Vegetation condition changes of the tree stands in the Tatra Mountains from 1984 to 2022 using Landsat satellite images

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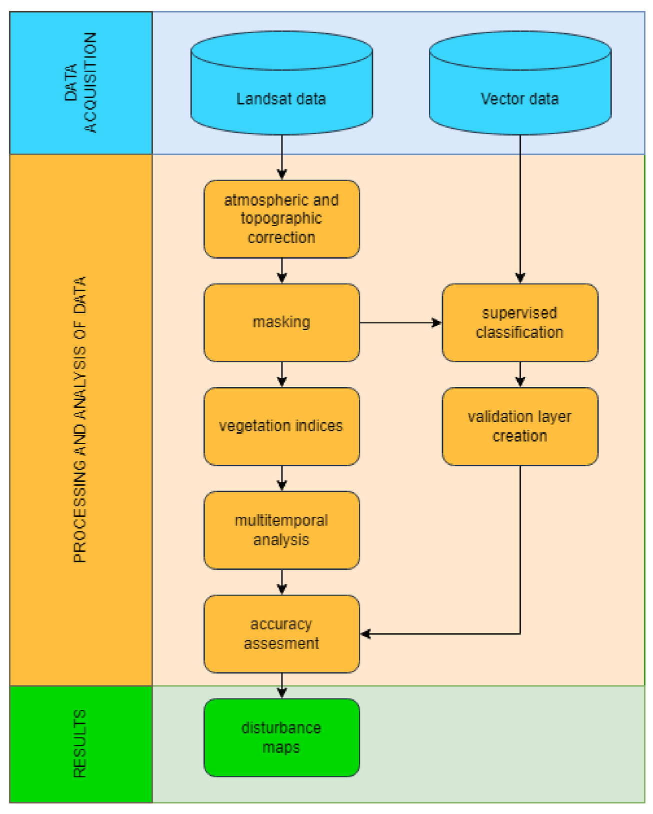
Introduction

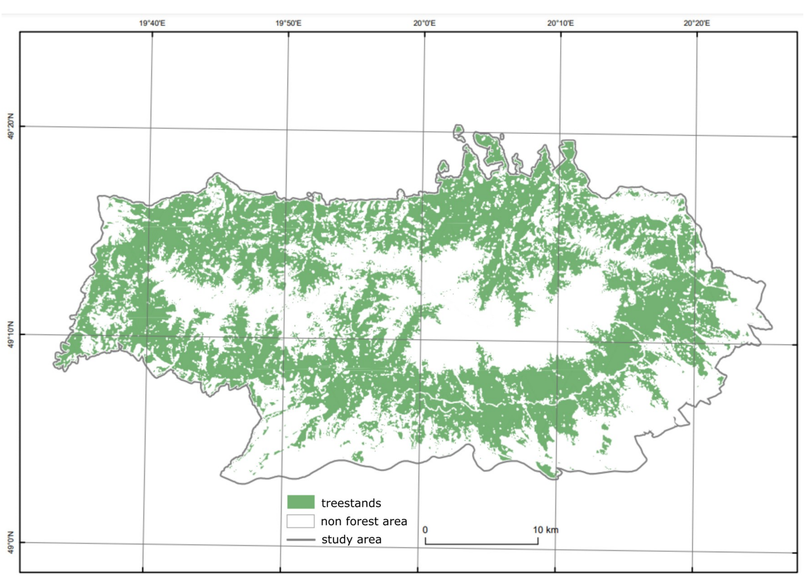
Vegetation condition monitoring and multi-temporal analysis of satellite imagery are becoming increasingly popular in environmental research. Spectral indices calculated based on remotely sensed imagery are used to study vegetation changes, allowing for the examination of chemical substances in plants such as water, carbon dioxide, chlorophyll, and many others. Remote sensing enables the study of hard-to-reach areas where field research is challenging, such as mountainous regions, tropical forests, or desert areas. In this study, will be presented a multi-temporal analysis of the changes in the forest stands of the Tatra National Park (TPN) and the Tatranský národný park (TANAP) and its buffer zone from 1984 to 2022 year. The aim of the mult-temporal analysis conducted in this study was to investigate changes in forest condition and evaluate the accuracy of the LandTrendr algorithm. Google Earth Engine (GEE) platform and LandTrendr tools were used in the study, along with data obtained from the Landsat satellite mission. Vegetation indices were calculated from satellite data, including NBR (Normalized Burn Ratio), NDVI (Normalized Difference Vegetation Index), NDMI (Normalized Difference Moisture Index), TCG (Tasseled Cap Greenness), and TCW (Tasseled Cap Wetness). Change maps generated using the LandTrendr algorithm were used to analyze changes in forest stands in the study area. The change maps exhibited a high level of overall accuracy, ranging from 93% to 97%. The forest stands condition from 1984 to 2022 underwent significant changes, and based on the results obtained, it was calculated that the total area affected by negative changes was 150 km², accounting for 20 percent of the forest area. . The study comprised four stages: creating multi-temporal composites, using the LandTrendr algorithm on the GEE platform, creating a validation layer, and evaluating the accuracy of the algorithm's results.

Methodology

The study comprised four main stages:

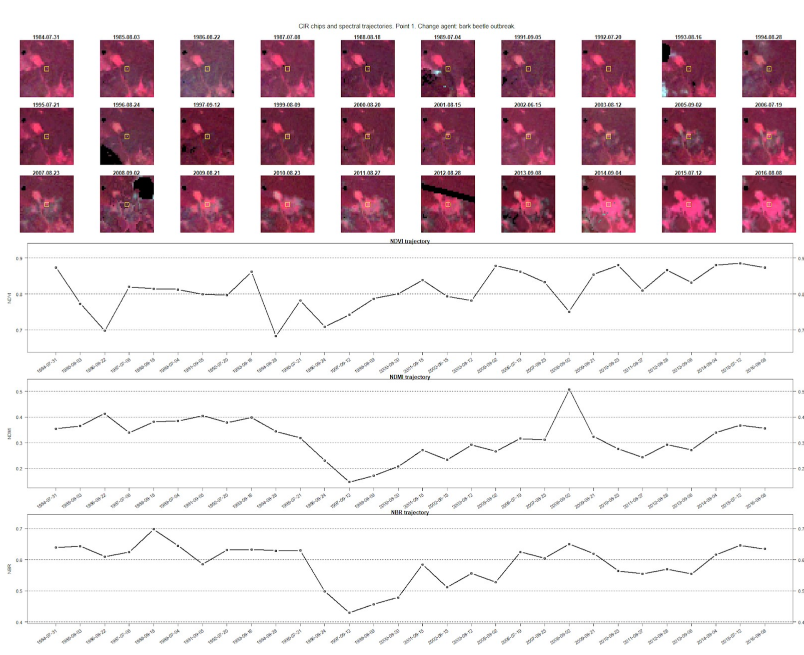
- creating multi-temporal composites,
- using the LandTrendr algorithm on the GEE platform
- creating a validation layer
- evaluating the accuracy of the algorithm's results.





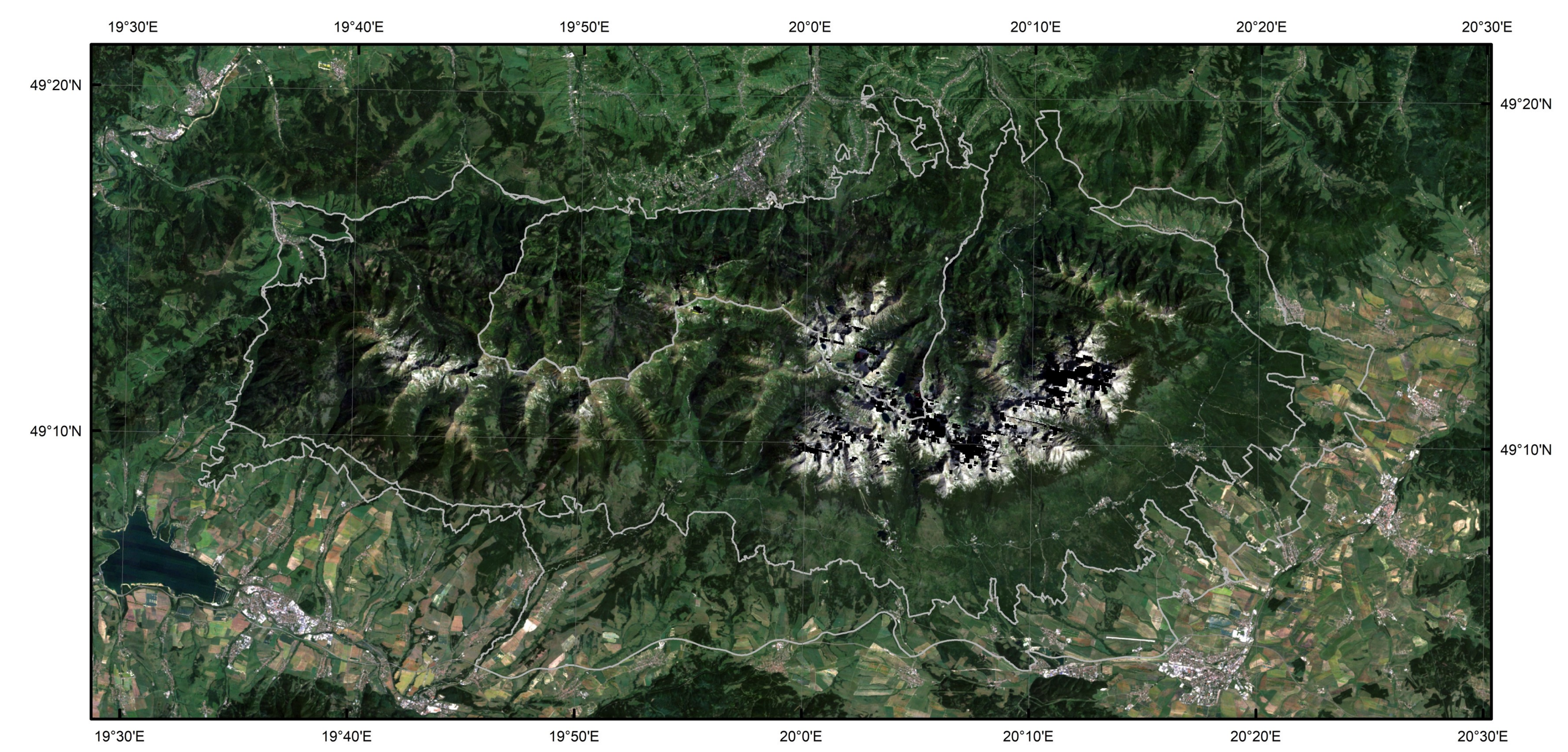
An important stage of the study was the development of a forest stand mask. For this purpose, supervised classification of satellite imagery of the study area for the years 1984 and 2022 was performed. Subsequently, the forest class was exported and combined into one range. In the further part of the study, the forest stand mask served as a range for the LandTrendr algorithm.

The next stage of the study involved developing a validation layer. For this purpose, 100 validation points were randomly selected from the forest stand mask. Then, for each point, a chip was created featuring the point's image in CIR (Color Infrared) composition and spectral trajectories of the indices NBR, NDMI, and NBR. Based on these indices and image interpretation, the years in which changes occurred at the selected points were determined. Subsequently, using the validation layer, the accuracy values of the algorithm were calculated. Ultimately, 59 changes were marked in the validation layer.



Study area

Tatra Mountains within Polish (TPN) and Slovak (TANAP) national parks borders including slovak buffer zone.



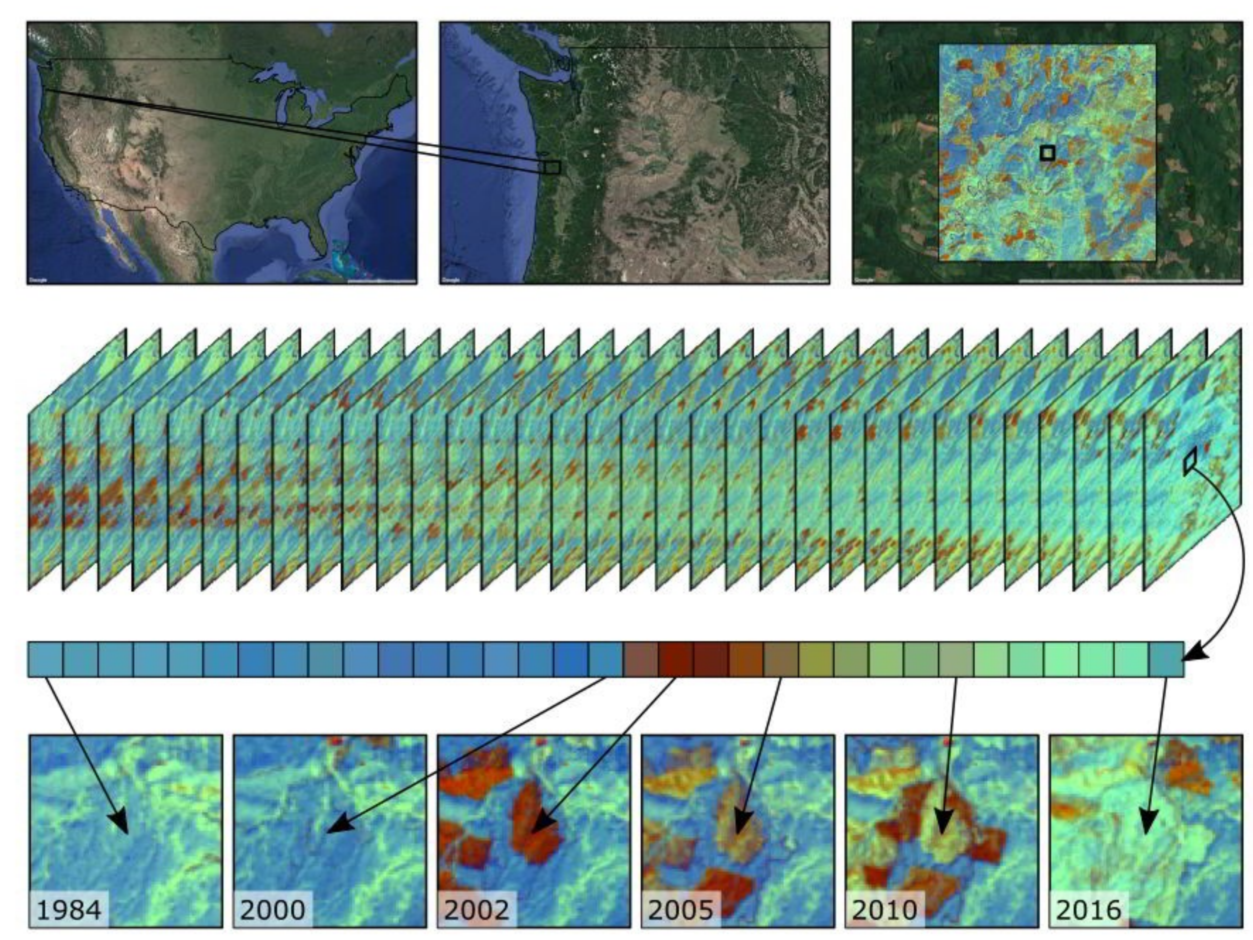
In the background is Landsat median composition from 2022 RGB 432.

Area of study

Coordinate system: WGS 1984 UTM Zone 34N
Datum: WGS 1984

LandTrendr

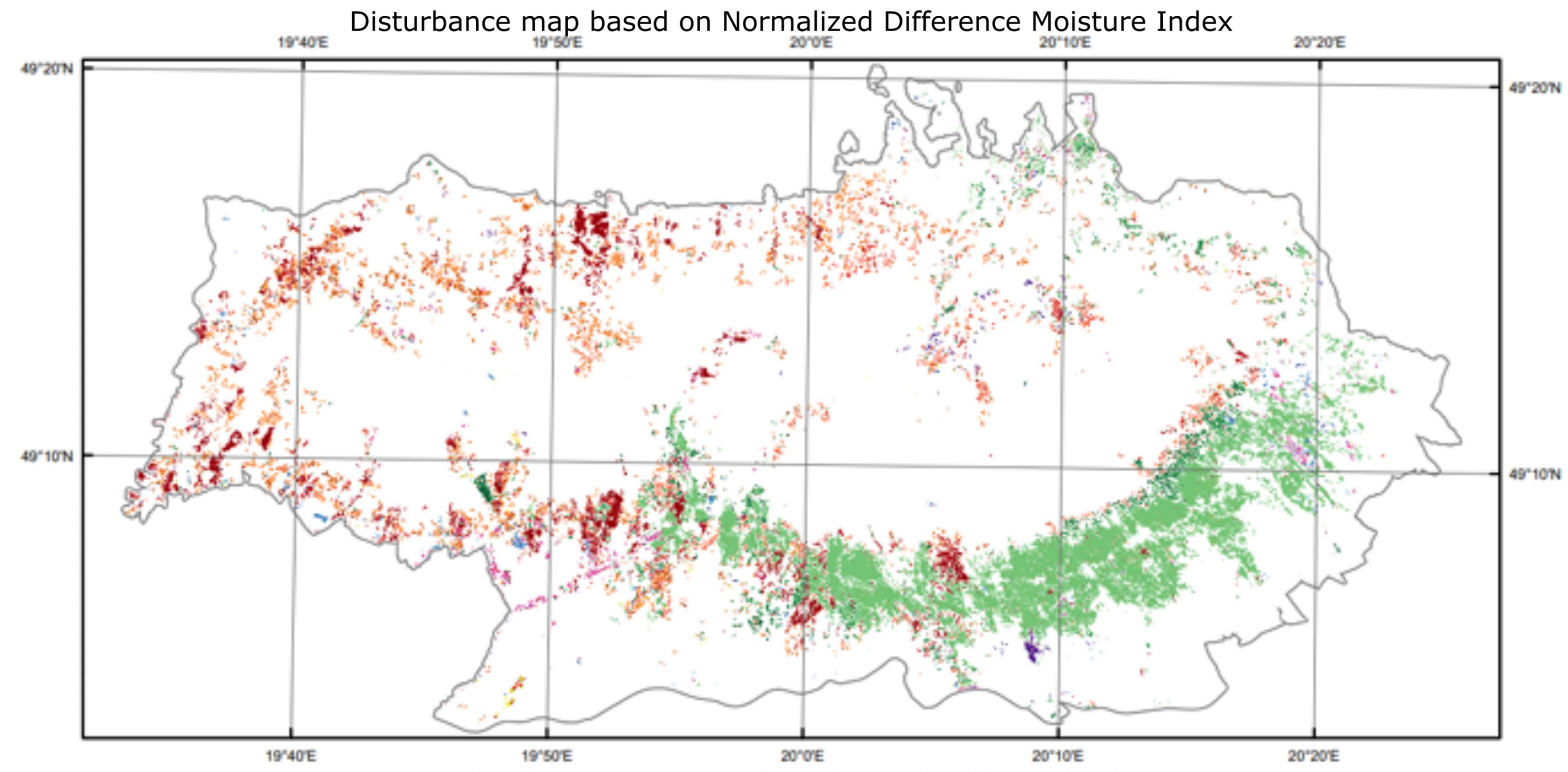
The LandTrendr algorithm (Landscape Change Monitoring, Research, and Tracking) is a tool for analyzing landscape changes using remote sensing data, mainly satellite images. The main goal of the algorithm is to identify trends in land cover changes and monitor them over time. LandTrendr utilizes time series of satellite images to detect changes in vegetation, such as deforestation, forest fires, or natural succession processes.



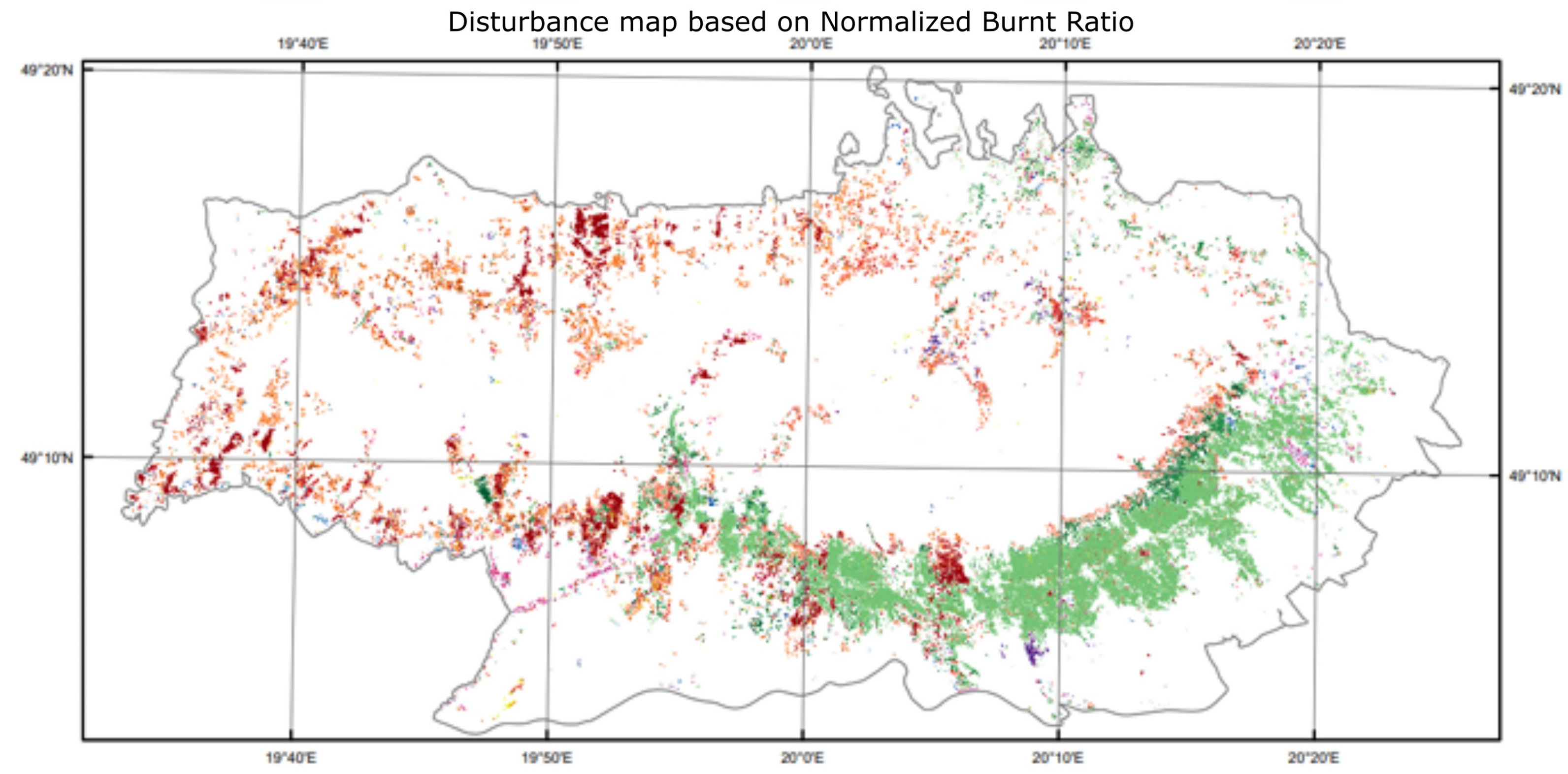
source: https://emapr.github.io/LT-GEE/landtrendr.html

Results

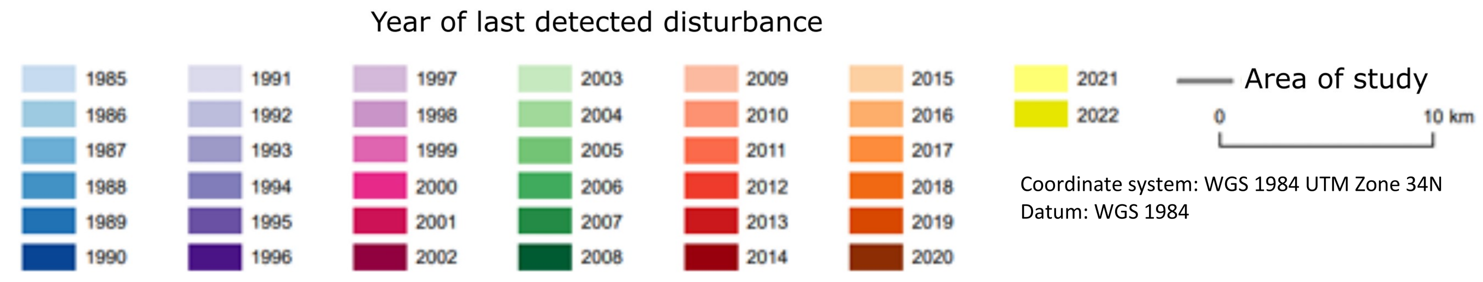
Disturbance map based on Normalized Difference Moisture Index



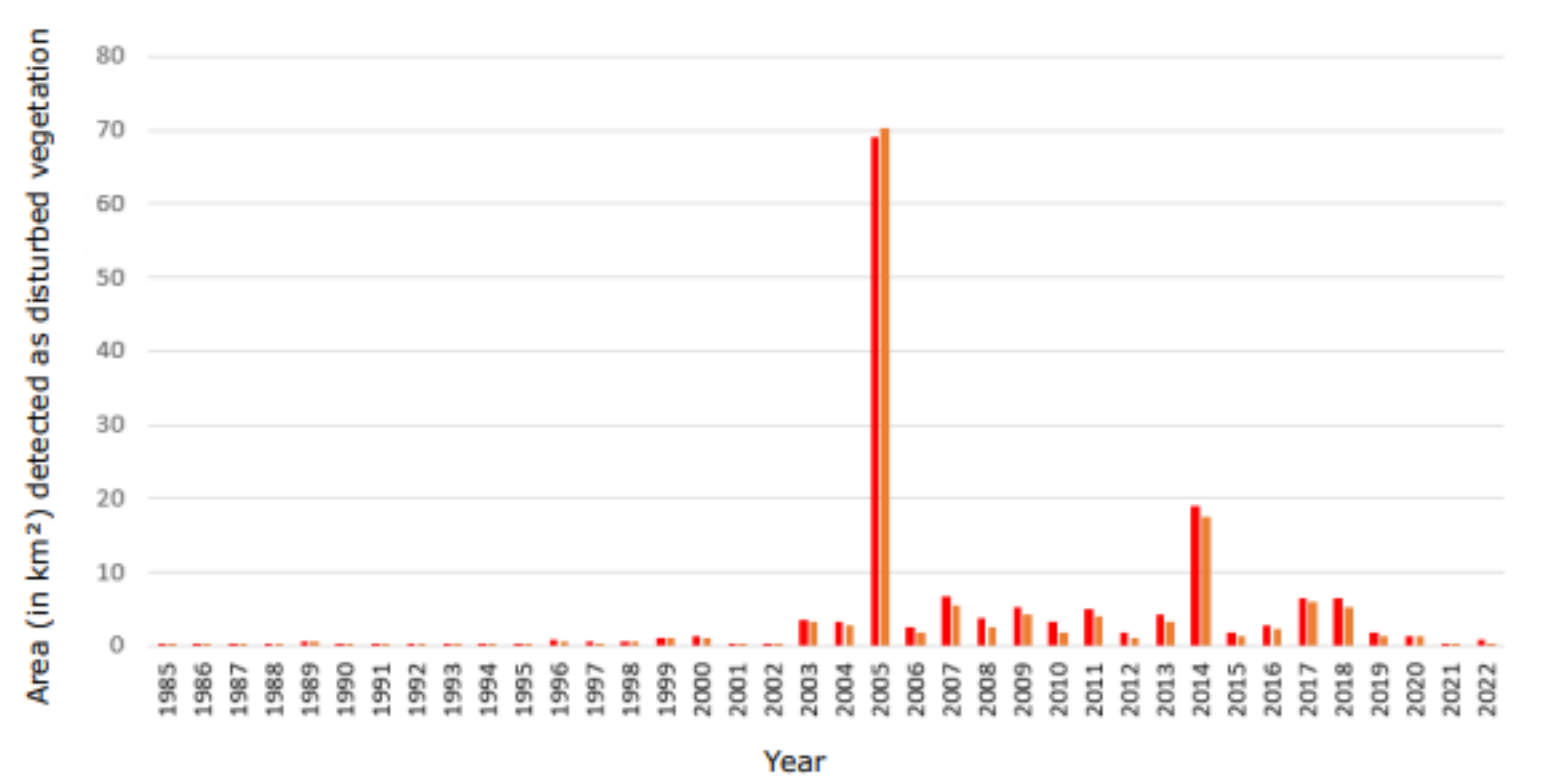
Disturbance map based on Normalized Burnt Ratio



Year of last detected disturbance



Coordinate system: WGS 1984 UTM Zone 34N
Datum: WGS 1984



results obtained based on NBR time series (red) and NDMI time series (orange)

Conclusions

- The forested area of the Tatra Mountains underwent significant changes between 1984 and 2022. According to the algorithm's results, an average of 150 km² of forest was destroyed during the study period.
- The results obtained show that the dynamics of forest changes have increased since 2003.
- The largest year-to-year changes were observed in 2005 (as a result of the windthrow on November 19, 2004, which occurred mainly in the Slovak part of the Tatras).
- The developed change maps showed high overall accuracy (93-97%), however, its value is overstated by periods without changes. The highest values characterized the change maps for the NBR and NDMI indices.
- Indices calculated based on short infrared channels provided higher accuracy values than those calculated based on the visible range. NBR had 97% overall accuracy while other indices ranged from 93% to 96%.
- Despite high values of overall accuracy, the algorithm has flaws. The TP values are low, and in the best case, the algorithm correctly detected 50% of the changes.
- Algorithm detects well rapid changes such a in year 2005 but struggles with slower changes such as those caused by bark beetle outbreaks.
- The detected disturbances were primarily caused by windthrows, bark beetle outbreaks and also harvesting, landslides and constructing.

E-TRAINEE

*Presented research is based on the exercise "Vegetation change and disturbance detection" presented within Module 2 of an open **E-learning course on Time Series Analysis in Remote Sensing for Understanding Human-Environment Interactions (E-TRAINEE**, Erasmus+Strategic partnership, ID 2020-1-CZ01-KA203-078308) developed within collaboration of four research groups from Charles University, Heidelberg University, University of Innsbruck, and University of Warsaw.*