Application of aerial remote sensing technologies in sustainable water management

Eszterházy Károly University
Research Institute of Remote Sensing and Rural Development

Envirosense Hungary Ltd.

Dezső Mikus

Geospatial Technologies for Sustainable Water Management 2017
ISEPEI workshop
Central European University, Budapest, Hungary
July 3-7, 2017

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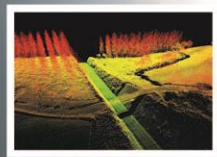
Overview

- Introduction of organisations
- Technical background
  - Airborne sensors
  - Field measurments
  - Data processing
- Case studies



Introduction

Eszterházy Károly University

Research **I**nstitute of **R**emote **S**ensing and **R**ural **D**evelopment

- Mission: **EKU RIRSRD** to conduct basic & applied RS research for the advancement of scientific knowledge about the environment.

- Team responsible for conducting all phases of RS operations (***flight/mission planning***, ***sensor maintenance***, ***data acquisition***, ***data processing***, ***data analysis*** *and* ***modelling)***

- **10+ years experience**:

  - R+D projects
  - Hyperspectral imagery
  - LIDAR and orthophoto
  - Image processing

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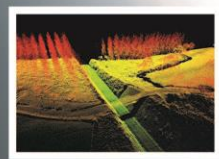



Introduction

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UNITED NATIONS | UNOOSA | UN-SPIDER

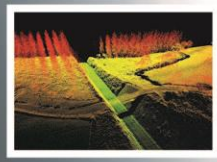
United Nations Platform for Space-based Information for Disaster Management and Emergency Response

INSTITUTIONAL SUPPORT OF THE DISASTER AND EMERGENCY RESPONSE PROGRAM OF THE UNITED NATIONS – UN SPIDER

United Nations Office for Outer Space affairs (UNOOSA) I.

UNOOSA is the United Nations office responsible for promoting international cooperation in the peaceful uses of outer space.

UNOOSA conducts international workshops, training courses and pilot projects on topics that **include remote sensing, satellite navigation, satellite meteorology, tele-education and basic space sciences** for the benefit of developing nations. It also maintains a 24-hour hotline as the United Nations focal point for satellite imagery requests during disasters and manages the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER).



Introduction
Envirosense Hungary Ltd

Envirosense Hungary Ltd. ⟶ spin off established in 2009.

- specialist of remote sensing, **production and processing** of images by **aerial** sensors
- Remote sensing **devices**:
  - aerial hyperspectral
  - airborne LiDAR technologies
  - digital imagery +processing of UAV and satellite images.
- **Fields of activities**:
  - Environmental protection / Nature conservation
  - Forestry
  - Agriculture
  - Urban development
  - Mining
  - etc.

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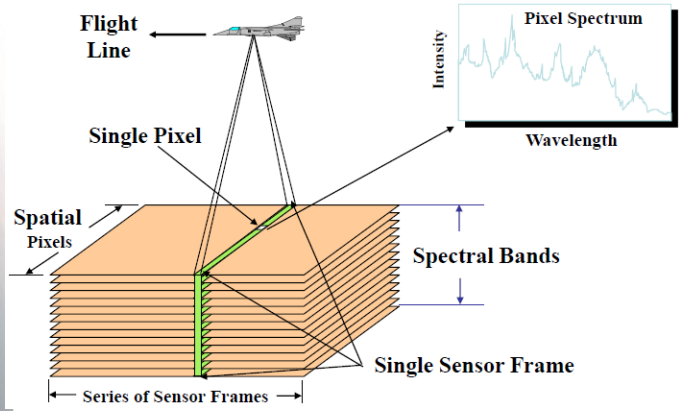
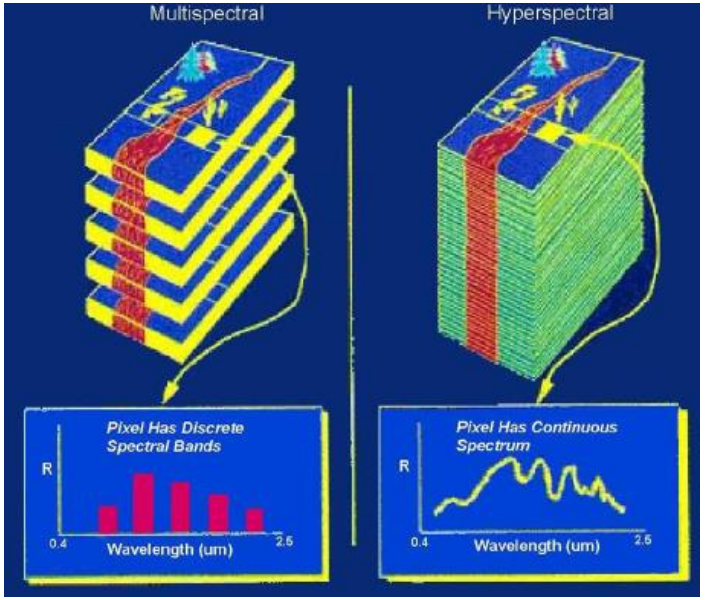
Airborne remote sensing
Hyperspectral imagery



What is spectral imaging? (hyperspectral imaging, imaging spectroscopy)

Each pixel is associated with simultaneous high resolution spectral information produced by a spectral camera



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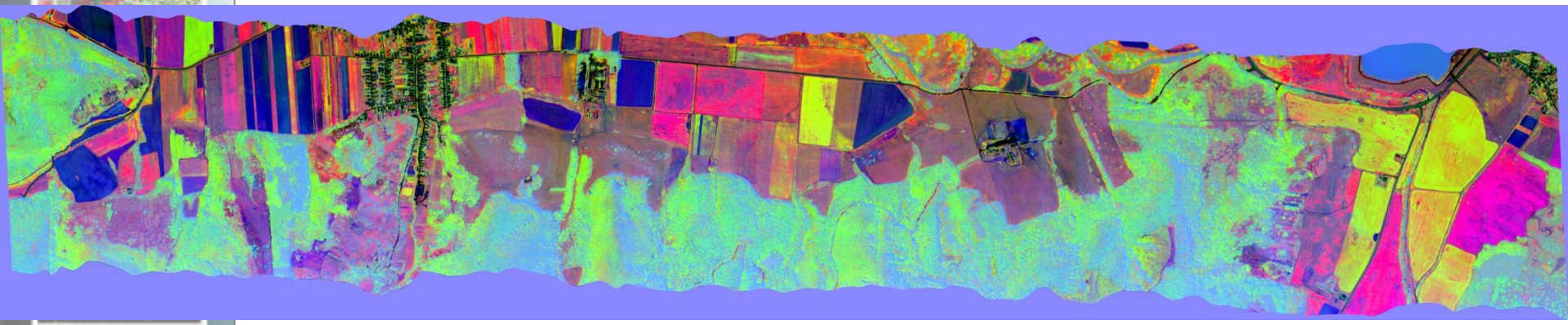
Airborne remote sensing
Hyperspectral imagery

Hyperspectral image in different displays
(Sajó valley, Hungary)

MNF (minimum noise fraction) – visible and near infrared bands



Data processing

AISA data processing chain

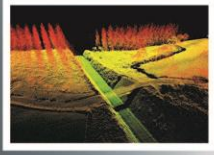
ow

image data set from the

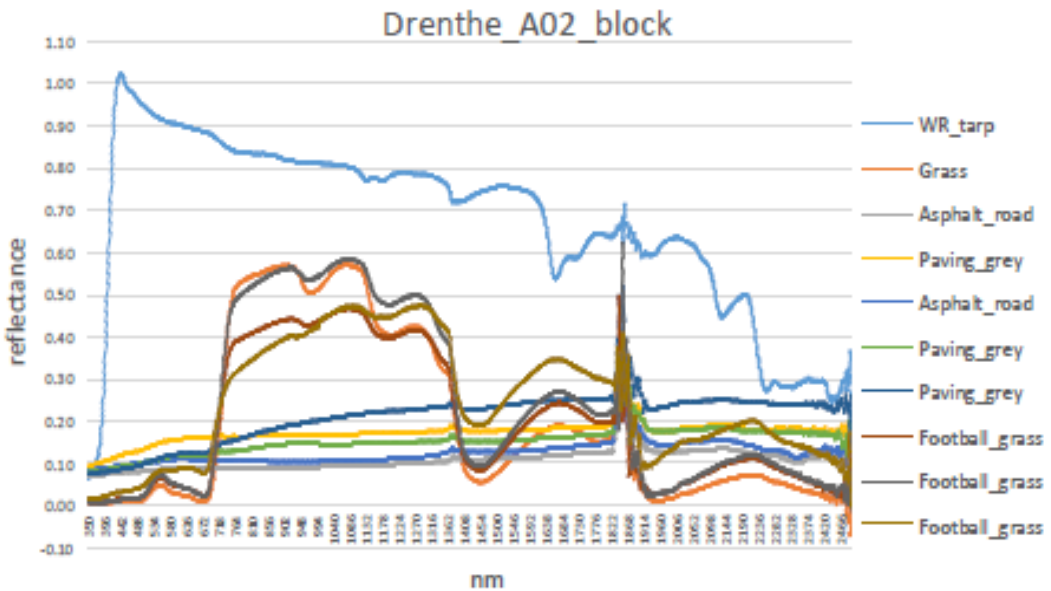
aircraft attitude) data

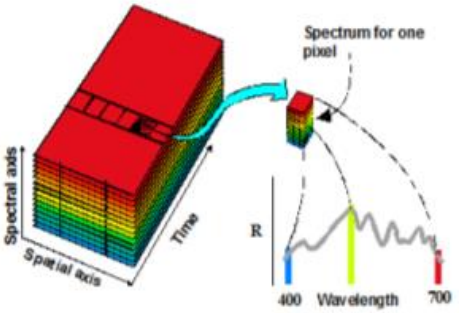
del (DEM)

Airborne remote sensing
Hyperspectral imagery








WR tarp


Grass


Concrete

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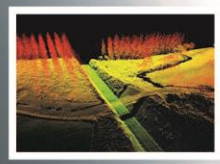
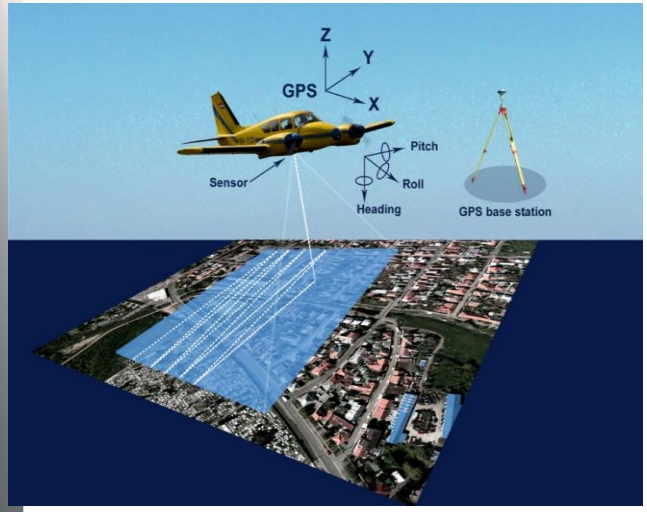
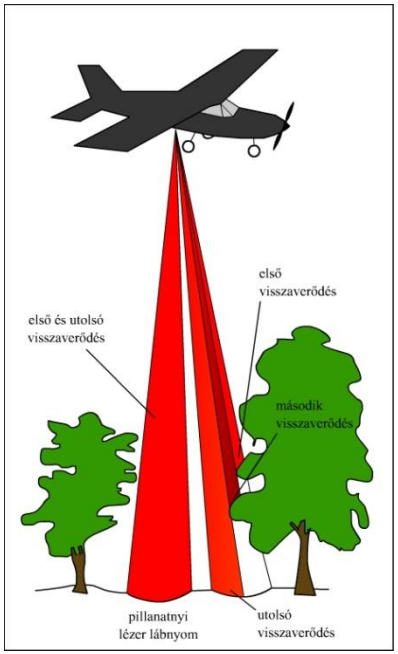
Airborne laser scanning (LiDAR)

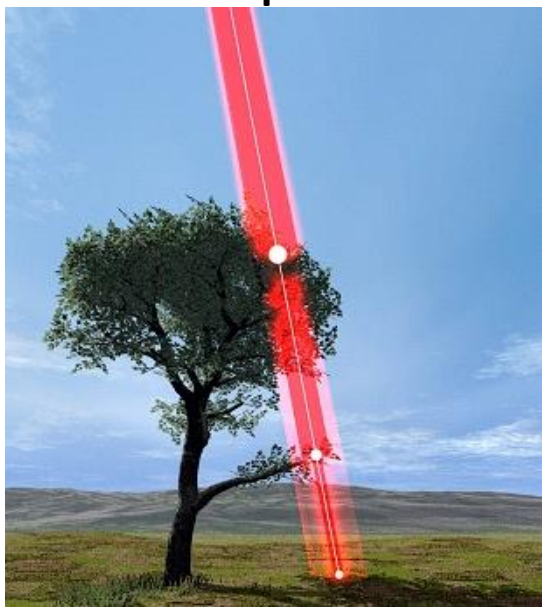
(**Li**ght **D**etection **A**nd **R**anging)







Multiple returnes



Point cloud classification

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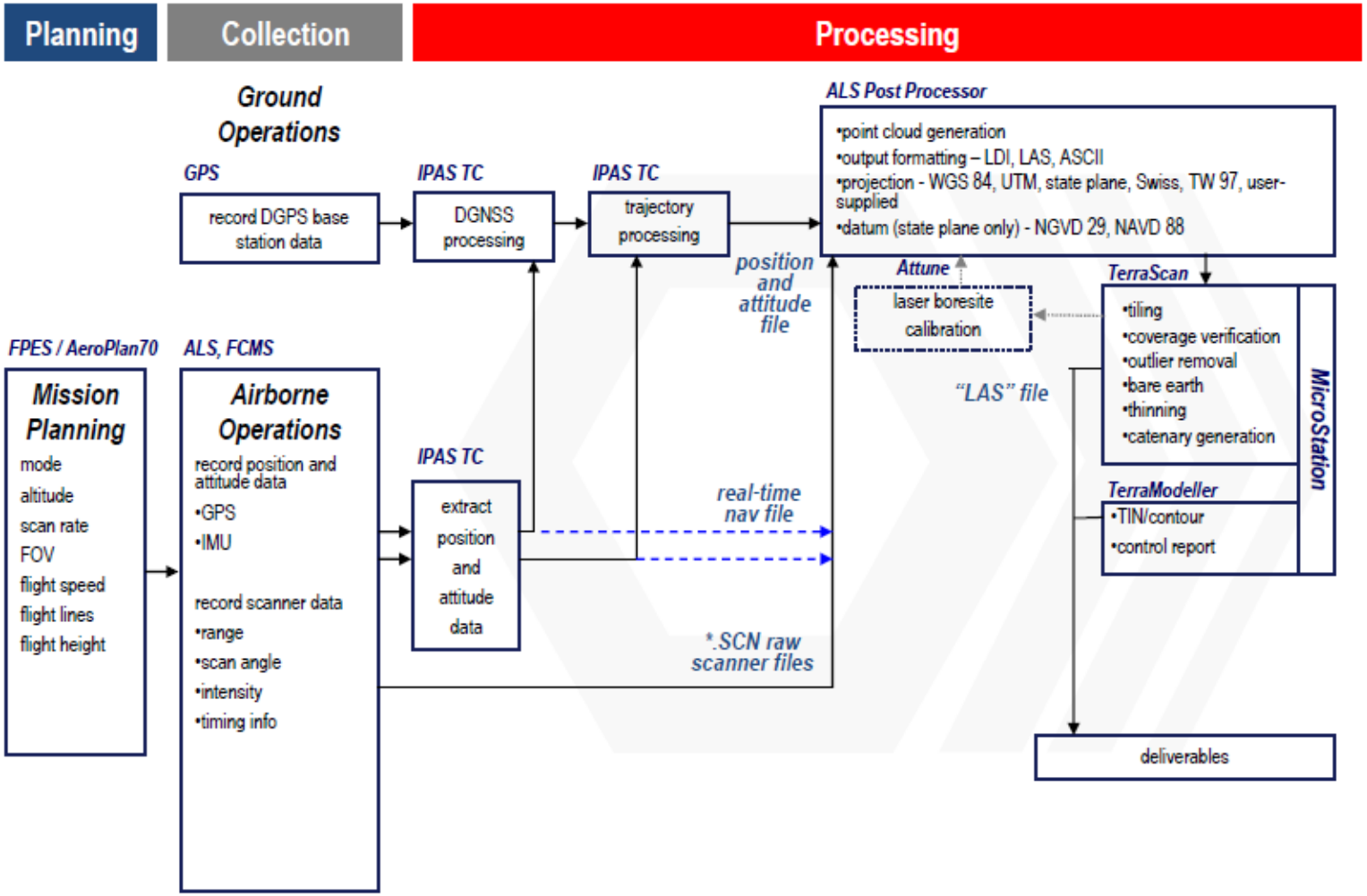
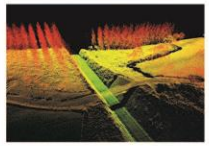
Data processing

Processing of LIDAR data and aerial digital images

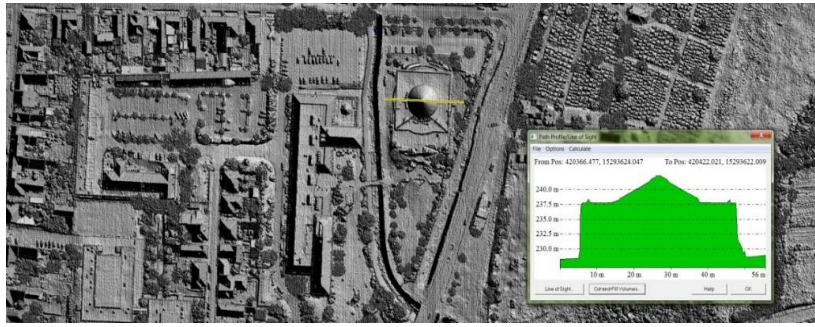
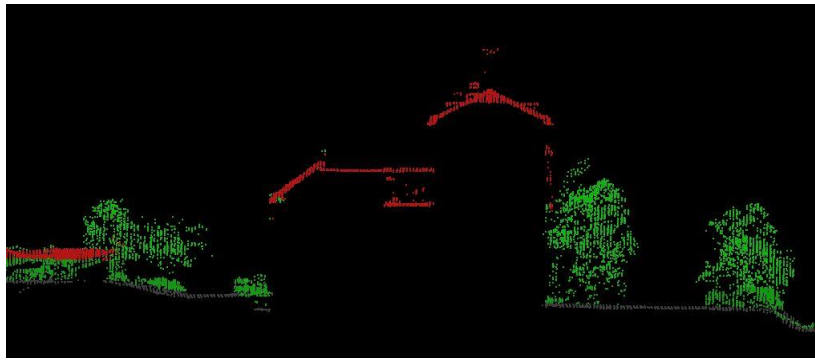
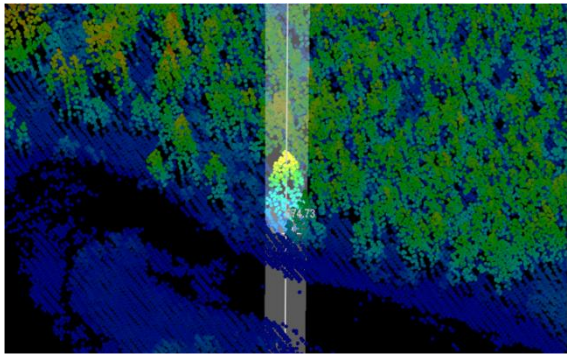


Airborne remote sensing
Advantage of LIDAR and aerial digital imagery



- Producing **DSM** and **DTM**, especially in **forested areas**
- **High accuracy** and very **dense measurement** applications, e.g., DTM generation and **volume calculation** in open pit mines, waste deposits, forest parameters
- DTM and DSM generation in **urban areas**, generation of **3D city models**
- Mapping of **corridors**, e.g., roads, railway tracks, pipelines, waterway landscapes
- Mapping of **electrical power lines** and **towers** including tree clearance
- Mapping **large area** (500-1000 km2/day)

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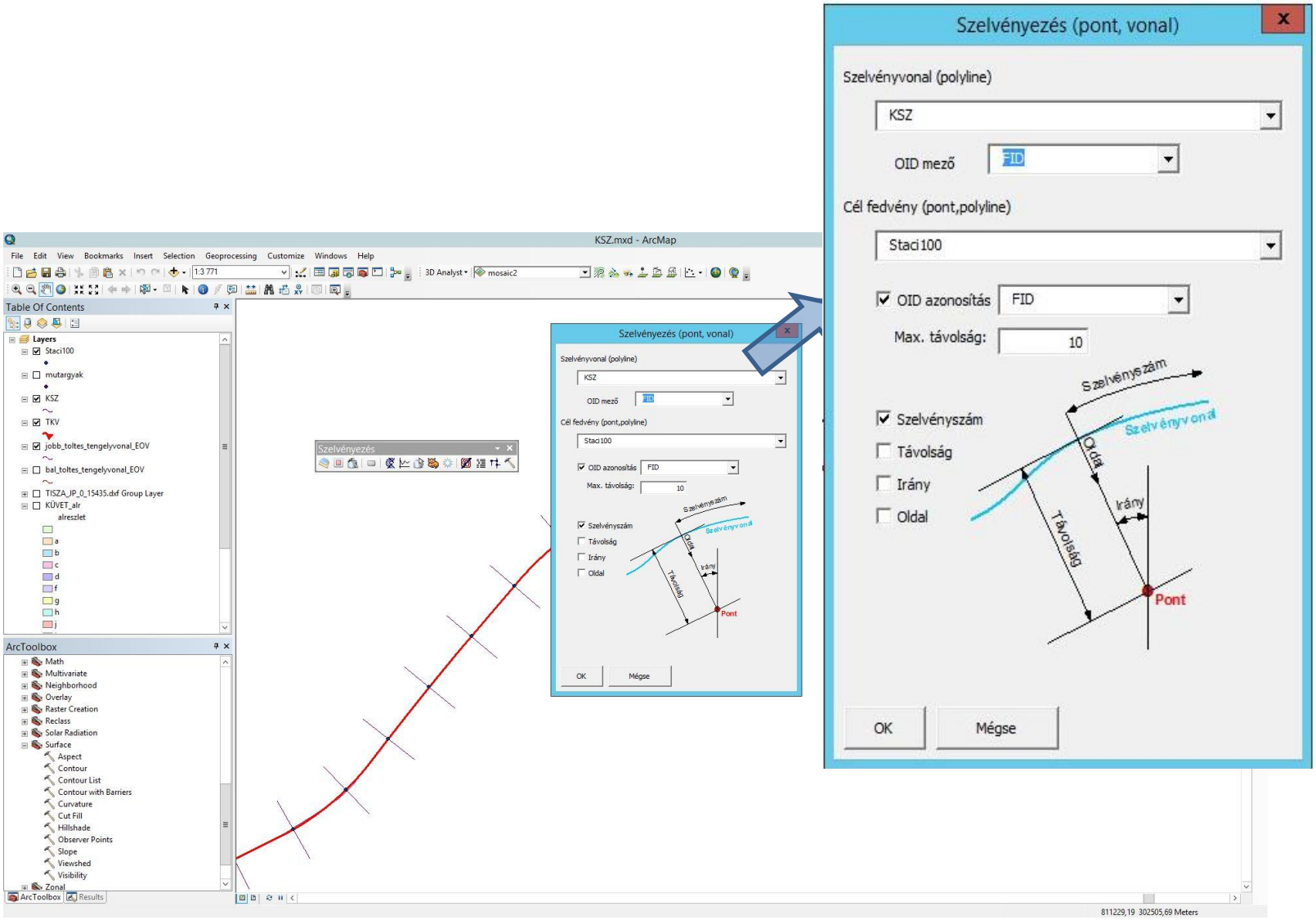
Cross-section generator application from LIDAR data

- Integreted to ArcMap software



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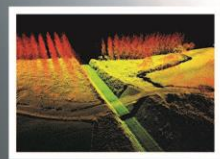
Ground based measurements
Airborne laser scanning (LIDAR) and aerial digital imagery



Ground survey with DGPS and base station for calibrating

- Reference points surveys with high accuracy DGPS
- Collecting GNSS data with base station (during airborne acquisition and post-process)


Airborne hyperspectral imagery :

- Reference surveys with field spectrometer
- Study and controll sites survey with DGPS
- Collecting ground samples (ASD FieldSpec3, etc)
- In situ measurments (WALZ Mini-Pam, etc.)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Data processing
Techniques and devices

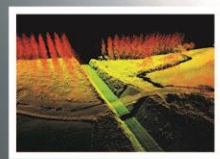
- **SGI supercomputer** SGI UV 2000 (24 db 2,4GHz Intel Xeon E5-4610 type CPU-144 core, total:1536 GB RAM)
- **SGI Octane III** high-performance graphics workstations
- **SGI C2108-TY11 server**
- **SGI C1104-2TY9 dual-node server**
- **RAID storage**

Case study I.

ASSESMENT OF FLOOD PROTECTION POTENTIALS IN THE SAJÓ VALLEY BY MEANS OF R/S SURVEYS

Aim of the project

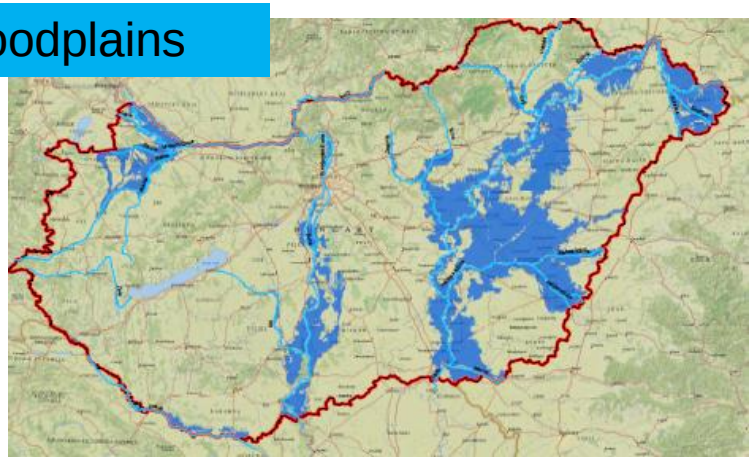
Improvement of flood protection and river basin management capabilities and
Improvement of the conditions of environmental protection and nature conservation of the crossborder region

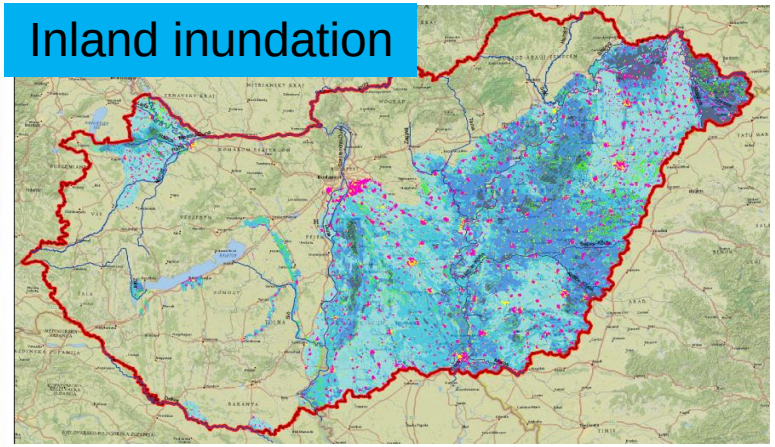


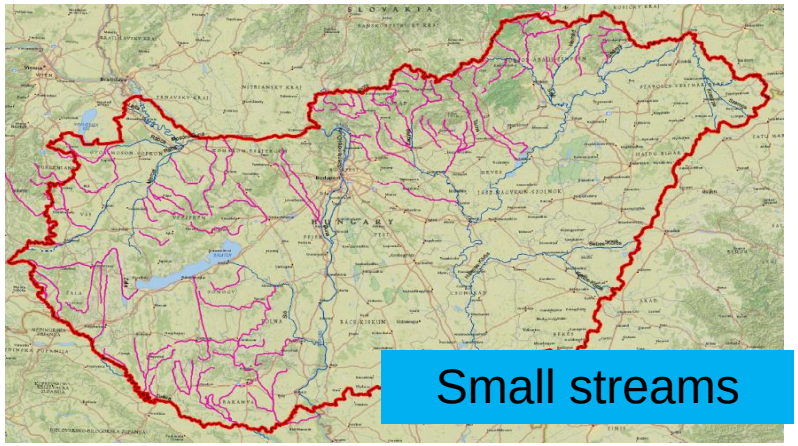
River basin management and flood protection are very important in Hungary

Floodplains



Inland inundation





Small streams

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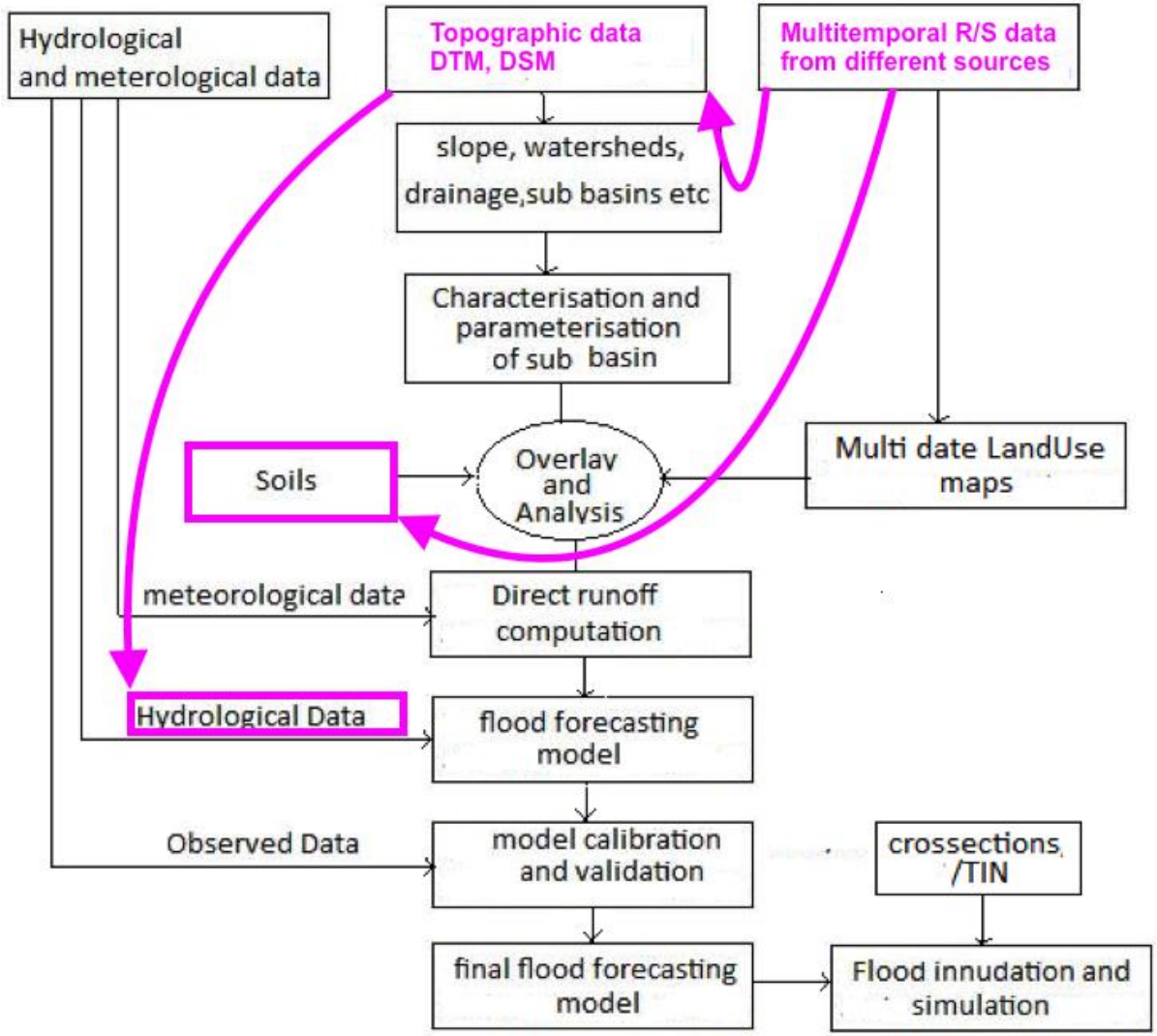

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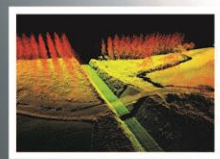
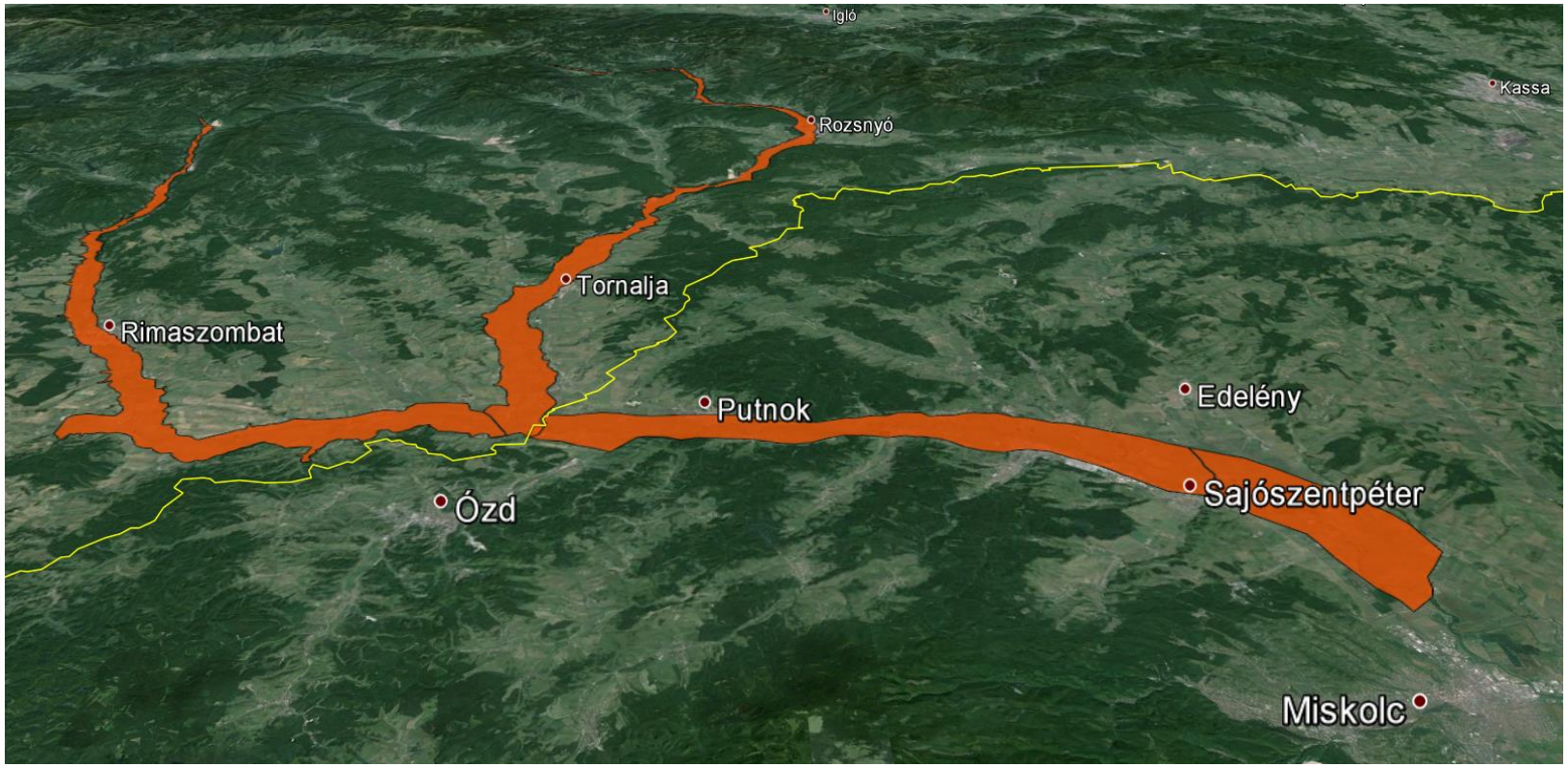




Total surveyed area: 300 km2



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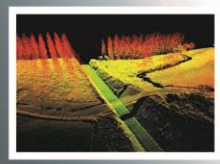




Airborne data collection:

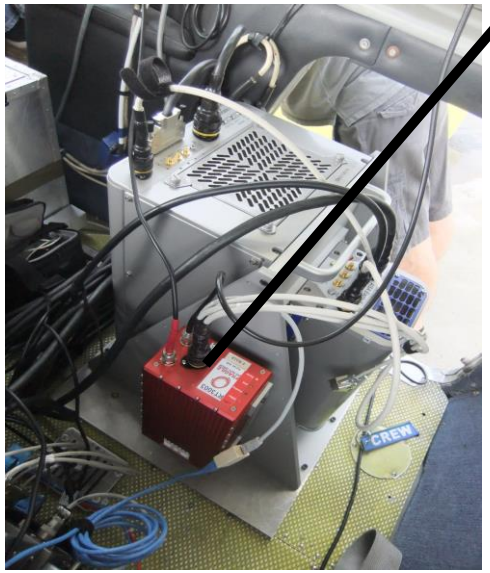
- hyperspectral imaging system (AISA)
- aerial laser scanning system (LEICA)
- digital camera (LEICA)
- in addition GCP and field spectrophotometer

Hyperspectral data aquisition

Main parameters:

Spectral range: 400-2450nm
Spectral sampling: 2.5-10nm
Number of spectral bands: 128-498
Swath width: 1024pixel
Scan rate: max. 150Hz
Radiometric resolution: 12bit

OxTS RT 3003 high accuracy GPS/INS



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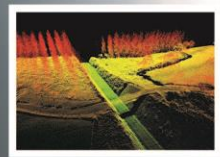
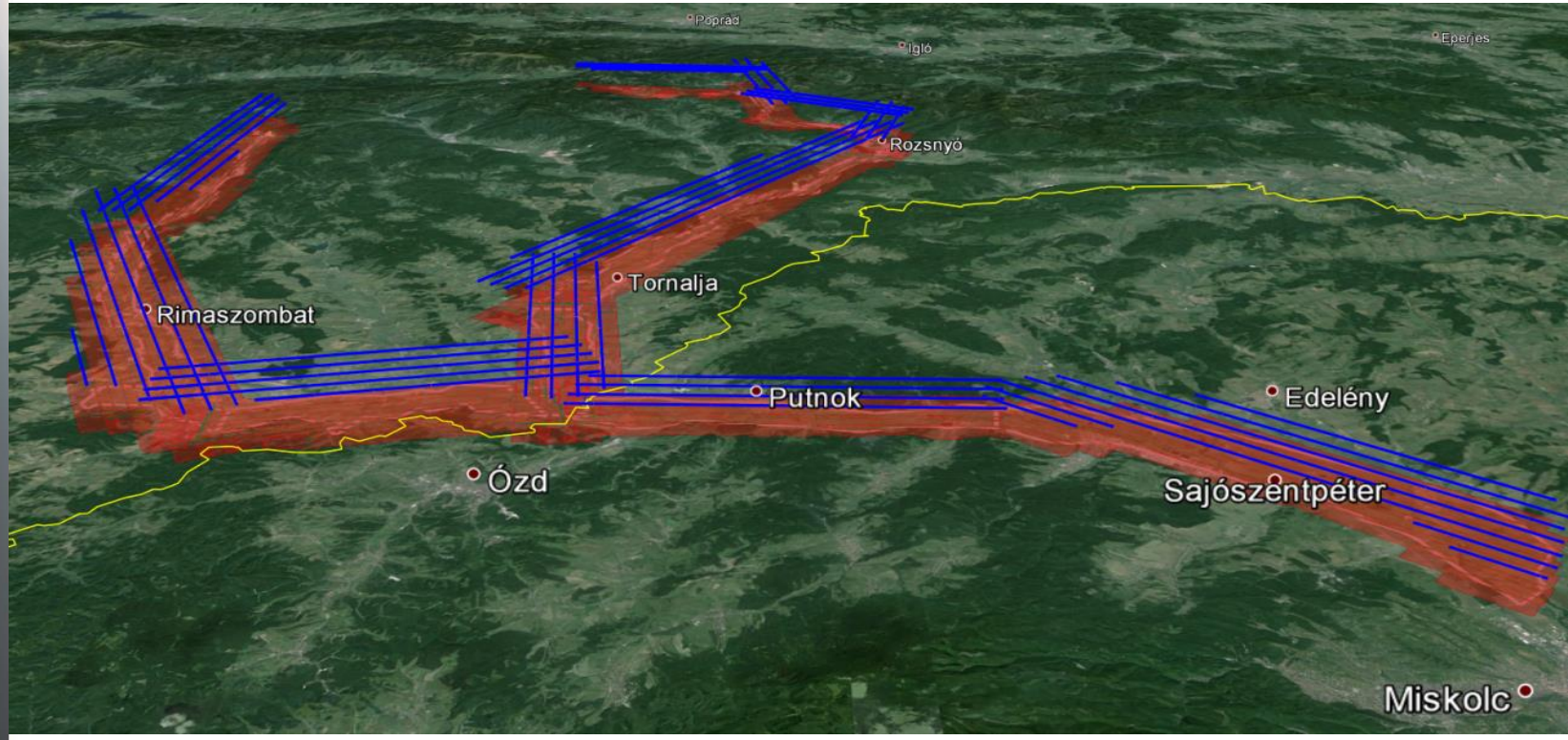




Hyperspectral flights

Number of flight lines: 51

Sensor: AISA Dual



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LiDAR and digital orto photo

Leica ALS-70 HP and Leica RCD 30 RGBN powerful digital aerial LIDAR sensor with built-in high precision GPS/INS system and 60 MP orthocamera

Maximum Flying Height (m AGL)	3500	
Maximum Measurement Rate (kHz)	500	
Field of view (degrees)	0–75 (full angle, user adjustable)	
Roll stabilization (automatic adaptive, degrees)	75–active FOV	
Scan patterns (user selectable) Maximum Scan Rate (Hz)	single	200
	triangle	158
	raster	120
Numbers of returns	unlimited	
Number of intensity measurements	3 (first, second, third)	
Accuracy	see graph	
Storage media	removable 500 GB SSD	
Storage capacity (hours @ max measurement rate)	6	

60 MP resolution (8956 x 6708 pixel)
Up to 4 cm GSD
Spectral resolution: RGB and NIR (780 – 900 nm)
50 mm focal length objective

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Data processing

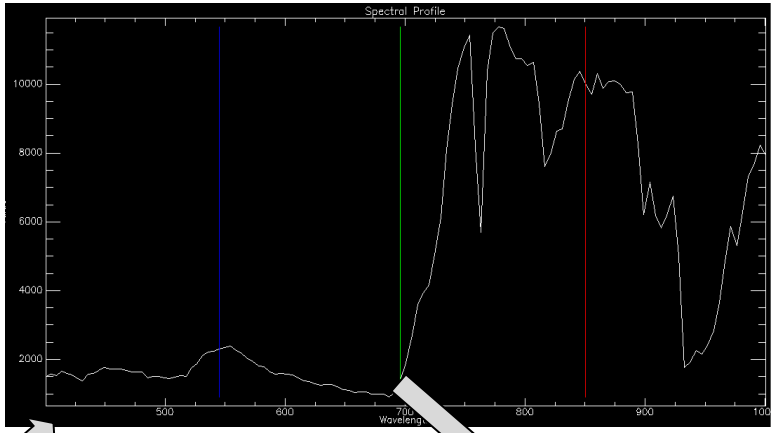
Softwares used:

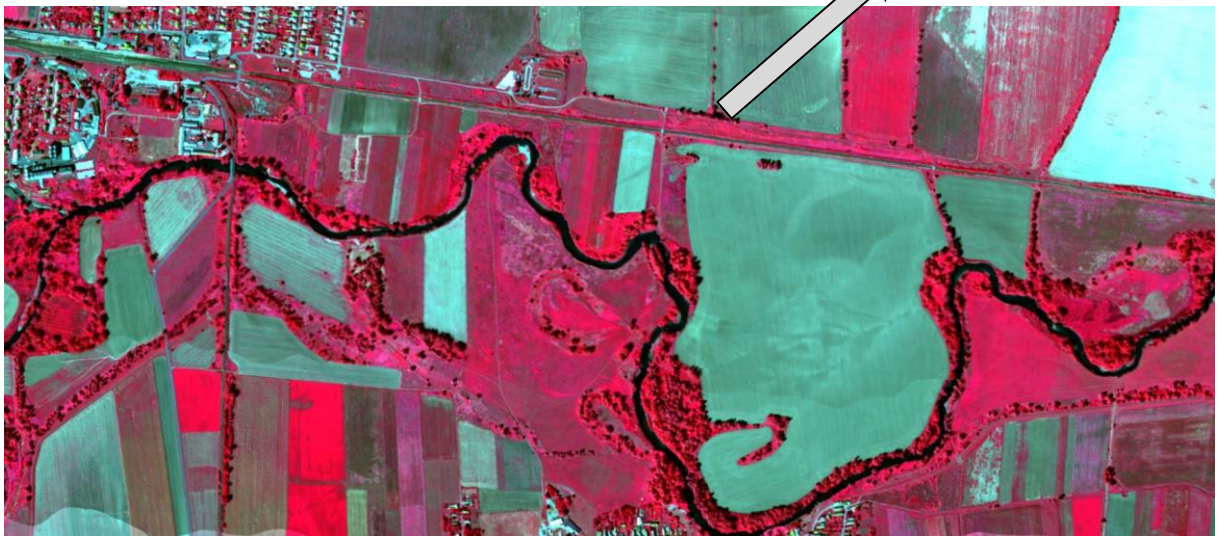
- ESRI ArcGIS 10.2
- ENVI/IDL 5.0
- Trimble eCognition 8.8
- OPALS (TU Wien)

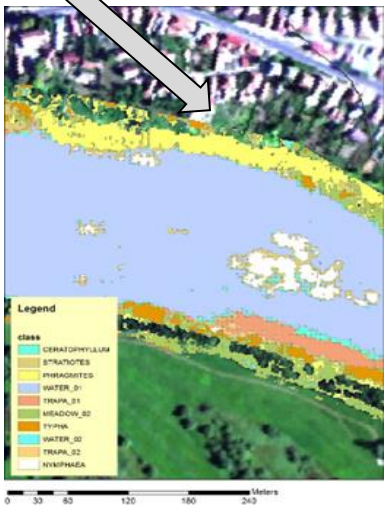
Results:

- Radiometric and geometric correction
- supervised classification
- object based image analysis
- normalized digital surface models

300 Gb of hyperspectral data
Spectral range: 400 – 970 nm
Spectral band width: 4,6 nm
Number of spectral bands: 128
Pixel size: 1,5 m







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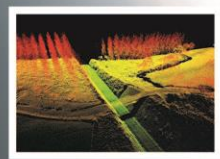
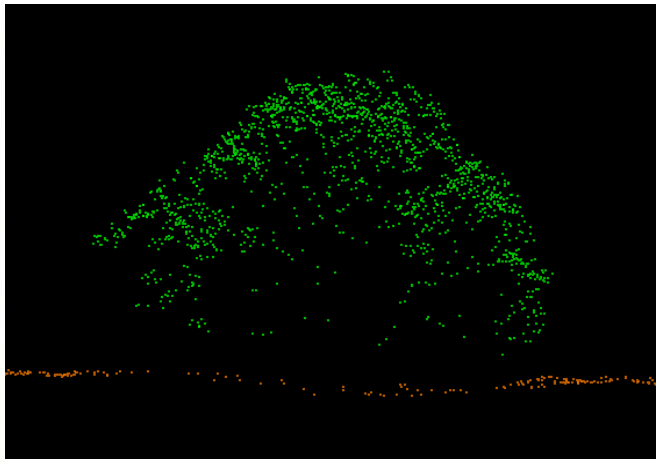
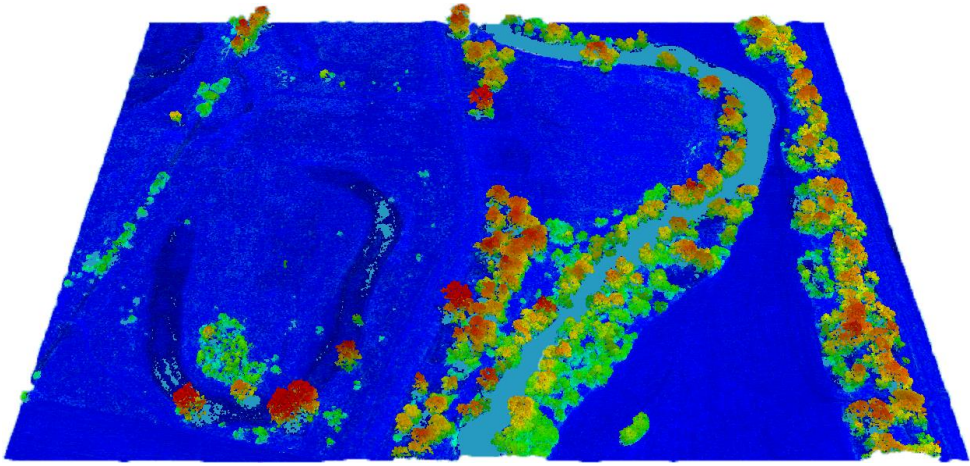




Total data size: 700 Gb
Full swath width: ~ 1300 m
Flight altitude : ~1400 m
Average point density:
5 point/m^2
Ortho GSD: 15 cm
Ortho accuracy: > 15 cm
RGB + NIR digital imagery





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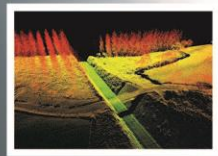
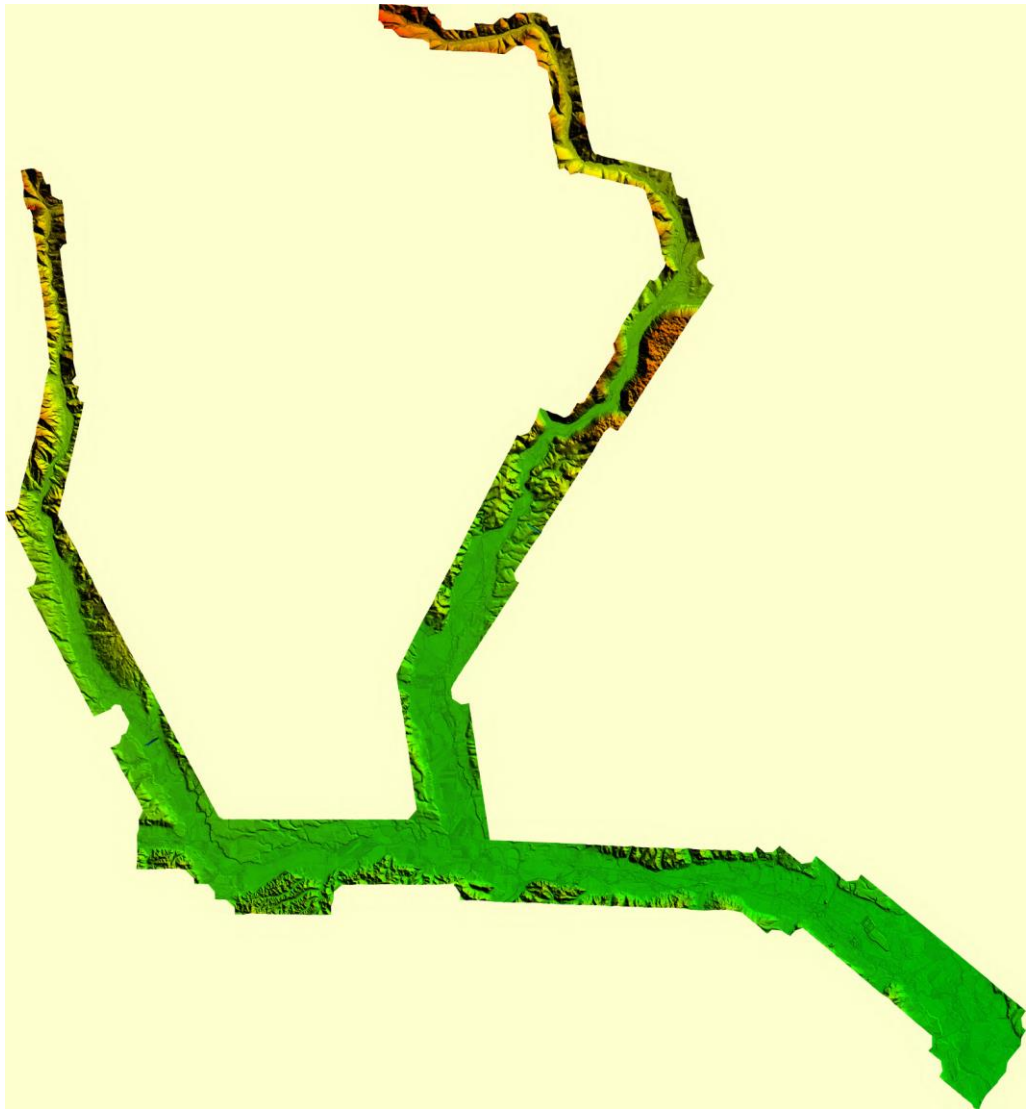
LIDAR based DTM of the total surveyed area



- 5 point/m^2
- classified pointcloud
- from 300 km^2 area more than 2 billion points recorded
- Digital Terrain Model
- Digital Surface Model



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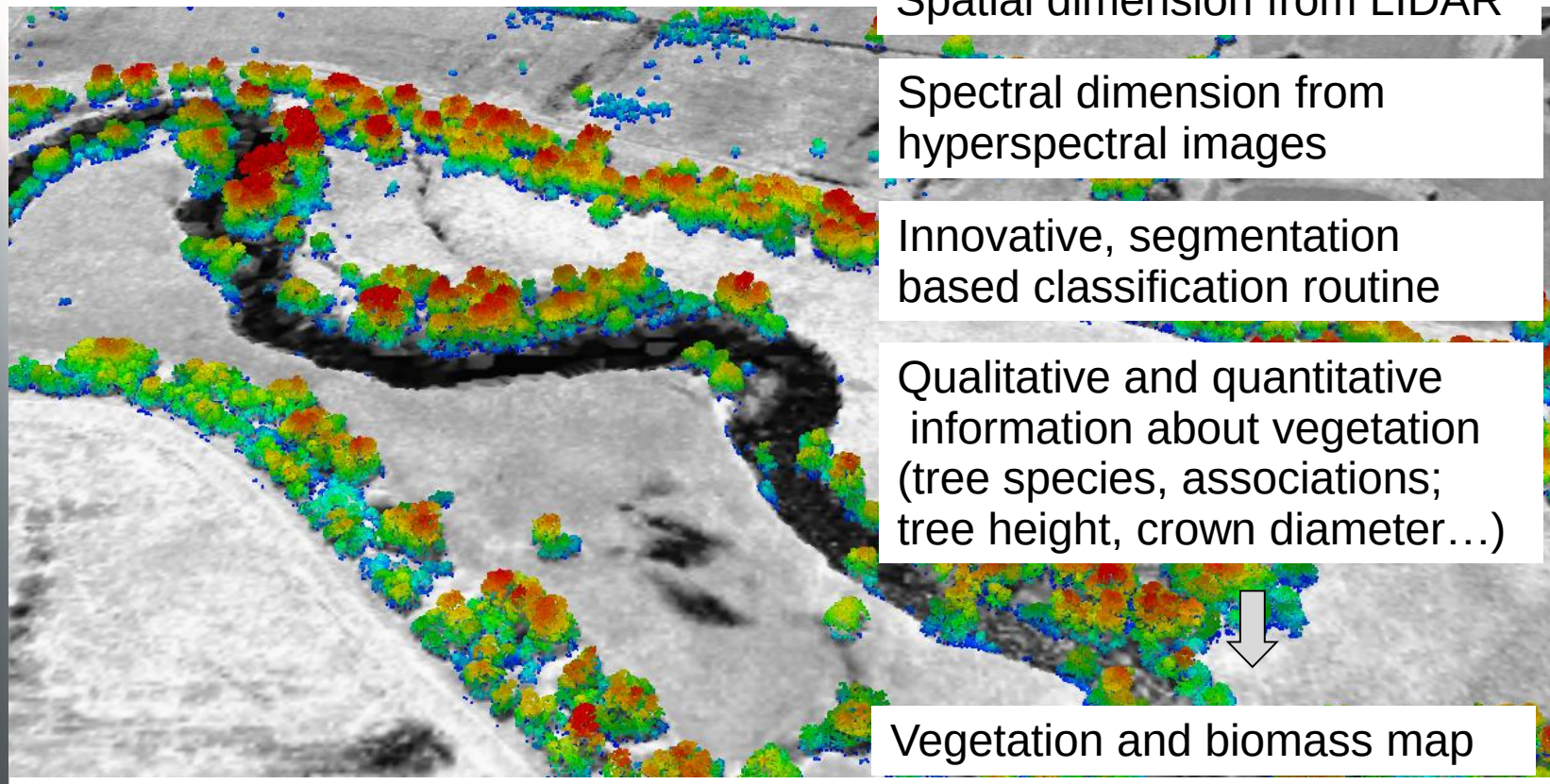
Vegetation map based on LiDAR & Hyperspectral data



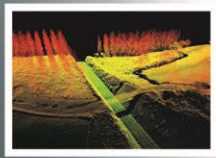
Spatial dimension from LIDAR

Spectral dimension from hyperspectral images

Innovative, segmentation based classification routine

Qualitative and quantitative information about vegetation (tree species, associations; tree height, crown diameter…)

Vegetation and biomass map



Modelling the use of emergencyflood water reservoirs

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Case study II.

Updating the flood-control plans on sections of River Tisza

Trans-Tisza Region Water Directorate (TIVIZIG) and North-Hungarian Water Directorate (ÉMVIZIG**)**

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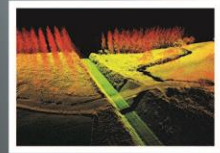
Aim of the project

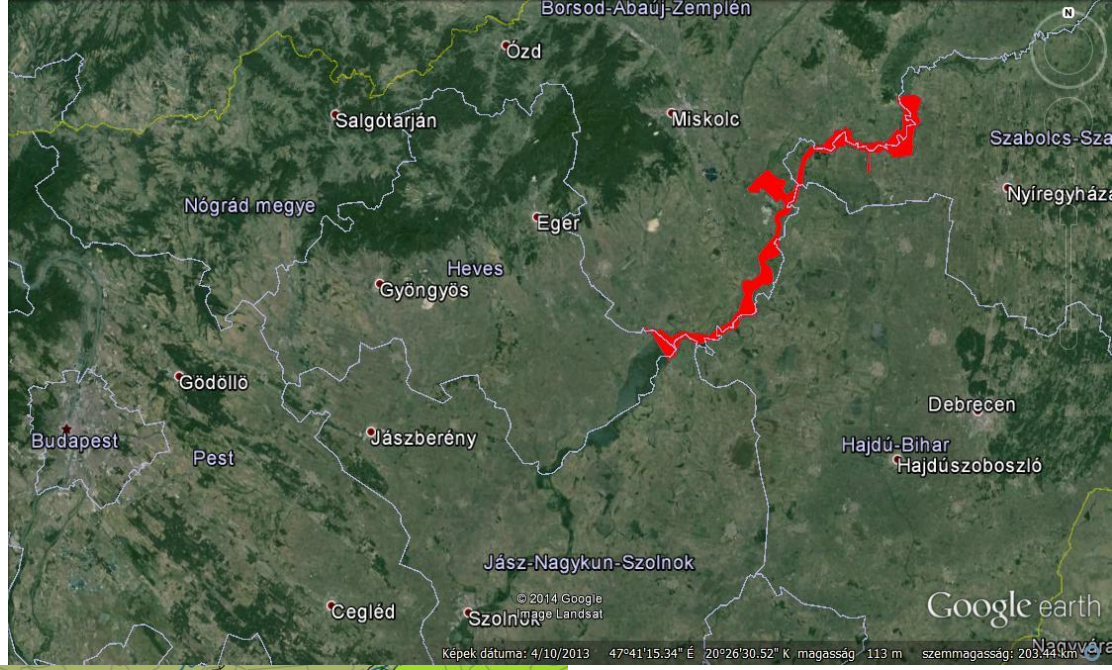
Updating flod-control plans

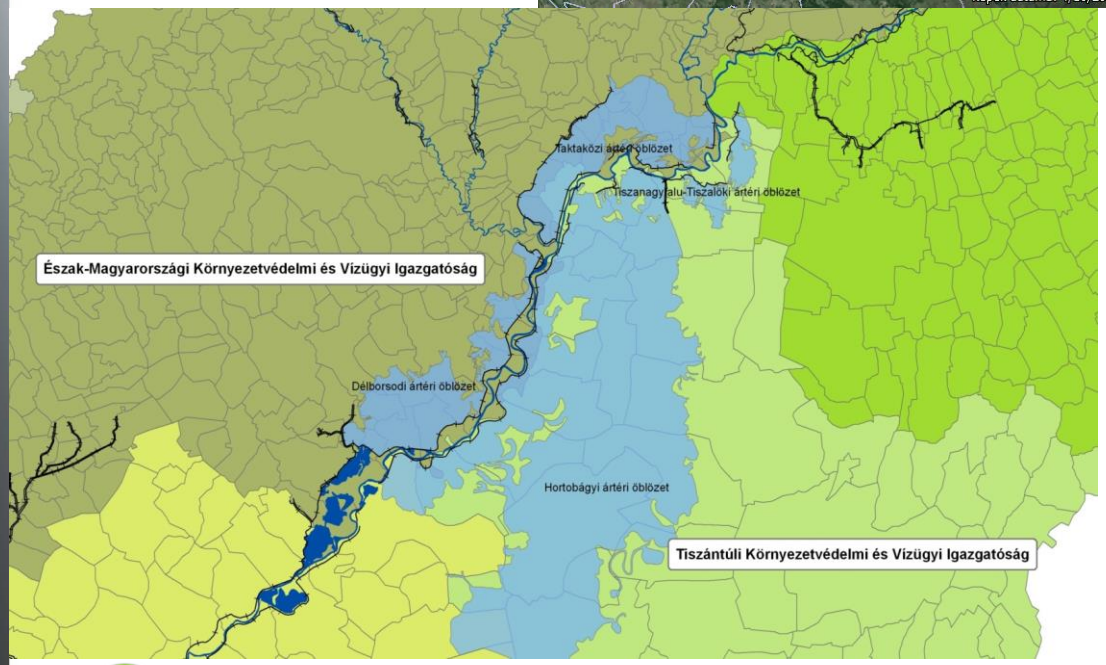
Mission:

- Airborne laser scanning (LIDAR)
- Aerial digital imagery (orthophoto production)
- Aerial hyperspectral imagery
- Landuse mapping and biomass estimation
- Ground based geodetic survey and data collection
- Bursting of dam simulation
- Compiling documentation of flood-control plan



The surveyed area (section of River Tisza, Hungary)





Floodplain bays impacted by the project

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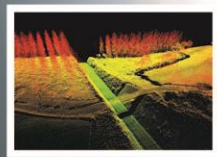
Applied remote sensing technolog

LiDAR and aerial digital imagery d*evice*

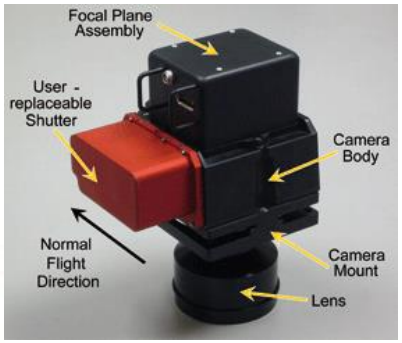


<u>LIDAR sensor (RIEGL LMS-Q680i) parameters:</u>

Range of the laser → up to 5000 m
Recommended maximum flight high → up to 3000 m above the ground
Laser impulse range → 80 – 400 kHz
Scanning frequency → 0 - 70 kHz
Field of view (FOW) → 30 -60°
Multiple echoes per impulse →1 - 4

Ortho images made with
Leica RCD105 digital medium format camera
together with LiDAR survey

Laser scanning (LIDAR) system
RIEGL LMS-Q680i



Leica RCD105

Aircraft
(Cessna TU-206E (285 HP)

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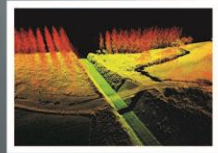
Airborne laser scanning (LIDAR) and aerial digital imagery

Acquisition and results



Georeferenced point cloud:

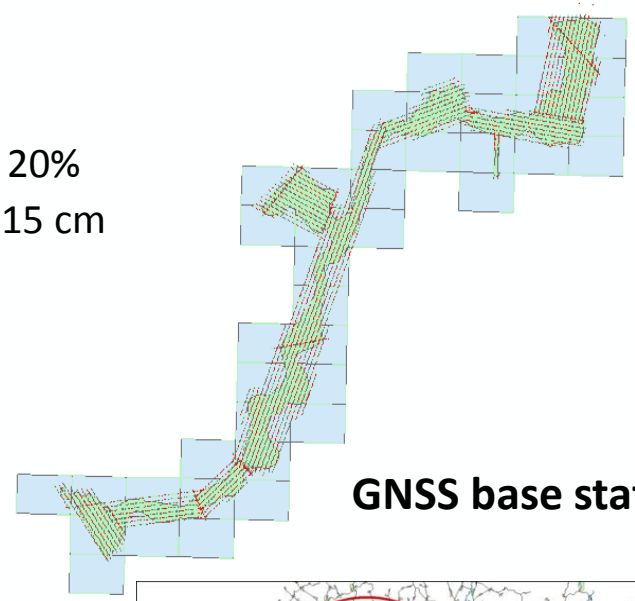
- average point density: 4 points/m2
- longitudinal overlap between each bands: 20%
- relative accuracy of the laser scanning: +/-15 cm (horizontal / vertical)
- 420 pcs UTM projection, LAS files

DTM, DSM, nDSM files

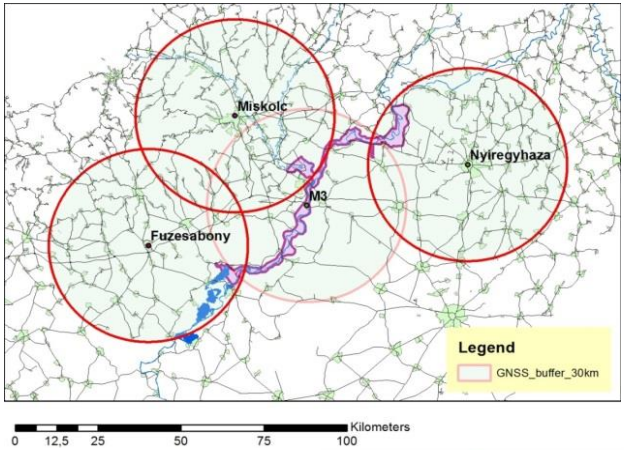
Orthophoto TIFF-s:

- ground resolution: 10 cm
- transverse overlap: 30% (average)
- longitudinal overlap: 60% (average)
- 5700 images

Project area and flight lines



GNSS base stations



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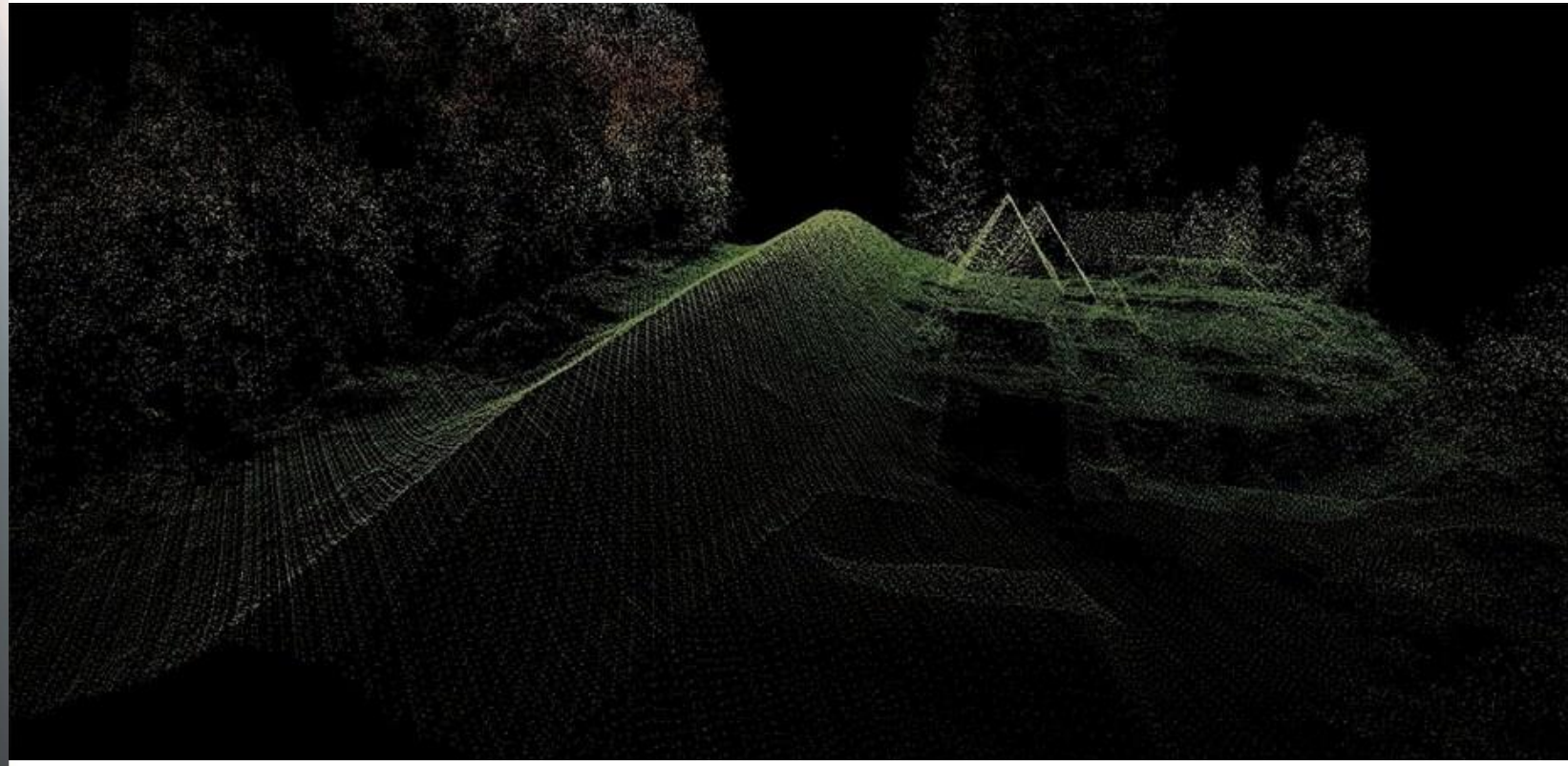
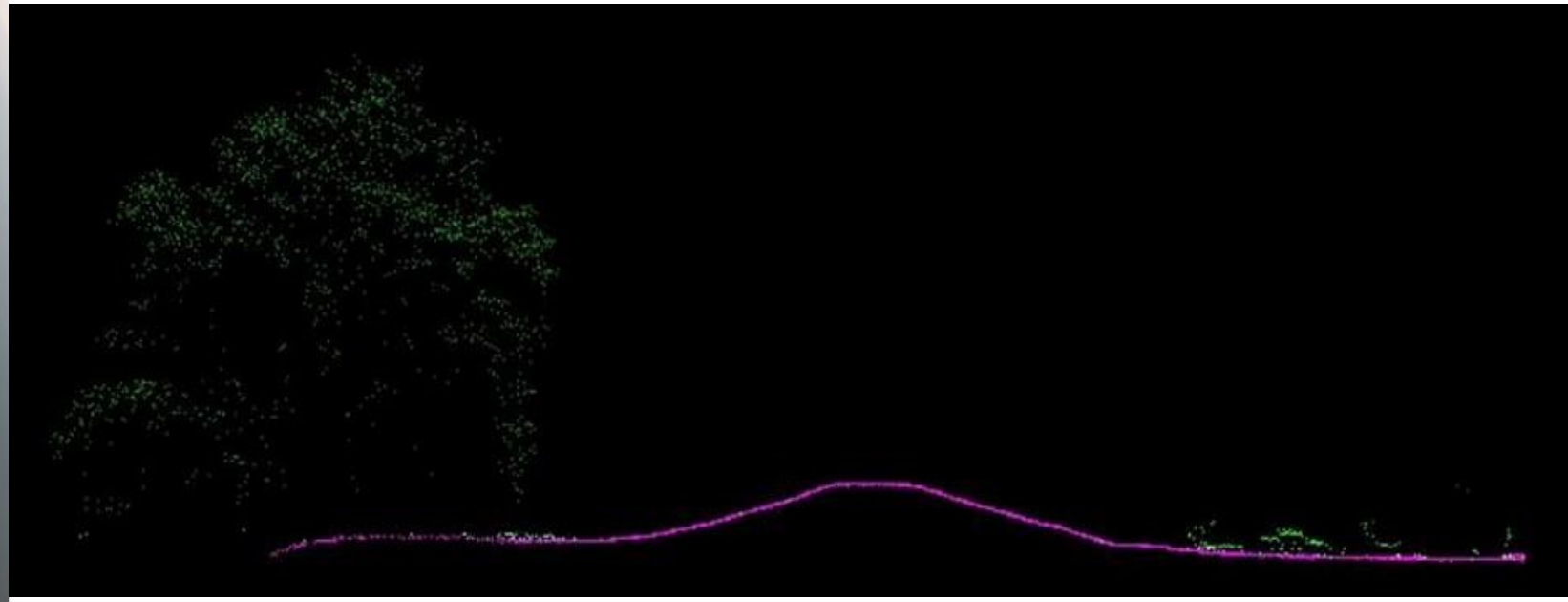
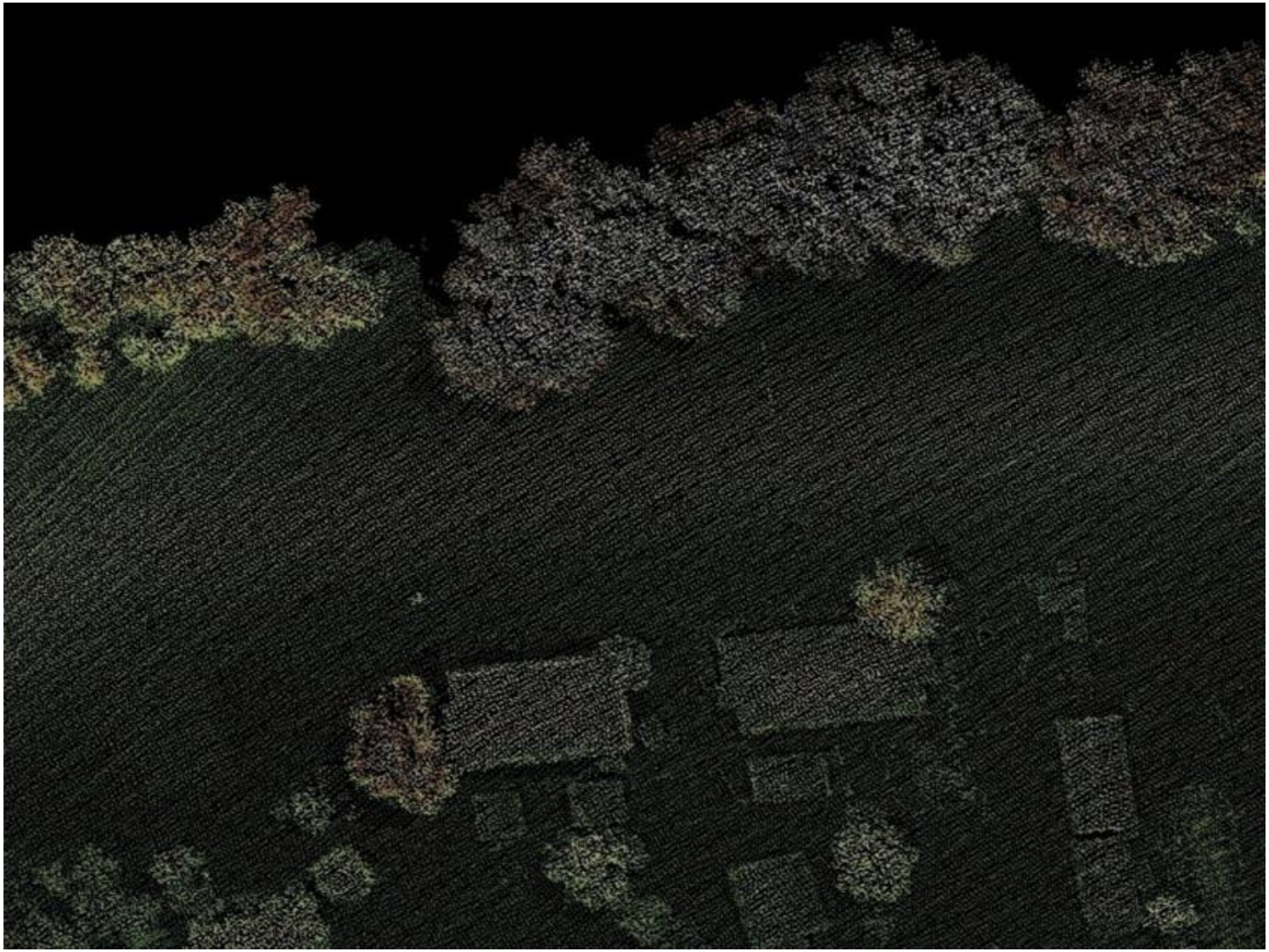
3D image of LIDAR point cloud



Profile image of LIDAR point cloud

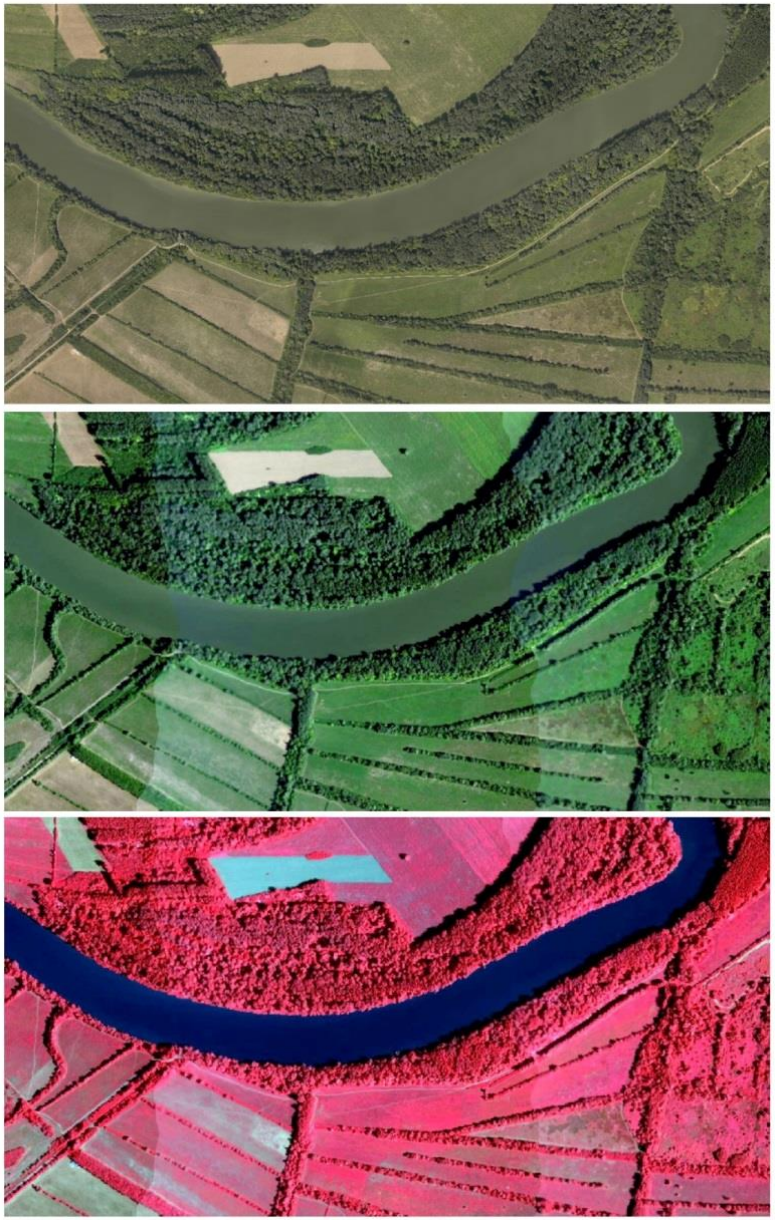


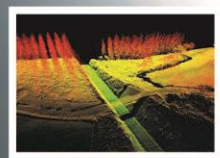
LIDAR point cloud
Plan view



Orthophoto and its enlarged details

RGB and NIR ortho images





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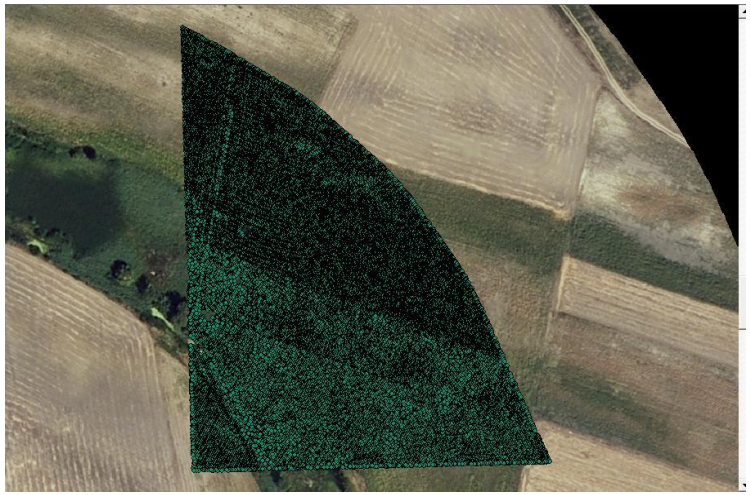
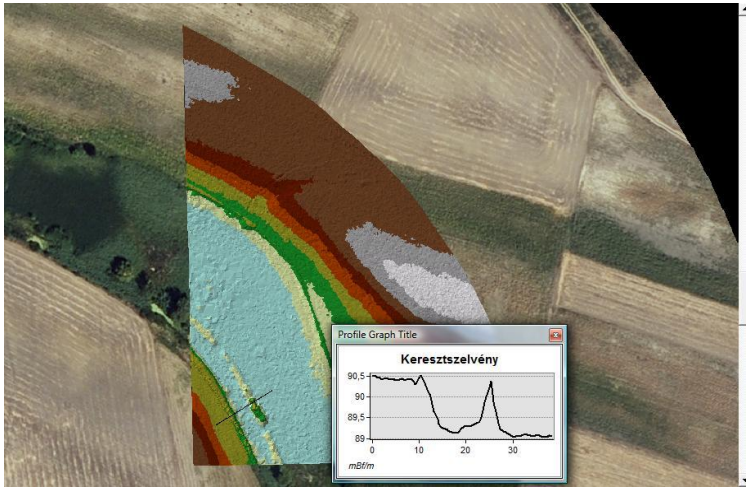
LIDAR image processing



LIDAR image

Orthophoto



TIN model
(triangulated irregular network)

Applied remote sensing technologies

Airborne hyperspectral imagery d*evices*

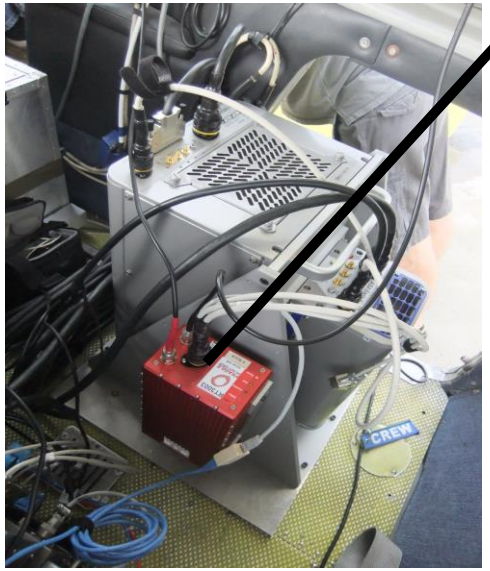
AISA Dual K1 hyperspectral sensor with high accuracy GPS/INS system (Ox RT 3003)

AISA Eagle (VNIR) + AISA Hawk (SWIR)

Parameters:

Spectral range: 400-2450nm
Spectral sampling: 2.5-10nm
Spectral band: 128-498
Bandwidth: 1024pixel
Maximum pulse rate: max. 150Hz
Radiometric resolution: 12bit
Geometric resolution (max), 0.5m

OxTS RT 3003 high accuracy GPS/INS



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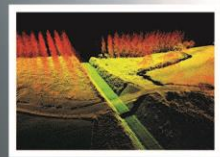
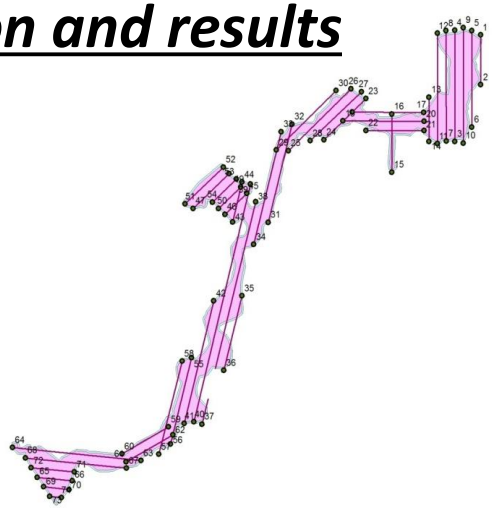
Airborne hyperspectral imagery *Acquisition and results*



- High accuracy vegetation and landuse map
- High ground resolution (0.5-1.5 m)
- Vegetation associations level and species-level data extraction from classified hyperspectral data
- Supervised and unsupervised classification methods applied for vegetation analysis.
- Digital spatial database of the vegetation prepared by the determination of the biomass of the floodplain.
- Caracteristics of digital spatial database of the vegetation :
  - Geometric resolution: min. 0.5*0.5 pixel size
  - Accuracy: min. 75% reliability for each vegetation categories
  - Total accuracy: min. 80%
  - EOV and UTM34N



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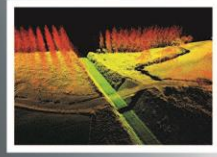
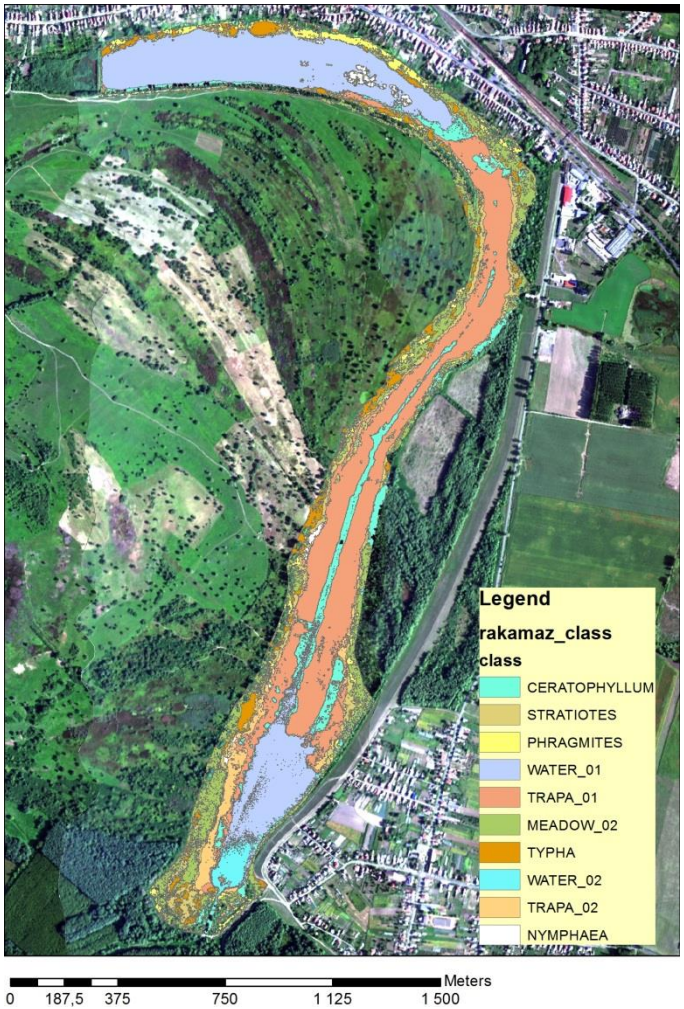




Vegetation map
(Rakamaz – Nagy-Morotva)



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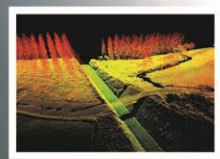
NIR hyperspectral mosaic in project area

Landuse map

- The landuse classification was based on ground based reference points.
- Species-level data were recorded by sub-meter accuracy GPS device.
- The 0.5 m ground resolution geometrically and radiometrically corrected hyperspectral images and DTM and DSM layers, generated from the LIDAR data, were applied for the image classification.

Biomass estimation



Several parameters used for tree biomass estimation:

- nDSM max: surface model produced from LIDAR DSM and DTM
- Canopy limit: surface smoothed canopy segments based on nDSM
- Tree species identification: classification performed on forest areas by the classification of hyperspectral images
- LIDAR layer indices: rates of the different reflectance values and intensity layer
- Cover test: for land cover assessment, model calculation was made by the Normalized Difference Vegetation Index (NDVI) calculated from the near infrared (799 nm) and red (677 nm) spectral channels of the hyperspectral image and the cover values measured on field.

Ground based surveys (Tiszakeszi)
Sample points

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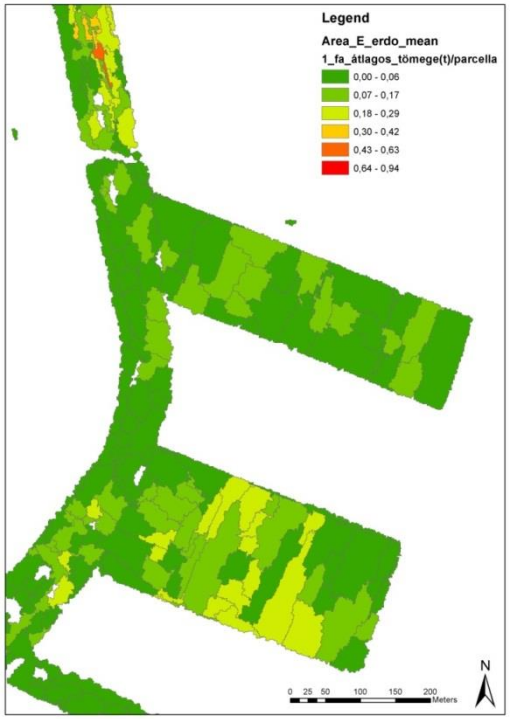
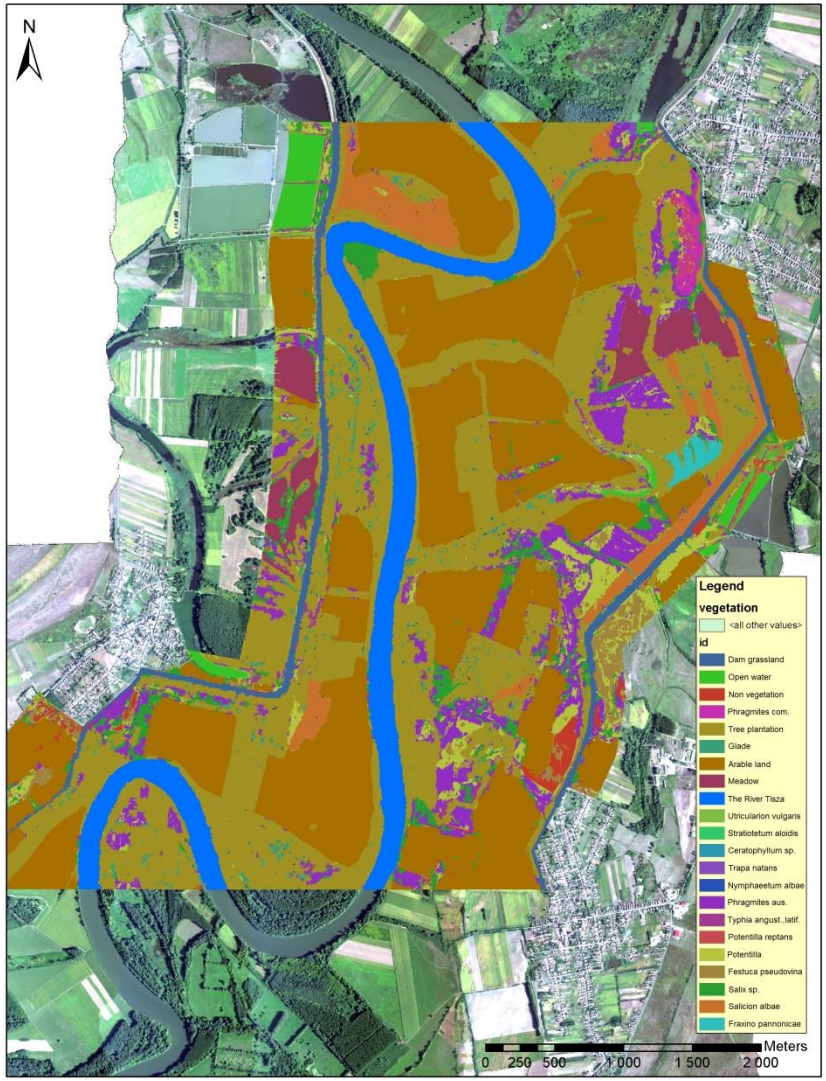
Sample area (Tiszakeszi)



- The regression equation: determination of tree diameters from the LIDAR nDSM height data.
- Tree volume estimation according to Király's function (Király, 1968) by tree height and trunk diameter parameters.
- Application of other, predetermined parameters for the different tree species (totally 9 parameter groups).
- Calculation of the living wet density (t/m3) of different tree species by the tree volumes

Integration of hyperspectral images, LIDAR data and aerial digital images

Hyperspectral image (RGB)



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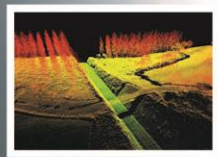
Ground based measurements - Geodetic surveys



- Floodgates: coordinate, bottom level (flood side and saved side), upper level of the opening (diameter), top level of pit
- Mile stones: above sea level (mBf)
- Barriers (axle center point coordinate)
- Traffic signs: traffic and section boundary signs (coordinate),
- other crossings (pressure pipes, irrigation pipes, cables, roads, railways, product lines): coordinates, height measured in the dike axis in case of air wires


Sign (GPS0144 ID


Milestone (GPS0147 ID)


Lift loading axle (GPS0146 ID)


Object (GPS0133 ID)


Iron pipe (GPS0142 ID)


Traffic sign (GPS0145 ID)

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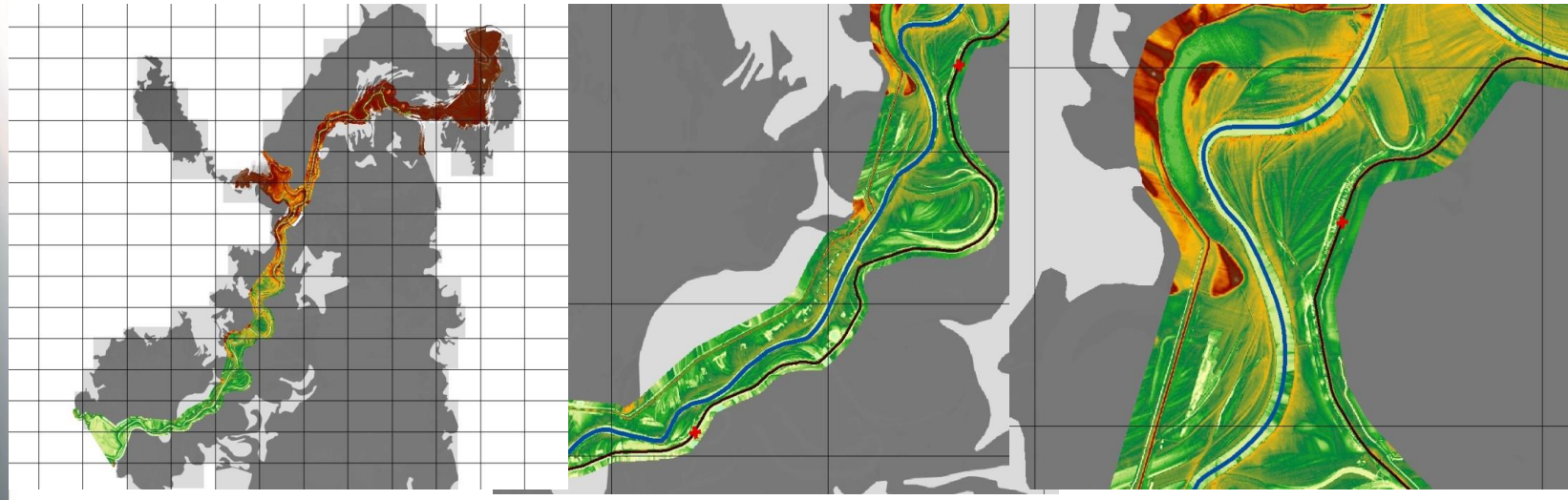
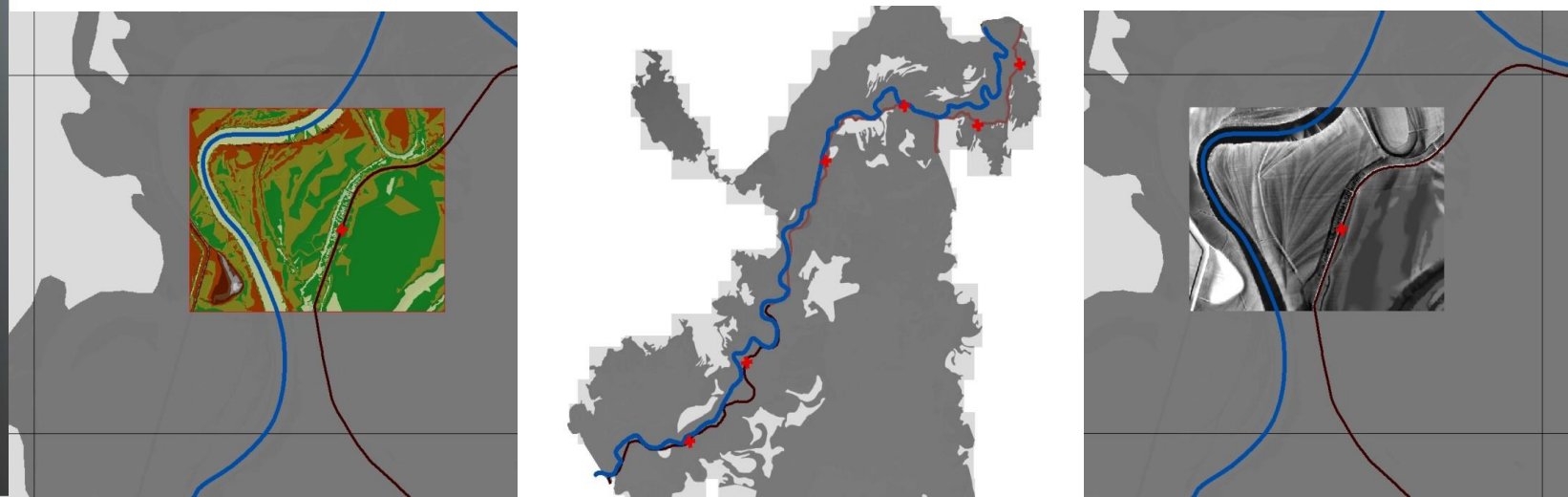
Dam bursting simulation
Flood area 2D hydrodynamic model

- FloodArea is a 2D hydrodynamic application for the simulation of flood and dam burst.
- It is fully integrated in the ESRI ArcGIS 9.x (and ArcView 3.x) products, as an extension.
- Its main goal is to delineate the flooded areas during the flood.
  - Modeling of dam bursting scenarios
  - Controlled outlet of emergency flood reservoirs
  - Other functions:
    - Making simulation using different data sources
    - Inquiry of the temporal dynamics of flooding
    - Determination of flow direction and velocity

Dam bursting simulation
Flood area 2D hydrodynamic model



DTM with potential burst points (in red)



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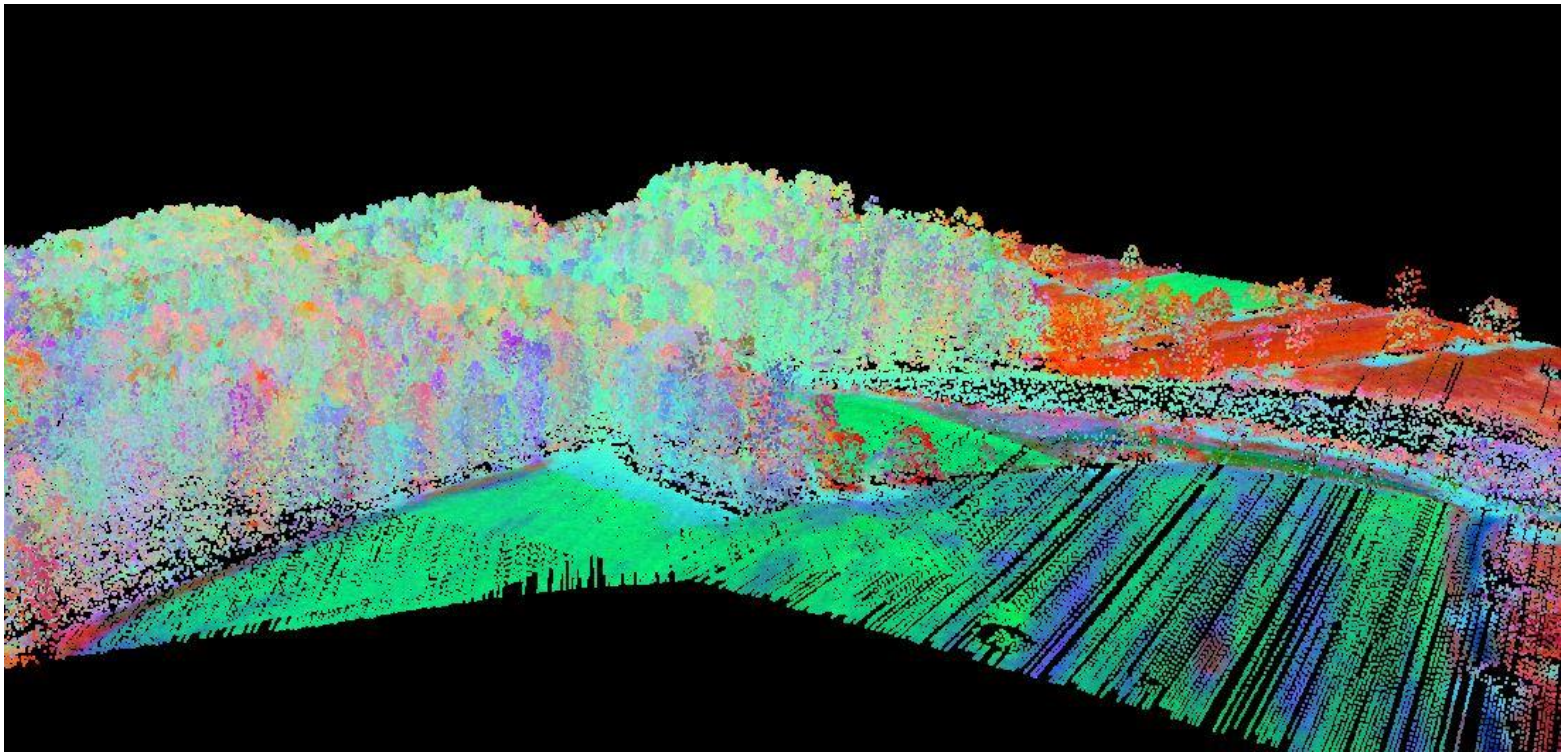
Thank you!



Dezső Mikus – mikus@envirosense.hu