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 Oldium 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 km²
- Mean temperature: 18° – 22°C
- Mean annual precipitation: 1,317 mm
- Wet season: May – November
- Dry season: December – April

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

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).

Methods
- Revision and selection of Landsat imagery (1985-2017) via Earth Explorer
- 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

References
- Zomer et al., (2015) Environmental stratification to model climate change impacts on biodiversity and rubber production in Xishuangbanna, Yunnan, China

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Fig. 1 Location of Xishuangbanna (a) and corresponding topography of the study area (b) (Zomer et al., 2015).

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).

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

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).

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).