A simple and robust automated approach to map rubber plantations from PALSAR, Landsat and MODIS

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ABSTRACT: Due to increasing global demand for natural rubber products, rubber (*Hevea brasiliensis*) plantation expansion has occurred in many regions where it was originally considered unsuitable. However, accurate maps of rubber plantations are not available, which substantially constrains our understanding of environmental and socioeconomic impacts of rubber plantation expansion. In this study we developed a simple algorithm for accurate mapping of rubber plantations in northern tropical regions, by combining a forest map derived from microwave data and unique phenological characteristics of rubber trees observed from multi-temporal MODIS and Landsat imagery. Temporal profiles of the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Land Surface Water Index (LSWI), and near-infrared (NIR) reflectance for rubber trees and natural forest were constructed. The results showed that rubber plantations were distinguishable from natural evergreen forests in two phenological phases: 1) the defoliation (leaf-off) phase in late February-March, when vegetation index (NDVI, EVI, LSWI) values were lower in rubber plantations than in natural evergreen forests; and 2) the foliation (new leaf emergence) phase in late March-April, when rubber plantations had similar NDVI and LSWI values but higher EVI and NIR reflectance values than natural forests. Phased Array type L-band Synthetic Aperture Radar (PALSAR) 50-m Orthorectified Mosaic images were used to generate a forest cover map and further integrated with the phenological information of rubber plantations extracted from multiple MODIS imagery or Landsat TM images during the foliation phase. The resultant map of rubber plantations has a high accuracy. This simple and integrated algorithm has potential to improve mapping of rubber plantations at the regional scale, e.g., Southeast Asia.

INTRODUCTION: Plantation development by the agroforestry industry, such as the expansion of natural rubber plantations, has been a critical driver of land cover change in Southeast Asia. However, an accurate map of rubber plantation extent with high accuracy and resolution is still unavailable, yet. The difficulty of mapping rubber plantations is two-fold: one is frequent cloud cover on optical image acquisition and the other is the similarity of spectral characteristics between rubber trees and other forest types. Our objective was to develop a simple, phenology-based approach for mapping rubber plantations at a finer spatial resolution at regional scale that enables a rapid and repeated execution. We used Hainan Island, China as case study area. To achieve this objective we integrated cloud-free PALSAR-based forest map with optical imagery based phenology characteristics. The validation was conducted by using geo-referenced field photos, which were stored and managed in the Global Geo-Referenced Field Photo Library (http://www.eomf.ou.edu/photos).

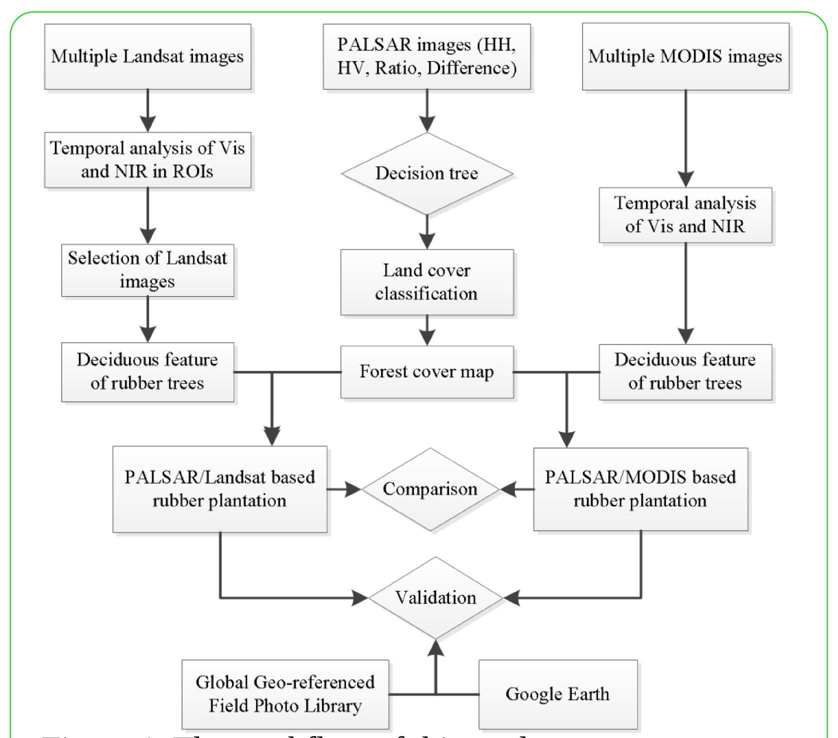

Figure 1. The workflow of this study.

RESULT AND ANALYSIS

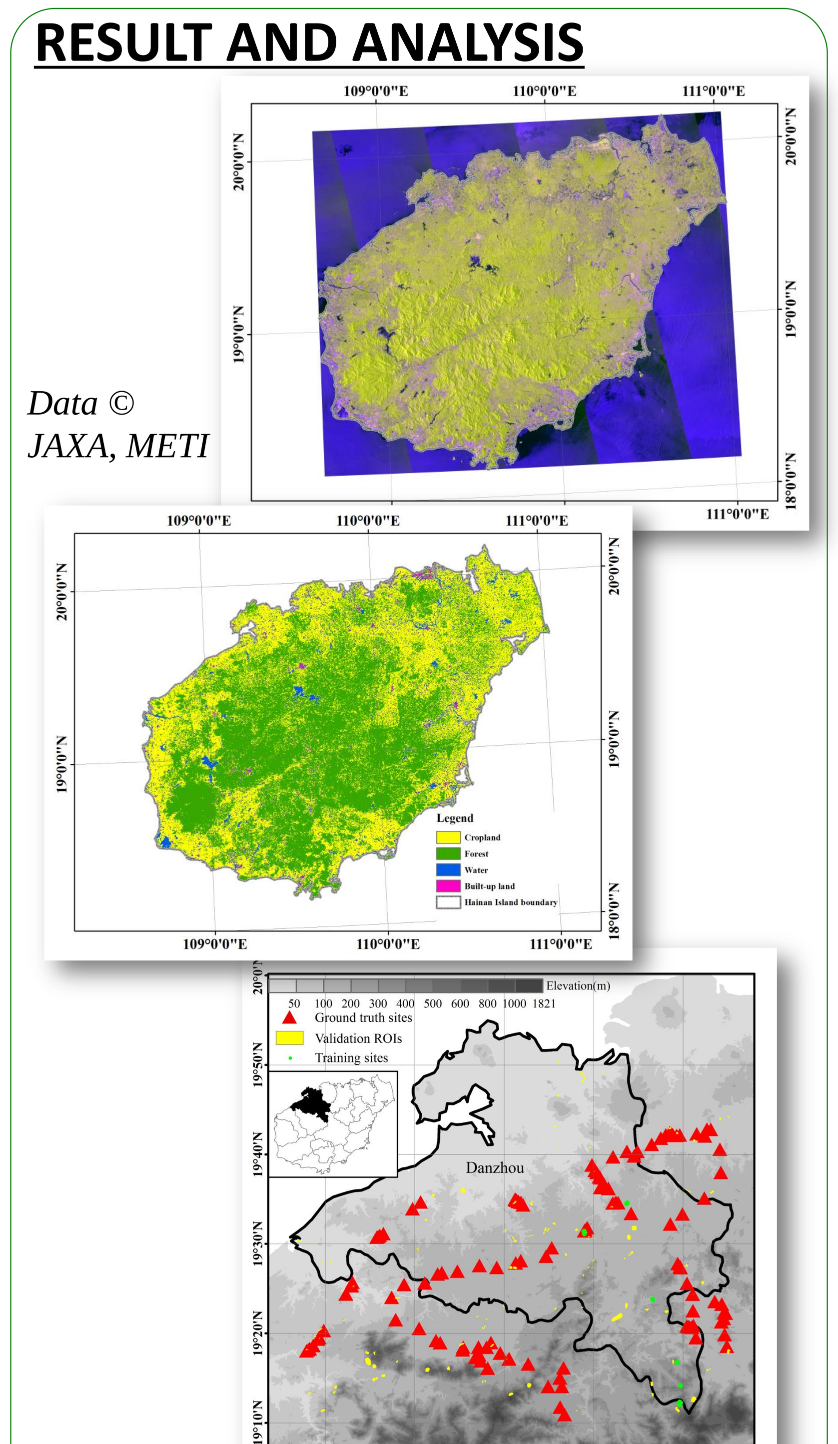

Figure 2. a) PALSAR-based color composite map (R/G/B=Polarizations HH/HV/HH-HV) in Hainan Island, China; b) PALSAR-based land cover map; and c) the distribution of geo-referenced field photos.

Phenology characteristics of rubber trees

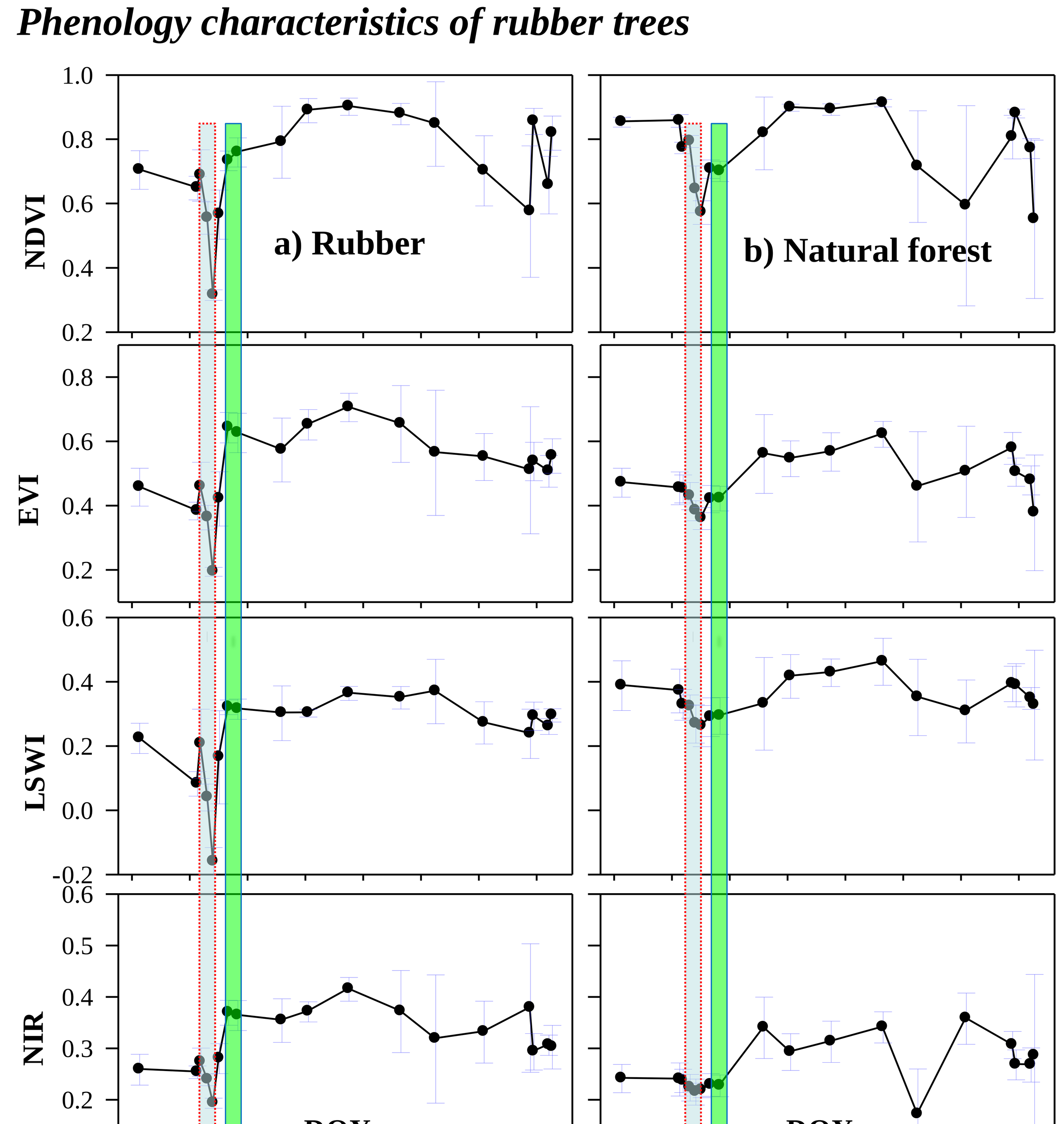

Figure 3. The temporal profiles of time series Landsat NDVI, EVI, LSWI and Near-Infrared (NIR) reflectance for (left) rubber plantations, and (right) natural evergreen forests. Twelve points of interest (POIs) were extracted for rubber plantations and 13 POIs for natural evergreen forests. The points and error bars show their average and standard deviation (SD) values. Rubber plantations and natural evergreen forests differ from each other in two phenological phases: defoliation (brown color bar) and foliation (green color bar) phases.

Phenology characteristics of rubber trees

Figure 4. Four field photos in different periods show seasonal changes of rubber trees' canopy. The photos were not taken in the same regions but they were all close to the selected points. It is clear that leaves of rubber trees fall off in March, and the canopy recovers rapidly in April.

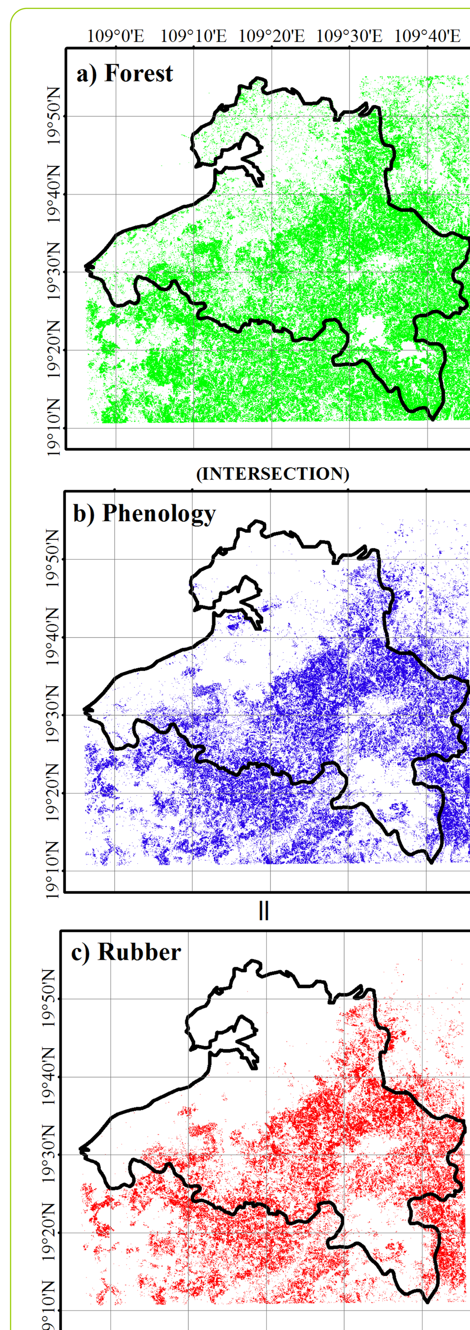

Figure 5. (a) The forest layer with a 30-m resolution, which was derived from the 50-m PALSAR-based land cover map (Fig. 2) and then resampled into Landsat scale; (b) The spatial distribution of the unique phenology feature (near-infrared reflectance > 0.29) of rubber plantations in foliation stage by using a selected image in certain phenology phase (March 24, 2010). (c) The resultant rubber plantation map at 30-m resolution by combining the forest layer (a) and the rubber phenological feature (b).

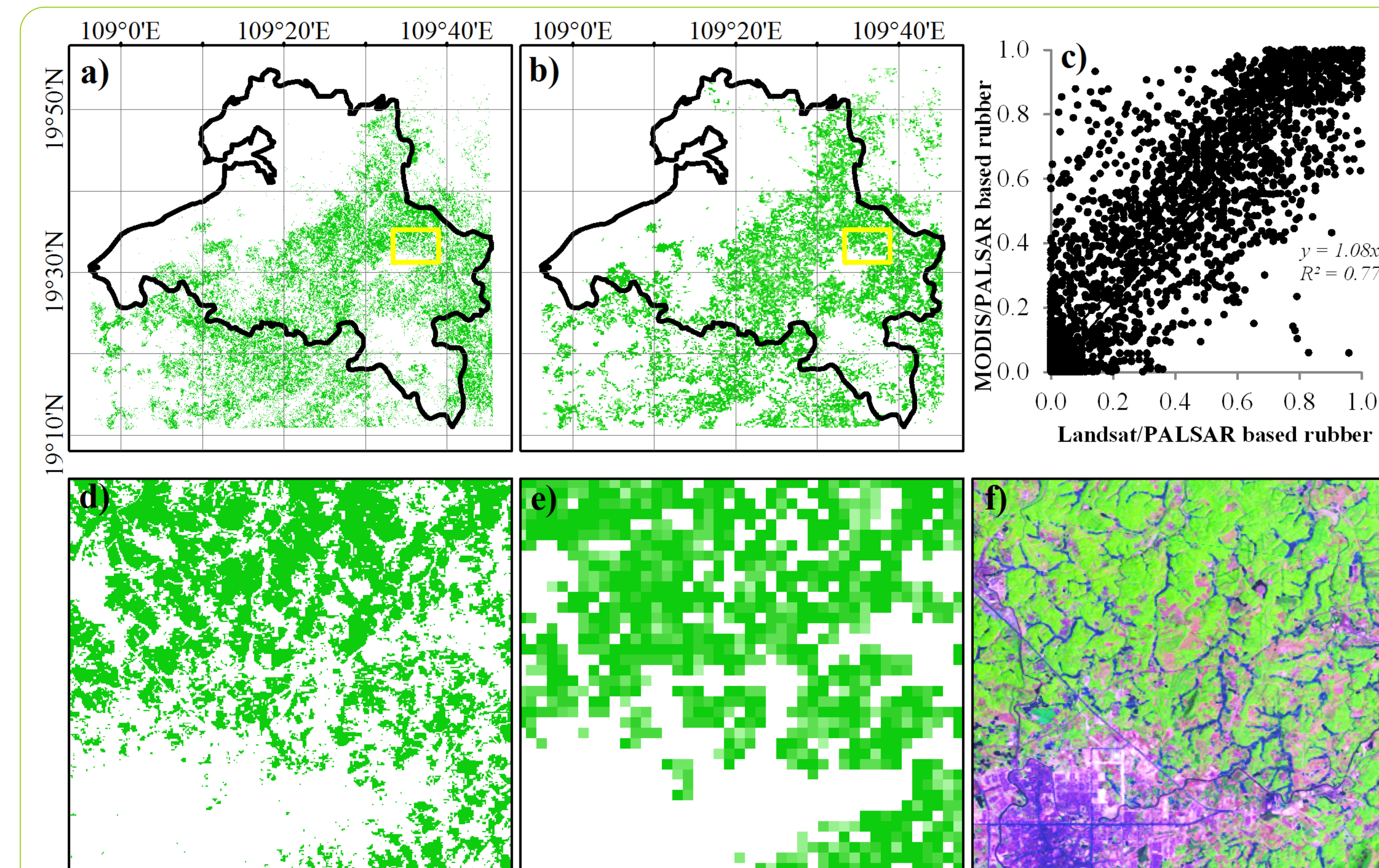

Figure 6. Comparison between (*a*) the rubber plantation map by using the PALSAR/Landsat-based approach and (*b*) the rubber plantation map by using the PALSAR/MODIS-based approach. (*c*) The scatterplot of two rubber plantation fractional maps from a random sample of pixels. The PALSAR/Landsat-based area percentage map is acquired by aggregating the binary rubber map (*a*) to an area percentage map at MODIS-scale. The rubber area estimates from both maps are significantly correlated. (*d*) The zoom-in image extracted from (*a*), and (*e*) the zoom-in image extracted from (*b*), showed PALSAR/Landsat-based rubber plantation map has a higher accuracy and resolution than that from MODIS/PALSAR, by referring to (*f*) the false color composite map of Landsat TM image.

SUMMARY

In this study, we explored the capability of a simple and phenology-based procedure in rubber plantation mapping in Hainan, China, a hotspot of rubber plantation expansion, by integrating a forest map from PALSAR data and rubber tree phenology features from Landsat imagery. We found that the unique phenological characteristics of rubber plantations can be retrieved in two critical phenological phases: the defoliation and foliation stages. Multiple temporal MODIS or Landsat imagery can support the phenology retrieval; in particular, the Landsat imagery in these key phenological phases can effectively support rubber plantation mapping at 30-m spatial resolution at a regional scale, which facilitates rubber plantation delineation and mapping in sub-tropical and northern parts of tropical regions. Other factors, such as the spatial heterogeneity of regional phenology, should also be considered and incorporated when the approach used in this study is applied to other regions.

Related Publications

Dong, J., Xiao, X., Sheldon, S., Biradar, C., & Xie, G. (2012). Mapping tropical forests and rubber plantations in complex landscapes by integrating PALSAR and MODIS imagery. *ISPRS Journal of Photogrammetry and Remote Sensing*, 74, 20-33

Dong, J., Xiao, X., Chen, B., Torbick, N., Jin, C., Zhang, G., Biradar, C. (2013). Mapping deciduous rubber plantations through integration of PALSAR and multi-temporal Landsat imagery. *Remote Sensing of Environment*, In press.

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