Comparison of Spectral Characteristic between LAPAN-A3 and Sentinel-2A

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Abstract. Indonesian National Institute of Aeronautics and Space (LAPAN) started building its experimental microsatellite back in 2007 and finally able to launch its first microsatellite dubbed as LAPAN-A1/LAPAN-Tubsat. With the launch of LAPAN-A3/LAPAN-IPB, Indonesian experimental satellite programme hit its third generation. LAPAN-A3 is carrying multiple payloads including multispectral push-broom imager, digital matrix camera, as well as video camera. This paper aims to highlight the spectral differences between LAPAN-A3 and the well-established Sentinel-2A multispectral to investigate the potential of using LAPAN-A3 data to complement the other well-established medium resolution satellite data. Comparisons between corresponding bands and band transformations were performed over a dataset. Three areas of interest were chosen as the test sites. Linear regression and Pearson correlation coefficient were then calculated between the corresponding bands. The preliminary results showed a moderate correlation between the two sensors with Pearson correlation coefficient ranging from 0.39 to 0.65. Some issues were found regarding the radiometric quality over the whole scene of LAPAN-A3.

Keywords: LAPAN-A3, Sentinel-2A, Microsatellite, Spectral Comparison

1. Introduction

LAPAN-A3/LAPAN-IPB was launched on October 2016 as part of the Indonesian National Institute of Aeronautics and Space program on Space Technology. LAPAN-A3 is carrying multiple payloads including multispectral push-broom imager, digital matrix camera, as well as video camera. The multispectral payload, dubbed as Line Imager Space Application (LISA), has four multispectral bands ranging from visible to near infrared spectrum. With 123 km swath width, it falls between the 185 km of Landsat-8 OLI and the 100km tiled Sentinel-2A/2B MSI data. With this successful launch, there have not been many comparative analyses between these platform in terms of image quality, classification, and accuracy assessment. The spectral comparison between multiple different sensors [1][2][3][4][5][6], especially for the newly launched platforms often performed to identify the sensors performance on board the satellite after its launch. Tabel 1 shows the multispectral characteristics of LAPAN-A3 compared to two aforementioned operational medium resolution EO satellites.

The nature of high cloud cover in tropical region remains a challenge on the availability of usable optical remote sensing data. The joint use of different satellite sensor boasting similar spatial and spectral characteristic offers the opportunity to build usable time series data for long time monitoring and disaster
mitigation [1][7]. Thus, the application of combining multiple Earth Observation (EO) satellite sensors for a combined use is attracting researchers and users in order to fill the gaps in observations [5].

Table 1. Multispectral Sensor characteristics of LAPAN-A3 LISA and Sentinel-2A MSI. Bands with bold font marked the corresponding bands of each sensor.

| Satellite Sensor                  | Band     | Spectral Range   | Spatial Resolution | Swath Width | Revisit time | Radiometric Quantification |
|----------------------------------|----------|------------------|--------------------|-------------|--------------|---------------------------|
| LAPAN-A3 LISA (Line Imager Space Application) | B1 - Blue | 0.41 – 0.49 μm | 18 m              | 122.4 km    | 21 days      | 16 bit                    |
|                                  | B2 - Green | 0.51 – 0.58 μm | 18 m              | 122.4 km    | 21 days      | 16 bit                    |
|                                  | B3 - Red   | 0.63 – 0.70 μm | 18 m              | 122.4 km    | 21 days      | 16 bit                    |
|                                  | B4 - NIR (Near Infrared) | 0.77 – 0.99 μm | 18 m              | 122.4 km    | 21 days      | 16 bit                    |
| Sentinel-2A MSI (Multi-Spectral Instrument) | B1 - Coastal Aerosol | 0.433 – 0.453 μm | 60 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B2 - Blue  | 0.458 – 0.523 μm | 10 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B3 - Green | 0.543 – 0.578 μm | 10 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B4 - Red   | 0.650 – 0.680 μm | 10 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B5 - Red Edge 1 | 0.698 – 0.713 μm | 10 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B6 - Red Edge 2 | 0.733 – 0.748 μm | 20 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B7 - Red Edge 3 | 0.765 – 0.785 μm | 20 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B8 - NIR   | 0.785 – 0.900 μm | 10 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B8A - NIR Narrow | 0.855 – 0.875 μm | 20 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B9 - Water Vapor | 0.930 – 0.950 μm | 60 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B10 - Cirrus | 1.365 – 1.385 μm | 60 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B11 - SWIR 1 | 1.565 – 1.655 μm | 60 m              | 290 km      | 10 days      | 12 bit                    |
|                                  | B12 - SWIR 2 | 2.100 – 2.280 μm | 20 m              | 290 km      | 10 days      | 12 bit                    |

Source: [8][9][10]

As the satellite itself is still an experimental satellite and yet reached its full operational capacity, we were not yet able to exploit the necessary information to perform the necessary radiometric and atmospheric correction. Therefore, the spectral comparison performed in this study was meant to be a first step towards a more comprehensive radiometric correction of LAPAN-A3 using relative radiometric normalization technique [11]. The image analysed in this study was provided by LAPAN’s Satellite Technology Center (PUSTEKSAT) for first assessment and feedback. This paper aims to point out the spectral differences between LAPAN-A3 LISA and Sentinel-2A MSI.

2. Material and Methods

LAPAN-A3 and Sentinel-2A were acquired on October 2016 in some part of Jember Regency, in East Java Province, Indonesia (Figure 1). This particular data was the one with the least cloud coverage. However, these datasets were not perfectly covered each other, and only portions of them were overlapped as shown in figure 1A.

In this preliminary assessment, we only used a single date, early stage LAPAN-A3 multispectral data. Considering the availability of LAPAN-A3 images was still limited due to its early stages and the cloud cover in Indonesian region, we were not able to obtain the same day image between the two sensors. What we have, instead, was images recorded in the same month, which is in October 2016, and within 1 day of each other. LAPAN-A3 was acquired on October 19th, and Sentinel-2A was acquired on October 18th.

The data preparation involved the geometric co-registration between LAPAN-A3 and Sentinel-2A. Sentinel-2A was used as the reference/base image; hence the final product would match Sentinel-2A coordinates (Universal Transverse Mercator, WGS 1984 Datum). Geometric co-registration involves
image resampling and is often reduced the image quality [12]. To minimize the influence of resampling procedure on spectral information, we selected the nearest neighbour interpolation method for our study, as it found to be able to maintain the original gray level compared to bilinear and cubic convolution interpolation [2]. We then resampled Sentinel-2A data to match LAPAN-A3 data to 18 meter using the aforementioned interpolation method.

![Figure 1](image-url)  
**Figure 1.** Overview of study area. (A). LAPAN-A3 full scene with RGB 432. Blue rectangle is the Sentinel-2A footprint. (B) Detailed look at the overlapped area. Coloured rectangles on the top figure represent three areas of interest in this study. Blue, yellow, and green rectangles are AOI 1, AOI 2, and AOI 3, respectively.

On this initial approach, three rectangular shape areas of interest (AOI) were created. These AOIs were chosen to represent different landuse/landcover characteristic. The AOIs distribution is shown in figure 2. AOI 1 is a steam power plant, known as PLTU Paiton Unit 9. As a power plant, it is mostly covered with concrete and asphalt. Large building blocks are also dominant with little vegetation. The vegetation is minimum compared to other impervious surface, which consist of well-maintained grass and sparse broadleaf trees. Being a steam generated power plant, a 50 meter wide canal is also existed within its parameter. AOI 2, Located in Kraksaan, Probolinggo, represents rural area that consists of a mixed of settlements and sparse vegetation. Impervious surface, however, considered more dominant than vegetation. AOI 3 represents a denser impervious surface than AOI 2, located in Besuki, Situbondo.
The spectral comparison were conducted on these areas are considered less affected by the seasonal and biological cycles [13]. These data then clipped based on previous AOIs.

Four original bands (B, G, R, NIR) and two spectral indices, NDVI and NDWI [14] were computed and compared using original digital number value without any prior radiometric correction. Considering the similar bandwidth between LAPAN-A3’s band 4 and Sentinel-2A band 8, we decided to use it, instead of the narrower Sentinel-2A’s band 8A for infrared spectrum. The use of spectral indices was to explore common land cover type, as well as to have a more comparable data in terms of radiometric quantifications, and computed as follows:

\[
\text{NDVI} = \frac{\rho_{\text{NIR}} - \rho_{\text{R}}}{\rho_{\text{NIR}} + \rho_{\text{R}}} \tag{1}
\]

\[
\text{NDWI} = \frac{\rho_{\text{G}} - \rho_{\text{NIR}}}{\rho_{\text{G}} + \rho_{\text{NIR}}} \tag{2}
\]

Where \(\rho_{\text{NIR}}, \rho_{\text{R}}, \rho_{\text{G}}\) are the digital number (DN) of near infrared, red, and green, respectively.

The comparisons were evaluated to obtain the correlation, by computing the coefficients of linear regression and the Pearson Correlation coefficient. Linear regression was computed with the assumption that the atmospheric differences between images on the same geographic location acquired at different times are linearly correlated [11][13][15]. The workflow used in this study is shown in figure 3.

![Figure 2. Workflow of the study](image-url)
3. Results and Discussion

The co-registration between the corresponding bands was performed using 25-30 tie-points. The total RMSE on the tie-points coordinates was ranging from 5 to 9 meters (less than LAPAN-A3 pixel size). These values are sufficient in order to do pixel-by-pixel comparison for the corresponding data [5][6][16][17]. Each RMSE for the corresponding bands are shown in Table 2. Finally, the Sentinel-2A data were resampled to LAPAN-A3 spatial resolution (18 m) with nearest neighbour algorithm.

| Bands | LAPAN-A3 | Sentinel-2A | RMSE (meter) |
|-------|----------|-------------|--------------|
| 1     | 2        | 6.5         |
| 2     | 3        | 8.8         |
| 3     | 4        | 4.9         |
| 4     | 8        | 9.2         |

Table 2. RMSE for each corresponding band

Six pairs of corresponding band were generated for each AOI. Linear regression and the correlation coefficient of the corresponding bands over these three AOIs were calculated. The results are as follows.

| Band | AOI | Linear Regression | Pearson Correlation |
|------|-----|-------------------|---------------------|
|      |     | Intercept Slope   | Coefficient         |
| LAPAN-A3 | Sentinel-2A |                   |                     |
| 1     | 2    | -309.09 0.1446    | 0.582               |
| 2     | 2    | -704.96 0.1698    | 0.514               |
| 3     | 2    | 51.534 0.1266     | 0.522               |
| 1     | 3    | -15.634 0.0454    | 0.544               |
| 2     | 3    | -84.356 0.0457    | 0.398               |
| 3     | 3    | 59.672 0.0546     | 0.479               |
| 1     | 4    | 122.54  0.054     | 0.528               |
| 2     | 4    | -149.75 0.0506    | 0.530               |
| 3     | 4    | 104.62  0.0514    | 0.420               |
| 1     | 8    | -189.83 0.1082    | 0.557               |
| 2     | 8    | -962    0.1259    | 0.548               |
| 3     | 8    | 588.26  0.1256    | 0.534               |
| 1     | NDVI (3,4) | 0.298 0.9255 | 0.599               |
| 2     | NDVI (4,8) | 0.3228 1.1387 | 0.655               |
| 3     | 0.2763 1.0253 | 0.527               |
| 1     | NDWI (2,4) | 0.2906 0.2625 | 0.449               |
| 2     | NDWI (3,8) | 0.3546 1.1964 | 0.655               |
| 3     | 0.3135 1.0156 | 0.578               |

Table 3. Spectral comparison between LAPAN-A3 and Sentinel-2A data on three different AOIs
Figure 3. Scatter plots of 4 corresponding bands and 2 spectral indices over 3 AOI
Linear models for three AOI are shown in figure 4. Visually, linear correlation can be seen on all of the corresponding spectral indices, except for NDWI at AOI 1 (Figure 3.P). Blue and green band on AOI 3 yield less linear correlation compared to the other (Figure 3B, 3C, 3E, 3F, 3I). The highest correlation coefficient was found on AOI 2 with NDWI and NDVI both scored 0.655 (table 2). Table 2 shows a complete correlation value. The lowest correlation coefficient was also found on AOI 2 with green band correlation at 0.398. Average correlation coefficient for three AOI gave moderate value (>0.5) (figure 6). Highest average correlation for all three AOIs was found on NDVI at 0.59. Over three AOIs, red and green band gave less than 0.5 correlation, with the latter was at the lowest with 0.47.

Correlations on NIR band for all three AOI are relatively constant. This was expected as the near infrared band with longer wavelength was less affected by atmospheric condition compared to visible bands, as explained by [18][19]. NDWI correlation on ROI 1 was poorer due to the existence of canal within the AOI. Upon visual evaluation on very high resolution Geo-eye data, this canal is a highly dynamic in terms of its current. Coupled with the difference in acquisition time, this would introduce an error within NDWI value. As reported by [20], dynamic water would cause high variability in the
reflectance value of green and infrared band. A calm, clear and deep open waterbody might fix this problem as it will reduce the aforementioned variability.

**Figure 7.** Uneven illumination across-track of LAPAN-A3 LISA Scene. (A) Visual evaluation for uneven illumination over LAPAN-A3 LISA’s whole scene. Red line indicates the transect line for spectral profile drawn from west to east. (B) Spectral profile over the transect line.

It is also worth to note that the spectral indices gave higher average value compared to the original bands as shown by figure 5. It is slightly different with [1], where they found how correlation coefficient may decrease when the number of bands involved increase, due to noises. To explain this phenomenon, it is better to look at the bands involved in the spectral indices that being used. Our study uses only two bands, for each index. Both of them used NIR band, which was less affected by atmospheric condition. In the other hand, [1] compared the FII (ferrous iron index) [21] which involved two more bands than NDVI or NDWI.

The 1-day difference on the acquisition time should also be carefully considered as it may cause some differences in radiometric value because of different atmosphere and illumination conditions. This should be minimized on our future work by using the same day image pair.

For our future works, we will try to makes the same day comparison between two datasets, provided that we managed to get a relatively cloud free data over different data scenes covered different area in Indonesia. The above explanation also emphasizes how the selection of test area should carefully be evaluated. A relatively homogenous area, located in flat topography, or calm, clear water body are great test site to perform spectral comparison.

This study found an issue regarding LAPAN-A3 LISA’s radiometric quality that needs to be addressed in order to fully utilize multispectral data acquired by the satellite. As shown in Figure 8, LAPAN-A3 suffers an uneven cross-track illumination (CTI). This type of error is a systematic error, which means that it can be resolved further along the way, provided that all the necessary parameters were acquired. Furthermore, several approaches have also been developed in order to correct this error[22][23][24]. While this approach works well with Hyperion data, its performance on LAPAN-A3 are still needs to be further evaluated. Alternatively, a relative radiometric normalization (RRN) could be applied to the image prior to spectral comparison process. [15] described these several RRN method, specifically on the methods that only used reference-subject image pairs. As mentioned in the introduction, this will be included on our future research.

The initial findings can be used as a reference point on how LAPAN-A3 LISA imagery correlates to other well-established medium resolution EO satellite data. A better radiometric correction, such as converting digital number to at-satellite reflectance would reduce the variation caused by sunlight and
atmosphere [2]. [25] further explained that this process would reduce the discrepancies between multi-platform satellite data acquired at different imaging times in terms of radiant quantities of incidence and reflections. Thus, would improve the correlation between the two sensors. This information also important as it can be used as a reference on choosing the appropriate method on utilizing LAPAN-A3 data. A landuse/landcover extraction where the training data extracted from the image itself is less affected by the difference, rather than imported from another image [26]. Another potential use is a change detection analysis where the images are analysed independently using post-classification change detection method [19][27][28].

4. Conclusions

The study provides an initial evaluation of LAPAN-A3 spectral characteristics compared to Sentinel-2A MSI data. This paper found moderate correlation, ranging from 0.39 to 0.65, between LAPAN-A3 and Sentinel-2A spectral information on visible-near infrared spectrum with one-day time gap. Near infrared and blue band performed better compared to two other bands. The use of spectral indices, particularly NDVI and NDWI can increase the correlation coefficient. A careful examination on the test area should be considered as it can affect the correlation coefficient. This initial finding will act as a reference point on how to better utilize LAPAN-A3 spectral information. However, several problems were found within LAPAN-A3 regarding the striping effect as well as uneven illumination across whole scene that needs to be addressed before LAPAN-A3 multispectral data can be fully utilized.

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References

[1] Mandanici E and G Bitelli 2016 Preliminary Comparison of Sentinel-2 and Landsat 8 Imagery for a Combined Use. Remote Sens [Internet] 8(12) p 1014. Available from: http://www.mdpi.com/2072-4292/8/12/1014
[2] Li G, Li X, Li G, Wen W, Wang H, Chen L, et al 2013 Comparison of spectral characteristics between China HJ1-CCD and landsat 5 TM imagery. IEEE J Sel Top Appl Earth Obs Remote Sens 6(1) pp 139–48.
[3] Wang L, Yang R, Tian Q, Yang Y, Zhou Y, Sun Y, et al 2015 Comparative analysis of GF-1 WFV, ZY-3 MUX, and HJ-1 CCD sensor data for grassland monitoring applications Remote Sens 7(2) pp 2089–108.
[4] Quintanilha JA, Filho LE and Beltrame AMK 2007 Spatial and spectral comparison among IKONOS, CBERS and ASTER images to identify and detect land occupation changes around urban railway in Sao Paulo - Brazil Int Geosci Remote Sens Symp pp 659–62.
[5] Phongaksorn N, Tripathi NK, Kumar S, Soni P 2012 Inter-sensor comparison between THEOS and landsat 5 TM data in a study of two crops related to biofuel in Thailand. Remote Sens 4(2) pp 354–76.
[6] Hill J and Aifadopoulou D 1990 Comparative analysis of landsat-5 TM and SPOT HRV-1 data for use in multiple sensor approaches Remote Sens Environ 34(1 pp :55–70.
[7] van der Werff H and van der Meer F 2016 Sentinel-2A MSI and Landsat 8 OLI provide data continuity for geological remote sensing Remote Sens 8(11).
[8] ESA 2015 SENTINEL-2 User Handbook. European Space Agency 64 p.
[9] Hakim PR and Permala R 2017 Analysis of LAPAN-IPB image lossless compression using differential pulse code modulation and huffman coding. In: IOP Conference Series: Earth and Environmental Science [Internet]. IOP Publishing; [cited 2017 Mar 6]. p. 12096. Available
Documents/Dropbox/NWT_BiBlio/DOC/ePrints-2014-ijrs96.pdf