IOP Conf. Series: Earth and Environmental Science **500** (2020) 012081 doi:10.1088/1755-1315/500/1/012081

Evaluation of atmospheric correction algorithms for Sentinel-2 over paddy field area

Kurnia Ulfa, Hendayani, Masnita Indriani Oktavia, Kuncoro Adi Pradono, Liana Fibriawati, Fadila Muchsin, Danang Surya Candra, Kiki Winda Veronica Damanik

Pusat Teknologi dan Data Penginderaan Jauh LAPAN

e-mail: kurnia.ulfa@lapan.go.id

Abstract: Atmospheric correction is essential in satellite data processing to reduce atmospheric and lighting effects by studying the physical parameter of the earth's surface. In this study, ATCOR and 6S algorithms were evaluated for Sentinel-2 over paddy field area. In this evaluation, level-1C Top of Atmosphere (TOA) Sentinel-2 image was used as an input data. The spectral pattern analysis of the results was used to assess the reliability of the methods. As a result, the both methods produced the correct spectral patterns. Moreover, the results showed that the longer the wavelength the less the improvement values. It starts from the blue band, 43,2% for the fallow phase and 60% for the vegetative phase of BOA corrected image. In the other hand, the NDVI values of fallow and vegetative phases that derived from the two methods are not greatly different.

1. Introduction

Atmospheric correction is an important step in deriving land surface properties from satellite data [1] [2]. There are two kinds atmospheric correction. TOA (Top of Atmosphere) correction is a correction on imagery done to eliminate radiometric distortion caused by the sun position. Correction of TOA done through radiometric calibration by converting the digital number's values to reflectance or radians values [3]. Whereas, the BOA (Bottom of Atmosphere) correction is done to reduce the atmospheric disturbance during the data acquisition such as aerosols, water vapor, and ozone .

Sentinel-2 is a constellation of two satellite imagery, Sentinel-2A and Sentinel-2B, that enables image acquisition over the same area every 5 days. It was launched in 2015 with polar-orbiting. The mission of this Satellites is dedicated for agriculture and forest monitoring, land cover change, mapping of biophysical variables such as chlorophyll leaf content, leaf moisture content, leaf area index, monitoring of coastal and inland water, and mapping risks and disasters. Sentinel-2 L1C satellite data has been corrected TOA ortho geometrically and radiometrically. It is become the input for the BOA correction.

Vegetation indices are optical measures of vegetation canopy "greenness," a *composite* property of leaf chlorophyll, leaf area, canopy cover, and structure [4]. Paddy field become an indicator of vegetation indices because it can be identified easily based on its land change's physical characteristics.

Objects found on the earth's surface have certain characteristics in reflecting or emitting energy to the sensor. Spectral is an interaction between electromagnetic energy and object. Some objects have a great absorption energy but low reflective power, and vice versa [5].

A radiative transfer model, Second Simulation of the Satellite Signal in the Solar Spectrum known as 6S, is widely used in remote sensing [6] [7] [8] [9] . The method gives the parameter of atmospheric correction. Different from 6S, Sen2Cor is an atmospheric correction processor which main purpose is to correct the atmosphere effects of single-date Sentinel-2 data level-1C. This paper studied about the spectral pattern of paddy field. The spectral pattern was determined by the Sen2Cor and 6S methods. The comparison of the results was briefly described in this paper. Moreover, the results of the both methods were used to determine the vegetation indices value. Then, the analysis of vegetation indices completed this paper.

2. Method

2.1. Satellite imagery and study area

This study was done in paddy field area at Sukabumi district, West Java. The satellite imagery used is Sentinel-2 with spatial resolution of 10m. The data was acquired at September 17, 2018. The atmospheric correction used in this study are Sen2Cor by SNAP and 6S radiative transfer model. The evaluation was applied to the spectral response of the vegetative and fallow phases.

2.2. Sen2Cor

Sen2Cor is applied to granules of Top of Atmosphere (TOA) Level-1C orthorectified reflectance products to deliver a Level-2A Bottom of Atmosphere (BOA) [10]. The basic framework of the Sen2Cor processor consists of file modules coordinating interaction as shown on the Figure 1.

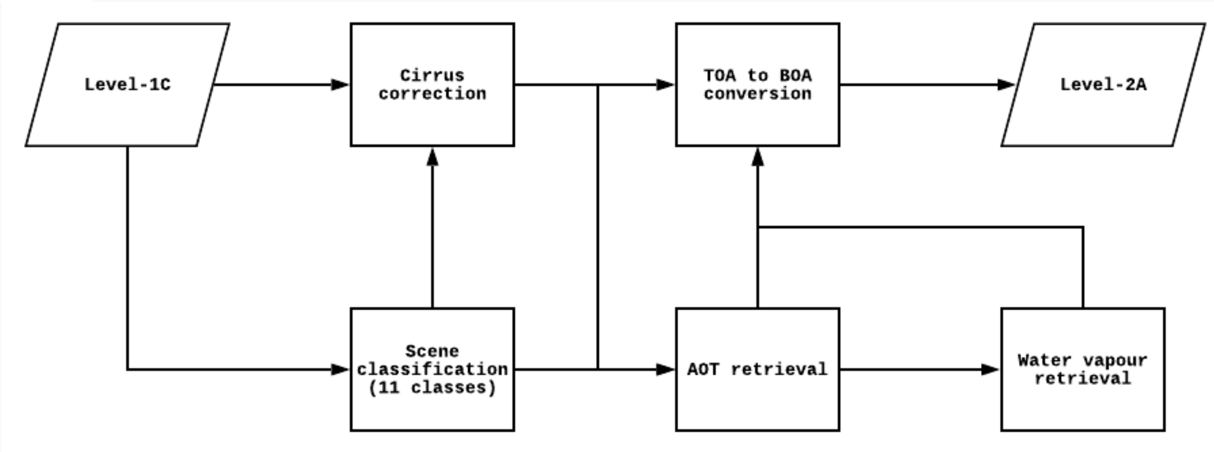

Figure 1. Level-2A processing schema with Sen2Cor. Source: [10]

Before starting the process, we have to input some parameter such as aerosol, water vapour, and ozone. The additional output from this process are Aerosol Optical Thickness mapping (AOT), Water Vapour mapping (WV), and Scene Classification mapping (SCL) with quality indicators for cloud and snow probabilities. Sen2Cor's output available in three types spatial resolution as seen in the Table 1 below [11].

Table 1. Characteristics of Sentinel-2 Images

Band	Wavelength (μm)	Spatial Resolution (m)
Band 1 – Coastal Aerosol	0,433 – 0,453	60
Band 2 – Blue	0,458 – 0,523	10
Band 3 – Green	0,543 – 0,578	10

Band 4 – Red	0,650 – 0,680	10
Band 5 – Vegetation Red Edge	0,698 – 0,713	20
Band 6 – Vegetation Red Edge	0,733 – 0,748	20
Band 7 – Vegetation Red Edge	0,765 – 0,785	20
Band 8 – NIR	0,758 – 0,900	10
Band 8A – Vegetation Red Edge	0,855 – 0,875	20
Band 9 – Water Vapour	0,930 – 0,950	60
Band 10 – SWIR – Cirrus	1,365 – 1,385	60
Band 11 - SWIR	1,565 – 1,655	20
Band 12 - SWIR	2,100 – 2,280	20

The figure 2a and 2b below show the Sentinel-2 image before and after the BOA atmosphere correction by *Sen2Cor*.

Figure 2a. The Sentinel-2 Top of Atmosphere (TOA) Level-1C image

Figure 2b. The Sentinel-2 Bottom of Atmosphere (BOA) Level-2A image

2.3. Second Simulation of the Satellite Signal in the Solar Spectrum/6S
The 6S is a development model of 5S which is improved in accuracy and application field with regard to Rayleigh and aerosol scattering effects. Globally, the input parameter and the structure of 6S are similar to 5S [12]. The 6S radiative transfer model is widely used to perform the atmospheric correction directly or to build a lookup table for the atmospheric correction [8]. In this study, we used the first option.

2.4. Vegetation indices
After the atmosphere correction using *Sen2Cor* and 6S, the next step is deriving the vegetation index especially the NDVI. In this case, we used the 10m spatial resolution.

The normalized difference vegetation index (NDVI) is a normalized ration of the NIR and red bands,

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

NDVI values range from -1 to 1. The negative value, close to -1, can be interpreted as water, the negative value, close to 0, generally correspond to barrens area of rock, sand, or snow. The low positive value represents shrub and grassland, while the high values, approaching 1, indicate temperature and tropical rainforests.

2.5. Assessment

In this study, visual and statistical assessments will be used to evaluate the results of atmospheric correction using Sen2Cor and 6S. In statistical assessment, we will compare spectral responses of fallow and vegetative phases of TOA and BOA correction. Moreover, we will use NDVI to investigate the reliability of the methods.

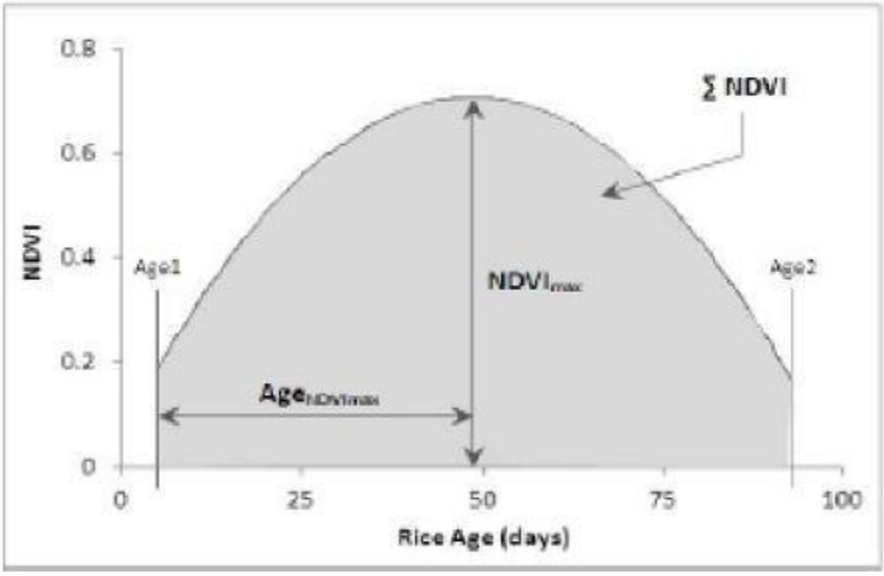

Figure 3. An illustration of method used to calculate AgeNDVI$_{max}$, NDVI$_{max}$, and ΣNDVI [13]

The best relationship between rice age and rice NDVI is a quadratic equation (see Figure 3). It can be seen from the equation, NDVI$_{max}$ value achieved during crop period. Based on the Figure, we can evaluate NDVI of fallow and vegetative phases from the results of Sen2cor and 6S correction.

3. Results and Discussion

In visual assessment, Figure 1 shows the BOA correction improved the contrast of the image. It makes the image more clearly and detail visually. The vegetation such as forest and cropland look greener and the open land and settlement look brighter. This atmospheric correction is useful especially in visual analysis as we can identify each object more clearly.

The discussion of the result divided by two phases of rice growth. Firstly, we will discuss about the fallow phases of rice growth. Generally, spectral response of fallow phase is similar to the spectral response of open field. Spectral response rises with increasing wavelength. The greater the waves emitted, the greater the spectral response. Figure 4 (a) shows that the fallow phase spectral response in the blue band that have been corrected by TOA is greater spectral response in the blue band that have been corrected by BOA. It is because the BOA correction process reduces the atmospheric disturbance that can't be solved by the TOA correction. In the blue band, BOA correction provides 43,2% improvement. The longer the wavelength, the less the improvement value.

(b)

Figure 4. Comparison of spectral responses between digital number atmospheric corrected TOA and BOA: (a) fallow phase and (b) vegetative phase

The spectral response of vegetative phase follows the spectral response of vegetative area. It is relatively low in blue and green bands but significantly increased in NIR band. BOA correction provides 60% improvement on TOA correction. Similar to the spectral response of fallow phase, the spectral response of vegetative phase has a less improvement for the longer wavelength. It is showed by Figure 4 (b).

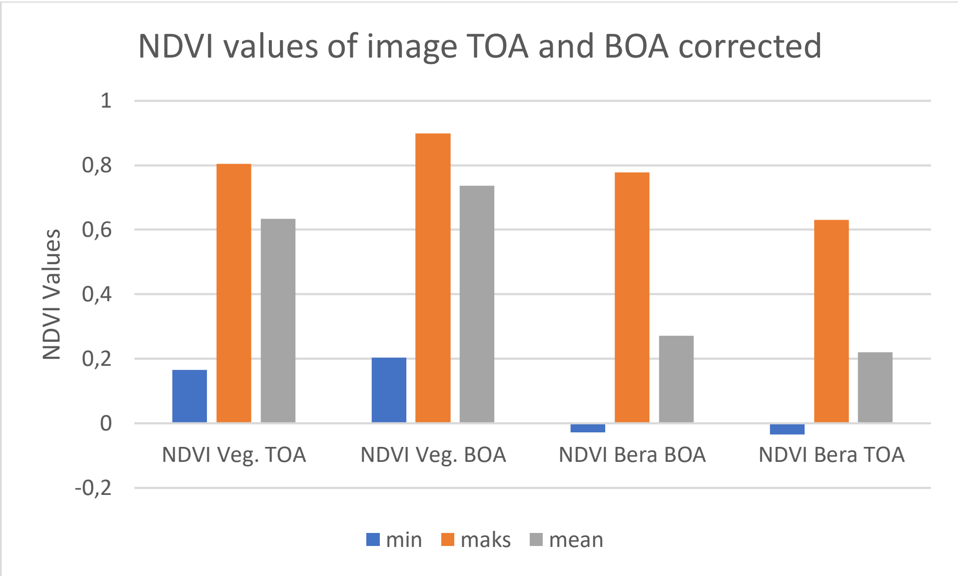

Figure 5. NDVI values of fallow and vegetative phase of TOA and BOA corrected image

Based on the quadratic equation shown in Figure 3, the range of NDVI values of vegetative phase is from 0.2 to 0.7. As a result, the NDVI of vegetative phase of BOA is from 0.2 to 0.9. On the other hand, the vegetative phase of TOA is slightly different. The NDVI values start from 0.18 and it reaches to 0.8.

Based on the Figure 5. The lowest mean values of NDVI of fallow and vegetative phase was image with TOA corrected. This is because the BOA correction improves the pixels values of TOA image. Therefore, the NDVI values of BOA corrected image is closer to the real values of NDVI. In the other hand, the NDVI values of fallow phase in 6S corrected image is greater than the BOA corrected, but the NDVI values of vegetative phase is lower than the NDVI values of vegetative phase in BOA corrected image. It is shown in the Figure 6. below.

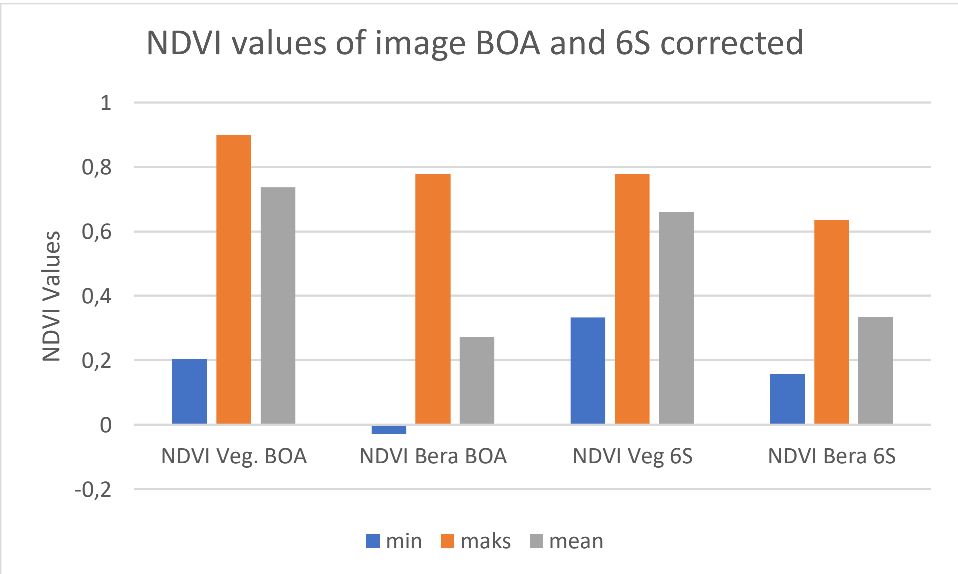

Figure 6. NDVI values of fallow and vegetative phase of BOA and 6S corrected images

4. Conclusion
The BOA correction makes images more clearly and detail visually. So that, we can identify each object more clearly. Therefore, this atmospheric correction is useful in visual analysis. In the fallow and vegetative phases assessment, BOA correction showed the increasing reflectance values to each band. The longer the wavelength the less the improvement values. It starts 43,2% and 60% in the blue band of fallow phase and vegetative phase, respectively. Because of the BOA correction effect decreased the radiometric distortion of the TOA image, the NDVI values of BOA corrected image is closer to the real values of NDVI. In the other hand, the NDVI values of BOA and 6S corrected image did not have a significant difference.

5. Acknowledgment
We would like to thank the Ministry of Research, Technology, and Higher Education for funding support by INSINAS Program 2019 and Remote Sensing Technology and Data Center – LAPAN for supporting and providing data and image processing facilities.

6. References
[1] E. F. Vermote and S. Kotchenova, "Atmospheric correction for the monitoring of land surfaces," vol. 113, no. June, pp. 1–12, 2008.
[2] I. Sola, A. García-martín, L. Sandonís-pozo, and J. Álvarez-mozos, "Int J Appl Earth Obs Geoinformation Assessment of atmospheric correction methods for Sentinel-2 images in Mediterranean landscapes," *Int J Appl Earth Obs Geoinf.*, vol. 73, no. June, pp. 63–76, 2018.
[3] R. Rahayu and D. S. Candra, "Koreksi Radiometrik Citra Landsat-8 Kanal Multispektral Menggunakan Top of Atmosphere (Toa)," *Pros. Semin. Nas. Penginderaan Jauh 2014*, no. Ldcm, p. 2014, 2014.
[4] A. Huete, K. Didan, W. Van Leeuwen, T. Miura, and E. Glenn, "Land Remote Sensing and Global Environmental Change," vol. 11, pp. 579–602, 2011.
[5] J. A. Prieto-amparan, F. Villarreal-guerrero, and M. Martinez-salvador, "Atmospheric and Radiometric Correction Algorithms for the Multitemporal Assessment of Grasslands Productivity," 2018.
[6] F. Muchsin *et al.*, "Comparison of atmospheric correction models: FLAASH and 6S code and their impact on vegetation indices (case study: paddy field in Subang District, West Java)," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 280, p. 012034, 2019.
[7] D. Wang, R. Ma, K. Xue, and S. A. Loiselle, "The assessment of landsat-8 OLI atmospheric correction algorithms for inland waters," *Remote Sens.*, vol. 11, no. 2, 2019.
[8] Y. Hu, L. Liu, L. Liu, D. Peng, Q. Jiao, and H. Zhang, "A landsat-5 atmospheric correction based on MODIS atmosphere products and 6s model," *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, vol. 7, no. 5, pp. 1609–1615, 2014.
[9] P. K. Srivastava and D. Han, "Estimation of land surface temperature from atmospherically corrected LANDSAT TM image using 6S and NCEP global reanalysis product," pp. 5183–5196, 2014.
[10] F. Gascon, C. Bouzinac, and O. Thépaut, "Copernicus Sentinel-2A calibration and products validation status," *Remote Sens.*, vol. 9, no. 6, Jun. 2017.
[11] M. Claverie *et al.*, "Remote Sensing of Environment The Harmonized Landsat and Sentinel-2 surface reflectance data set," *Remote Sens. Environ.*, vol. 219, no. August 2017, pp. 145–161, 2018.
[12] E. F. Vermote, D. Tanré, J. L. Deuze, M. Herman, and J.-J. Morcrette, "Second Simulation of The Satellite Signal in the Solar Spectrum, 6S: An Overview," *IEEE Trans. Geosci. Remote Sens.*, vol. 35, no. 3, pp. 675–686, 1997.
[13] I. W. Nuarsa and F. Nishio, "Relationships Between Rice Growth Parameters and Remote Sensing Data," *Int. J. Remote Sens. Earth Sci.*, vol. 4, no. 1, 2010.