Measuring deforestation using remote sensing and its implication for conservation in Gunung Palung National Park, West Kalimantan, Indonesia

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Abstract. Gunung Palung National Park (1,080 km², 1°3′ – 1°22′ S, 109°54′ – 110°28′ E) was first protected in 1937 and is now one of the largest remaining primary lowland mixed dipterocarp forests on Borneo. To help inform conservation efforts, we measured forest cover change in the protected area using 11 multi-temporal Landsat series images with path/row 121/61. Annual deforestation rates have declined since measurement began in 1989, to around 68 hectares per year in 2011 and 112 hectares per year in 2017. Halting deforestation in this protected area requires to tackle its underlying economic and social causes, and find ways for communities to meet their needs without resorting to forest clearing. Community empowerment, forest rehabilitation, and health care incentives as payment for ecosystem services can help reduce deforestation in Gunung Palung National Park. This becomes a positive trend which we must continue to always work in forest conservation. Future forest monitoring will be dependency with remote sensing analysis and open source remote sensing data such as Landsat and Sentinel data remain an important data source for historical forest change monitoring.

1. Introduction
Tropical deforestation is a major cause of global biodiversity loss and carbon emissions. The island of Borneo, including its Indonesian controlled territory known as Kalimantan, contributes to this problem. Between 1973 and 2010, Kalimantan lost 30.7% (123,941 km²) of its forest, and Borneo as a whole lost 73.55% [1]. Industrial plantations were the biggest cause of deforestation since the 1970s [2,3], followed by agriculture, wildfires, and climate change [1]. Currently, less than 10% of forests in Southeast Asia are protected, and even protected areas are threatened with deforestation [4].

Gunung Palung National Park in West Kalimantan protects one of the largest remaining primary lowland mixed dipterocarp forests in Borneo. It is home to approximately 2,500 wild orangutans, or about 10% of the world’s surviving population [5]. But the park suffers from high rates of deforestation, with 38% of its lowland forests lost between 1999 and 2002 [6]. This forest loss is partly due to a large number of people (up to 47-72% of households in some areas) who rely on illegal logging for their primary source of income [7]. To achieve zero deforestation, we must therefore not only protect the park, but also address the problem at its roots by empowering people to make a living without logging.

Here we describe deforestation using remote sensing and its implication to conservation efforts in Gunung Palung National Park. We measure forest cover using satellite remote sensing technology, because it is less costly and time intensive than field-based methods [8] and allows us to assess long
term changes in landscape composition over the entire area of the park at multiple scales [9,10]. Maps produced from remote sensing techniques also provide information for conservation planning and forest management [11].

2. Methods

2.1. Study area
Gunung Palung National Park was first protected in 1937 with an area of 300 km², and later expanded to a total of 1,080 km². It is located in the regencies of North Kayong and Ketapang, in the province of West Kalimantan, Indonesia (1°3’ – 1°22’ S, 109°54’ – 110°28’ E, elevation 0 to 1,031 meters above sea level, figure 1). The park conserves many habitat types, including mangrove forest, peat swamp forest, lowland rainforest, and montane forest, and is home to several threatened species, such as Bornean orangutans (Pongo pygmaeus), proboscis monkeys (Nasalis larvatus), sun bears (Helarctos malayanus), and helmeted hornbills (Rhinoplax vigil).

2.2. Data
We used the following 11 multi-temporal Landsat series images (path/row 121/61) to map forest cover over time and determine rates of forest loss in the park:
1. Landsat TM acquired on 12 September 1989 and 3 October 3 1989.
2. Landsat TM acquired on 21 July 21 1997, 22 August 1997 and 28 December 1997.
3. Landsat ETM+ acquired on 25 June 2002, 11 July 11 2002 and 28 August 28 2002
4. Landsat TM acquired on 7 July 2007.
5. Landsat TM acquired on 30 September 2011.
6. Landsat 8 (OLI) acquired on 22 March 2017.

Figure 1. Study area in Gunung Palung National Park.
The spatial resolution for Landsat images is 30 meters. The data were geometrically corrected and projected to the Universal Transverse Mercator zone 50S (WGS 1984 datum). We used the newest version of the national park’s borders, issued by the Ministry of Environment and Forestry of Indonesia decree number SK.733/Menhut-II/2014.

2.3. Analysis
We classified land cover in the park using visual interpretation aided by maximum likelihood methods [12]. For classification classes, we used a modified version of the method of [13] which classifies land cover into: (1) montane forest, (2) peat forest, (3) lowland forest, (4) mangrove, (5) secondary forest, (6) young regenerating forest, (7) scrub or open land, (8) logged forest, (9) mixed agriculture, (10) mixed plantation, and (11) settlement. After conducting targeted ground checks for validation and to assess map accuracy, we found that our methods correctly classified land cover in over 95% of cases. Measuring annual deforestation rate we using Compound Interest Law were mathematically calculated as (equation 1):

\[ r = \frac{1}{(t_2 - t_1)} \ln \frac{A_2}{A_1} \]  

(1)

Where \( A_1 \) and \( A_2 \) are forest cover at time \( t_1 \) and \( t_2 \), respectively (unit % per year) [14].

3. Results and Discussions

3.1. Forest loss measurement
At the time of the first measurement in 1989, the park had already lost around 11,607 ha or 10.74% of its forest area (table 1, figure 2). From 1989 to August 1997, the annual deforestation rate was 0.87% or around 800 ha/year. In one four-month period in 1997, the park lost nearly 22,000 ha of forest or 20.3% of the park’s area. By 2011 the deforestation rate had declined to around 68 ha/year, and was around 112 ha/year in 2017. These rates are nearly 200 and 120 times less than the peak deforestation rate in December 1997, or 19 and 11 times less than rates in 2002. Corresponding with this decline in deforestation, since 2002 many logged areas in the park lowlands have been regenerating into secondary forest (figure 3). These patterns mirror global deforestation rates, which have decreased by half from the 1990s to 2010 [15]. But deforestation rates in Gunung Palung are still around three times as high as the global average of 0.08% per year [17].

This forest loss is related to a growing population and Indonesia’s transmigration policy that encourages development [3]. The main causes of forest change in this park are illegal logging and conversion to community’s plantations and agriculture. In low elevation areas near settlements, forests are converted to mixed agriculture, such as paddy farming or gardening [17]. In hilly areas far from settlements, forests are converted into mixed plantations of rubber, durians, chilies, or other products. In southern areas of the national park, forests were cleared and logged through a timber concession operated by PT. Marsela Wana Sekawan [18]. The timber concession exacerbated the logging problem and allowed deforestation to penetrate into the interior of the park. After logging, cleared areas around the park perimeter were colonized by alang-alang grass (Imperata cylindrica), which encourages and tolerates wildfires, creating large areas of anthropogenic grassland.
Table 1. Land cover change in Gunung Palung National Park from 1989 to 2017.

| No | Landuse                   | 1989   | Aug-97  | Dec-97  | 2002   | 2007   | 2011   | 2017   |
|----|---------------------------|--------|---------|---------|--------|--------|--------|--------|
| 1  | Lowland forest            | 48,741.55 | 46,921.43 | 28,360.32 | 24,060.45 | 19,579.92 | 19,125.77 |
| 2  | Peat forest               | 24,561.19 | 19,892.65 | 17,244.91 | 14,085.23 | 13,265.14 | 12,951.78 |
| 3  | Montane forest            | 22,790.20 | 22,790.04 | 22,200.86 | 22,149.86 | 22,126.82 | 22,126.82 |
| 4  | Mangrove forest           | 311.91  | 311.91  | 213.78  | 213.78  | 196.96  | 169.62  | 118.04 |
| 5  | Mixed agriculture         | 83.30   | 136.96  | 235.08  | 1,800.03 | 2,330.43 | 2,479.78 | 2,764.48 |
| 6  | Mixed plantation          | 3,653.29 | 4,714.56 | 4,714.56 | 5,192.37 | 5,332.56 | 6,346.62 | 6,842.24 |
| 7  | Scrub or open land        | 2,807.31 | 6,243.31 | 14,017.88 | 7,607.28 | 8,800.11 | 7,068.74 | 7,097.09 |
| 8  | Degraded forest           | 5,063.86 | 6,889.85 | 20,913.32 | 26,523.77 | 29,821.87 | 28,756.91 | 11,107.40 |
| 9  | Young regenerating forest | 0.00    | 111.90  | 111.90  | 6,267.93 | 6,345.52 | 7,621.28 | 2,517.68 |
| 10 | Secondary forest          | 0.00    | 0.00    | 0.00    | 111.90  | 111.90  | 740.76  | 23,330.37 |
| 11 | Settlement                | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 30.96   |        |
|    | Total                     | 108,012.61 | 108,012.61 | 108,012.61 | 108,012.61 | 108,012.61 | 108,012.61 | 108,012.61 |

3.2. Implications for Conservation
To achieve zero deforestation we must address the causes of forest loss in Gunung Palung National Park. Conservation can encompass a range of activities, from total preservation of natural resources to sustainable extraction, and is not limited to public policy [19]. Forest monitoring and reporting are important to measure forest condition or natural resources for conservation and management. An up-to-date forest information need fast assessment and reliable method. The result from measuring forest cover change using remote sensing is we can know the annual rate of deforestation and its distribution. We can also differentiate between deforestation and forest degradation or partial canopy cover loss.

Satellite remote sensing area contribute to multi-temporal monitoring to better understanding impact of anthropogenic activities [20]. These including current information of habitat extend and its change, habitat condition, species diversity and the threats [21]. In recent years, the trend of logging activities are decreased and reforestation effort are increased [17]. Knowing how and why the changes over times is important especially in long-term forest loss or gained forest (e.g. afforestation). Knowing forest losses and gain help scientist to monitor carbon stock and gauge forest ability to reduce greenhouse gasses.

In Gunung Palung National Park, degraded forest are becoming young regenerating forest or secondary forest with rate up to 6.5% in 2011 and 18.8% in 2017. The gained forest due to increased law enforcement and global conservation effort to save remaining rain forest. This part also influenced by Reducing Emissions from Deforestation and Forest Degradation (REDD+) mechanism where work to slow rates of forest degradation. We also identified a fragmented forest where separate from main forest in Gunung Palung. In hilly areas inside the park around the settlement, from images we found reforested area. However, ground-checking reveal reforested area is durian or rubber tree plantation. Hence, ground-checking always important part in forest assessment using remote sensing.
Figure 2. Land cover map of Gunung Palung National Park. Deforestation reached a peak in 1997, when a fifth of the park’s area was cleared in just four months. Deforestation rates have declined since then, and many degraded areas are growing into secondary forest.
Figure 3. Pattern of forest loss in Gunung Palung national Park. Primary forest extent has declined every year, but some logged forests are beginning to regrow into secondary forest.

3.3. Discussion
National Park is closely with environmental, water, land use, educational, and social term that must be understood. Forest conservation is linked to many aspect such as environmental, economic and social, and government regulation. The base part of forest conservation in Gunung Palung National Park is save remaining forest with tackling its underlying economic and social causes. What is no conservation effort to save forest?  
Biodiversity will remain decrease, fragmentation, and habitat for endangered species will lose. We also facing lower stock carbon if we still loss many forest. In the future, enhance forest management which good management base on social factor should be part of conservation. And remote sensing is an effective way to monitor forest cover with multi-temporal analysis [10]. The increase availability of remote sensing data including hyperspectral images, radar, LiDAR, and utilization of unmanned aerial vehicles (UAV), allow us to study broader forest monitoring [22]. Future forest monitoring will be dependency with remote sensing data and analysis [23]. We highlighted that free and open source remote sensing data such as Landsat and Sentinel data remain an important data source for historical forest change monitoring. The majority of conservation research have used Landsat images to assess change in protected area, with consideration of continues data [21]. But, we need better spatial resolution to get more detailed information, e.g. canopy density, tree height, vegetation health, anthropogenic threat assessment, etc. these information can give impact for conservation management in future.

In practical conservation program, people participation for conservation is important part. Halting deforestation in this protected area requires us to tackle its underlying economic and social causes, and find ways for communities to meet their needs without resorting to forest clearing. Increase willingness to participate in forest management and conservation with increasing people's knowledge about the benefits due to conservation and land use right security become positive thing in conservation [24]. Conservation efforts that have been done is community empowerment, forest rehabilitation, and health care incentives as payment for ecosystem services can help reduce deforestation in Gunung Palung National Park.

Failing to account for social factors around protected areas can lead to repeated deforestation in the future [25]. Poverty, for example, is a major cause of deforestation [26], as poor people living near protected areas often rely on livelihoods that cause forest loss, such as shifting agriculture, timber harvesting, or plantations. We should emphasis to solve land tenure problem to people who cultivated
land inside national park. Maybe we should promote forest farming or agroforestry, a sustainable way to use forest resources as a non-timber forest products (NTFPs) as a more comprehensive concept of forestry land use [27]. The NTFPs product such as wild boars, deer, wild fruits, firewood, wild vegetables, and wild mushrooms; and valued range from 34 – 169 USD/ha [17]. Even tough, the NTFPs contribution from forest to poverty alleviation is minor at present [28], but still income from forest can give an average 5.8% contribution to total household income [29].

4. Conclusion

Our forest monitoring in Gunung Palung National Park using remote sensing show deforestation rate now reduce to 0.21% in 2017, lower up to 120 times in peak of deforestation in December 1997. We found remote sensing is the effective way to map forest change in Gunung Palung Park. To stop this deforestation in protected area, we should finding way for communities to meet their needs without resorting to forest clearing or we fight deforestation at its source by tackling its underlying economic and social causes. Community empowerment, forest rehabilitation, and provide health care as an environmental payment service is the conservation can do in Gunung Palung National Park to reduce deforestation. The increased prosperity, community loggers started to quit his job. This becomes a positive trend which we must continue to always work in forest conservation. The increase availability of remote sensing data including hyperspectral images, radar, LiDAR, and utilization of unmanned aerial vehicles (UAV), allow us to study broader forest monitoring and its conservation. We highlighted that free and open source remote sensing data such as Landsat and Sentinel data remain an important data source for historical forest change monitoring.

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