Using Sentinel-2 data for bark beetle detection in the Czech Republic
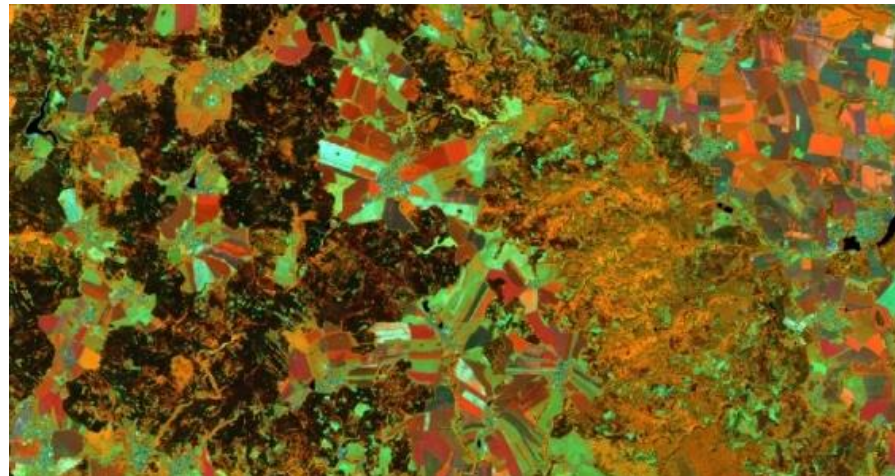
Ángel Fernández Carrillo

GMV

MySustainableForest

- Commercial service platform to integrate Earth Observation data into daily forest stakeholders' decision making.

- Public and private stakeholders engaged across Europe
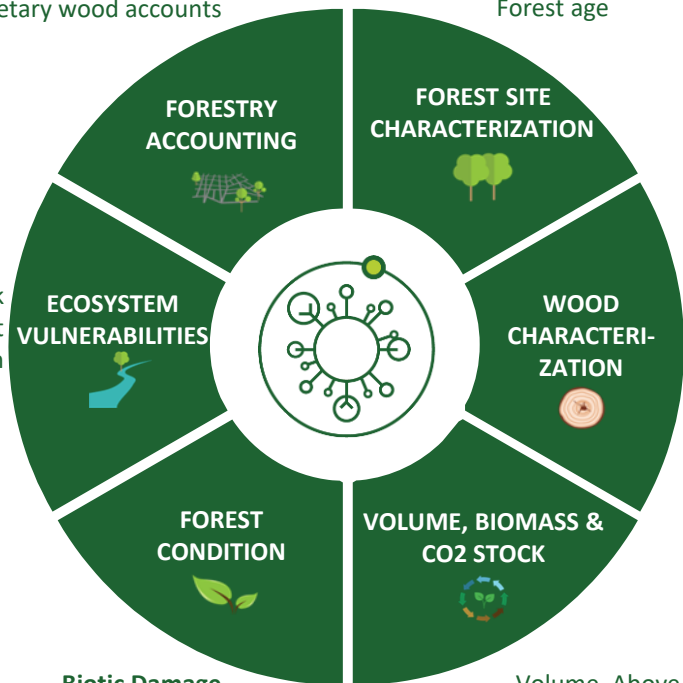
- Portfolio of 21 products

My Sustainable Forest

Earth observation services for silviculture

Land physical accounts
Physical wood accounts
Monetary wood accounts

Forest mask
Forest Infrastructures
Main forest types
Stand height
Forest age

Burnt scars
Clear cuts
DEM-Terrain
Site Index
Stand Density

FORESTRY ACCOUNTING

FOREST SITE CHARACTERIZATION

Basin & Stream Network
Biodiversity-Habitat
Fragmentation

ECOSYSTEM VULNERABILITIES

WOOD CHARACTERI-ZATION

Wood Density Rank
Wood Stiffness
Strength Class

FOREST CONDITION

VOLUME, BIOMASS & CO2 STOCK

Biotic Damage
Drought Damage

Volume, Above Ground Biomass, and CO2 Stock

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Study area

- **Czech Republic:** Exponential increase of *Ips typographus* from 2015 triggered by extreme drought and storm events

Volume of infested spruce wood harvested from 2005 to 2019. (Ministry of Agriculture of the Czech Republic, 2020)
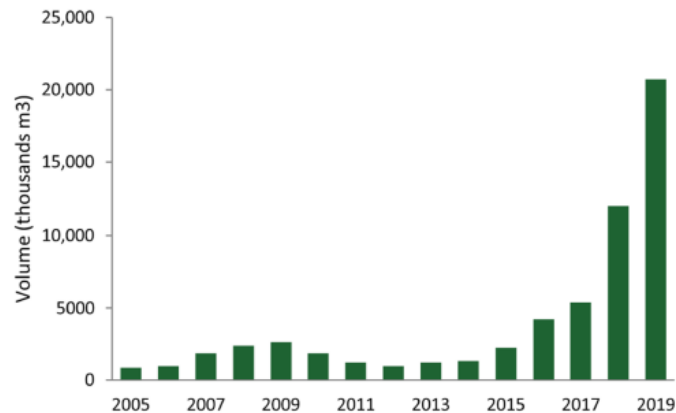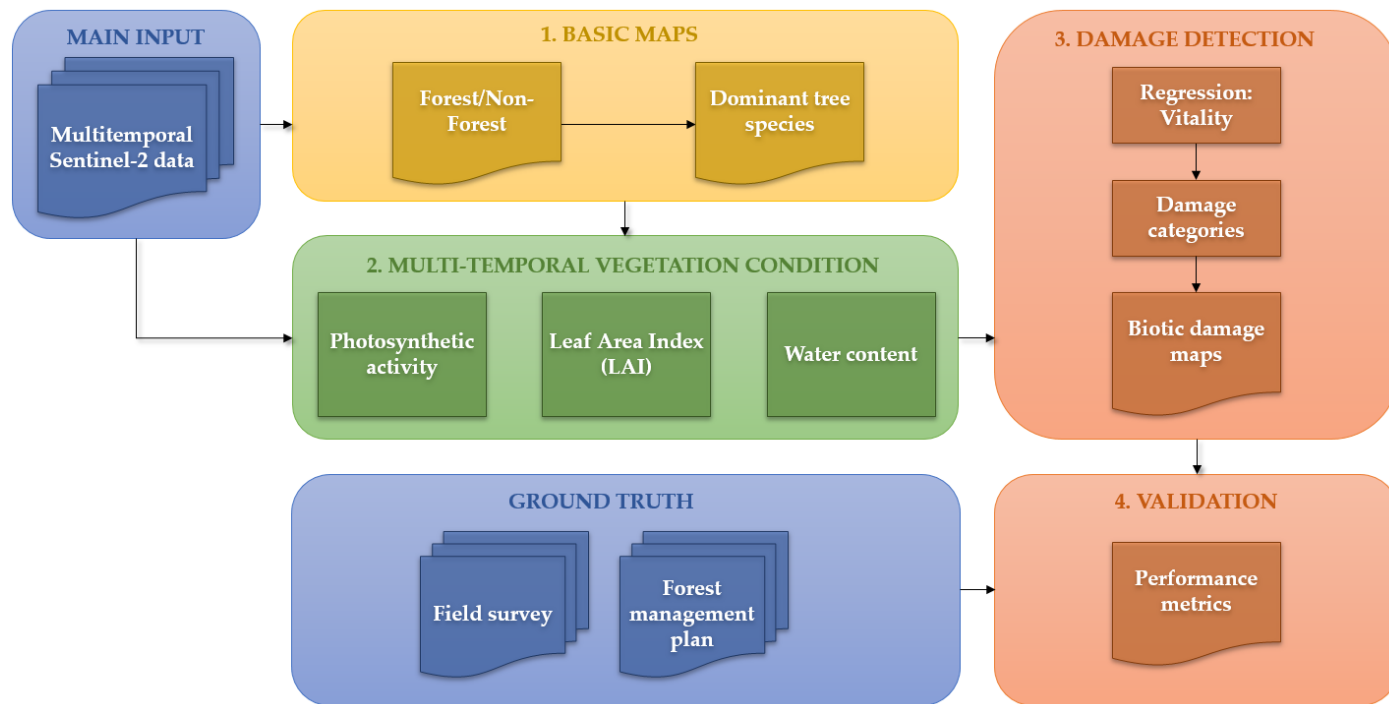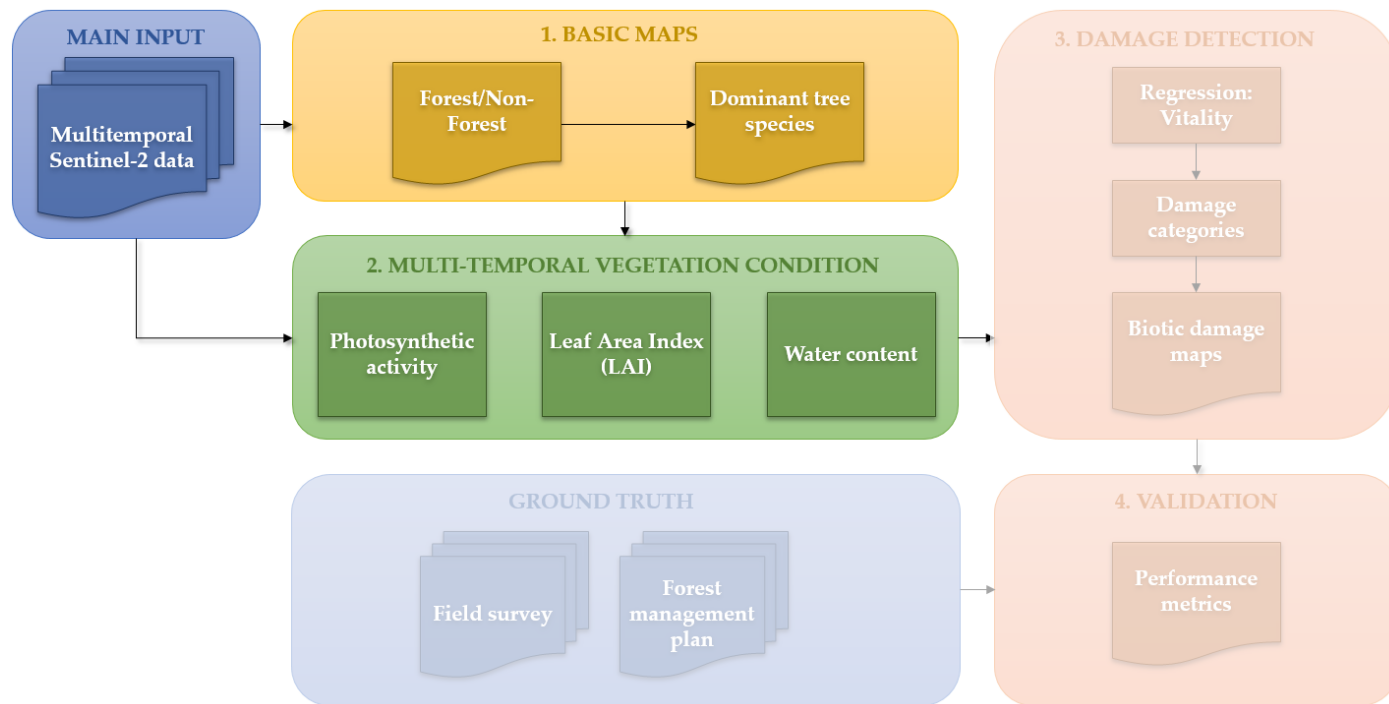
- 10,000 ha of forest owned by Mendel University in Brno and managed by the University Forest Enterprise (UFE)

- 20% of spruce

Damage maps

Damage maps

MAIN INPUT
- Multitemporal Sentinel-2 data

1. BASIC MAPS
- Forest/Non-Forest
- Dominant tree species

2. MULTI-TEMPORAL VEGETATION CONDITION
- Photosynthetic activity
- Leaf Area Index (LAI)
- Water content

3. DAMAGE DETECTION
- Regression: Vitality
- Damage categories
- Biotic damage maps

GROUND TRUTH
- Field survey
- Forest management plan

4. VALIDATION
- Performance metrics

Damage maps

Forest/Non forest

Methods: Supervised and Unsupervised Machine Learning algorithms
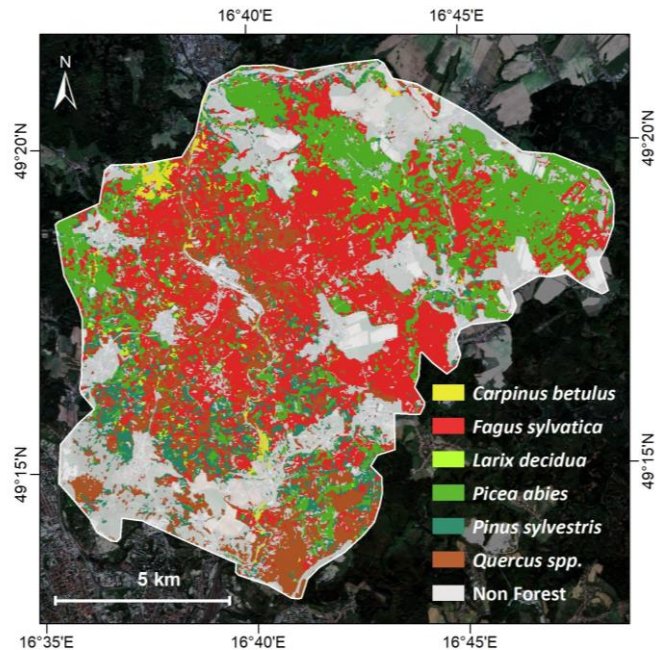
Spatial Resolution: 10m
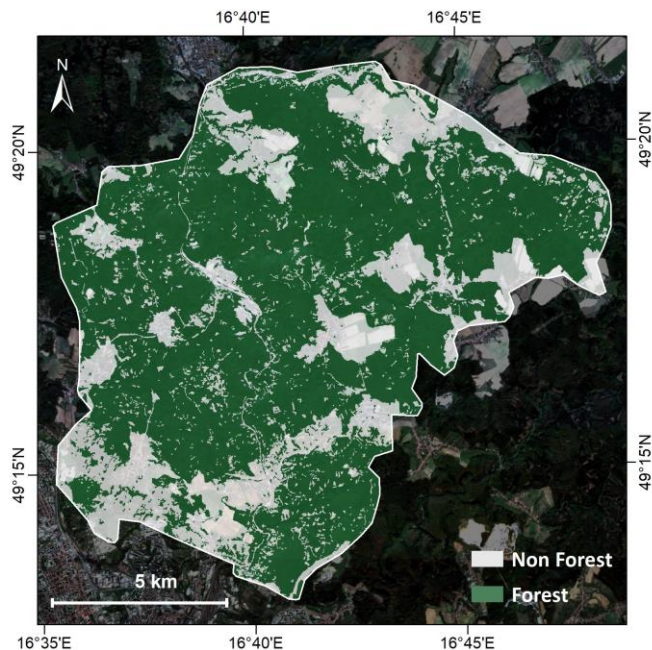
Dominant tree species

Methods: Supervised Machine Learning

Spatial Resolution: 10m

Damage maps

ALERT
- Typical season
- User defined
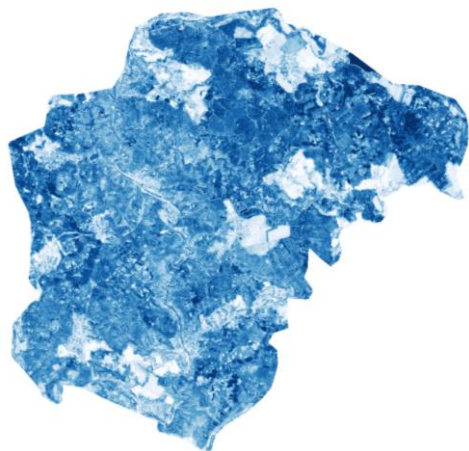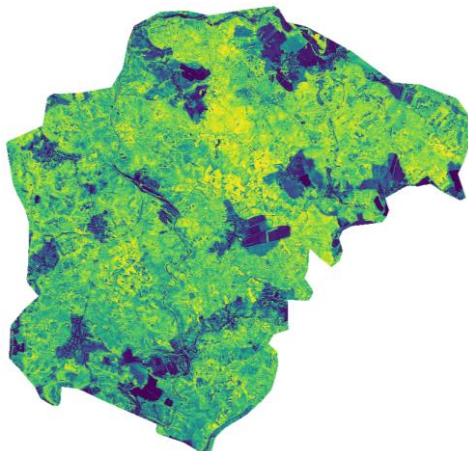- Media
- Others

PEST OUTBREAK

Forest / Non-forest
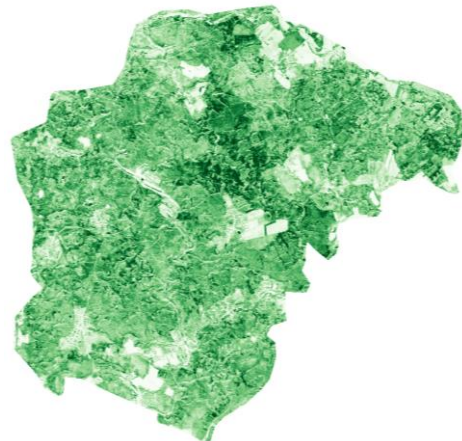
Dominant tree species

Vegetation Condition Baseline
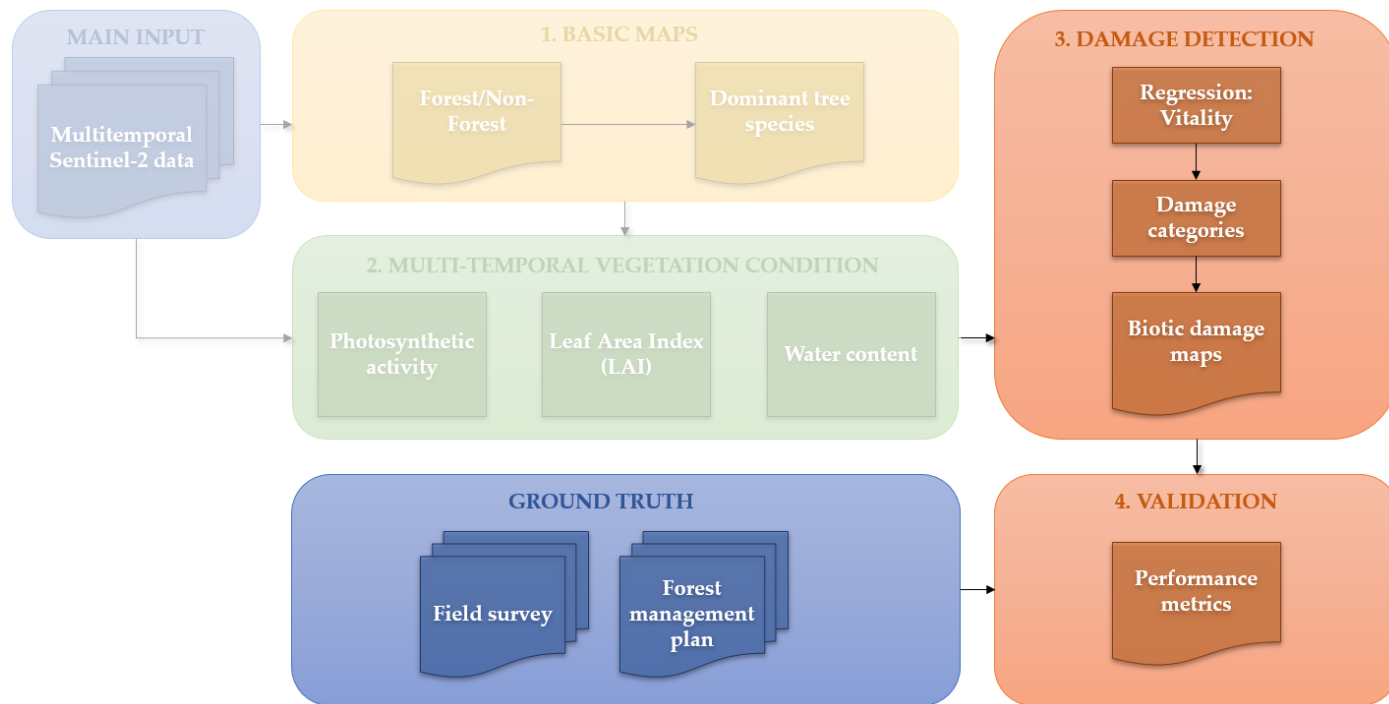
VEGETATION STRESS ?

Water Content

Leaf Area Index (LAI)

Photosynthetic activity

gmv

Damage maps

Damage maps

Results

Frequency

Customizable. Minimum production update 5-days

Spatial Resolution

10 m

Outputs

- Biotic Damage Classification
- Forest Vitality

Validation

- Forest Management Plan
- Field survey

Spruce vitality 2019

-7.5   4.5

Biotic Damage 2019

- No damage
- Minor damage
- Moderate damage
- Severe damage
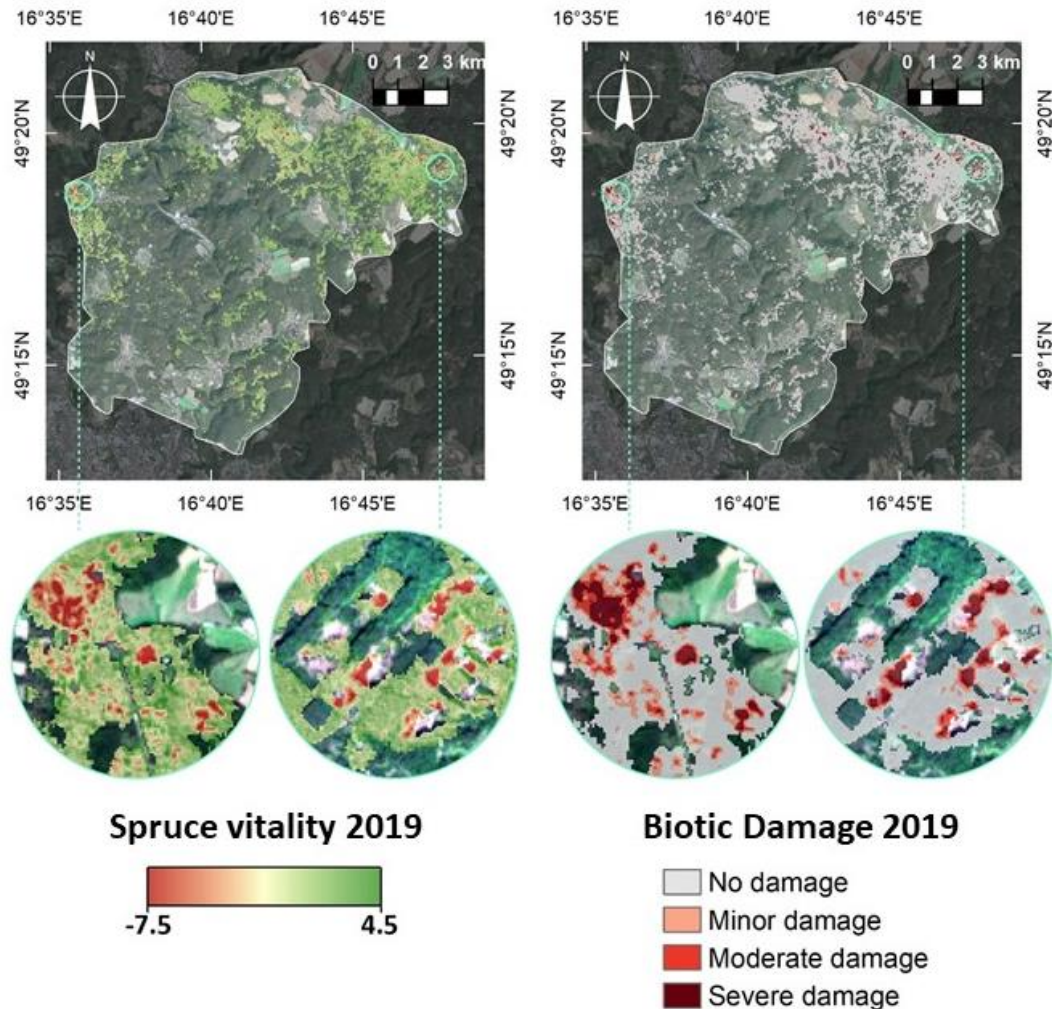
Damage Maps

Validation

- Overall accuracy between 85% and 90%

- Areas with severe damage were identified with accuracy higher than 95% and F1 close to 90%

- Errors were in general low and balanced

- Commission was prioritised over ommission

remote sensing

Monitoring Bark Beetle Forest Damage in Central Europe. A Remote Sensing Approach Validated with Field Data

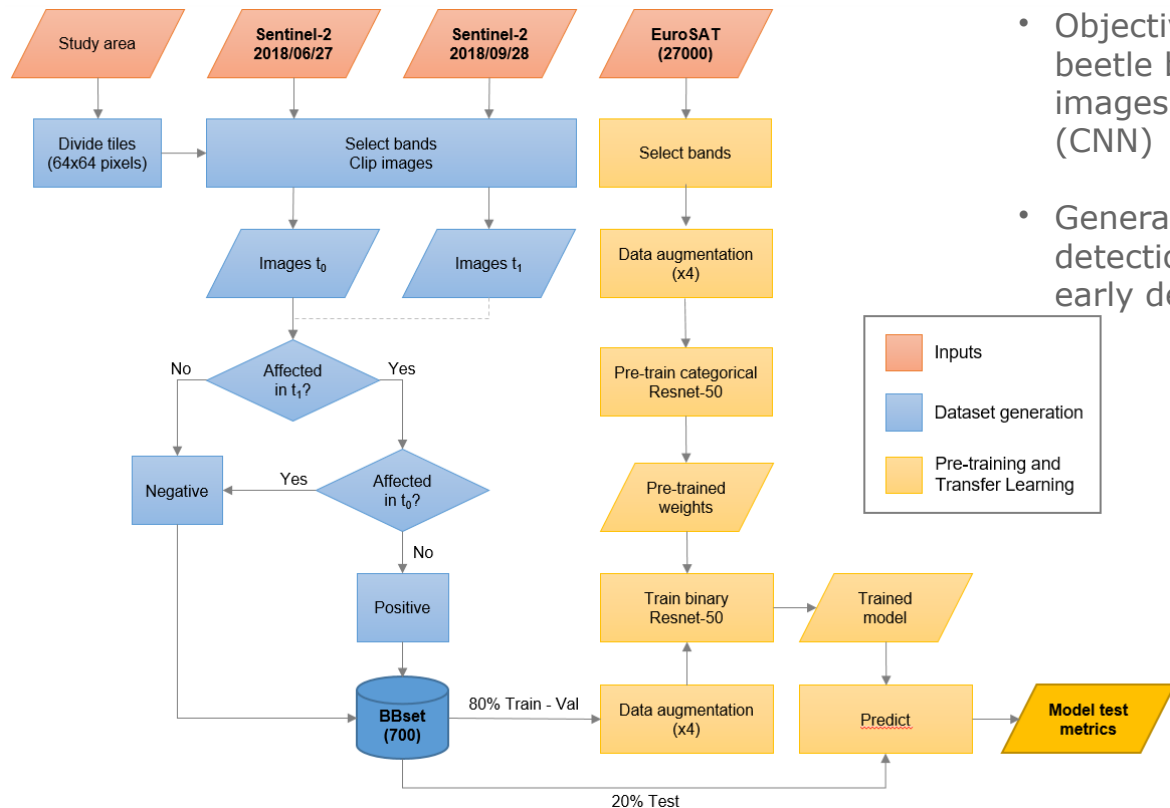A. Fernandez-Carrillo, Z. Patočka, L. Dobrovolný, A. Franco-Nieto and B. Revilla-Romero

https://www.mdpi.com/2072-4292/12/21/3634

	Class	acc.	F1	CE	OE	relB
2019	No damage	0.90	0.83	0.00	0.30	0.42
	Minor damage	0.95	0.89	0.20	0.00	-0.20
	Moderate damage	0.97	0.93	0.14	0.00	-0.14
	Severe damage	0.98	0.96	0.08	0.00	-0.08
2020	No damage	0.86	0.76	0.06	0.36	0.46
	Minor damage	0.97	0.93	0.14	0.00	-0.14
	Moderate damage	0.94	0.86	0.20	0.07	-0.14
	Severe damage	0.95	0.88	0.20	0.02	-0.18

acc: accuracy, F1: F1-score, CE: commission error, OE: omission error, relB: relative bias
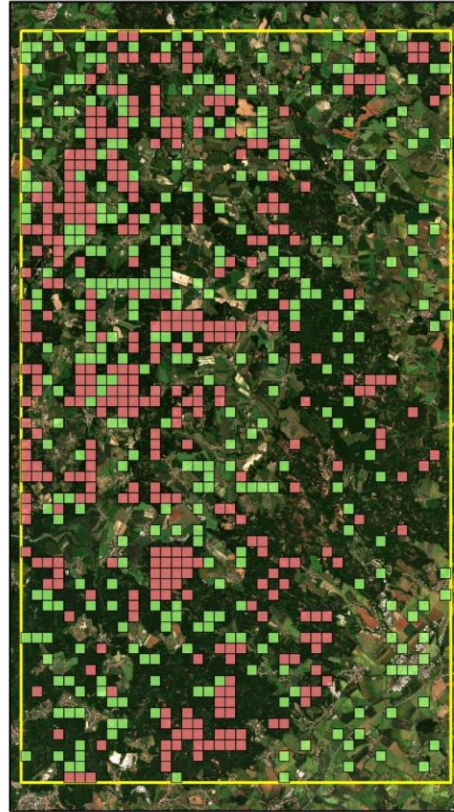
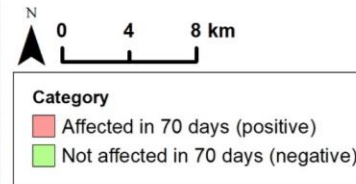# Early detection

Neural Networks and Deep Learning

- Objective: Predict areas affected by bark beetle before signs of decay in Sentinel-2 images using Convolutional Neural Networks (CNN)

- General idea: adapt algorithm for cancer detection in medical images to perform early detection of bark beetle

Early detection

Dataset generation

- Bi-temporal Sentinel-2 images

- 700 patches of areas affected and not affected by the bark beetle

Category
- Affected in 70 days (positive)
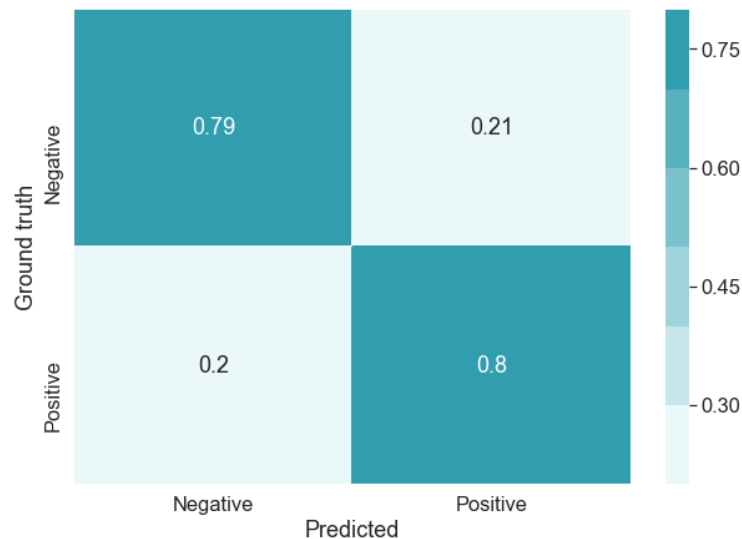- Not affected in 70 days (negative)

Early detection

Results and validation

- Accuracy = 80%

- Prediction of mortality of forest 70 days before signs (in S2 images) with 80% agreement

- Errors balanced, around 20%

Class	Precision	Recall	F1-score	Support
Negative	0.80	0.79	0.79	284
Positive	**0.80**	0.80	0.80	292
macro avg	0.80	0.80	0.80	576
weighted avg	0.80	0.80	0.80	576
accuracy			**0.80**	576

Conclusions

1. Damage mapping

- Sentinel-2 images are useful to accurately map different levels of bark beetle impact (acc. > 90%)

- Areas with higher impact are easier to identify

- The model performed similarly in different years

2. Early detection with Deep Learning

- It is possible to detect affected areas at least 70 days before first clear visible signs in Sentinel-2 images

- It is possible to discriminate affected areas in green attack phase using CNN

3. Future

- Deep Learning and predictive models

- Reference datasets must be created

- More work will be required in DL model tuning

Thank you

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776045

My Sustainable Forest
Earth observation services for silviculture

gmv INNOVATING SOLUTIONS