The potential of dense Landsat time series for deforestation monitoring in human-modified rainforests of Indonesia

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Forests are central to the breakthrough 2015 Paris climate agreement; a standalone article encourages countries to increase activity in the Reducing Emissions from Deforestation and Forest Degradation (REDD+) program. The tropical region of insular South East Asia, notably the country of Indonesia, is a well-known global hotspot of deforestation. In this study, we demonstrated for the first time the potential of using the 30-m Landsat Time Series (LTS) data and data-driven dense time series (DTS) algorithms for deforestation monitoring in tropical rainforests of Kalimantan, Indonesia, at sub-annual time scales. We investigated three algorithms for deforestation detection, namely 1) Algorithm 1: the standard BFAST (Breaks for Additive Season and Trend) Monitor, 2) Algorithm 2: BFAST Monitor modified with consecutive anomalies criterion (CAC), and 3) Algorithm 3: an algorithm based on CAC and an alternative decision boundary (detection threshold). An accuracy assessment in spatial (user's accuracy (UA), producer's accuracy (PA), and overall accuracy (OA)) and temporal (median temporal lag (MTL)) domain was carried out using 435 high-confidence reference sample pixels interpreted from multi-temporal very high spatial resolution (VHSR) image series.

Our results show, in terms of data availability, combining data from all Landsat sensors provided on average 4-8 (during 1999-2012 period) and 4-12 (during 2013-2016 period) cloud-free observations per year for most area in the Kalimantan mega-island. This indicates the feasibility for sub-annual deforestation mapping and monitoring in the region. In terms of the algorithm for detecting deforestation event, Algorithm 1 was found to be highly prone to commission errors (67.4%) due to noise in LTS caused by remnant clouds, providing UA: 32.6%, PA: 100.0%, and OA: 43.0%. Application of CAC in Algorithm 2 improved the spatial accuracy as compared to Algorithm 1, providing UA: 41.3%, PA: 99.3%, and OA: 53.3%. Algorithm 3 on the other hand dramatically improved spatial accuracy, providing UA: 94.5%, PA: 93.2%, and OA: 93.8% when three consecutive anomalies were required to confirm a deforestation event. When we decreased the required number of consecutive anomalies from three to two, the spatial accuracy decreased (UA: 87.0%, PA: 89.9%, OA: 88.7%), but the temporal accuracy improved from MTL: 112 days (2 observations) to MTL: 40 days (1 observation). We conclude that the presented methodology based on LTS data and DTS Algorithm 3 is promising to support Indonesia in satisfying two REDD+ requirements, namely 1) mapping historical deforestation events to aid in establishment of reference emission levels, and 2) realizing an operational national forest monitoring system, with a priority on confident alert to deforestation events.