The potential of Sentinel-2 spatial resolution for LAI derivation in Alpine grasslands

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Aim

Assessing the suitability of Sentinel-2 spatial resolution for Leaf Area Index (LAI) derivation in an heterogeneous environment dissected by settlements, forest patches and small grassland areas.

Idea

Deriving and validating LAI on different scales from original (6.5 m) and simulated (19.5, 32.5, 45.5, and 97.5 m) RapidEye data using an radiation transfer modeling (RTM) approach that has been recently applied to MODIS (232 m) for LAI estimation over Alpine grasslands [1].

Data & Methods

RapidEye:
- 4 scenes (May 9, May 25, July 16, September 6, 2011)
- 6.5 m spatial resolution, 5 bands in the VIS and NIR
- Preprocessing: geo- & orthorectification, atmospheric correction [2].

MODIS:
- 8-day composite for 2011 generated from daily reflectance time series
- 232 m spatial resolution, red and NIR bands [1]

in situ LAI:
- LICOR LAI-2000 PCA and destructive sampling: LAI = 1.5 - 7.4
- 2-stage nested design [3] → 14–33 plots (RapidEye scale) and 3-4 plots (MODIS scale) [4]

The LAI derivation is based on the inversion of the RTM **PROSAIL** [5]. The model is parameterized based on in situ and literature values [6-8]. Additionally to the bands, vegetation indices are used as input features. For the inversion, look up tables (LUT) are used (Fig. 1).

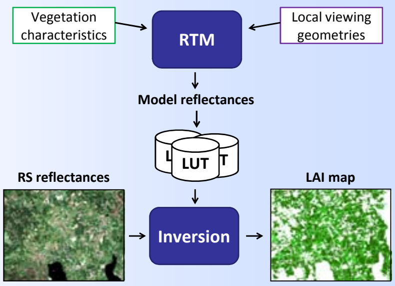

Fig. 1: PROSAIL workflow for LAI estimation

Results

RapidEye and MODIS time series

The grassland LAI based on RapidEye fit the *in situ* LAI with RMSEs ranging from 0.6 - 1.1. The spatial patterns of growth stages of individual meadows are clearly distinguishable (Fig. 3). Due to the heterogeneity of the landscape, the algorithm achieved considerable lower results for MODIS data (RMSEs ranging from 1.4 - 2.3), whereby they tend to overestimate *in situ* LAI (Fig. 2). With regard to the temporal coverage, the 8-day MODIS LAI time series maps the phenological patterns and harvests satisfactorily. However, it does not catch the sites full variability. Especially, local minima caused by mowing of some of the underlying meadows are not always detected, probably due to a non-linear contribution to the MODIS reflectance from densely vegetated plots.

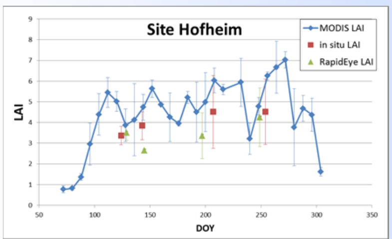

Fig. 2: Example plot of the temporal signature of the MODIS pixels associated with one test site for the year 2011. In green and red, the according RapidEye and *in situ* LAI values are displayed.

Results

Analysis of scale effects

Synthetic datasets with intermediate resolutions were simulated from the four RapidEye scenes and used for the PROSAIL inversion. With regard to the persistence of spatial patterns, the 19.5 m and 32.5 m resolution maps provide a sufficient level of detail for the specific landscape (Fig. 3). Although small fields are no longer recognizable on the 45.5 m scale, the pattern and range of LAI is captured. With 97.5 m resolution the general structure is also still discernible, but growth stages or management of single fields cannot be derived. The MODIS LAI shows only few similar patterns compared to the high resolution data.

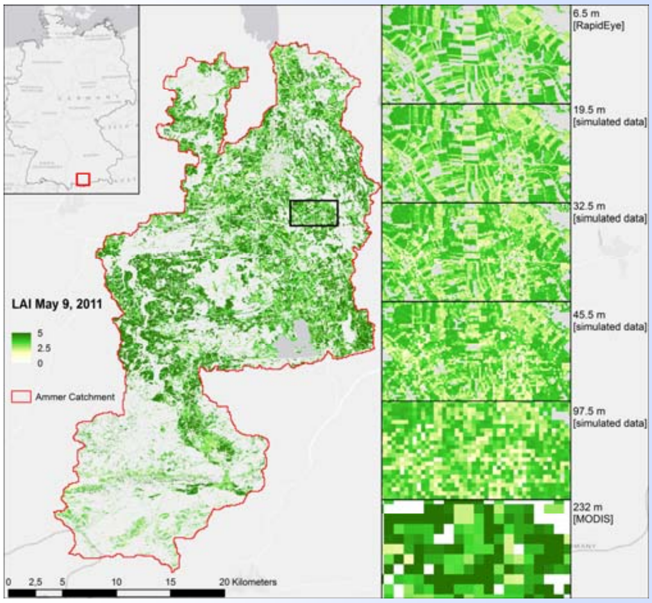

Fig. 3: Grassland LAI of the Ammer catchment in the Bavarian alpine upland on May 9, 2011 based on original and scaled RapidEye data. The black box marks the subset location, in which LAI on six different scales is displayed.

A reduction of spatial resolution up to 20 m does not contribute substantially to accuracy loss (0.89 to 0.99) and decreases the range of RMSEs. The further LAI maps show mostly increasing overall RMSEs of 0.92 (32.5 m resolution), 1.01 (45.5 m), 1.13 (97.5 m), and 1.93 (232 m) with coarser resolutions (Fig. 4).

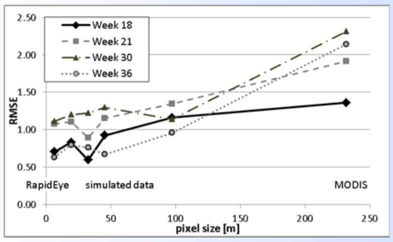

Fig. 4: RMSE values of the LAI maps based on the original (RapidEye and MODIS) and synthetic remote sensing data sets, evaluated against *in situ* measurements.

Conclusions

- A high suitability of future Sentinel-2 data for grassland LAI mapping in Alpine environments is indicated by the high accuracies achieved using 20 m resolution data. Additionally its spatial resolution is a good compromise between accurate results and computational efficiency.
- The red edge and SWIR of Sentinel-2 bands are promising as they might increase the RTM inversion stability.
- The revisit time of Sentinel-2 should enable mapping of sudden LAI reductions not provided by present high spatial resolution sensors.

References

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