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Forest Carbon Mapping Using Remote Sensed Disturbance History in Borneo

By Yoshiki Yamagata, et al. , posted on September 21st, 2010 in Articles, Earth Observation, Ecosystems, Technology

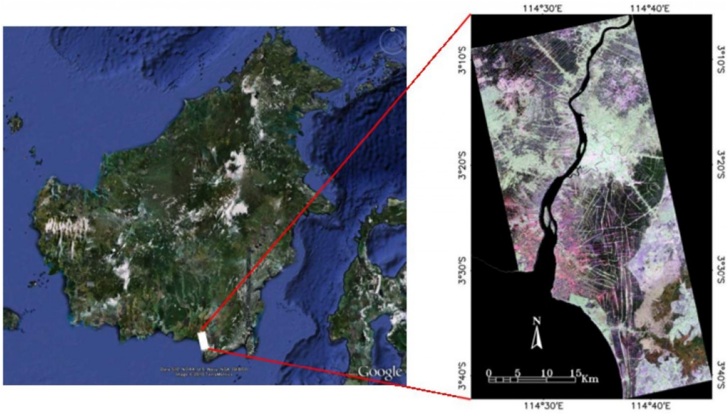

Figure 1: Location of the study area. The left-hand image shows the location of the study area on Borneo Island extracted from © Google Earth. The right-hand image is the full-scene PALSAR image acquired on 25 March 2010 (RGB = HH, HV, and VV).

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Introduction

Estimated CO_2 emission due to deforestation is as large as 20% of the global emissions (IPCC/AR4,2007). Reducing Emissions from Deforestation and forest Degradation (REDD) is currently negotiated as a part of the new "post-Kyoto" climate regime under the UNFCCC. REDD is an emission reduction option to achieve forest conservation in the developing (host) countries with support from the developed (investing) countries which participate the REDD mechanism. It is clear that the REDD activities are critically important to be able to realize the global CO_2 stabilization scenario (low-carbon pathway), such as achieving a 50 % reduction of the global emission by 2050.

Once the REDD option is agreed, it requires the development of operational forest carbon monitoring systems of signatory nations as a part of the MRV (Monitoring, Reporting and Verification) system for the REDD. The Forest Carbon Tracking (FCT) task of the GEOSS is coordinating relevant remote sensing, in situ measurement, and modeling activities to facilitate the establishment of such monitoring systems.

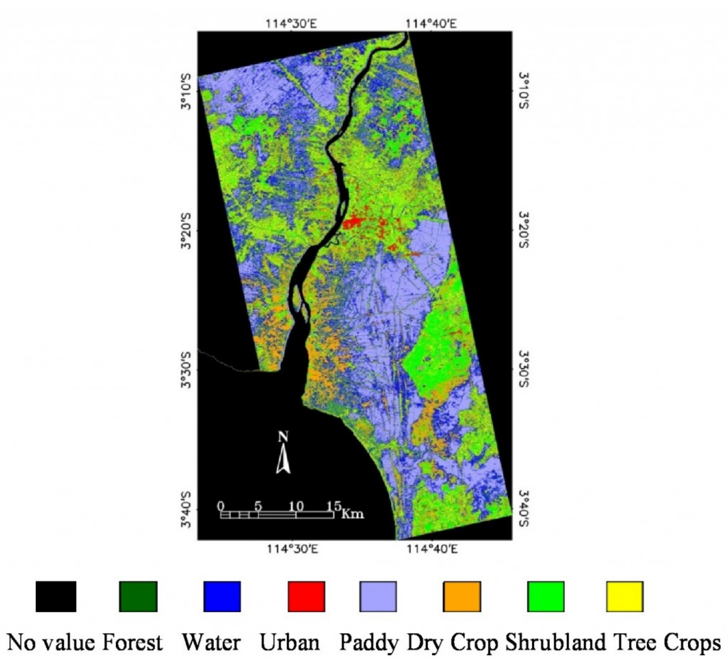

Figure 2: Land cover classification map derived from 13 bands of HH, HV, VH and VV, and the coherency T3 matrix classified by the subspace method. The overall classification accuracy is 72.4% with κ = 0.6762.

In our research to develop a forest carbon monitoring system to contribute to the FCT, we have tested the use of time-series satellite (optical and radar) remote-sensing data to track forest disturbance history, and estimated the resulting forest carbon budget using a terrestrial ecosystem model. We found that the active radar sensor PALSAR (Phased-Array L-Band Synthetic Aperture Radar) was especially advantageous for monitoring tropical forest cover under cloudy conditions, and that the time series of forest changes could be detected using MODIS data (MODerate resolution Imaging Spectroradiometer).

We have also tested the use of a new process-based terrestrial ecosystem model to estimate forest carbon stock changes that were induced by disturbances due to both natural (e.g. forest fire: Langner and Siegert, 2009) and human factors (e.g. logging and deforestation: Curran et al., 2004) during the last 25 years on Borneo Island which is registered as one of the national demonstration sites of FCT/GEOSS.

As PALSAR and its follow-on sensor time series data will be available until 2020, with more validation studies on the ground (forest cover and biomass etc.), this terrestrial ecosystem model-based forest carbon mapping approach will be able to contribute to the operational forest carbon monitoring system on a national scale.

Methodological Development

In this study, we used composite normalized-difference vegetation index (NDVI) images from optical satellite sensors such as MODIS, NOAA-AVHRR, and SPOT-VEGETATION to map the time series of forest cover change on Borneo from 1983 to 2008. PALSAR images were then used as training data for the forest cover map because PALSAR images are more stable under difficult weather (e.g., cloud) conditions and the spatial resolution (15 m) is higher than that of MODIS images (1000 m).

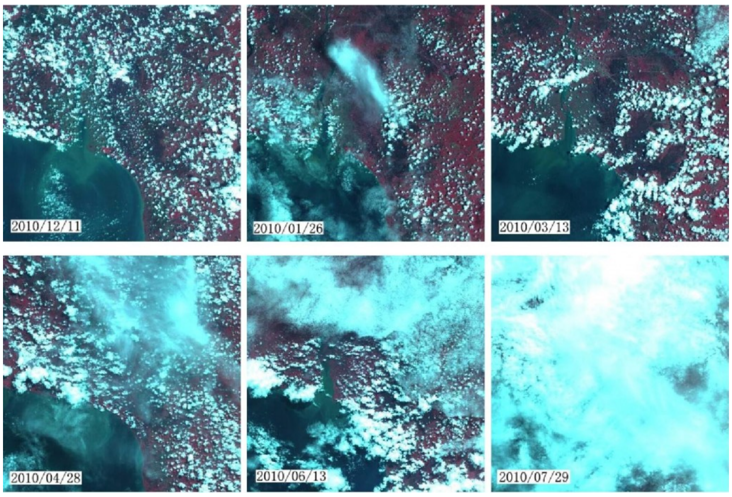

Figure 3. Six scenes of ALOS/AVNIR-2 optical sensor images acquired from 11 December 2009 to 29 July 2010 in the study area (extracted from © JAXA website:

The forest/non-forest map from PALSAR and the existing land cover map produced by Boston University were used to determine the threshold of forest versus non-forest areas. First, we mapped the forest/non-forest areas in Borneo using a 2007 PALSAR mosaic image (50-m spatial resolution). Then we determined the threshold value between forest and non-forest areas in a 2007 MODIS composite NDVI image. The areas classified as forest on both the forest/non-forest map and the existing land cover map were defined as forest in the MODIS composite image, and the threshold was determined. Finally, we mapped the forest/non-forest area from 1983 to 2008 by applying the 2007 threshold value to MODIS, NOAA-AVHRR, and SPOT-VEGETATION images from other years.

The Synthetic Aperture Radar (SAR) sensor provides accurate measurements during both daytime and night-time that are nearly independent of weather conditions. Therefore, the SAR technology provides an effective solution to mapping land cover in rainforest regions, which are often covered by consistent clouds. Especially, the PALSAR sensor has a full polarimetric mode that is able to transmit and receive both orthogonal components (horizontal [H] and vertical [V] polarization) of an electromagnetic wave, and these full polarimetric data allow more accurate mapping of the land cover types.

In this case study, we investigated the ability of PALSAR L-band data at quad polarization (HH, HV, VH, and VV) and 15-m resolution to produce accurate maps of land cover types. Figure 1 shows the study area in south Kalimantan (Borneo), Indonesia. Here, we adopted the recently developed subspace method for land cover classification (Bagan & Yamagata, 2010). Experimental results indicated that when combining the polarimetric coherency T3 matrix, which is derived from the full polarimetric Single Look Complex PALSAR data set, with intensity images, the classification accuracy was higher than when using only four-band (HH, HV, VH, VV) amplitude data. Figure 2 shows the classification results.

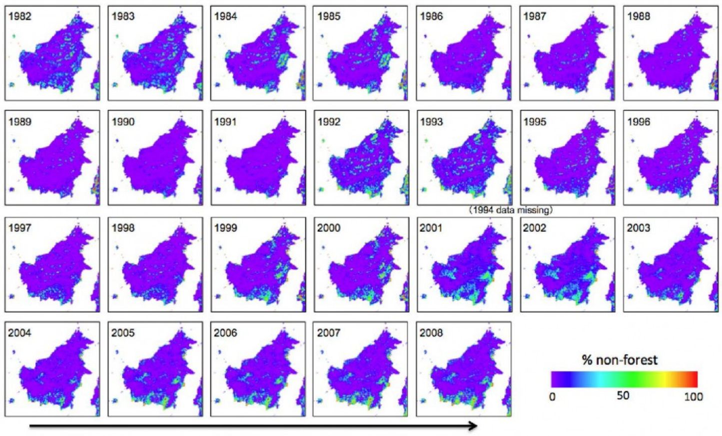

Figure 4: Time-series of forest/non-forest cover of Borneo Island captured by optical remote sensing data.

Gastellu-Etchegorry (1988) reported that very few Landsat and SPOT scenes had cloud cover percentages less than 10 percent during 1972-1987 in Indonesia. Figure 3 also shows the cloud cover situation of ALOS/Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) optical sensor images acquired from 11 December 2009 to 29 July 2010 in the study area. In Figure 3 we can see that it is difficult to extract land cover information by using only a single optical image due to constant cloud cover.

In combination with the time-series forest cover change (disturbance) mapping due to deforestation and forest degradation, we have developed a terrestrial ecosystem model-based carbon accounting method to estimate the dynamic carbon budget induced by historical disturbances. This process-based eco-system model VISIT (Vegetation Integrative SImulator for Trace gases: Ito, 2010) can simulate atmosphere–ecosystem gas exchange and carbon–nitrogen–water cycles in the disturbed forest ecosystems. The model also allowed us to estimate changes in carbon sinks and sources induced both by climate change and by natural and human disturbances, including land-use conversion from primary forest to cropland (e.g., oil-palm plantation).

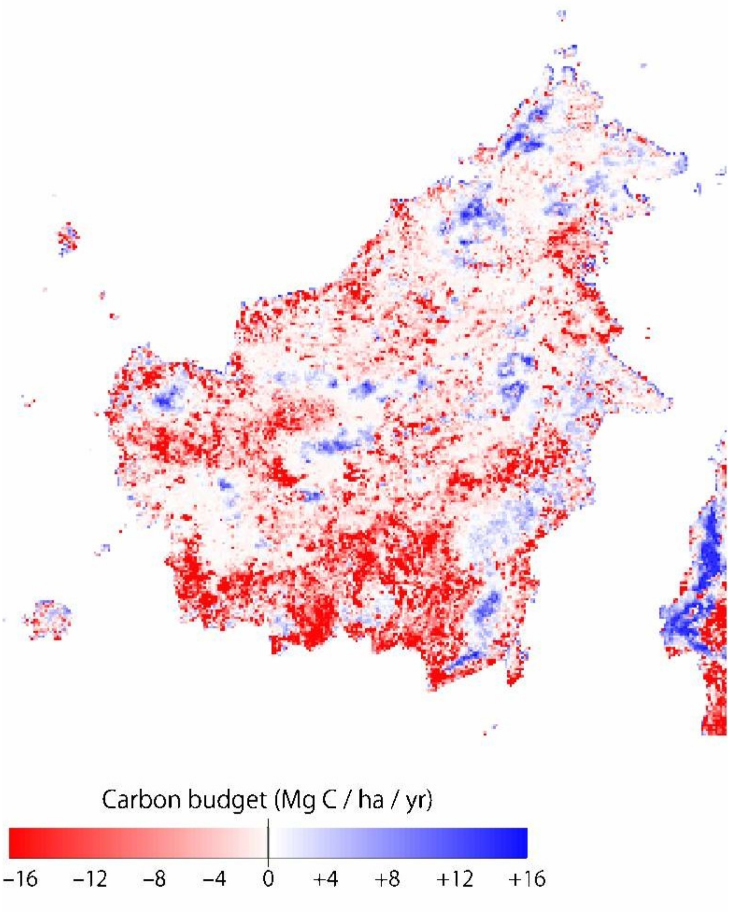

Figure 5: Net carbon budget of Borneo Island in 2008 as a result of cumulative forest cover change during the period of 1982–2008 (Figure 3) estimated by the terrestrial ecosystem model. Red areas show net carbon sources to the atmosphere, and blue areas show net carbon sinks.

The VISIT has been calibrated and validated using field data from Southeast Asian tropical ecosystems. By combining the satellite-based forest/non-forest map and the terrestrial model, we were able to develop a prototype of a broad-scale, spatially explicit forest carbon monitoring system.

A Case Study On Borneo Island

Historical deforestation (forest degradations and regenerations) on Borneo Island was estimated using the time-series remote-sensing data (MODIS, SPOT, PALSAR). Figure 4 shows the time series of forest cover change during the last three decades (1982 – 2008). In each area where a forest cover decrease was detected, the ecosystem model estimated immediate carbon emissions due to the forest decrease (deforestation or forest degradation), followed by gradual carbon absorption due to the forest re-growth.

By integrating the carbon dynamics due to remotely sensed time series disturbances, we produced a map of the net carbon budget induced by deforestation (including forest degradation and regeneration) on Borneo Island (Figure 5). We can see that ongoing deforestation induce large carbon emissions from the tropical forest, especially in southern areas.

We are currently improving the prototype system by using multi-time ALOS/PALSAR data, because cloud-induced noise still remains in the current forest map created from MODIS. Also, since our estimate does not include forest/peat fires emissions, we need to improve our remote sensing and terrestrial ecosystem model methods to accurately estimate the forest/peat land disturbed area and estimate the fire induced carbon emissions.

Acknowledgement

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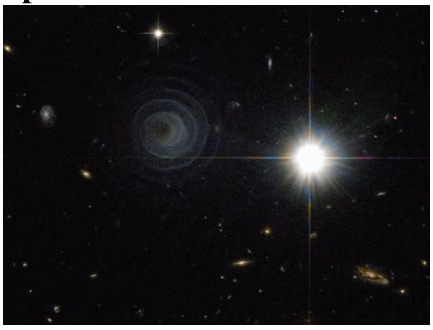

Scientists have yet to discover what caused the strange spiral structure. Nor do they know why it glows. The glow may be caused by light reflected from nearby stars. As for the spiral itself, current supposition is that this is the result of a star in a binary star system entering the planetary nebula phase, when its outer atmosphere is ejected. Given the expansion rate of the spiral gas, a new layer must appear about every 800 years, a close match to the time it takes for the two stars to orbit each other. The above image was taken in near-infrared light by the Hubble Space Telescope. Image Credit: NASA, ESA, Hubble, R. Sahai (JPL)

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