Towards global mapping of canopy chlorophyll content from Sentinel-2

1. Introduction

Information on the amount and distribution of CCC has been utilized to answer many ecological questions related to monitoring and evaluating terrestrial ecosystem properties (Dash et al., 2009). CCC helps to assess and report indicators related to ecosystem processes and functional aspects of biodiversity.

Remote sensing provides the opportunity to drive comprehensive variables globally (Skidmore et al., 2015), and fill gaps left by in situ observations. However, transferring prediction models developed for one biome, universally across all biomes is challenging. To our knowledge, there are no algorithms validated across biomes for global mapping of CCC from high resolution satellite remote sensing data (e.g., Sentinel 2). This study evaluated the robustness and spatiotemporal consistency of selected methods for large scale mapping of CCC.

2. Methodology

2.1. Test sites

In order to consider diverse vegetation types across gradients of climate, altitude, and latitude, four test sites from terrestrial biomes considered: 1) Kytalyk (Boreal Taiga and Arctic Tundra), 2) La Camargue (wetland ecosystem), 3) Bavarian Forest National park (Temperate / Mediterranean forests), and 4) Lambir national park (Tropical / sub-tropical rain-forests).

2.2. Methods

2.2.1. Selected Algorithms

We investigated the robustness, and spatiotemporal consistency of four methods: a) two simple ratio vegetation indices optimized for forests and non-forest vegetation, b) partial least square regression (PLSR) trained on a spectral subset of eight bands of Sentinel-2 with five components, c) INFORM and PROSAIL inversion using Look-up table (LUT), and d) the PROSAIL and ANN combination approach (Baret, 2016) that has been implemented in the Sentinel Application Platform (SNAP) toolbox.

2.2.2. Assessment of methods transferability

a) Spatial distribution consistency:

The spatial distribution of CCC maps produced using the four methods visually and quantitatively investigated in the four biomes. The ranges of the generated CCC products were compared to the expected CCC range in each biome, and statistical analysis performed to measure disparities among pairs of CCC products.

b) A measure of agreement among pairwise CCC products

The closeness of the CCC predicted values by pairs of methods was evaluated by computing the strength of the correlation, prediction errors, and precision.

c) Temporal consistency

Predictions of CCC were performed using time series Sentinel-2 data, and evaluated whether the relationship of the predicted CCC values by a pair of methods significantly change through time.

3. Results

3.1. Spatial distribution consistency

INFORM and PROSAIL inversion by LUT elucidated ranges closer to expectations in three of the four biomes. The Violin plot in Figure 1 depicted the similarities and differences of CCC products generated by the selected methods. PLSR compared to INFORM showed a significant measure of distribution disparity in temperate forest. All of the pairs of CCC products showed distribution disparity in tropical rain forests. PROSAIL and SRVI in La Camargue exhibited similar distribution, whereas non-significant distribution disparity was observed between the SNAP toolbox and SRVI in tundra biome.

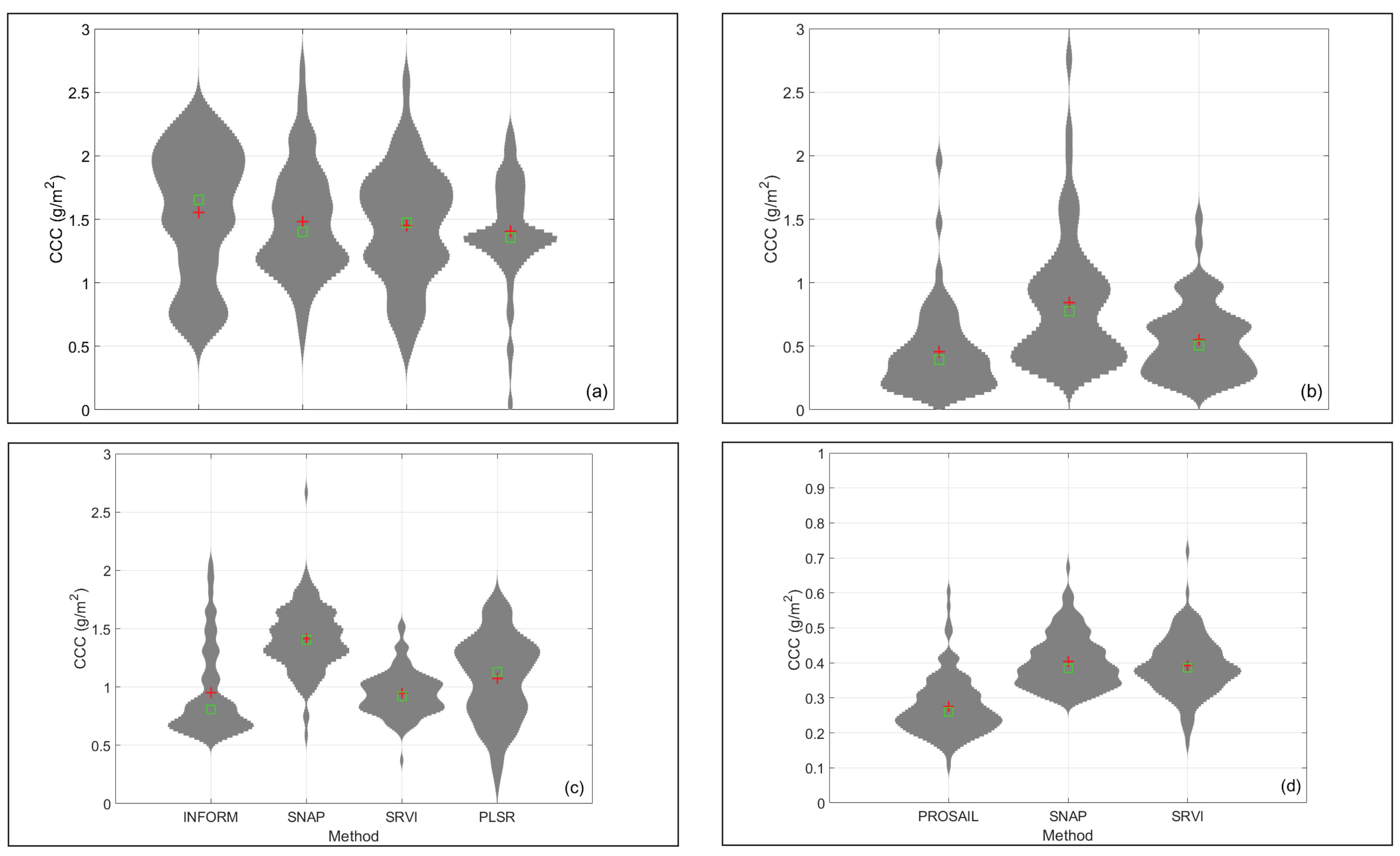


Figure 1: Violin plots of predicted CCC (g/m2), showing the differences in frequency distribution among four biomes; (a) temperate forest, (b) wetland, (c) tropical forest, and (d) arctic tundra. The square and plus sign indicate the median and mean of the predicted CCC by each method.

3.2. The agreement of CCC values predicted by the selected methods

As illustrated in Figure 2 and Figure 3, SRVI better agree with radiative transfer models (RTMs) inversions. The predictions made using the SNAP toolbox approach (Baret 2016) showed a tendency of overestimation, particularly in a wetland (Figure 3).

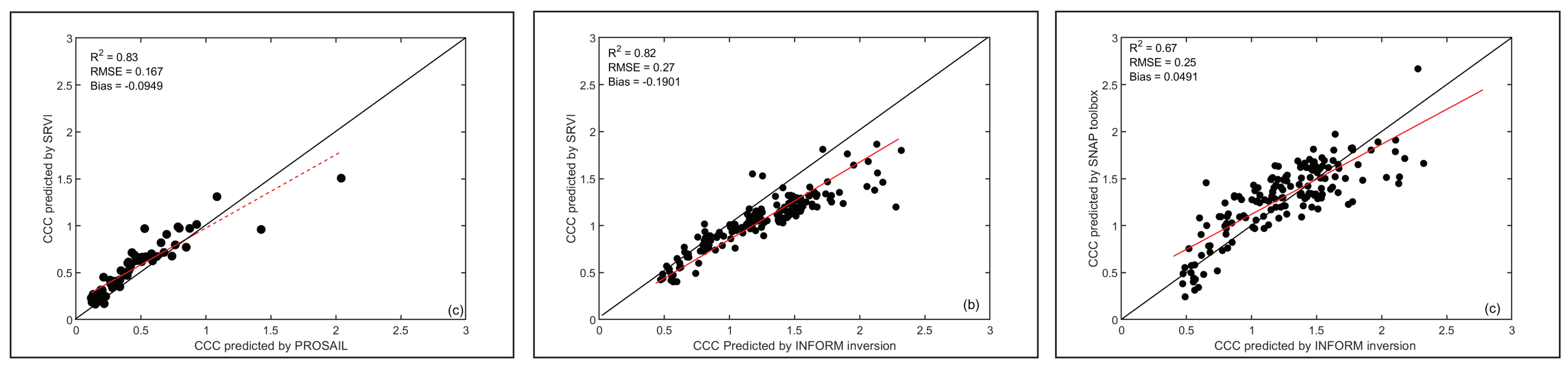


Figure 2: Robustness of the SRVI against the SNAP toolbox approach (a) and INFORM inversion using LUT approach (b), and the SNAP toolbox approach against INFORM inversion (c) in predicting CCC in Lambir tropical forest ecosystem.

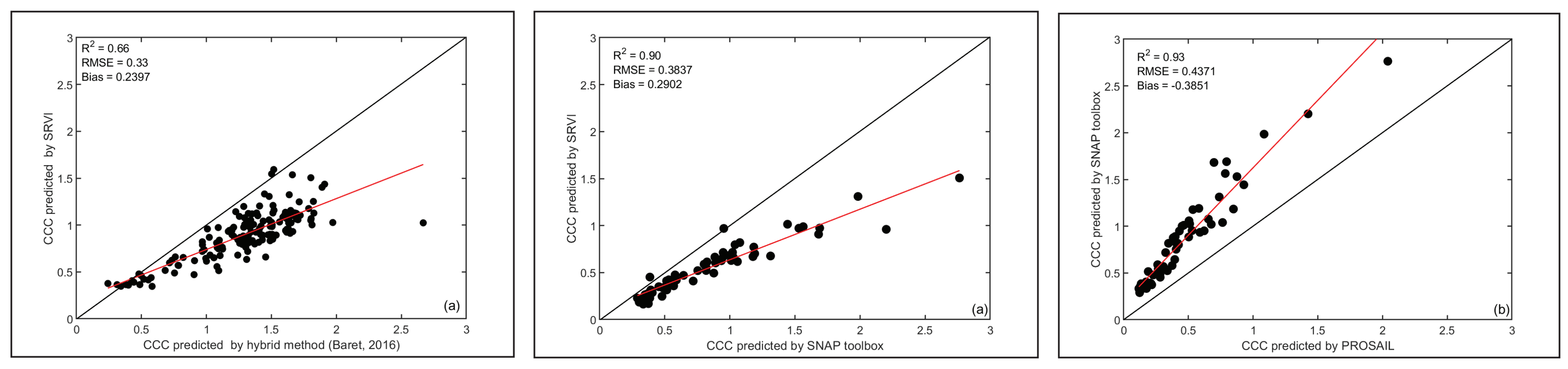
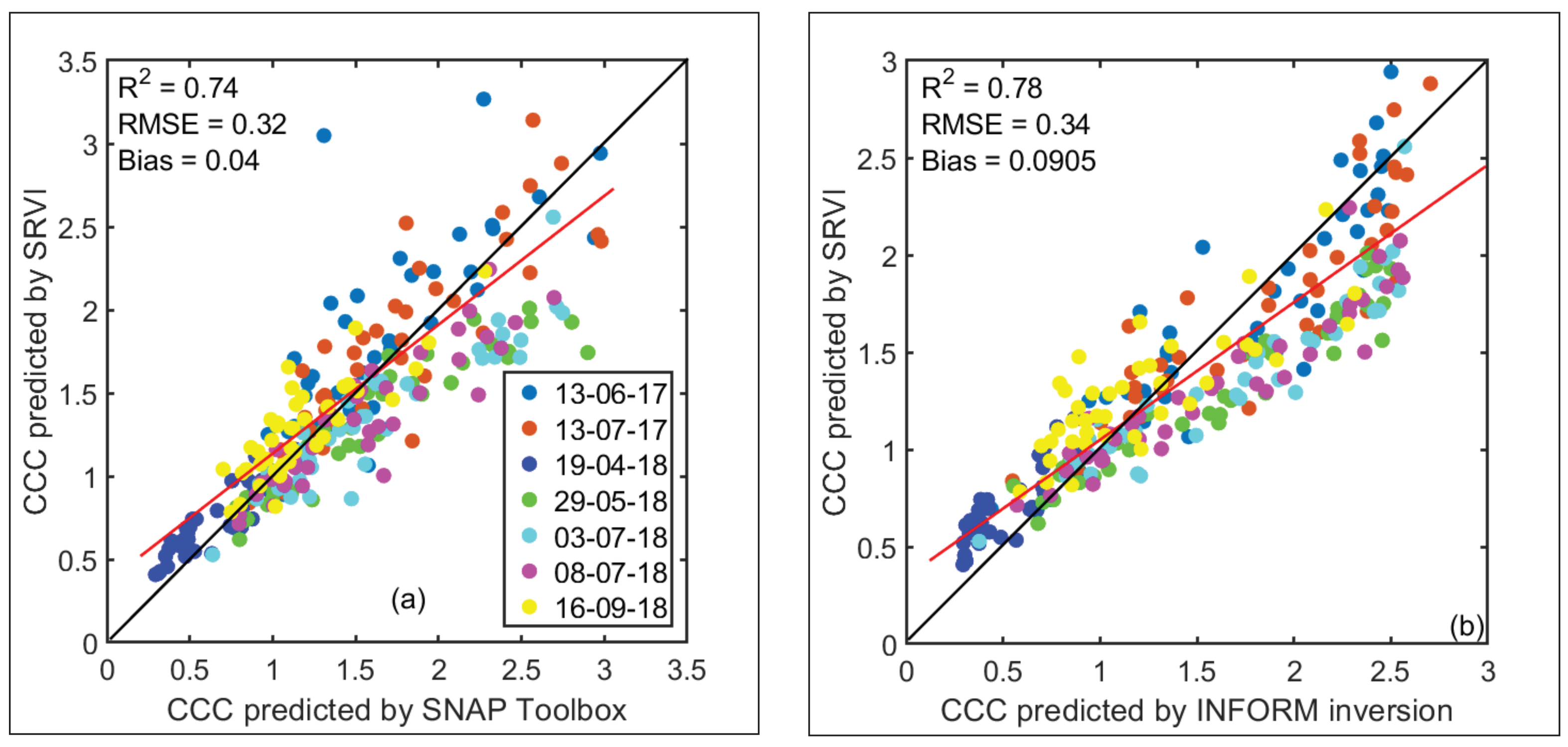


Figure 3: Comparison scatter plots of the SRVI against The SNAP toolbox approach (a), PROSAIL inversion by using LUT approach (b), and the SNAP toolbox approach against PROSAIL inversion (c) in predicting CCC in Camargue Mediterranean wetland ecosystem.

3.3. Temporal consistency

Plotting the predictions in BFNP against each other for several dates did not show a significant difference over time (Figure 4).



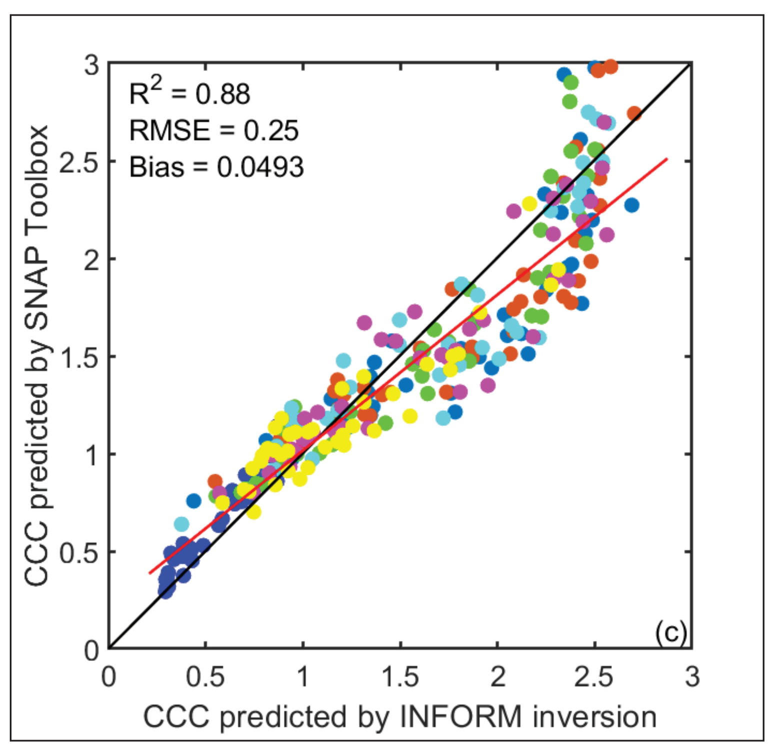


Figure 4: The goodness of fit between CCC values predicted by the SRVI, the SNAP toolbox approach (Baret, 2016) and INFORM inversion for seven dates of Sentinel 2 data available for BFNP.

4. Discussion and conclusions

The purpose of this work was to determine the best-practice approach that can be implemented to map canopy chlorophyll content globally from high spatial resolution remote sensing data. The predictions made using SRVI and the SNAP toolbox approach resulted in a systematic over/under-estimation of CCC when applied in different biomes. CCC predictions by INFORM and PROSAIL inversion by LUT exhibit ranges closer to expectations, which confirms RTM based approaches robustness and their applicability in different biomes. Temporal consistency verification also portrayed the robustness of the RTM based approaches.

Therefore, the RTM inversion using LUT approach particularly INFORM for 'forest' and PROSAIL for 'short vegetation' ecosystems are recommended for large scaling mapping of CCC from Sentinel-2 data.

For more information

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