THRESHOLD AND TREND-BASED VEGETATION CHANGE MONITORING ALGORITHM BASED ON THE INTER-ANNUAL MULTI-TEMPORAL NORMALIZED DIFFERENCE MOISTURE INDEX SERIES: A CASE STUDY OF THE TATRA MOUNTAINS

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EnviLink – międzynarodowa platforma wymiany doświadczeń młodych naukowców w badaniach przyrodniczych
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MOTIVATION

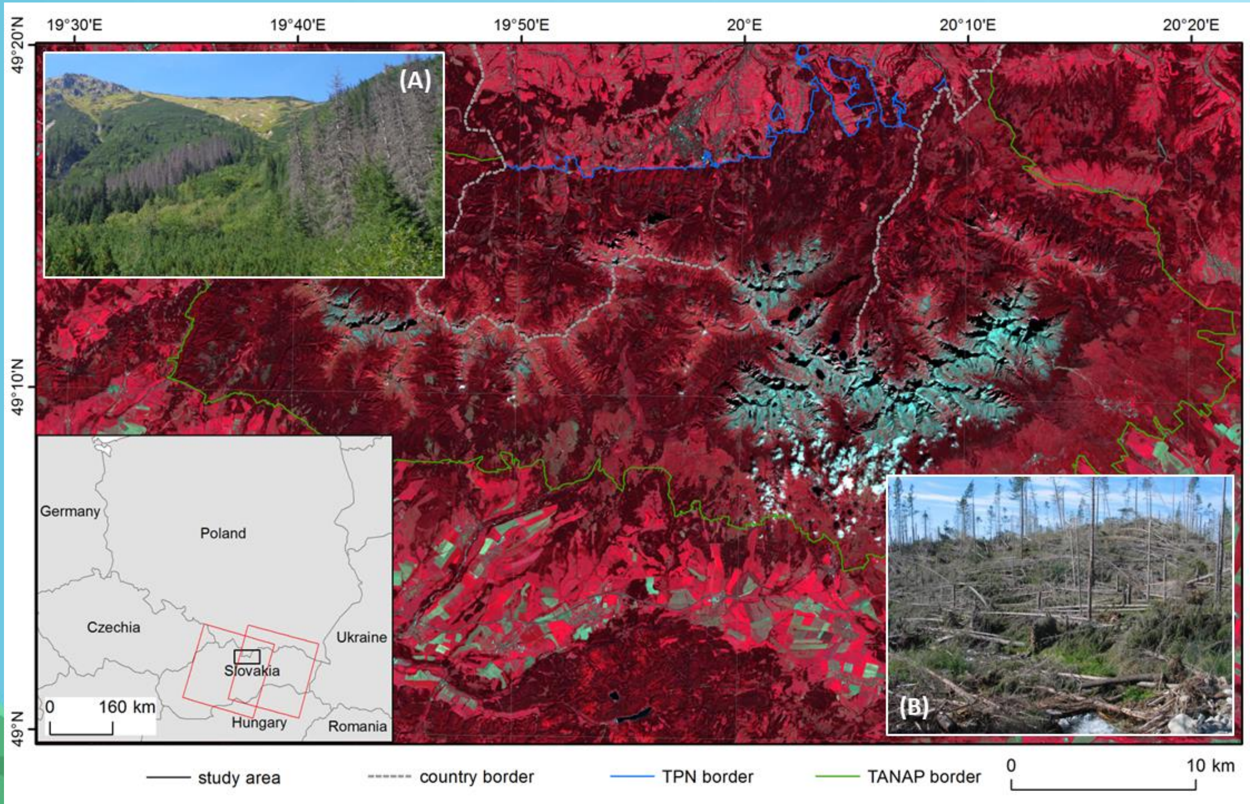
- Vegetation plays a significant role in climate regulation processes
- Changes of vegetation occurs on different spatial scales
- Temporal-scale changes are abrupt and gradual, there are also seasonal changes
- Many algorithms have been developed
- Satellite imagery provides opportunities to monitor such changes e.g. Landsat imagery (acquired within 16 days interval from one satellite)

Disturbance agents: A – windthrow (https://portaltatrzanski.pl); B – bark beetle (own picture); C – landslide (http://www.poznajtatry.pl); D – construction (https://www.slovakia.com).

AIM OF THE STUDY

- Develop a simple and flexible algorithm for the monitoring of abrupt and gradual changes in the vegetation using annual Landsat time series based on thresholding and regression
- **Threshold- and Trend-based Vegetation Change Monitoring Algorithm** (TVCMA)
- Validate the effectiveness of the selected vegetation indices for the monitoring of vegetation disturbances based on satellite data

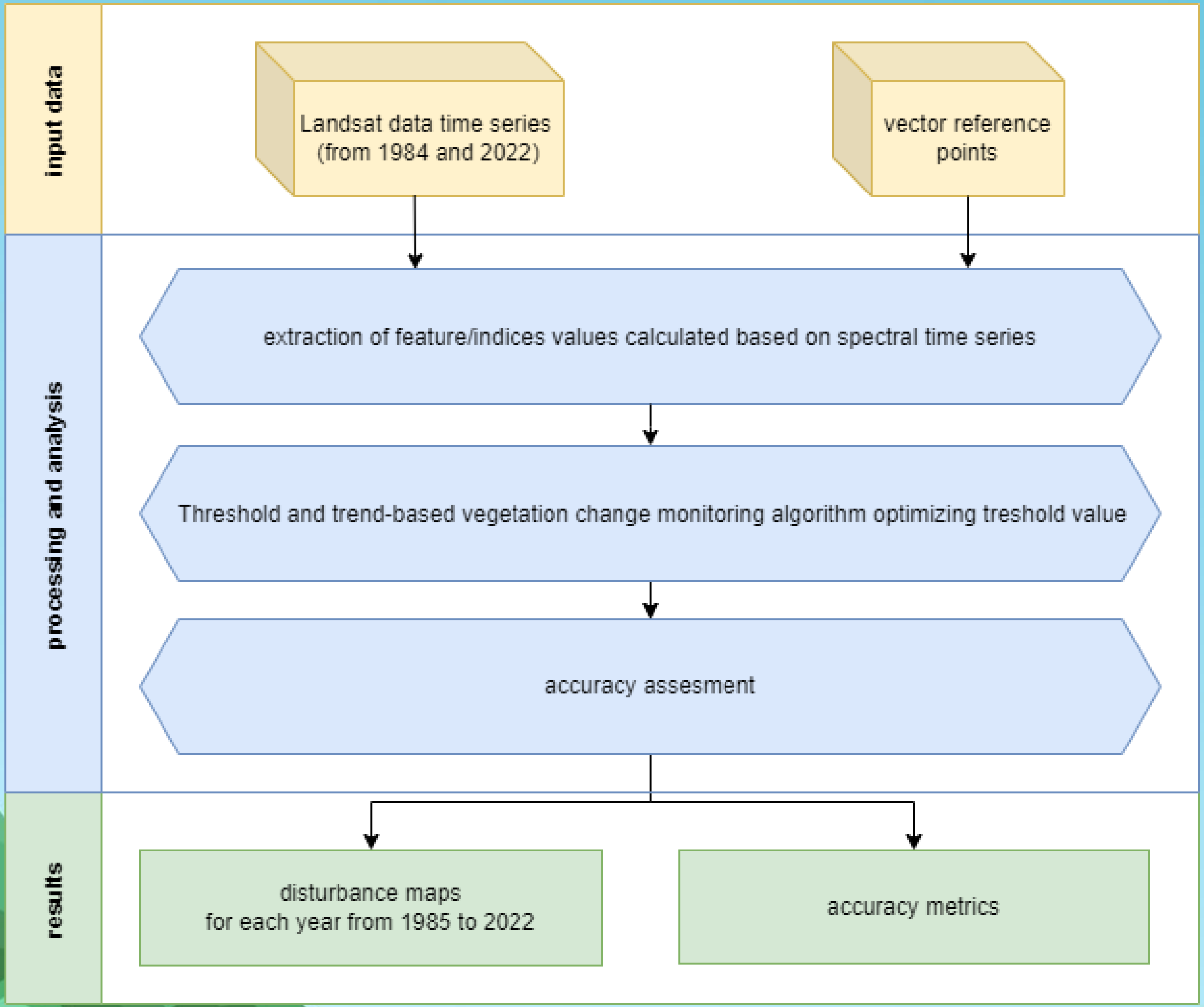
STUDY AREA



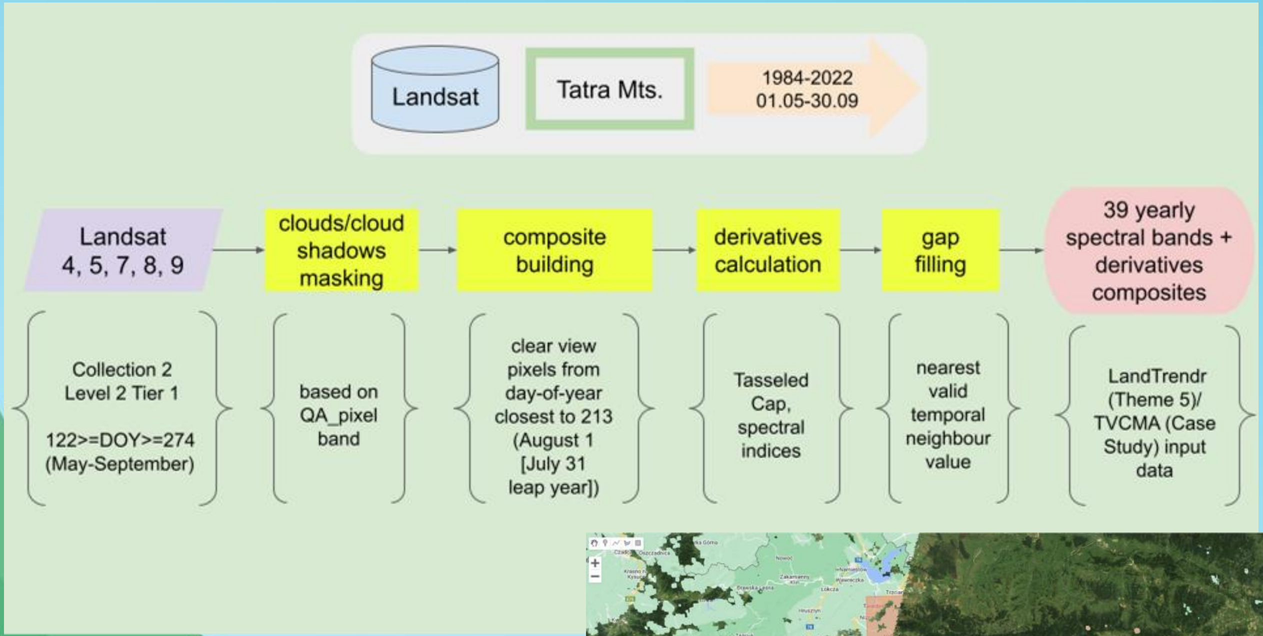
Landsat 8 courtesy of the USGS,
(A) bark beetle outbreak (own photo)
(B) bora wind (photo by Falťan et al., 2020)

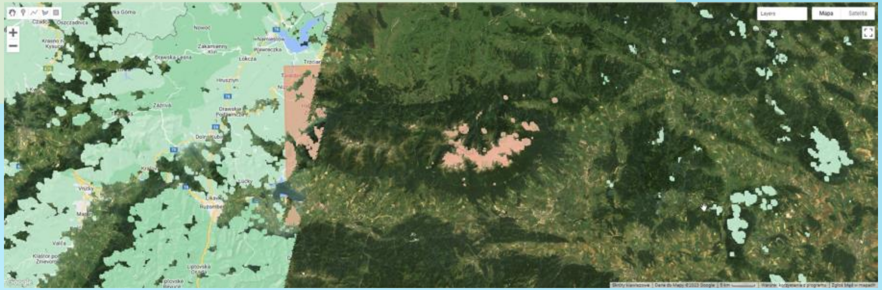
(TPN - Tatrzański Park Narodowy,
TANAP - Tatranský Národný Park)

METHODS

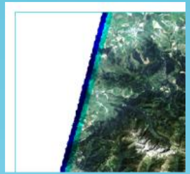

input data
Landsat data time series (from 1984 and 2022)
vector reference points
processing and analysis
extraction of feature/indices values calculated based on spectral time series
Threshold and trend-based vegetation change monitoring algorithm optimizing treshold value
accuracy assesment
results
disturbance maps for each year from 1985 to 2022
accuracy metrics

INITIAL SATELLITE DATA PREPARATION

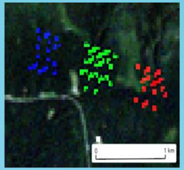




Example of cloud free image, Google Earth Engine

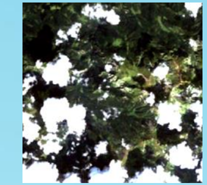


background

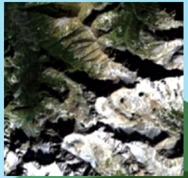


scanning errors

missing scan lines



clouds and shadows



topographic shadows

TESTED VARIABLES

Selected vegetation indices (B in formulas indicates spectral band of Landsat sensors).

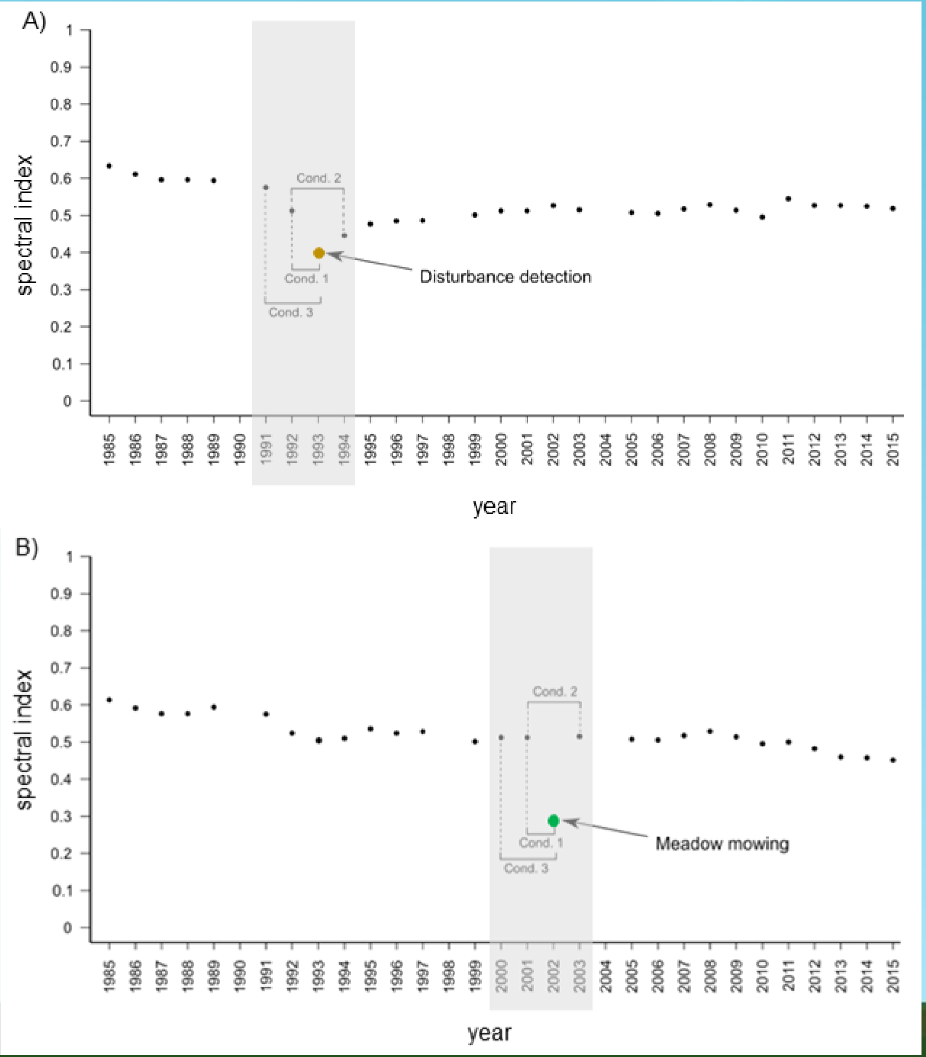
Index name	Calculation on Landsat data	Reference
Enhanced vegetation index	$EVI = \frac{NIR - RED}{NIR + 6 * RED - 7,5 * BLUE + 1}$	Huete et al., 2002
Green normalized difference vegetation index	$GNDVI = \frac{NIR - GREEN}{NIR + GREEN}$	Gitelson and Merzlyak, 1998
Moisture stress index	$MSI = \frac{SWIR1}{NIR}$	Hunt and Rock, 1989
Normalized difference moisture index	$NDMI = \frac{SWIR1 - NIR}{SWIR1 + NIR}$	Hardisky and Klemas, 1983
Normalized difference vegetation index	$NDVI = \frac{NIR - RED}{NIR + RED}$	Rouse et al., 1973
Normalized pigment chlorophyll index	$NPCI = \frac{RED - BLUE}{RED + BLUE}$	Peñuelas et al., 1993
Optimized soil adjusted vegetation index	$OSAVI = \frac{1,5\,(NIR - RED)}{NIR + GREEN + 0,16}$	Rondeaux et al., 1996
Plant senescence reflectance index	$PSRI = \frac{RED - BLUE}{NIR}$	Merzlyak et al., 1999
Simple ratio	$SR = \frac{NIR}{RED}$	Birth and McVey, 1968
Wide dynamic range vegetation index	$WDRVI = \frac{0,2 * NIR - RED}{0,2 * NIR + RED}$	Gitelson, 2004

Tasseled Cap transformation products: Brightness, Greenness and Wetness (Kauth, Thomas, 1976).

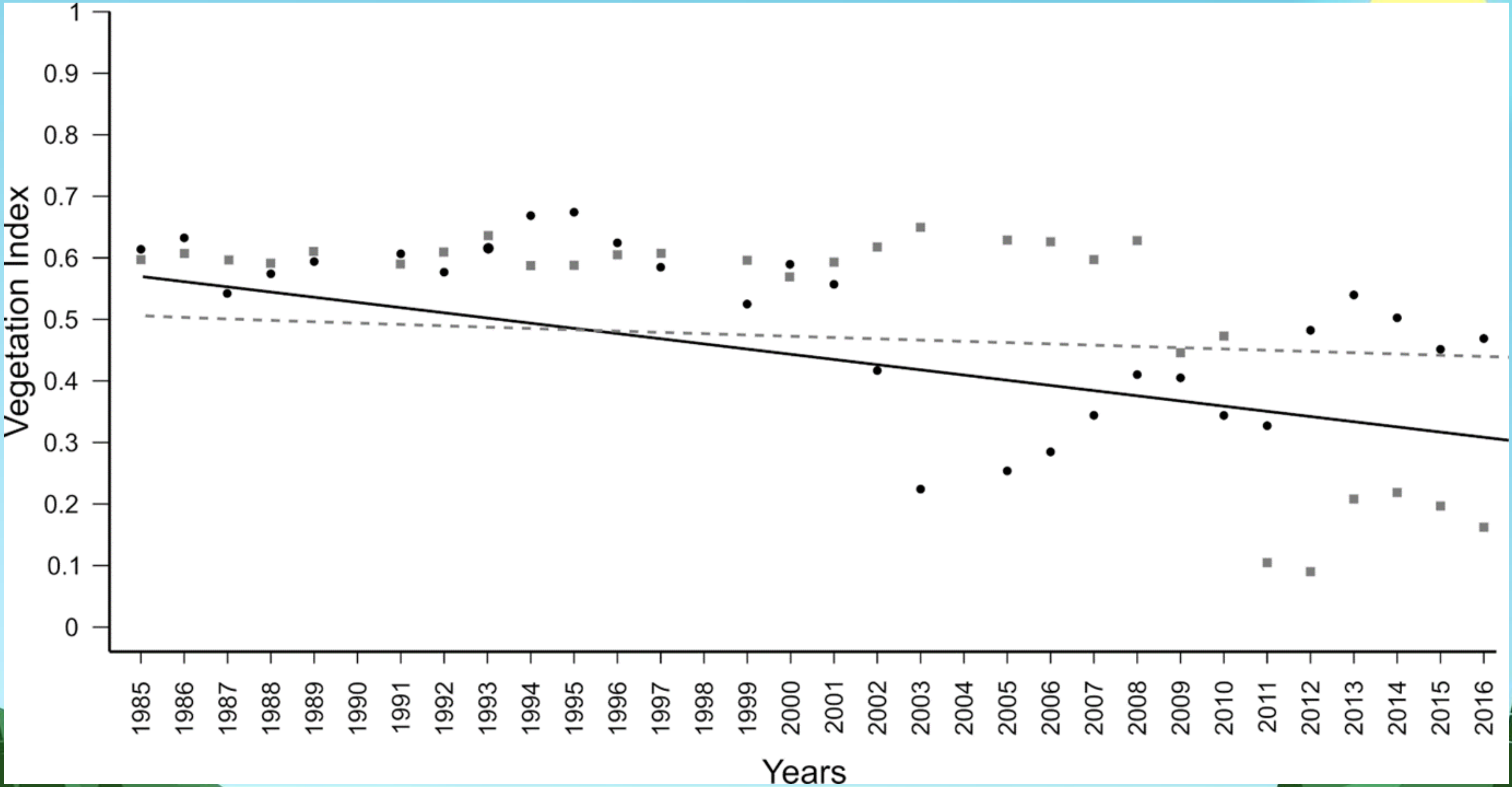
TVCMA CONDITIONS

Conditions:

1. If the difference between the variable value on the date currently being analyzed (x_{t-3}) and the preceding date (x_{t-2}) exceeds the threshold value is indicated as a potential vegetation disturbance (x_{t-3}–x_{t-2}).
2. If the difference between the variable value on the date following the date of analysis (x_{t-4}) and the preceding date (x_{t-2}) exceeds the threshold value is indicated as a potential vegetation disturbance (x_{t-4}–x_{t-2}).
3. If the difference between the variable value on the date of analysis (x_{t-3}) and the date preceding the said date by two dates (x_{t-1}) exceeds the threshold value is indicated as a potential change (x_{t-3}–x_{t-1}).



MULTI-TEMPORAL ANALYSIS OF SATELLITE DATA – REGRESSION

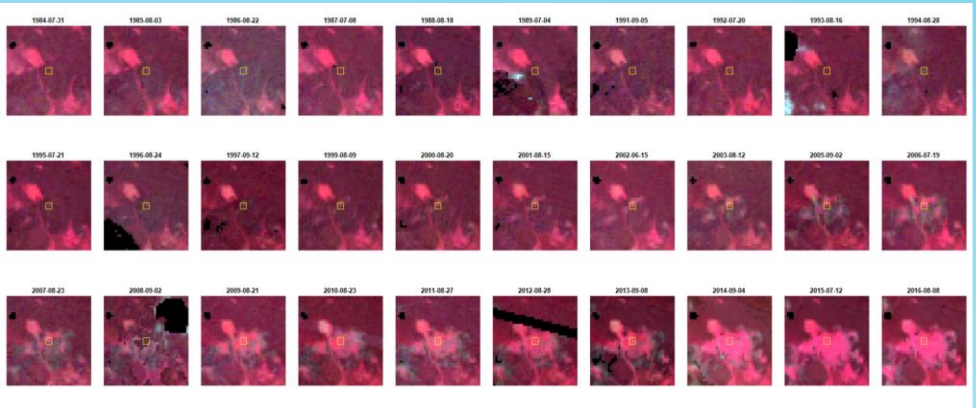


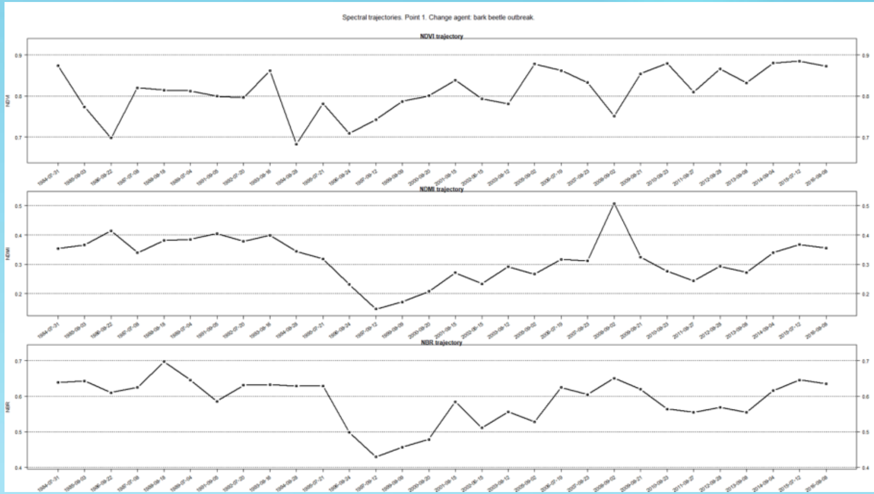
Example trends for two data series. The trends show long-term changes in the vegetation index values.

PRODUCTS OF TVCMA (IMAGES)

- **direction and magnitude** of change expressed by the sign and value of the angle between the modeled trend line and the x-axis.
- **Spearman's correlation coefficients** for each pixel – the goodness of fit of the modeled trend line that represents the rate of change.
- **p-values** for Spearman's correlation tests – statistical significance of the given correlation coefficients.
- information on the **number of disturbances** that occurred in a given pixel during the analysis period.
- spatial **location and time** of the disturbance.

REFERENCE DATA PREPARATION





id	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

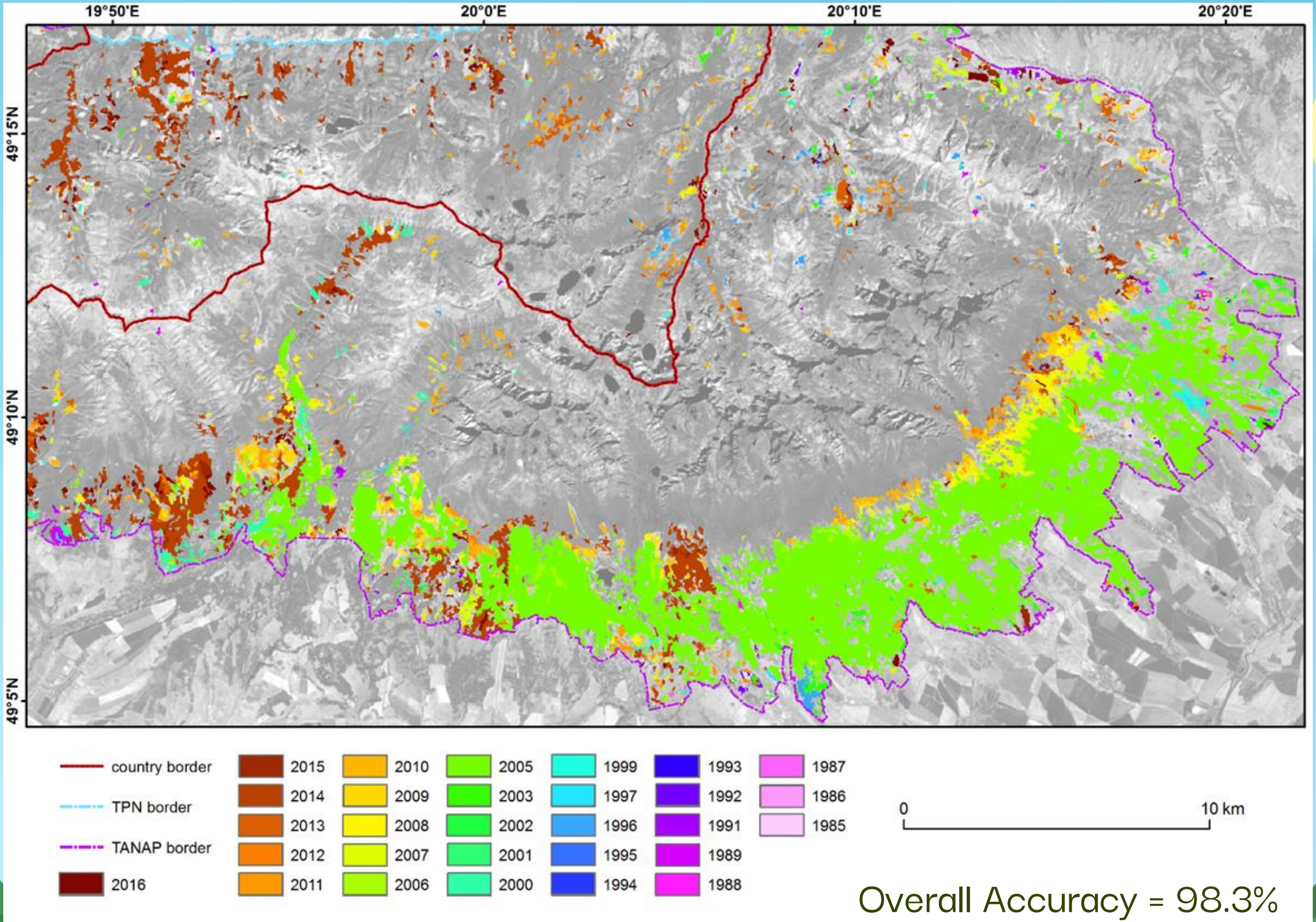
ACCURACY ASSESSMENT

- 100 randomly selected pixels
- 38 years in time series
- 3800 validation observations
- 69 observed disturbance events

	Reference	Algorithm	Accuracy
TP - true positives	1	1	☺
FP - false positives	0	1	☹
TN - true negatives	0	0	☺
FN - false negatives	1	0	☹

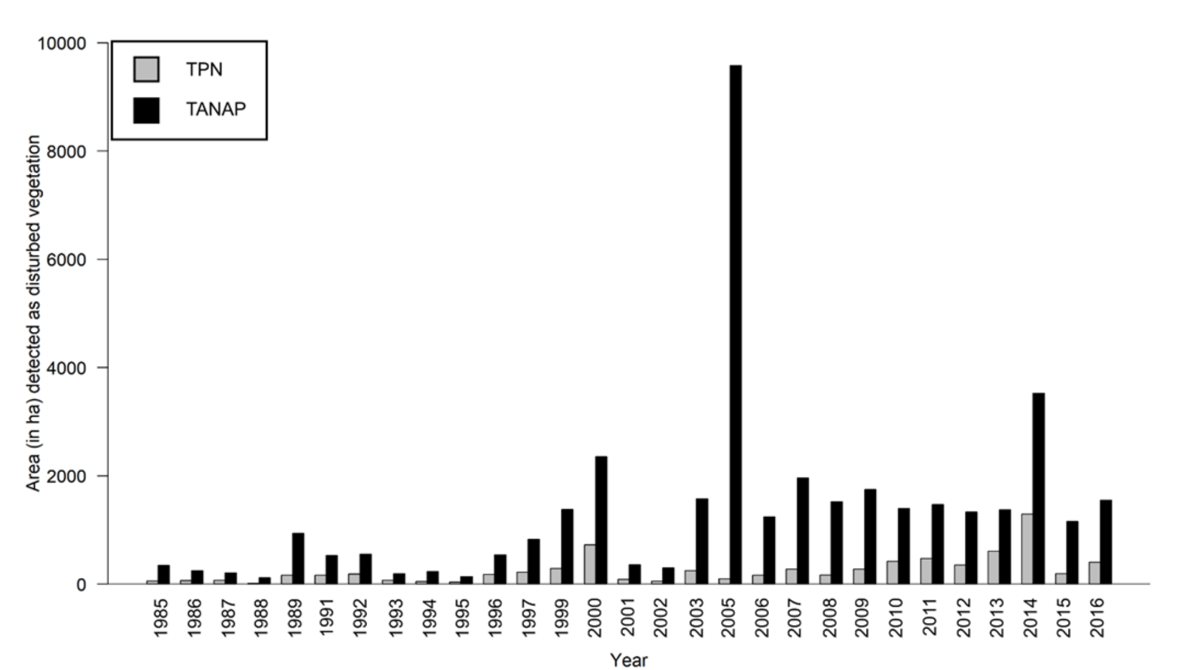
Results for NDMI values

1	Set	TP	FP	TN	FN	Accuracy	Precision	Sensitivity	Specificity	F1_Score
2	Threshold_-0_01	59	528	3203	10	0,858421	0,100511	0,855072	0,858483	0,179878
3	Threshold_-0_02	56	376	3355	13	0,897632	0,12963	0,811594	0,899223	0,223553
4	Threshold_-0_03	53	278	3453	16	0,922632	0,160121	0,768116	0,925489	0,265
5	Threshold_-0_04	52	197	3534	17	0,943684	0,208835	0,753623	0,947199	0,327044
6	Threshold_-0_05	48	138	3593	21	0,958158	0,258065	0,695652	0,963013	0,376471
7	Threshold_-0_06	47	100	3631	22	0,967895	0,319728	0,681159	0,973198	0,435185
8	Threshold_-0_07	45	63	3668	24	0,977105	0,416667	0,652174	0,983114	0,508475
9	Threshold_-0_08	39	46	3685	30	0,98	0,458824	0,565217	0,987671	0,506494
10	Threshold_-0_09	37	35	3696	32	0,982368	0,513889	0,536232	0,990619	0,524823
11	Threshold_-0_1	37	28	3703	32	0,984211	0,569231	0,536232	0,992495	0,552239
12	Threshold_-0_11	37	22	3709	32	0,985789	0,627119	0,536232	0,994103	0,578125
13	Threshold_-0_12	33	15	3716	36	0,986579	0,6875	0,478261	0,99598	0,564103
14	Threshold_-0_13	29	10	3721	40	0,986842	0,74359	0,42029	0,99732	0,537037
15	Threshold_-0_14	27	6	3725	42	0,987368	0,818182	0,391304	0,998392	0,529412
16	Threshold_-0_15	26	6	3725	43	0,987105	0,8125	0,376812	0,998392	0,514851
17	Threshold_-0_16	24	5	3726	45	0,986842	0,827586	0,347826	0,99866	0,489796
18	Threshold_-0_17	22	4	3727	47	0,986579	0,846154	0,318841	0,998928	0,463158
19	Threshold_-0_18	17	3	3728	52	0,985526	0,85	0,246377	0,999196	0,382022
20	Threshold_-0_19	17	3	3728	52	0,985526	0,85	0,246377	0,999196	0,382022
21	Threshold_-0_2	13	3	3728	56	0,984474	0,8125	0,188406	0,999196	0,305882

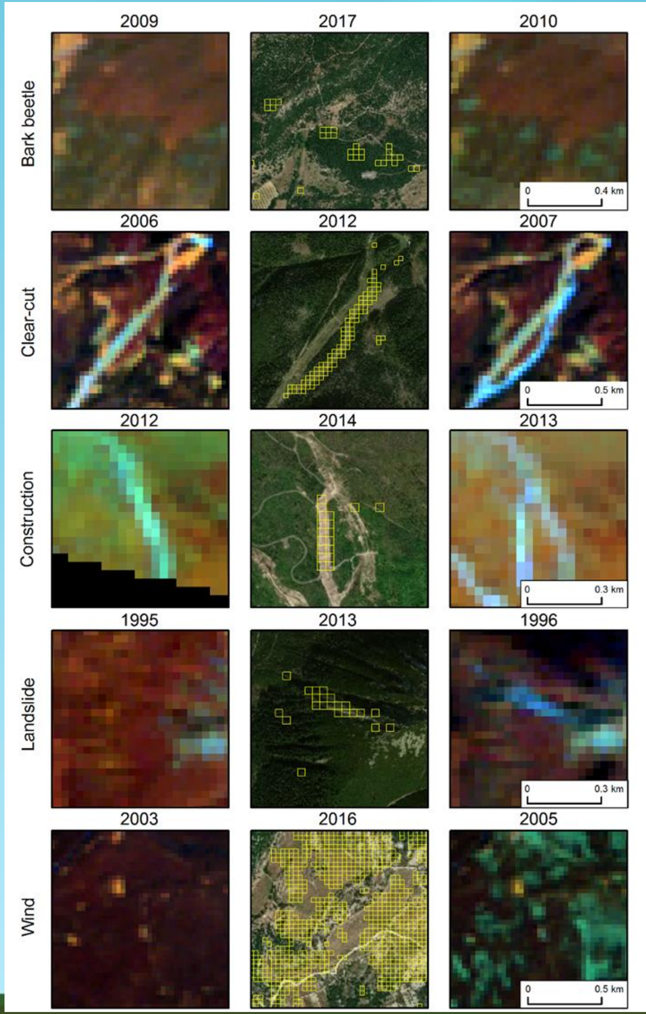


Overall Accuracy = 98.3%

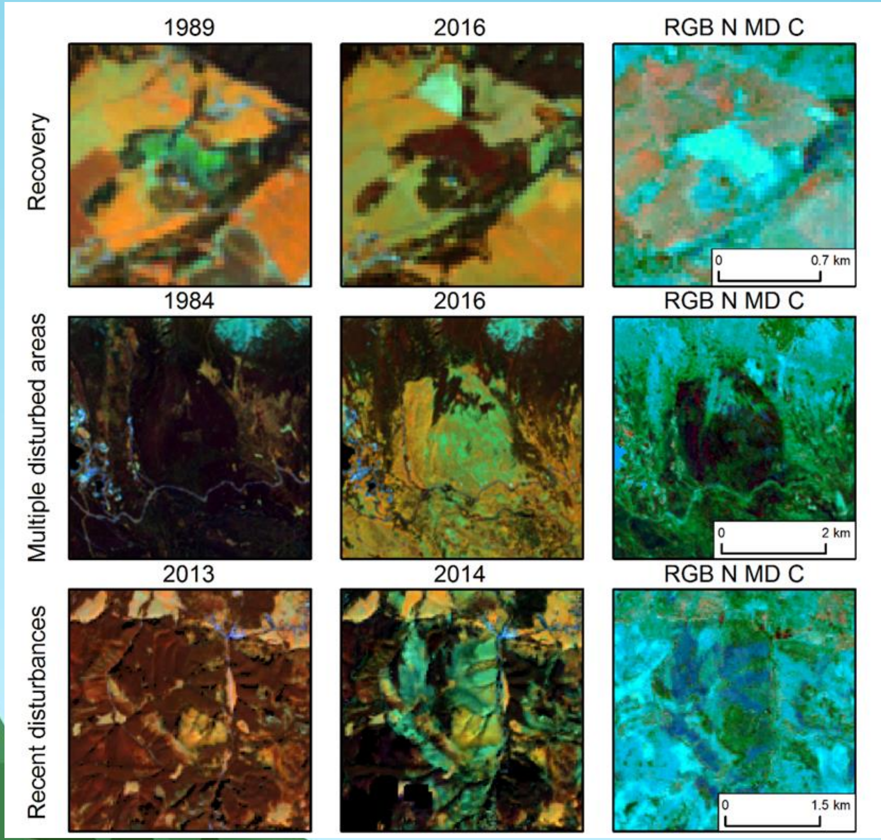
Year of latest detected disturbance events



Detected disturbance areas in the Polish and Slovak National Parks



DISTURBANCE MAPPING



RGB composition created by using the resulting TVCMA images:

N – number of the disturbances for a given pixel,

MD – magnitude and direction of changes,

C – Spearman's correlation coefficient.

SUMMARY & CONCLUSIONS

- Using TVCMA we obtained 38 images that mapped the spatial distribution of disturbed areas in Tatra Mountains from 1985 to 2022 (spatial resolution 30 meters).
- The detected disturbances were primarily related to windthrow and bark beetle outbreaks.
- By using the thresholding approach, the algorithm easily recognizes **abrupt changes** such as windthrows because of their sudden nature, and these typically appear as a rapid drop in the spectral indices values.

CONCLUSIONS

- For more **gradual changes**, such as the spread of bark beetle infestations, the measured differences are less pronounced, thus resulting in a slightly lower detection accuracy.
- A regression approach allows to map not only the disturbed areas, but also the **recovery** process.
- The analysis can be **reproduced** for other terrains by fitting the threshold value to the characteristics of the site-specific.

THANK YOU

Do you have any questions?

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ELSEVIER

Threshold- and trend-based vegetation change monitoring algorithm based on the inter-annual multi-temporal normalized difference moisture index series: A case study of the Tatra Mountains

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E-TRAINEE

Erasmus+

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