Powerful, secure and flexible: open source gives you the freedom to "Do Geo" your way.
[Open source geo](#)

Helping you succeed
Support provided by local chapters, service providers and research collaboration.
[Connect with OSGeo](#)
[Science and Education](#)

Community news

- Estandarizando la biodiversidad marina con el ICM
July 9th, 2026
- Europa necesita tecnología propia: también lo pide la ciudadanía
July 9th, 2026
- Swiss QGIS User Group Meeting – 2026
July 9th, 2026

[View all community news](#)

Foundation news

- Using AI in OSGeo projects
July 2nd, 2026
- How OSGeo can work better with government policy (and as a foundation)
July 2nd, 2026
- Sol Katz Award for Geospatial Free and Open Source Software - Call for Nominations
May 17th, 2026

GRASS GIS – basic facts

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

Documentation

Tools - GRASS 8.5 Documentati

Getting Started - GRASS 8.5 Do

grassoosgeo.org/grass85/manuals/full_index.html

 **GRASS 8.5 Documentation**

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).

Table of contents

Display tools (d.)

Database tools (db.)

General tools (g.)

Imagery tools (i.)

Miscellaneous tools (m.)

PostScript tools (ps.)

Raster tools (r.)

3D raster tools (r3.)

Temporal tools (t.)

Vector tools (v.)



<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

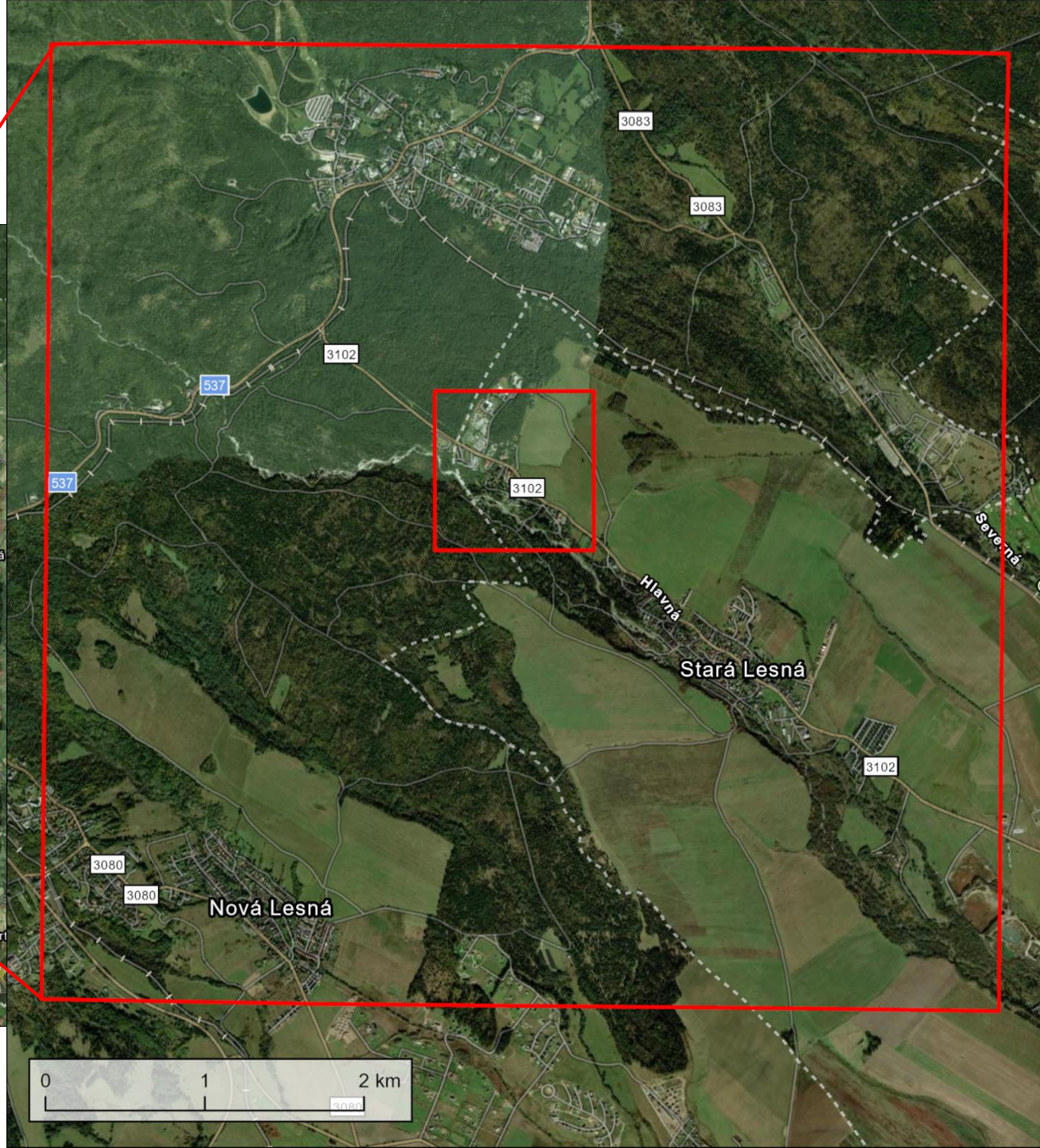
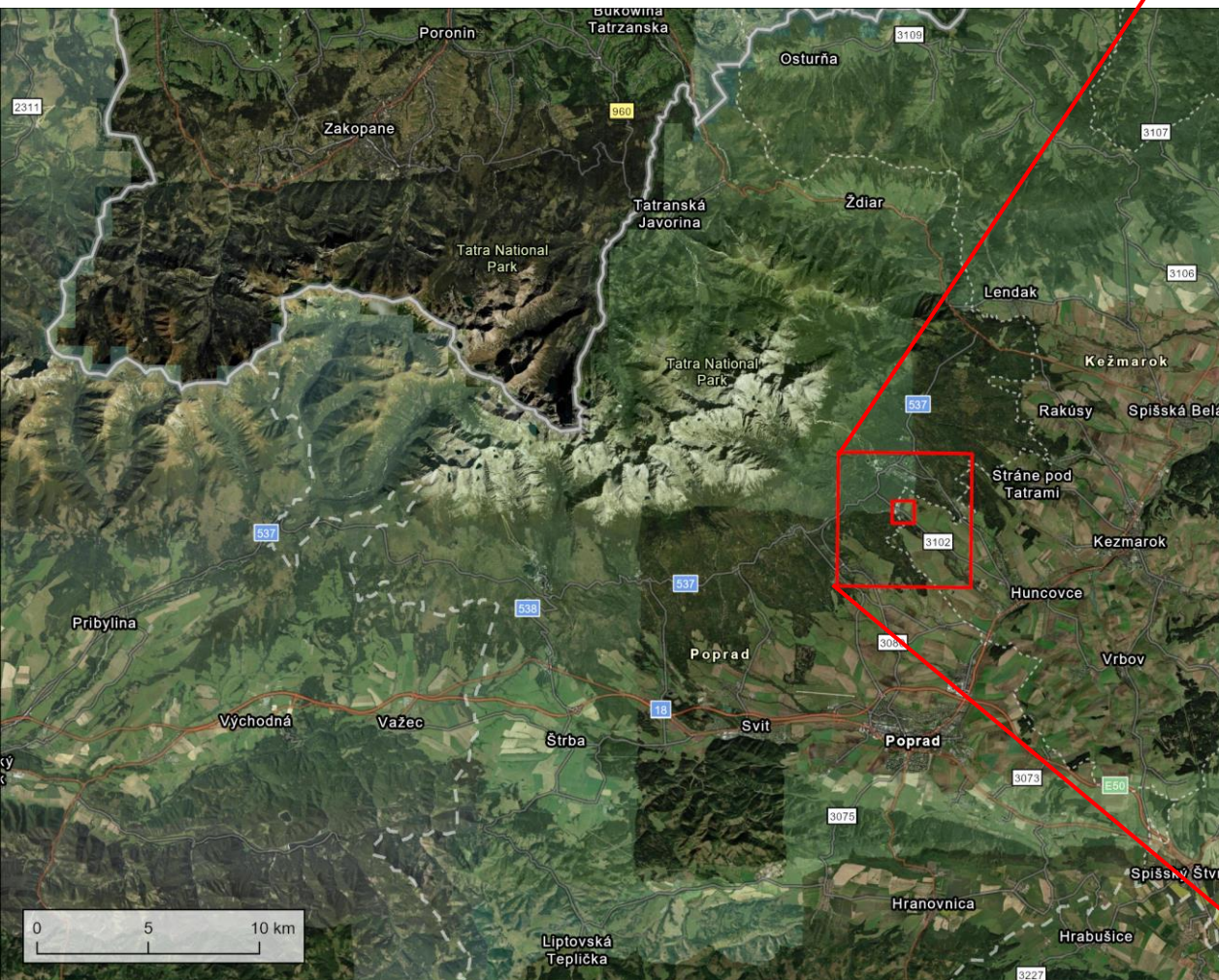
https://grasswiki.osgeo.org/wiki/GRASS_and_Python

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

Study area



Study area – Land cover

Sentinel RGB (10 m)

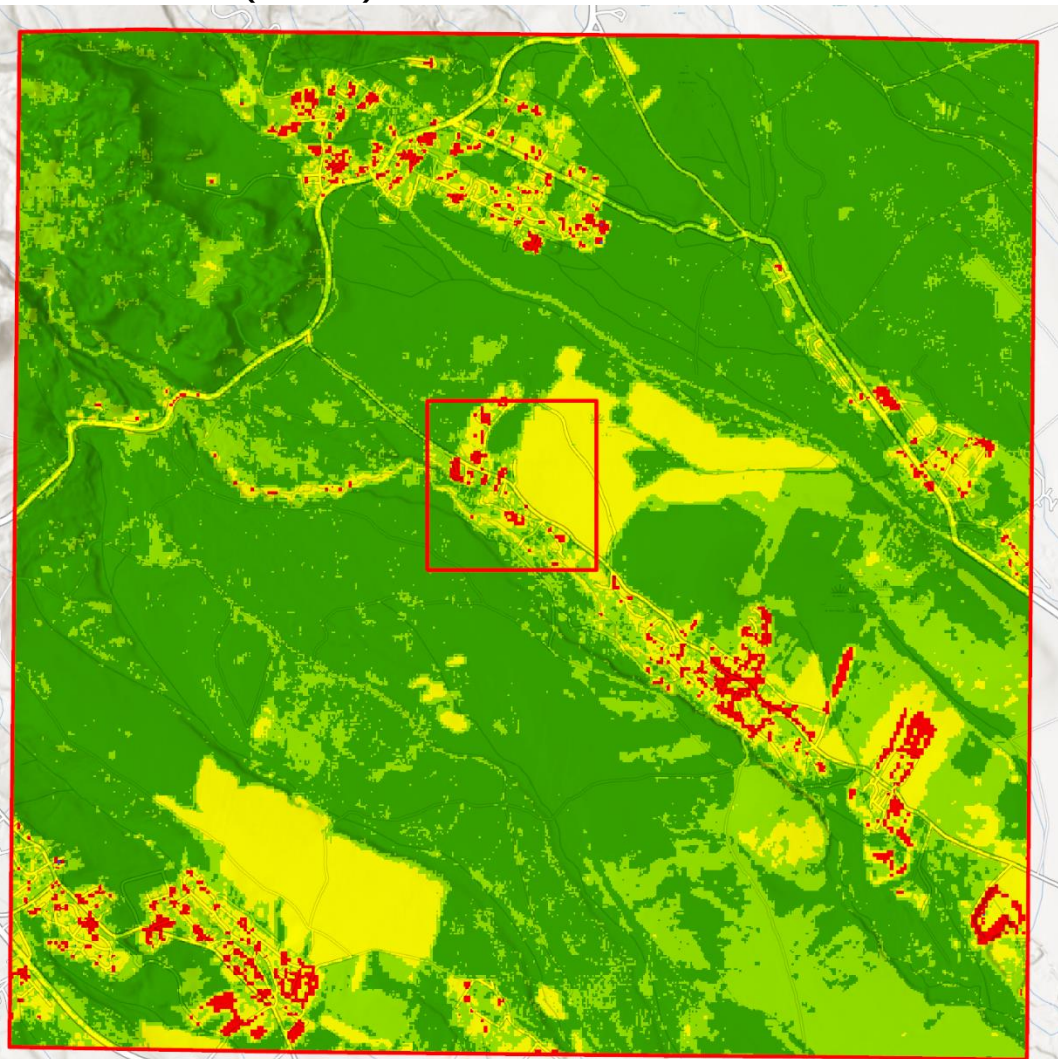


ZBGIS Orthophoto (0.20 m)



Study area – Land cover

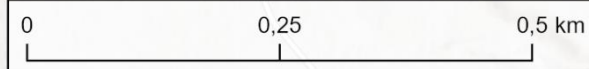
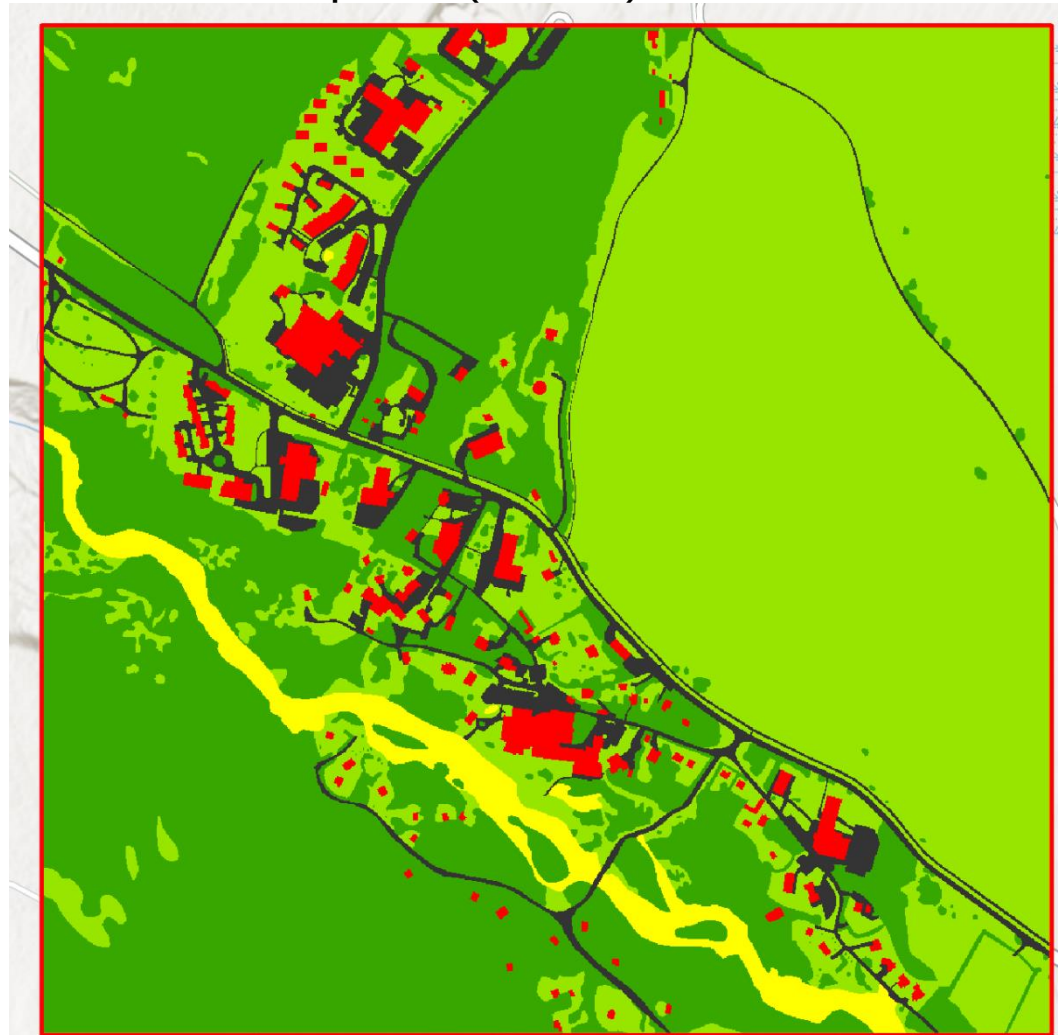
Sentinel 2 (10 m)



-  High vegetation
-  Low vegetation
-  Bare soil
-  Built up area
-  Paved surface

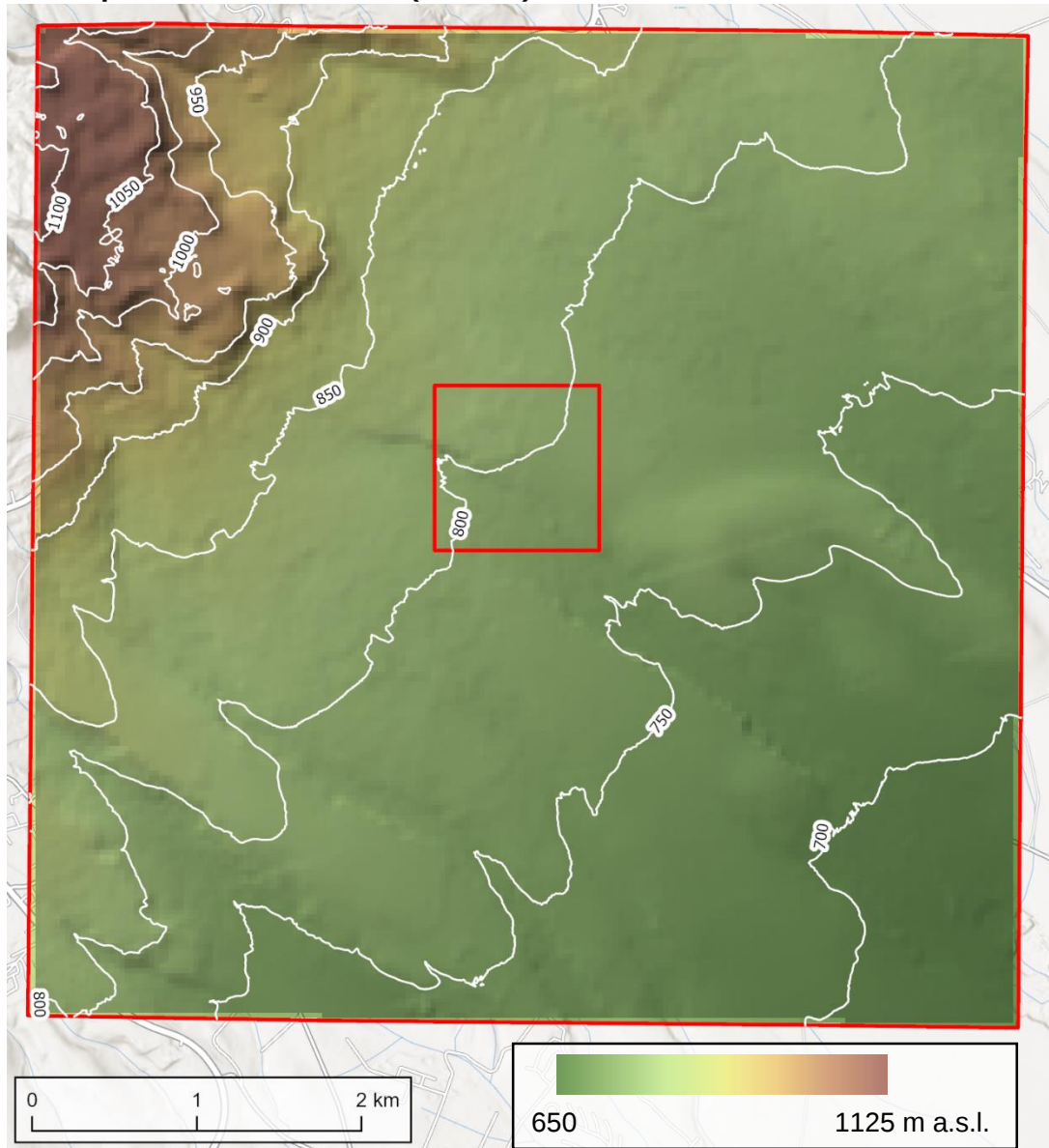


ZBGIS Orthophoto (0.20 m)

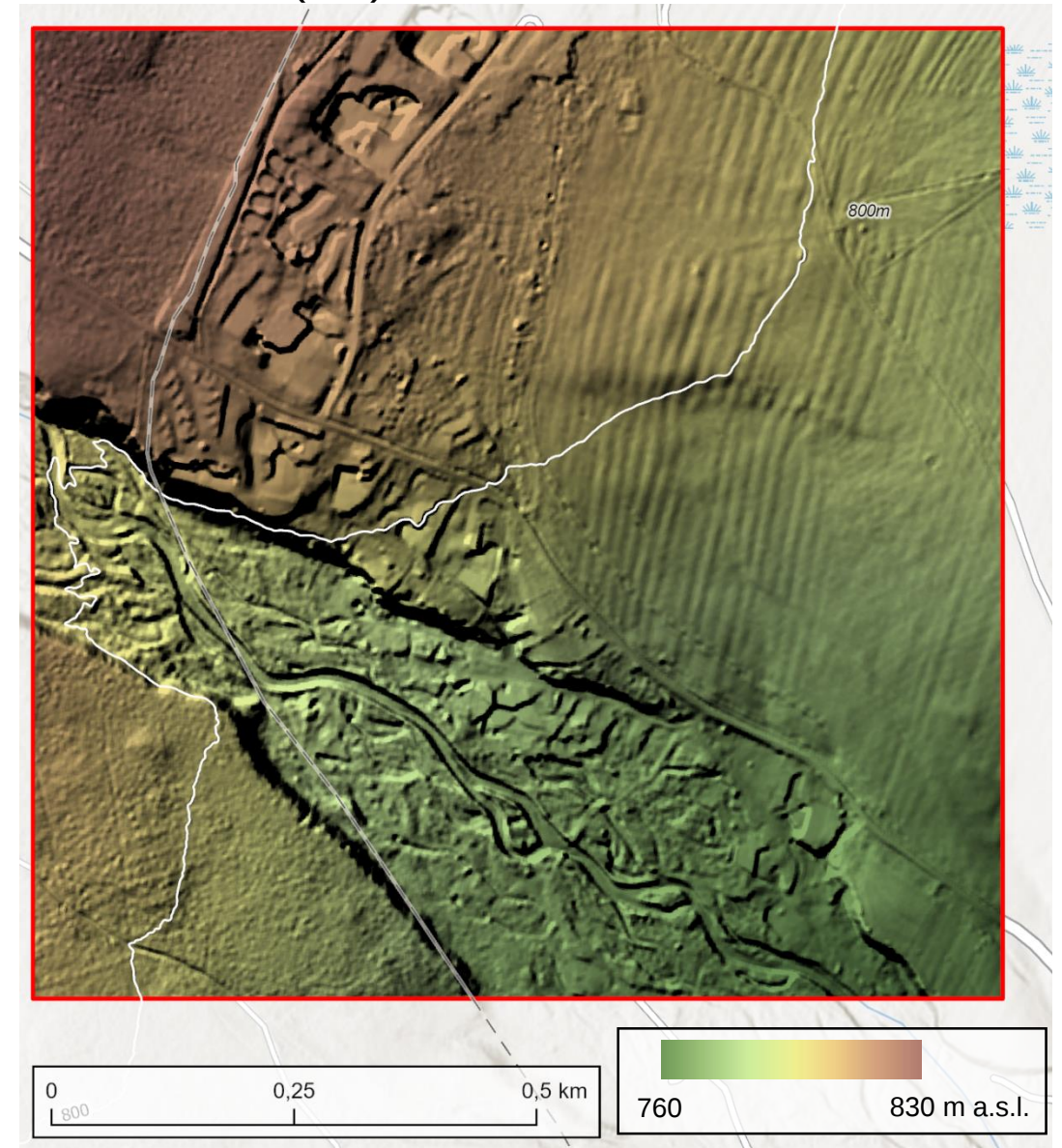


Study area – Elevation

Copernicus DEM (30 m)



ZBGIS DEM (1m)



Input Data for Practical Exercise

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, NDBaI, 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!



<http://uge.science.upjs.sk>



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



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



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