Satellite-based monitoring of forest cover change in Indonesia using Google Earth Engine from 2000 to 2016

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Abstract. The Google Earth Engine (GEE) is a cloud computing system providing data analysis platform with various satellite based observation data and other earth observation datasets. Therefore, application of the GEE enable us to analyze terrestrial environmental changes in an effective way. This study aims to test GEE capability to monitor forest cover change in Indonesia from 2000 to 2016 by performing raster and vector manipulations using Landsat-based forest cover datasets. Deforestation is one of the most important environmental problem in Indonesia, and monitoring of forest cover changes is urgent task for environmental protection. The found that GEE is very effective to analyze large amount of remote sensing data quickly, and estimated forest cover area in 2000 and its interannual variations in Indonesia. Factors affecting land cover in Indonesia will be elaborated in further detail in this paper.

1. Introduction

One of the most important indicators of environmental conditions is the forest cover area. Forest Resource Assessment (FRA) 2015 estimated that the global forest area in 2015 was about 4,000 million hectares [1], equal to 30.6 percent of the world’s land area. At the end of the 20th century the area of tropical forest that covered about 20 percent of the dry land area on Earth, dropped to less than 7 percent [2]. The tropical region experienced the greatest loss and acquisition of forests among the four climate domains, and the highest loss ratio (3.6 to >50% tree cover), indicating the prevalence of the dynamics of deforestation [3]. Tropical deforestation in developing countries contributes to greenhouse gas emissions and is one of the causes of global warming [4].

Indonesia has 91 million hectares of forest cover, and the third-largest area of tropical forest after Brazil and the Democratic Republic of Congo [1]. However, Indonesia has experienced high rates of deforestation. According to Hansen et al. (2013) [3], tree-cover loss in Indonesia averaged around 1.38 million hectares per year. Meanwhile, the annual rate of deforestation and forest degradation in Indonesia increased from 700,000 ha in the mid 1980s to around 2.4 million in early 1999 [5]. The FRA 2010 reported the rate of forest loss in Indonesia was 0.31Mha per year from 2000 to 2005 and 0.69Mha per year from 2005 to 2010 [6].

Remote sensing has been an important method to monitor of forest cover change [7, 8]. Remote sensing technology includes a variety of tools ranging from sophisticated sensors to simple cameras...
and film systems. Each imaging system is as valid and important as others, depending on the usefulness of the application, and the need to create a two-to-dimensional image product that can be analyzed or interpreted [9].

The value of satellite data in Earth observation for environmental monitoring has been improved. Temporary and spatial synchronization of observations over large areas have significantly improved the quality and quantity of environmental observation data, which is becoming increasingly important in environmental monitoring. Because of the increase of availability of satellite images, spatially and temporally detailed monitoring of terrestrial environment is becoming capable. In particular, a series of high spatial resolution (e.g. 30m) satellite data provide spatially detailed information on land cover and land use changes.

One of the bottleneck of analysing high spatial resolution data at large scale (e.g. country level study) is the huge amount of the data size. For example, Landsat satellite data, typically used to monitor vegetation from local to global scales with its high spatial resolution, requires huge number of datasets to cover the study areas [10].

Nowadays, the capability to carry out simultaneous spatial and temporal aggregations over a collection of satellite imagery is required for processing very large geospatial datasets, without having to suffer the information technology pains, free, easy to access, and high resolution image data. Google Earth Engine (GEE) seems to be among the best candidate to meet these criteria. GEE is a cloud-based platform that makes it easy to process huge geospatial datasets using high-performance computing resources [11]. GEE is a system designed to visualize geospatial data sets, enable petabyte scales, and scientific analysis. Earth Engine provides a consolidated environment including a very large catalog of data and is located with thousands of computers to analyze [12].

Purpose of this study is to analyze forest cover status and its changes in Indonesia with GEE and demonstrate how GEE is effective to monitor large areas. Using GEE platform, we attempted to evaluate forest cover in 2000 to from 2000 to 2016. Furthermore, we discussed the feasibility of GEE to analyze forest cover change monitoring at country scales.

2. Methods

2.1. Google Earth Engine Platform

An online environment data analysis platform that combines data from various institutions such as the National Aeronautics and Space Administration (NASA) and Landsat programs is GEE (Google Earth Engine). Google sees an opportunity to use its cloud computing resources to allow recording of Landsat images to be accessed and processed through its online system. After USGS opened access to records of Landsat images in 2008. Because this allows users to reduce processing time in analyzing Landsat images and making global scale Landsat projects more feasible [3].

The 30 m spatial and multispectral resolution of Landsat is ideal to monitor local scale environmental changes, and current revisiting time is sufficient to monitor land cover change [13]. From 1972 until now Landsat is a popular platform used for analysis of land cover changes including urban and vegetation [14, 15, 16, 17]. Ability to analyze Landsat data provided by GEE cloud computing services for more than 40 years. Therefore, using GEE helps us to analyze global data rapidly [18].

GEE enable us to handle large volume datasets of remote sensing and other ancillary datasets in a cloud computing platform. The cloud-based platform for analyzing planet-scale environmental data is GEE. Therefore, decided to use GEE in this study. A web-based IDE for the Earth Engine code.earthengine.google.com JavaScript API in the Google Earth Engine Code Editor. Code Editor features are designed to make developing complex geospatial workflows easy and fast.
2.2. Dataset

2.2.1. Satellite-based forest cover data. This study uses global forest change by Hansen et al. (2013) [3]. The dataset is created based on the multi-year Landsat imageries to identify forest cover at year 2000 and forest cover loss year detected by the multi temporal satellite images. The dataset has a 30m spatial resolution. The dataset contains year-by-year information when the forest cover was lost. In addition, forest cover gain pixels are also identified.

2.3. Analysis
We analyzed forest cover status in the year 2000 and temporal variation of forest cover losses from 2001 to 2016. First, forest cover in year 2000 was assessed using GEE. The used google earth code editor with JAVA script API to pick up whole Indonesia, and calculate forest cover fraction in the year 2000. Second, using forest cover datasets with google earth engine, we estimated the forest loss areas in each year from Hansen et al. datasets. Finally, discussed the estimated values of forest cover changes and extracted the specific regions with large forest cover loss and gains. and discuss temporal changes in forest cover across Indonesia.

3. Results

3.1. Forest cover area in year 2000
The estimated that forest cover area across Indonesia is about 338,000 km$^2$ in year 2000. The results of the time series analysis of Landsat images with forest area and changes are characterized by 2000. Trees are defined as vegetation that is more than 5m high. Trees are expressed as '2000 Percent Tree Cover' percentage per output plot cell. Forest Cover Loss is defined as a change from forest to non-forest status in the period 2000-2016. Advantages of Cover Forest is defined as the opposite of loss, namely the change in non-forest to forest in the period 2000-2016. The Year of Forest Loss is the total separation of 'Forest Loss' with an annual time scale. Reference images 2000 and 2016 are observations of the median of a series of observations of the quality of the planting season that passed in the assessment.

![Figure 1. Spatial distribution of forest cover fraction in Indonesia in 2000 based on Hansen et al. (2013) [3] forest cover and change data](image)

A map of Indonesia, taken as an output of GEE, was created (Figure 1). To adjust the appearance of the layer added to the map, the layer manager is used in the upper right corner of the map. Specifically, we can adjust transparency with the slider or change the layer's visibility. Then used yellow to highlight Indonesia on a map to see location of major cities in Indonesia. Actually, this yellow color can be changed according to the color we want, because we can change the color in the editor code. For forest cover, the bands in global forest change are the data description tree cover of 2000 is the percentage of tree cover in the 0-100-pixel range. The results of monitoring satellite-based
land cover changes using GEE show that GEE easily handle large volume data, such as Landsat data obtained from the Hansen Forest search in the editor code.

3.2. Changes in Forest Cover Fraction from 2000-2017
The results of monitoring satellite-based land cover changes using GEE show landsat data obtained from Hansen Forest search in the code editor. The first three ribbons of the image are selected red, green, and blue respectively when multi-band images are added to the map and stretched according to the data type of each band. The reason the image looks green is the 2000 tree cover, red is the loss and blue is the gain. The 2000 tree cover band is expressed as percent and has a much higher value than the loss (red) and gain (blue) which is binary \( \{0, 1\} \). The yellow is pick up Indonesia on the map.

![Figure 2. Custom visualization of Hansen (2000-2017) forest change data](image)

It can be observed that there are three addLayer calls. Every call on addLayer adds a layer to the map. At the top right of the map the Layers button reveals these layers. Each layer can be turned off using a check box next to it and layer opacity can be affected by the slider next to the layer name.

3.3. Changes in forest loss from 2000 to 2016
Temporal changes in forest loss areas were calculated from 2000 to 2016 based on Hansen et al. (2013) forest cover change data. Whole Indonesia region was summarized can also be seen in Figure 3.

![Figure 3. Changes in forest loss areas in each year from 2000 to 2016 on Indonesia](image)

This is a form of loss in Indonesia from year to year. The highest peak of losses was in 2011, this happened because of land cover by human growth so that it took land to make buildings, then there was a loss year.
4. Conclusion
Satellite monitoring can be used to monitor land changes, to illustrate how humans use land and physical features that cover the land surface using GEE. Based on the analysis that has been conducted in Indonesia from 2000-2016, interannual variations in forest loss area were detected with the highest change occurred in 2011 and then in 2015. The behind mechanisms of these year to year variation will be discussed in the future studies.

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