Detecting spatial patterns of change in vegetation condition inside Bavarian Forest National Park using Multi- and Hyperspectral spaceborne datasets

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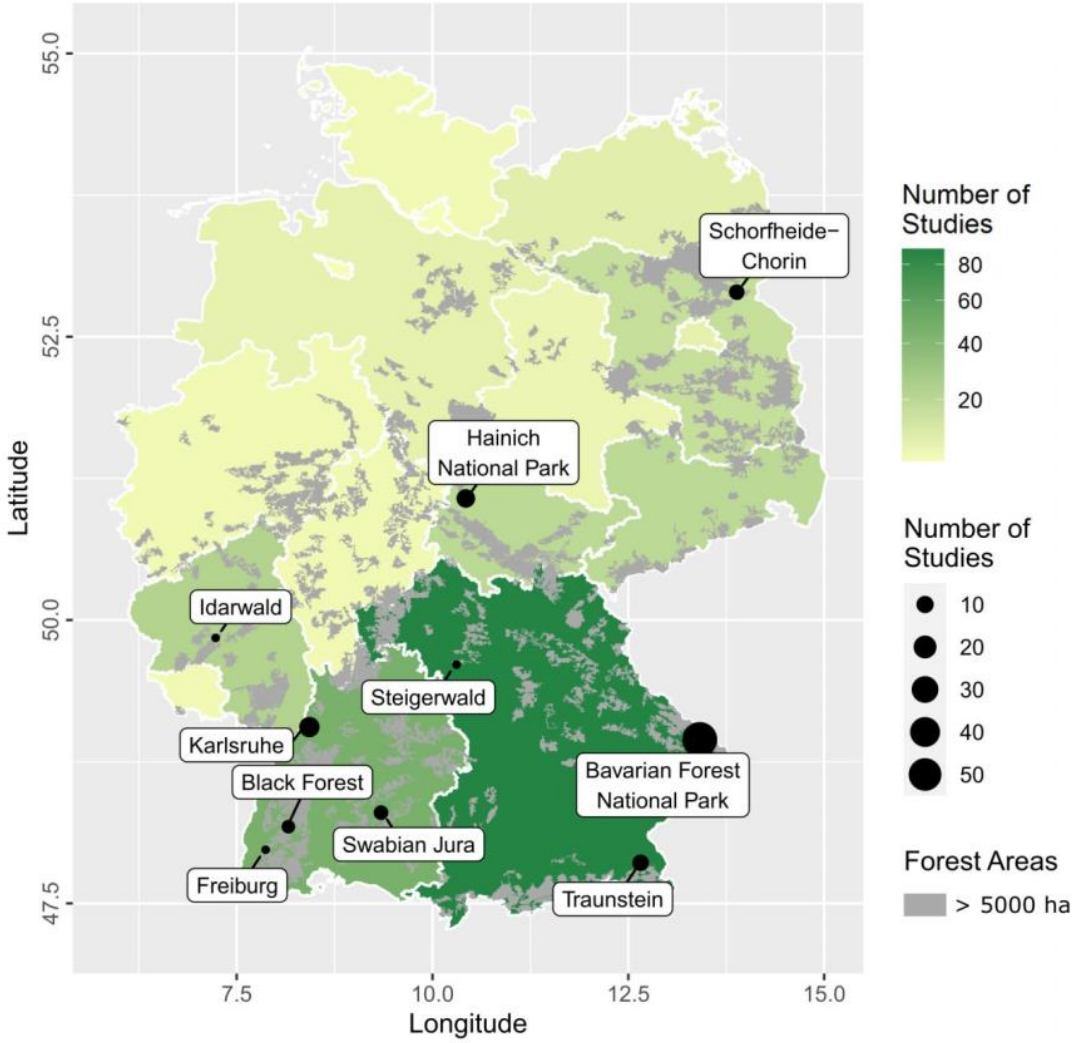
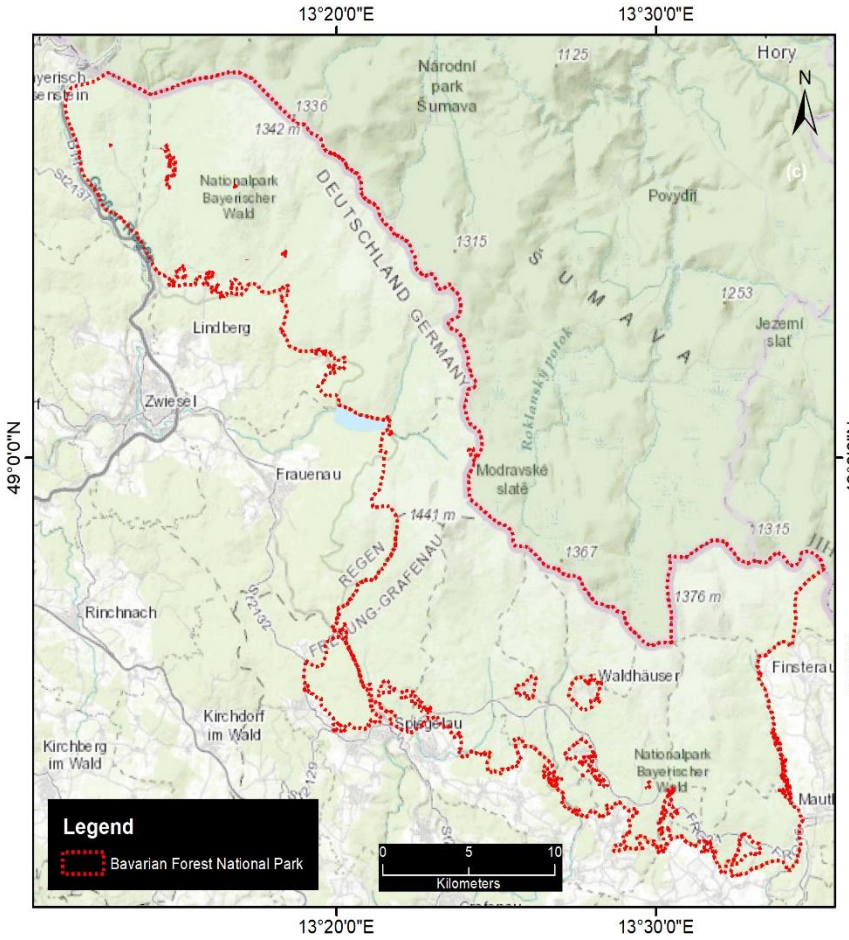
DLR

Nationalpark Bayerischer Wald

Study Site: Bavarian Forest National Park (BFNP)





- Heterogeneous mountainous forest
- Norway spruce dominant species
- 24,250 ha
- established 1970

(S. Holzwarth et al., 2020)

DLR Earth Sensing Imaging Spectrometer (DESIS) Mission

- Operated by DLR (scientific) and Teledyne Brown Engineering (commercial)
- Installed on the International Space Station (ISS)
- Target lifetime from 2018 – 2023
- Average revisit frequency of 3 – 5 days, BUT no mapping mission

Parameter	Value
Spectral coverage	402 nm – 1000 nm
Spectral sampling	2.55 nm (w/o binning) **~ 10.2 nm (binning 4)**
Ground sampling distance (GSD) at nadir	~ 30 m (depends on the flight altitude of the ISS)
Swath at nadir	~ 30 km (depends on the flight altitude of the ISS)

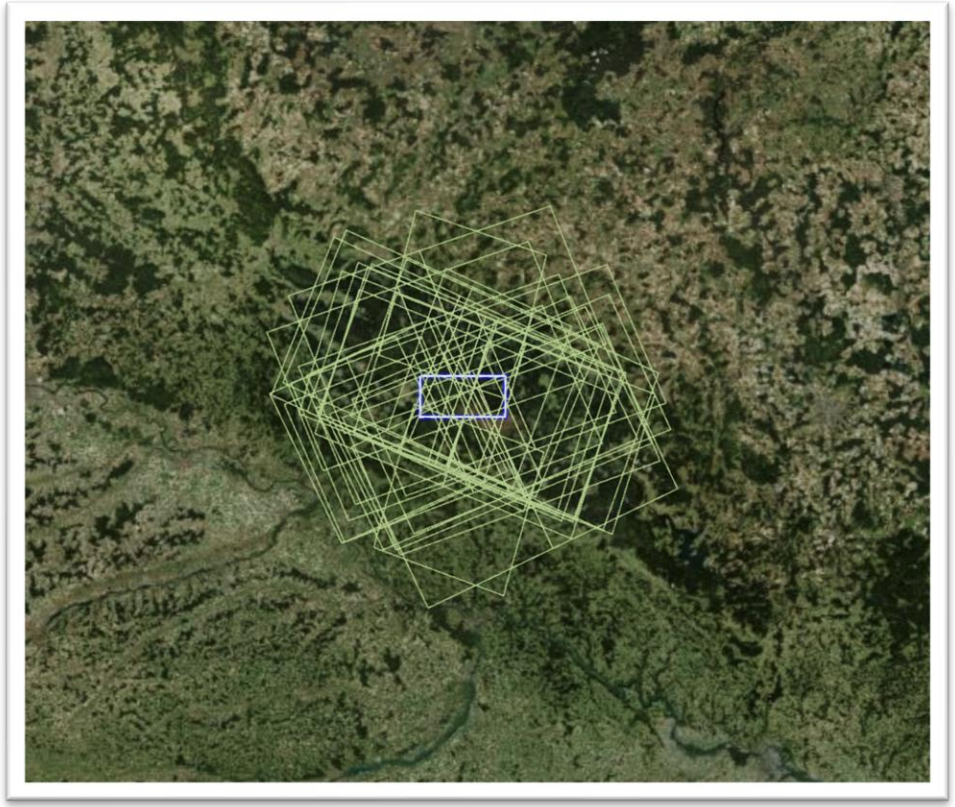
(K. Alonso et al., 2019)

DESIS Data of the BFNP

Search Results

Products | Coverage Areas

Name	Acquisition Date	Cloud Coverage Per	Acquisition Time	Quality Rating
DESIS-HSI-20190611T	6/11/2019	From 50 to 75	15:32:56 GMT	Acceptable
DESIS-HSI-20190611T	6/11/2019	From 75 to 100	15:33:01 GMT	Acceptable
DESIS-HSI-20190612T	6/12/2019	From 0 to 25	11:29:42 GMT	Acceptable
DESIS-HSI-20190612T	6/12/2019	Clear	11:29:47 GMT	Acceptable
DESIS-HSI-20190618T	6/18/2019	From 50 to 75	12:59:32 GMT	Acceptable
DESIS-HSI-20190618T	6/18/2019	From 25 to 50	12:59:37 GMT	Acceptable
DESIS-HSI-20190623T(	6/23/2019	From 75 to 100	07:15:04 GMT	Acceptable
DESIS-HSI-20190623T(	6/23/2019	From 75 to 100	07:15:09 GMT	Acceptable
DESIS-HSI-20190626T(	6/26/2019	From 0 to 25	09:36:53 GMT	Acceptable
DESIS-HSI-20190626T(	6/26/2019	From 0 to 25	09:36:57 GMT	Acceptable
DESIS-HSI-20190627T(	6/27/2019	Clear	05:33:36 GMT	Acceptable
DESIS-HSI-20190627T(	6/27/2019	Clear	05:33:41 GMT	Acceptable
DESIS-HSI-20190629T(	6/29/2019	Clear	08:44:52 GMT	Acceptable
DESIS-HSI-20190629T(	6/29/2019	Clear	08:44:57 GMT	Acceptable
DESIS-HSI-20191027T(	10/27/2019	From 25 to 50	08:53:24 GMT	Acceptable
DESIS-HSI-20191027T(	10/27/2019	From 0 to 25	08:53:29 GMT	Acceptable
DESIS-HSI-20200422T	4/22/2020	Clear	10:35:05 GMT	Acceptable
DESIS-HSI-20200422T	4/22/2020	Clear	10:35:10 GMT	Acceptable
DESIS-HSI-20200612T	6/12/2020	From 25 to 50	10:53:58 GMT	Acceptable
DESIS-HSI-20200612T	6/12/2020	From 0 to 25	10:54:02 GMT	Acceptable
DESIS-HSI-20200623T	6/23/2020	From 50 to 75	10:11:49 GMT	Acceptable
DESIS-HSI-20200624T(	6/24/2020	From 0 to 25	06:09:58 GMT	Acceptable



- 40 acquisitions from June 2019 – October 2021
- 12 data takes with clear condition (incl. no haze and no contrails)
- 8 scenes with solar zenith angles < 50 degree
- 6 tiles without snow
- 2 dates with full coverage: **29.06.19 & 17.06.21 => leaf-on season**

Observed Weather Extremes in the BFNP 2019-2021

2019:
- the third hottest year
- 350 millimeters less precipitation than average

2020:
- second lowest number of days with snow
- lowest number of days with sub-zero temperatures

2021
- 20°C mark was exceeded in March for the first time

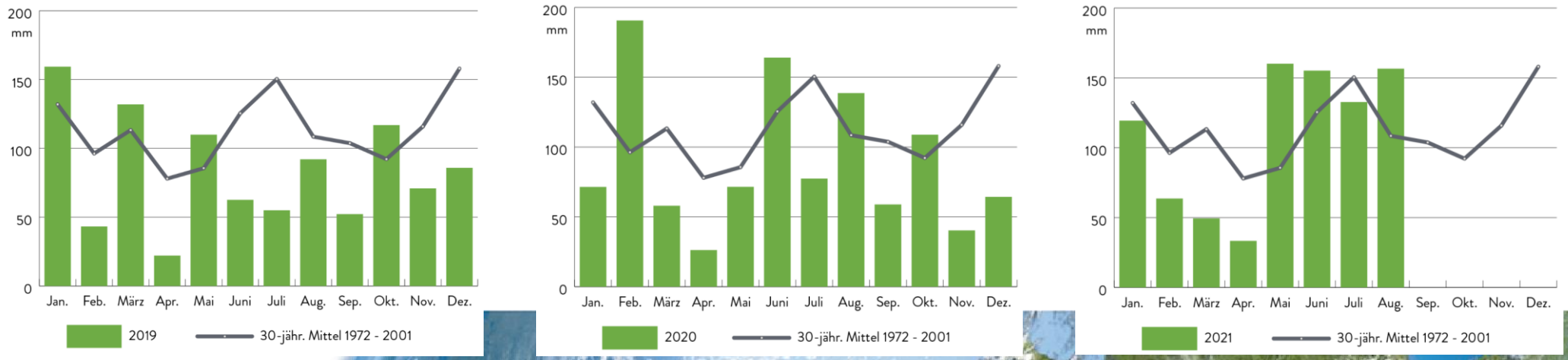
Effects on the National Park

→ increased emergence of bark beetle

→ infestation of native spruce trees

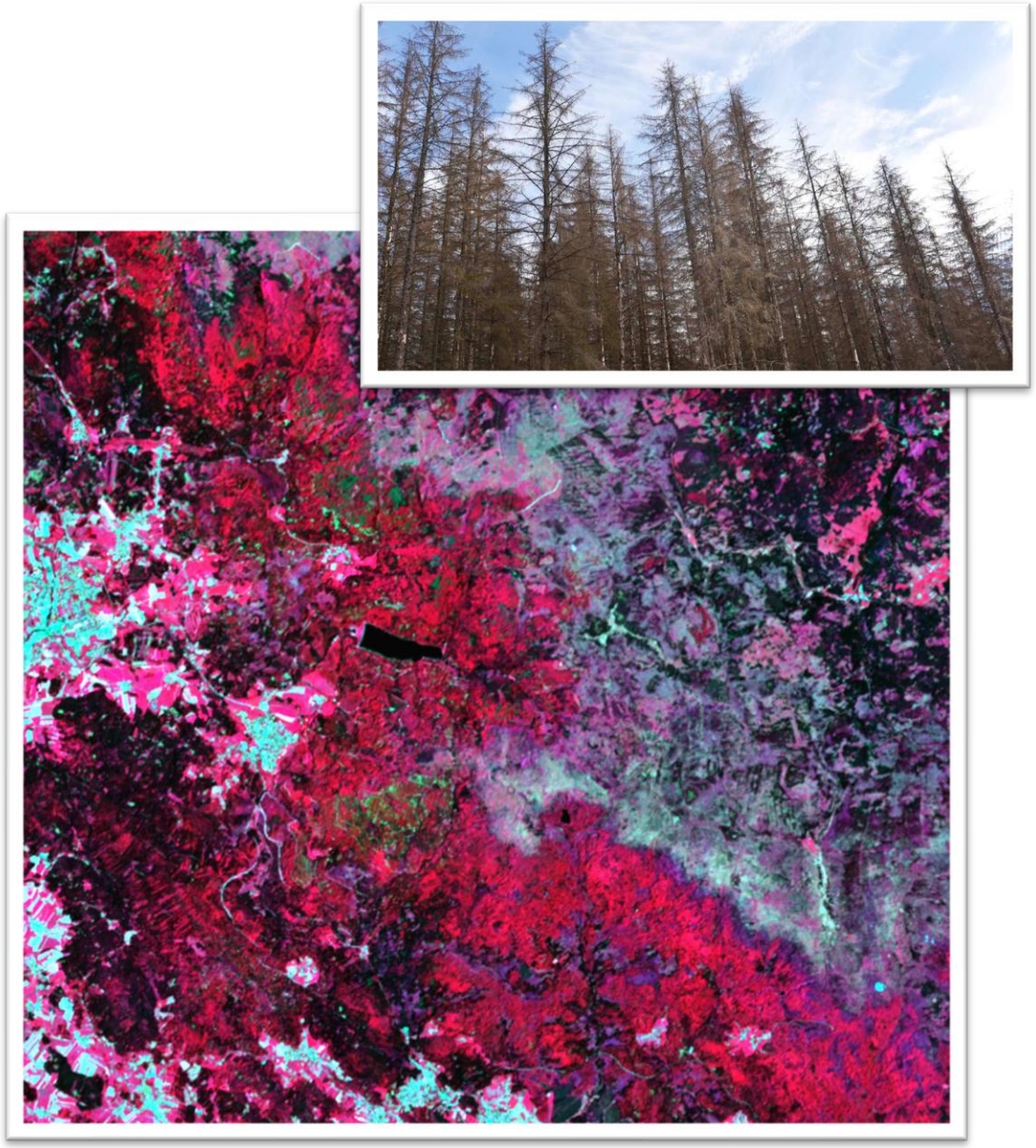
→ beech trees still cope with climate change

Monthly precipitation in BFNP (Jan 2019 – Aug 2021)



Research Questions

- How can DESIS data be used to observe changes in vegetation status over time?
- Which spectral index is most suitable to detect bark beetle infested trees in the National Park?
- Do the results add value compared to results obtained with Sentinel-2 data?
- Does the combination of DESIS and Sentinel-2 improve the accuracy of detected changes?



Supporting Data from the National Park

- Information on forest type
- Information on deadwood types
- Information on infestation year

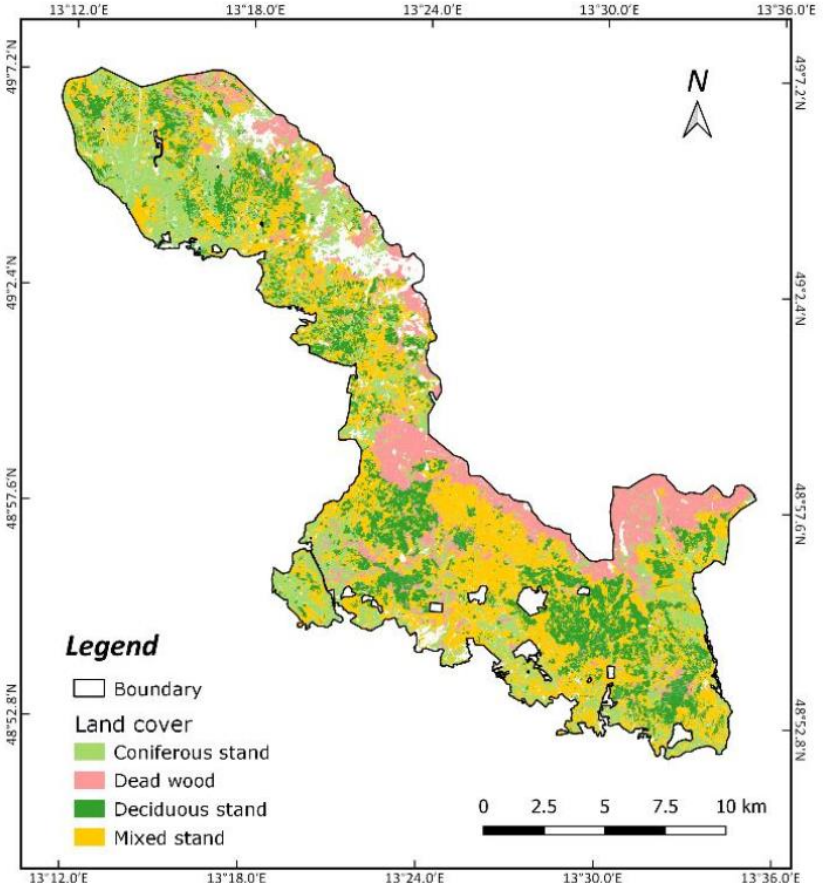
Concentrate analysis on coniferous areas

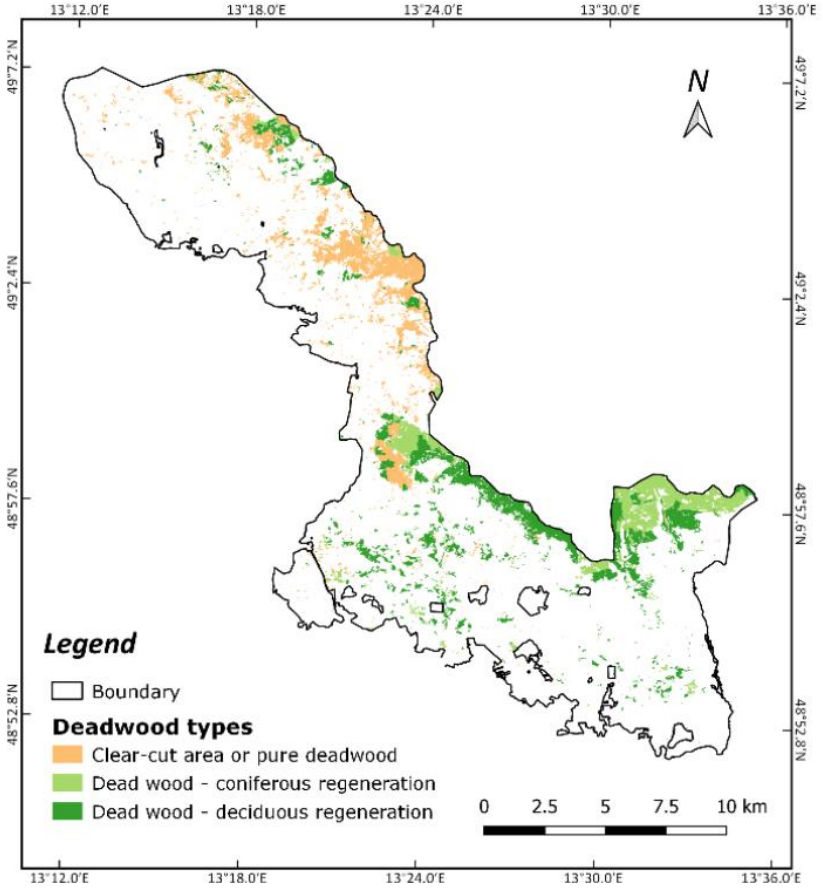
✓ Evergreen

✓ Less pronounced seasonal changes

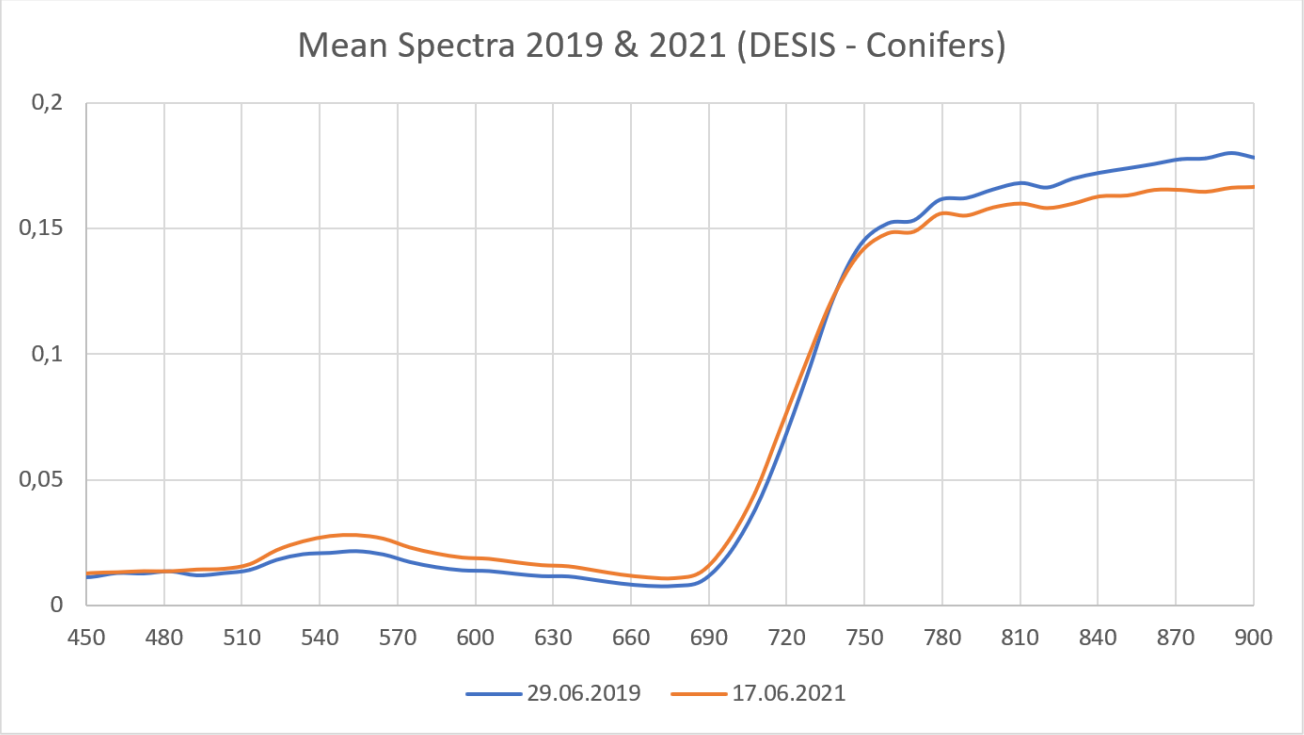
✓ Link to bark beetle infestation

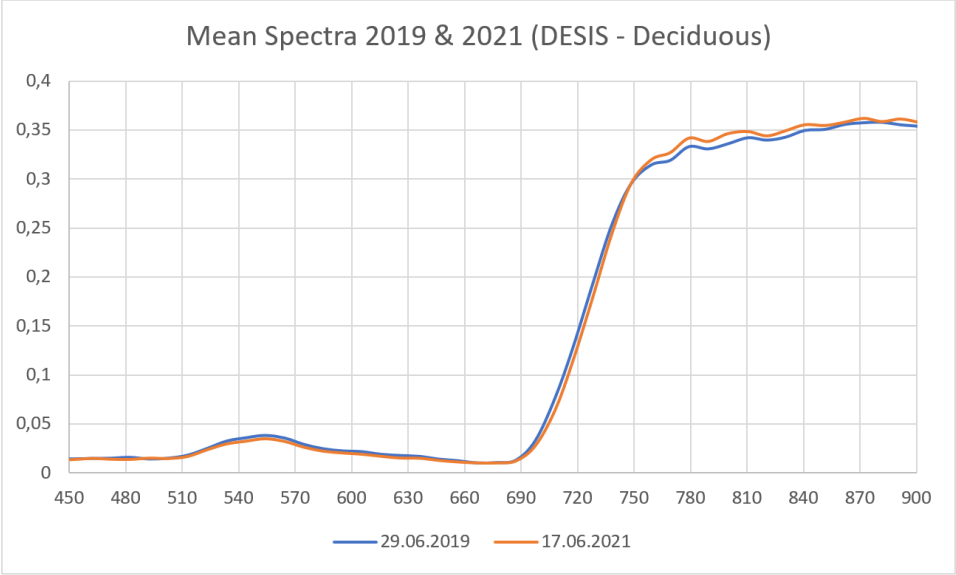
Validation data of the years 2020 and 2021

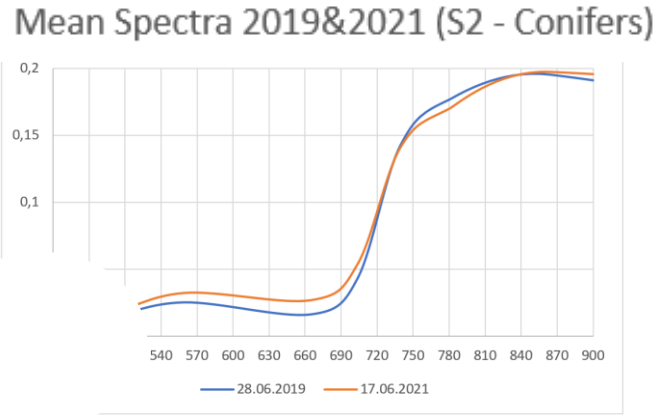


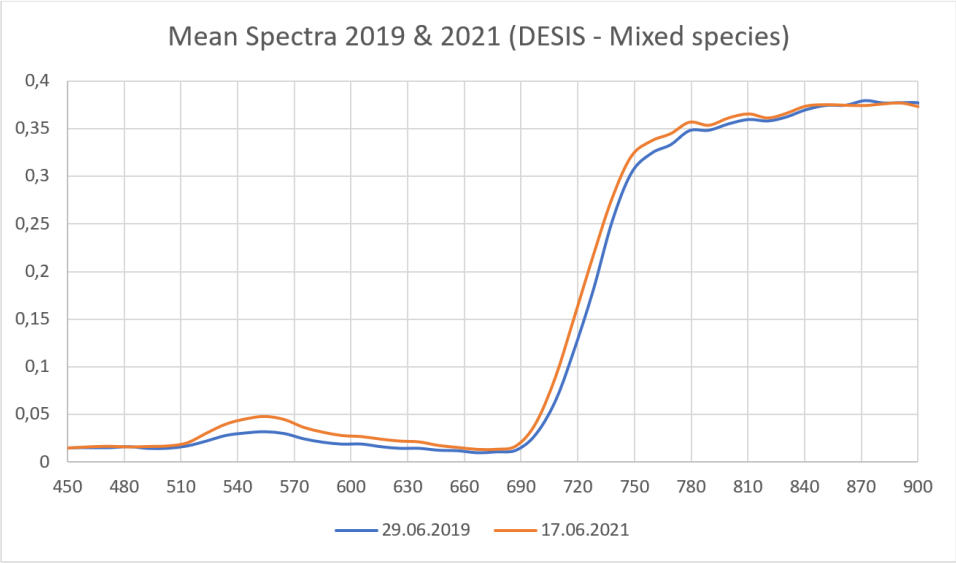


Spectral Changes 2019-2021

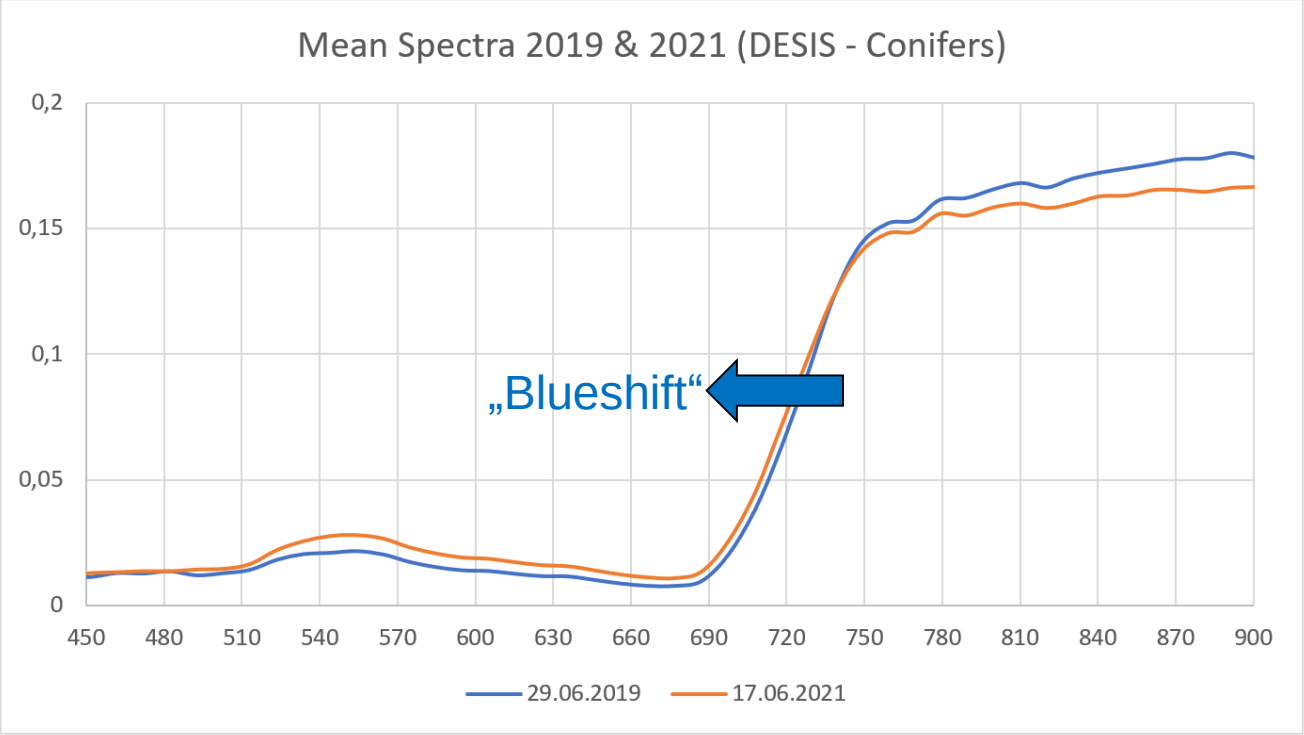


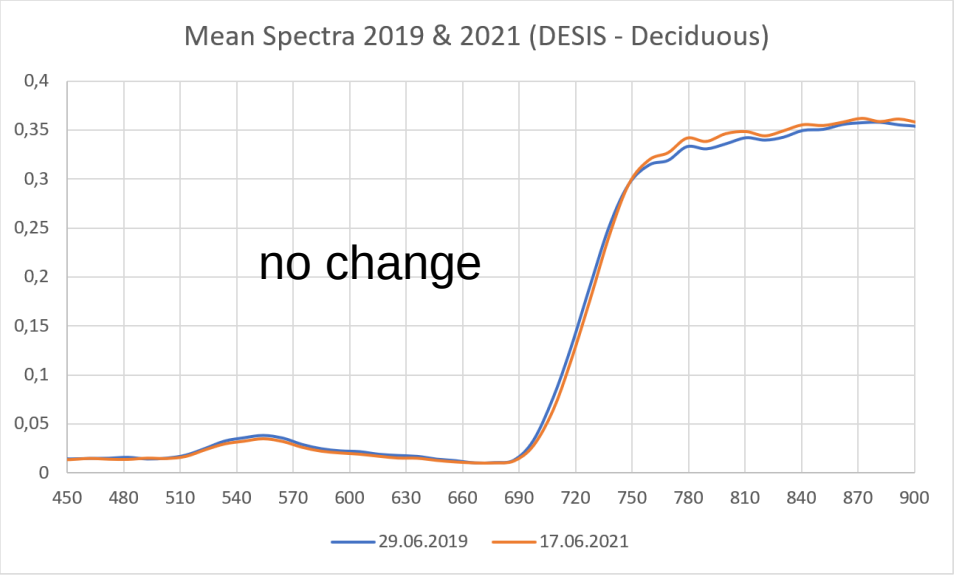


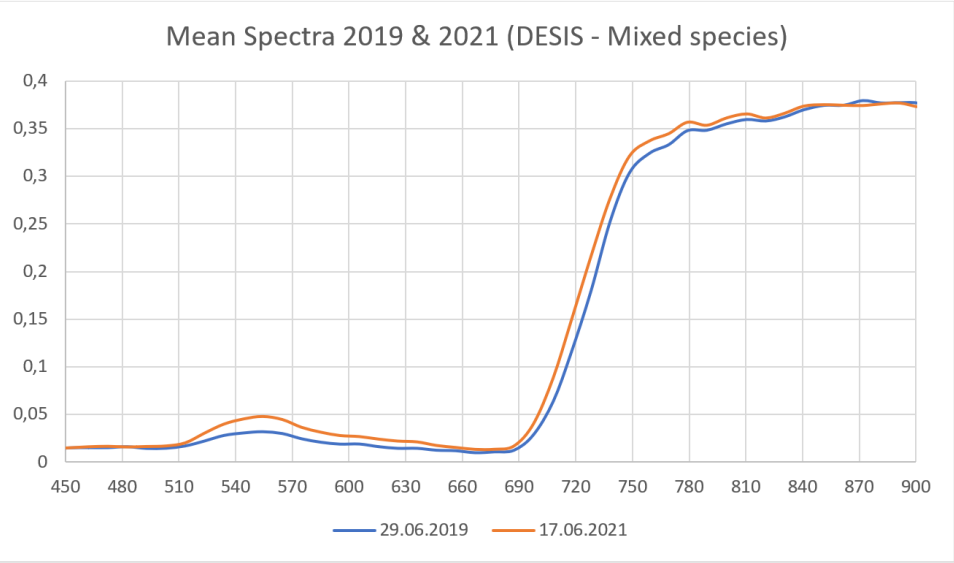


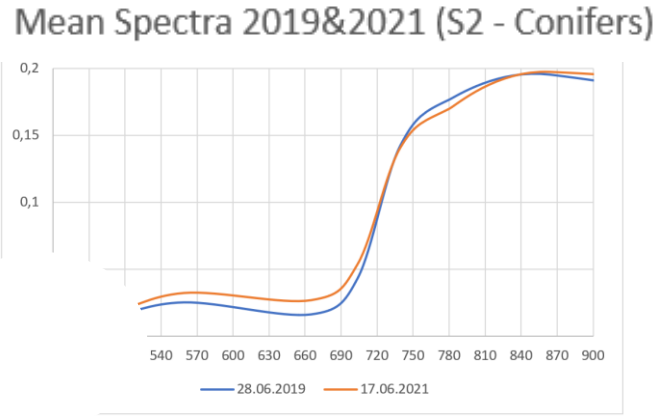


Spectral Changes 2019-2021









Spectral Indices Selection

Structural

- Normalized Difference Vegetation Index (NDVI) – **D & S2**
- Green Normalized Difference Vegetation Index (GNDVI) - **S2**
- Specific Leaf Area Vegetation Index (SLAVI) – **S2**

Chlorophyll & RedEdge

- Normalized Difference Red Edge Index (NDRE) - **D & S2**
- Photochemical Reflectance Index (PRI) - **D**
- Modified Chlorophyll Absorption Ratio Index (MCARI) - **D**
- Modified Red Edge Simple Ratio (MRESR) - **D**
- Vogelmann Red Edge Index 1 - **D**

Other Leaf Pigments

- Visible Atmospherically Resistant Indices Green (VIGreen) - **D & S2**
- Carotenoid Reflectance Index 2 (CRI) – **D**
- Anthocyanin Reflectance Index (ARI) – **D**

Spectral Indices Selection

Evaluation of DESIS derived indices
→ potential for mapping barkbeetle infested areas

Structural

- Normalized Difference Vegetation Index (NDVI) – **D & S2**
- Green Normalized Difference Vegetation Index (GNDVI) - **S2**
- Specific Leaf Area Vegetation Index (SLAVI) – **S2**

Results: Structural

- Structural indices showed negligible differences
- Sensitive to background reflectance
- Difficult to interpret changes in conifers
- Potential for broadleaf canopy

Chlorophyll & RedEdge

- Normalized Difference Red Edge Index (NDRE) - **D & S2**
- Photochemical Reflectance Index (PRI) - **D**
- Modified Chlorophyll Absorption Ratio Index (MCARI) - **D**
- Modified Red Edge Simple Ratio (MRESR) - **D**
- Vogelmann Red Edge Index 1 - **D**

Results: Chlorophyll & RedEdge

- Narrow band indices that incorporates red edge range strongly correspond to the affected infested/deadwood areas
- Especially MCARI performs well

Other Leaf Pigments

- Visible Atmospherically Resistant Indices Green (VIGreen) - **D & S2**
- Carotenoid Reflectance Index 2 (CRI) – **D**
- Anthocyanin Reflectance Index (ARI) – **D**

Results: Other Leaf Pigment

- Indices sparsely matched with the infested/dead regions
- Needle like leaves of conifers shows minimal variation

Spectral Indices Selection

Evaluation of DESIS derived indices
→ potential for mapping barkbeetle infested areas

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- Normalized Difference Vegetation Index (NDVI) – **D & S2**
- Green Normalized Difference Veg[illegible]tion Index (GNDVI) - **S2**
- Specific Leaf Area Vegetation Inc[illegible]

Chlorophyll & RedEdge

- Normalized Difference Red Edge Index (NDRE)
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- Modified Chlorophyll Absorption Ratio Index (MCARI) - **D**
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Other Leaf Pigments

- Visible Atmospherically Resistant Indices Green (VIGreen) - **D & S2**
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Used for further investigation:

- MCARI (DESIS)
- Combined Vegetation Index CVI (S2) [Hill et al. 2019]

Results: Structural

- Structural indices showed negligible differences
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- Potential for broadleaf canopy

[illegible]dge

- [illegible]corporates red edge range strongly
- [illegible] infested/deadwood areas
- Especially MCA[illegible]ns well

Results: Other Leaf Pigment

- Indices sparsely matched with the infested/dead regions
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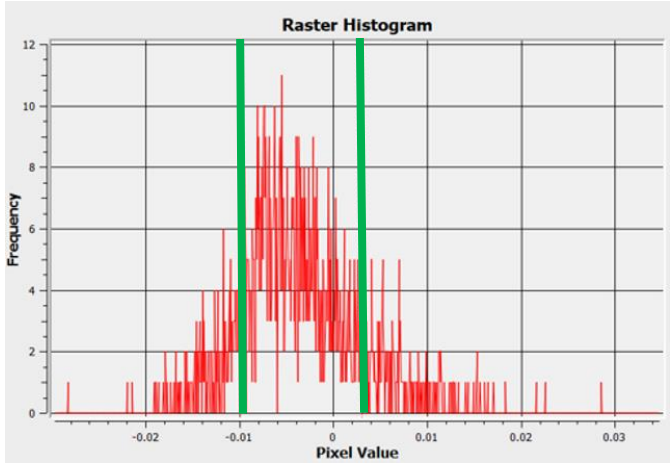
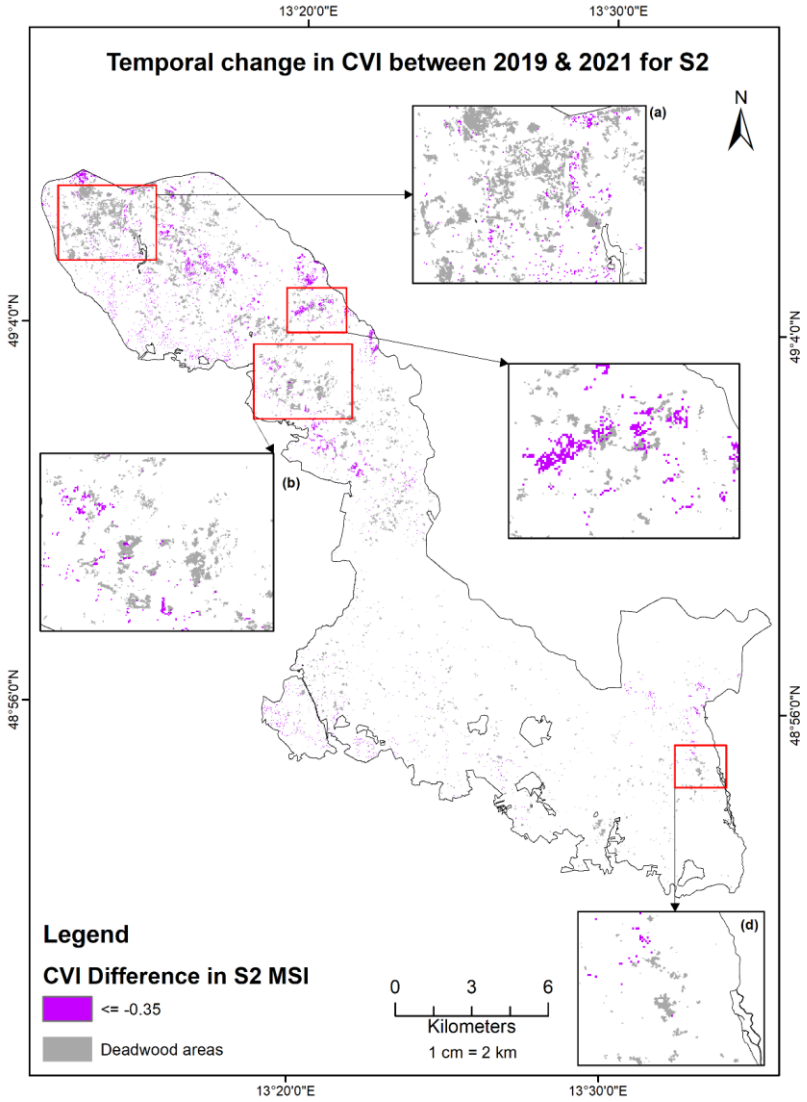
Temporal Changes

Differences in index values for infested regions

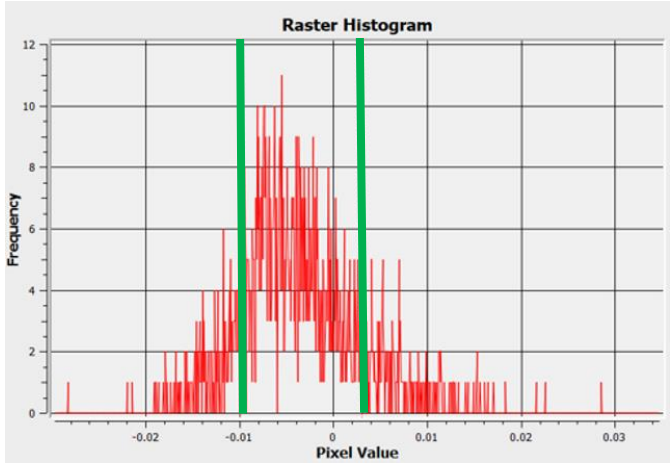


→ interactive threshold selection
→ aim: minimize false positives



Temporal Changes

Differences in index values for infested regions



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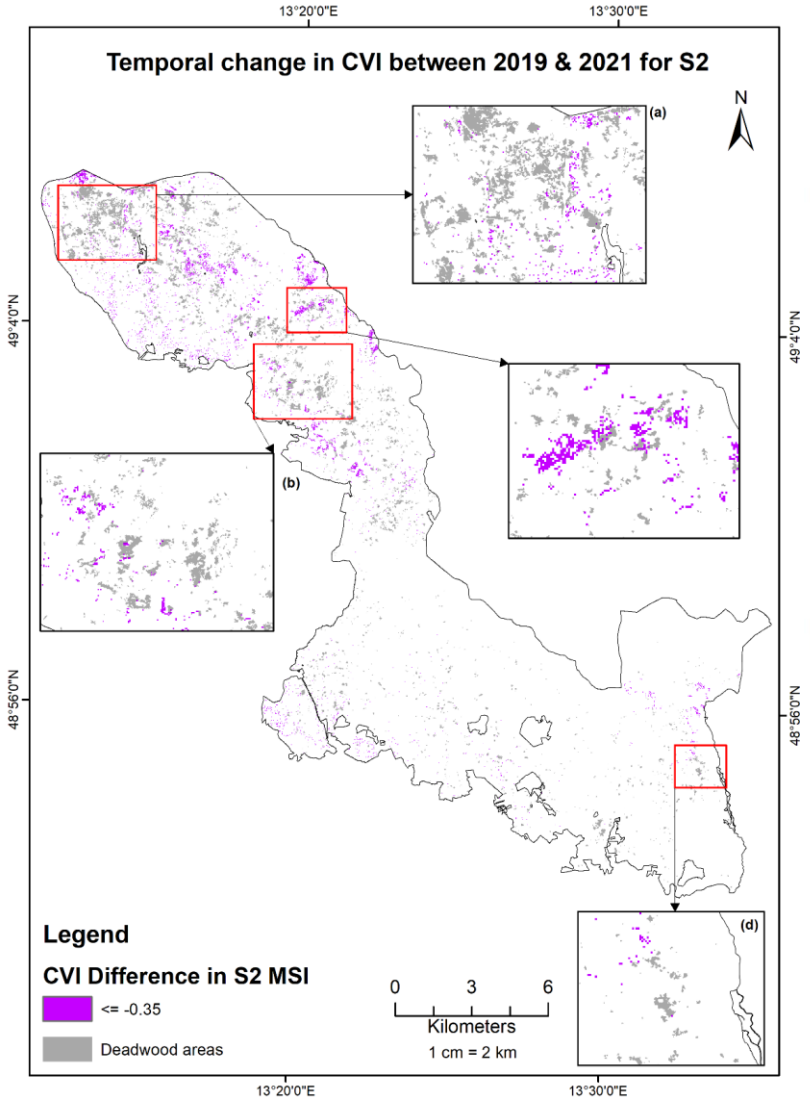
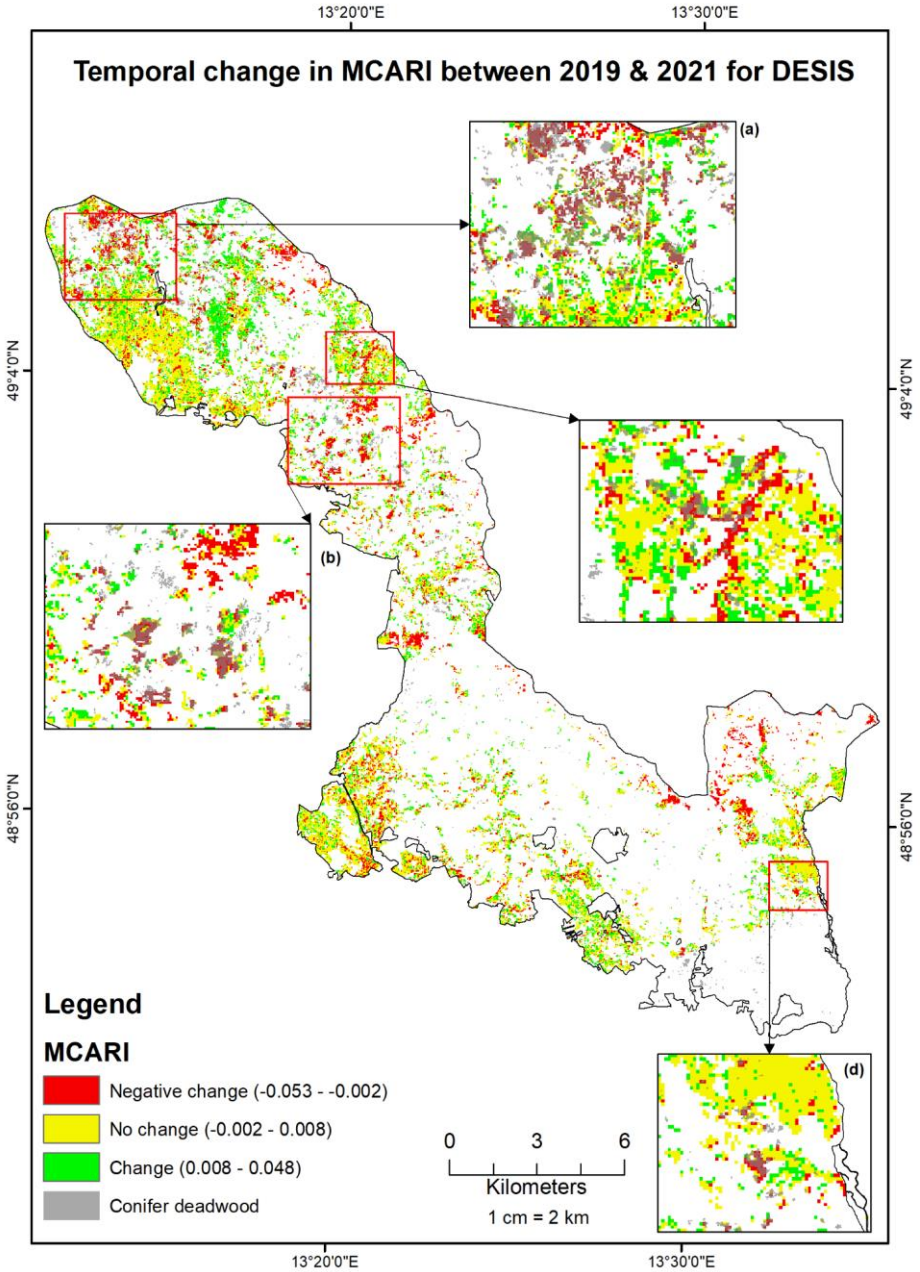


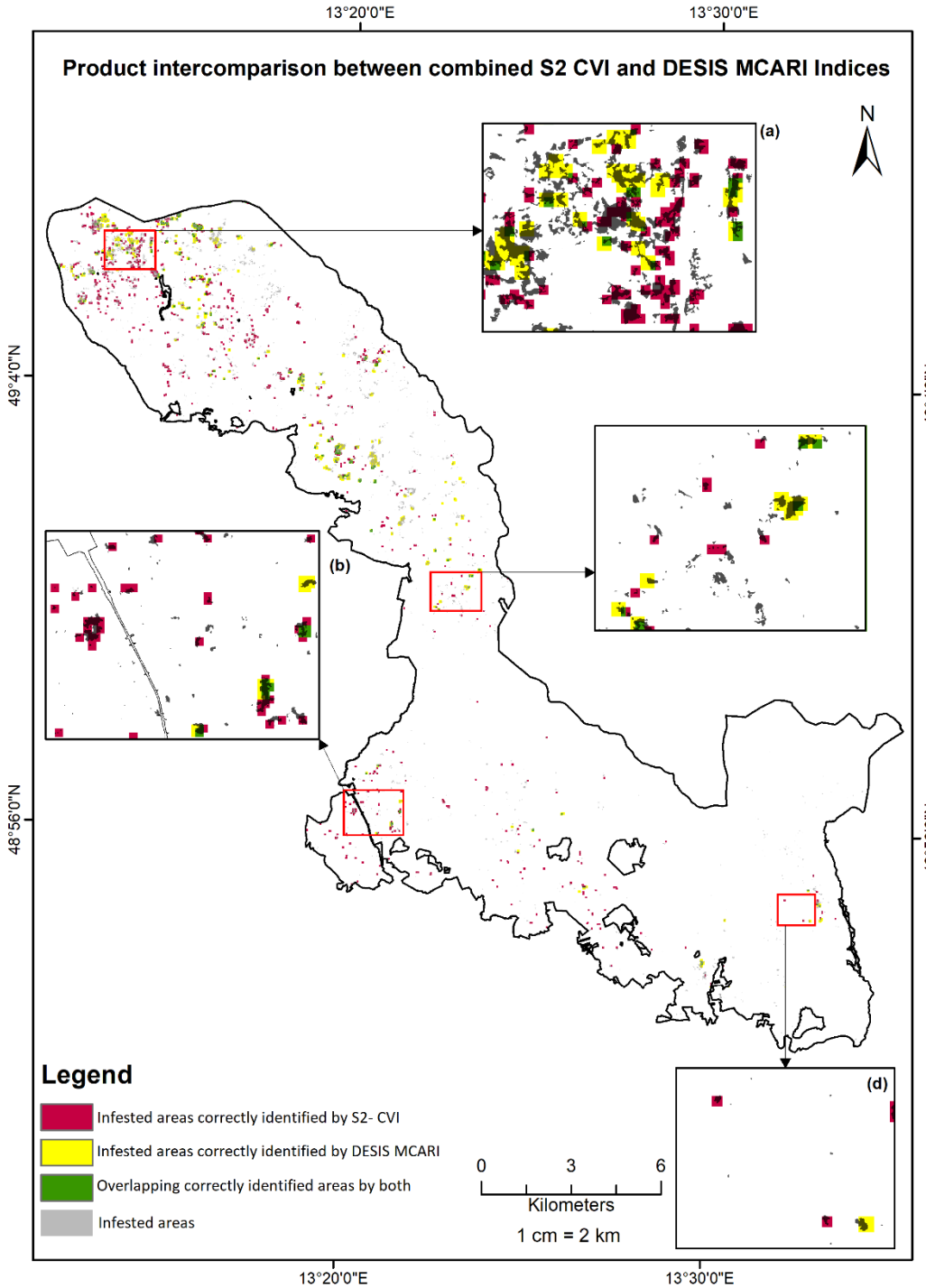


Comparison / Combination of Results

- Matching pixel size to 30m and apply buffering to reduce geometrical mismatches
- Apply morphological operator „clump“ to cluster connectivity

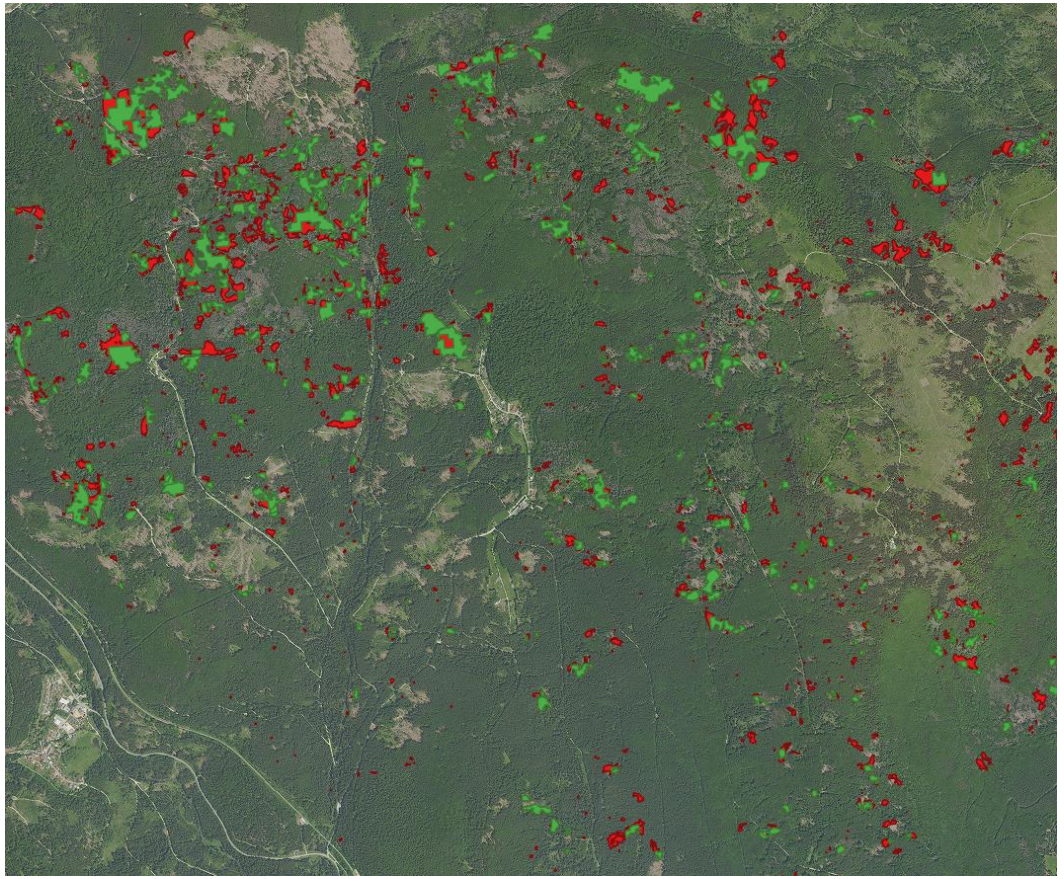
	Infested areas (number of polygons)	Number of correctly identified polygons
All infested areas	3365	1269 / 38%
Areas > 225 m^2	1439	685 / 48%
Areas > 900 m^2	707	900 / 57%
Areas > 2025 m^2	350	208 / 59%

	Correctly identified (DESIS)	Correctly identified (S2)	Correctly identified (DESIS ∩ S2)	Correctly identified (DESIS U S2)
All infested areas	49 %	50 %	45 %	54 %



Conclusions

- DESIS data is suitable to detect changes in vegetation status over time also in ***heterogeneous*** natural forests
- Bark beetle infested areas can be detected with DESIS and Sentinel-2 (no early warning!)
  - ✓Biophysical indices (esp. RedEdge parameters) reflect vegetation stress
- **Combined detection rate higher than individually**



Barkbeetle infested area
Correctly identified by DESIS and Sentinel-2