Split-windows algorithm (swa) methods using fractional vegetation cover (fvc) on landsat 8 oli/tirs

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Abstract. Landsat 8 OLI/TIRS has the ability to generate Land Surface Temperature (LST) with band 10 (10.60 - 11.19 µm) and 11 (11.50 - 12.51 µm). That condition has led to the development of methods for Landsat 8 in LST processing. The SWA has various methods of extracting LST, one using FVC. This research aims to establish the level of accuracy of using FVC methods on SWA methods to ground temperature. LST method is a combination of NDVI and water vapor derived from MODIS Terra. SWA-FVC processing shows a difference between data processing with field conditions. A difference indicated is 2°K (two-degree Kelvin) for urban areas with checks is the road and rooftop. Furthermore, 1°K (one degree Kelvin) for vegetation with middle covered until the high cover of the canopy. SWA-FVC methods have a focus on vegetation index with a similar value of emissivity and can’t to reflect the actual condition of various land-use in the field. LST extraction with SWA-FVC methods proved vegetation index can’t optimum to using for emissivity values for detection LST in the field.

1. Introduction
Land Surface Temperature (LST) becomes an important part of science [1-2]. LST has information that correlates with most parameters such as land surface interaction with the atmosphere as well as temporal and spatial information [3-4]. The importance of LST being able to be used to determine land conditions such as land cover changes, evapotranspiration, monitoring vegetation, climate change, and urban climate [5-7]. It requires a quick and broad measurement to determine the rate of LST changes. Vegetation, topography, and soil have influenced LST changes to the distribution of LST [8]. Remote sensing methods have the ability to verify LST distribution like temporal and spatial with mid-to-high accuracy [9-11].

Thermal imaging measures for land surface temperature are done with calibrating thermal bands as well as correcting for atmospheric absorption, atmospheric emissivity, and surface emissivity [6,12-13]. One method developed was Split-Windows Algorithm (SWA) [10-11, 14-16]. The SWA method has been developed with several such models as Sobrino’s Split-Window Algorithm (SWA-S), Qin’s Split-Window Algorithm (SWA-Q), Mono-Windows Algorithm (MWA), and Single Channel Methods (SCM) [14-18]. Each model has a difference in the thermal data processing. Especially the SWA-S model uses vegetation indexes approach to discovering canopy cover that affects atmospheric absorption [15,19]. The vegetation index was obtained from remote sensing image to get the Fractional Vegetation Cover (FVC) information [20]. FVC has correlated with climate change and affects the land surface temperature condition emitted by objects [19,21]. The FVC effects on land surface temperatures are not
being observed thoroughly of SWA methods because many researchers have used secondary data input in water vapor values where the value should be derived from remote sensing images [7-13]. The SWA-S method of Sobrino et al [14,15] used the water vapor value from the extraction of remote sensing image. The water vapor value has an effect on rising land surface temperature [11]. Hence, it aims to use water vapor and FVC to apply to SWA-S method. All data inputs use primary data for the preparation of the SWA-S methods. That condition makes SWA-S Methods have predominance to used for extraction Land Surface Temperature from image especially Landsat 8 TIRS.

2. Methods
This research uses remote sensing image of Landsat 8 OLI/TIRS on an extraction into land surface temperature with a combination of vegetation indexes and water vapor in the SWA-S method. Flowchart research can be shown in Figure 1.

2.1. Study area
Buleleng regency is one of nine regencies in Bali province. Astronomically Buleleng regency between 8°03′40″ S – 8°23′00″ S and 114°25′55″ E – 115°27′28″ E. Buleleng regency varies the topography from the northern coast to the hilly and mountainous condition of the south [24]. The research focus is on the downtown area and its surrounding areas so that it is not restricted by the administration. The SWA-S method could be thoroughly known under varying topographical conditions.

2.2. Remote sensing data and methods
2.2.1. Land surface temperature (LST)
The Landsat image used is that Landsat 8 OLI/TIRS (The Operational Land Imager and the Thermal Infrared Scanner) is gained for free on the official website http://usgs.gov/. Landsat 8 OLI/TIRS was used on May 19, 2019, with clouds of less than five percent and no rain in May. Landsat 8 OLI/TIRS uses two thermal bands, band 10 (10.60 - 11.19 µm) and band 11 (11.50 - 12.51 µm) to process land surface temperature extraction. Before using the SWA-S method then band 10 and 11 first extract the brightness temperature. Brightness temperature is the method developed by the USGS [25,46] for acquiring radian temperature indicated on the Equation 1.

\[ T_{rad} = \frac{K_2}{\ln\left(\frac{K_1}{T_{sensor}} + 1\right)} \]
Where $T_{rad}$ is brightness temperature; $K_1$ and $K_2$ is constant band 10 and band 11 can be obtained from metadata Landsat 8 OLI/TIRS; $L_{sensor}$ is spectral radiance from band 10 and 11; As for the extraction into land surface temperatures, using a method developed by Sobrino et al. [14,15] with combination of FVC and water vapor is shown on the Equation 2.

$$\text{LST} = TB_{10} + C_1(TB_{10} - TB_{11}) + C_2(TB_{10} - TB_{11})^2 + C_0 + (C_3 + C_4W)(1 - m) + (C_5 + C_6W)\Delta m$$  \hspace{0.5cm} (2)

Where LST is Land Surface Temperature; $TB_{10}$ and $TB_{11}$ is brightness temperature; $C_1 - C_6$ is constant from Table 1; $W$ is water vapor values can be obtained from MODIS image with equation (7); $m$ is the average value from Land Surface Emissivity (LSE), and $\Delta m$ is difference value from LSE band 10 and band 11.

**Table 1. Split-Windows coefficient value.**

| Constant | Value |
|----------|-------|
| $C_0$    | -0.268 |
| $C_1$    | 1.378 |
| $C_2$    | 0.183 |
| $C_3$    | 54.300 |
| $C_4$    | -2.238 |
| $C_5$    | -129.200 |
| $C_6$    | 16.400 |

2.2.2. Vegetation index

The vegetation index obtained from Landsat 8 OLI especially bands 4 (red channel) and band 5 (infrared channel). The algorithm used for vegetation index using Equation 3 developed by Huete et al. [29] to obtained FVC. FVC develop of Sobrino et al. [15] to the difference value of vegetation and soil is shown in Equation 4.

$$\text{NDVI} = \frac{\text{Band 5} - \text{Band 4}}{\text{Band 5} + \text{Band 4}}$$  \hspace{0.5cm} (3)

$$\text{FVC} = \frac{\text{NDVI} - \text{NDVI}_{soil}}{\text{NDVI}_{soil} + \text{NDVI}_{vegetation}}$$  \hspace{0.5cm} (4)

Where NDVI is vegetation index; FVC is Fractional Vegetation Cover; NDVI$_{soil}$ is the value of soil from NDVI; NDVI$_{vegetation}$ is the value of vegetation from NDVI. Sobrino et al. [15] research indicates for NDVI$_{soil}$ value is 0.2 and NDVI$_{vegetation}$ value is 0.5. This research using NDVI$_{soil}$ and NDVI$_{vegetation}$ adapted from research location and that values always different from the other location.

2.2.3. Land Surface Emissivity (LSE)

LSE is estimation from information that can be obtained from the red channel and infrared channel on FVC [28]. Equation 5 is a method for obtaining LSE with anticipating FVC condition and emissivity value from the thermal band.

$$\text{LSE} = \varepsilon_S * (1 - \text{FVC}) + \varepsilon_V * \text{FVC}$$  \hspace{0.5cm} (5)

Where LSE is surface emissivity; $\varepsilon_S$ and $\varepsilon_V$ is emissivity value from the thermal band can be obtained from Table 2.

**Table 2. Emissivity Value.**

| Emissivity | Band 10 | Band 11 |
|------------|---------|---------|
| $\varepsilon_S$ | 0.971   | 0.977   |
| $\varepsilon_V$  | 0.987   | 0.989   |

LSE used to obtain average value emissivity (m) and difference of emissivity ($\Delta m$) from the thermal band. Both of which were inputs in the LST calculations. The algorithm is shown in Equation 6 and 7.
The calculation can be obtained water vapor using remote sensing image. MODIS image has capabilities to give water vapor value with the method to develop of Sobrino et al. [30]. Equation 8 is an algorithm used for extraction water vapor from MODIS image.

\[ W = f_{17}w_{17} + f_{18}w_{18} + f_{19}w_{19} \] (8)

Where W is water vapor totally in location research; \( f_x \) is weighting factor from band 17, 18, and 19; \( w_x \) is water value from band 17, 18, and 19 from MODIS image. Nugraha [11] uses that algorithm as for the extraction of land surface temperature and the detailed can be seen in that research.

### 3. Results and Discussion

#### 3.1. Brightness temperature of landsat

Landsat 8 OLI/TIRS processing with the thermal band must change from digital number to spectral radiance. The digital number can’t process directly to become brightness temperature values [25]. Brightness temperature gained not from land surface temperature value but from brightness temperature object so that value will be increased [31-33]. Brightness temperature values from Landsat 8 TIRS shown in Table 3.

| Band | Min   | Max   | Mean  | Standard of Deviation |
|------|-------|-------|-------|-----------------------|
| 10   | 294.20| 306.13| 299.01| 2.19                  |
| 11   | 293.09| 302.36| 296.90| 1.68                  |

Brightness temperature results have a condition with no shadows and clouds. Therefore, the result unaffected with condition increase or decrease land surface temperature effect from shadows and clouds [34-36]. This value from Brightness Temperature is conditioning the object affected with the environment because that, this value can’t be used to processing and get directly land surface temperature.

#### 3.2. Vegetation index threshold

Vegetation index appearance has an effect on condition land surface temperature because vegetation represents emissivity value for each object [9,37]. The important for extraction vegetation index with NDVI is a distribution of pixel value for soil and vegetation. NDVI values have a range -1 to 1 and that value represents soil and vegetation. The determination for all values such as soil and vegetation is important because influencing the results of FVC especially LSE value for band 10 and band 11 [15]. The result of LSE is shown in Table 4. The impact of pixels’ values, particularly soil values, will have the effect of raising the land surface temperature, especially urban areas. This research using NDVI\text{soil} pixel is 0.6 and NDVI\text{vegetation} pixel is 0.98 to represent soil and vegetation condition.

| Band | Min | Max | Mean | Standard of Deviation |
|------|-----|-----|------|-----------------------|
| 10   | 0.93| 0.99| 0.98 | 0.0077                |
| 11   | 0.95| 0.99| 0.98 | 0.0058                |

Source: Data Processing, 2019
LSE values dominated by 0.96 until 0.99, different with Curran [38] emissivity values have variation emissivity values such as 0.90 until 0.97 and divided into urban areas and objects capable of emitting emissions. Nugraha [11] using Curran emissivity values for land cover to each object represent emissivity value. That result gave raising accuracy for land surface temperature although used a different method for extraction land surface temperature. LSE method has dominated value ≥ 0.96 for each processing data [7,22-23], but the emissivity value can know from each object with those conditions for estimation of land surface temperature [12,39].

3.3. Land surface temperature validation

SWA-S method show increasing land surface temperature Table 5 compared to the result from brightness temperature. Land surface temperature processing not just influenced by vegetation index conditions but also water vapor produced by MODIS Terra image. The result of water vapor processing shown the average value of water vapor (w) matches the date of Landsat 8 OLI/TIRS taken image is 0.12. The processing result of MODIS terra for water vapor has resulted in condition 5% error and water vapor have influenced increasing land surface temperature for emissivity value [40-41].

Table 5. Land Surface Temperature (Kelvin)

| Name | Min  | Max  | Mean  | Standard of Deviation |
|------|------|------|-------|-----------------------|
| LST  | 296.25 | 317.54 | 304.13 | 3.82                  |

The measurement for land surface temperature on field survey used Thermometer infrared and measuring several objects such as soil, rooftop, road, and vegetation. The measurement all objects have the same time with Landsat 8 OLI/TIRS taking an image and measuring limit between an image with field condition about 3 – 4 hours, if the measurement exceeds the limit then the result of land surface temperature gives big different value [36,42]. The different result between image and field survey is shown in Table 6.

Table 6. Different land surface temperature result for Landsat 8 OLI/TIRS and field survey.

| Object  | Land Surface Temperature (Kelvin) | Differences |
|---------|----------------------------------|-------------|
|         | Landsat 8 OLI/TIRS | Field |
| Soil    | 312.8 | 313.1 | 0.3 |
| Rooftop | 317.2 | 319.5 | 2.3 |
| Vegetation | 304.5 | 305.2 | 1.3 |
| Road    | 313.1 | 312.6 | 0.5 |

The largest difference in the residential areas measured from the rooftops. The difference in value on the image on the field is influenced by vegetation possible within a one-pixel image given impact decrease or increase land surface temperature [43-45]. SWA-S method proved emissivity value gave impact for determination of land surface temperature not optimum. That condition gave high different value (Table 6) and Nugraha [11] proved for the usage emissivity value which is implemented by Curran [38] gave a small different value. The land surface temperature distribution is shown in Figure 2. The distribution of LST influenced by topography, therefore, topography condition for low land is higher than topography condition for upland and have high vegetation density. LST with the SWA-S method can use to detect phenomenon Urban Heat Island (UHI) condition because downtown has high LST value compared to surrounding. The other research proved the SWA-S method has the same values but several locations different because influenced by topography [7,22-23].
Figure 2. The result of land surface temperature (in Kelvin) around Buleleng regency

4. Conclusion
The emissivity value can be obtained from vegetation index for FVC especially LSE processing proved distribution emissivity value not optimum to represent each object in land cover. Except for vegetation, water vapor conditions to give effect decrease or increase condition for land surface temperature. SWA-S method proved differences result especially rooftop is 2°K. The difference is caused condition Landsat image and emissivity value so giving decreases or increases the land surface temperature. Land surface temperature processing can be combined with emissivity value more evenly or comparing methods for land surface temperature with different conditions and topography. That situation possible can give increasing accuracy.

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