Assessing phenological patterns of rubber tree plantations (Hevea brasiliensis) in Xishuangbanna (China) with Landsat satellite imagery

Till Montag, Philip Beckschäfer and Christoph Kleinn | Forest Inventory and Remote Sensing, University of Goettingen

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Background

The timing of phenological events, such as leaf onset and senescence, may have essential implications for hydrological and biogeochemical cycles as well as for organisms and ecological communities. For rubber trees in Xishuangbanna, Yunnan, China, it is assumed that the timing of the foliage onset is related to the trees' susceptibility to powdery mildew disease, a disease caused by the fungus *Oidium heveae* that predominantly infests young and tender leaves after sprouting. Therefore, information on the timing of the foliage onset is crucial for the scheduling of disease control. In the context of monitoring and assessing plant phenology, ground-level surveys are very time consuming and expensive so that remote sensing techniques may be employed for indirect observations.

This study was carried out to map phenological patterns of rubber plantations using Landsat Surface Reflectance-derived spectral indices products. Furthermore, a subsequent analysis of the relationships between the timing of phenological events and topographic variables was implemented.

Study Area

Prefecture of Xishuangbanna (Fig. 1)

- Area: 19.164 km^2
- Mean temperature: 18° – 22°C
- Mean annual precipitation: 1.317 mm
- Wet season: May – November
- Dry season: December – April

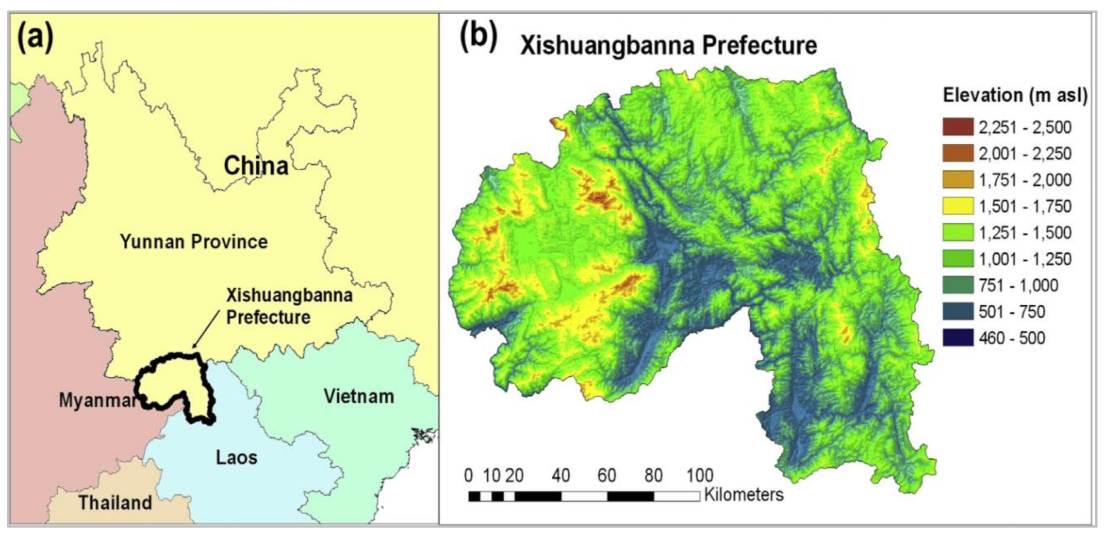

Fig. 1 Location of Xishuangbanna (a) and corresponding topography of the study area (b) (Zomer , et al., 2013).

Methods

- **Revision and selection** of Landsat imagery (1985-2017) via Earth Explorer
- **Download of Normalized Burn Ratio** Spectral Index (NBR) images for 1991, 1995, 2003, 2014, 2015, 2016 and 2017
- **Cubic spline interpolation** (Fig. 2) for the determination of the day of leaf onset (**DON**) using R
- Deriving topographic variables (Long., Lat., Elevation, Slope, Exposition, TPI) in QGIS
- Analysis of relationships between foliage onset and topographical factors within R using scatterplots and **linear regression models**

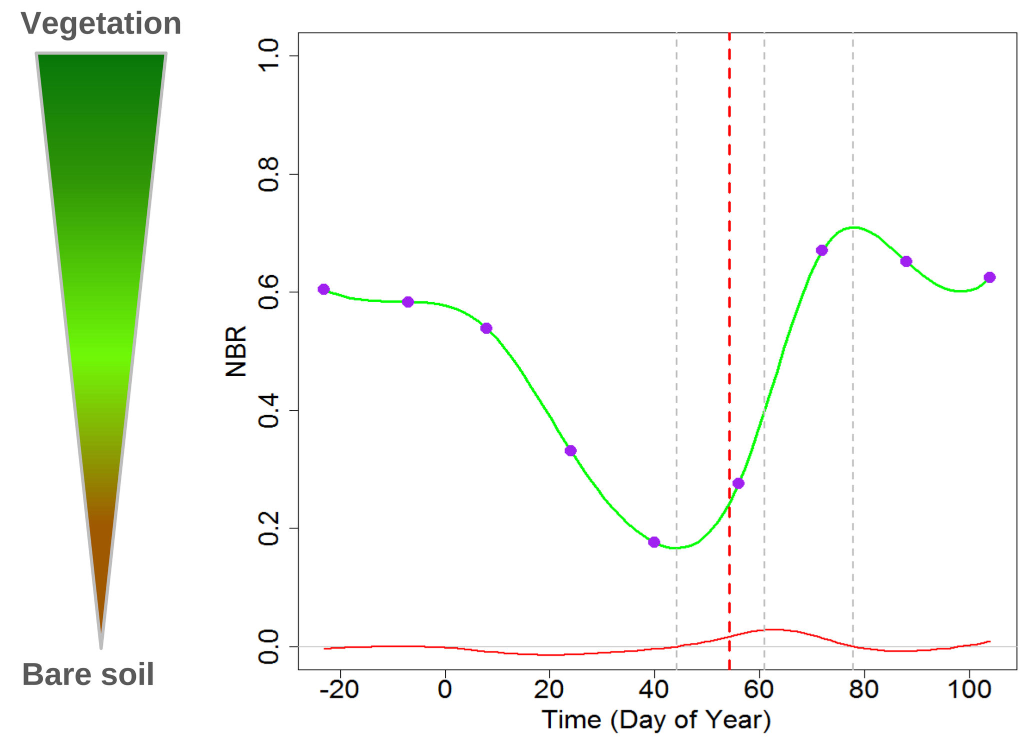

Fig. 2: Cubic spline interpolation for one pixel in 2014. NBR values from zero to one indicate the increase in vegetation density (y-axis). The blue dots represent NBR value of the corresponding Landsat scene. The blue dotted lines display extreme values (minimum and maximum) along the modelled time series and the red dotted line represents the day of foliage onset (defined as 5% increase between the minimum and maximum value).

Results

- Fig. 3 represent the average day of leaf onset (DON) for all processed years
- The average DON varies from day 31 in 1995 to day 60 in 2016
- The regrowth time (difference between minimum and maximum) varies from 26 days in 1991 to 44 days in 1995

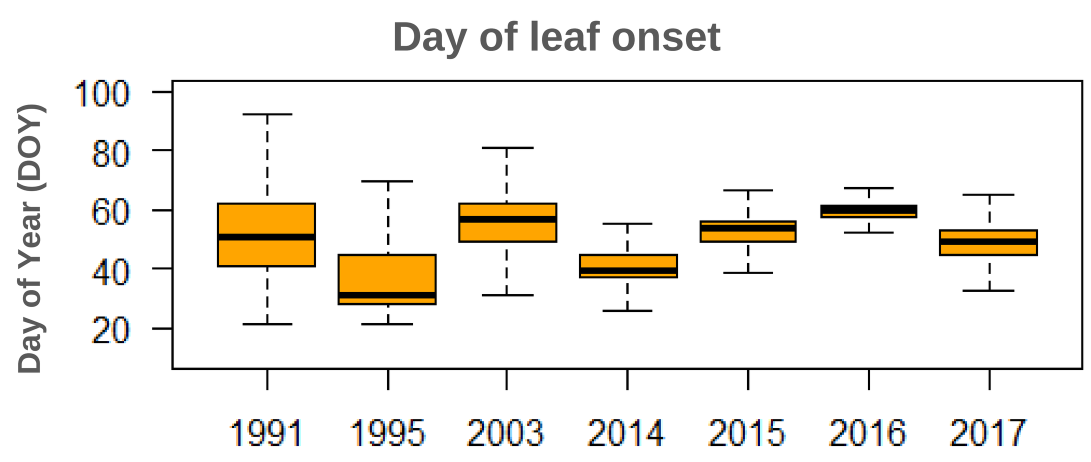

Fig. 3:Boxplots for the predicted days of leaf onset for all available years.

- Fig. 4 and 5 demonstrate the spatial distribution of the day of foliage onset in 2014 and 2015. The two maps are an indication that plantations in the north sprouted later compared to the southern parts of Xishuangbanna.

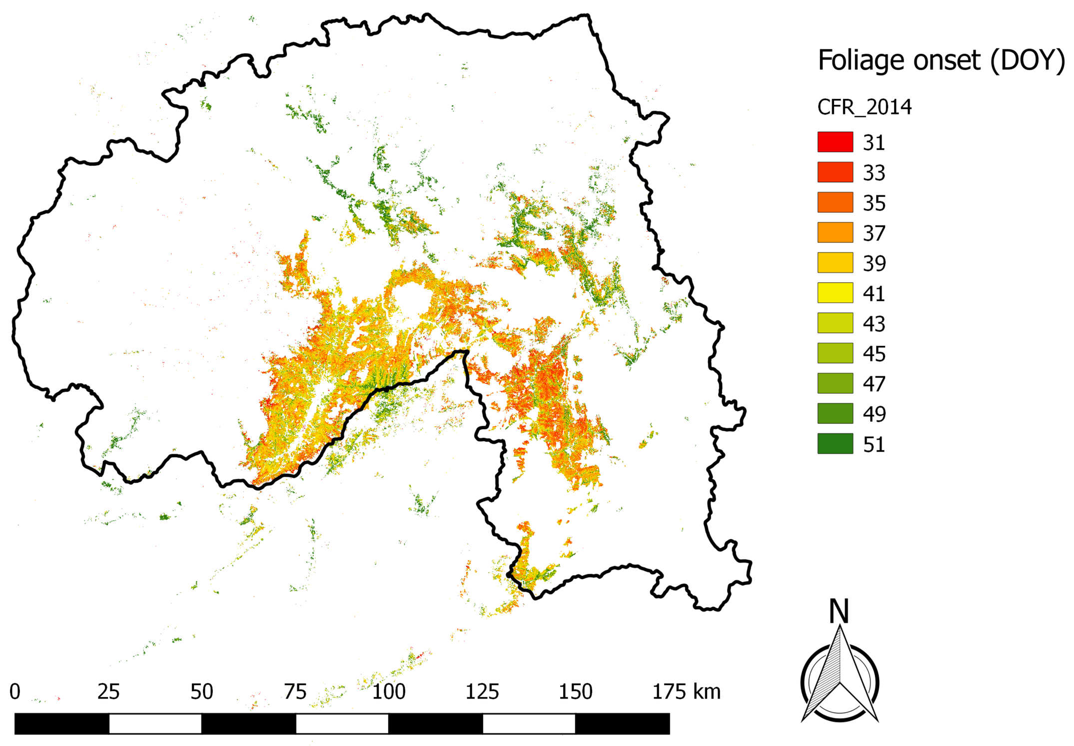

Fig. 4: Map of derived days of leaf onset in 2014 for cloud free rubber pixels (CFR)

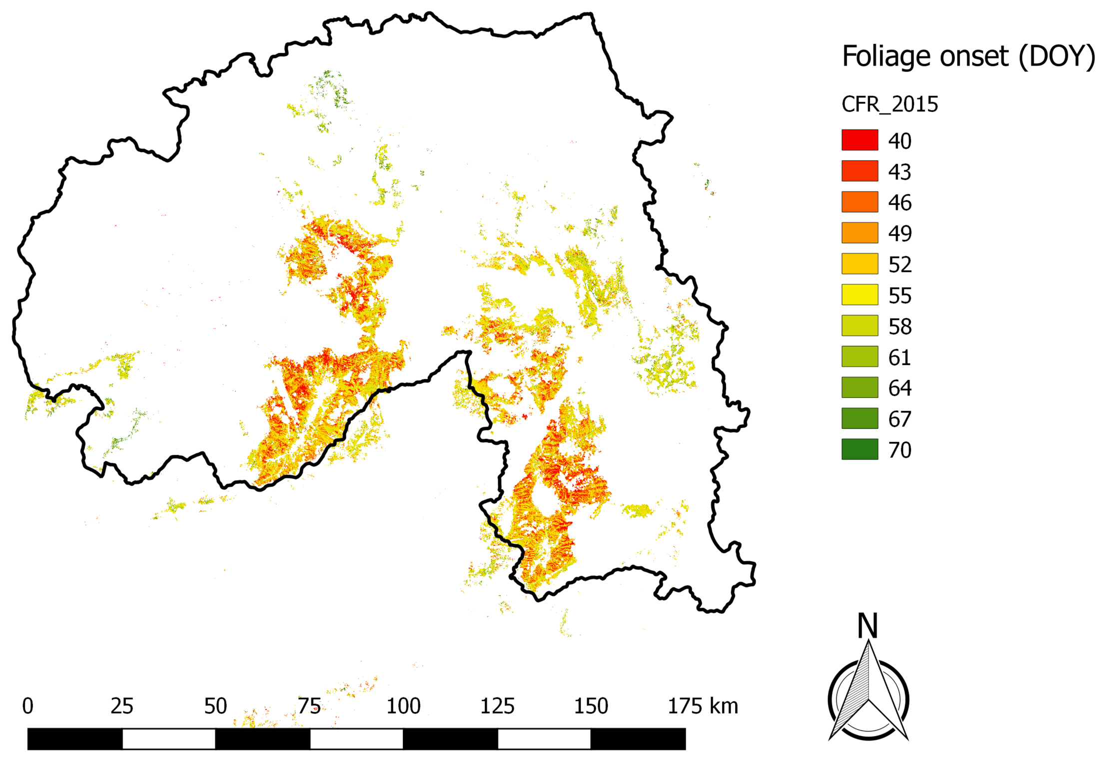

Fig. 5: Map of derived days of leaf onset in 2015 for cloud free rubber pixels (CFR)

Leaf onset vs. topographic factors

Elevation and the topographic position index exhibit the same trend for all years:

- The higher the elevation the earlier the leaf onset
- Earlier leaf onset on ridges (positive TPI- values) (Fig.6)
- The variable longitude indicates a later leaf onset in northern parts in 2014, 2015 and 2017 (compare Fig. 4 & 5)
- Latitude, slope and aspect exhibit no relationship with DON in all years

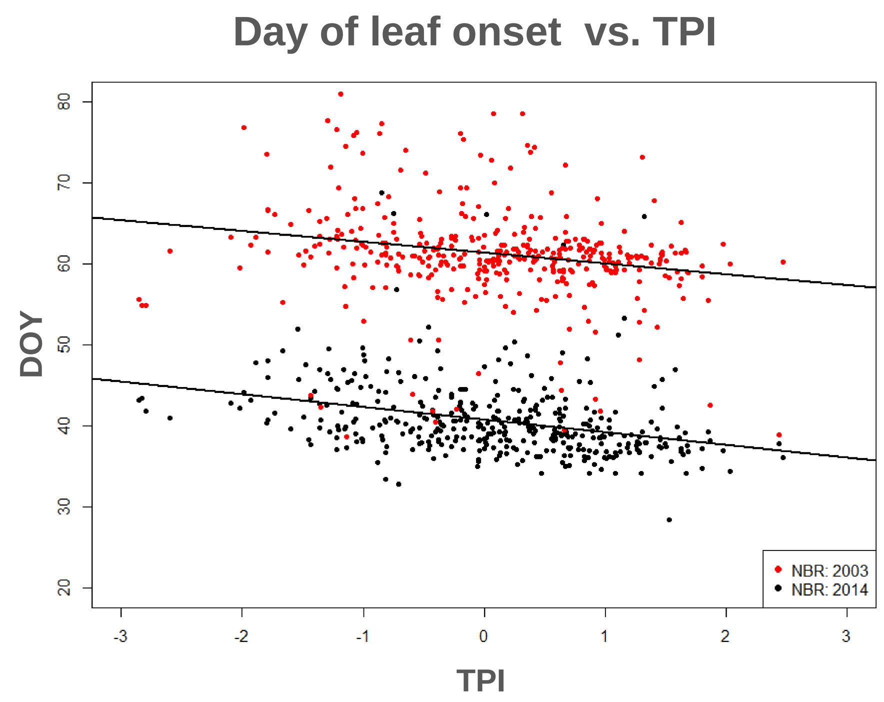

Fig 6. Scatterplot of TPI values (x-axis) in relation to the corresponding DON (y-axis) in 2003 and 2014 (negative TPI-values = valleys, positive values = ridges)

Discussion & Conclusions

The study shows the opportunity and limitation of Landsat satellite imagery in order to derive phenological events. In a heavily fragmented area a spatial resolution of 30 m seems to be satisfactory. However, the temporal resolution of Landsat (16 days) leads to the problem that the determination of the phenological events is problematic, especially when cloud contamination requires the omission of images. As future solution, a higher temporal and spatial resolution appears to be beneficial (e.g. satellite imagery of the Copernicus programme with 10 m pixel size and a revisit time of 10 days).

Furthermore, time consuming ground observations of phenological events should be made in order to verify the remote sensing based results. The results of this study show to what extent the topography influences the timing of the phenological event. However, ancillary variables about meteorological conditions (temperature, precipitation or wind speed) as well as information of soil properties are essential for the subsequent research.

References

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Contact

Till Montag
Chair of Forest Inventory and Remote Sensing
Faculty of Forest Sciences and Forest Ecology
University of Goettingen

till.montag@stud.uni-goettingen.de