Early detection of beetle infestations using dense time series of Sentinel-2 data

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based on

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Report says 50 percent of Czechia's forests are threatened by bark beetle

10/08/2019

Report says 50 percent of Czechia's forests are threatened by bark beetle

Length of audio 3:16

Photo: Martina Schneibergová

Forest owners in the Czech Republic face damages of up to 40 million crowns this year from an escalating spread of bark beetle, suggests a report by the think-tank Czech Forest, an independent group of experts in the forestry sector. The report warns that in the future,

Bark beetle infestation worst in over 200 years

07/08/2018

The Czech Republic's largely coniferous forests are facing the worst bark beetle infestation in at least 200 years. The lower house of Parliament is due on Tuesday to discuss both emergency and long-term measures to combat the voracious insect, which kills spruce trees.

The amount of spruce wood damaged by bark beetles has risen steadily in the past few years, from 2 million cubic metres of spruce wood in 2015 to more than 5.5 million cubic metres in 2017. Experts are warning that the nation's forests could be wiped out if the current monoculture forestry format is not unchanged.

Author: Brian Kenety

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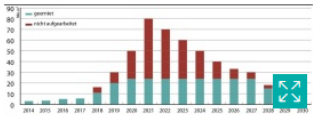
CZECH REPUBLIC

Up to 60 million m³ of bark beetle damage this year

450 million m³ of spruce at risk in the Czech Republic

Article by **Gerd Ebner (adapted for holzkurier.com; translated by Eva Guzely)** | 18.02.2020 - 08:53

In 2020, bark beetle infestation will continue in the Czech Republic. After 27.5 million m³ in 2019, this year could see between 40 and 60 million m³, predicts the think tank Czech Forest.



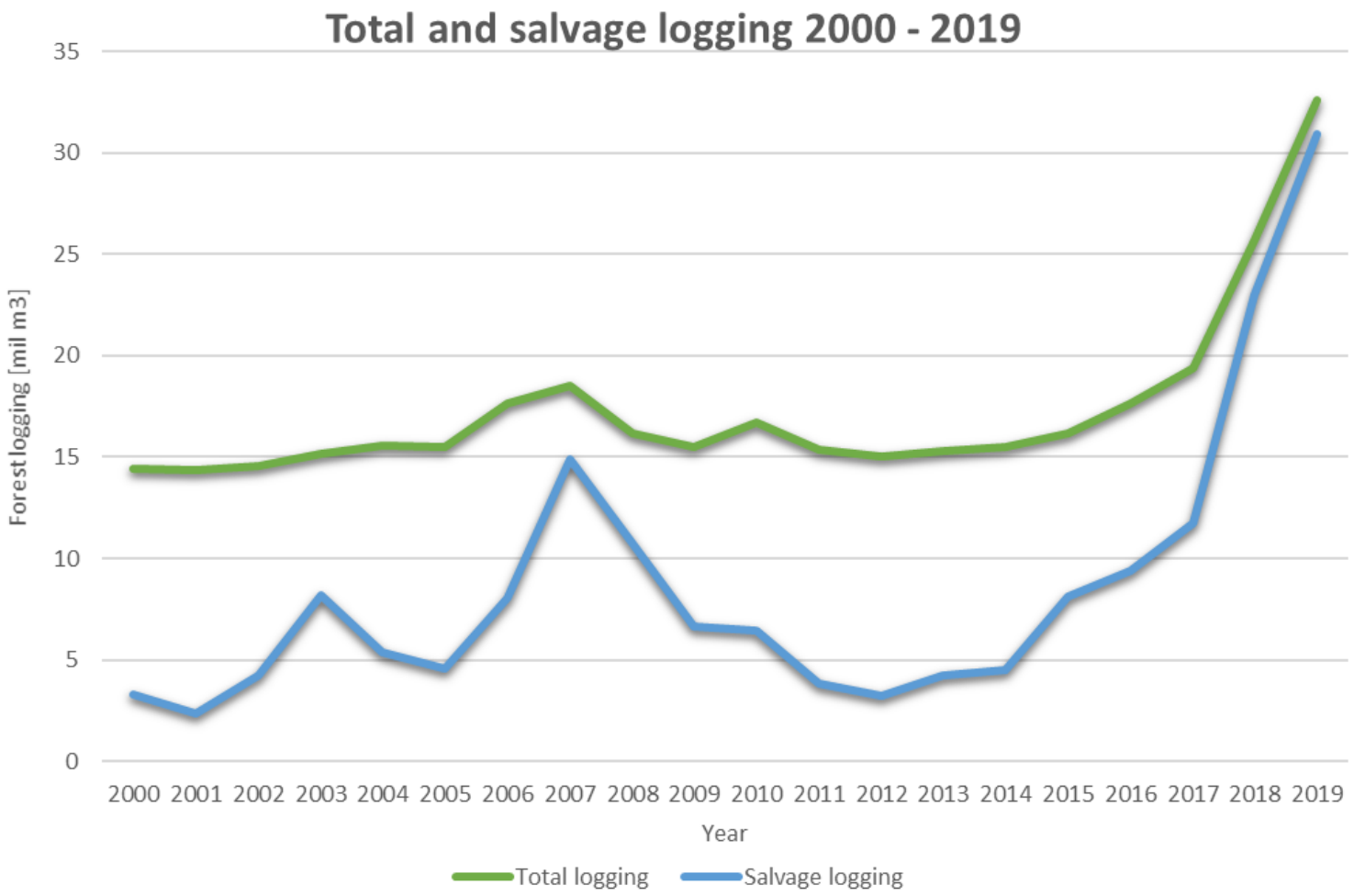
green: harvested, red: not removed

This chart is based on several key figures analyzed by Czech Forest. In addition to trends, geographic peculiarities were taken into account, i.e. spruce stocks at individual altitudes and regions, the current extent of the infestation, the temporal distribution of the bark beetle disaster in the Vysocina region, capacity and processing possibilities. The chart is not the result of a mathematical-statistical algorithm, but of a professional discussion of the members of the Czech Forest think tank about the available data. There are many

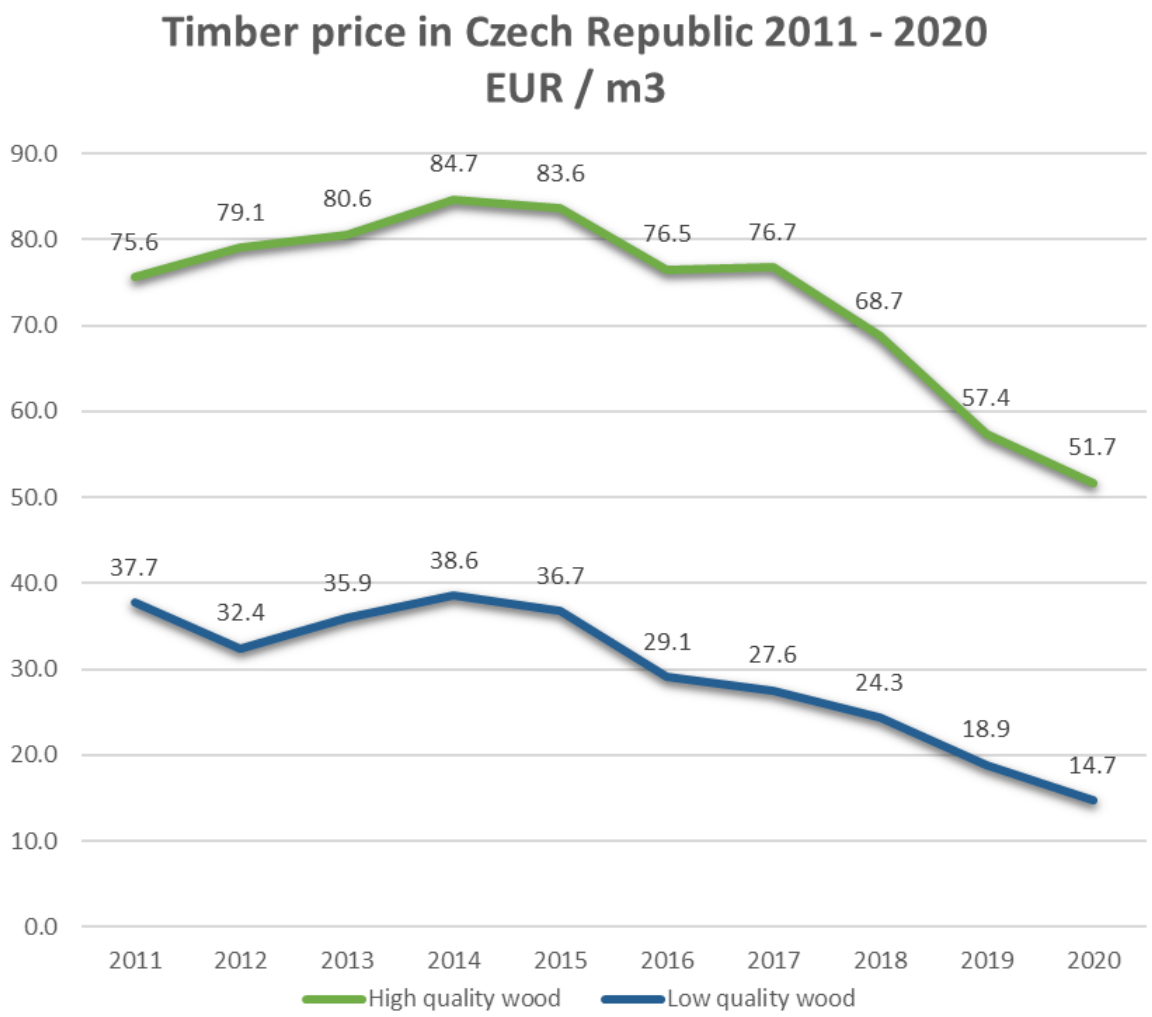
The pace of bark beetle infestation should continue in 2021, unless there are extreme weather conditions which are unfavorable for bark beetles and favorable for trees. With a doubling of infested trees in 2021, the volume of damaged wood would reach 80 to 120 million m³ already.

According to Czech Forest, 450 million m³ of spruce are at risk in the country.

After 2021, a decrease in infestation is to be expected which is mostly due to a general reduction of spruce stock. Czech Forest expects that a gradual shift of the calamity towards higher altitudes is likely which is also going to slow the spread of the parasites.



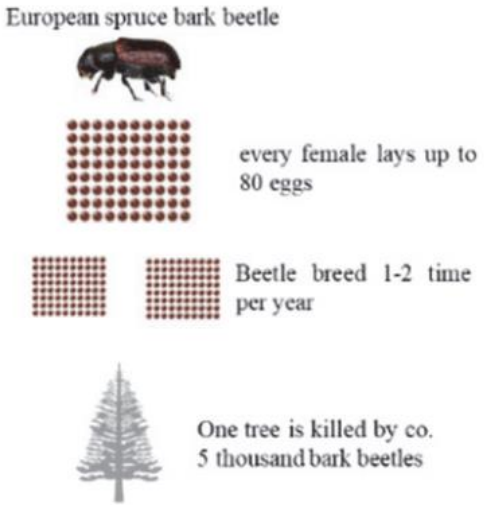
Source: Czech Statistical Office

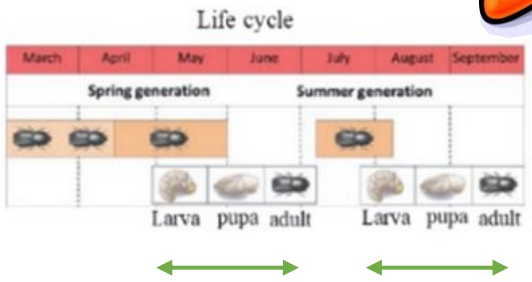


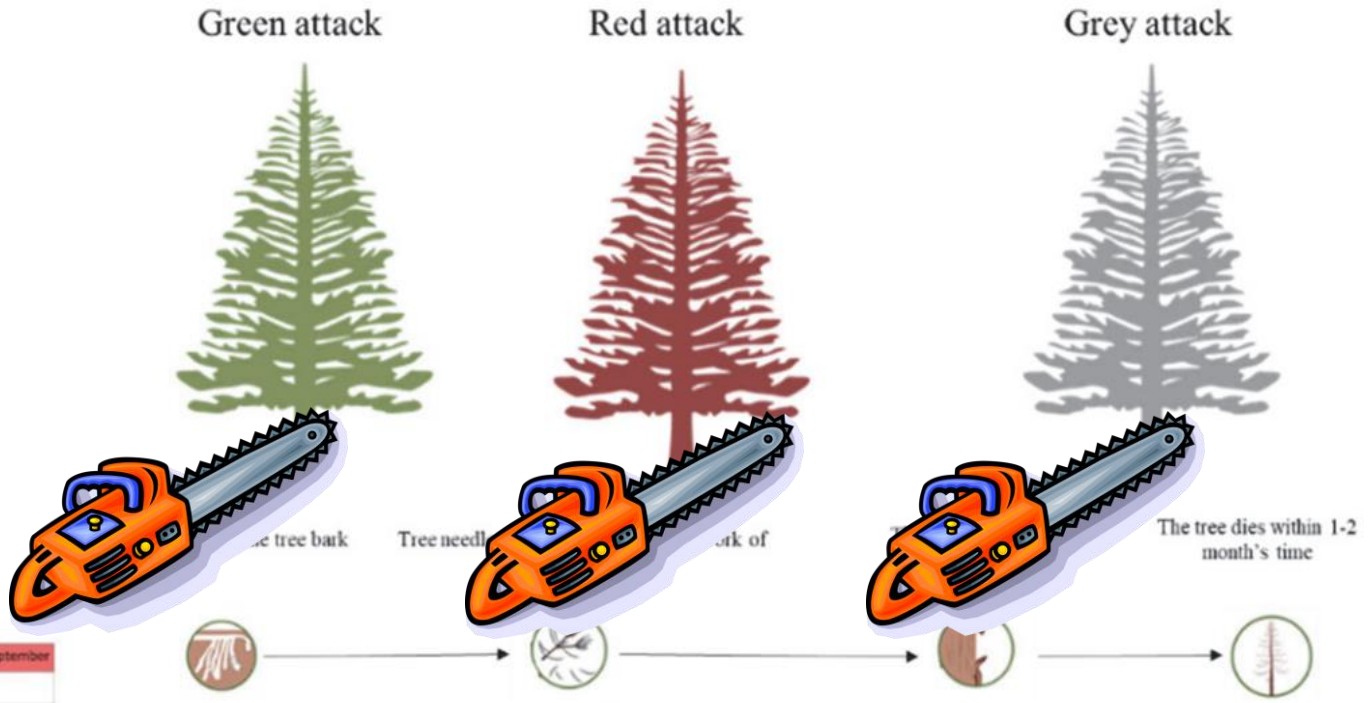
Source: Czech Statistical Office

Bark beetle and its attack stages

pre-visual visual **very** visual
(but not common in managed forests)







+ “clear-cut attack”

Heidi Abdullah, 2019, PhD thesis

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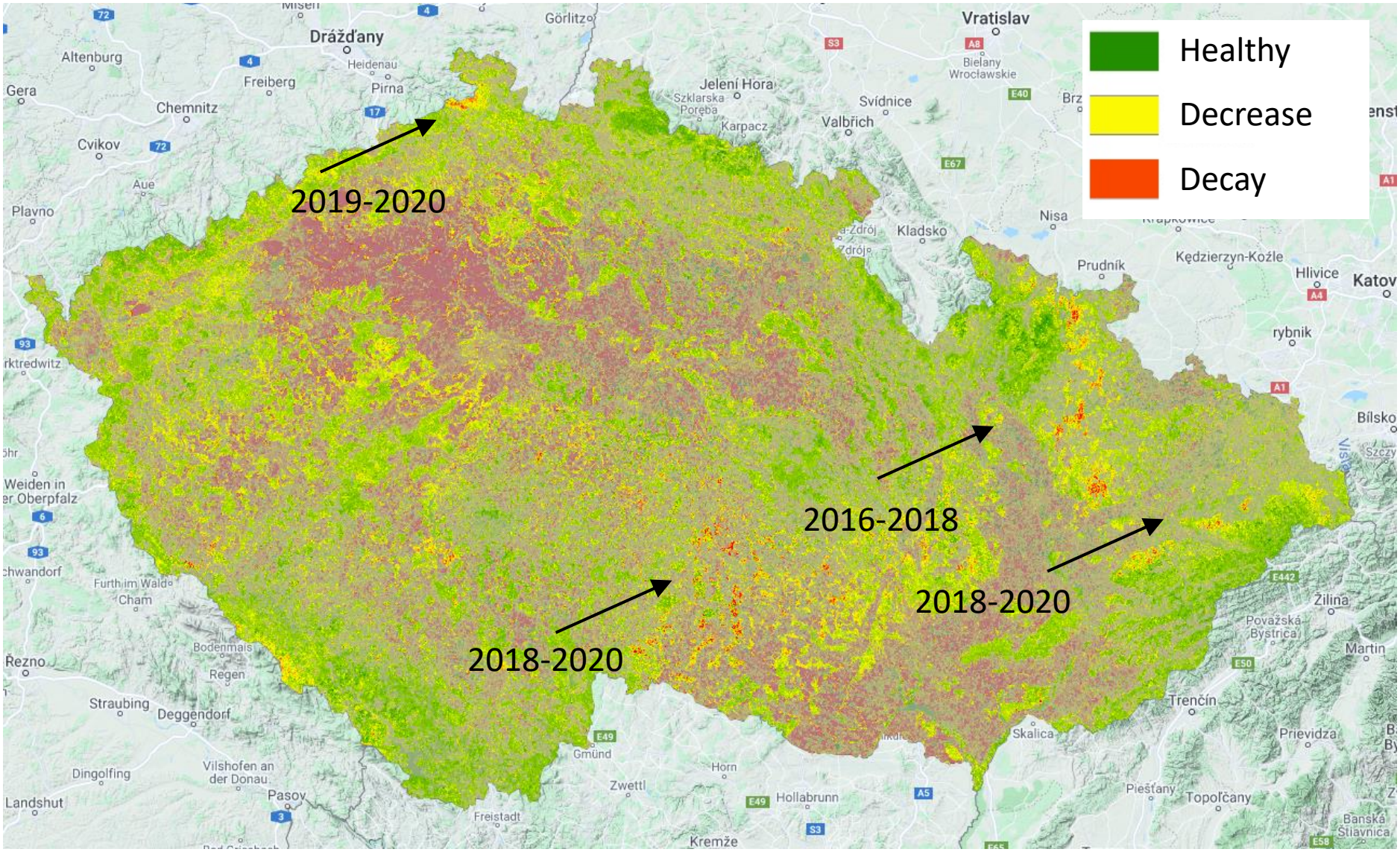
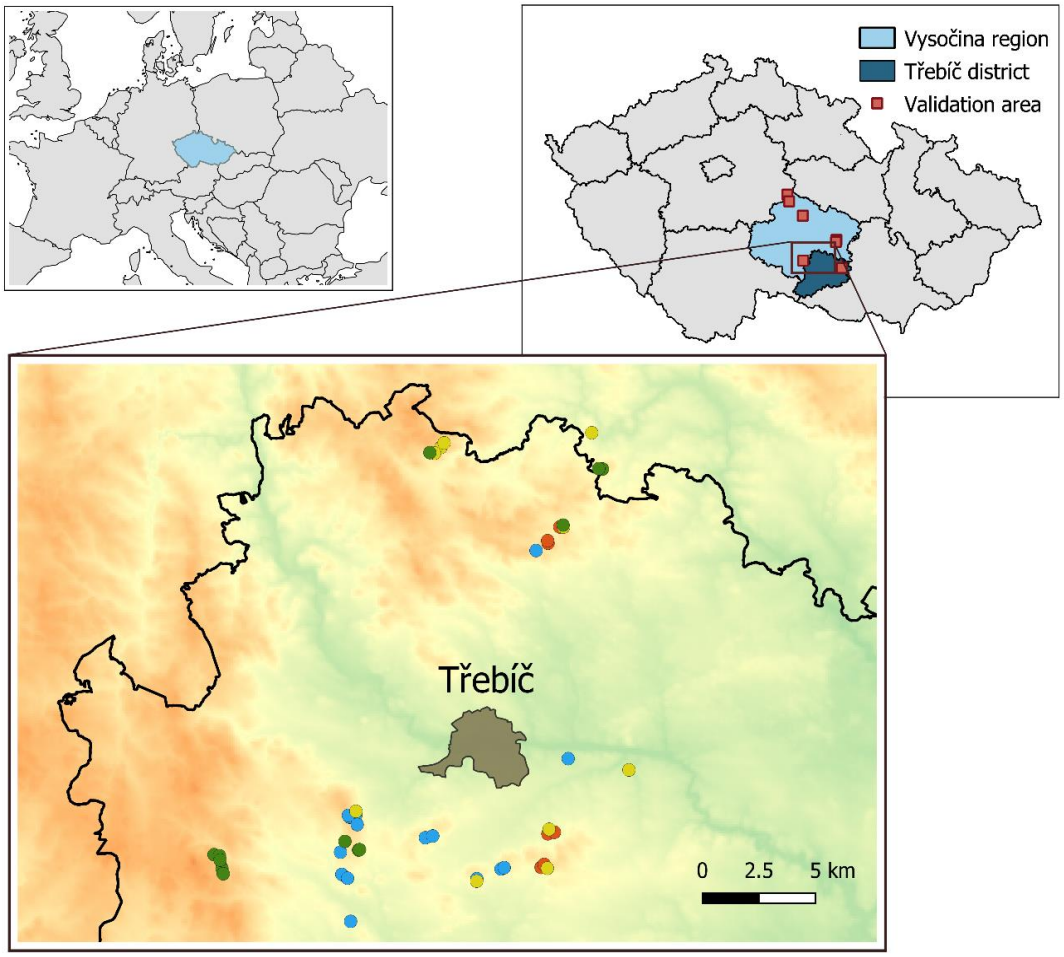
Spread of the bark beetle calamity



Data collection



No.	Date	Day of year (DOY)	Satellite platform
1	11 April	101	S2B
2	21 April	111	S2B
3	6 May	126	S2A
4	31 May	151	S2B
5	30 June	181	S2B
6	9 August	221	S2B
7	19 August	231	S2B
8	29 August	241	S2B
9	13 September	256	S2A
10	18 September	261	S2B
11	28 September	271	S2B
12	13 October	286	S2A
13	18 October	291	S2B
14	17 November	321	S2B

2018 dataset - spectral trajectories
2019 dataset - evolution of forest plots

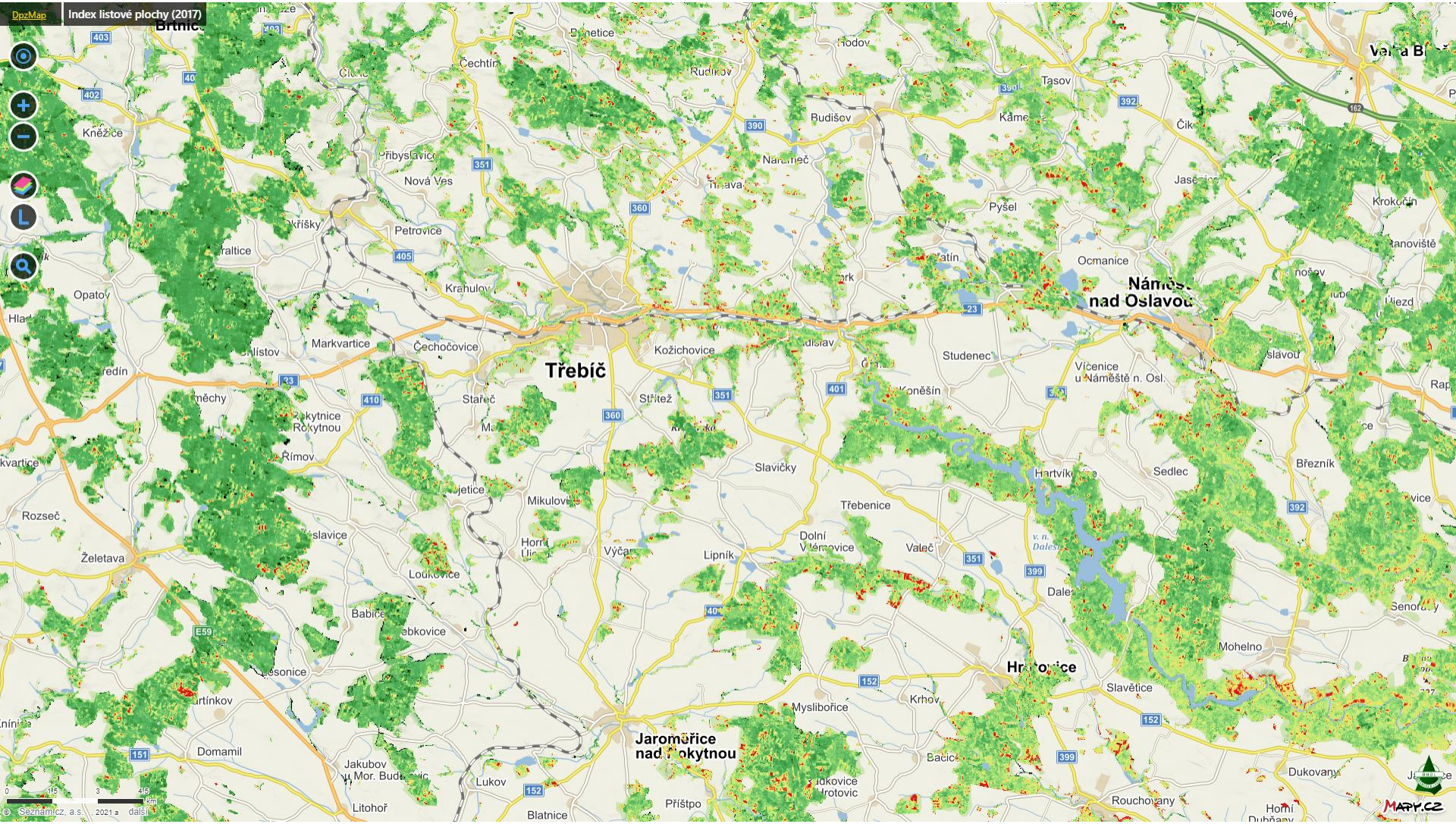
Třebíč region, 2015

Healthy forest stands

Třebíč region, 2016

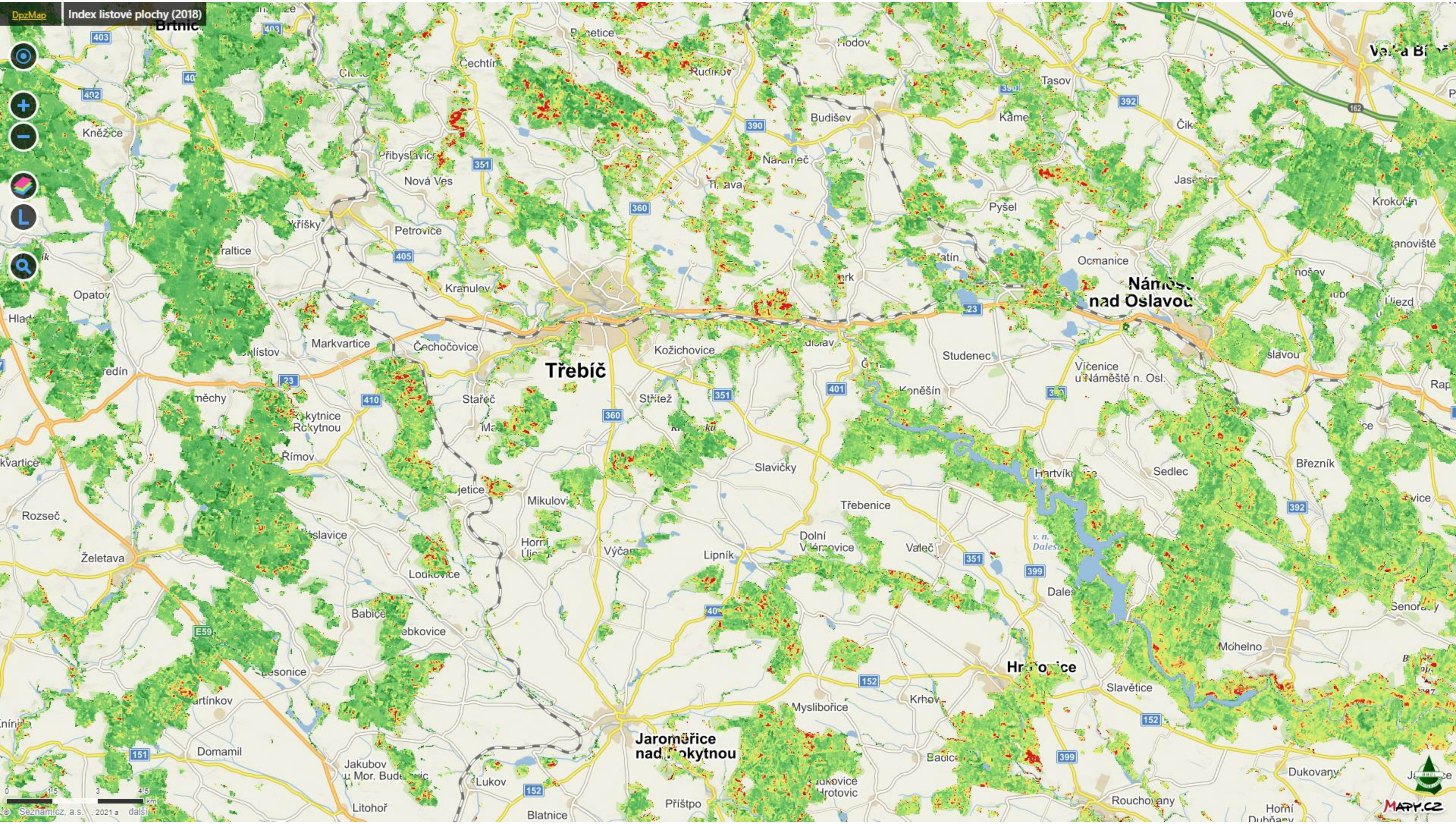
Healthy forest stands

Třebíč region, 2017



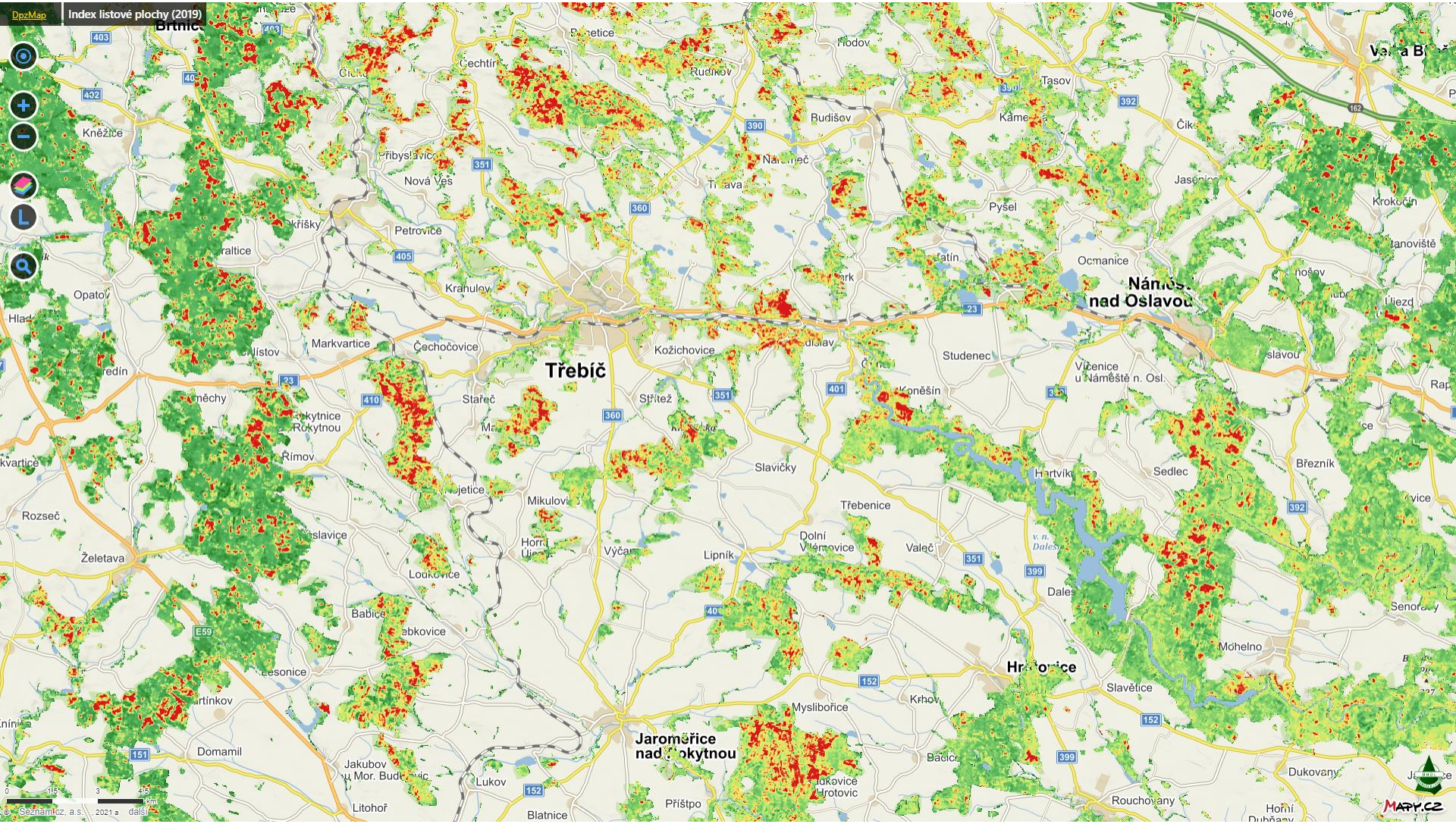
First forest decay observed

Třebíč region, 2018



Majority of trees in green attack phase

Třebíč region, 2019



Massive salvage logging – removal of red/grey attack trees visible as clearcut

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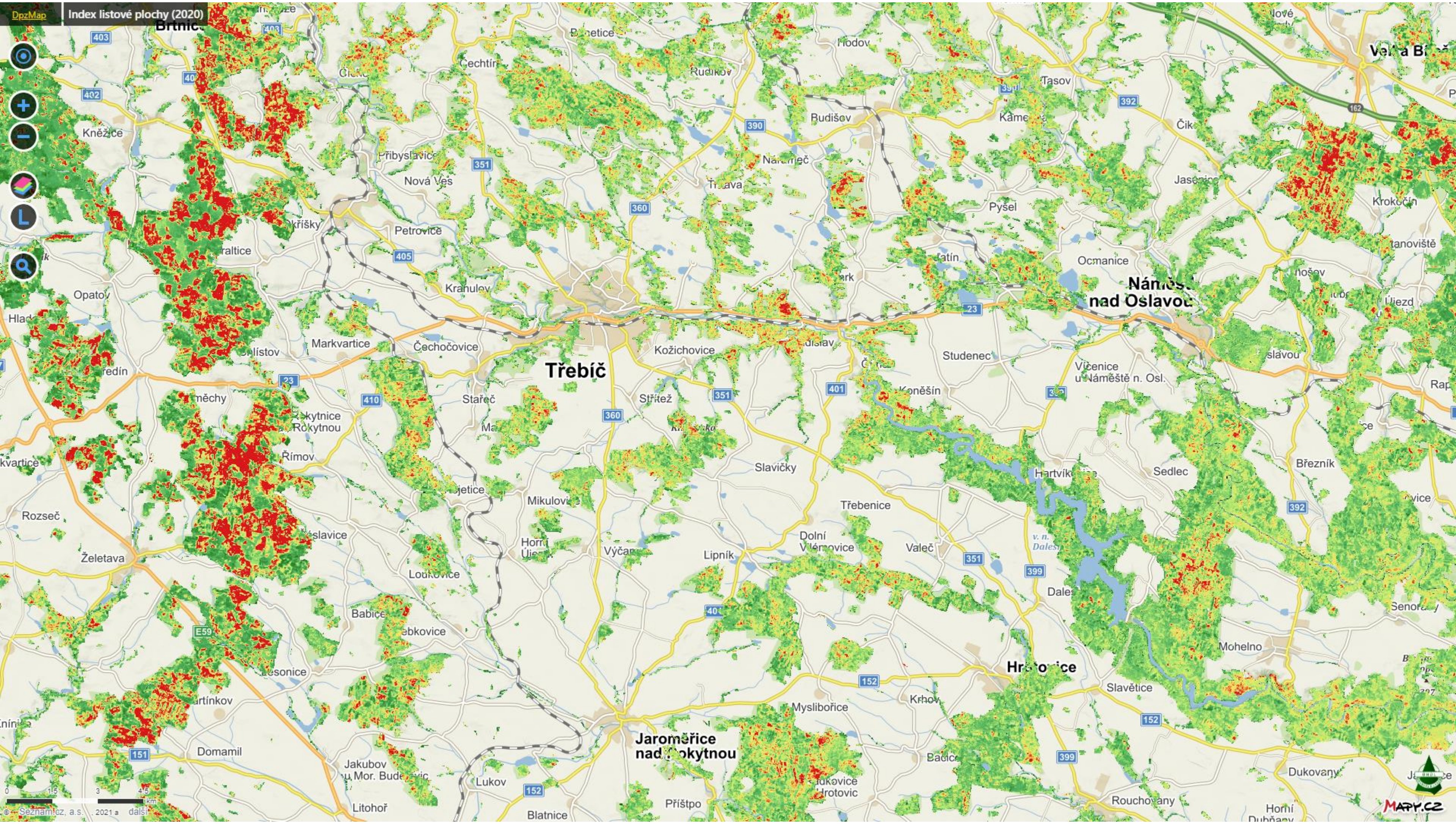
Třebíč region, 2020

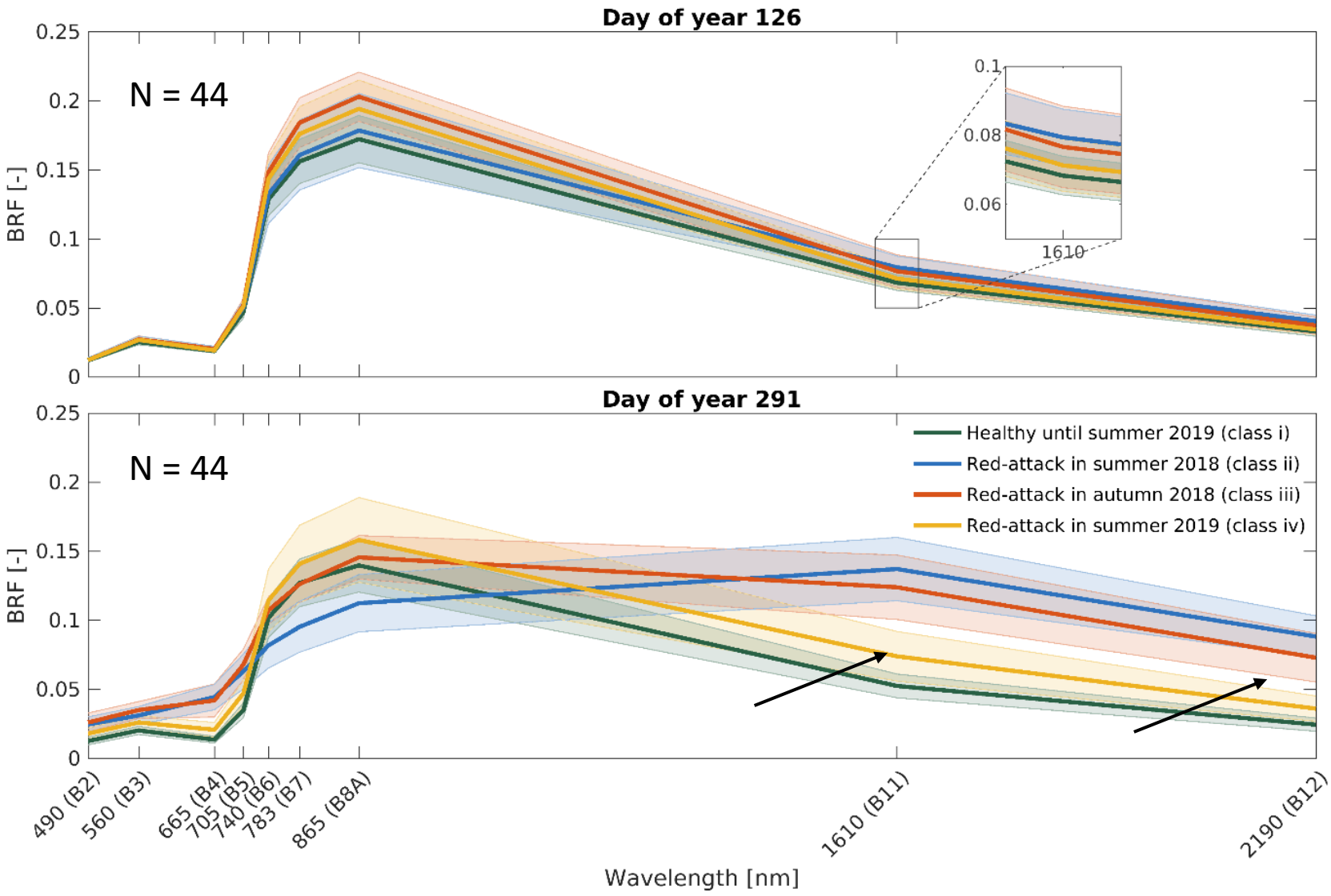


Massive salvage logging – removal of red/grey attack trees visible as clearcut

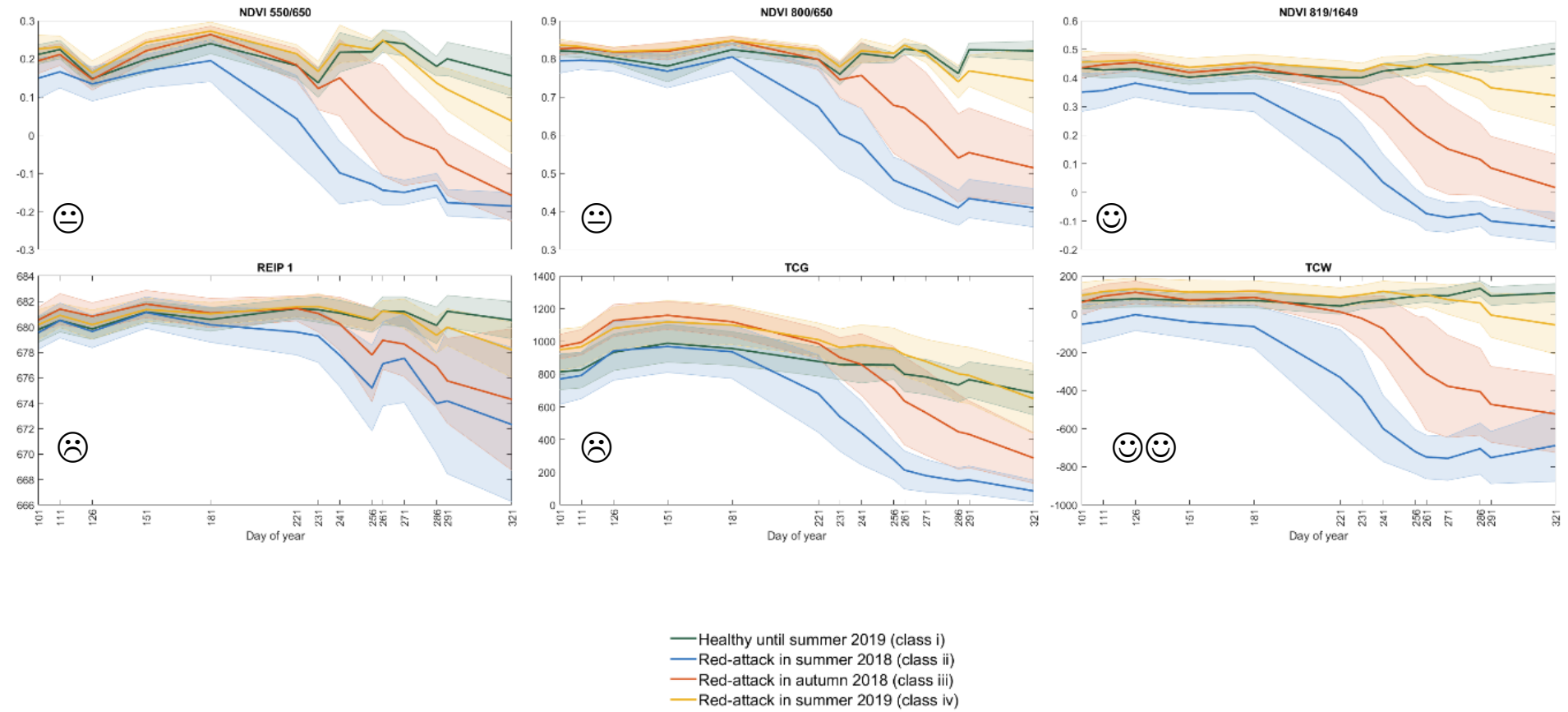
Vegetation indices

Index	Formula	Reference	Examples of bark beetle detection
Normalized difference vegetation index – green	NDVI 550/650 = (B3 – B4)/(B3 + B4)	Metternicht, 2003	Abdullah et al., 2019a; Klouček et al., 2019
Normalized difference vegetation index – NIR	NDVI 800/650 = (B8a – B4)/(B8a + B4)	Tucker, 1979	Klouček et al., 2019; Meddens et al., 2013; Tane et al., 2018
Normalized difference vegetation index – SWIR	NDVI 819/1649 = (B8a – B11)/(B8a + B11)	Wilson and Sader, 2002	Abdullah et al., 2019a; Meddens et al., 2013; Meigs et al., 2011; Tane et al., 2018
Red-edge inflection point	$\mathrm{REIP} = 700 + 40\left(\frac{\left(\frac{B4+B7}{B2} - B5\right)}{B6 - B5}\right)$	Herrmann et al., 2011	
Tasselled cap – greenness	TCG = 0.2848B2 – 0.2453B3 – 0.5436B4 + 0.7243B8a + 0.0840B11 – 0.1800B12	Crist and Cicone, 1984	Meddens et al., 2013; Tane et al., 2018
Tasselled cap – wetness	TCW=0.1509B2+0.1973B3+0.3279B4+0.3406B8-0.7112B11-0.4572B12		Hais et al., 2016; Meddens et al., 2013; Skakun et al., 2003; Tane et al., 2018

Average spectral trajectories of different infestation classes

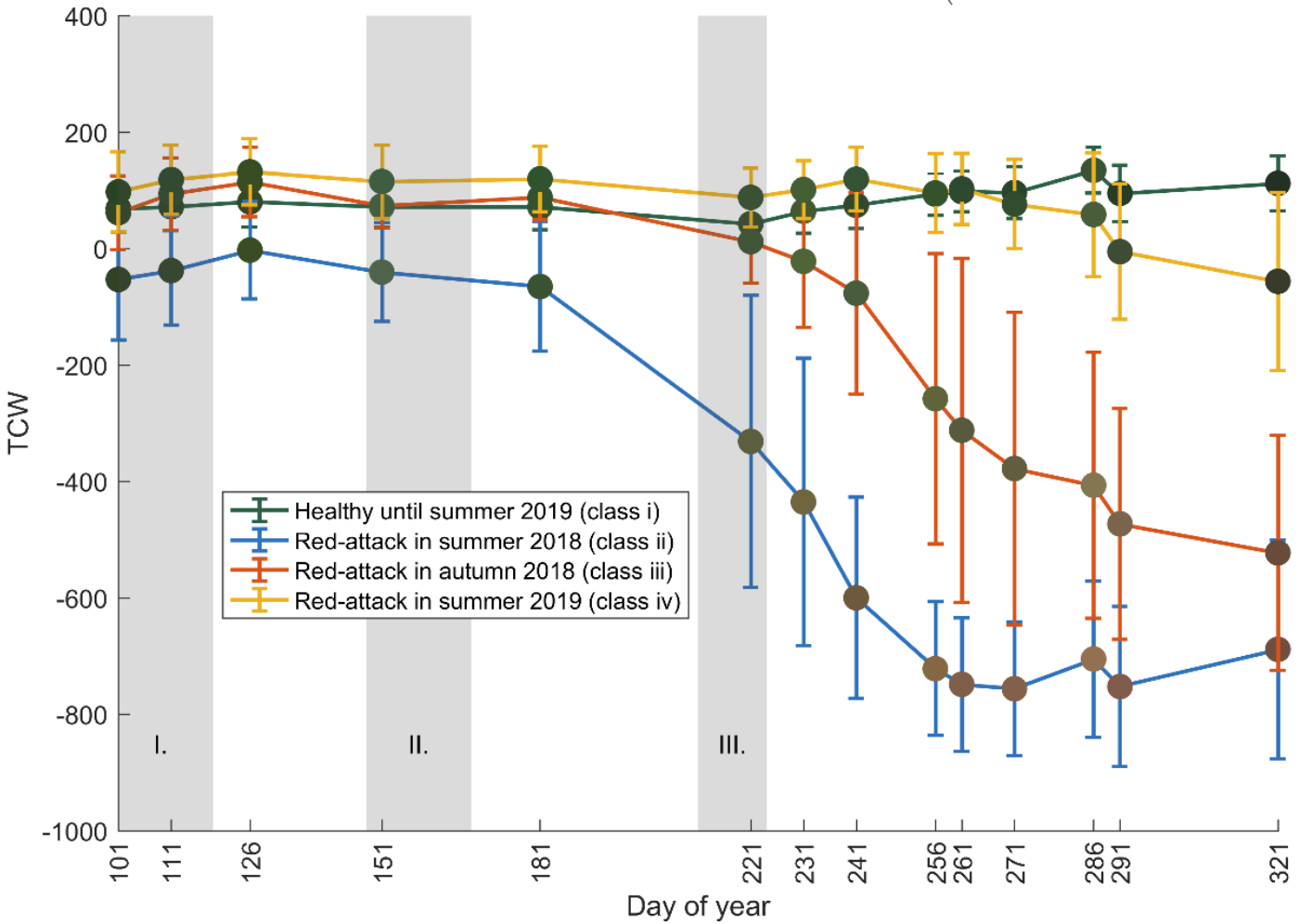


Time series of Vis for different infestation classess

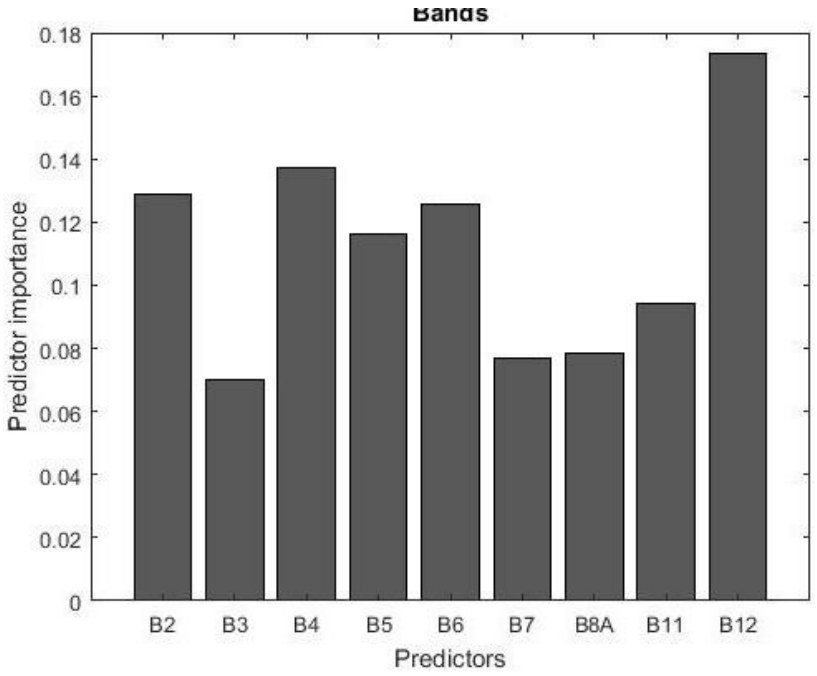


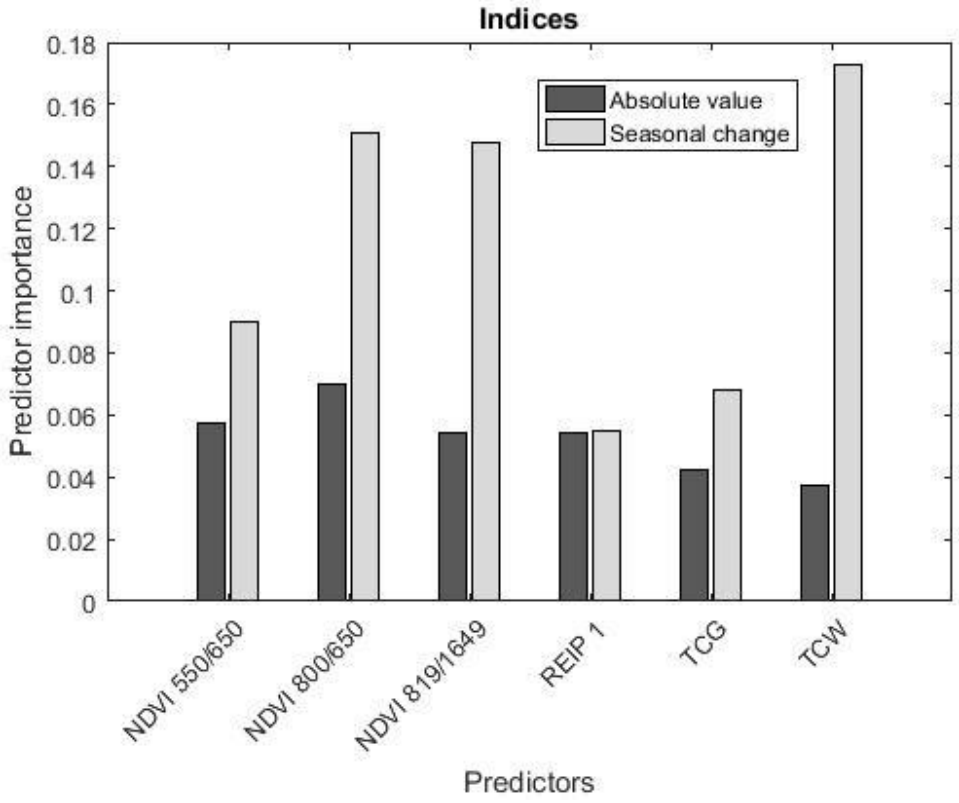
Time series of TCW – best early detection potencial

$$\text{Seasonal change} = \left(\frac{1}{n} \sum_{i=1}^{n} Actual_{DOYi} - \frac{1}{m} \sum_{j=1}^{m} Baseline_{DOYj} \right)$$

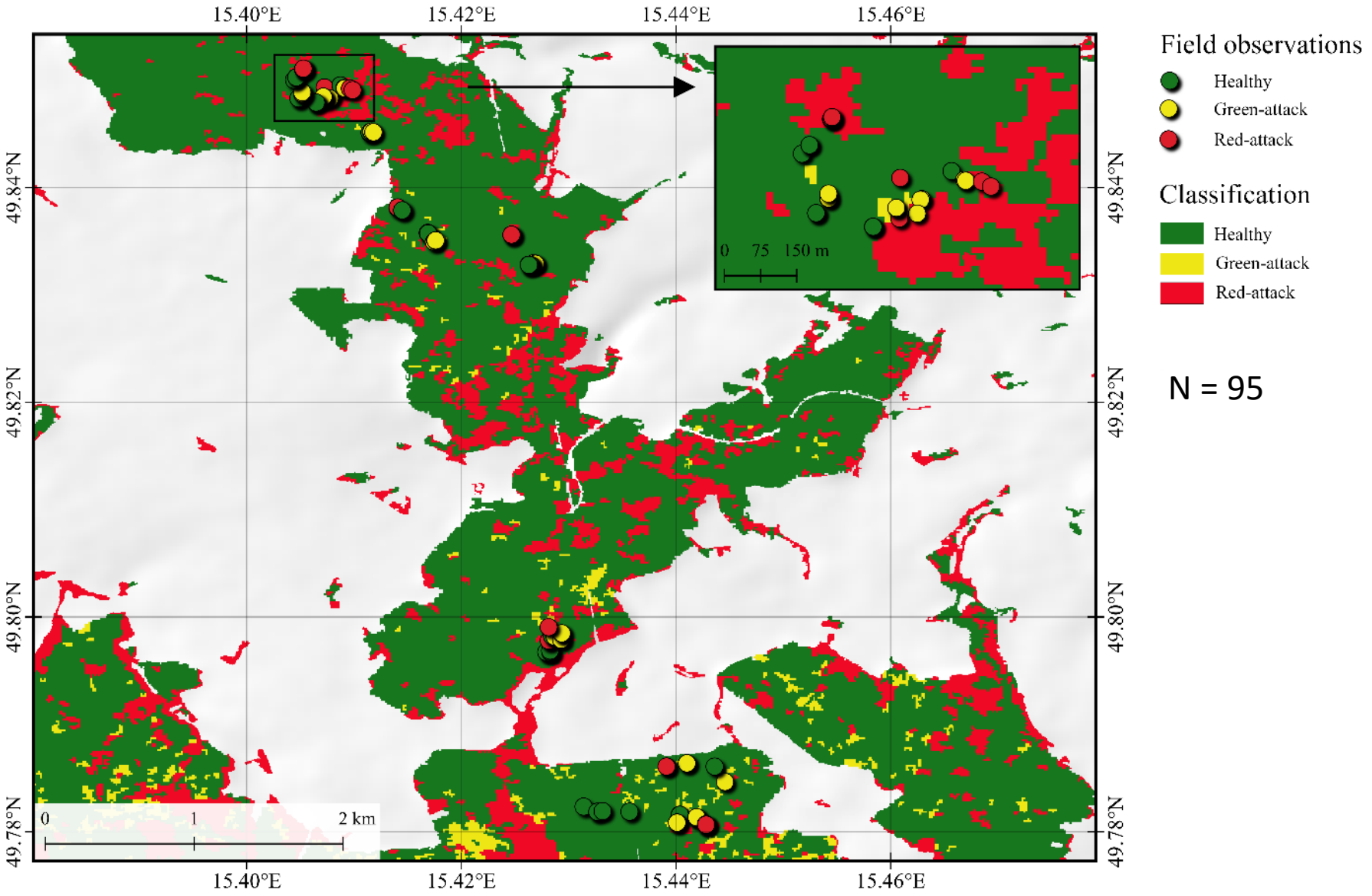


Importance of individual bands and VIs





Classification model of early infestation detection



Accuracy of classification

		Field observations			
		Healthy	Green-attack	Commission rate	User's accuracy
Classification	Healthy	32	8	20%	80%
	Green-attack	10	30	25%	75%
	Omission rate	24%	21%	Overall accuracy = 78%	
	Producer's accuracy	76%	**79%**		

N = 95

- Best separation for SWIR-based VIs, TCW in particular
- Timing is crucial – separation between healthy and green attack stages visible from DOY 231 for spring swarm (red-attack already in autumn) and after DOY 286 for summer swarm
- Change-based model better than absolute value
- Potential for detection of green-attack (dormant) trees in October-November and their removal before spring swarm