REMOTE SENSING TECHNIQUE TO ASSESS ABOVEGROUND BIOMASS DYNAMICS OF MANGROVE ECOSYSTEMS AREA IN SEGARA ANAKAN, CENTRAL JAVA, INDONESIA

Sigit D. Sasmito[1]*, Daniel Murdiyarso[1, 2], Arief Wijaya[1], Joko Purbopuspito[1, 3] and Yosuke Okimoto[1, 4]
[1]Center for International Forestry Research (CIFOR), Jl. CIFOR, Situgede, Bogor Barat 16115, Indonesia.
[2]Department of Geophysics and Meteorology, Bogor Agricultural University, Dramaga Campus, Bogor, Indonesia
[3]Faculty of Agriculture, Sam Ratulangi University, Manado, Indonesia
[4]Faculty of Agriculture, Saga University, 1 Honjo-machi, Saga, 840-8502, Japan

*Corresponding author: s.sasmito@cgiar.org

ABSTRACT

Mangroves are unique tropical coastal wetland ecosystems that have important roles to climate change adaptation and mitigation. Recent studies showed that mangroves have been severely threatened by deforestation, land use change, aquaculture and other human activities. This study shows that remote sensing techniques can assess the spatial extent and aboveground biomass spatial data of mangrove ecosystems in Segara Anakan lagoon, southern coast of Central Java Province. By combining Landsat 7 ETM+ satellite and aboveground biomass field data in 2009 there was increasing pattern of aboveground biomass with mean value of 359 Mg ha^{-1} and 547 Mg ha^{-1} for 2001 and 2013 respectively. The increasing biomass value implies that mangrove ecosystems in this lagoon could survive and grew well although severely threatened due to mangrove conversion. Despite of some limitation data availability and processes, this study fills the gap information on aboveground biomass mapping and may be very valuable to support monitoring on deforestation and degradation and other activities like measuring, reporting, and verification (MRV) of carbon stocks and reducing emission from deforestation and degradation (REDD+) especially on coastal mangrove forests.

Keywords: Landsat 7 ETM+, Landsat 8 OLI, climate change, MRV, REDD+

INTRODUCTION

Mangroves are unique tropical coastal wetland ecosystem that have important roles to climate change adaptation and mitigation. They provide not only numerous ecosystem services to local communities e.g. fisheries resources, ecotourism, timber value, protecting coastal area from sea level rise and storm, but also store more soil carbons to combat climate change compared to terrestrial forests because of their high net productivity (Bouillon *et al*., 2008; Donato *et al*., 2011). Despite of their potential roles, this ecosystem has been one of the world’s severely threatened major tropical environment e.g. by deforestation, coastal disturbance, land use change and other human activities (Valiela *et al*., 2001). Monitoring by spatial technology may increase the time and area effectiveness in the identification of the roles of and threats on mangrove ecosystem.

This study examines if remote sensing technique can illustrate the spatial extent and above ground biomass dynamics. Many study on mangrove forests area mapping has been conducted (Giri *et al*., 2011), but mapping on their aboveground biomass dynamic are still limited (Fotoyinbo *et al*., 2008; Kuenzer *et al*., 2011). This study fills the gap of information on aboveground biomass mapping by combining satellite and field data in mangrove ecosystems.

MATERIALS AND METHODS

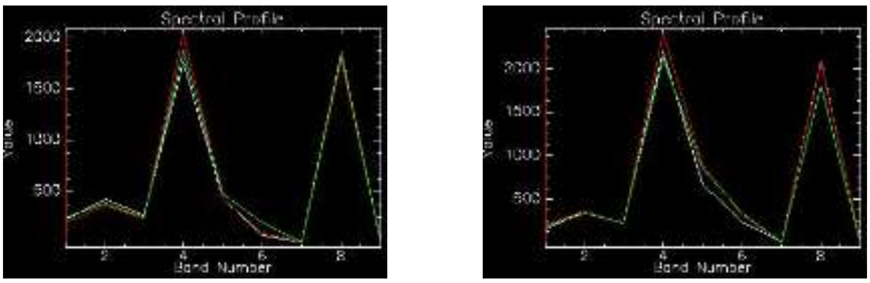
Study sites and data used

This study focuses on mangrove ecosystems in Segara Anakan, southern coast of Central Java Province. The area is lagoon-mangrove complex ecosystem with agriculture and aquaculture activities that are major threats to the ecosystem sustainability. Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) which acquired in 2001 had been used to produce mangroves map and Landsat 8 OLI (Operational Land Imager) for 2013.

Figure 1. Study location Segara Anakan, Central Java, Indonesia

Classification methods

Remote sensing technique was employed by combining multispectral bands of Landsat 7 ETM+ and 8 OLI images and vegetation indices (i.e. NDVI, MSAVI and EVI) to classify spatial extent of these mangrove ecosystems. We used three vegetation indices to enhance the quality of classification result, namely simple ratio (SR), normalized difference vegetation index (NDVI) and enhance vegetation index (EVI) as reported by Vina *et al*. (2012). The classification was conducted using different combinations of input, namely reflectance values and vegetation indices. Mangrove map was produced by the same maximum likelihood classification (MLC) method but in different image sensor Landsat 7 ETM+ for 2001 and Landsat 8 OLI for 2013. There was different calibration method between both sensors to derived top atmosphere reflectance since new launched Landsat 8 has different band pass wavelength. We could not produce other mangroves map between 2001 and 2013 because of Landsat SLC off sensor limitation data set.



Cilacap 1 Cilacap 2

Figure 2. Spectral profile of two transect location of Segara Anakan lagoon

Figure 2 shows spectral profile characteristic of mangrove forest in two transect location of Segara Anakan lagoon. Band number on Figure 2 represented several surface reflectance of landsat bands and indices (band 1, 2, 3, 4, 5, 7, SR, NDVI, and EVI respectively). From these graphs confirmed that mangroves have similar spectral profile even in different point of places. Spectral profiles have been used as signature samples and also characterized spectral surface reflectance and indices value. Based on these mangrove spectral profile graphs, machine could easily determined mangrove class.

Aboveground biomass mapping

In different with classification procesess, aboveground biomass mapping used field data and satellite combination. Aboveground biomass field data measurement was extracted from Murdiyarso *et al*. (2009) and Landsat 7 ETM+ SLC off aquired in 2009 sensor was used as satellite image representation. We had examined data set to find good relationship among number of field measurement and band surface reflectance or indices. We used NDVI to estimate how much biomass stored in aboveground trees in each pixel images since it has good relationship with aboveground biomass.

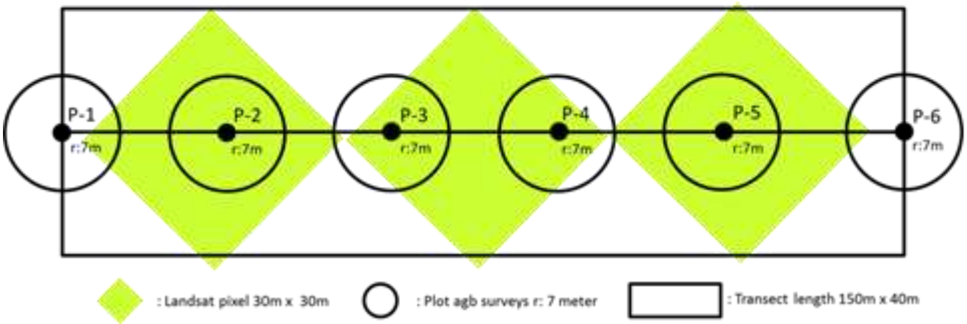


Figure 3. Image pixels and field data colocation

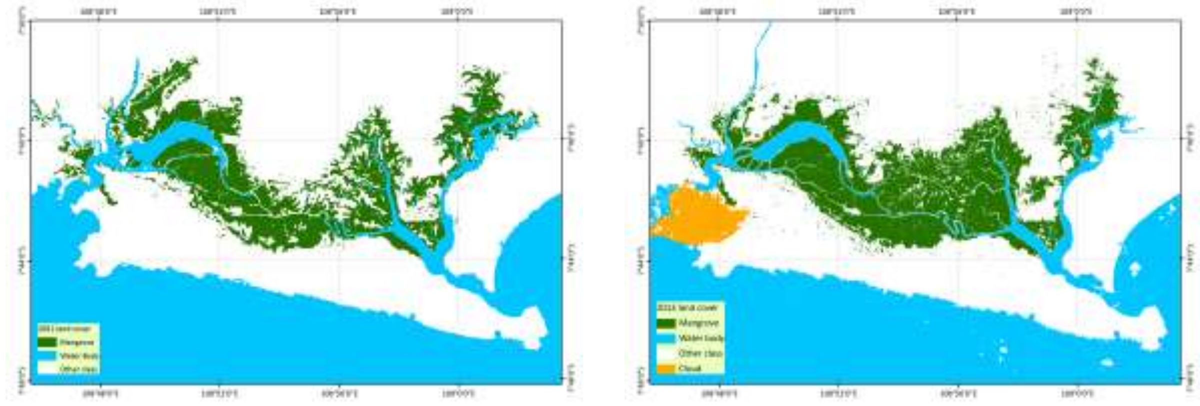
NDVI was derived from surface reflectance images and collocated with field work data based on survey layout protocol as shown in Figure 3 by Kauffman and Donato (2012). Simple regression model was analyzed by using all pixel point data and used to map mangrove biomass in different time scale. As shown in Figure 3, the transect layout allowed authors to extract three pixel image points. Each transect consist of six plots and we averaged data of plot 1 and plot 2 as one pixel value. It means there are six pixels extracted from Cilacap 1 and Cilacap 2 transects.

Figure 4. Landsat 7 ETM+ colocation with transect layout in 2009 at Segara Anakan lagoon

Figure 4 shows colocation between image pixel and image pixel in two transects of Cilacap 1 (red highlight) and Cilacap 2 (white highlight). Luckily, both of transects have fallen into stripped on than off due to SLC off sensor problems in Landsat 7 ETM+ 2003-present. We used additional field data points from other mangrove ecosystem Bunaken and Tanjung Puting as reported by Murdiyarso *et al*. (2009) since two numbers of transect value were not good enough to develop statistical regression and they still represented aboveground biomass of mangrove forests. Both of sites data used similar field survey protocol with Cilacap data (Kauffman and Donato, 2012).

RESULTS AND DISCUSSION

Mangroves mapping



2001 2013

Figure 5. Segara Anakan lagoon mangroves area map in 2001 and 2013

Figure 5 shows mangrove spatial extent in differences time frame of 2001 and 2013 in Segara Anakan lagoon as classification result. We didn't mapped mangroves in 2009 because of broken data on satelite image since SLC off sensor problems in Landsat 7 ETM+. There were several area changes from and to mangroves class between 2001 and 2013. We found dificulty to determined exactly the conversion drivers since there was no ground truthing. Different satellite sensors inputs between ETM+ in 2001 and OLI in 2013 also brought quite big uncertainties like many noises in 2013 map.

Aboveground biomass mapping

The difficulties in mapping of vegetation biomass using optical satellite images are the limited number of image parameters correlated with field measurement parameters. In order to find good relationship among number of field measurement and pixel data, both of data availability also became problems in biomass mapping. In this case, we extracted aboveground biomass data from Murdiyarso *et al*. (2009) and plotted into images pixel of satellite data of the same time as the field measurement.

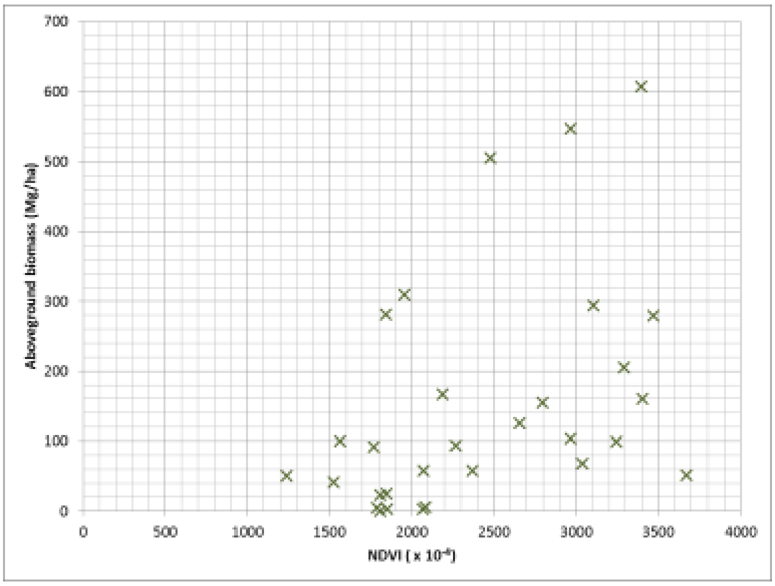


Figure 6. NDVI versus aboveground biomass data

All data from three sites (Cilacap, Bunaken and Tanjung Puting) were extracted with their NDVI pixel values and plotted as shown in Figure 6. We found a wide range of aboveground biomass in three locations between 23−607 Mg ha^{-1}. That wide range might imply an overestimation of aboveground biomass dynamics. In contrary, field data measurement range for Cilacap was 0.14−24 Mg ha^{-1}.

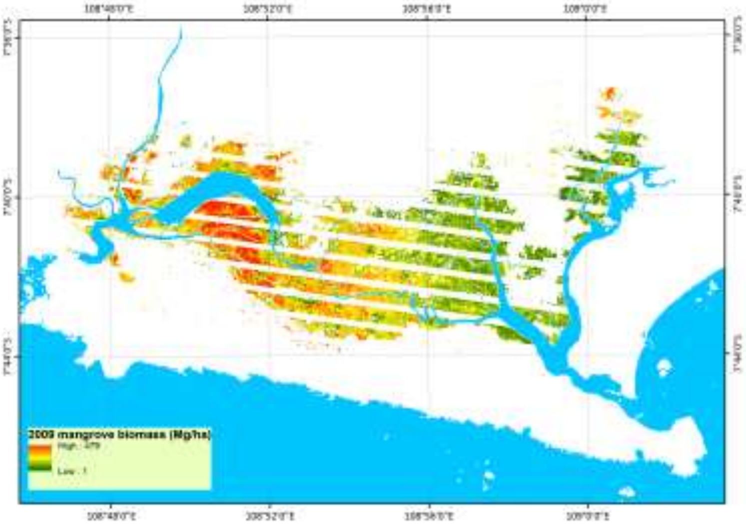
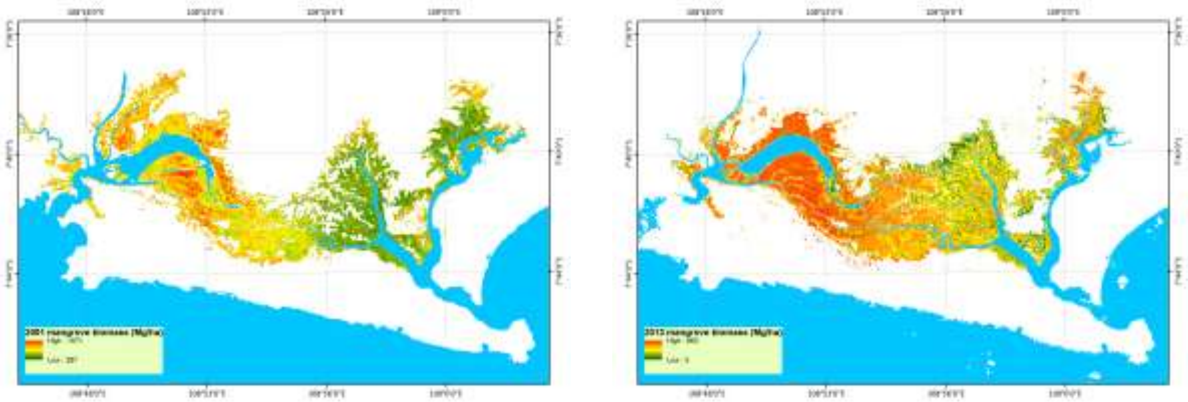


Figure 7. Mangrove aboveground biomass dynamics in 2009 with 2013 mangroves area adjustment at Segara Anakan lagoon



2001 2013

Figure 8. Mangrove aboveground biomass dynamics in 2001 and 2013 at Segara Anakan lagoon

The aboveground biomass dynamics map for 2009, 2001 and 2013 respectively was showed in Figure 7 and 8. Figure 7 show a reliable aboveground biomass dynamic with mean 182 Mg ha^{-1} because of field data availability in 2009, but there was limitation with no mangrove area extent classified due to SLC off satellite sensor. Extrapolation result from 2009 data also showed for 2001 and 2013 mangrove aboveground biomass dynamics in Figure 8. There was similar dynamic pattern of aboveground biomass with mean 359 Mg ha^{-1} and 547 Mg ha^{-1} for 2001 and 2013 respectively. Overall, the result was overestimated due to lack of data availability, methodology and ground check.

CONCLUSION

By combining field data and satellite images, this study could provide spatially data of mangrove aboveground biomass. This preliminary study shows that optical data are useful for estimating area extent and aboveground biomass dynamics if properly preprocessed using certain criteria. Authors suggest that exploration on methodology and sensor combination (e.g. combine radar and optical sensor), and establish more ground truthing as well as field data may be beneficial to follow up our results.

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