Comparison of atmospheric correction models: FLAASH and 6S code and their impact on vegetation indices (case study: paddy field in Subang District, West Java)

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Abstract. Landsat-8 data (level 1T) received by users are still in digital number and can be used directly for mapping land use / land cover. However, the data still has low radiometric accuracy when it is used to derive information such as vegetation index, biomass, land use/ land cover classification, etc. so that so that it requires radiometric / atmospheric correction. In this study, we use atmospheric correction method of the second simulation of satellite in the solar spectrum (6S) and Fast Line-of-sight Atmospheric Analysis of Spectral Hypercube (FLAASH) to eliminate atmospheric influences and compare the results with field measurements. The atmospheric parameters used were aerosol optical depth (AOD), water vapour column and ozone thickness from MODIS data with the date and time of acquisition approaching with Landsat-8 data. From the analysis conducted on the spectral response of atmospheric corrected image shows the 6S model has better accuracy for the spectral response from the rice growth phase compared to the FLAASH model. The analysis of the values of vegetation indices (NDVI, EVI, SAVI and MSAVI) shows that the 6S model has better accuracy for NDVI while for EVI, SAVI and MSAVI the FLAASH model has slightly better accuracy than 6S.

Keywords: Landsat-8, FLAASH, 6S, vegetation index

1. Introduction
Landsat OLI from remote sensing ground station has the highest standard level is level 1T which has corrected precision geometry (using GCP and DEM) and corrected systematic radiometry (www.usgs.gov). Systematic radiometric correction only corrects radiometric disturbances that occur internally on the sensor. Radiometric disturbances due to external conditions such as differences in the position of the sun due to different seasons, object geometry (viewing angle) and atmospheric disturbances due to scattering and absorption by particles in the atmosphere such as dust, water vapor and aerosols have not been corrected. The method for remove it is called atmospheric correction [1]–[3]

There are several methods for atmospheric corrections, among others, using Fast Line-of-sight Atmospheric Analysis of Spectral Hypercube (FLAASH) model based on modtran-4 [4], [5], Atmospheric Topographic Correction (ATCOR) model [6] and the Second Simulation of Satellite Signal method in the Solar Spectrum (6S) [2], [7]. Atmospheric correction using FLAASH and ATCOR provides excellent accuracy [8]–[10] but these modules cannot be used freely because it is licensed. The 6S model is widely used today because it has very good accuracy and can be run online
through the website http://6s.ltdri.org/. Besides that, the 6S model can be developed specifically to find the appropriate parameters to achieve maximum correction accuracy.

Factors that determine the accuracy of the results of atmospheric correction both FLAASH, ATCOR and 6S are atmospheric parameters in the form of aerosols, water vapor and ozone, but these parameters are rarely available from field measurements. To overcome this, it can use satellite data available near real time, namely Terra / Aqua data MODIS (Chen, Chen, & Li, 2010; Hu et al., 2014). Therefore, this study aims to make atmospheric correction of Landsat-8 level 1T data using the 6S method using aerosol, water and ozone parameters from Terra/Aqua MODIS data. The results of atmospheric correction will be analyzed in paddy fields to see the suitability of the spectral response of objects in the image and vegetation index with field measurements.

2. Methods

2.1. Satellite imagery and study area

The satellite imagery used is Landsat OLI with a spatial resolution of 30 m, Path/Row: 122/064 and acquisition date is September 24, 2018 with local time is 09.59'45.7 a.m. Landsat-8 OLI was provided by LAPAN Ground Station at Parepare, South Sulawesi, Indonesia. The image is used because it has a fairly clear cloud coverage of less than 6% (http://landsat-catalog.lapan.go.id/).

The location of the study was carried out in agricultural areas in Subang Regency, West Java Province, where the distribution of objects was quite homogeneous so that the reflections of the surrounding objects did not significantly affect the reflection value of the observed objects. The objects observed were vegetative and generative rice fields in the districts Ciasem, Binong and Sukamandi. (Fig. 1). The Subang area is included in the area in West Java which has the largest rice harvesting area of 173,635 ha with production reaching 991,003 tons [11]. Distribution of rice in the Subang region is found in the northern part for irrigated rice fields and in the south for rainfed rice fields.

![Study area foot print: path 122 row 064](image_url)

**Figure 1.** Study area: foot print of Landsat OLI and validation area
2.2. Atmospheric correction and parameter setting

2.2.1. 6S models. The 6S model was developed by Vermote et al. based on the 5S model [2]. It considers the atmospheric effects of the entire radiative transfer process and can better eliminate the influence of Rayleigh scattering and aerosols, which has been widely used in applications [9] [10]. Before atmospheric correction, Landsat-8 imagery are converted from the digital number to radian and then to the TOA reflectance [12]. The condition of aerosol was setting using the continental model [13]. Atmospheric correction parameters such as Aerosol Optical Depth (AOD) at 550 nm wavelength (MOD04) and water vapour columns (MOD05) are obtained from level 2 MODIS atmosphere products collection. For this study we use the average value of AOD, water vapour and ozone [14]. The average value of AOD and water vapor in the study area are respectively 0.273 at 550 nm and 0.566 gr cm⁻².

Ozone thickness parameters obtained from MODIS surface reflectance products is MYD09CMG. The average value of ozone in the study area is 0.142 cm atm. MODIS atmospheric products are downloaded from https://ladsweb.modaps.eosdis.nasa.gov. The value of each parameter is taken from the average value included in all Landsat OLI scene data on acquisition date and time adjacent to the date and time Landsat OLI. The output of the 6S model is the surface reflectance image.

2.2.2. FLAASH model. The FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubus) model is a software package developed by the Air Force Research Laboratory, Space Vehicles Directorate (AFRL/VS), Hanscom AFB and Spectral Sciences, Inc. (SSI) to support the analyses of visible-to-shortwave infrared (Vis-SWIR) hyperspectral and multispectral imaging sensors. FLAASH derives its 'physics-based' mathematics from MODTRAN4 [4] [15] [16]. It can correct cascade effect caused by diffuse reflection, and is an excellent atmospheric correction method [9]. The atmospheric parameters used for the FLAASH model in this study are visibility (34.12 km) obtained from equation 1 [17], AOD at 550 nm is 0.273 and angstrom exponent is 0.471. The altitude is 0.05 km and the aerosol type selection is maritime. The output of the FLAASH model is the surface reflectance image.

\[
\text{Visibility} = -15\ln(\text{a} (l) ^{\alpha}) / 0,613
\]

\[
\text{a} (l) = \text{AOD at 550 nm}
\]

\[
\alpha = \text{angstrom exponent}
\]

2.3. Vegetation indices

Calculation of vegetation index values uses four vegetation indices commonly used specifically for applications in agriculture [18] including the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Adjusted Vegetation Index (SAVI) and Modified Soil Adjusted Vegetation Index (MSAVI). This study uses a vegetation index formula for surface reflectance products from Landsat OLI data from USGS [19] as follows:

a. Normalized Difference Vegetation Index (NDVI)

\[
\text{NDVI} = (\rho_{\text{NIR}} - \rho_{\text{Red}}) / (\rho_{\text{NIR}} + \rho_{\text{Red}})
\]

b. Enhanced Vegetation Index (EVI)

\[
\text{EVI} = 2.5 (\rho_{\text{NIR}} - \rho_{\text{Red}}) / (\rho_{\text{NIR}} + 6\rho_{\text{Red}} - 7.5\rho_{\text{blue}} + 1)
\]

c. Soil Adjusted Vegetation Index (SAVI)

\[
\text{SAVI} = (\rho_{\text{NIR}} - \rho_{\text{Red}}) / (\rho_{\text{NIR}} + \rho_{\text{Red}} + 0.5)(1.5)
\]

d. Modified Soil Adjusted Vegetation Index (MSAVI)

\[
\text{MSAVI} = (2\rho_{\text{NIR}} + 1 - \sqrt{((2\rho_{\text{NIR}} + 1)^2 - 8(\rho_{\text{NIR}} - \rho_{\text{Red}}))}) / 2
\]
2.4. Spectral Measurement

Measurement of object spectral response aims to validate the results of atmospheric correction. Measurements are made using spectrometers ASD HandHeld-2 that work on visible wavelengths up to near infrared. The objects measured were vegetative and generative phase rice fields (according to the conditions of the objects in the field) located in Binong, Ciasem and Cijambe Districts as shown in Figure 2. The measurement method uses vicarious calibration [20] with a distance between samples of 10 meters in a sample of 30 square meters (equivalent to the size of 1 pixel multispectral Landsat OLI). At each distance of 10 meters, a re-calibration of the spectrometer equipment was carried out to improve the accuracy of the measurement results. The results of the spectrometer measurements are then compared with the results of atmospheric correction.

![Vegetative-1](image1)
![Vegetative-2](image2)

![Generative-1](image3)
![Generative-2](image4)

**Figure 2.** Example of the type of rice growth phase measured in the district Binong, Ciasem and Cijambe Kab. Subang
3. Results and Discussion
The atmospheric correction of Landsat OLI images using atmospheric parameters from MODIS atmosphere products result in surface reflectance that can be used to obtain an accurate vegetation index [18]. Furthermore, the discussion refers to the comparison of the spectral response of the object to atmospheric corrected imagery with field measurements and the vegetation indices.

3.1.1. Comparison of Object Spectral Response with Spectral Measurements in The Field. The spectral response of rice growth phases in Figure 3 show that the 6S model has a better spectral response compared to the FLAASH model, especially in the blue band (1%) and NIR (17%). Whereas the green and red bands have the same RMSE value of 2% (Table 1).

![Figure 3](image)

**Figure 3.** Comparison of the spectral responses between surface reflectance from atmospheric corrected imagery and field measurements in the rice growth phase: (a) vegetative phase-1, (b) vegetative-2, (c) generative-1, and (d) generative-2.

| Rice growth phases | RMSE Blue 6S/FLAASH | RMSE Green 6S/FLAASH | RMSE Red 6S/FLAASH | RMSE Near infrared 6S/FLAASH |
|--------------------|---------------------|----------------------|-------------------|--------------------------|
| Vegetative-1       | 0.008/0.012         | 0.008/0.002          | 0.008/0.001       | 0.190/0.165              |
| Vegetative-2       | 0.026/0.028         | 0.018/0.027          | 0.016/0.021       | 0.142/0.115              |
| Generative-1       | 0.007/0.011         | 0.025/0.015          | 0.026/0.020       | 0.269/0.241              |
| Generative-2       | 0.014/0.019         | 0.030/0.017          | 0.044/0.036       | 0.182/0.161              |
| All phases         | 0.02/0.01           | 0.02/0.02            | 0.02/0.02         | 0.17/0.20                |

**Table 1.** The mean RMSE values of surface reflectance for each band on rice growth phases.
3.1.2. **Vegetation Indices.** Calculation of the NDVI, EVI, SAVI and MSAVI vegetation index was carried out in three measurement locations by taking the average value of the sample measured in the rice fields including rice vegetative and generative phases. To find out the accuracy of the correction results, RMSE is calculated [21]. The results of the RMSE calculation are shown in Table 2.

**Table 2.** The mean RMSE values of vegetation indices: NDVI, EVI, SAVI and MSAVI for corrected images

| Rice growth phases | NDVI 6S/FLAASH | EVI 6S/FLAASH | SAVI 6S/FLAASH | MSAVI 6S/FLAASH |
|--------------------|----------------|--------------|----------------|-----------------|
| Vegetative-1       | 0.03/0.05      | 0.18/0.16    | 0.16/0.15      | 0.22/0.21       |
| Vegetative-2       | 0.11/0.12      | 0.17/0.14    | 0.17/0.15      | 0.24/0.22       |
| Generative-1       | 0.03/0.02      | 0.18/0.12    | 0.18/0.12      | 0.21/0.21       |
| Generative-2       | 0.04/0.09      | 0.03/0.06    | 0.09/0.05      | 0.11/0.06       |

Based on the RMSE calculation in Table 1, the lowest value was NDVI and the highest was MSAVI in all types of rice plant growth phases. The RMSE value of EVI and SAVI is between NDVI and MSAVI. In the 6S model, the value of RMSE NDVI between 0.03 - 0.11 and MSAVI is between 0.11 - 0.24. In the FLAASH model, the RMSE NDVI value between 0.02 - 0.12 and MSAVI is between 0.06 - 0.22. The 6S model has better accuracy for NDVI while for EVI, SAVI and MSAVI the FLAASH model has slightly better accuracy than 6S.

4. **Conclusion**

The 6S model has better accuracy for the spectral response from the rice growth phase compared to the FLAASH model. Based on the calculation of the vegetation indices values, it is known that the vegetation index which has good accuracy with field measurements is NDVI and the lowest is MSAVI.

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