Szilárd burkolatú utakon kívüli off-road mozgékonysági térkép meghatározás és azon alapuló pályatervezés.

024

Application of LiDAR technology to derive cross-country movement map for the ZalaZONE autonomous vehicle proving ground

Authors.

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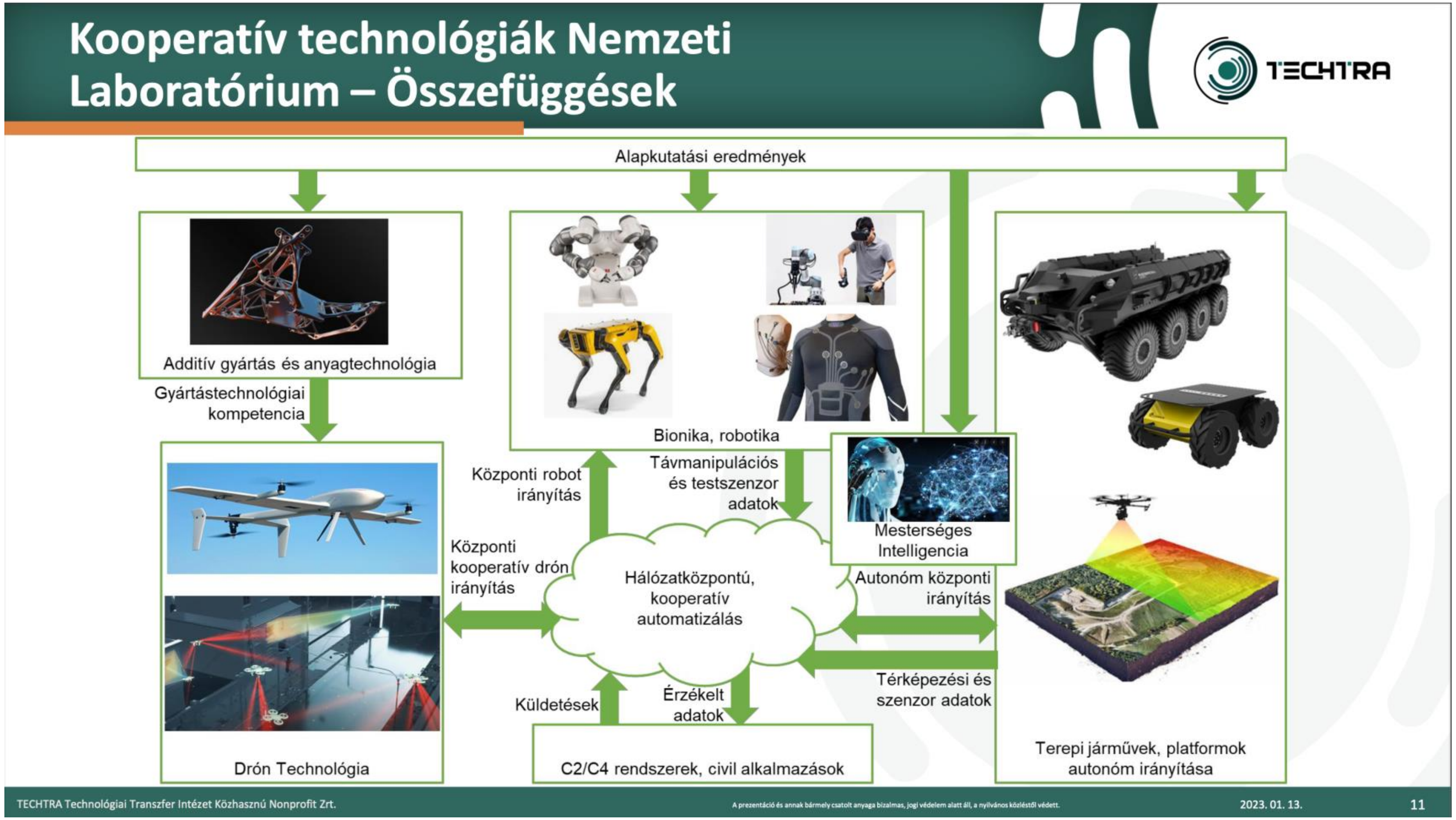
About HUN-REN SZTAKI.

- Established in 1964, as Research Institute of the Hungarian Academy of Sciences (MTA)
- Staff of 300, +90 have PhD or higher degree
- Bridge the gap between Theoretical Results and Industry Needs
- Membership in the European Res. Cons. For Informatics and Mathematics (ERCIM), 1994
- EU CoE in IT, Computer Science and Control, 2001
- Virtual Inst. on Production and Business Management, PBM, 2002
- Fraunhofer Project C. for Production Management and Informatics PMI, 2010
- EU CoE in Production Informatics and Control, EPIC), 2017
- Common legal entity with Fraunhofer, EPIC InnoLabs Ltd, 2018
- 45 FP7 projects, 22 H2020 projects, ERC advanced grant
- Eötvös Loránd Research Network (ELKH), 2019
- Autonomous Systems National Laboratory, 2020
- Artificial Intelligence National Laboratory, 2020
- HUN-REN Hungarian Research Network, 2023

Cooperative Technologies Nat. Lab

- Motivation and funding: dual-use technology for autonomous offroad vehicles



AGV - CPR Husky A200

- Medium sized AGV
  - 75 kg payload
  - 3-4 hour uptime
- Unique equipment
  - 3D LiDAR
    - 300 m range
  - 2x 3-band RTK-s GPS
    - Location (<cm)
    - Orientation (<0.2°)
  - Stereo camera
  - Companion Computer
- Future plan: Hydrogen power

Cross Country Movement (CCM) models

- Military approach

- In a traditional sense:
  - Static approach

- In case of automation:
  - Realistic approach →
  - Dynamic approach

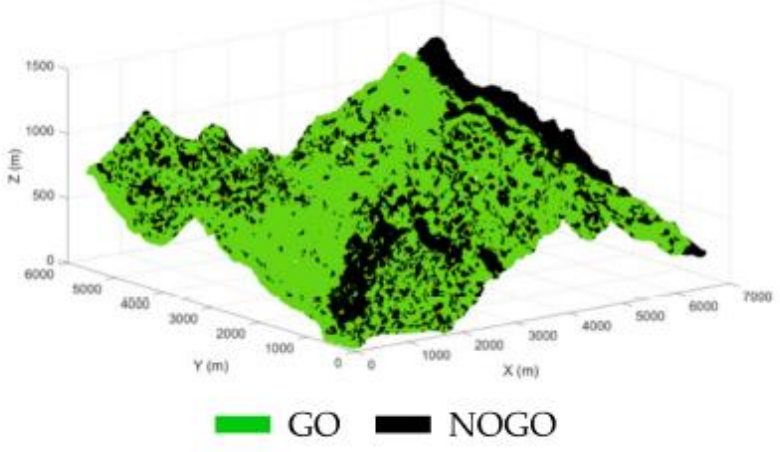
- To model it needs some criteria

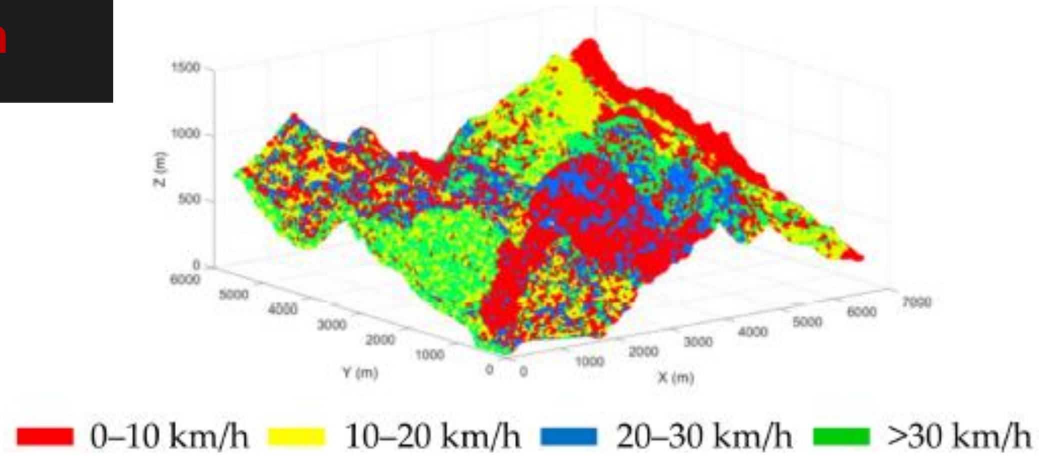
Criteria for route planning

- Slope of terrain relief
- Vegetation
- Hydrology
- Soil Conditions
- Climate conditions
- Urban areas
- Roads
- Natural and man-made objects

CCM levels:

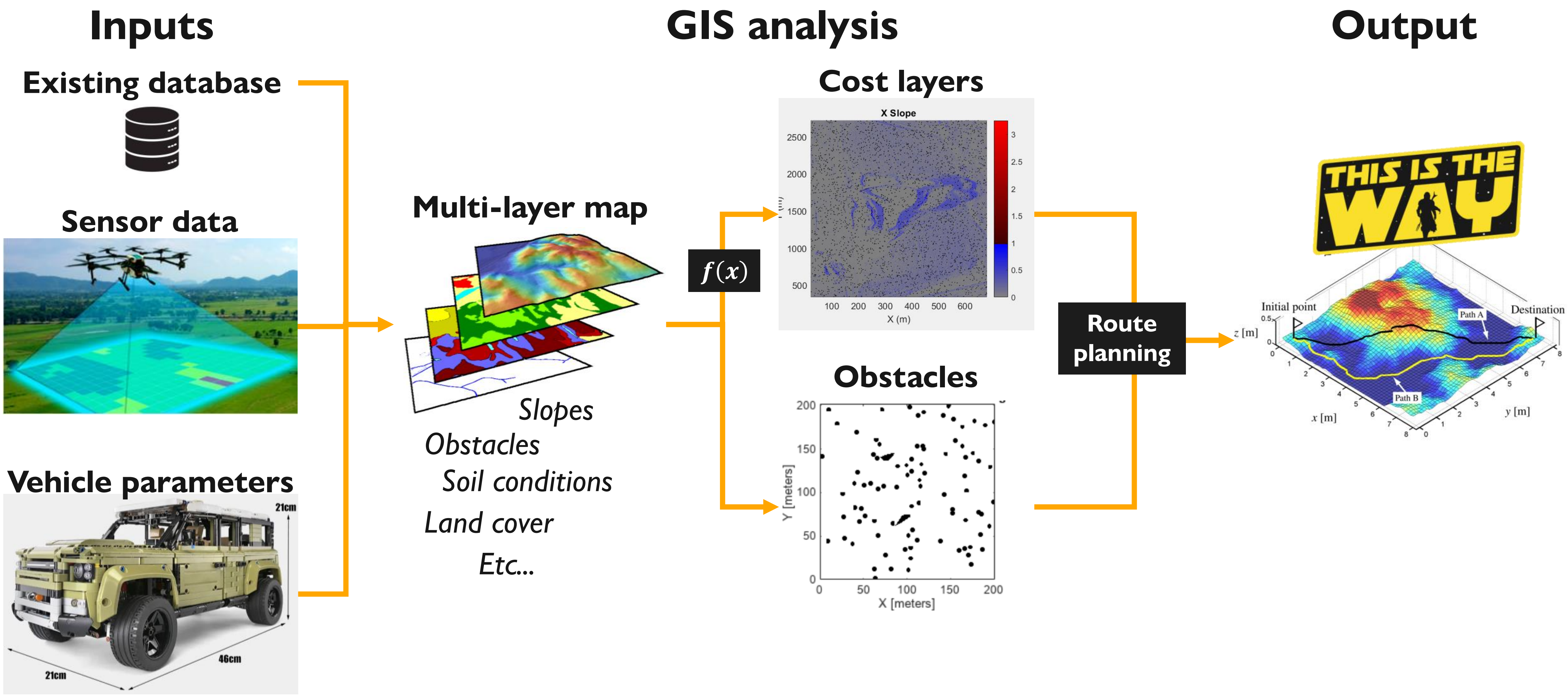
- **GO terrain**
- **SLOW GO terrain**
- **NO GO terrain**





Source: NATO Documents & Hua et al. 2022.

Principle of route planning



Route Planning

- $V(km/h) = F1 x F2 x F3 x F4_{D/W} x F5$
- F1 is **slope factor** as it determines the extent that any slope will deteriorate the vehicle's speed without consideration for any other physical factor;
- F2 is **slope-intercept-frequency (SIF) factor**. SIF is the number of times the ground surface changes between positive and negative slopes over a 1km distance;
- F3 is **vegetation factor** that determine impact of the vegetation density and distributing pattern on the mobility of vehicle's movement;
- F4 is **soil factor** that informs impact of the soil characteristics on vehicle's mobility. The analysis is normally separated into wet (W) and dry (D) conditions; and
- F5 is **surface roughness factor** that depends on the surface materials.

Factor	Formula	Note
F1	$F1(\text{kph}) = \frac{\text{Max off- road gradability (\%)} - \text{Surface slope (\%)}}{\text{Max on- road gradability (\%)}}$ x Max road speed (kph); Max = maximum,	If F1 $\leq$ 0, F1 = 0 (No Go).
F2	$F2 = (-0.0008888)\,[\text{slope}] + 1$	–
F3	$F3 = V_R \text{ x } \max(V_1, V_2)$; $V_1 = V_F \text{ x } V_C$; $V_C = \frac{SS - SD}{W}$, $V_2 = 1 - \left[V_T \text{ x } \frac{SD^2}{OD^2}\right]$; $V_T = \frac{(W + SD)}{SS}$, V_R = Vegetation roughness factor, V_F = Vehicle factor, W = Vehicle width (m), SS = Stem spacing (m), SD = Stem Diameter (m), OD = Override diameter of the vehicle.	1. If $V_1 \leq 0$, $V_1 = 0$, 2. If $V_1 \geq 1$, $V_1 = 1$, 3. If F3 $\geq$ 1, F3 = 1, 4. If F3 $\leq$ 0, F3 = 0 (No Go), 5. If values of SS/SD are not available, F3 = V_R.
F4	$F4_{D/W} = \frac{RCI_{D/W} - VCI_1}{VCI_{50} - VCI_1}$; RCI_D = RCI value for dry condition, RCI_W = RCI value for wet condition, VCI_1 = Vehicle cone index (1 pass), VCI_{50} = Vehicle cone index (50 pass).	1. If F4 $\leq$ 0, F4 = 0 (No Go), 2. If F4 $\geq$ 1, F4 = 1.
F5	F5 = Surface roughness factor (0 - 1)	–

W. PIMPA, et al.: TERRAIN ANALYSIS OF CROSS COUNTRY MOVEMENT FOR PATHFINDING OF COMBAT MOBILITY IN MILITARY OPERATIONS, 33rd Asian Conference on Remote Sensing

ZalaZONE

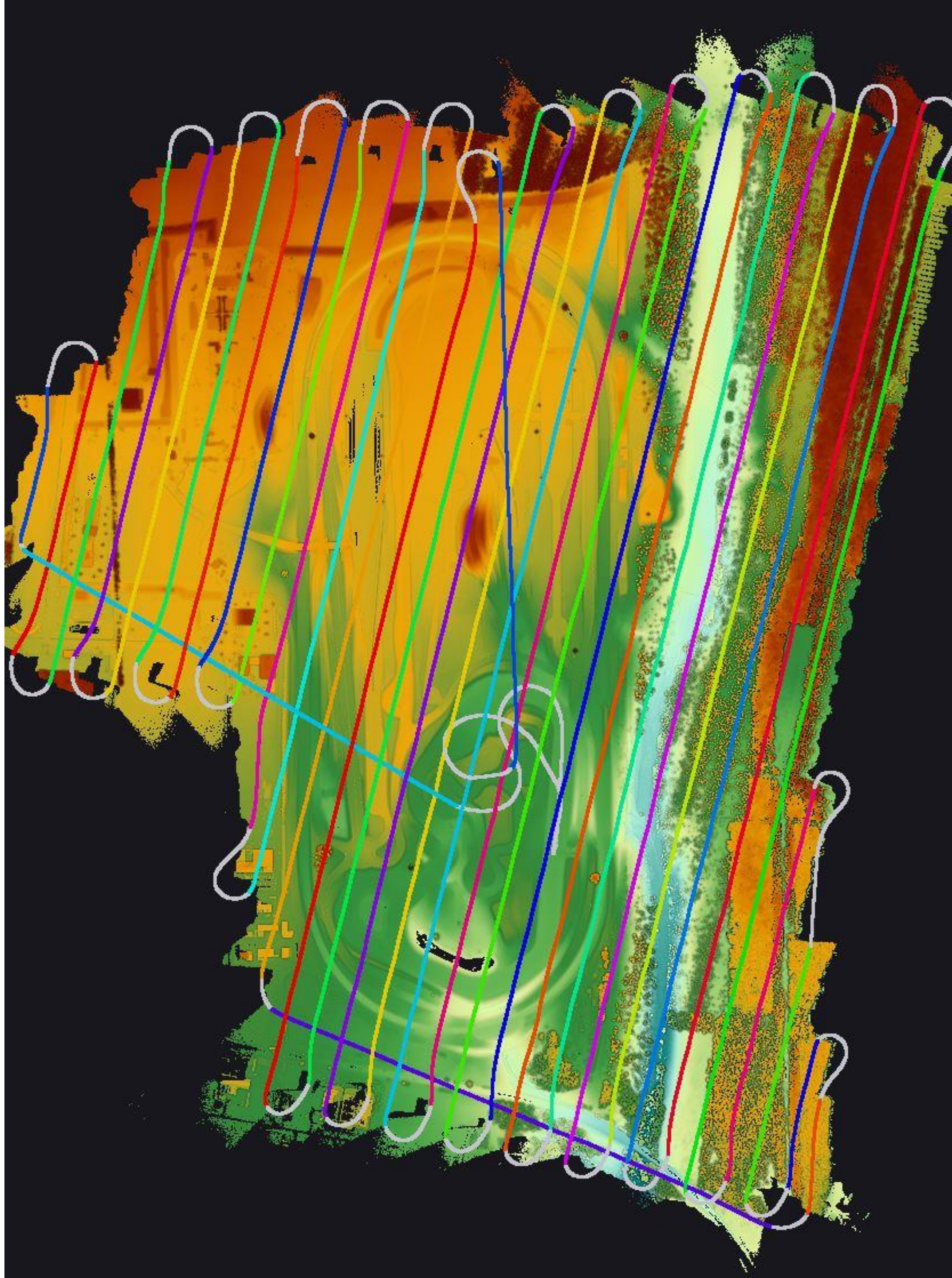
- AVL ZalaZONE is a brand-new, 250-hectar vehicle proving ground in Hungary.
- AVL ZalaZONE offers complete test solutions with engineering services, technical equipment, workshops and offices.
- Member of the Széchényi University

Fighter Fixed Wing Platform

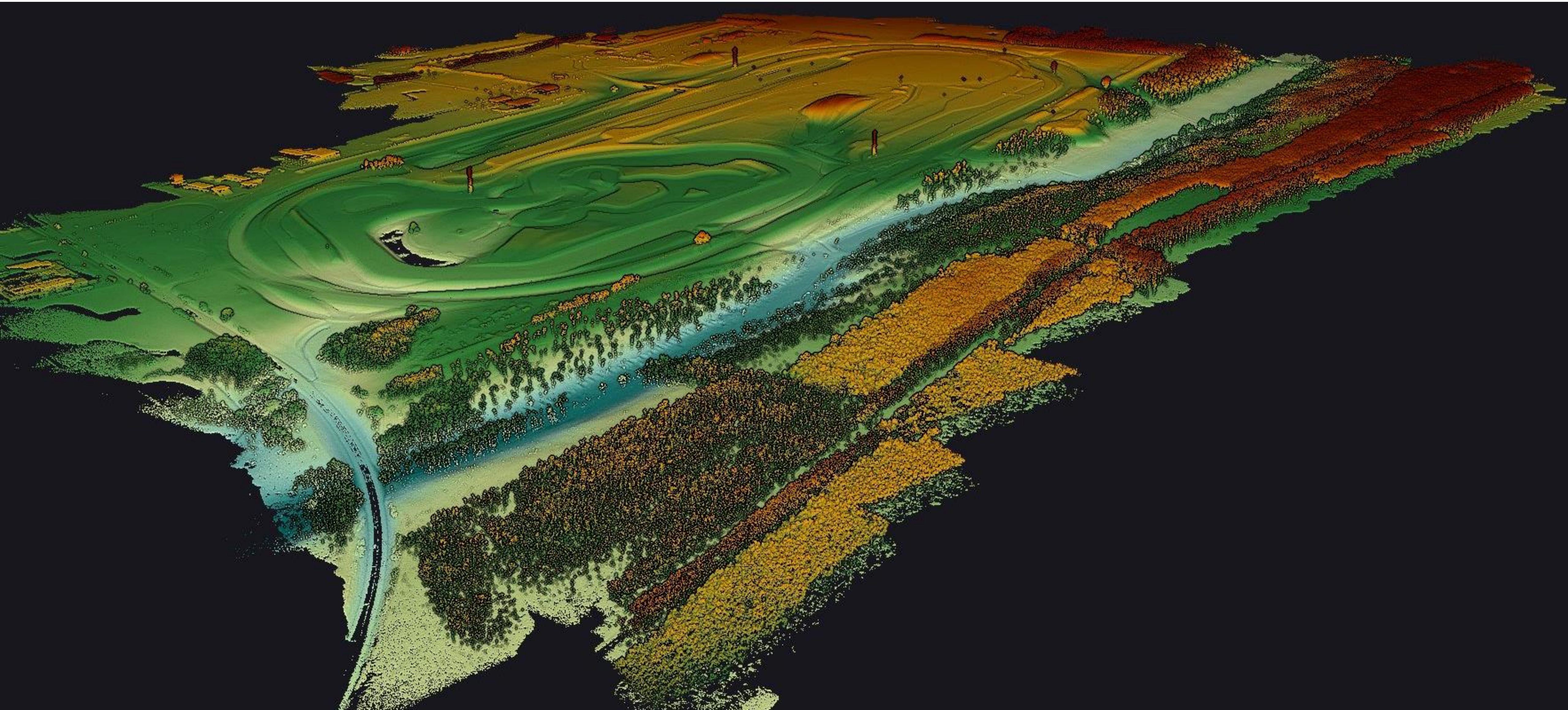
- Custom LIDAR payload bay

YellowScan CloudStation

- 3.9 km2: 609 million pt, 150 pt/m2
- 34 lines @90-100 m AGL
- 4.4 cm error after line matching
- Offroad area on the South side
- Fixed wing flight post processing is more demanding than multicopter



YellowScan CloudStation

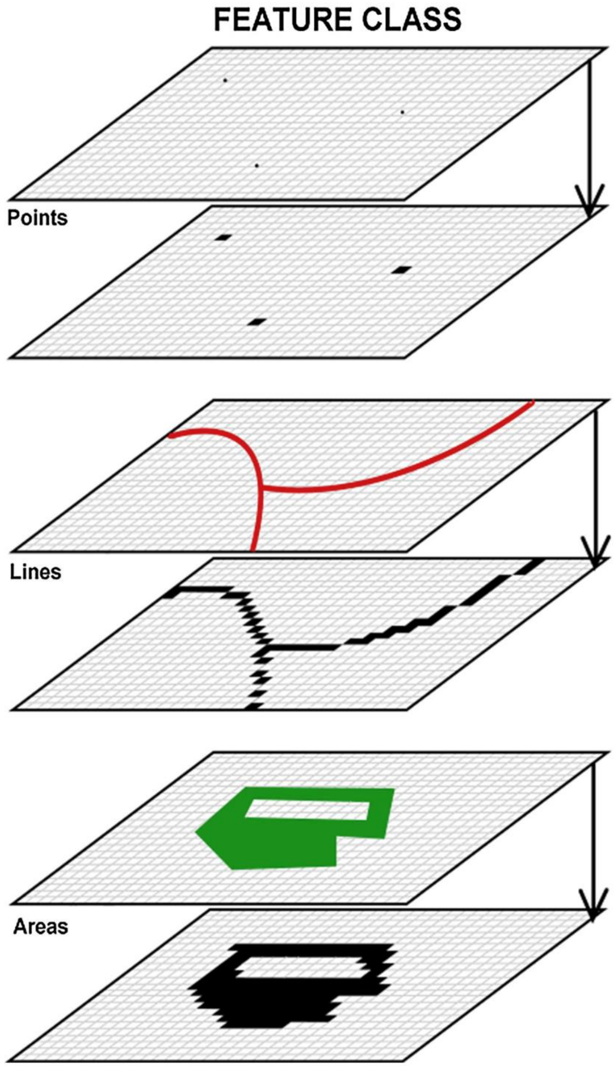


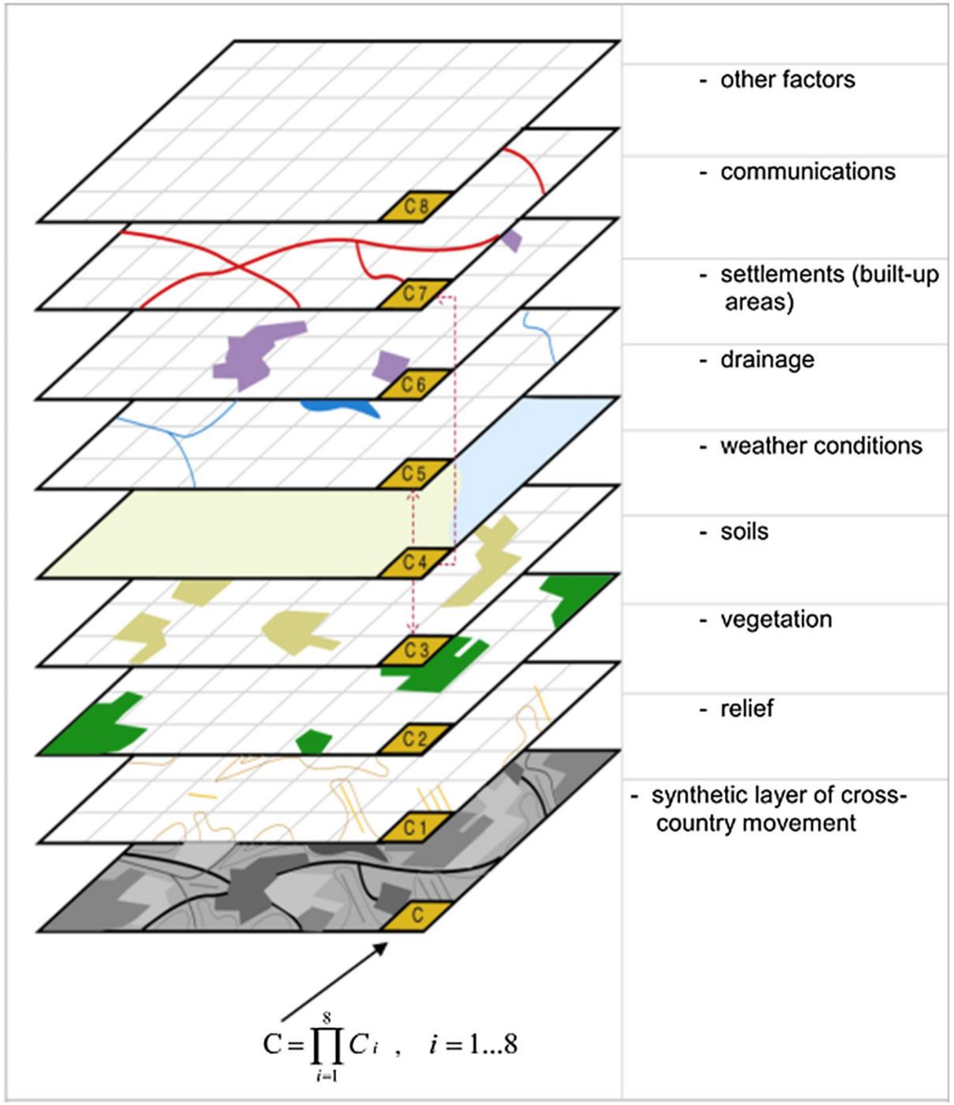
Post Processing for CCM

- Raster DTM
- Pixel size and interpolation methods do matter
- Central part of off-road track

Transformation of vector layers into raster layers

- Gather all the data
- Transform them to raster layers
- Generate non-vehicle specific base maps

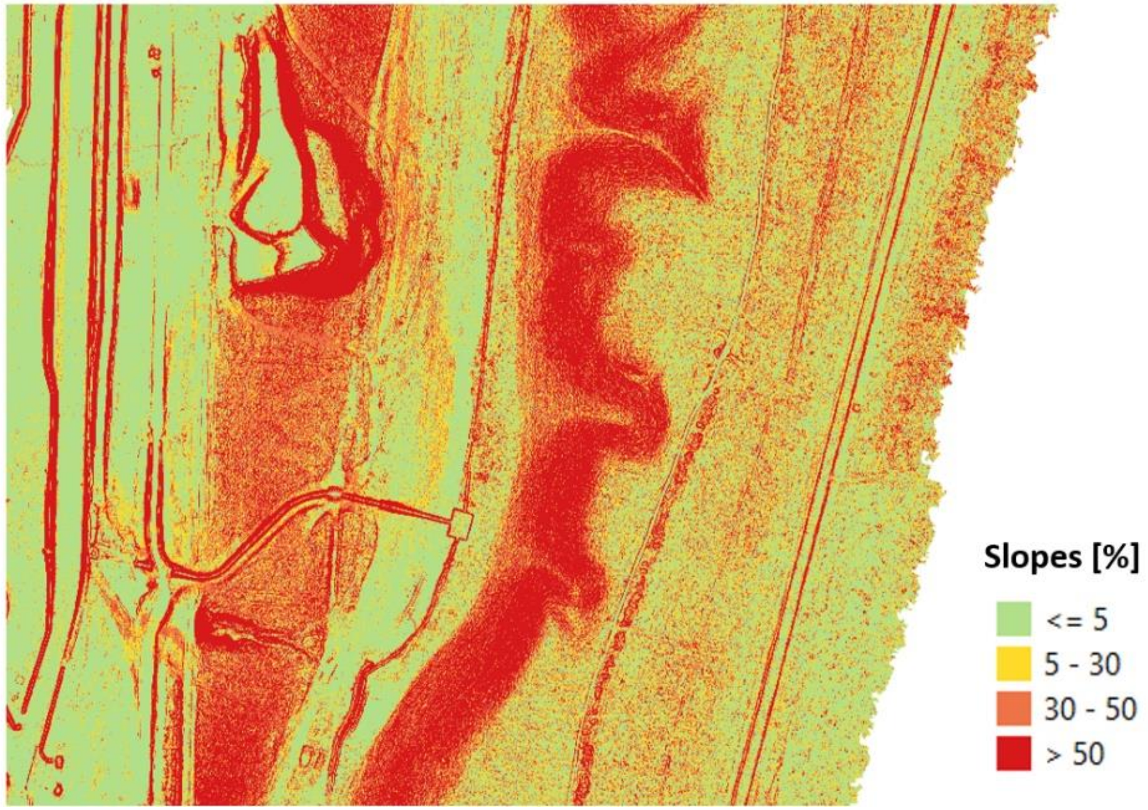


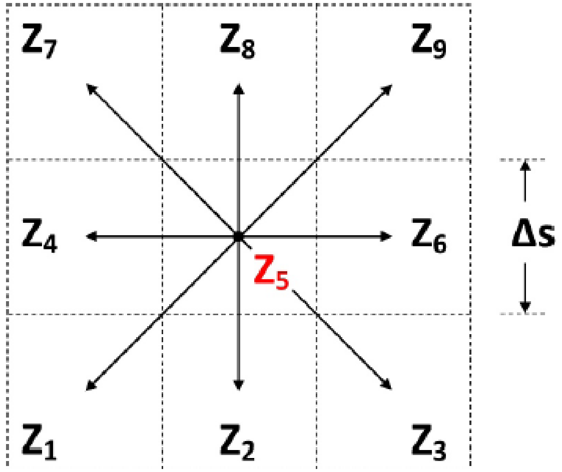


- M. Rybansky et al.: Environ Earth Sci (2015) 74:7049–7058

GIS layers of off-road capability

- Slopes
  - Horn method





$$\left[\frac{dz}{dx}\right] = \frac{(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)}{8\Delta}$$

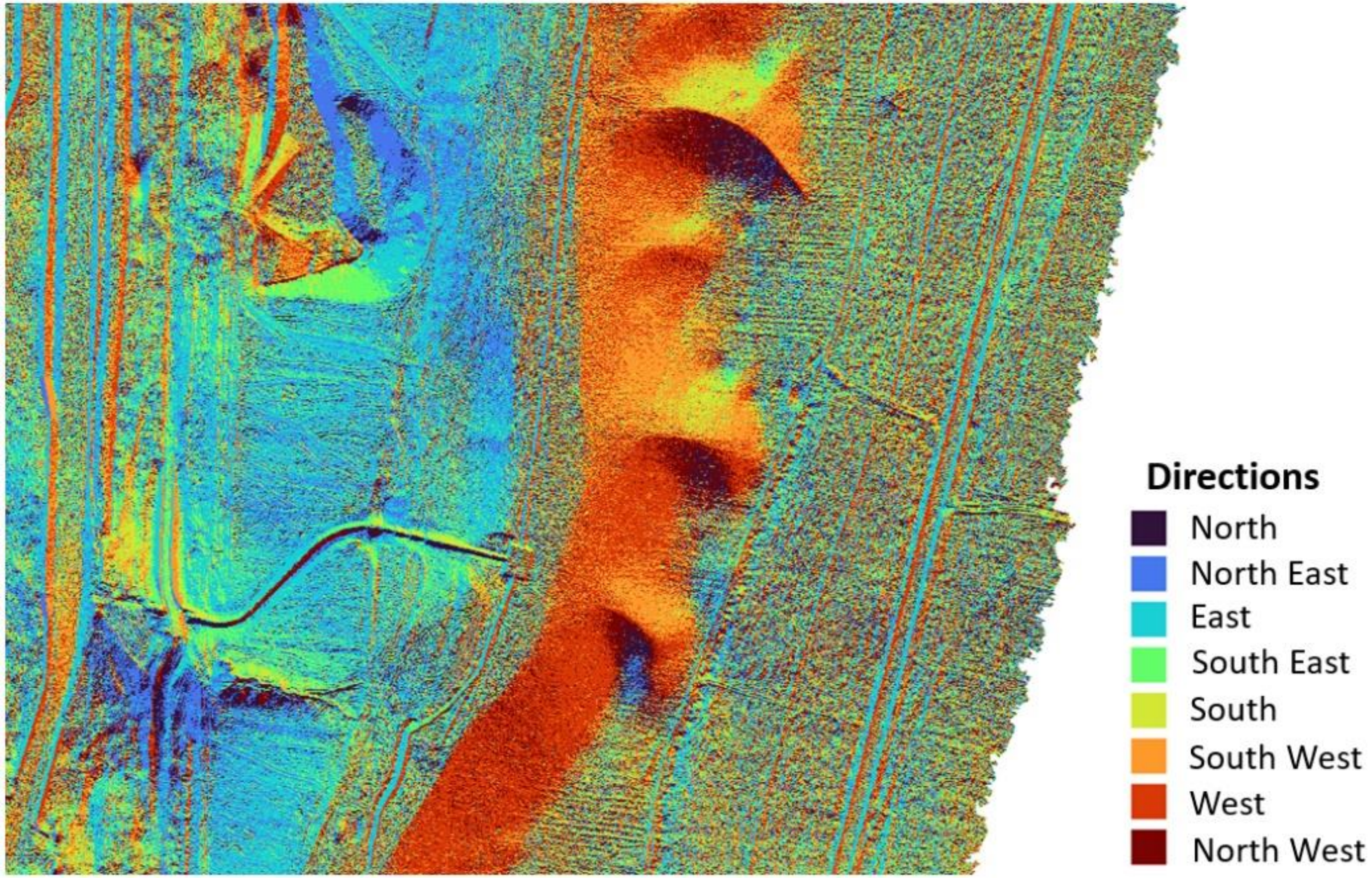
$$\left[\frac{dz}{dy}\right] = \frac{(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)}{8\Delta}$$

$$m = \sqrt{\left[\frac{dz}{dx}\right]^2 + \left[\frac{dz}{dy}\right]^2}$$

Source: Badora – Wawer 2022.

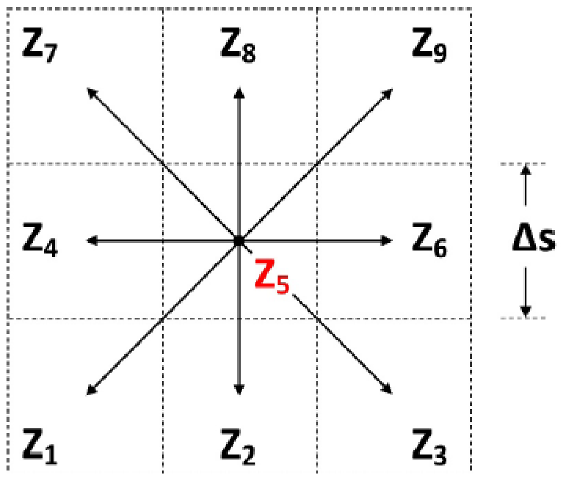
GIS layers of off-road capability

- Aspect
  - Direction of slopes

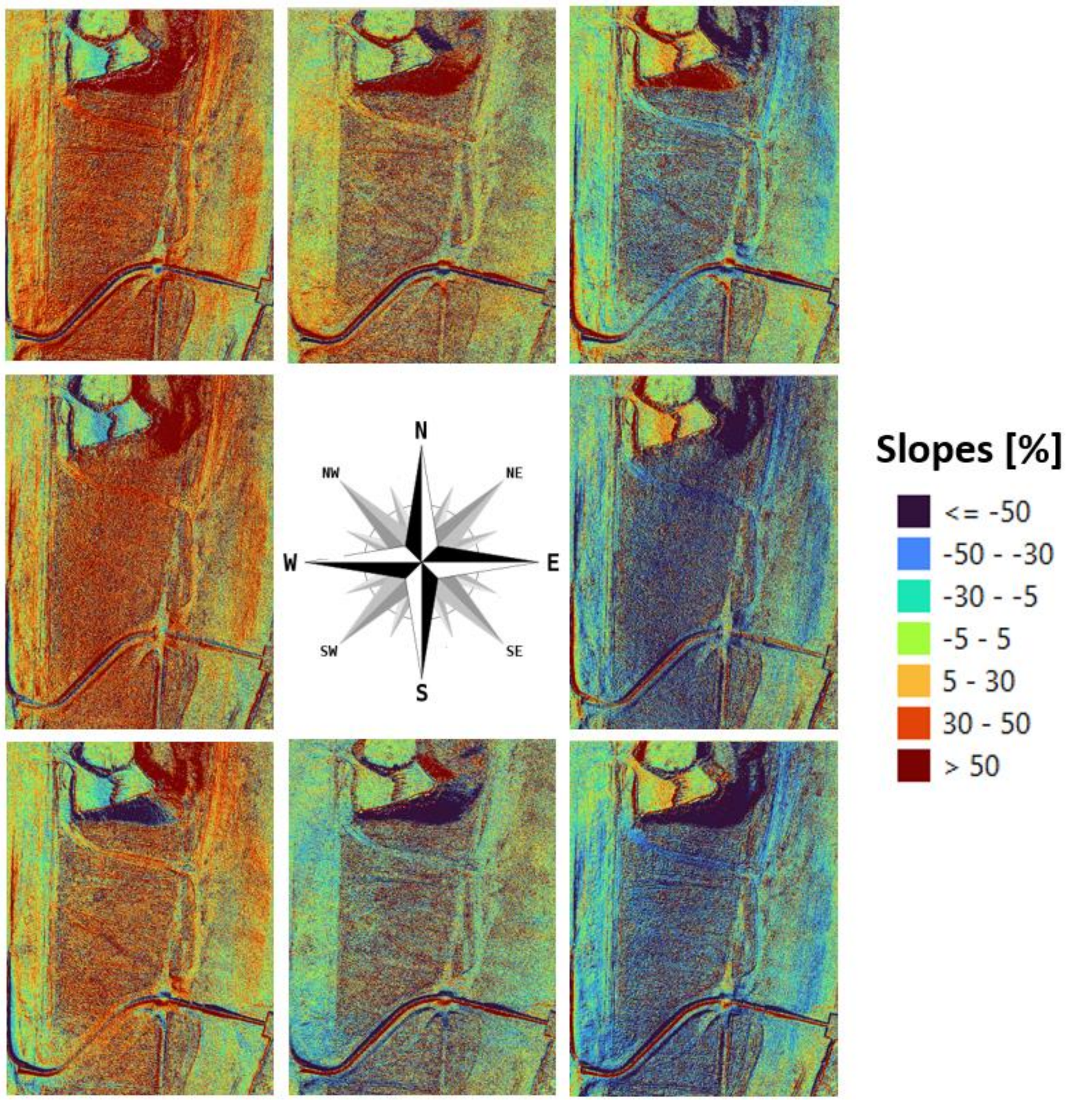


GIS layers of off-road capability

- Directionality of Slopes
  - 8 (4?) directions
  - From neighboring points

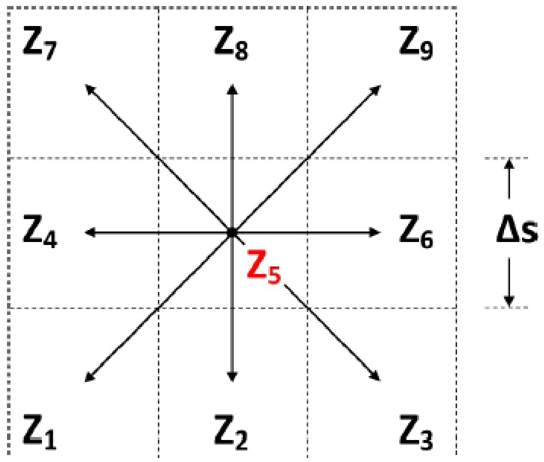


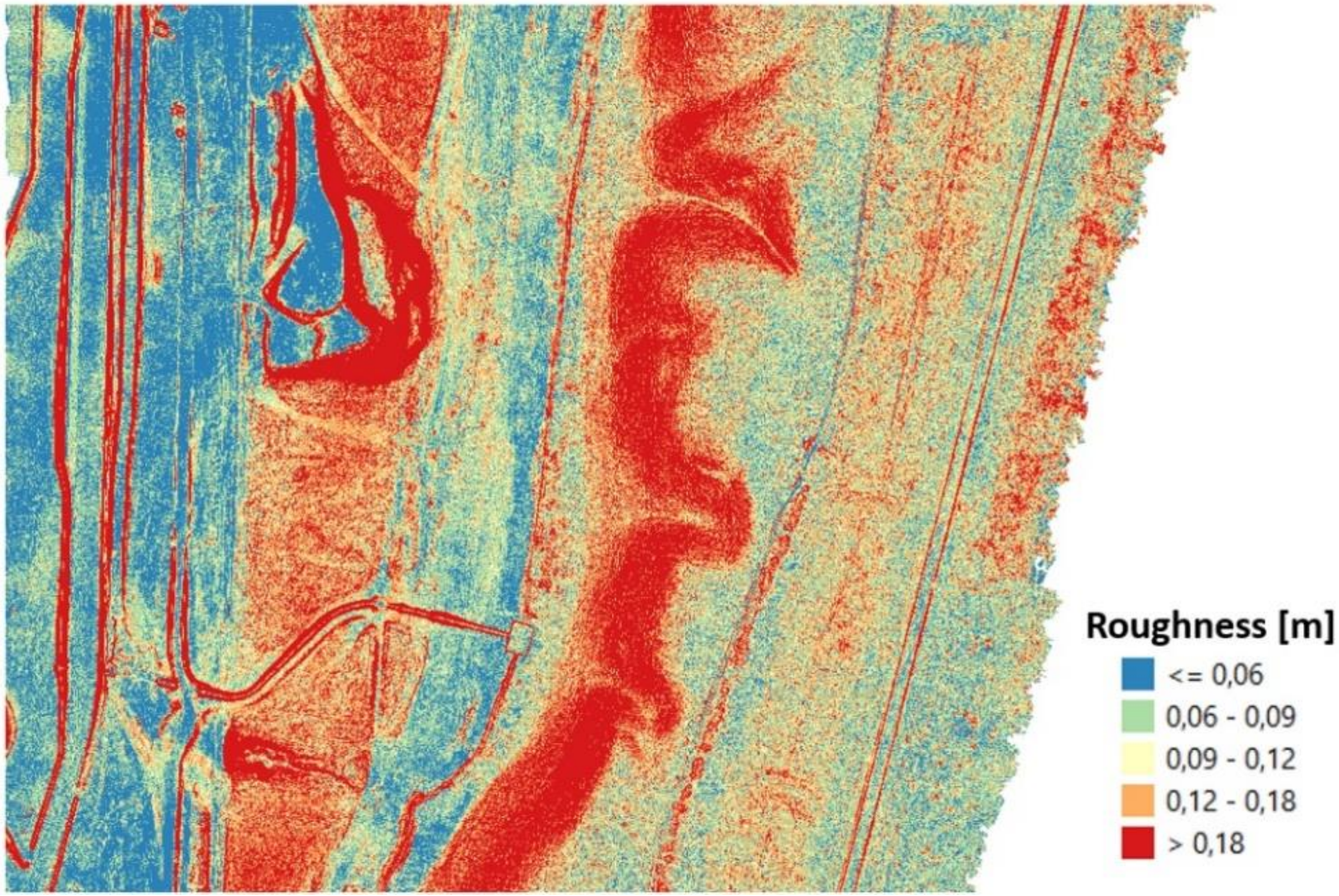
  - Longitudinal and lateral aspects



GIS layers of off-road capability

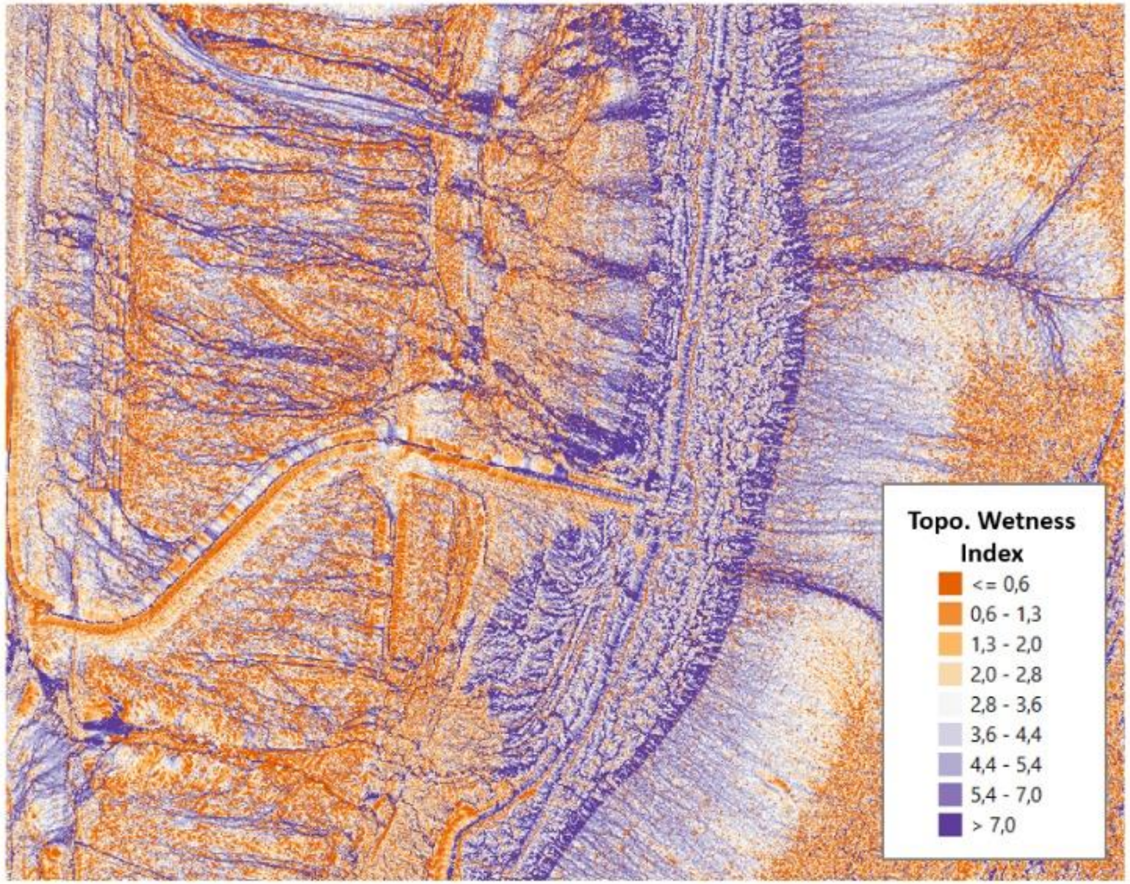
- Roughness
  - Degree of irregularity
  - From elevation
  - Surrounding cells
  - Largest difference





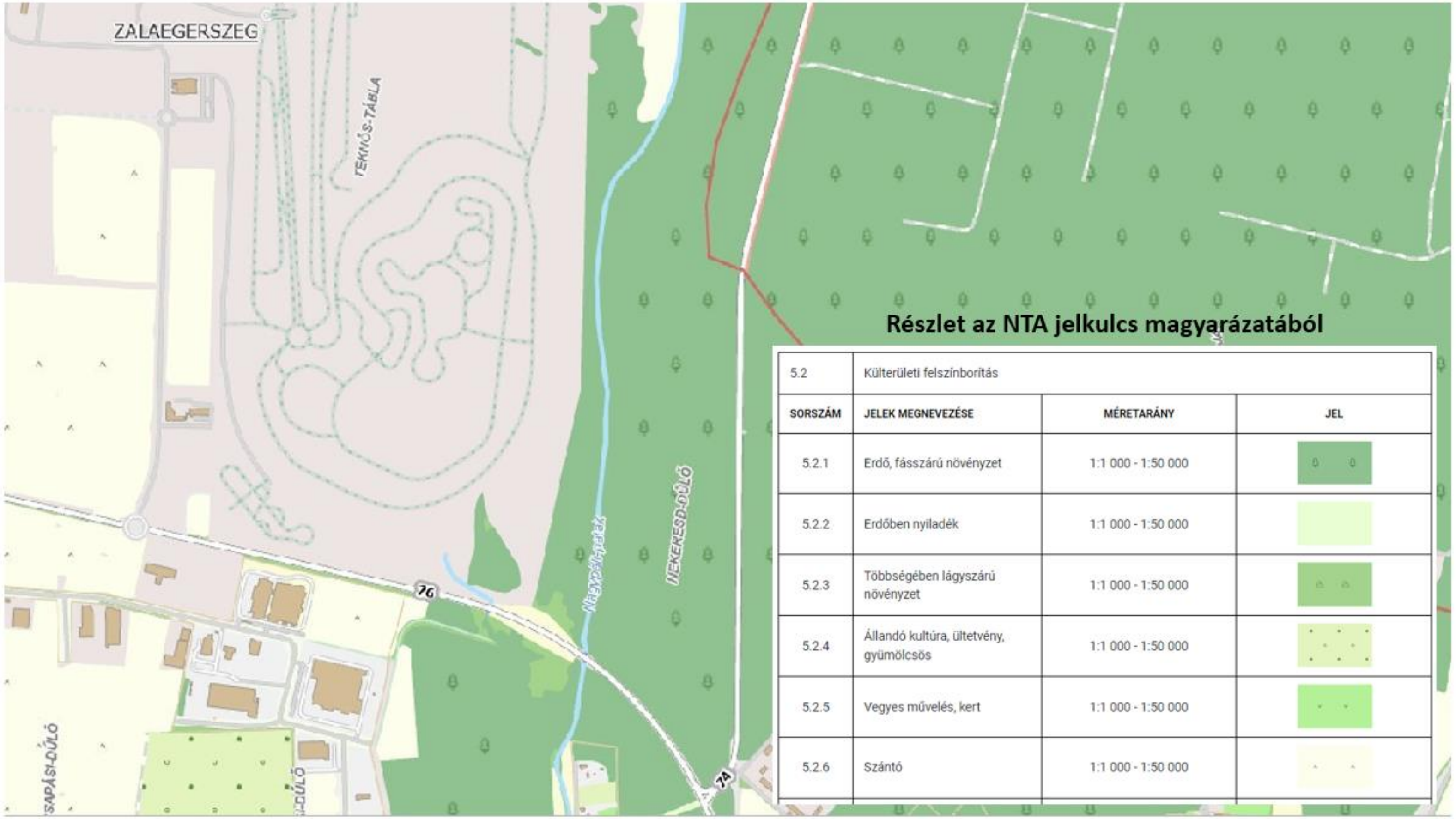
GIS layers of off-road capability

- Hydrology and weather conditions
  - Water surfaces
    - Land coverage
  - Weather conditions
    - Possible catchment areas
    - Topographic Wetness Index



GIS layers of off-road capability

- Vector data
  - Roads
  - Powerlines
  - Buildings
  - Water
- Land coverage
  - Data from other sources
    - National GIS Map (NTA)



5.2	Külterületi felszínborítás		
SORSZÁM	JELEK MEGNEVEZÉSE	MÉRETARÁNY	JEL
5.2.1	Erdő, fásszárú növényzet	1:1 000 - 1:50 000	
5.2.2	Erdőben nyiladék	1:1 000 - 1:50 000	
5.2.3	Többségében lágyszárú növényzet	1:1 000 - 1:50 000	
5.2.4	Állandó kultúra, ültetvény, gyümölcsös	1:1 000 - 1:50 000	
5.2.5	Vegyes művelés, kert	1:1 000 - 1:50 000	
5.2.6	Szántó	1:1 000 - 1:50 000	

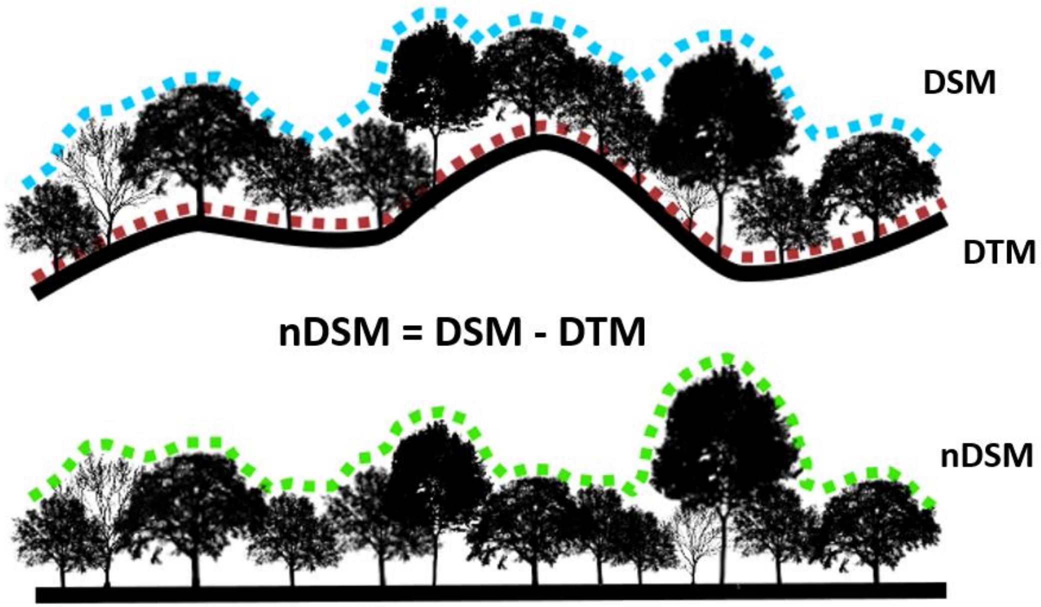
Source: https://nta.lechnerkozpont.hu

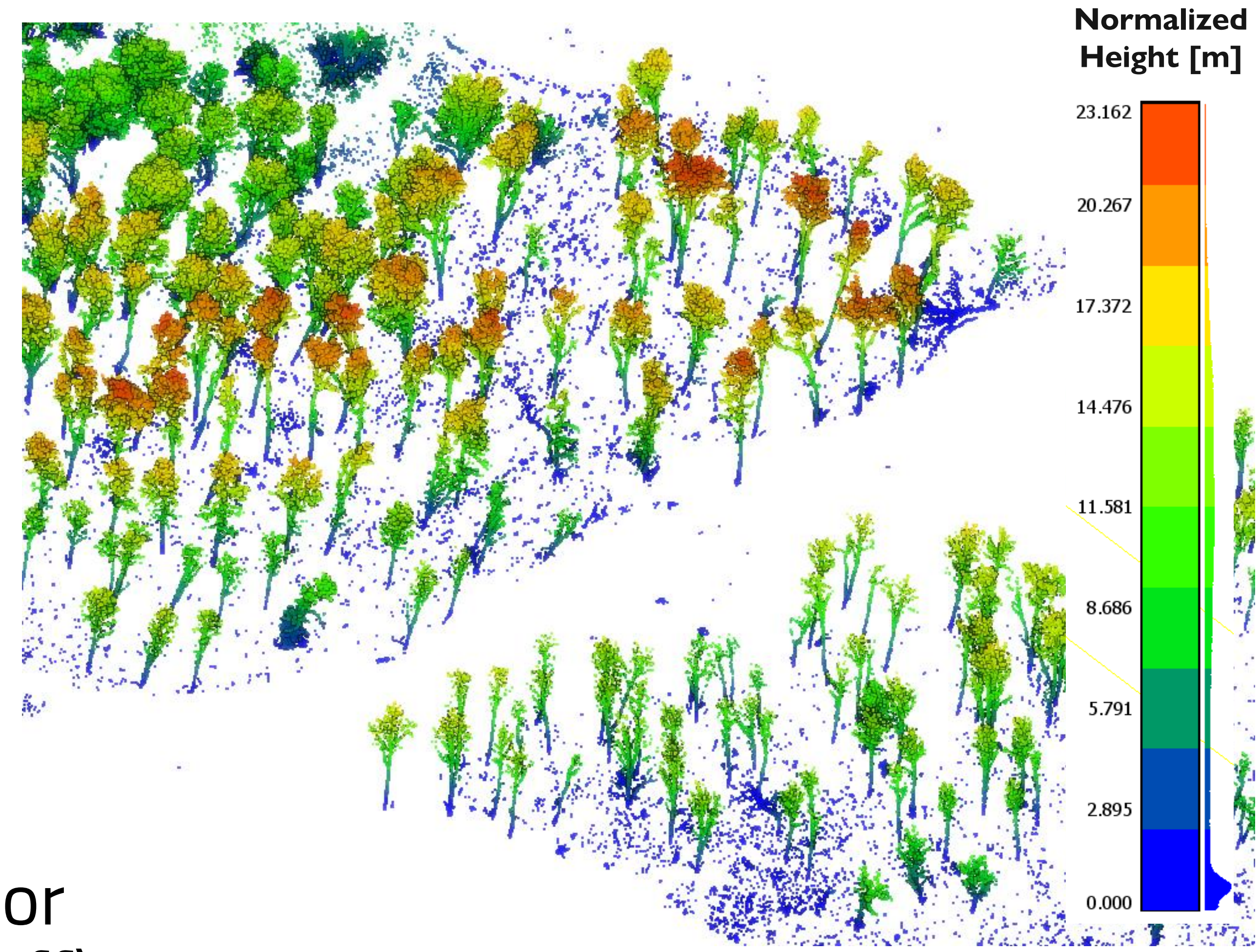
GIS layers of off-road capability

- Land coverage
  - From orthophoto
    - Orthophoto
    - Multispectral data
    - Machine Learning

GIS layers of off-road capability

- Vegetation

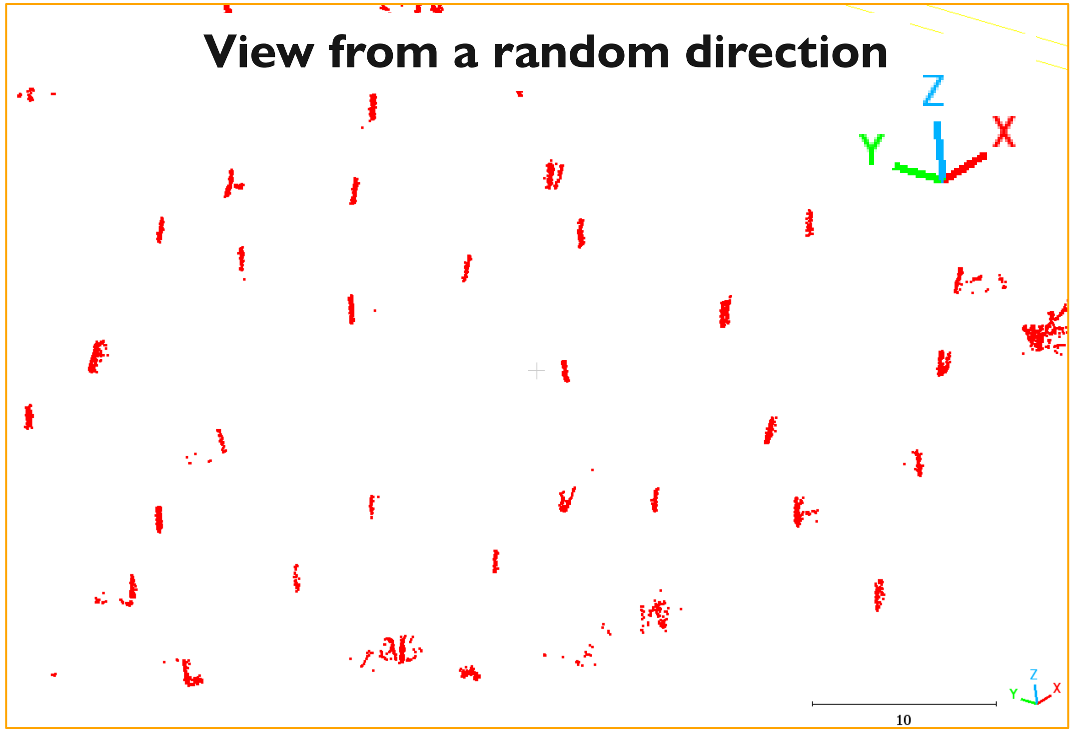


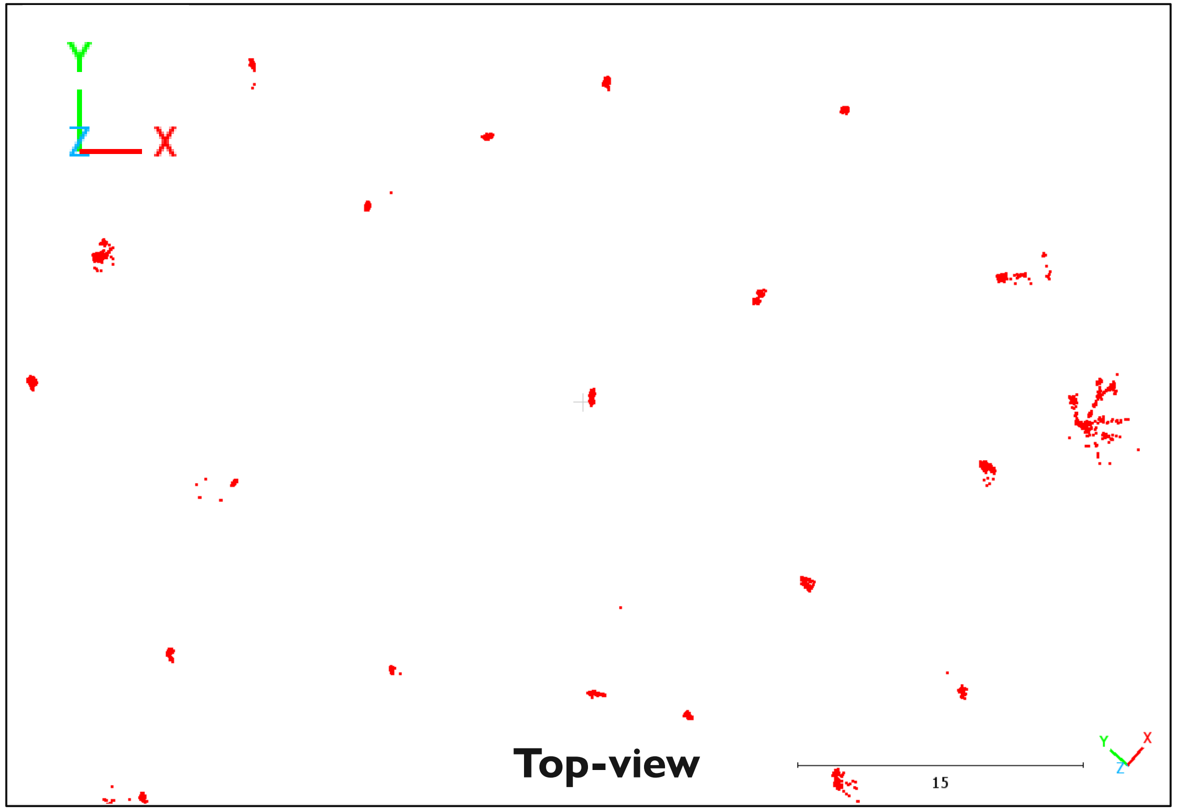


- Obtained from earlier YS Surveyor flight (40-50 m AGL, 45 deg cutoff)

GIS layers of off-road capability

- Vegetation
  - Section (1 – 2.5 meters)
  - DBSCAN

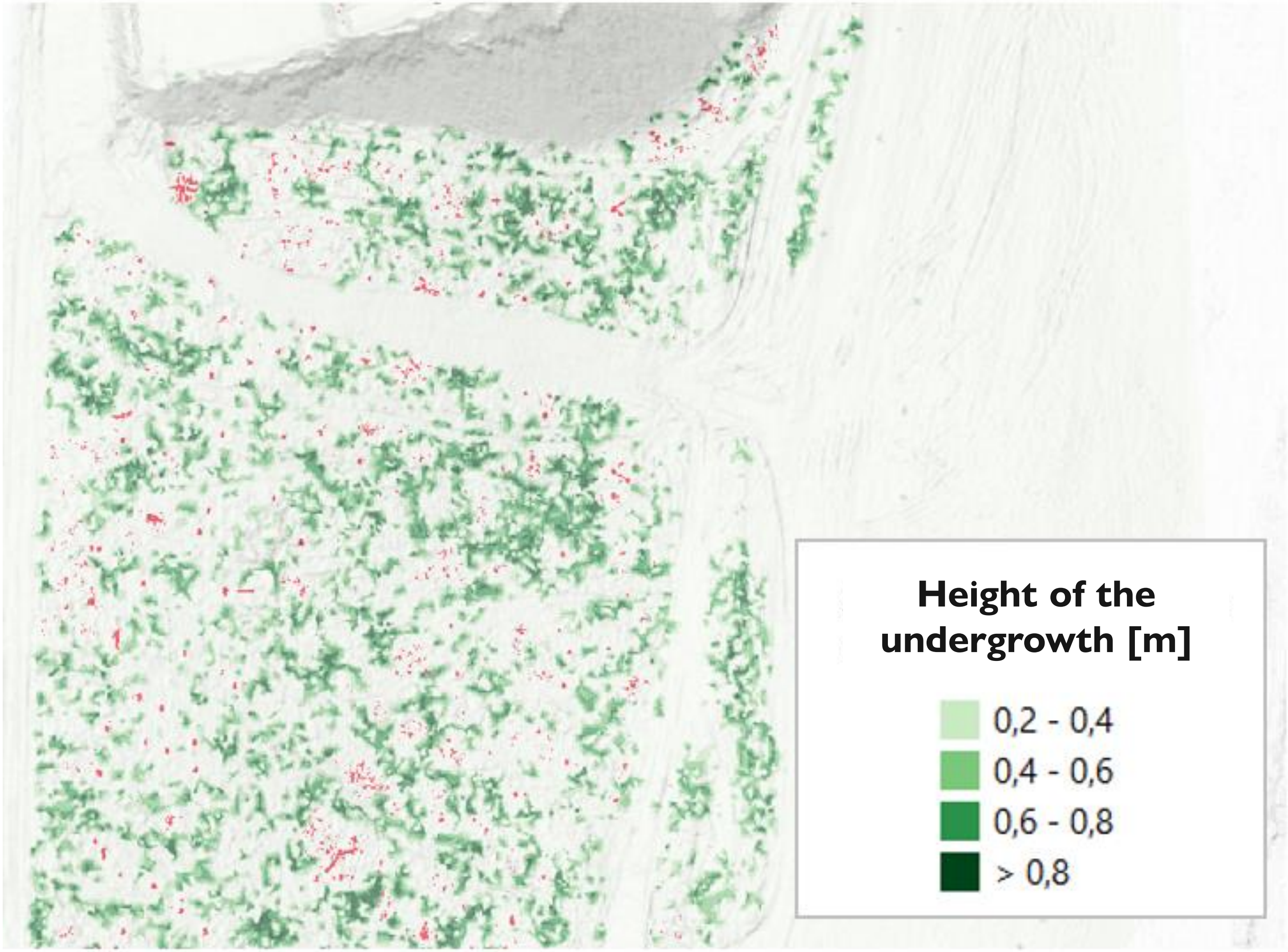




- Obtained from earlier YS Surveyor flight (40-50 m AGL, 45 deg cutoff)

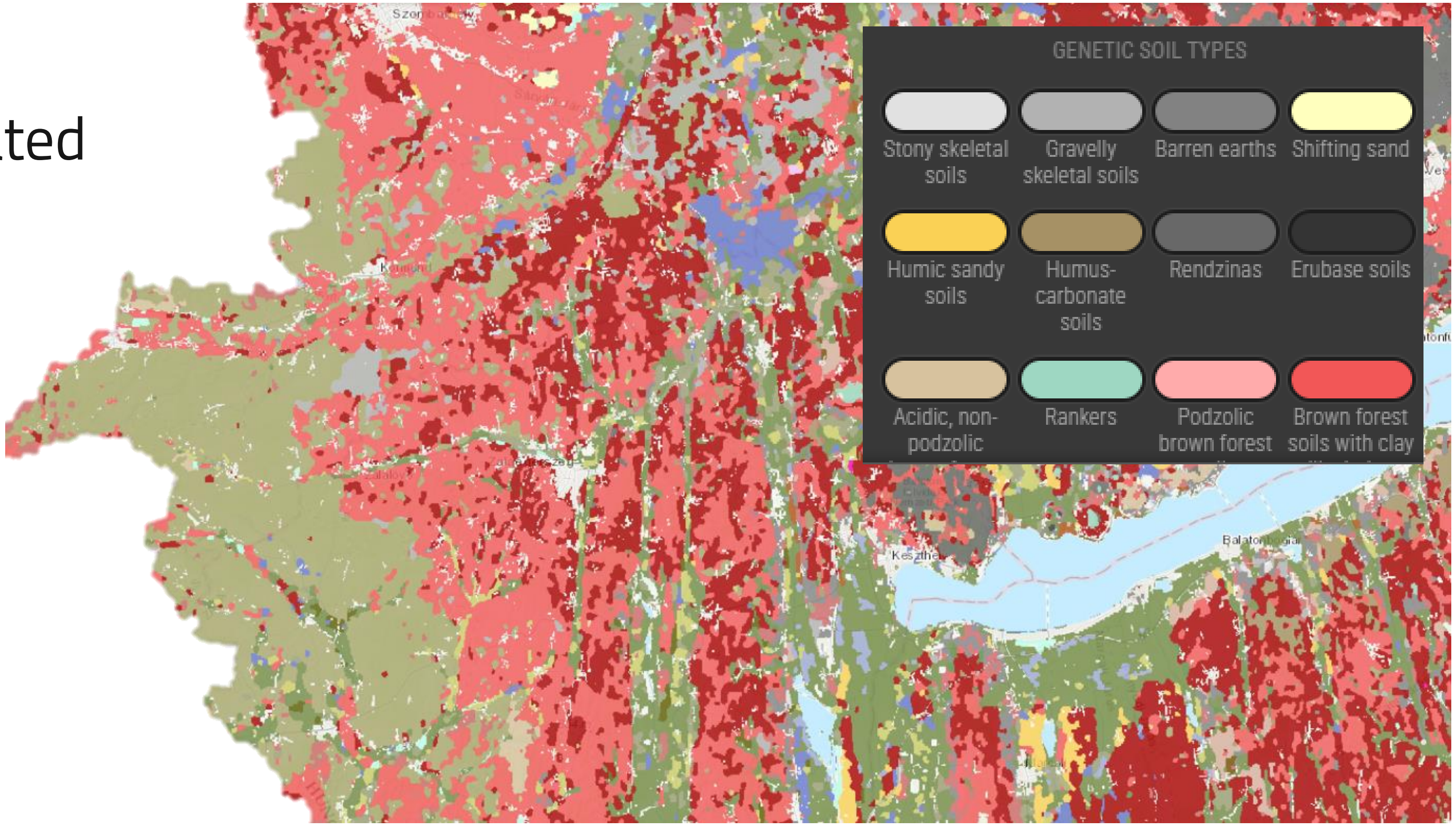
GIS layers of off-road capability

- Vegetation
  - Raster layer
    - Relative height of low-vegetation
    - Position of trunks



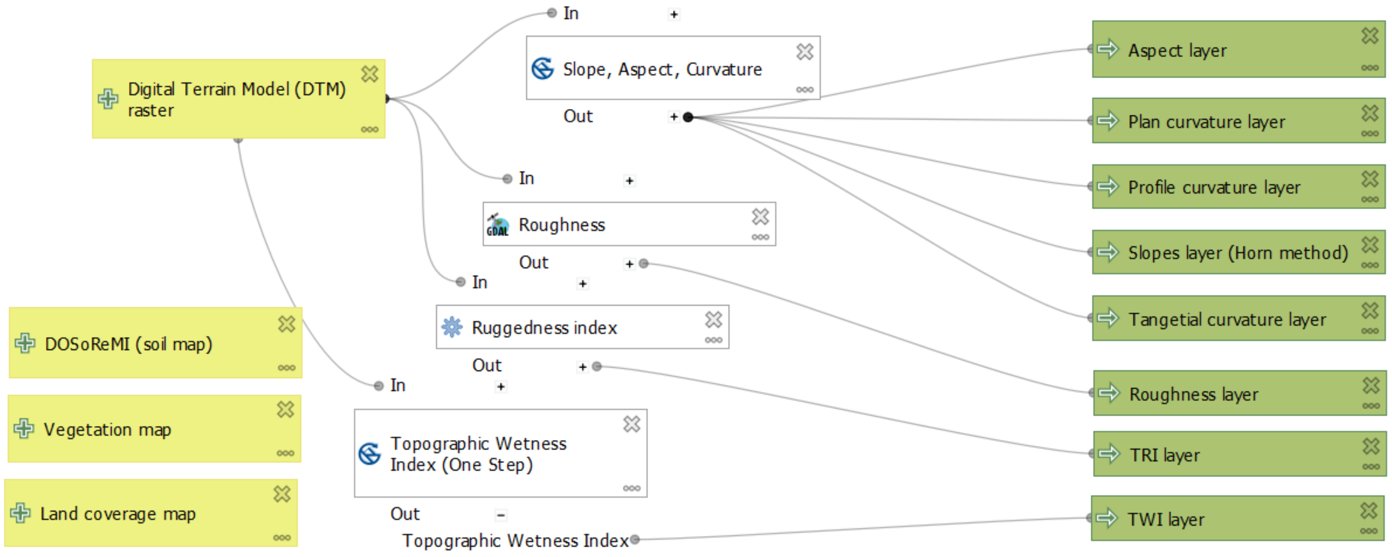
Further GIS layers of off-road capability

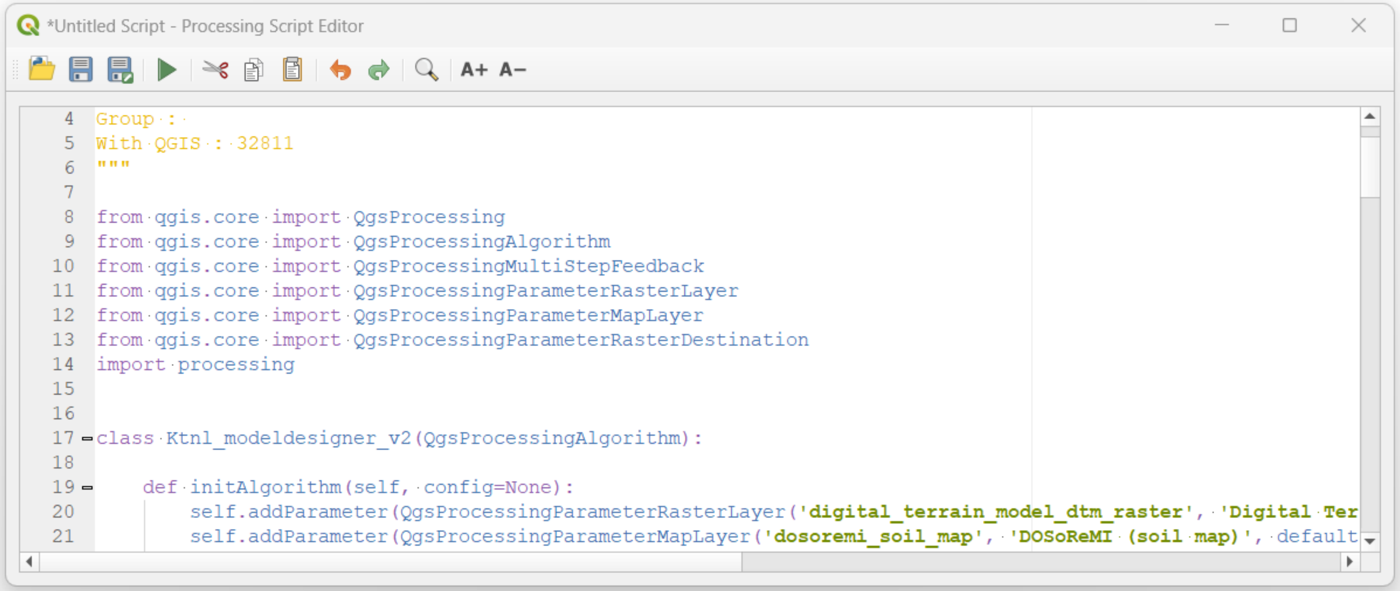
- Soil model
  - Static
  - **D**igital, **O**ptimized, **So**il **Re**lated **M**aps and **I**nformation
  - **= DOSoReMI**
- In-site measurements
  - Dynamic
  - Focused on:
    - Soil compaction
    - Soil moisture



Processing with open-source tools

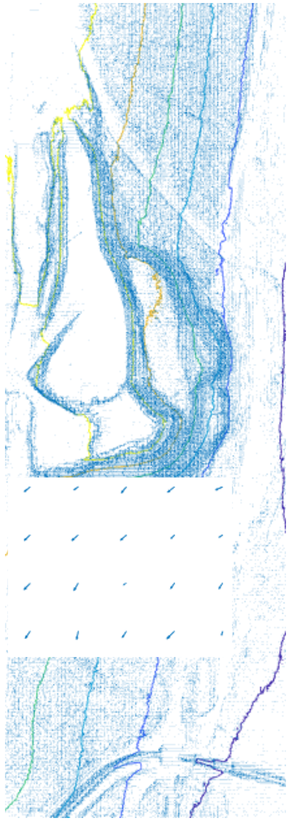
- Point cloud processing
  - CloudCompare
  - Python scripts
  - → DTM
  - → Vegetation
- GIS analysis
  - QGIS
    - GRASS GIS
    - SAGA GIS
  - Python

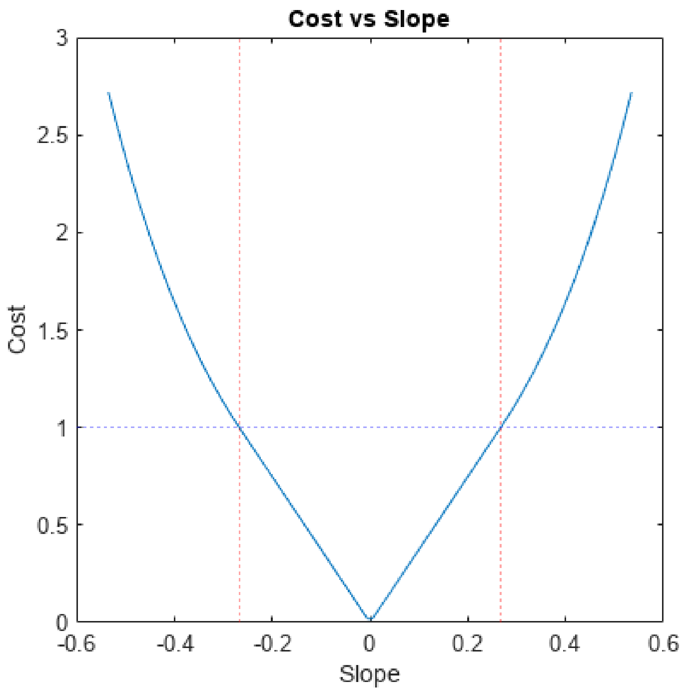


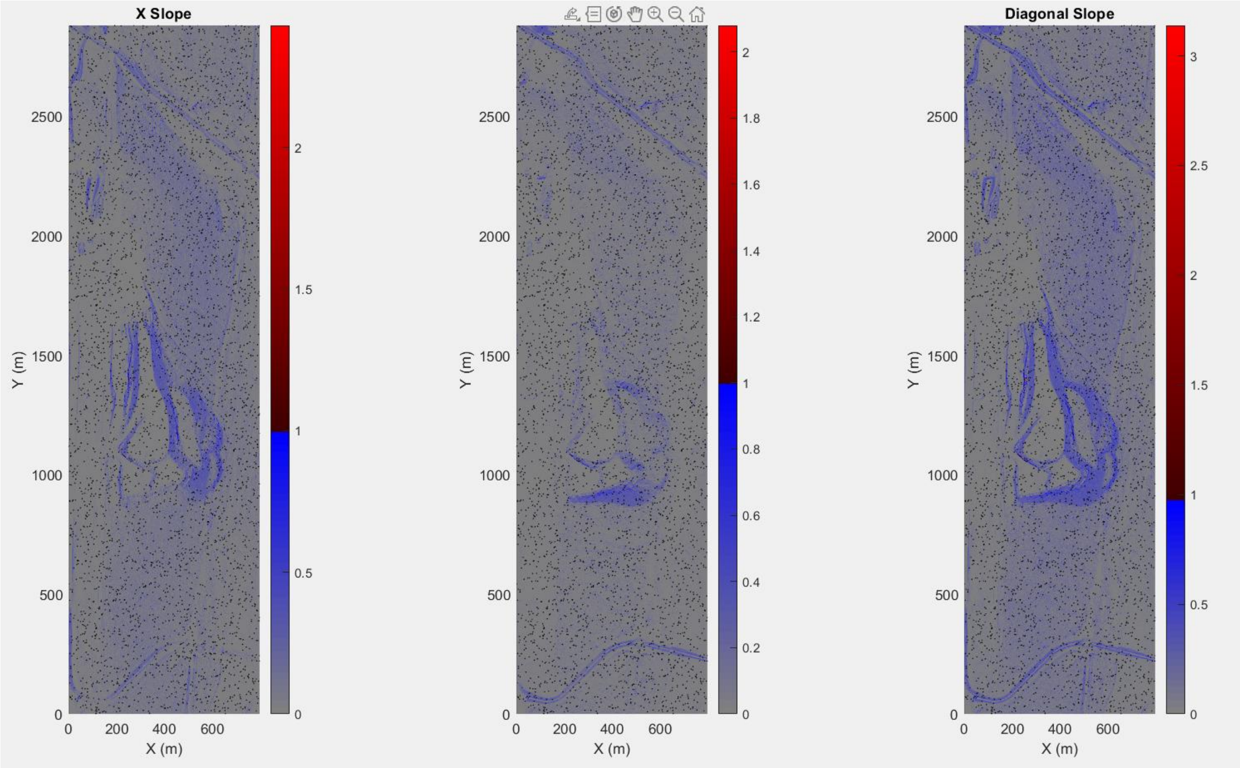


Preliminary results for CCM route planning

- Most data and corresponding weights required are available

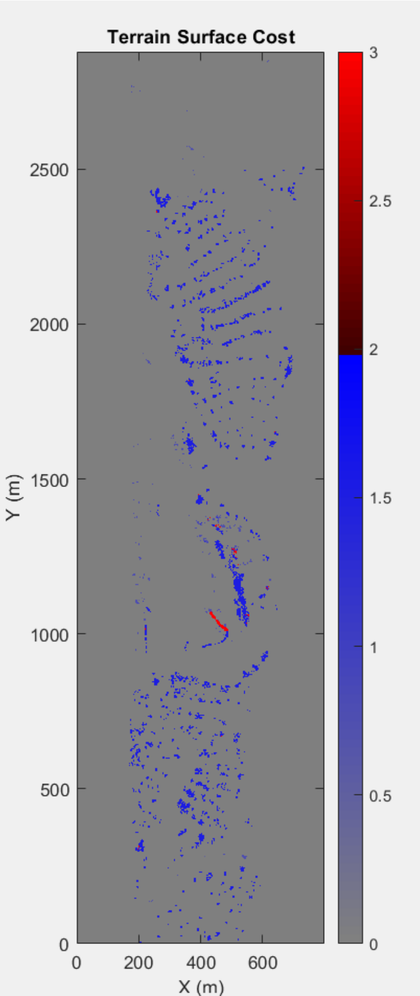


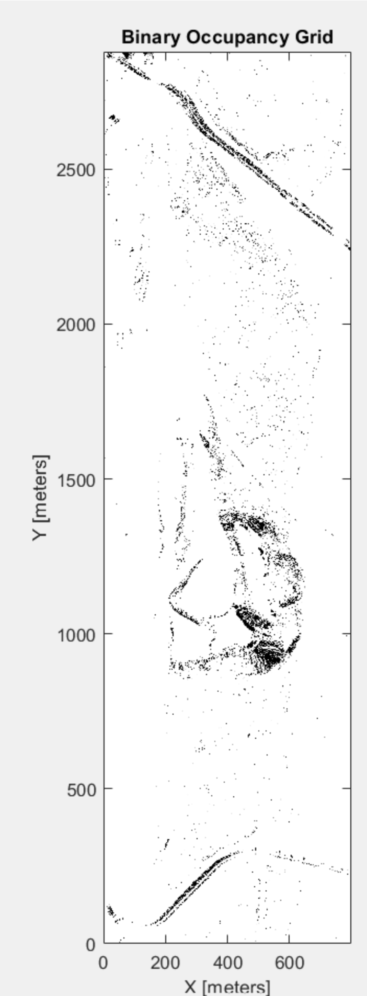


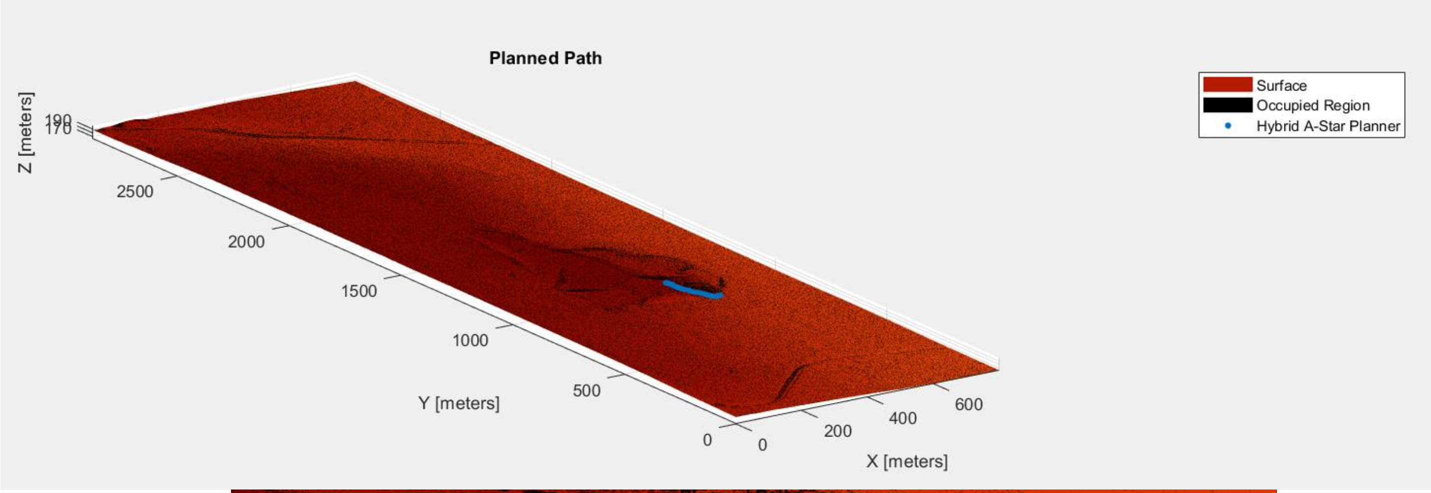


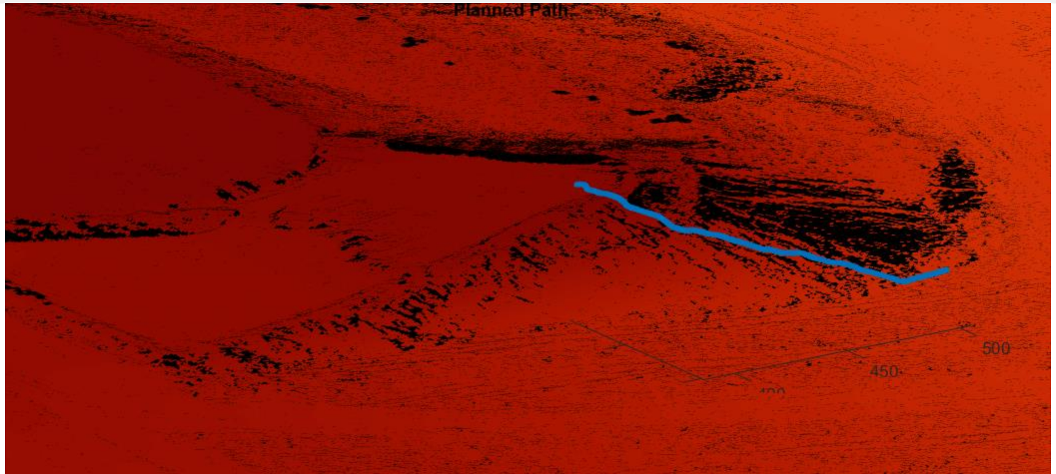
Preliminary results for route planning

- Hybrid A-start algorithm for trajectory planning (D. Dolgov et. al. Darpa Urban Challenge)



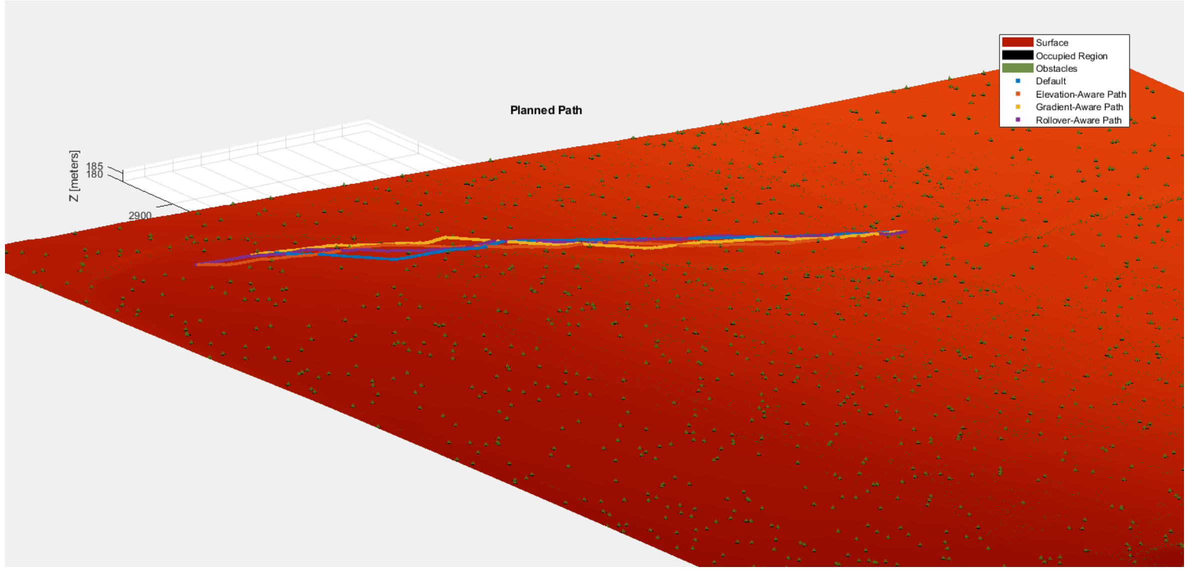


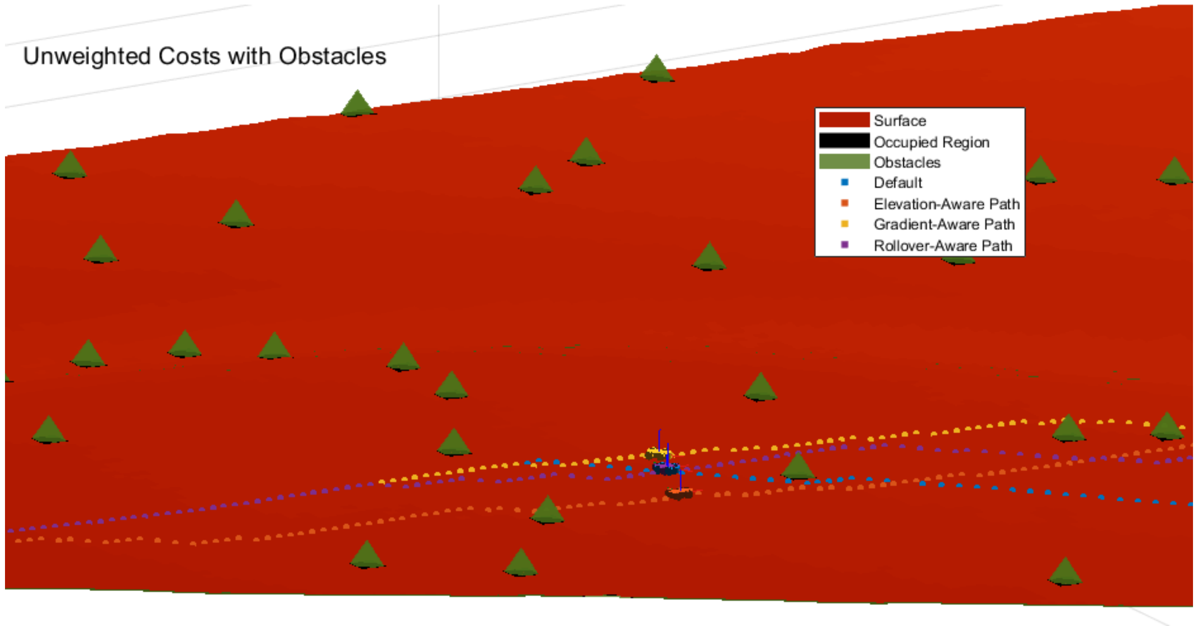




Examples

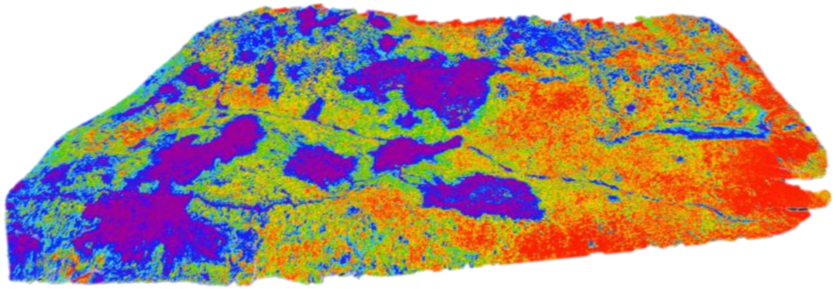
- Different weights and vehicle parameters lead to (slightly) different routes

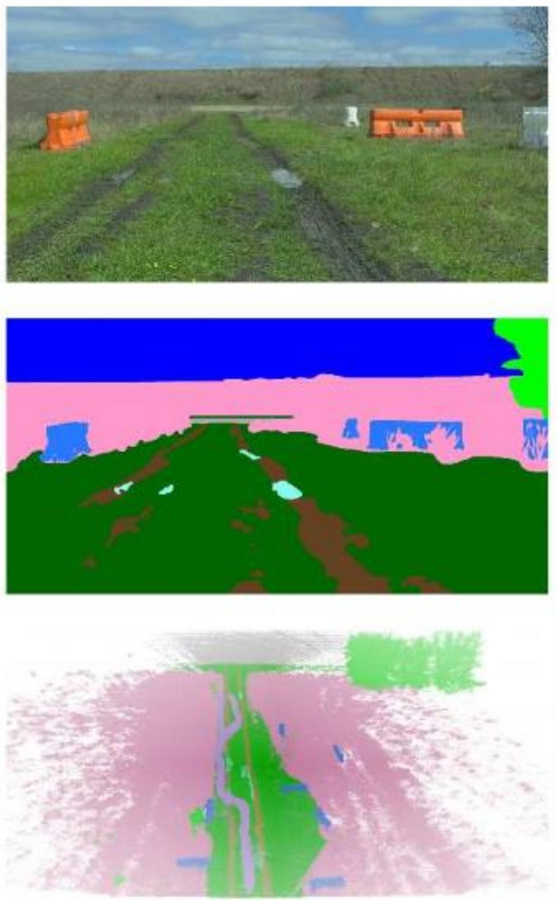




Future plans

- Real-time UAV-UGV cooperation
- Point cloud processing
  - ML-based object detection
  - Change detection
  - Updating map
- Other layers
  - From multispectral data
- Connection between layers
  - Based on vehicle parameters
  - Cost functions
- Automated processing
  - In Python environment





Source: https://github.com/unmannedlab/RELLIS-3D

Q&A.

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