Analyzing spatial patterns of change in vegetation & monitoring health status in Bavarian Forest National Park using multi- and hyperspectral datasets

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Aim

The study aims to analyze the spatial patterns of change in vegetation inside Bavarian Forest National Park (BFNP) using spaceborne hyperspectral and multispectral datasets.

Objectives

- To estimate seasonal variation in vegetation from 2017 to 2021.
- To compare Vegetation Indices (VI's) results of the multi-temporal S2 with the multi-annual DESIS.
- To validate results with additional information like deadwood areas from BFNP team and other supporting datasets.

Fig. 1. Study area location

Scenario in BFNP

→ **Bark beetle outbreaks -** large-scale breakdown of conifer forests

→ **Seasonal change in vegetation –** observed from precipitation patterns

→ **Climate trend –** favors growth of bark beetle population

→ **Focus on conifers –** as it shows less phenological changes season wise.

Research questions

→ What are the spatial patterns of vegetation change when analyzing time series for Sentinel 2 and multi-annual DESIS datasets?

→ Which spectral indices are well suited to observe change in vegetation pattern?

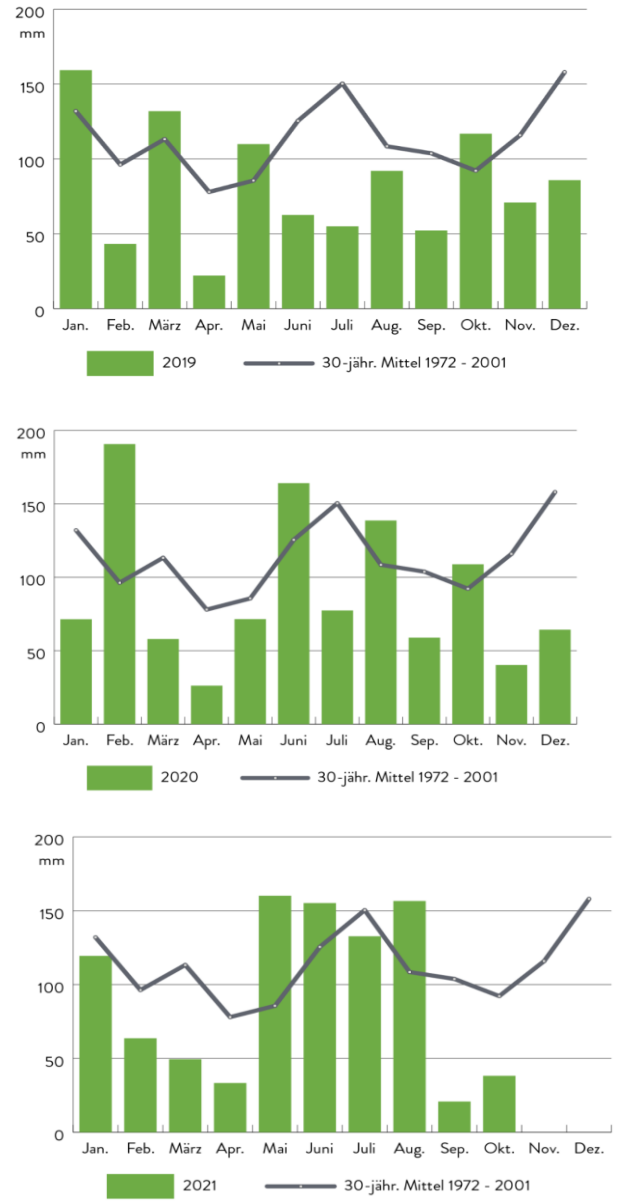


Fig. 2. Monthly precipitation observed in BFNP from Jan 2019 to Oct 2021

Source: https://www.national-park-bayerischerwald.bayern.de/aktuelles/wetterstation/index.htm

DLR Earth Sensing Imaging Spectrometer (DESIS) Mission

→ Hyperspectral mission operated together by DLR and Teledyne Brown Engineering (TBE).

→ Instrument integrated in the Multi-User-System for Earth Sensing (MUSES) platform installed on the International Space Station (ISS) (R. Müller et al., 2016).

→Uses a push broom spectrometer which is sensitive for visible and NIR wavelength range from 400 – 1000 nm with spectral sampling of 2.55 nm.

→ Target lifetime from 2018 – 2023 with average revisit frequency of 3 – 5 days.

Band Information

DESIS (L2A Product – used for this study)

- 4 * binning with 60 spectral bands (54 spectral bands considered for analysis)
- at ~10.20 nm FWHM (Alonso et al.,2019)
- Spatial resolution - 30 meters
- Wavelength ranging from 430 – 975 nm (after removal of noisy bands).

Band Information

Sentinel 2 (L2A MAJA Corrected used for this study)

- 12 bands (9 spectral bands considered for analysis)
- Spatial resolution - 20 meters (for all bands, resampled)
- Wavelength ranging from 490–2185 nm (taken till 1000 nm)

Cloud free datasets available

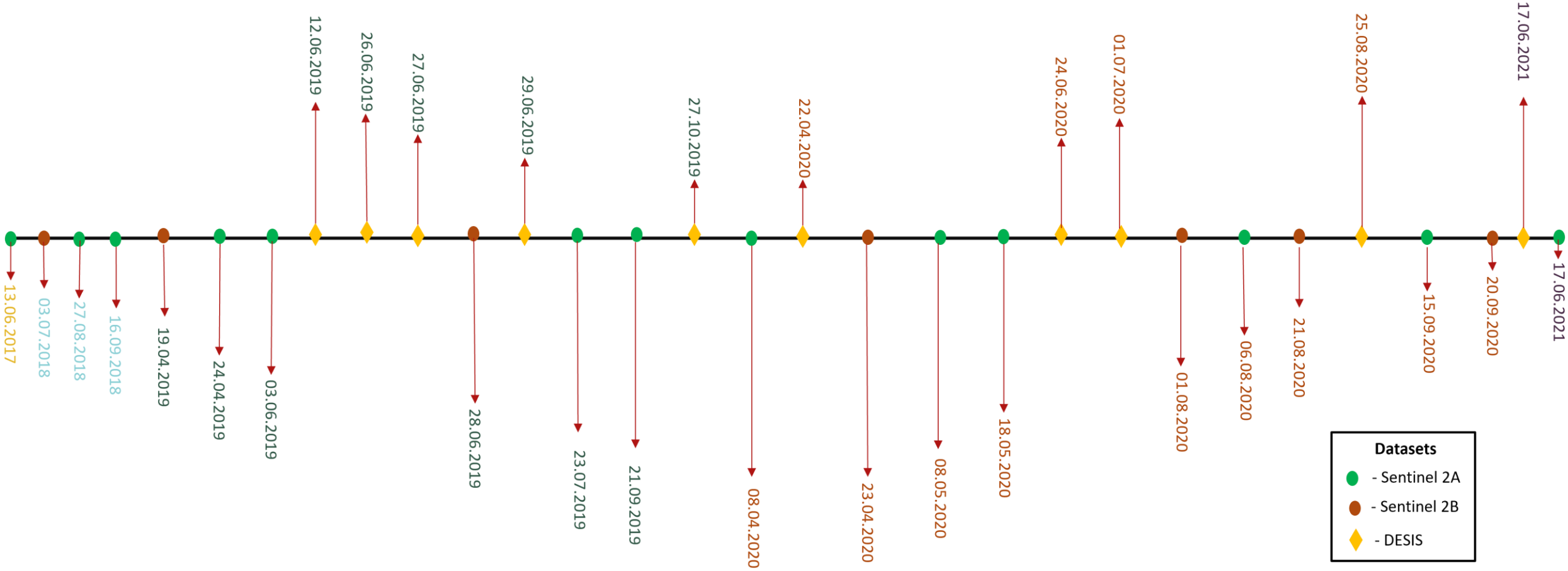
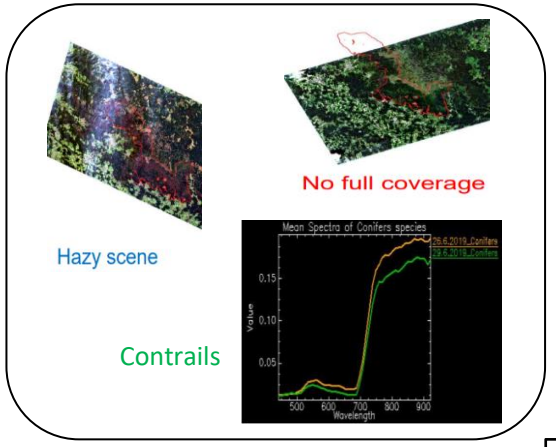


Fig. 3. Multi-annual DESIS and Time series of Sentinel 2 MAJA Corrected datasets

Methodology



DESIS (2019-2022) hyperspectral data

Data quality control check (Cloud/ haze removal)

Solar zenith <40°

No

Elimination of data from processing

Yes

DESIS taken for further analysis

Comparison of reflectance spectra of L2A products

Multispectral datasets 2017 - 2021

VI's for

DESIS

MSI sensor imageries

Interpretation of the VI's in relation to bio-physical variables

Combined Vegetation Index (specially Conifers)

Narrow Band Vegetation Indices (specially Conifers)

Season wise vegetation change

Annual vegetation change

Comparison of MSI data and DESIS to identify spatial patterns of shift

Source of information from BFNP

Extract tree species from habitat map

Conifers (young/medium/mature)

Deciduous

Mixed

Conifers deadwood

Annual information of deadwood region

- Records of estimated VI's
- Additional information from the BFNP (ground truth / high resolution imageries for cross-verification)

Validate the information

Fig. 4. Formulated Workflow

Indices estimation

→ Assess if negative change in vegetation coincides with deadwood areas

→ Evaluate DESIS with narrow band indices to determine suitable spectral indices.

→ Compare with high temporal resolution S2 and see if there are changes in vegetation pattern.

List of Vegetation Indices estimated (Morcillo-Pallarés et al., 2019)

Bio-physical variables :

Structural

Normalized Difference Vegetation Index (NDVI) – **D & S2**

Green Normalized Difference Vegetation Index (GNDVI) -**S2**

Specific Leaf Area Vegetation Index (SLAVI) – **S2**

Chlorophyll

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**

Leaf pigment

Visible Atmospherically Resistant Indices Green (VIGreen)-**D & S2**

Carotenoid Reflectance Index 2 (CRI) – **D**

Anthocyanin Reflectance Index (ARI) – **D**

Vegetation Indices of Multi-temporal Sentinel 2

→ VI's for Conifers represents changes that are easily visible.

→ Entire forest health cannot be determined from a single VI hence vegetation vitality index called "CVI" is used for this study.

→ CVI is Equal weightage to one index from every bio-physical variable (Hill et al., 2018)

Combined Vegetation Index (CVI) = (NDVI + VIgreen + NDRE)/3

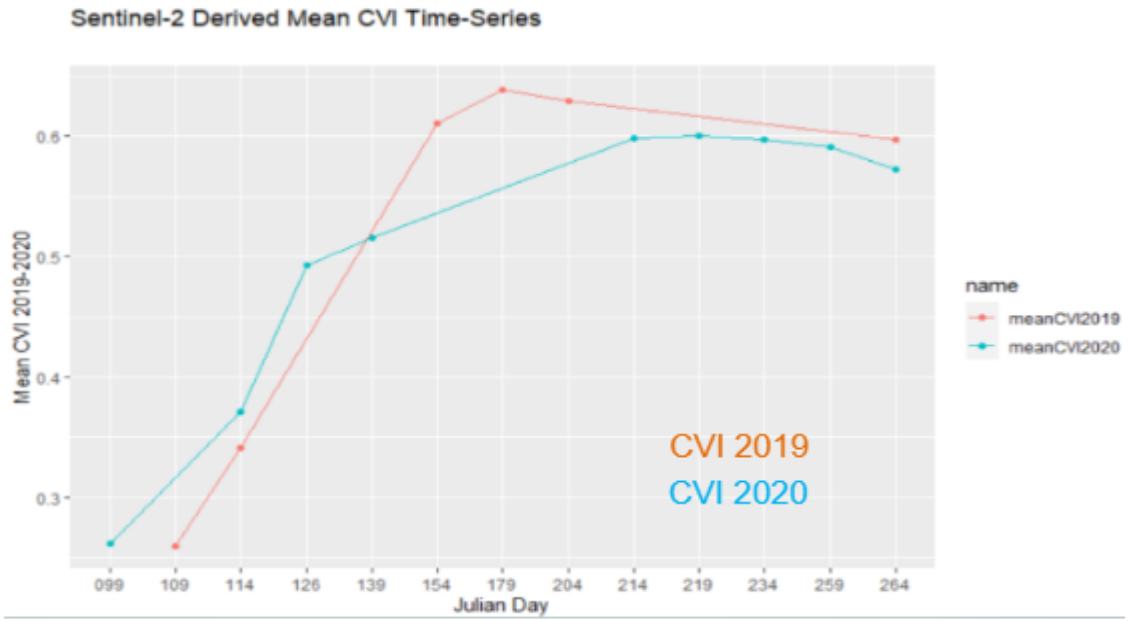


Fig. 5 (a) Time series plot for Mean CVI Sentinel 2 conifers 2019 & 2020

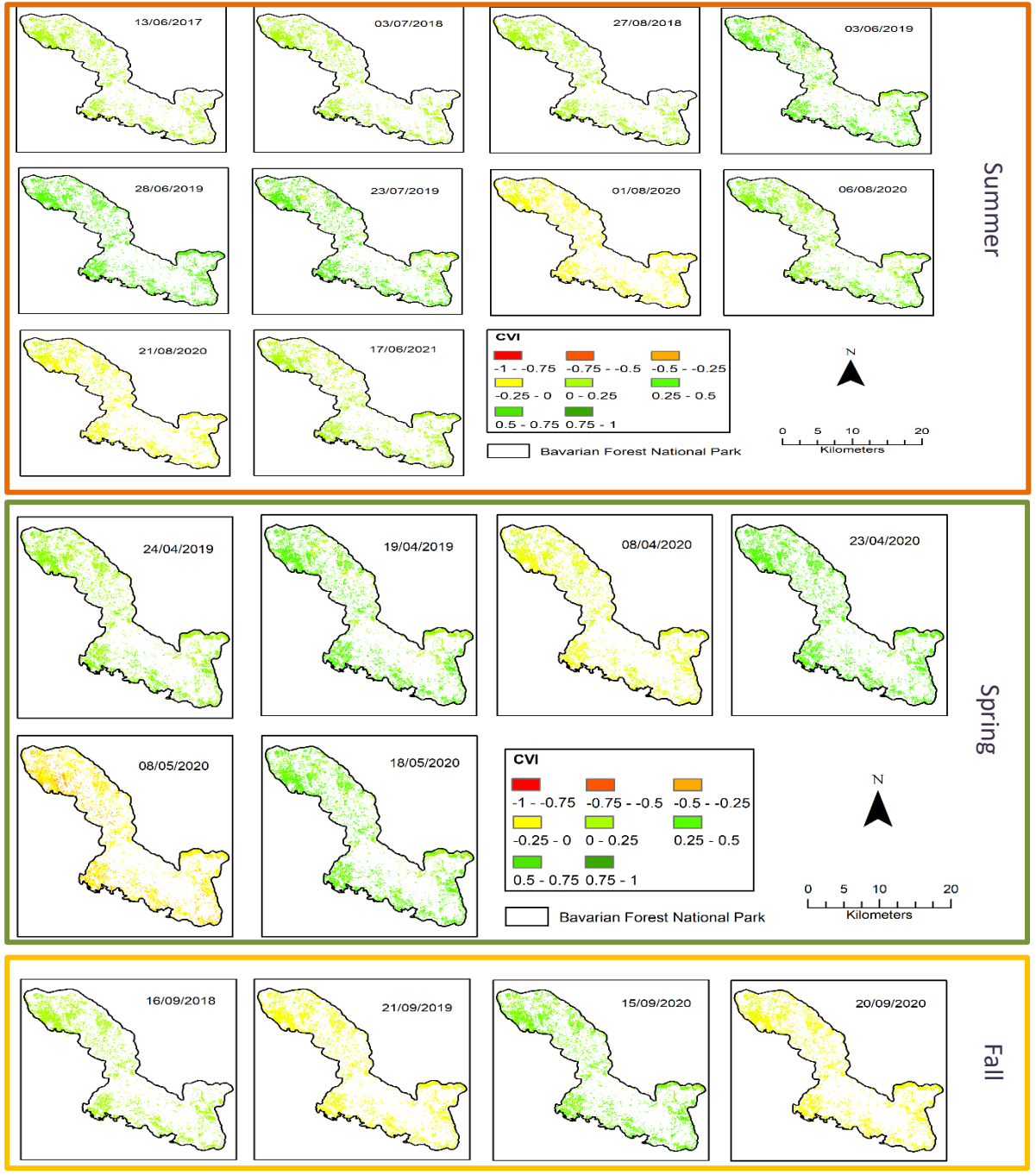
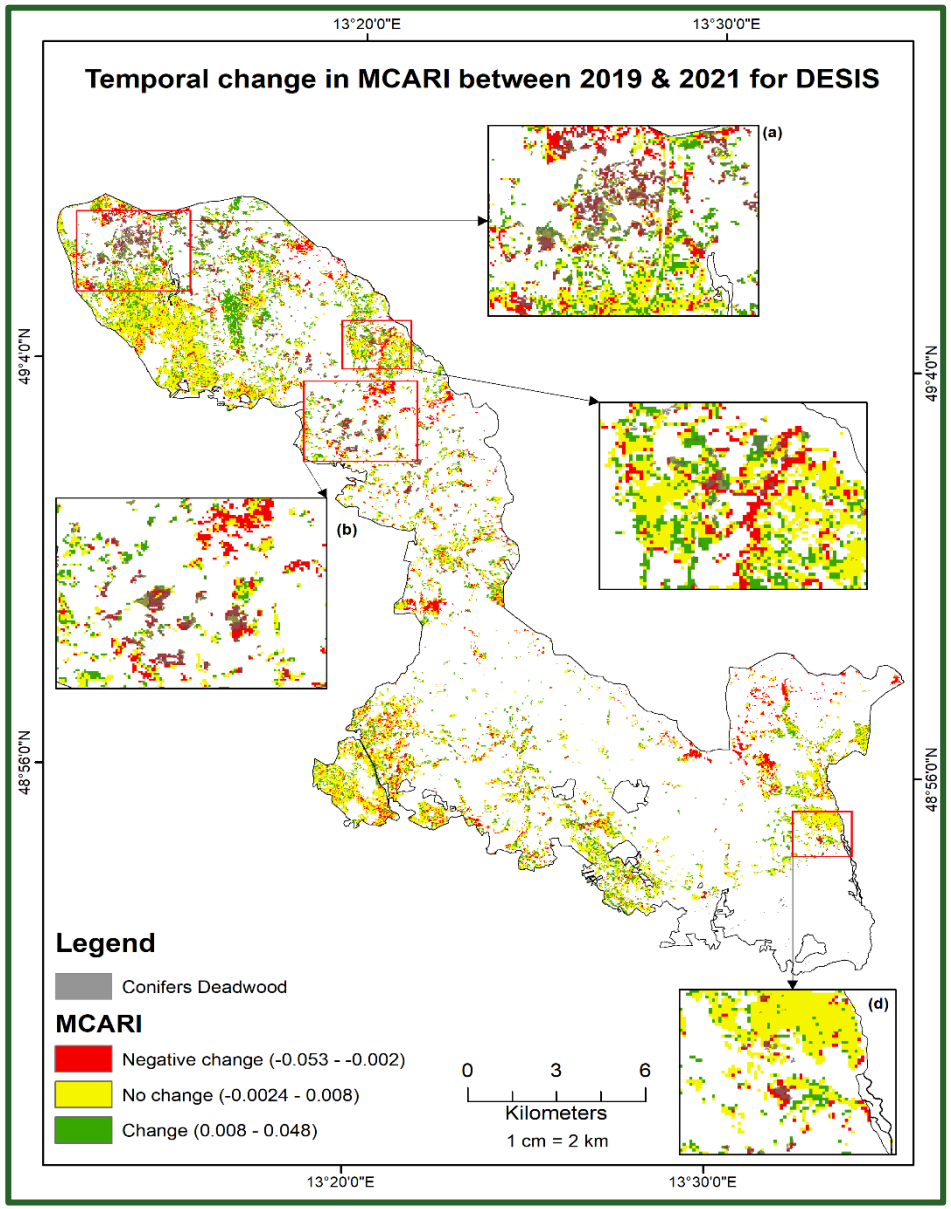
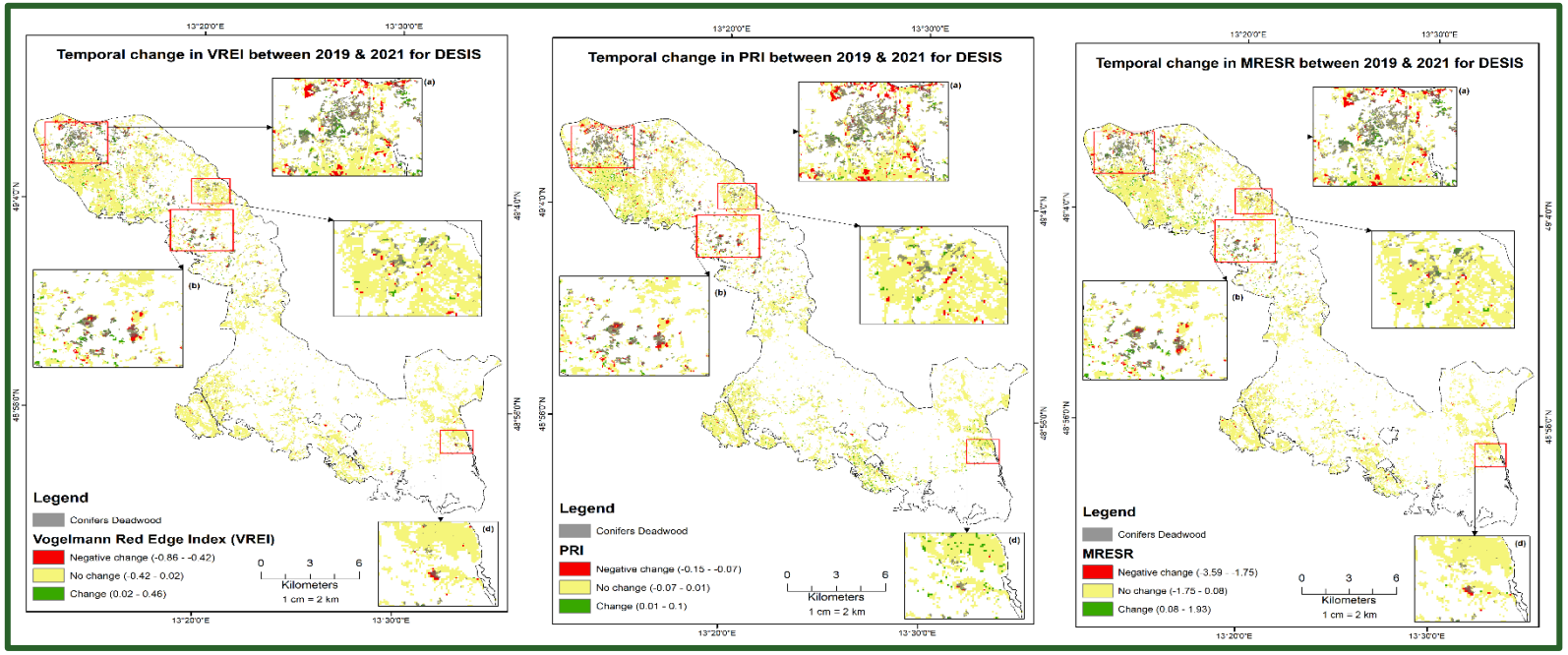


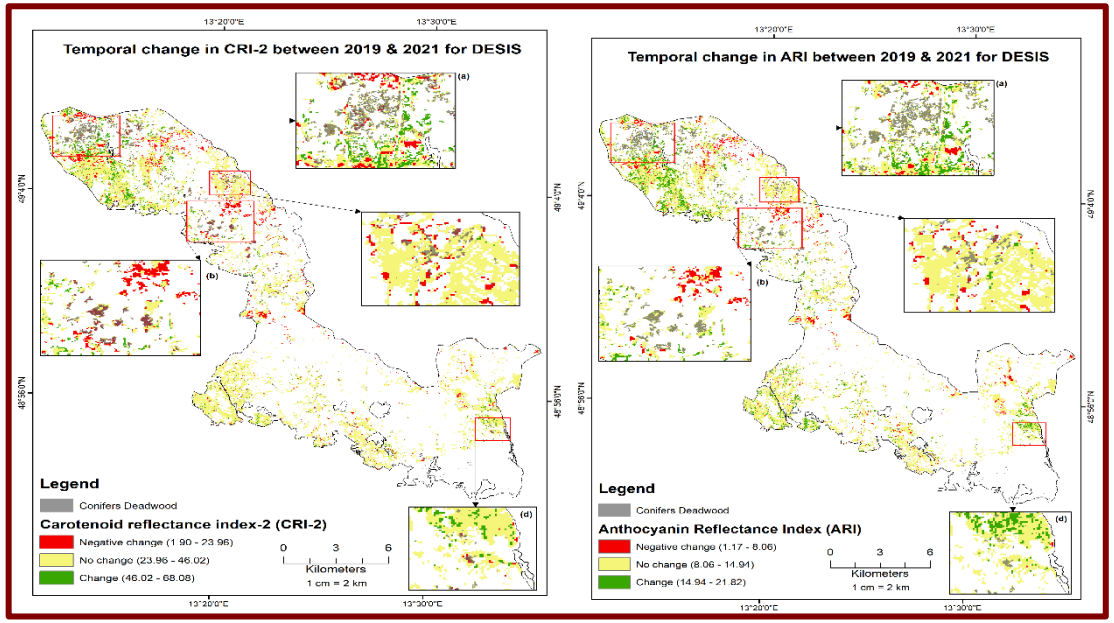
Fig. 5 (b) Season wise CVI estimated for Sentinel – 2 MAJA Corrected dataset for Conifers *(Hill et al., 2018)*

Vegetation Indices of DESIS

Fig. 6 Narrow band vegetation indices for DESIS







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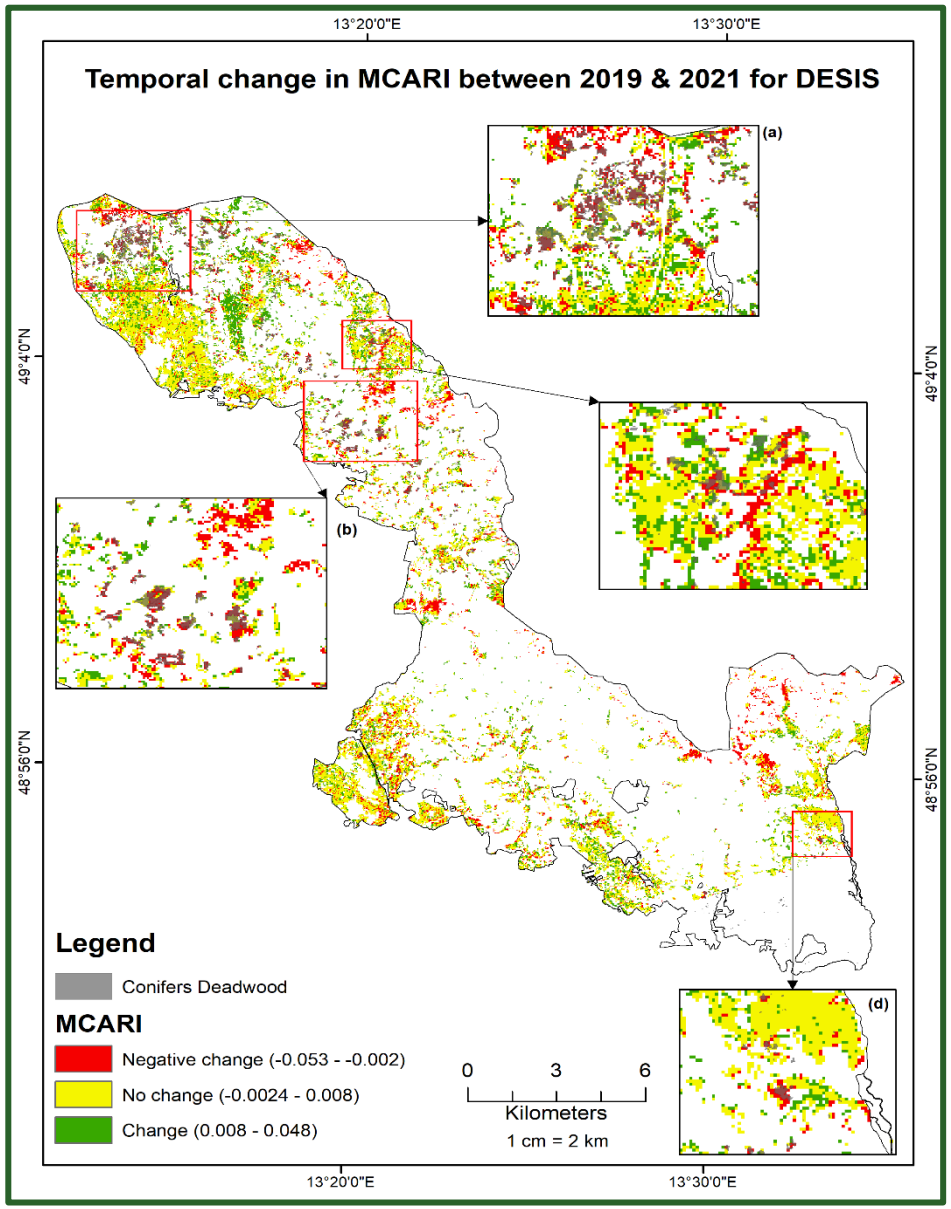

Summary

INDICES IN CORRESPONDENCE WITH DEADWOOD AREAS

Chlorophyll

- Narrow band indices that incorporates red edge range strongly corresponds to the affected deadwood areas.
- MCARI outperforms well than other chlorophyll indices.
- MRESR, PRI and Vogelmann Red Edge - partially matches with deadwood.

Leaf pigment

- Indices like Carotenoid 1, 2 and Anthocyanin – sparsely matched with the deadwood regions.
- Needle like leaves of conifers shows minimal variation.

Structural

- Structural indices like NDVI - showed negligible differences
- Sensitive to background reflectance and difficult to interpret changes in conifers
- Potential for broadleaf canopy

Inferences

- CVI from Sentinel 2 MSI - seasonal change variation suitable for mapping changes in conifers.
- VI from high spectral information DESIS - renders clear details corresponding to deadwood locations.
- For future work: examining acquired results – any recent real time information available for validation (2021)?

Discussion

- When is a tree dead (any specific season), are infected trees cut down showing canopy gaps or covered with understory?

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THANK YOU !!