Comparative Study of Methods to Estimate Historical Peat Burnt Area in Gaung – Batang Tuaka River of Peat Hydrological Unit (KHG)

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Abstract. As a country with 14.9 ha of peatland, Indonesia is a major contributor of GHG emissions, especially from peat ecosystems. These emissions were caused by peat decomposition and peat fires. However, accurate estimation of peat burnt area was still a barrier that prevented the inclusion of peat fire emission in the document of Forest Reference Emission Level (FREL) as a followup document to REDD+ activities. This research has the objective to analyse two different approaches to estimate peat burnt area used in the FREL document and the most recent semi-automatic approach suggested by the Ministry of Environment and Forestry (MoEF). The study focused on the Gaung – Batang Tuaka River Peat Hydrological Unit (KHG), as one of the KHG priorities in Indonesia. The results showed that the average total annual burnt area from the FREL approach was 58% higher than that of the semi-automatic approach, which could lead to an overestimate of peat fire emissions from this approach. The burnt area identified in this study was found to occur within the production forest area. As stepwise approach is allowed for FREL submission, improvements to a higher precision method are necessary to increase the accuracy of burnt area estimation.

1. Introduction

Forestry, agriculture, and fishery sectors are contributing to 14% of the national GDP. However, the development from these sectors affects GHG emissions level in Indonesia, particularly emissions from Agriculture, Forestry, and Land Use (AFOLU) sector. Based on the recent document of Indonesia’s 2nd Biennial Update Report, the AFOLU sector (including peat fire) contributed to 51.59% of the national emissions in 2016, where the highest emission occurred in 2015 due to a very strong El Niño that led to a massive peat fire event [1]. Estimation of peat fire emission was still the main issue faced in Indonesia due to the low uncertainty of activity data that might lead to an overestimation of peat fire emission. Therefore, peat fire emission is excluded in the Forest Reference Emission Level (FREL) document. However, comparative analyses of various approaches of peat burnt areas, mainly between FREL and semi-automatic approach, suggested by the MoEF is currently unavailable, yet necessary as a supporting result to improve the previous method used.
The majority of fire events in Indonesia have occurred in Sumatra, followed by Kalimantan and Papua Islands [2]. Based on spatio-temporal cluster analysis of hotspot distribution in Sumatra, one of the widest hotspot distribution was located in Indragiri Hilir District [3]. Indragiri Hilir and Indragiri Hulu are two districts where Gaung – Batang Tuaka River Peat Hydrological Unit (KHG) is located, one of the KHG priority in Indonesia. Thus, estimation of peat burnt area in this KHG priority became crucial to provide insights of the historical and current conditions of peat ecosystem in the scale of KHG level.

2. Data and method

Data used in this paper consisted of daily historical hotspot data obtained from MODIS, remote sensing data of LANDSAT Thematic Mapper (TM) 8 and 5 for path 125 – 126 and row 60 that covered the study area, merged using mosaic analysis. Thematic map consisted of peat map, forest boundary area, and land cover map. The research process was conducted based on the flowchart given in Figure 1. For the semi-automatic approach, a visual analysis of the burnt area was done using composite RGB of band 654 for LANDSAT TM 8 and composite RGB of band 543 for LANDSAT TM 5 [4], and the initial automatic approach was conducted using point density analysis of hotspot data (with ≥80% confidence level) from spatial analyst tools. For FREL approach, the burnt area was defined through the analysis of hotspot in a pixel of 1 x 1 km, assuming that burnt area occurred in the 75% of the pixel that have at least one hotspot with ≥80% confidence level [2]. Burnt area for both approaches was calculated using 3 years data (El Niño (2015), La Niña (2010), and normal year (2013)) in order to represent various ENSO events as the main mode that affected climate variability in Indonesia [5].

![Flowchart of the research process](image-url)
LANDSAT data used in this research consisted of two periods for each path/row as a representative of before and after burnt conditions (Table 1). Two periods of acquisition dates determined based on the date before and after hotspot peak period given in Figure 2. It was assumed that peat fires were mainly occurred during the period of peak hotspot, particularly in the dry season [6,7]. However, longer acquisition date was used for processing because cloud disturbance might have lead to bias when determining burnt area visually, due to the fast regeneration of vegetation during post-fire [8,9]. Thus, it is necessary to use multiple acquisition dates of LANDSAT to complete another map with an unclear view.

| Year of burnt | Period       | Acquisition Date of LANDSAT Path 125 row 60 | Path 126 row 60 |
|---------------|-------------|--------------------------------------------|-----------------|
| 2010          | Before peak | 31/03/2010, 26/01/2010                      | 02/02/2010      |
|               | After peak  | 06/08/2010                                  | 16/10/2010      |
| 2013          | Before peak | 24/04/2013, 27/06/2013                      | 18/06/2013      |
|               | After peak  | 02/11/2013                                  | 08/10/2013, 09/11/2013, 22/09/2013 |
| 2015          | Before peak | 03/07/2015                                  | 16/02/2015      |
|               | After peak  | 12/02/2016                                  | 17/12/2015, 18/01/2016, 03/02/2016 |

Accuracy was measured in error matrix, consisted of error of omission and commission (Table 2). Omission error refers to the total area unidentified as burnt, based on reference map, semi-automatic approach, while commission error refers to the total area misclassified as a burnt area by FREL approach. Valid data, a total area identified as the burnt area from both approaches, omission error, and commission error was then used to calculate the user’s, producer’s, and overall accuracy [10].

| Reference Map (semi-automatic) | Estimated burnt area (FREL) | Overall accuracy (%) |
|--------------------------------|-----------------------------|----------------------|
| Burnt (ha)                     | Valid data (V)              | {V/(V+O+C)} x 100%   |
| Not burnt (ha)                 | Omission (O)                |                      |
| User’s accuracy (%)            | Commission (C)              |                      |
| Producer’s accuracy (%)        | {V/(V+C)} x 100%            |                      |
|                                | {V/(V+O)} x 100%            |                      |

3. Result and Discussion

3.1. Peat burnt area

Based on historical hotspot data, the period of maximum amount of hotspot in the study area varied for three years with different ENSO occurrences (Figure 2). During La Niña year, there was no peak amount of hotspot for the whole year, with the maximum amount of only 18. During the normal year (2013), the maximum number of hotspots was higher than El Nino year. However, the pattern of hotspot only reached its peak in August and relatively low for other months. During El Niño year, the amount of hotspots was relatively prevalent during the dry season (July – Oct). Information of historical hotspot pattern is necessary to decide the time range of LANDSAT map used as a visual interpretation of the burnt area.
Based on the results of peat burnt area estimation, semi-automatic approach have resulted in lower peat burnt area compared to the FREL approach (Figure 3). This difference allegedly originated from the assumption used by FREL approach. Though the estimation process of peat burnt area using FREL approach was relatively simpler, the assumption used of using only hotspot data with confidence level >=80% could lead to the misleading extent of burnt spreading. Hotspot data with low confidence level provided accurate information of burnt spreading area, as indicated on the different spatial location of the burnt area detected from the LANDSAT map, compared to the grid obtain from FREL approach (Figure 4). No threshold for the number of hotspot, which lies in the pixel of FREL approach was also resulted in misinterpretation of a fire event, particularly in La Niña year (Figure 4). In general, the assumption of burnt area, which occurred on 75% of the pixel area was the major factor which overestimated burnt area in FREL approach, compared to the high resolution (30 m) of LANDSAT map that could provide better detail results of the burnt areas.

Figure 2. Number of hotspots in 2010, 2013, and 2015.

Figure 3. Peat burnt area estimation.
Figure 4. Result of peat burnt area during peat fire (a) 2010, (b) 2013, and (c, d) 2015.

The peat fire in the study area of Gaung – Batang Tuaka KHG was found to occur only within the production forest area. Based on the overlay of spatial information process of land cover map with the results from semi-automatic approach, the majority of the previous land cover types before the 2010, 2013, and 2015 peat fires were secondary swamp forest, wet shrub, and both secondary swamp forest and wet shrub respectively (Table 3). Peat fire recurrent occur in 2015 of which 314.66 ha area was burnt during the 2013 peat fire and 13.45 ha area was burnt during 2010 peat fire.
Table 3. Result of peat burnt area using semi-automatic approach.

| Land cover type                  | 2010 | 2013 | 2015 |
|----------------------------------|------|------|------|
| Primary Swamp Forest (ha)        | -    | -    | 39.6 |
| Forest Plantation (ha)           | -    | 173.7| 338.6|
| Estate Crop (ha)                 | -    | -    | 957.3|
| Bare Ground (ha)                 | -    | 40.5 | 245.4|
| Secondary Swamp Forest (ha)      | 103.3| 105.4| 1220.9|
| Wet Shrub (ha)                   | 0.6  | 1303.0| 1851.2|
| Mixed Dryland Agriculture (ha)   | -    | -    | 30.2 |

3.2. Accuracy test

Accuracy test of the results obtained between FREL and semi-automatic approach was necessary to analyse the fitness level from both methods. The accuracy analysis of this study used only descriptive accuracy measure which consisted of user, producer, and overall accuracy. Due to unavailability of field data to validate the results from this study, descriptive accuracy assumed the results from semi-automatic approach as a reference, as this method has higher spatial resolution. However, it should be noted that visual interpretation of LANDSAT map to determine the burnt area (from semi-automatic approach) might result in subjective justification of burnt area or land cover change, which led to the varied percentages of LANDSAT accuracies from various studies [11,12].

Table 4. Result of descriptive accuracy assessment of FREL.

| Accuracy parameter    | 2010  | 2013  | 2015  |
|-----------------------|-------|-------|-------|
| Valid data (ha)       | 68.9  | 1458.0| 3899.5|
| Omission (ha)         | 35.0  | 164.6 | 783.7 |
| Commission (ha)       | 381.1 | 2892.0| 4725.5|
| User’s accuracy (%)   | 15.3  | 33.5  | 45.2  |
| Producer’s accuracy (%)| 66.3  | 89.9  | 83.3  |
| Overall accuracy (%)  | 14.2  | 32.3  | 41.4  |

The result of the accuracy given in the Table 4 above showed that user’s accuracy for the three years of analyses were maintained below 50%, consistent with another study [13], while producer’s accuracy measured was higher. The percentage of overall accuracy tent to increase from La Niña, normal, to El Niño year. This could be an additional evidence that FREL approaches was more accurate and best to be used as an estimation of peat burnt area during the El Niño event.

4. Summary and Concluding Remarks

Activity data of peat burnt area remained a barrier to obtain an accurate result of peat fire emission in Indonesia. The previous method used in FREL document had overall accuracy below 50%, with an average difference between FREL and semi-automatic approach of 58%, where higher peat burnt area was indicated on the result obtained through FREL approach. This indicated that FREL assumption of burnt area that occurred on 75% area of the pixel was overestimated. The result of the error matrix showed that FREL accuracy varied for the three different ENSO years, where the highest accuracy measured in the El Niño year, followed by Normal and La Niña year. Improvement of FREL accuracy for El Niño year could be achieved by taking into account hotspots with lower confidence level to capture the spreading of burnt area, while for La Niña year, the threshold for the amount of hotspot should be set, and hence the pixel would focused on the area with dense hotspots only.
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