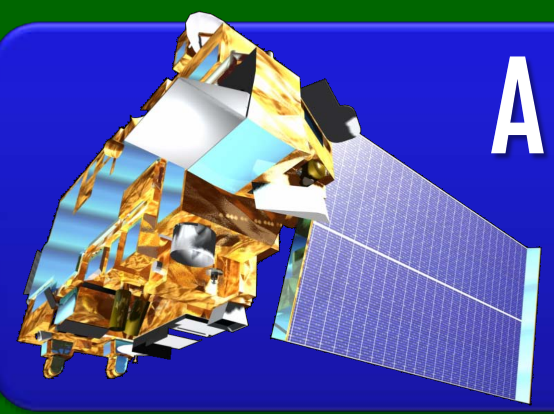

A simple and novel algorithm for large-scale mapping of evergreen forests in tropical America, Africa and Asia

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INTRODUCTION

The areal extent and spatial distribution of evergreen forests in the tropical zone are important for the study of climate, carbon cycle and biodiversity. However, frequent cloud cover in the moist tropical region makes it a challenging task to map evergreen forests. In this study we developed a simple and novel mapping algorithm that is based on the temporal profile analysis of Land Surface Water Index (LSWI), which is calculated as a normalized ratio between near infrared and shortwave infrared spectral bands. The 8-day composites of MODIS Land Surface Reflectance data (MOD09A1) in 2001 at 500-m spatial resolution were used to calculate LSWI. The LSWI-based mapping algorithm was applied to map evergreen forests in tropical America, Africa and Asia (30ºN – 30ºS).

MATERIALS & METHODS

MODIS land surface reflectance data and vegetation indices

The MOD09A1 (2001, version 5) data were acquired from the USGS EROS Data Center (EDC; http://edc.usgs.gov) and organized in a tile system with the Sinusoidal projection; datasets cover the tropical zone (ranging from 30ºN to 30ºS). For each MOD09A1 file, the quality of individual observations (e.g., clouds, cloud shadow) was identified, and three vegetation indices are calculated:

Normalized Difference Vegetation Index (NDVI) (Tucker 1979), Enhanced Vegetation Index (EVI) (Huete et al., 1997), and Land Surface Water Index (LSWI) (Xiao et al., 2002a), using Blue, Red, NIR1 (841–875 nm) and SWIR2 (1628–1652 nm) spectral bands.

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$

$$EVI = 2.5 \times \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + 6 \times \rho_{red} - 7.5 \times \rho_{blue} + 1}$$

$$LSWI = \frac{\rho_{nir} - \rho_{swir}}{\rho_{nir} + \rho_{swir}}$$

The vegetation indices data products are available to the public (http://www.eomf.ou.edu).

Temporal profile analysis for identifying and mapping evergreen forests --- leaf phenology-based approach

A green leaf has higher NIR reflectance than SWIR reflectance, resulting in a LSWI value of above 0.0 (positive value). A senescent leaf and soils have lower NIR reflectance than SWIR reflectance, resulting in a LSWI value of below 0.0 (negative value). LSWI values of evergreen plants remain >0.0 for all good-quality observations throughout a year, while all the other land cover types have a number of observations with LSWI <0.0 values in a year (Figure 1). Based on this unique feature of LSWI time series data for evergreen plants, we developed a mapping algorithm to identify evergreen forest. The first step is to count number of good-quality observations that have LSWI values to be >0.0 in a year for a pixel. The second step is to assign a pixel that all of the good-quality observations have LSWI value of > 0.0 to be evergreen vegetation pixel.

RESULTS & DISCUSSION

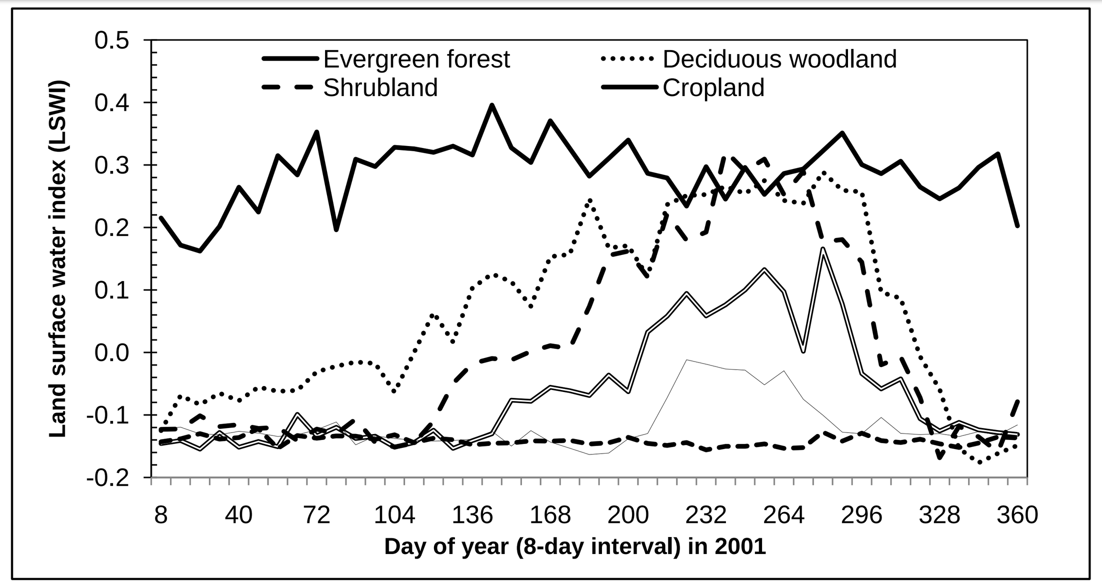

Fig. 1. The seasonal dynamics of Land Surface Water Index (LSWI) in 2001from six sites that represent major land-cover types in the tropical Africa. The evergreen forest site (20.9086ºE, 2.3042ºS) was located at the Salonga national park of Democratic Republic of Congo (IUCN/WWF (1985)); the deciduous woodland site (3.8437ºW, 9.4417ºN) at the Comoé National Park of Côte d'Ivoire; the savanna shrubland site (2.4341ºE, 11.7463ºN) at the Benin National Park of Republic of Benin (http://sea.unep-wcmc.org); the cropland site (8.3158ºE, 12.2098ºN) in Nigeria (selected from an IKONOS image of November 7, 2000); the savanna grassland site (30.4783ºE, 12.2829ºN) at the CO2 flux tower site in Demokeya, Sudan (http://www.fluxnet.ornl.gov/fluxnet); and the desert site (28.2478ºE, 18.2083ºN) in Sudan.

The resultant evergreen forest map in 2001 (MOD100) was compared with ancillary data (FAO FRA), including other forest maps derived from more complex algorithms such as MOD12Q1 and GLC2000. (Friedl et al., 2002; Mayaux et al., 2006).

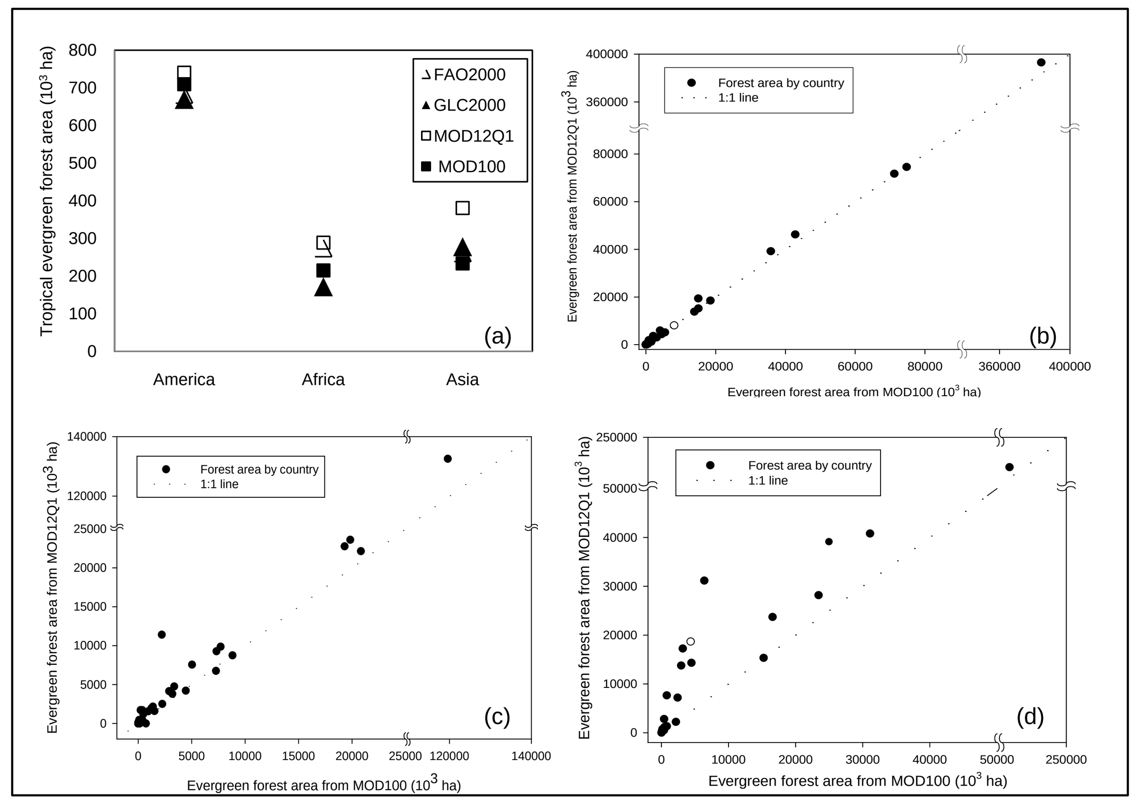

Fig. 2. A comparison of evergreen forest areas in the tropical America, Africa and Asia (30ºN – 30ºS); (a) among the four global forest datasets (MOD100, MOD12Q1, GLC2000 and FAO FRA2000); A country-level comparison for the area estimates of evergreen forests between the LSWI-based algorithm in this study (MOD100) and the standard MODIS Land Cover Product (MOD12Q1) in 2001 for (b)America; (c) Africa and (d) Asia.

The LSWI-based algorithm (the MOD100 dataset) estimates a total area of 709.7 ×10^6 ha evergreen forest in tropical Central and South America ~40.4% of the total land area 215.2 ×10^6 ha , (~9%) in Africa, and 233.7 ×10^6 ha (~ 14.5%) in Asia.

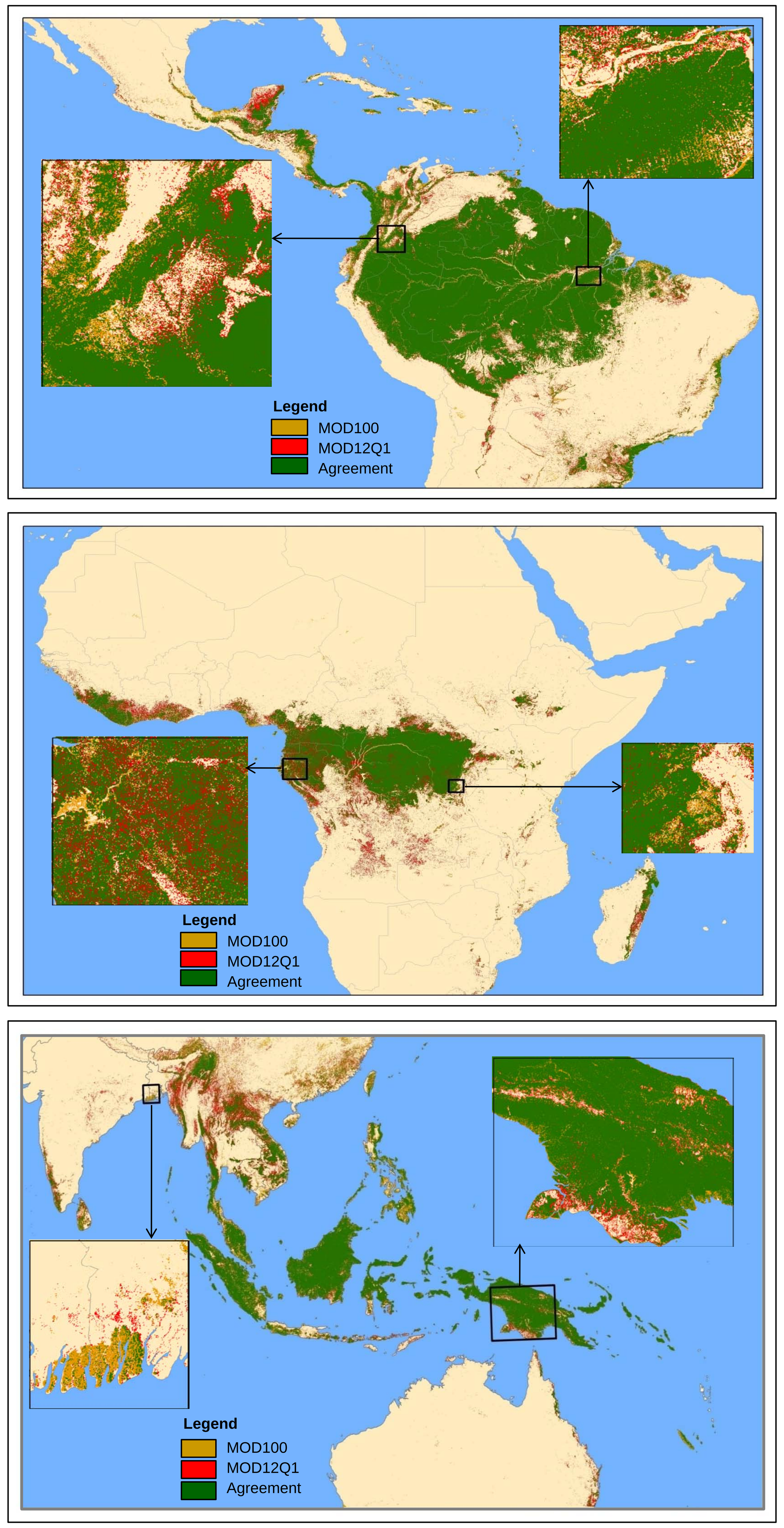

Fig. 3. Spatial distribution of evergreen forests in tropical America, Africa and Asia (30ºN – 30ºS) in 2001 as estimated by the LSWI-based algorithm in this study (MOD100) in comparison to the MOD12Q1 dataset. In the figure legend, "Agreement" – evergreen forest pixels from both MOD100 and MOD12Q1; "MOD100" – evergreen forest pixel from MOD100 only; "MOD12Q1" – evergreen forest pixels from MOD12Q1 only.

Table 1. A summary of spatial comparison between MOD100 and MOD12Q1 datasets at the scale of continent and the entire tropical zone (30ºN - 30ºS)

	America	%	Africa	%	Asia	%	World	%
MOD100	2446968	7	903025	6	2839807	14	6189800	9
MOD12Q1	3515233	10	4001688	28	3789844	18	11306765	16
Agreement	30617252	84	9295988	65	13961799	68	53875039	75
Total	36579453	100	14200701	100	20591450	100	71371604	100

CONCLUSIONS

In this paper, we reported a simple and novel algorithm for mapping evergreen forests in the tropical zone, and the advantage of the LSWI-based temporal profile analysis is that it does not require a large number of training datasets (including Landsat TM/ETM+ images), as it is based on leaf phenology. The LSWI-based algorithm was applied to quantify the area and spatial distribution of evergreen forests in 2001 in tropical America, Africa, and Asia, using the MODIS data at 500-m spatial resolution and 8-day temporal resolution in 2001. The areal extent and spatial distribution of evergreen forests in tropical Africa, America, and Asia from this LSWI-based mapping algorithm are similar to those of the standard MODIS Land Cover Product (MOD12Q1) that was generated from complex mapping algorithms (Friedl et al., 2002), although there are large discrepancies in Asia and Africa. The results from the inter-comparison of the four global forest datasets in the tropical zone suggested the potential of this LSWI-based mapping algorithm for identifying and mapping evergreen forests in the tropical zone. The implication of this study is that this LSWI-based mapping algorithm might be useful for operational monitoring of evergreen forests in the tropical world at moderate spatial resolution.

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