

# Forest Cover Dynamics in South East Asia Evidenced from MODIS Data

Sandeep N Kundu\*

Department of Geography, National University of Singapore, Singapore-117570

## Review Article

Received: 12/11/2016

Accepted: 15/01/2017

Published: 20/01/2017

### \*For Correspondence

Sandeep NK, Department of Geography, National University of Singapore, Singapore-117570.

**E-mail:** geosnk@nus.edu.sg

**Keywords:** Remote sensing, Change mapping, Land cover, Deforestation, GIS

### ABSTRACT

Land cover data sets are essentially spatial representation of our earth's surface, categorised into units like forests, grasslands etc. The availability of satellite platform based land cover classification products have largely advantaged mapping of changes in land cover revealing patterns and trends. Such studies are gaining importance in environmental risk assessment studies. Forest area is depleting fast giving way to expansion of agriculture and commercial plantations in South East Asia. In this study we attempt to map the dynamics of land cover between 2001 and 2012 in South East Asia using the Global Land Cover data product of Moderate Resolution Imaging Spectroradiometer (MODIS) platform using statistical and spatial methods. We found evidences of large scale forest conversion but the overall sum of changes was insignificant for the region in general. The suitability of MODIS against other platforms like Landsat for land cover change assessment and the opportunities for multivariate analysis is also discussed.

## INTRODUCTION

Land cover dynamics are driven by synergetic combinations of climate change and anthropogenic pressures on land resources reflected through urbanization, agricultural land use and climatic factors like natural hazards and extreme events<sup>[1]</sup>. Such influences in the tropics of South East Asia are driving high rates of forest conversion into agricultural farming and commercial plantations for palm, rubber and cocoa resulting in removal of vegetation cover at various temporal and spatial scales. It is therefore critical to map land cover and characterize the trends on a temporal basis to improve our understanding on the interactions and influence policies for a better sustainable land use and environment. Until the last few decades, regional and global land cover mapping involved the time taking process of collecting and integration information at local scale into a regional database. This was a time taking process and also produced error-prone results. With the advent of Earth Observing satellites, the task of faithfully characterizing the state of land cover at large scales has become possible. Digital image processing techniques based automatic land cover classification methods reduce the time in which a land cover product can be achieved<sup>[2]</sup>. The rich temporal range of various satellite platforms support time series analysis of change<sup>[3]</sup>, both statistically and spatially, in a Geographical Information System (GIS). Land cover changes include the conversion from one land-cover class to another which essentially goes through the process of land clearing and deforestation<sup>[4]</sup> which is detrimental to our environment both ecologically and environmentally. In this study, we use the annual time series of global land cover data derived from MODIS to study the scale and pattern of land cover change in South East Asia.

## THE STUDY AREA

South East Asia is a sub region of Asia, consisting of the countries that are geographically south of China, east of India, west of New Guinea and north of Australia (**Figure 1**). This is home to the tropical rain forests which receive a fairly distributed rainfall between 60-160 inches each year. The region is abundant with many species of wildlife and vegetation, being home to over 50% of all life forms on earth.



**Figure 1.** The region of South East Asia.

South East Asia is home to 11 countries and their collective economy is growing at 8% as per the World Bank report of 2012, a rate higher than any other part of the world. Such growth rates are a result of activities like urbanization, mining, commercial farming, all of which transform land cover in a major way. An average of around 1.5% increase in urbanization was also reported by the in the same period [5]. It has been reported that Indonesia and Malaysia, the two large countries in South East Asia has witnessed 50-100% increase in commercial palm plantation area in the study area (Malaysian Palm Board & Indonesian, Palm Oil Commission) which has taken the region through stages of acute deforestation. It is evident that the transformations in the region for the period have brought forth land cover transformations which cannot escape the roving eye of satellite platforms.

## DATA AND METHODS

### MODIS Platform

Remote sensing data acquired by space-borne platforms are of paramount importance for systems aiming to provide large-scale mapping and monitoring of forest extents [6]. Remote sensing of the tropical region is often difficult using optical sensors owing to the endemic cloud cover, which is why hyper spectral platforms are preferred for land cover studies. However, the MODIS sensor offers a view of our Earth's surface every 1-2 days. It collects data within 36 spectral bands, ranging in wavelengths from 0.4  $\mu\text{m}$  to 14.4  $\mu\text{m}$  and provides us with imagery at a nominal resolution of 250 m at nadir for two bands, 500 m resolution for 5 bands, and the remaining 29 bands at 1 km. MODIS is ideal for monitoring large-scale changes in on land and water that are yielding new insights into land cover land and land use changes. The wide swath supports homogeneous interpretation at a regional scale whereas the daily repeat imaging cycle provides a rich archive of images which can be blended for elimination effects of clouds and seasonal variability in land cover classification.

### MODIS Land Cover

Global mosaic of the standard MODIS land cover type data product is available for download from the University of Maryland, Global Land Cover Facility (NASA). The global mosaics of the standard MODIS land cover type data product (MCD12Q1) in the IGBP land cover type classification [7] available in two spatial resolutions that are spatially aggregated for years between 2001 and 2012 [8]. The 5' resolution product was used for the current study. The algorithms and results from global land cover mapping from MODIS has been elaborated by Friedl et al. [9].

### Data Preparation

A spatial subset of the global data was derived by clipping off the information outside of the study area. Bi-annual colour coded land cover maps from 2001 to 2011 are shown in **Figure 2**. The count of pixels for each land cover type for each particular year was listed in a spread sheet and the respective area in  $\text{km}^2$  calculated by multiplying the area of each pixel. Out of the 10 land cover classes for the region, 9 were used as the water class was excluded.

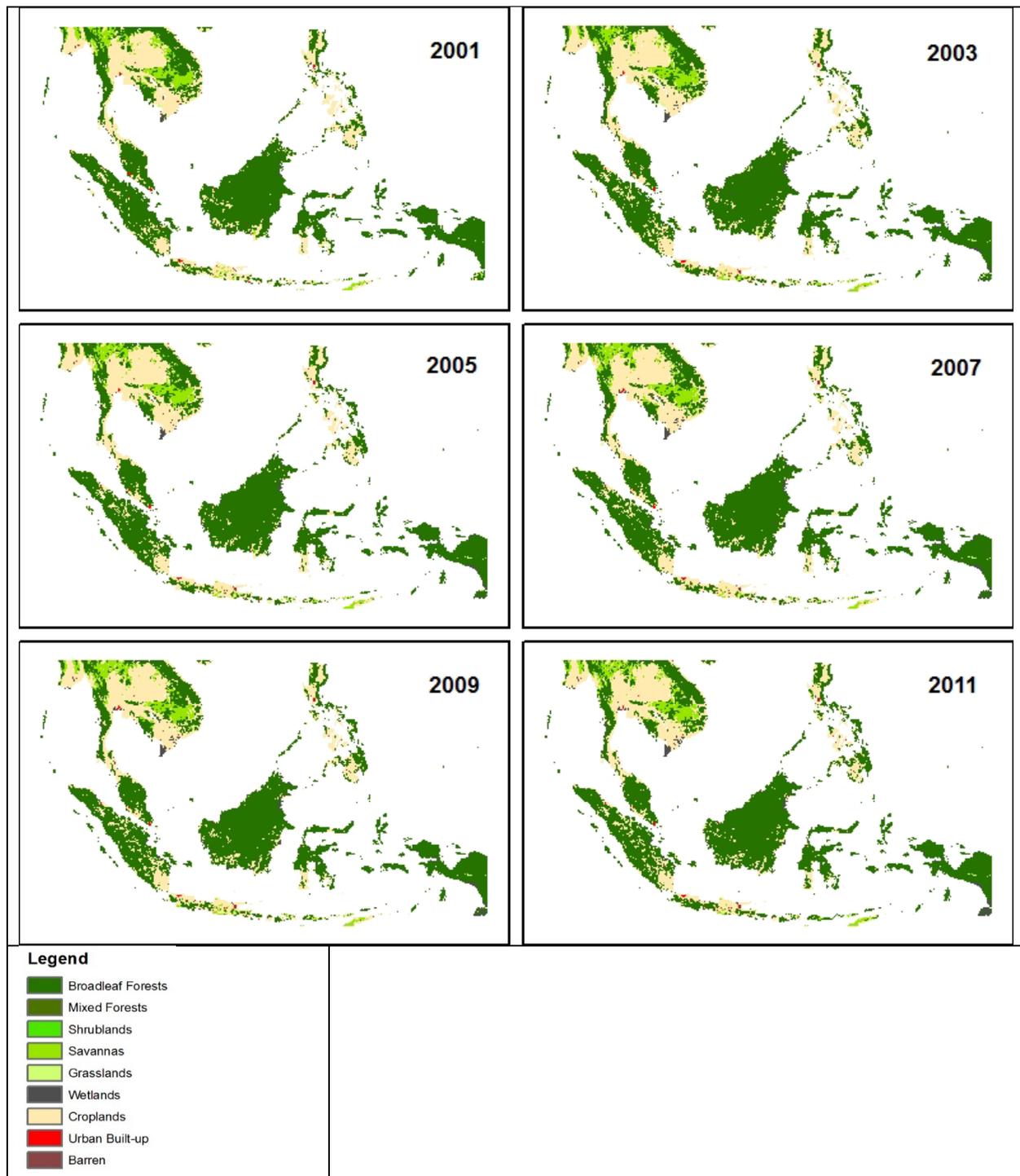


Figure 2. Bi-annual land cover maps from 2001 – 2011 over South East Asia (NASA).

**Information Extraction**

Statistical information from each image were extracted into a spread sheet with an aim to perform time series analysis of trends and spatial change analysis using GIS. The statistical plots provided an overall comparison of the changes from 2001 to 2012. The GIS-based spatial cross-tabulation capability provides a from-to relationship between a pair of land cover classes, which was done in this study for a decadal insight.

**RESULTS**

**Annual Changes**

From 2001 to 2012, we do not see much changes in the area of croplands and urban built-up environment (**Figure 3**). The unchanged built-up environment is in line with the population growth which hovered between 1.16 to 1.36 for the period<sup>[6]</sup> with migration rates from rural to urban areas being lower. This also explains why croplands have not increased much in the study period.

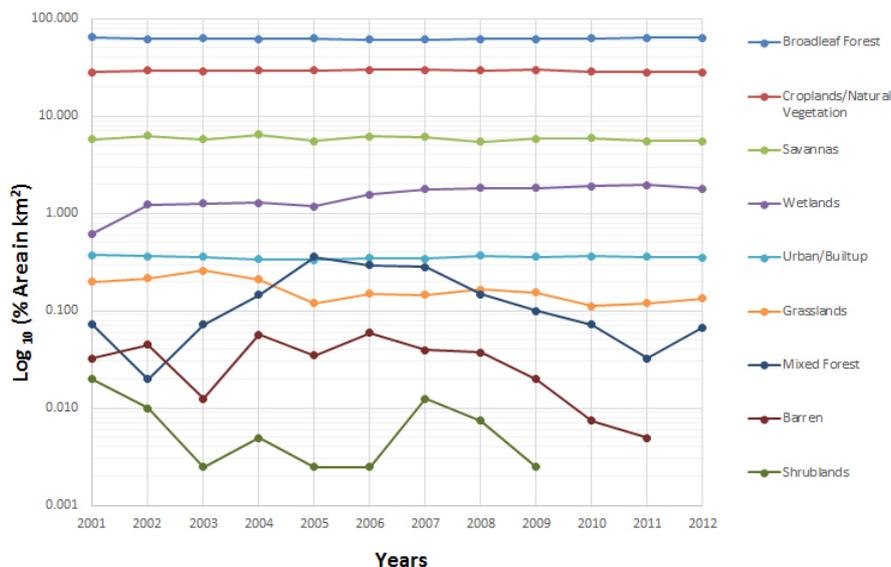


Figure 3. Annual variations of Land cover type by area in South East Asia.

One important aspect of land cover change mapping is to characterise deforestation. This is essentially defined by reduction in forest cover and an increase in barren or other categories like grasslands and shrub lands. It is evident from the time series plot that mixed forests increased from 2001 onwards until 2005 after which it continues to wane till 2011. This could be attributed to large scale forest conversion into rubber, cocoa and palm plantations in Indonesia and Malaysia. Deforestation for commercial plantations go through stages of barren land (forest clearings), grasslands (early plantations), and shrub lands (immature trees) to forests (full grown producing trees). Therefore the change patterns of grasslands, shrub lands and barren lands closely follow the mixed forest pattern. One peculiar observation however was the unchanged area of broad leaf forests and savannas, something that needs further study. Increase in wetlands can be explained in specificity if corroborated with precipitation and excavation activities in the region at a smaller scale.

**Decadal Spatial Change**

Spatial change characterised the change from one land cover class to another and this was achieved in a GIS. The MODIS data for 2002 and 2012 was used to characterise decadal spatial change in the region. The 3D plot (Figure 4) reveals the % area for each land cover category in 2001 that was converted to another categories in the 2012. This revealed interesting facts which was not brought forth by the simple statistical time series plot (Figure 3).

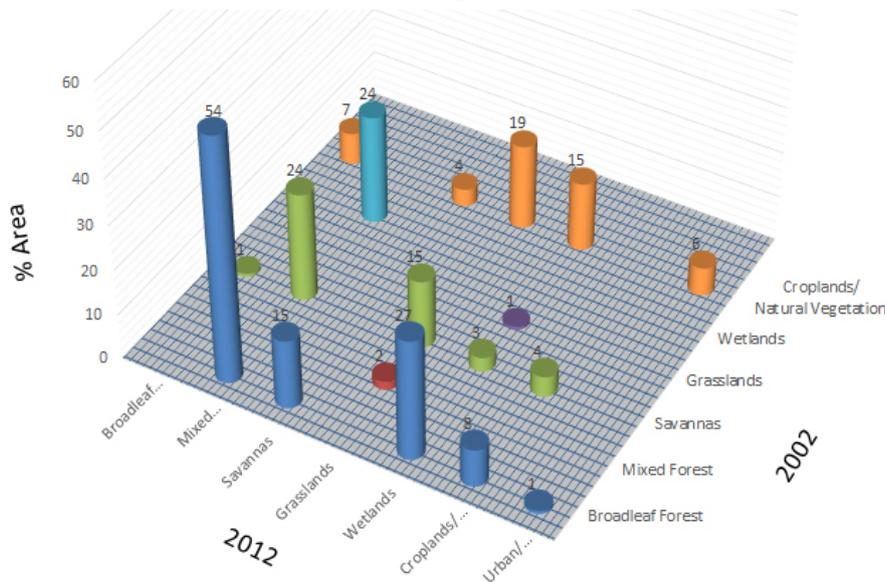


Figure 4. Decadal spatial land cover type change (% area) between 2002 and 2012.

Although the total broadleaf forest area remained unchanged between the years as observed in the previous section, it was evident from the 3D plot that area in 2002 had undergone changes in 2012. 99% of the original broadleaf forest area in 2002 was changed to croplands (8%), wetlands (27%), Savannas (15%) and mixed Forests (54%). As we had characterised that mixed forests are mostly because of commercial plantations, we now see evidence of more than 50% broad leaf forests being converted to commercial plantations. Not only the forests but the Savannas and wetlands of 2002 were converted to mixed

forests (plantations) in 2012. Another important change is the transformation of natural vegetation into other categories, which can also be explained based on the large scale impetus on commercial oil palms in the region.

## DISCUSSION

South East Asia region has therefore has witnessed large scale land cover changes between 2001 and 2012. The statistical and spatial change combined brought forth interesting patterns of land cover change, some of which could be explained in relation to the population dynamics and the economic thrust on the commercial plantations. The use of medium scale MODIS land cover product for studying land cover change was also demonstrated to great satisfaction although certain observations need to be explored further either through corroboration of related events or through the use of high resolution spatial imagery to track and reason changes at a local scale.

### MODIS or LANDSAT

Swath, spatial, spectral and temporal resolution of satellite platforms influence the scale and details of land cover studies. The IGBP land cover type classification which was used on the MODIS datasets could potentially be extended to another level of classification detail should we use Landsat instead. Landsat has a much better spatial resolution but its repeat imaging of 16 days requires a richer archive to conduct a regional study like the one here. Moreover, the area covered by one MODIS scene is covered by 45+ Landsat scene which introduces the complexity to mosaic scenes with acceptable spectral matching algorithms<sup>[10]</sup>. This also shall increase the time and cost spent on efforts to produce a land cover product comparable to the one used in this study. Blending multi-resolution and multi-spectral platforms has been an approach that has been successfully utilised and reported in literature<sup>[11]</sup>.

### Opportunities and Limitations

Time series of remote sensing data reveal that land cover changes do not always occur in a progressive and gradual way, but they may show periods of rapid and abrupt change followed either by a quick recovery of ecosystems or by a non-equilibrium trajectory. Such short-term changes often caused by the interaction of climatic and land-use factors have an important impact on ecosystem processes. Further subdividing the statistics to smaller spatial units e.g. based on geomorphic<sup>[12]</sup> or administrative would support multivariate analysis and insights. Such correlation of the observed changes could also be potentially performed with climate information which could influence growth of natural processes and phenological characteristics of vegetation cover increase (or decrease). Opportunities to integrate multivariate studies to include geomorphological units in relation to earth's surface processes like hydrology, erosion and sediment transport also exist<sup>[13]</sup>.

### Foreword Path

Improved understanding of the complex dynamic processes underlying land use change will allow more reliable projections and more realistic scenarios of future changes. Land-use change is associated with other societal and biophysical changes through a series of transitions. This has led emphasis on the potential for ecological restoration through land management in the event of sparse policies preventing the deteriorated of land cover. Multivariate analysis using temporal land cover and their correlation with other ground based information is key to cause-effect relationship of environmental variables which is the way for future research.

## ACKNOWLEDGEMENTS

The author acknowledges NASA and the University of Maryland for their provisioning of the MODIS land cover data product for this study. The author also declares that there is no conflict of interest in this publication.

## REFERENCES

1. Lambin EF, et al. Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources*. 2003;28:205-241.
2. Bartholomé E and Belward AS. GLC2000: A new approach to global land cover mapping from earth observation data. *International Journal of Remote Sensing*. 2005;26:1959-1977.
3. Kundu SN, et al. Change analysis using IRS-P4 OCM data after the Orissa super cyclone. *International Journal of Remote Sensing*. 2001;22:1383-1389.
4. Achard F, et al. Determination of deforestation rates of the world's humid tropical forests. *Science*. 2002;297:999-1002.
5. UN, World Population Prospects: The 2015 Revision. Department of Economic and Social Affairs, Population Division. 2015.
6. DeFries R, et al. Earth observations for estimating greenhouse gas emissions from deforestation in developing countries. *Environmental Science & Policy*. 2007;10:385-394.
7. Di Gregorio A. Land Cover Classification System, Food and Agriculture Organization of the United Nations, Rome; 2016.

8. Channan SK, et al. Global mosaics of the standard MODIS land cover type data. University of Maryland and the Pacific Northwest National Laboratory, College Park, Maryland, USA; 2014.
9. Friedl MA, et al. Global Land Cover Mapping from MODIS: Algorithms and Early Results. *Remote Sens Environ.* 2002;83: 287-302.
10. Czaplewski RL. Can a sample of Landsat sensor scenes reliably estimate the global extent of tropical deforestation? *Int J Remote Sensing.* 2002;24:1409-1412.
11. Jean H and Achard F. A new approach for tropical forest area monitoring using multiple resolution data. *Int J Remote Sensing.* 1997;18:2455-2461.
12. Kundu SN and Pattnaik DS. Geomorphic characterization of seafloor using Digital Elevation Model derivatives—a case study around Bombay High, Western Indian offshore. *Geocarto International.* 2014;29:185-197.
13. NASA, Global Mosaics of the standard MODIS land cover type data product (MCD12Q1), University of Maryland, Department of Geography and NASA; 2014.