Satellite Remote Sensing Application for Forest Productivity and Carbon Stock Analysis: A Sustainable Forest Management System for Indonesia

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Abstract

Regional monitoring of forest productivity and carbon cycle is highly required for sustainable forest management in Indonesia. However, climate change and anthropogenic activity has significant impact on Tourism Recreation Forest (TRF), Convertible Protection Forest (CPF), Permanent Production Forest (PPF), Limited Production Forest (LPF), Wildlife Reserve Forest (WRF) and Nature Reserve Forest (NRF) zones of South Sumatra. Satellite remote sensing and webGIS system can be integrated to analyze forest productivity and carbon stock estimation from forest phenological properties and Land Use Land Cover (LULC) map. Therefore, the purpose of this research is to apply satellite remote sensing datasets (LANDSAT 7 ETM+ LANDSAT 8 OLI and MODIS and Sentinel 2) to analyze phenological properties, LULC change to evaluate forest productivity and carbon stock analysis.

First, research was conducted to determine the changes in forest land use change for the forest zone of south Sumatra of Indonesia from 2003 to 2018 to assess change detection using Normalized Vegetation Index (NDVI). The maximum likelihood classifier method was based on a parametric classification algorithm and divided into four classes: urban, vegetation, forest and water bodies. In the changing trend, TRF, CPF and PPF was found decreasing trend from 2003 to 2018 by 20%, 13% and 40% respectively. LPF region had undergone major changes according to the LULC and dropped by 72%. The Analytical Hierarchy Process (AHP) was used with incorporating expert opinions for priority of criteria related to possible forest extension areas. The higher weight was observed for settlements, elevation, distance from roads, and distance from rivers. CPF, PPF, and LPF had the potential to expand the coverage of production forests in the highly suitable

classification (30%) and moderately suitable classification (41%) areas. WRF had the ability to extend into highly suitable classification areas (30%) and moderately suitable classification areas (52%) to protect biodiversity and wildlife habitats. NRF had the potential to extend in highly suitable classification (39%) and moderately suitable classification (48%) areas to protect forests for wildlife and biodiversity.

Second, Gross Primary Productivity (GPP), Net Primary Productivity (NPP) was analyzed from NDVI according to Indonesian forest resilience regulations, divided into 5 classes: High forest productivity (V1), moderate forest productivity (V2), marginal forest productivity (V3), very low forest productivity (N1) and no forest productivity (N2). It was found that CPF had an increasing trend (0.20%) for all levels of forest productivity. A web-based GIS system was developed to obtain information of forest productivity. A system dynamic method was introduced for predicting productivity till the 2030 using NDVI and forest areas along with the variation of solar radiation. The results of the system dynamic model had two scenarios for forest productivity with solar radiation positive for increasing productivity) and solar radiation negative for decreasing productivity.

Third, the LULC change analysis was performed in the forest zone to understand aboveground biomass (AGB) distribution using IPCC (Intergovernmental Panel on Climate Change) approach. Areas belonging to each forest class in the South Sumatra was reported for AGB, and carbon fraction values have been used to estimate carbon stock. Deforestation and emission factors were considered on the basis of the AGB. An estimation of carbon density of 47% was used to calculated carbon stocks in each of the

forest type. In case of NRF, the AGB was 300 t/ha with a natural distribution. WRF and CPF had larger forest areas than the others and had an average carbon stock of 40,000 tC/ha. NRF had a carbon stock of 35,000 tC/ha, and LPF and PPF had average carbon stocks of 17,000 tC/ ha and 9000 tC/ha, respectively. TRF had a very small carbon stock of 900 tC/ha.

This research concluded that forest productivity and carbon stock analysis from NDVI and LULC can be established from satellite remote sensing datasets. Expert opinions are used to prioritize for potential forest extension areas in South Sumatra based on LULC and soil conservation practices with WebGIS. NDVI phenology index could be used to refer forest productivity and carbon stock estimates for long term policy planning for sustainable forest management. In this research forest productivity and carbon stock analysis was conducted for Tourism Recreation Forest Convertible Protection Forest, Permanent Production Forest, Limited Production Forest, Wildlife Reserve Forest, and Nature Reserve Forest zones of South Sumatra according to Indonesian forest resilience regulations referring high, moderate, marginal, very low and no forest productivity categories.