HUMANITA Online Green Academy

Remote monitoring of erosion

Interreg CENTRAL EUROPE

Co-funded by the European Union

HUMANITA

Training material for Citizen Science Projects

Authors:
Dana Sitányiová
Daša Smrčková
Jakub Chromčák

UNIVERSITY OF ŽILINA

Participatory monitoring is the regular collection of measurements or other kinds of data (monitoring), usually of natural resources and biodiversity, undertaken by local residents of the monitored area (pilot sites), who rely on local natural resources and thus have more local knowledge of those resources.

[Authors]

HUMANITA

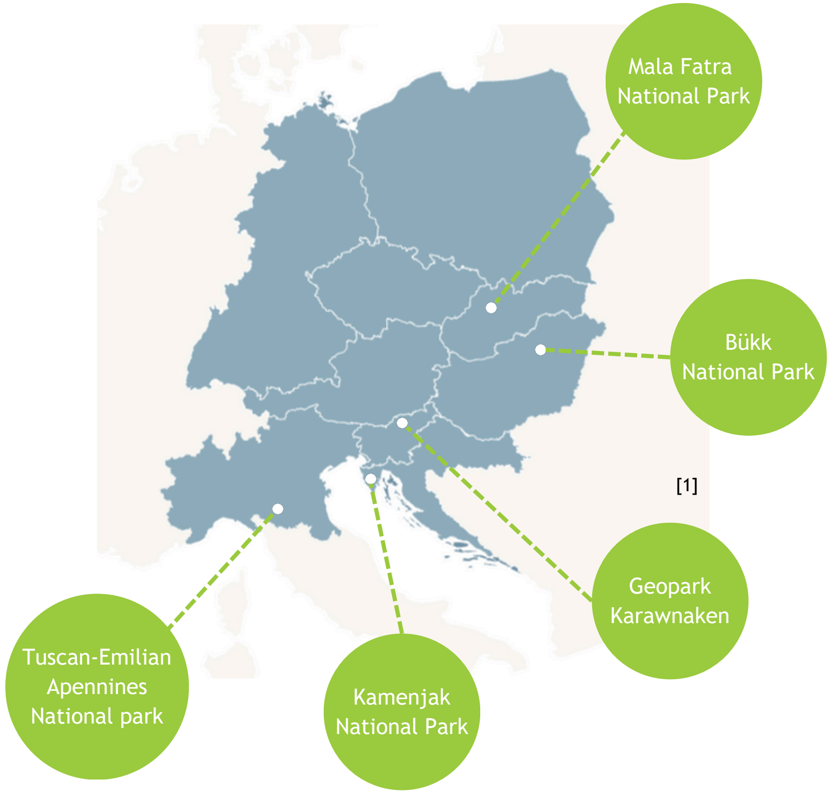
Project Pilot Sites and Participatory monitoring

Within the HUMANITA project, 5 pilot sites were selected in Central Europe where, in addition to studying the impact of tourism, it is planned to carry out participatory monitoring.

The selected sites represent a significant natural wealth in terms of uniqueness of biodiversity, which attracts a huge number of tourists.

The pilot sites represent National Parks and Protected areas in Slovakia, Hungary, Slovenia, Croatia and Italy.

The research ranges from the coastal areas of Croatia, through forest sites in Hungary, mountainous meadows and mountains in Slovakia, Italy and Slovenia.



Participatory monitoring

- Participatory monitoring brings new technologies and approaches to the public, which can collect huge amounts of data for processing and research purposes.
- Within the HUMANITA project, several approaches, projects and applications for participatory monitoring have been tested based on specific monitoring.

Vegetation monitoring →

iNaturalist application to monitor rare or invasive species in pilot sites NP Malá Fatra, Kamenjak and Geopark Karawanken

Pollution monitoring →

Hulladék Radar application to monitor and report illegal waste dumps in Bükk National Park

Erosion monitoring →

UAS and LiDAR approach for the monitoring, analysis and evaluation of soil erosion by the University of Zilina and the University of Parma

Water monitoring →

Direct monitoring and online forms for data collection for spring monitoring in Tuscan-Emilian National Park


[Authors]

[Authors]

Training material for Citizen Science Projects

The training material is a compilation of procedures and knowledge for data collection so that the public can be involved in the collection or processing of data.

Training material is based on monitoring in Malá Fatra National Park.

Our aim: specific approach for data collection using remote sensing data acquisition procedures

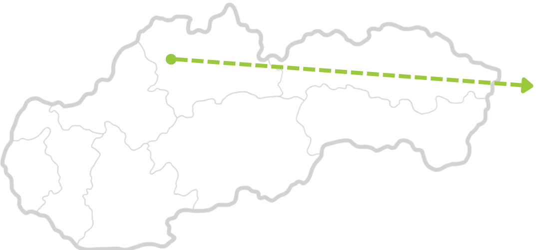
Our task: introducing the public to new ways of collecting, processing and analysing data

Pilot Area:

Malá Fatra National Park

[2]

Malá Fatra National Park is located in the part of Malá Fatra mountains called *Kriványska Malá Fatra (*named after the heighest peak Veľký Kriváň - 1709 m a. s. l.), NW Slovakia - Zilina district.



- NW Slovakia
- Zilina district

Malá Fatra NP was established in 1988 and is one of the 9 National parks in Slovakia, with an area of 226.3 km^2.

[4]

[5]

[4]

[4]

[3]

Malá Fatra National Park

Unique geology and conditions

- Krivánska Malá Fatra is a fold mountain in terms of its geological structure. It consists of a crystalline core and a mantle of Mesozoic sedimentary rocks.
- Situated within a landscape of limestone and dolomite ridges, with deep gorges and canyons, as well as karst underground corridors and caves, this national park is characterised by a particularly varied geomorphology.
- Gorges, waterfalls, rock peaks, ridges or canyons are geomorphological structures in Malá Fatra NP that can be visited and admired.

Relief, or georelief,

in Earth science terms,

is the structure of the Earth's surface. The different landforms of the Earth's surface express the momentary state of interaction of endogenous (volcanism, mountain building and other tectonic movements) and exogenous processes (weathering and erosion) that take place in different climates, geological structures and rocks of different properties at a given time.

[6]

Malá Fatra National Park

What makes Malá Fatra NP unique?

specific geological and climatic conditions

vegetation diversity and endemic species

permanent habitat of large carnivores

Malá Fatra National Park is special for its extraordinary diversity of geological and climatic conditions. This, together with the vertical irregularity, has contributed to the great diversity of plant and animal communities that have developed here.

Malá Fatra National Park is the westernmost Carpathian National Park with a permanent presence of large carnivores (bear, wolf, lynx) and original and relatively well-preserved ecosystems in which the basic ecological and evolutionary processes are still maintained.

For Central and Western European industrialised landscapes, it is important as an eco-stabilising element of transnational significance, as it enables the penetration of Western Carpathian species into neighbouring territories where these species have retreated or been extirpated as a result of intensive human activity.

[7]

[8]

[9]

Plants here have to cope with (or adapt to) extremely varied climatic conditions, depending on the relief and geological conditions, often varying considerably over small distances.

There are also 4 endemics of Malá Fatra - *Alchemilla sojakii, Alchemilla virginea, Euphrasia stipitata and Normeyera margittaiana.*

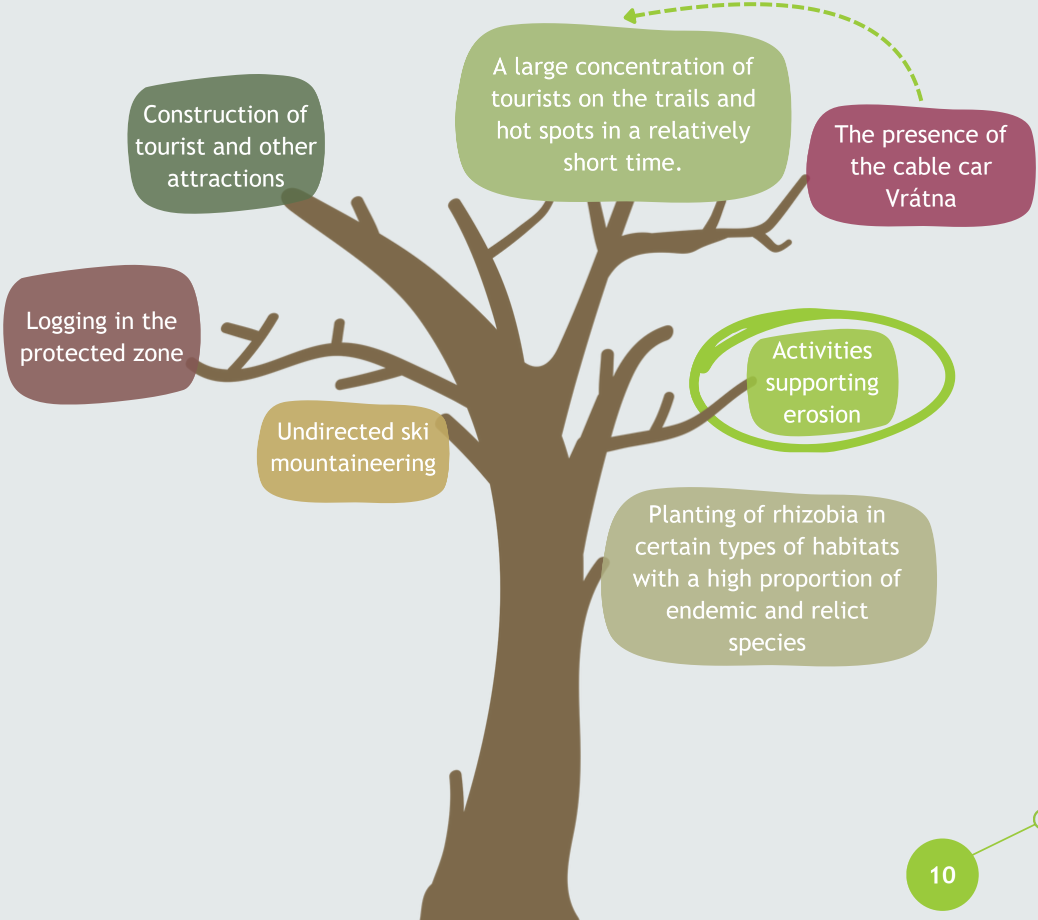
These species do not grow anywhere else than in Malá Fatra. On the limestone rock walls we can admire protected species such as the *Pulsatilla slavica, the Dianthus serotinus, the Aster alpinus, and the Gentiana Clusii.*

Pilot Area: Malá Fatra National Park

Human activities and impacts affecting protected areas in Malá Fatra

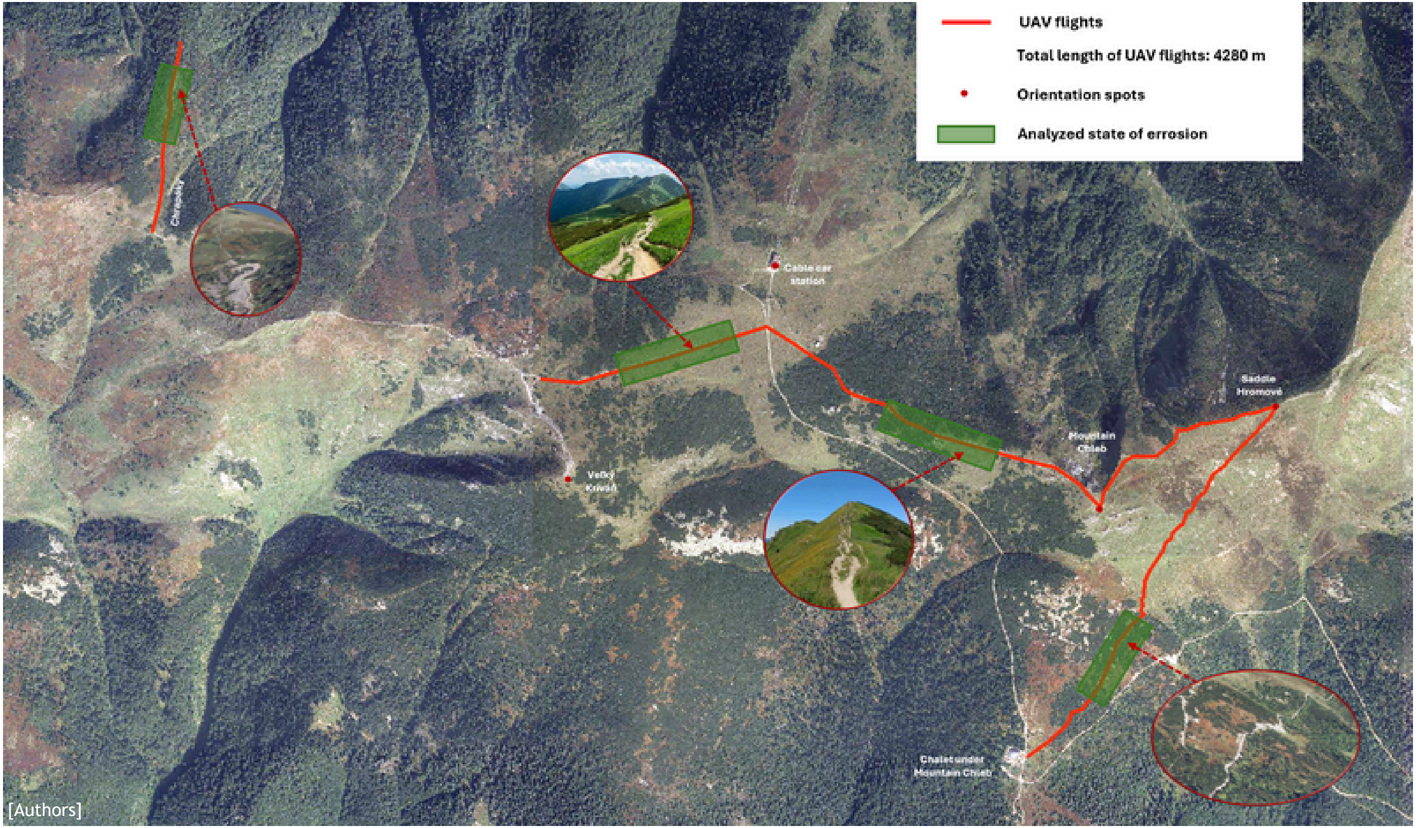
[Authors]

[Authors]



Pilot Area monitoring

Selected parts of tourist trails significantly affected by tourism



Soil erosion

Methods and approaches for soil erosion monitoring

- **Direct measurements**
- **Remote Sensing**
- **Geographic Information System (GIS)**
- **Hydrological and erosion models**
- **Photogrammetry and LiDAR**
- **Isotopic Dating Methods**
- **Biological and vegetation methods**

World's most destructive land degradation hazard

Healthy soil ecosystems support life on Earth and enhance agricultural output. However, one of the challenges threatening these ecosystems is soil erosion.

Recent climate changes and improper human activities pose a threat to the health of soil ecosystems.

[10]

Soil erosion

Geodetic and remote sensing methods and approaches for soil erosion monitoring

Photogrammetry

- Photogrammetry is a set of methods to obtain cartographic or geodetic coordinates, coordinates of dimensions of structures, buildings, rooms and individual objects on the basis of analogue or digital photography. The result is a 3D representation of the imaged area in the form of a digital terrain model together with a realistic texture.

Global Navigation Satellite System (GNSS)

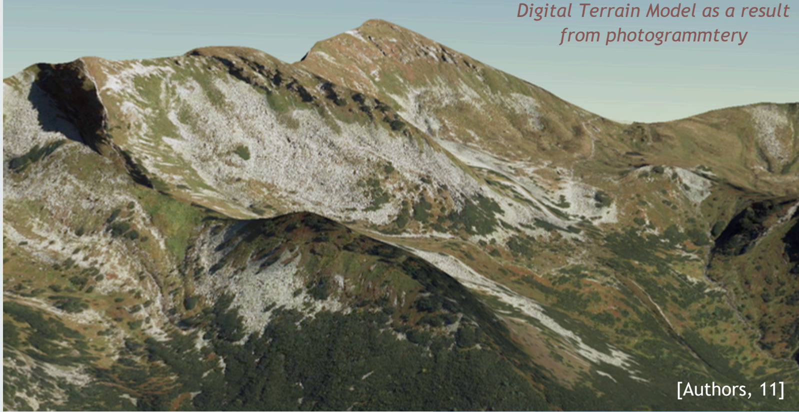
- The GNSS method of determining the spatial position of a point on the Earth's surface is based on the principle of spatial intersection from spheres defined by the position of satellites with a known position in the global geodetic system. The result is a 3D position of a point on the Earth's surface determined by a special GNSS receiver with an accuracy of about 2cm in real time.

Remote Sensing

- Utilizing satellite images for long-term monitoring of land and soil changes, identifying areas of erosion using satellite imagery.

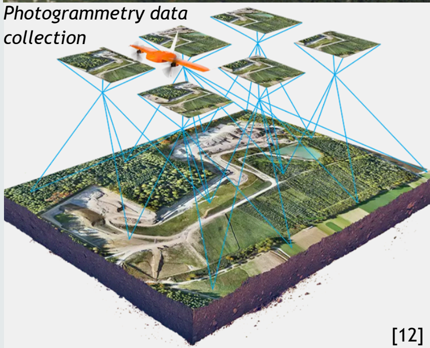
LiDAR

- Using laser pulses to measure distances from a sensor (usually mounted on an aircraft or drone) to the Earth's surface. The final Digital Terrain Model is a highly accurate, 3D representation of the bare ground surface, showing the natural contours of the land, including valleys, ridges, and slopes. It is used in various applications like topographic mapping, flood risk analysis, urban planning, and environmental monitoring.



Digital Terrain Model as a result from photogrammtery

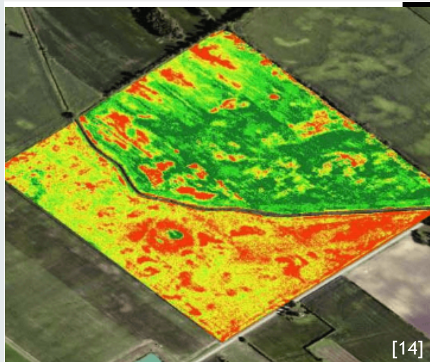
[Authors, 11]



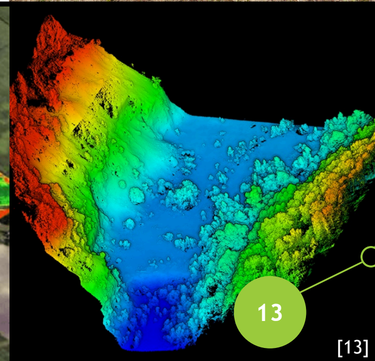
Photogrammetry data collection

[12]

[Authors]



[14]



[13]

lidaretto
Your personal LiDAR

[Authors]

Why do we use LiDAR technology for soil erosion monitoring?

LiDAR
Light Detection and Ranging

LiDAR is a remote sensing method used to examine (not only) the surface of the Earth. It uses light in the form of a pulsed laser to measure ranges to the observed surface/object to generate precise spatial information in the form of a point cloud.

What do we use for data acquisition?

Lidaretto mobile 3D scanning system for capturing reality combining LiDAR, GNSSS and IMU technology to produce highly accurate point clouds.

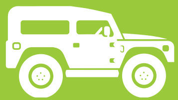
Lidaretto system

Installation possibilities and basic parameters

Lidaretto mobile 3D scanning system represents a multiplatform data acquisition for various professional applications.

UAV (drone)

- topography mapping
- mining
- agriculture
- forestry
- archaeology
- environmental



Car

- street mapping
- construction site mapping
- GIS data collection
- road construction
- virtual surveying

Backpack

- city center mapping
- railways mapping
- ski slopes modelling
- environmental
- architecture
- cadastral mapping

[15]

Lidaretto is an outdoor LiDAR technology. Data acquisition process needs to be adapted to the outdoor conditions - temperature, rain/snow etc. Proper choice of time and conditions for data acquisition are essential for the required quality of output data.

Basic parameters

LiDAR measure range:	120m/300m
Range accuracy:	± 1cm
LiDAR accuracy:	± 3 cm
GNSS accuracy:	PP 1 - 2 cm

[13]

Lidaretto mobile 3D scanning system is protected against water and dust, but such particles in the environment may have an impact on final quality.

Lidaretto system

Professional applications in many fields

Surveying
Scan all the necessary points instead of using RTK rovers or total stations.

Environmental assessment
Microtopography data acquisition, biotype search, soil erosion analysis, finding areas affected by human.

Construction (road, railway...)
Continuous 3D mapping of the Earth surface during the work progress to compute volumes, surfaces.

GIS Data collection
Geospatial data collection for database creation, spatial analysis and statistic purposes.

Agriculture
Detection of areas requiring fertilisation and creation of elevation maps for spatial analysis.

Mining and Quarrying
Volume and surfaces measuring, operational planning, slope stability exploration. Safest with UAV.

Forestry
Forest managment, measuring the vertical structure of the forest canopy, its base height etc.

Powerlines
Inspection of power transmission lines providing the outputs critical for securing uninterrupted electricity distribution. [15]

Multipurpose application

Time saving

Spatial data complexity

Lidaretto system - backpack carrier variant

Pros

- targeting trees and vegetation in the forest
- easy to carry
- possibility to collect data directly in the city without endangering the public
- does not require a pilot licence

Cons

- slower data collection
- walking (smoothness, speed, turning) affects data accuracy
- smaller data collection range
- emphasis on the absence of moving elements at a range of at least 50 m behind the device

[Authors]

[Authors]

[Authors]

[Authors]

Lidaretto system - UAS carrier variant

Pros

- fast data collection
- wide range of data collection in good weather conditions without affecting the accuracy of the data
- mapping of large areas

Cons

- measurement of forest vegetation from height only
- requires an aviation authorisation and licence
- noisy carrier equipment
- cannot collect data over people
- low battery life
- necessity of good weather conditions

Lidaretto system

Outputs

1

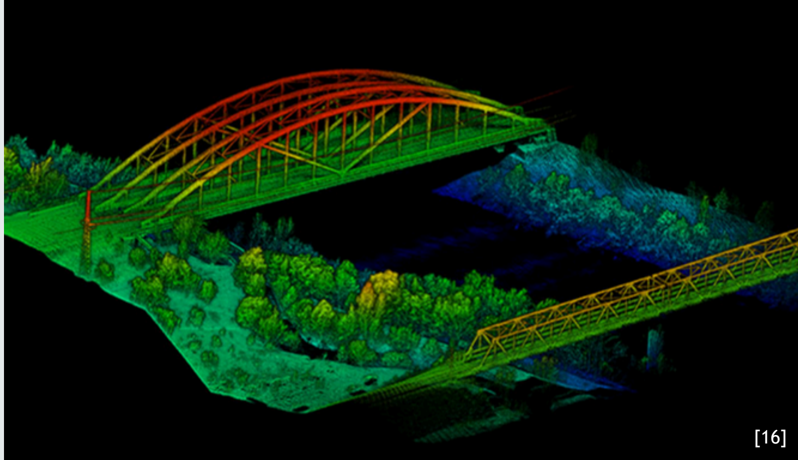
Point cloud for geometry analysis

Collected data create dense point cloud coloured according to intensity quality of the surface/object during signal reflection.

2

Point cloud with real texture

If the resulting point cloud is required to represent the object/surface to be imaged also with real colors, the lidar data collection is complemented with real-time camera footage using a 360° camera, and thus the final point cloud is colored with a real texture.



[16]

[16]

Lidaretto system in terrain

Pre-measurement preparation - data acquisition - completion of data collection

Preparation before measurement

Why and how?

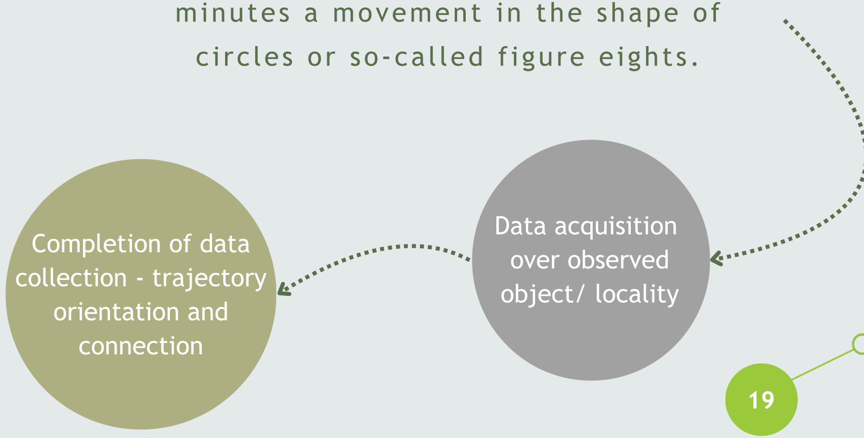
Before the Lidaretto system starts collecting data, it is necessary to prepare the measuring equipment and the IMU unit for the planned data collection. The principle of data post-processing is primarily based on the correct alignment of the flight trajectory during data collection. Proper trajectory alignment is a necessary step and is ensured by defining the trajectory as a bilaterally connected and oriented polygon thrust. The docking and orientation of the measurement system is performed in two steps before and after the data acquisition (but in reverse order) to make the flight bilaterally docked and oriented:

1 ***Static preparation***

Trajectory connection (polygon stroke): a static collection of satellite data using the GNSS antennas of the measurement system for 2 - 3 min.

2 ***Inertial Measuring Unit IMU orientation***

Orientation of the polygon travers: the carrier together with the measuring system and the IMU unit performs for 3 minutes a movement in the shape of circles or so-called figure eights.



Lidaretto system in terrain

Pre-measurement preparation - data acquisition - completion of data collection







Photos from data collection [Authors]

Lidaretto system in office

Data collected. *What next?*

Data post-processing

Correct processing of the measured data is essential to obtain relevant, accurate and meaningful results. The individual specialised software ensures that the measured data are processed with the required precision, so that the subsequent steps enable the most accurate and highest quality results to be obtained. Post-processing requires several steps in different software environments.

1

Trajectory alignment in Inertial Explorer

Precise GNSS data from RINNEX file

Boresight angles computation

2

Point cloud to trajectory alignment in Lidaretto Creator

Point cloud alignment

Real texture overlap (optional)

Export to *.las format

3

Point cloud analysis and classification

Vector, Raster or point cloud approach

LiDAR 360

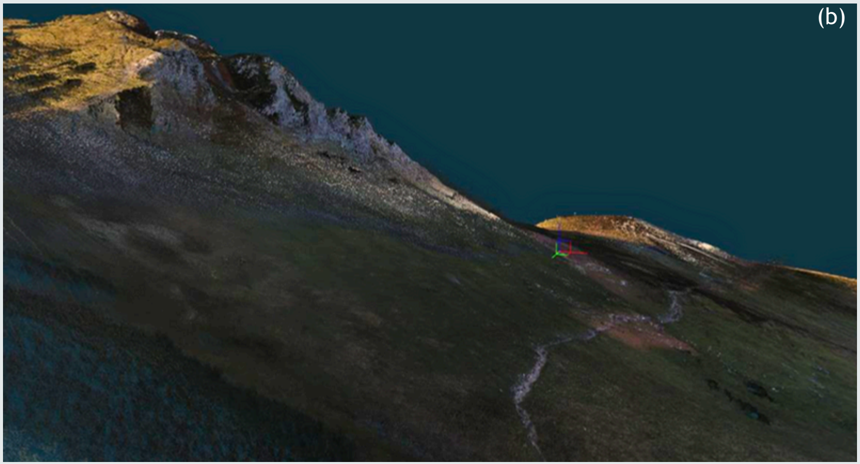
3D Survey

ArcGis Pro

ArcMap

Lidaretto system in office

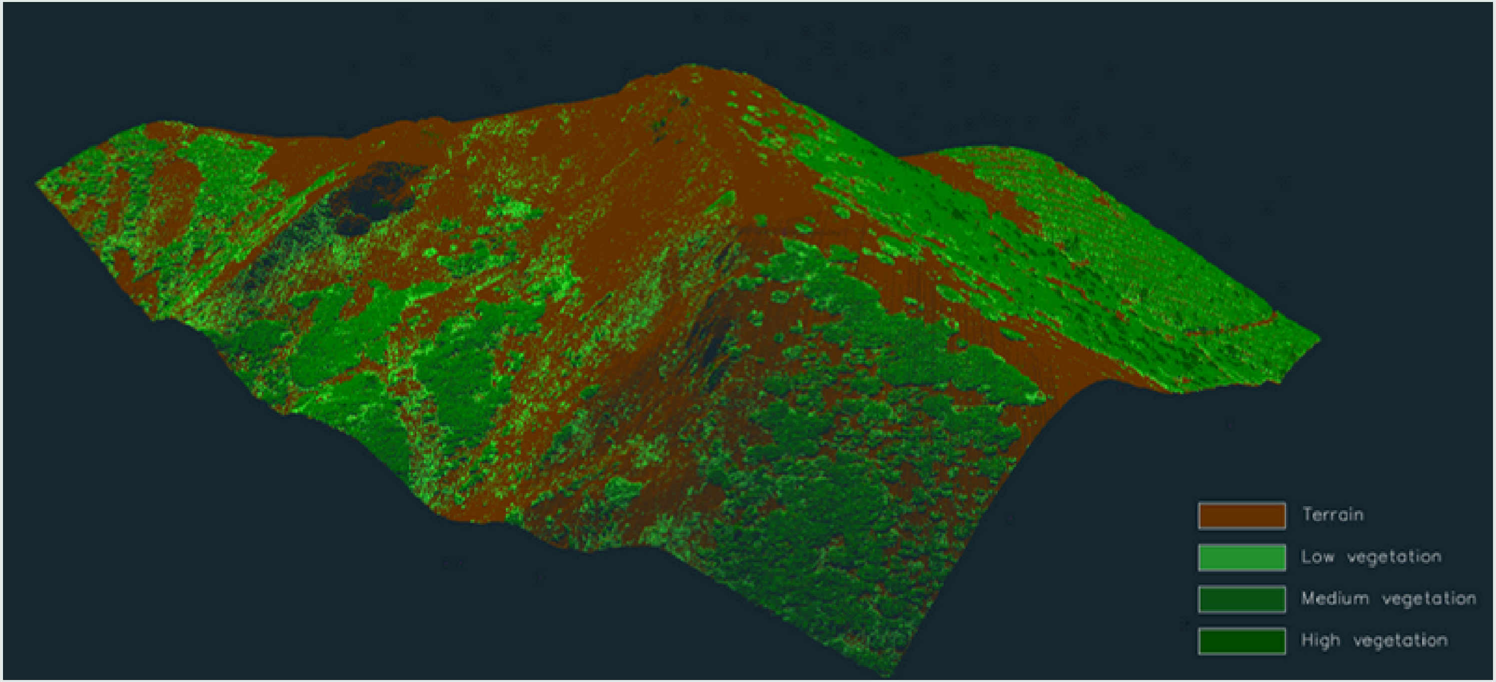
Data post-processing samples



(a) Trajectory alignment and final precision illustration (5 - 10 mm)
(b) (c) Point cloud with real texture from Malá Fatra NP [Authors]

Lidaretto system in office

Data post-processing samples



Point cloud representing surface in Malá Fatra NP (Chleb) classified into categories (see legend) [Authors]

Methods of terrain interpretation

How can be Earth surface/terrain visualised and assessed?

1 *Point cloud*

A point cloud consists of a collection of discrete data points in space, often representing a 3D object or shape. Each point has a specific location defined by its Cartesian coordinates (X, Y, Z). Points can store other information such as RGB color values, surface normals, timestamps etc. Point clouds are typically generated by 3D scanners or photogrammetry softwares, which capture numerous points from the outer surfaces of surrounding objects.

2 *TIN model*

TIN (Triangular Irregular Network) is a vector based representation of continuous spatial data (a list of X, Y, Z nodes) connected by edges, which is ideal for representing 3D surfaces.

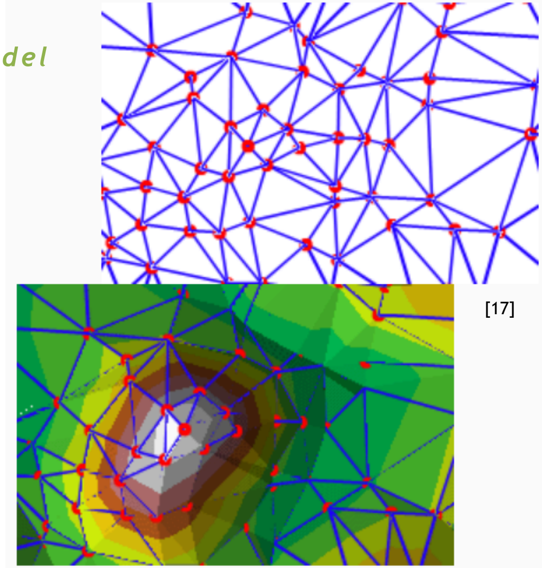
TIN model is ideal for irregularly spaced datasets (LiDAR, UAV based photogrammetry).

The TIN model represents a surface as a set of continuous, non-overlapping triangles. Within each triangle the surface is represented by a plane. The triangles are made from a set of points called point cloud.

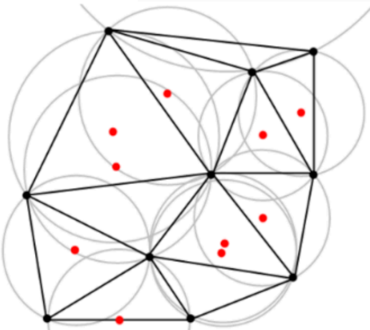
3 *Raster*

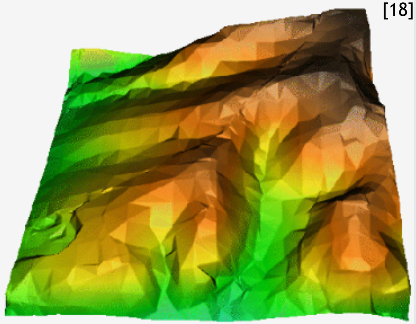
Raster surface representation consists of cells (pixels) where each cell contain an information on height or other required information (slope, hillshade etc.). Rasters represent the height data continuously across a landscape (surface). With the Raster Surface a terrain landform represented by a digital elevation model can be quantified and visualized.

TIN model



[17]



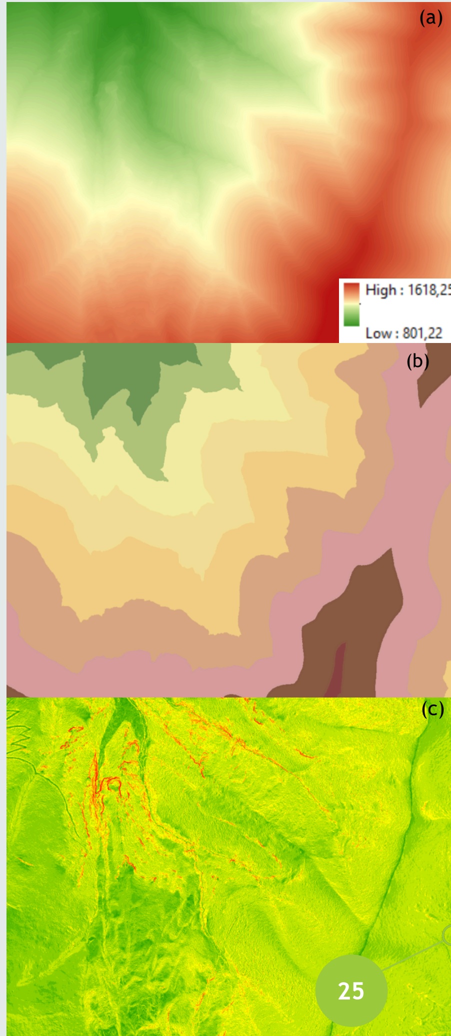


[18]

Figures illustrate the connection of spatial point information in the form of TIN with edges and colorized TIN accoriding to specified height intervals (hypsography).

Raster surface interpretation

Figures illustrate surface representation in the form of raster coloured according to local height (a), (b) and slope parameter (c) [Authors]



Height above sea level [m]

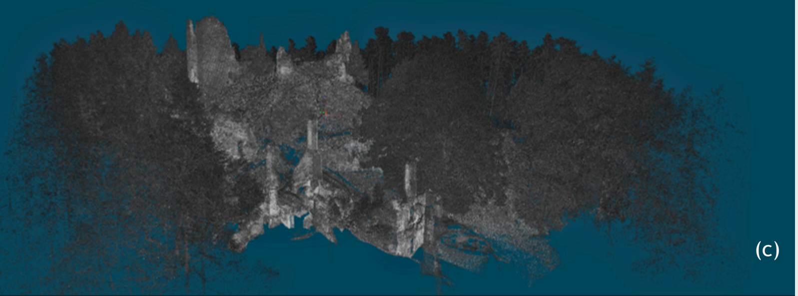
- 801 - 900
- 900 - 1 000
- 1 000 - 1 100
- 1 100 - 1 200
- 1 200 - 1 300
- 1 300 - 1 400
- 1 400 - 1 500
- 1 500 - 1 600
- 1 600 - 1 618,25

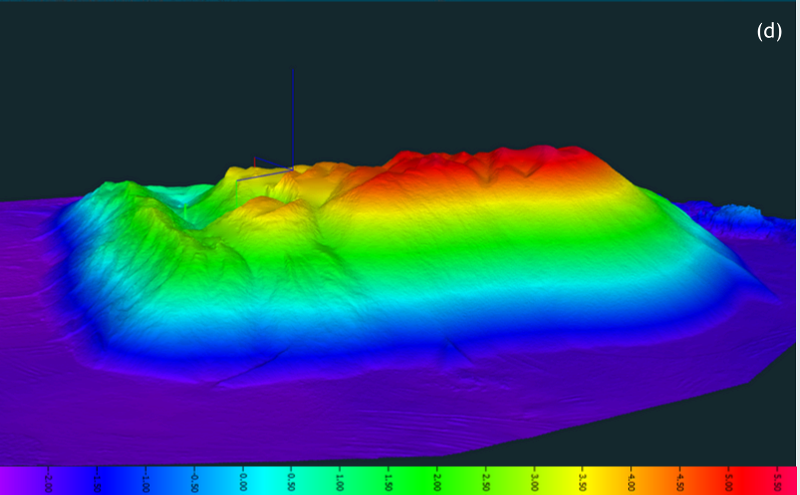
Slope [°]

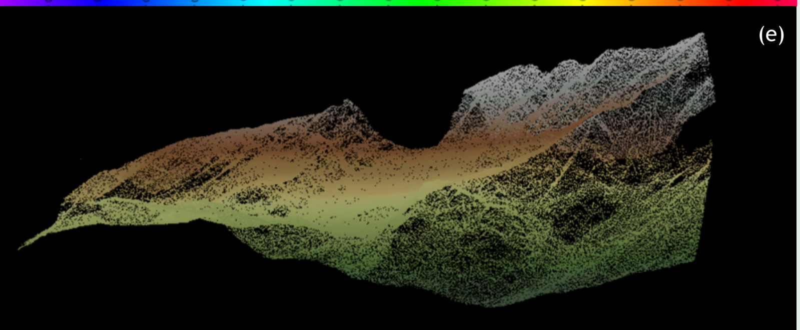
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90

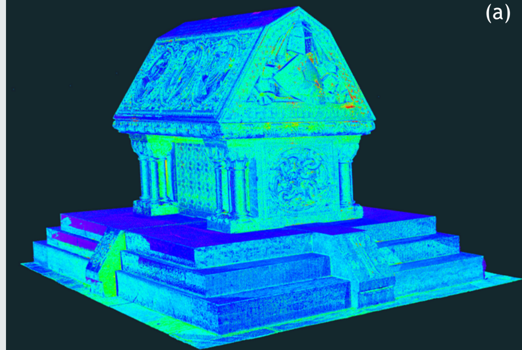
Point cloud

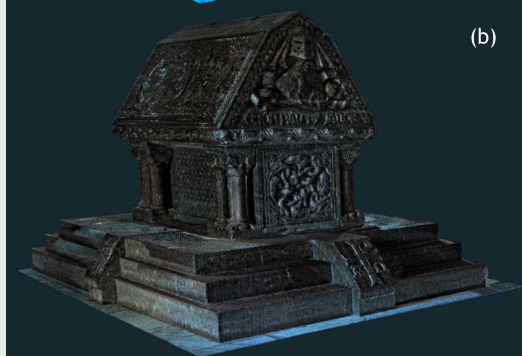
Figures illustrate the surface/object representation in the form of point cloud coloured according to reflection intensity (a), real texture (b), height remoteness in black-white scale (c), colorful scale (d), elevation hypsography scale (e) or real texture (f) [Authors]

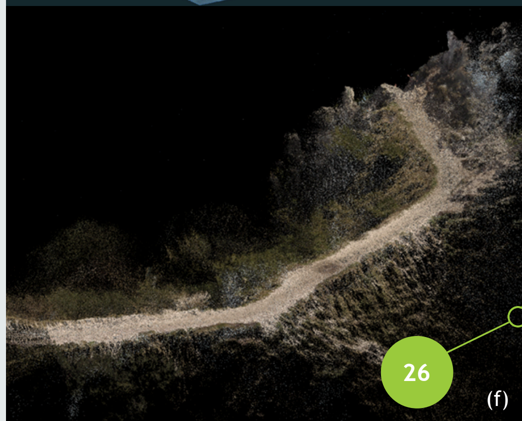












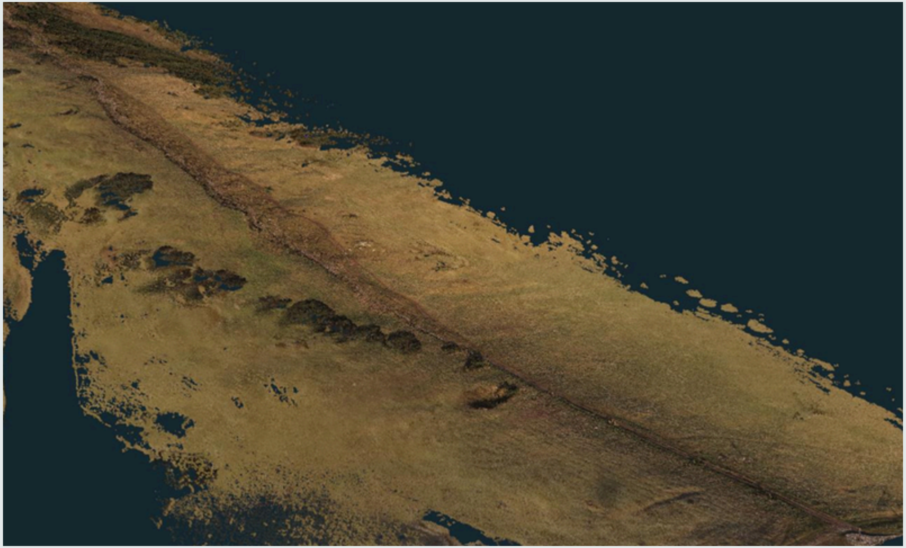
Lidaretto system in office

Erosion determination from point cloud

Figures illustrate the presence of soil erosion: Trail Snilovské saddle - Chleb [Authors]

Lidaretto system in office

Erosion determination



Figures illustrate the presence of soil erosion: Trail Snilovské saddle - Veľký Kriváň [Authors]

Lidaretto system in office

Erosion change anaylsis

Erosion analysis approach

The analysis of the erosion condition of hiking trails in the studied area is possible on the basis of comparison of epoch measurements before and after the hiking season, or between the summer hiking seasons themselves.

Two approaches were chosen to analyse, illustrate and interpret the results of spatial analysis of soil erosion.

1 ***Vector analysis***

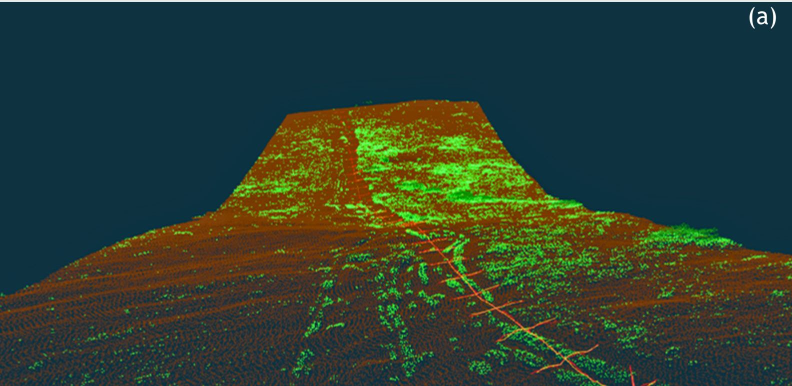
Input data format: Point cloud
Profile line selection
Creation of longitudinal profile and cross sections in a defined line
Comparison of the course of the hiking trail in longitudinal and lateral direction between epochs

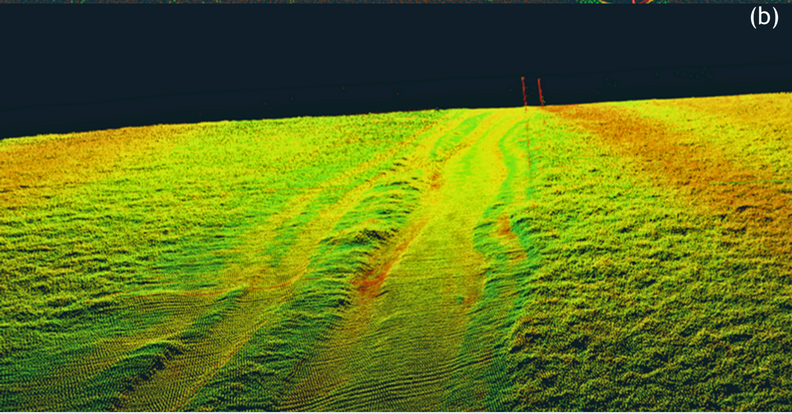
2 ***Raster analysis***

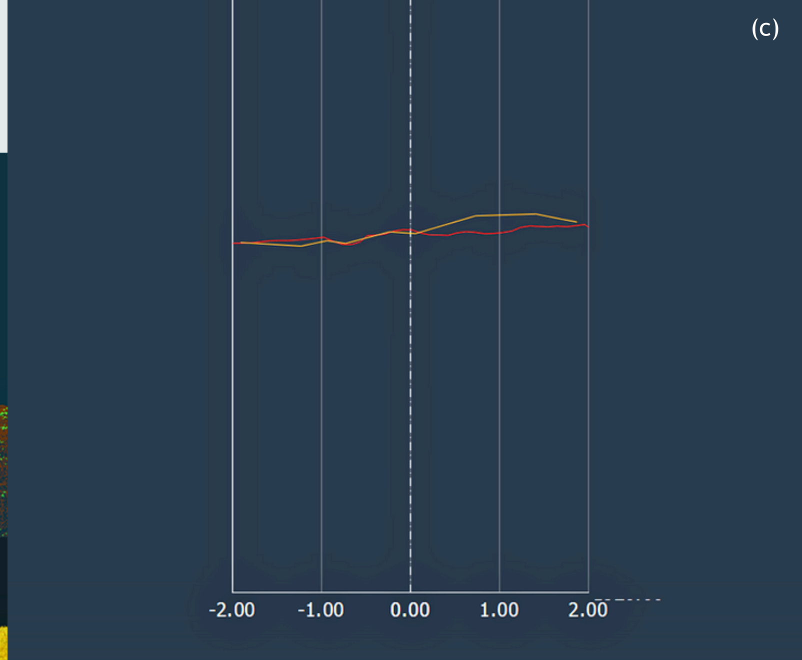
Input data format: Point cloud
Point cloud to TIN model
TIN model to Raster
Raster analysis and erosion definition

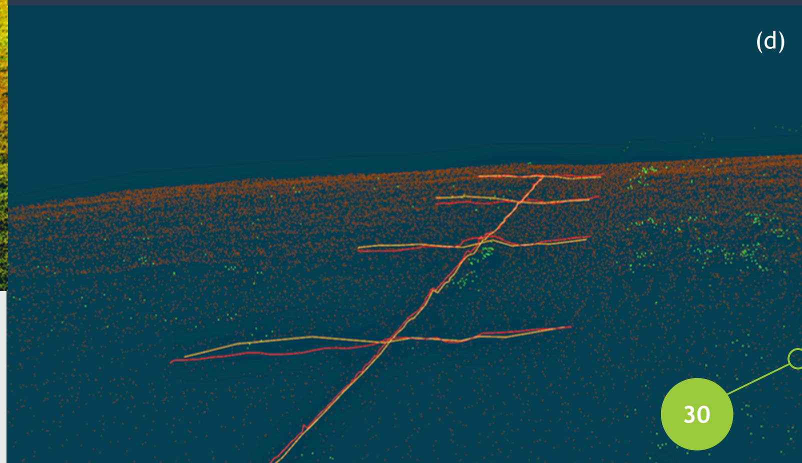
Erosion analysis results

Vector analysis results









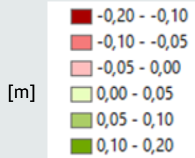
The orange profile line indicates the course of the terrain during the 2023 season, the red profile line shows the course at the beginning of the season in 2024. It can be seen that there has been a loss of mass due to the creation of the side walk shown in the figure (b). [Authors]

Erosion analysis results

Raster analysis results

(a)

(b)



(a) TIN model from point cloud
(b) and (c) show the change in the course of the hiking trail between the 2023 and 2024 seasons in the form of mass loss and mass gain, respectively [Authors]

(c)

How can you participate?

What do we search for?

Are you interested in the impact of tourism in the Mala Fatra National Park and would you like to know the level of impact of human activity in this area?

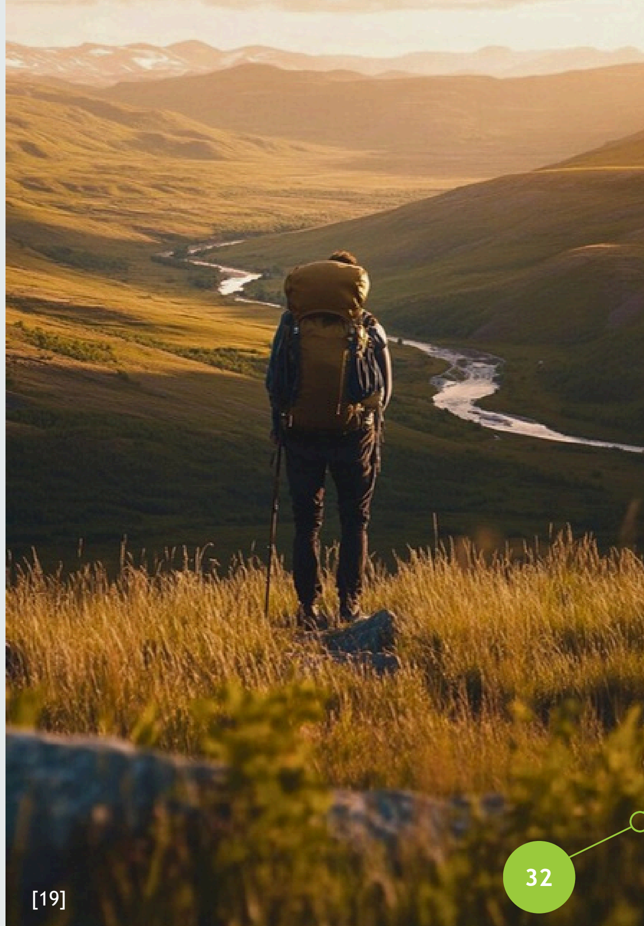
Do you like to visit Mala Fatra National Park and do you perceive the impact of human activity on nature?

Do you like to record geospatial data using mobile applications or other smart devices?

Do you like capturing the real state of nature reserves or do you prefer to analyse, compare and interpret such and many other data?

Do you enjoy GIS (Geographic Information System) or are you tempted to start working with your own data in such an environment?

Whichever option suits you better and if you are tempted to work with an expert team and actively contribute to participatory monitoring, don't hesitate to do so.



[19]

Visualisation and modelling preference?

If you enjoy visualizing your own photos or videos into spatial models, your own mobile phone will allow you to transform such data into 3D models!

How to do it?

Capture multiple photos of a landslide or erosion and free photogrammetry software (e.g. Meshroom) will create a 3D model from them. Or split the HD video into frames and continue as with photos.

If you have a device with implemented LiDAR technology, you can use a huge number of applications (Polycam, Scaniverse...) to directly create a scan and have your own point cloud or Mesh model!

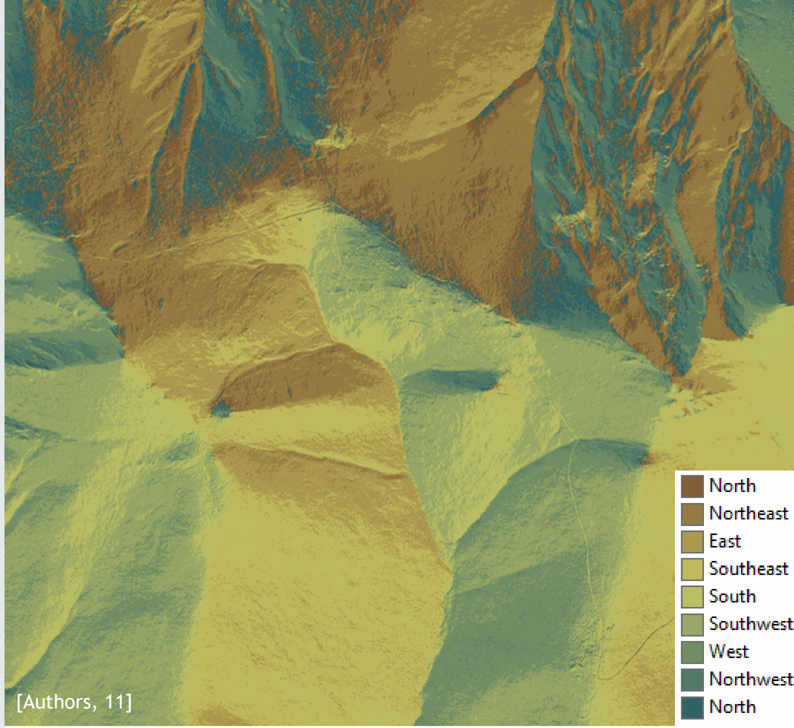
[20]

Geographic Information System

GIS software offers the ability to not only visualize, but more importantly analyse and compare different types of data - from orthophotos, to digital elevation models (DEM), digital terrain models (DTM) or digital surface models (DSM), to point clouds.

An indispensable advantage is the possibility of adding and updating various attributes to the spatial representations of the studied sites - precipitation, vegetation changes, geolocations of observed plant and animal species, or tourist concentrations, and much more.

The freely available GIS software - QGIS allows a wide variety of spatial analyses.
Analyse your own data or use huge databases of geospatial data from aerial photogrammetry, aerial photography, remote sensing or satellite imagery.



[Authors, 11]

[Authors, 11]

Online Data and Analysis

Many online platforms allow the wide public not only to browse satellite data, but also to work with them. However, satellite data are no longer just images of the Earth's surface taken from a satellite carrier. Geolocated and georeferenced imagery is enriched and supplemented with all sorts of data - vegetation cover, temperature maps, smog concentration data and much much more. Results of satellite measurements from a wide variety of satellite missions are available.

Where can such data be found?

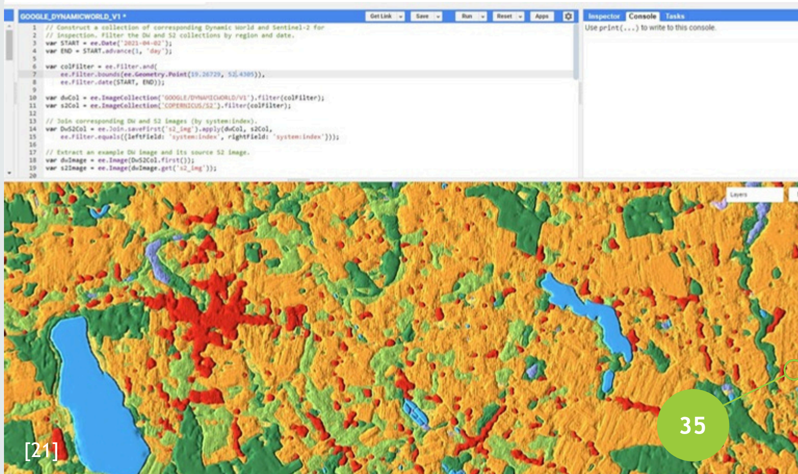
- NASA Worldview
- United States Geological Survey - EarthExplorer
- Coprenicus Browser
- ESRI

And many others!

Do you also dare to do your own analysis and programming?

Google Earth Engine makes just that possible!

Choose the location you want to track over time, change the layers and the data available in them, get started with basic operations through a simple programming environment, and watch how you can reveal changes in our natural environment and surroundings.



[21]

There are different ways of working together to monitor the impact of tourism on protected areas. The positive impact itself is in the awareness of the individual's contribution to changes in nature and education in this regard. The more active members who are interested in participatory monitoring can participate in the production and analysis of GIS data from different sources and documents in different directions and applications.

Feel free to give it a try and share your results with the rest of us!

[22]

UNIVERSITY OF ZILINA
Faculty of Civil Engineering
Department of Geotechnics
Department of Geodesy

Univerzitná 8215/1
010 26
Žilina
Slovakia

Assoc prof. Dana Sitányiová
dana.sitanyiova@uniza.sk

Dr. Jakub Chromčák
jakub.chromcak@uniza.sk

Eng. Daša Smrčková
dasa.bacova@uniza.sk

https://www.svf.uniza.sk/index.php/katedra-geotechniky-kgt/
https://www.svf.uniza.sk/index.php/katedra-geodezie-kgd

Interreg CENTRAL EUROPE

Co-funded by the European Union

HUMANITA

UNIVERSITY OF ŽILINA

Faculty of Civil Engineering

References

[1] Inetrreg Central Europe: Our programme. Available online [https://www.interreg-central.eu/our-programme/]
[2] Narodný park Malá Fatra: Ochranné známky/logá. Available online [https://www.npmalafatra.sk/sprava-np/znak-malej-fatry/]
[3] Mapy Sveta. Available online [https://www.worldmaps.sk/nastenna-mapa-Mala-a-Velka-Fatra-52x100cm-panoramaticka-lamino-listy-d1832.htm?tab=description]
[4] Taláč, Martin for Slovakaktion: Relaxed Hiking Across National Parks of Slovakia – Private Tour. Available online [https://www.slovakation.com/tour/relaxed-hiking-across-national-parks-of-slovakia-philip/]
[5] Žilinský turistický kraj: Veľký Rozsutec. Available online [https://zilinskyturistickykraj.sk/kam-na-vylet/horne-povazie/velky-rozsutec-1610-m-n-m/]
[6] Hotel diery: Jánošíkové diery. Available online [Jánošíkove Diery | NP Malá Fatra | Mapy - Trasy - Fotky - Video (hotel-diery.sk)]
[7] Learn about Slovak wildlife: Adventoura. Available online [Learn about Slovak wildlife in the High Tatras (adventoura.eu)]
[8] Duchoň, Mário for Botany. Available online [Mário Duchoň | BOTANY.cz]
[9] Babiak, Peter and Khalid, Alim.
[10] Jafari, M. et al.: Soil Erosion Factors, Processes and Effects. In: Soil Erosion Control in Drylands. Springer, Cham. https://doi.org/10.1007/978-3-031-04859-3_1
[11] ZBGIS: Základná mapa - Ortofotomapa. Available online [https://zbgis.skgeodesy.sk/mapka/sk/zakladna-mapa?pos=48.800000, 19.530000,8]
[12] Photogrammetry vs. LIDAR: what sensor to choose for a given application. Available online [https://wingtra.com/drone-photogrammetry-vs-lidar/]
[13] Lidaretto: původní slovenský Lidar. Rozhovor o možnostech použití s Erikem Frohmannem. Available online [https://www.zememeric.cz/lidaretto-geotech-bratislava/]
[14] NDVI Analysis of crops: AZDynamics. Available online [NDVI analysis of crops » AZDynamics]
[15] Lidaretto: Lidaretto with Hesai. Available online [https://www.lidaretto.com/lidaretto-with-hesai/]
[16] Commercial UAV news: Lidaretto is a Lidar Drone Mapping Solution for Multiplatform Use. Available online [https://www.commercialuavnews.com/energy/lidaretto-lidar-drone-mapping-solution]
[17] Herring, J., Roswell, C., Danko, D. (2022). Modeling of Geographic Information. In: Kresse, W., Danko, D. (eds) Springer Handbook ofGeographic Information. Springer Handbooks. Springer, Cham. https://doi.org/10.1007/978-3-030-53125-6_1
[18] Massachusettes Institute of Technology: Delaunay Triangulations: Computational Geometry - Algorithms and Applications (Ch. 9). Available online [https://jshun.csail.mit.edu/6886-s20/lectures/lecture6-1.pdf]
[19] AI Genrated: Photoleapapp.com
[20] Jonas Buske: Nachhaltige Entwicklung: Dänemark ist laut EPI das ökologischste Land der Welt. Available online [EPI: Dänemark ist das nachhaltigste Land der Welt - wmn]
[21] Google Earth Engine. Available online [https://earthengine.google.com/]
[22] Daniel Ernst Photography