Forest and land fire smoke detection using GCOM-C data (case study: Pulang Pisau, Central Kalimantan)

K I N Rahmi*, N Febrianti and I Prasasti

Remote Sensing Application Centre, LAPAN
Jl. Kalisari No 8 Pekayon, Pasar Rebo, Jakarta 13710, Indonesia

*email : khalifah.insan@lapan.go.id

Abstract. Forest/land fire give bad impact of heavy smoke on peatland area in Indonesia. Forest/land fire smoke need to be identified the distribution periodically. New satellite of GCOM-C has been launched to monitor climate condition and have visible, near infrared and thermal infrared. This study has objective to identify fire smoke from GCOM-C data. GCOM-C data has wavelength range from 0.38 to 12 µm it covers visible, near infrared, short-wave infrared and thermal infrared. It is relatively similar to MODIS or Himawari-8 images which could identify forest/land fire smoke. The methodology is visual interpretation to detect forest/land fire smoke using near infrared band (VN08), shortwave infrared band (SW03), and thermal bands (T01 and T02). Hotspot data is overlaid with GCOM-C image to represent the location of fire events. Combination of composite RGB image has been applied to detect fire smoke in Pulang Pisau, Central Kalimantan.

Keywords: GCOM-C, smoke, forest/land fire, VN08, SW03

1. Introduction

Forest and land fire occur every year in Indonesia especially in peatland area and increased in dry season. Fire could be divided into three categories: ground fire, surface fire and crown fire. In Indonesia, especially in peatland area, fire usually ground fire which caused smoke in long time period. In 2015, 2.6 million hectares are burned [1] because of El-Nino. It gives bad impact to land environment also to the air pollution. Big fire smoke detected from satellite image in 2015 [2, 3] that comes from ground fire.

Satellite remote sensing image has category in spatial and temporal resolution. High resolution image could detect object in detail but small scope and vice versa. Fire smoke could be detected from remote sensing image all resolution. However big event of smoke better detected using moderate and low resolution. Each image gives complementary data since it records in complement time. Remote sensing image could detect fire smoke using MODIS image [4] Himawari-8 image [3] Landsat-8 [2]. This technology could monitor the distribution of fire smoke in near real time.

The Global Change Observation Mission-Climate (GCOM-C) is satellite was developed by Japan Aerospace Exploration Agency (JAXA). This satellite has been launched in December 2017 to monitor climate condition. The sensor called Second Generation Global Imager (SGLI). It has 19 bands i.e.
visible, near infrared and thermal infrared bands which has wavelength range of 0.38 µm – 12.0 µm. It has spatial resolution from 250 – 1000 m and cover same area in 2-3 days [5]. GMCOM-C has primary purpose to observe and understand the mechanisms of heat flow in the earth and the distribution of ecosystem changes due to global warming, and further use the obtained knowledge to improve the numerical models that predict future climate change [5–7].

In Indonesia which have issues on disaster regarding climate, this satellite not yet used by researcher or practitioner to monitor climate condition or earth surface phenomena. Even though this image has potential to complement low resolution image i.e. MODIS, VIIRS, Himawari-8 to monitor climate or disaster mitigation such as forest/land fire. Study about GCOM-C has been conducted to monitor volcano activity using infrared sensor [8], to investigate ice cloud [9], but not yet conducted to monitor forest/land fire which one of climate phenomena. GCOM-C data has one- or two-days temporal acquisition which could complement other image to detect fire smoke. This study has objective to detect smoke of forest and land fire using GCOM-C data which never been conducted in Indonesia before.

2. Data and Methods

Data and methods used in this study are described in the following paragraph:

2.1. Study Area

Based on BNPB, 2018 forest and land fire occurred in Central Kalimantan 24 times. Hotspot is one of parameter of forest/land fire occurrence which have three categories i.e. high (CL > 79%), middle (30% < CL < 79%), and low (CL < 30%) confidence. The confidence show the potential hotspot become fire events, the higher the confidence the higher potential fire happened. In 2018, hotspot highly occur in September based on Figure 2 below. In September occur 3286 hotspots which divided into hotspot 137 low confidence, 1879 mid confidence, and 1270 high confidence (Figure 1). Hence, this study focus on September data.

Study area is Central Kalimantan Province which is area prone to forest and land fire. Central Kalimantan has 14 regencies i.e. Kapuas, Katingan Kotawaringin Timur, Kotawaringin Barat, Sukamara, Barito Timur, Kota Palangkaraya, Puliangpisau, Barito Selatan, Lamandau, Seruyan, Gunungmas, Barito Utara, Murung Raya. In this study, forest/land fire smoke was found in Puliangpisau Regency Central Kalimantan Province. It located in 113°30’ – 114°30’ E and 1°30’ – 3°30’S which shows in Figure 3.

Figure 1. Hotspot distribution of (a) Juli (b) Agustus (c) September (d) Oktober 2018 in Central Kalimantan (Source: http://modis-catalog.lapan.go.id/)
2.2. Data
Global Change Observation Mission - Climate (GCOM-C) is the climate change observation satellite developed by JAXA (JAXA, 2018) and first launched to the public in December 2018. This data has one or two day revisit time which records Indonesia at 9.50 a.m. SGLI is an optical sensor operated by this satellite carrying two radiometer components: Visible Near Infrared radiometer (VNR) and InfraRed Scanning radiometer (IRS) each radiometer consist of spectral, this spectral characteristics could be seen in Table 1 below.
Table 1. GCOM-C characteristic [5]

| No | Band | Central wavelength (µm) | IFOV |
|----|------|-------------------------|------|
| 1. | VN1  | 0.38                    | 250/1000 |
| 2. | VN2  | 0.412                   | 250/1000 |
| 3. | VN3  | 0.443                   | 250/1000 |
| 4. | VN4  | 0.490                   | 250/1000 |
| 5. | VN5  | 0.530                   | 250/1000 |
| 6. | VN6  | 0.565                   | 250/1000 |
| 7. | VN7  | 0.6735                  | 250/1000 |
| 8. | VN8  | 0.6735                  | 250/1000 |
| 9. | VN9  | 0.763                   | 250/1000 |
| 10.| VN10 | 0.8685                  | 250/1000 |
| 11.| VN11 | 0.8685                  | 250/1000 |
| 12.| P1   | 0.6735                  | 1000  |
| 13.| P2   | 0.8685                  | 1000  |
| 14.| SW1  | 1.050                   | 1000  |
| 15.| SW2  | 1.380                   | 1000  |
| 16.| SW3  | 1.630                   | 250/1000 |
| 17.| SW4  | 2.210                   | 1000  |
| 18.| T1   | 10.8                    | 250/500/1000 |
| 19.| T2   | 12.0                    | 250/500/1000 |

In this study, bands of GCOM-C data used are VN8, SW3, T01, and T03. VN8 which located in 0.735 µm central wavelength has potential to minimize the error of detection due to reflection of sun glint, coast, and clouds (Giglio et al, 2016). SW3 has sensitivity to clouds over snow (JAXA, 2018), T01 and T02 usable for fire detection through thermal sensor and minimizing error of detection from clouds and forest clearing (Giglio et al, 2016). The four bands are estimated could identified fire smoke based on the usability. Table 2 shows the other data used in this study to validate fire smoke data are Terra/Aqua MODIS of bands 1, 2, and 18 (Tjahjaningsih, 2005) Landsat 8 of bands 6, 5, 4 (LAPAN, 2016) and hotspot data from LAPAN.

Table 2. Remote sensing image data used in this study

| Data           | Bands           | Date        |
|----------------|-----------------|-------------|
| GCOM-C         | VN8, SW3, T01, T02 | 28 Sept 2018 |
| Terra/Aqua MODIS | 1, 2, 18        | 28 Sept 2018 |
| Landsat 8      | 6, 5, 4         | 28 Sept 2018 |
| Hotspot        | MODIS and SNPP  | 28 Sept 2018 |

Landsat 8 has higher spatial resolution than GCOM-C. It has 30 m spatial resolution for reflectance bands (band 1-9 except band 8) 15 m for panchromatic band (band 8) and 100m for thermal bands (band 10 and 11). While it has medium resolution, it has revisit time each 16 days in same location. Landsat 8 used in this study is recorded image of 28 September 2018 path/row 118/062 with low cloud cover percentage (4.63 %). The data get from [http://landsat-catalog.lapan.go.id/](http://landsat-catalog.lapan.go.id/) which has L1GT geometric corrected. Composite image to detect forest and land fire is RGB 654 which is combination of short wave infrared band, near infrared band, and red band. Table 3 shows the characteristics of Landsat 8 image.
Table 3. Landsat 8 OLI and TIRS characteristic [10]

| Bands            | Wavelength (µm) | Resolution (m) |
|------------------|-----------------|----------------|
| Band 1 Coastal/Aerosol | 0.435 – 0.451  | 30             |
| Band 2 Blue      | 0.452 – 0.512   | 30             |
| Band 3 Green     | 0.533 – 0.590   | 30             |
| Band 4 Red       | 0.636 – 0.673   | 30             |
| Band 5 NIR       | 0.851 – 0.879   | 30             |
| Band 6 SWIR-1    | 1.566 – 1.651   | 30             |
| Band 7 SWIR-2    | 2.107 – 2.294   | 30             |
| Band 8 Panchromatic | 0.503 – 0.676  | 15             |
| Band 9 Cirrus    | 1.363 – 1.384   | 30             |
| Band 10 TIR-1    | 10.60 – 11.19   | 100            |
| Band 11 TIR-2    | 11.50 – 12.51   | 100            |

Figure 4 shows the data of Landsat 8 image used in this study. Focus study shows in red circle which is location of fire smoke. The smoke located in Pulang Pisau Regency, Central Kalimantan.

Figure 4. Composite image RGB Himawari-8 and Landsat8

2.3. Method
LAPAN [11] describe the real occurrence of forest/land fire could be identified based on criteria of:
1. Clustered hotspot, large enough forest/land fires are not detected as only one hotspot because the heat effect spreads, so if the hotspot is clustered then it can be ascertained that there were forest/land fires.
2. Hotspots accompanied by smoke, forest/land fire could be marked if there is smoke in RGB image following the hotspots.
3. Hotspots happen repeatedly, there is possibility of fires in the area.

Radiometric and geometric corrected GCOM-C data of bands VN8, SW03, T01, and T02 analysed visually to detect. Then combination of the bands using composite RGB were applied to know the best model composite to detect fire smoke. This fire smoke from GCOM-C data then compare to fire smoke from composite RGB 6-5-4 Landsat 8 and fire smoke from RGB 1-2-18 Terra/Aqua MODIS. To identified the real forest/land fire smoke also overlay with hotspot data based on the second criteria above. This method is conceived in the Figure 5 below.
Figure 5. Flowchart of this study

The validation process refers to images with higher resolution and adjacent recording times using Landsat 8 images. The spatial resolution of Landsat 8 data that is 30 m can be used to validate the smoke conditions of GCOM-C images which have a resolution of 250 m - 1000 m. Meanwhile, the recording time in the territory of Indonesia is also quite close at 9.34 on Landsat 8 and 9.50 for GCOM-C, suitable for validation of dynamic natural conditions such as fire smoke.

3. Result and Discussion
The GCOM-C image has visible, infrared and thermal infrared wavelengths. In this study, the appearance of smoke is observed in the VN8 band (0.673 μm), SW3 band (1.63 μm), T01 band (10.8 μm) and T02 band (12.0 μm). The VN8 band in the near infrared spectral range is representative for distinguishing water and land objects because of the significant spectral range between the. It is based on the spectral curve of the object (Figure 6). The SW3 band is representative for land identification (vegetation and soil) while the thermal band is for surface temperature detection.
The visual appearance of smoke objects based on these bands can be seen in Figure 7. Based on VN8 band, it is good at detecting fire smoke. Fire eventss from hotspot data that are overlayed with GCOM-C imagery show the presence of smoke originating from fire. In the VN8 greyscale image (Figure 7a) the smoke object has a higher brightness value than the land, but has similarity to the cloud object. The smoke object has a smooth texture with a thin long pattern extending in the direction of the wind and associated / sourced from hotspots. While other bands are visually less representative detect smoke objects.

Smoke detection using composite images was applied in this study. The combination of composite bands is shown in the picture above. Figure 8a is an RGB composite of VN8-SW3-VN8. Smoke has a white-purple color but has the same color as a high layer cloud. Figure 8b shows the composite RGB SW3-VN8-VN8. This composite shows smoke as a white-blue color but still has the same color as a high layer cloud. In the third combination, where the thermal band is used as a composite. Figure 8c shows a composite RGB image of VN8-SW3-T01. This composite has fire smoke with white-purple color and has a different appearance with high layer clouds. High layer clouds are orange which has different whithe smoke. The clouds have lower temperatures than the fire smoke detected by the thermal band.
Figure 8. RGB Composite of GCOM-C image (a) VN8-SW3-VN8 (b) SW3-VN8-VN8 (c) VN8-SW3-T01

Figure 9. Images comparison of (a) Himawari-8, (b) Landsat 8, and (c) GCOM-C
Figure 10. Overlay of smoke from Landsat-8 and GCOM-C

Figure 9 shows the comparison of GCOM-C images with other images with adjacent recording times. The Himawari image was recorded at 09.00 WIB, the Landsat 8 image was recorded at 09.34 WIB, while the GCOM-C was at 09.50 WIB. The smoke locations and patterns that form in this time span are almost the same, but there are changes from time to time. Overlay of smoke location and pattern from Landsat 8 and GCOM-C could be seen in Figure 10. The pattern of smoke distribution is expanding over time. Smoke detected from GCOM-C has a difference of 37% of the area of Landsat 8 smoke. This is due to the difference in recording time of 16 minutes so that the smoke has spread following the wind direction and the addition of smoke from fires that occur. But spatially, the source location of smoke objects between Landsat 8 and GCOM-C is appropriate at coordinates UTM Zone 50 X 166652 Y – 334600.

Figure 11. Condition of smoky fire location (a) field photo (b) drone map

The field check process shows the smoking conditions from the land fires (Figure 11). Land cover at the location is dominated by shrubs interspersed with woody trees. It is peatland area and causes ground fire. Smoke originated from smouldering which still occurs, while little flaming is found. Drone recording with a flying altitude of 100 m with Phantom DJI 4 shows smoking conditions in all locations. This location corresponds to smoke detected from GCOM-C image.
4. Conclusion
Utilization of GCOM-C data could detect smoke of forest and land fire in Indonesia. Near infrared band could detect forest/land fire smoke especially VN08 which has 0.6735 µm of wavelength. Combination of infrared and thermal bands in composite image VN8-SW3-T01 could differentiate between forest/land fire smoke and high layer cloud. Forest/land fire in Pulangpisau distribute the smoke to the west and northwest. This study needs follow-up activities to know of spectral value analysis of fire smoke from GCOM-C data.

References
[1] World Bank 2016 The Cost of Fire: An Economic Analysis of Indonesia’s 2016 Fire Crisis Jakarta: World Bank https://documents.worldbank.org/en/publication/documents-reports/documentdetail/776101467990969768/the-cost-of-fire-an-economic-analysis-of-indonesia-s-2015-fire-crisis
[2] Kustiyo, Dewanti R 2015 Penentuan Ambang Batas Temperatur untuk Pendeteksian Sumber Asap Kebakaran Hutan / Lahan dari Data Landsat-8 ( Studi Kasus Wilayah P. Kalimantan pada Musim Kemarau 2015 )
[3] Pandjaitan BS, Panjaitan A 2015 Pemanfaatan Data Satelit Cuaca Generasi Baru Himawari 8 Untuk Pendeteksi Asap Akibat Kebakaran Hutan dan Lahan di Wilayah Indonesia ( Studi Kasus : Kebakaran Hutan dan Lahan di Pulau Sumatera dan Kalimantan Pada Bulan September 2015 ) J Semin Nas Penginderaan Jauh 2015 636–651
[4] Tjahjaningsih A, Sambodo K A, Prasasti I 2005 Analisis Sensitivitas Kanal-Kanal MODIS untuk Deteksi Titik Api dan Asap Kebakaran PIT MAPIN XIV 14–15
[5] JAXA 2018 GCOM-C “ SHIKISAI ” Data Users Handbook First Edition Japan: JAXA
[6] Igarashi T 2010 Global Change Observation Mission - Climate ( GCOM-C ) International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives
[7] Imaoka K, Kachi M, Fujii H, et al. 2010 Global Change Observation Mission (GCOM) for Monitoring Carbon, Water Cycles, and Climate Change Proc IEEE 2010 98 717–734
[8] Kaneko T, Yasuda A, Takasaki K, et al. 2020 A new infrared volcano monitoring using GCOM-C (SHIKISAI) satellite: applications to the Asia-Pacific region Earth, Planets Sp; 72 Epub ahead of print 2020. DOI: 10.1186/s40623-020-01246-7
[9] Letu H, Ishimoto H, Riedi J, et al. 2016 Investigation of ice particle habits to be used for ice cloud remote sensing for the GCOM-C satellite mission Atmos Chem Phys 16 12287–12303
[10] USGS 2019 Landsat 8 ( L8 ) Data Users Handbook South Dakota: USGS
[11] LAPAN 2016 Informasi Titik Panas (hotspot) Kebakaran Hutan/Lahan. 1st ed. Jakarta: Deputi Bidang Penginderaan Jauh LAPAN
[12] Sanjaya H, Alhasanah F 2012 Perekaman Spectral Daun Tanaman Padi Terakibat Organisme Pengganggu Tumbuhan Wereng Batang Coklat ( WBC ) Bunga Rampai Penginderaan Jauh Indonesia Bandung: Pusat Penginderaan Jauh ITB

Acknowledgments
This study is part of SAFE Project, a collaboration between LAPAN and JAXA. Authors wishing to acknowledge Dr. M. Rokhis Komarudin as the head of Remote Sensing Application Centre LAPAN which already facilitate this study. We would like to thank JAXA which provide and give access to GCOM-C data.