Remote Sensing Data, Landsat 8 Oli / Tirs For Identification of Evapotranspiration Spatial Distribution in Sub DAS Cisangkuy West Java Indonesia

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Abstract. The Cisangkuy sub-watershed area, West Java is mostly up land farming. In the dry season the region often experiences drought. Efforts to anticipate regional drought can be done by calculating the balance of water availability of the region. One of the most important water balance calculation parameters is evapotranspiration. Direct evapotranspiration measurements in the field represent actual circumstances, but for large areas require large and long-term costs. One way to get regional evapotranspiration data is by reducing evapotranspiration information from remote sensing data. LANDSAT 8 OLI / TIRS satellite imagery is one of the resource satellites commonly used in agriculture. This study aims to determine the estimated value of evapotranspiration in the sub area of Cisangkuy watershed using LANDSAT 8 OLI / TIRS satellite imagery. The method used in this research is the energy balance model with descriptive analysis. The results showed that the highest value of evapotranspiration on August 17 in Cisangkuy Sub-Basin area in mixed forest was 4,190 mm / day. The results of data reliability analysis using root mean square (RMS) error indicate that satellite image can be used to identify evapotranspiration in Cisangkuy sub watershed with RMS error value of 1.124. The RMS value is still smaller than the average evapotranspiration field measurement difference, so it can be said that the evapotranspiration estimation is accurate.

1. Introduction

Evapotranspiration is one of the important information in agricultural planning, especially with regard to establishing cropping patterns and irrigation planning [1]. Evapotranspiration is the amount of water lost from the land due to evaporation of the land surface and transpiration by plants that take place simultaneously [2,3], so that it can be known the amount of water lost and must be replaced through the purchase of water to the land or known as irrigation water. Evapotranspiration data are also widely used in water balance analysis, groundwater availability, runaway water analysis and flood analysis plans, especially with regard to watershed management [4,5].

The actual measurement of evapotranspiration is usually carried out through field measurements or calculations based on environmental parameters usually using the Penman-Montied method as a reference [6], but the weakness of this conventional method is that evapotranspiration information is only for homogeneous regional characteristics [6]. Information on actual evapotranspiration for large areas with diverse variations in land use requires enormous time and costs. Therefore technology is needed that is able to provide information on evapotranspiration as a whole in a wide range of spatial diversity.

Remote sensing data is one of the recording data by a remote sensing vehicle that provides an integral view of the earth's surface, so as to provide a comprehensive picture of the earth's surface information. Remote sensing data is potentially used as a spatial data source because it has advantages in temporal, spectral and spatial resolution referring to data requirements.
The use of remote sensing data is expected to provide evapotranspiration information accurately for large areas. Mass balance approach to reduce evapotranspiration information through image analysis using the SEBAL method [2,3].

Cisangkuy Sub-watershed with an area of 34,024 Ha is part of the upper Citarum watershed in Bandung Regency [5]. Most of the Cisangkuy sub watershed area is rainfed agricultural land, so that when entering the dry season, agricultural areas that mostly rely on rainwater will experience drought. Cropping and irrigation pattern planning in the Cisangkuy Das area is needed so that irrigation water needs and water availability can be calculated, so that cropping planning provides accurate results. One of the information needed in analysing water availability in cropping planning is land evapotranspiration.

The spatial information of evapotranspiration provided in the study area is still lacking because in the area around the study only represented by one weather station. Research on the reduction of spatial information on evapotranspiration using remote sensing data is necessary because of the superiority of remote sensing images in spatial and temporal resolution. This study aims to determine the spatial distribution of evapotranspiration in the Cisangkuy sub-watershed area using LANDSAT 8 OLI / TIRS satellite imagery data and determine the ability of satellite image analysis in estimating the spatial distribution of evapotranspiration values in the Cisangkuy watershed.

2. Methods
This research was conducted in the Cisangkuy watershed, Citarum Hulu, West Java. Data processing was carried out at the Land and Water Engineering Laboratory, Faculty of Agricultural Industrial Technology, Padjajaran University. Analytical descriptive method is used to reduce spatial information on evapotranspiration from remote sensing data using an energy balance model. The remote sensing data used is the Landsat 8 OLI / TIRS image obtained from the USGS page. The root mean square error is used to analyse errors that occur between predictive data and actual data as a measure of research reliability. Image processing module is used as a series of remote sensing digital data processing to obtain spatial distribution of region evapotranspiration.

2.1. Initial image processing of Landsat 8 OLI/TIRS
The remote sensing data used is the LANDSAT 8 OLI / TIRS recording image on August 17, 2016, which was downloaded from the USGS page. Cutting the radiometric correction image and geometric correction is done before the process of identification of soil moisture. Image cutting is done to determine the boundary of the study, adjusting the area in the image with the location of the study and for reducing the size of the data. Radiometric correction is useful for reducing errors due to interference with reflection values due to interference and sharpening the image. The technique used in radiometric correction of this image is linear contrast stretching. Geometric correction is used to correct projection errors and add image coordinate accuracy. Geometric correction is done by referring several points using the coordinates of the earth map as a reference for Ground Control Point with the maximum root mean square error value is 1.

2.2. Image processing to identify evapotranspiration spatial distribution
Calculation of evapotranspiration using satellite imagery in this study uses an energy balance model by passing several calculation stages, namely brightness temperature (Tb) calculation, land surface temperatures (Ts), net radiation (Rn), G soil heat fluxes, air heating flux (H), latent heat flux (LE) and evapotranspiration (ET) using a digital image processing module. Calculation of surface temperature estimates using remote sensing data uses the equation:

\[ Tb (\text{brightness temperatures}) : K2 \ln \left( k1 l1 + 1 \right) \]  
Where: \( K1 = 774,885 \text{ wm-2sr-1}\mu m-1 \) dan \( K2 = 1321.08 \text{ K} \), so that the surface temperature (Ts) is determined by the equation:

\[ Ts (\text{land surface temperatures} ) : Tb + (\lambda T b \delta) L n e \]  
Where: \( Tb = \text{brightness temperatures} \), \( \lambda = \text{average wavelength of emission radiation} 11,5\mu m \), \( \varepsilon = \text{object emissivity} \), \( \delta = 1,438 10^{-2} \text{ Mk} \)
2.3. Energy balance methods to extract evapotranspiration spatial distribution

Determination of evapotranspiration values using the formulation of the method of the energy balance concept. The main equation model is: \( Rn = H + G + \lambda E \) with the derived equation is as follows:

\[
Rn = \text{Rs in} - \text{Rs out} - RL\text{out}
\]
\[
\text{Rs in} = \text{Rs out}/\alpha
\]
\[
\alpha = \pi L:\lambda d2/\text{ESUN}\lambda\cos\theta
\]
\[
\text{Rs out} = \pi x L:\lambda x d2 x 1/\text{band}
\]
\[
RL\text{out} = \varepsilon\sigma T^4
\]
\[
G/Rn = T_s (0.0038\alpha+0.0074\alpha^2)(1-0.98\text{NDVI}^4)
\]
\[
H = \beta(Rn-G)/1+\beta
\]
\[
LE = Rn - G - H
\]
\[
ET = LE x 0.0864MJ/m^2/\text{hari} \ast 0.408 \text{mm/hari}
\]

where: \( Rn = \) net radiation, \( G = \) soil heat fluxs (W/m\(^2\)), \( H = \) sensible heat fluxs (W/m\(^2\)), \( \text{Rs in} = \) short radiation in, \( \text{Rs out} = \) short wave radiation out, \( RL\text{out} = \) long radiation out, \( L:\lambda = \) bands spektral radiance, \( d2 = \) astronomy distance sun to earth, \( \text{ESUN} = \) averages solar spectral irradiance, \( \theta_s = \) sun zenith angle, \( 1/\text{band} = \) median wave length of band used, \( \varepsilon = \) emisivitas, \( \sigma = \) Stefan-Bolztman constant (5.67 x 10\(^{-8}\) Wm\(^{-2}\)K\(^{-4}\)), \( \beta = \) water body, \( \alpha = \) surface albedo \( n \)

NDVI = Normalized Difference Vegetation Index, \( LE = \) energy latent

Data reliability test is done by comparing the actual soil moisture data and soil moisture data from the LANDSAT image digital analysis process. Reliability test uses the Root Mean Square equation.

3. Result and discussion

3.1. Surfaces temperatures, net radiation, and albedo in Cisangkuy sub watershed

Surface temperature (\( T_s \)) is the temperature that comes from the outermost part of an object that gets energy from sunlight. Surface temperature is affected by emissivity, object heat and thermal conductivity. The highest surface temperature in the study area occurred in the corn field (Banjaran) 25.25\(^\circ\) C, the lowest temperature occurred in mixed forest land 21.38\(^\circ\) C. Increased emissivity of corn plantations (Banjaran) is higher than other research locations with low conductivity values, resulting in an increase in higher temperatures. Mixed forest (Pangalengan) has an increase in emissivity lower than other sample points, but the conductivity value is higher, so the increase in temperature is the lowest.

Net radiation is the difference between short and long waves that come to the surface of the earth with short waves and long waves coming out of the earth’s surface. The Cisangkuy sub-watershed area is dominated by high net radiation, marked in red in most areas of each sub-district in Figure 1. Areas with low net radiation values are found in several locations scattered in several districts, such as Pangalengan, Banjaran and Cimaung subdistricts. in blue. The highest net radiation value on satellite imagery in the study area is mixed forest (Pangalengan) with a value of 388,798 W/m2 and the lowest net radiation value from grassland (Banjaran) with a value of 346,527 W/m2.

The smaller the value of reflected or albedo radiation in a field, the greater the net radiation value of the land, such as in mixed forests (Pangalengan) with the highest \( Rn \) value among other sample points. In the grasslands in Banjaran, the albedo value is greater than the value of radiation absorbed compared to other sample points, so the \( Rn \) value is the smallest. In addition, mixed forests with higher plant heights compared to other regions make the net radiation value produced also greater. Small albedo values on vegetated land cover are also caused by multilevel canopies that can absorb solar radiation at several levels of canopy [7]. Net radiation distribution, soil heat fluxes in the area of the Cisangkuy watershed is presented in Figure 1.
3.2. Distribution soil heat fluxes in Cisangkuy sub watershed

Soil Heat Flux (G) is heat that reaches the surface of the soil and is used for physical and biological processes of the soil. The sub-watershed area of Cisangkuy is dominated by high soil heating flux values, characterized by brown color in almost all sub-districts in Figure 1 and low color markings scattered in several points such as Pangalengan, Cimaung, Banjaran and Arjasari districts. The measurement results show the highest results in the G value among the sample points taken located in the corn field in Banjaran with a value of 39,348 W/m² and the lowest value is located in mixed forest in Baleendah worth 29,329 W/m².

Soil heat fluxes (G) are directly proportional to surface temperature (Ts), can be seen at the highest point at G and surface temperature (Ts) which is at the same point, namely the corn field. Vegetation density also affects the G value because land with moderate vegetation cover such as gardens gets a greater percentage of G value, because the amount of net radiation that is passed to the soil and absorbed into the soil is greater than that of tightly closed vegetation.

3.3. Distribution spatial sensible heat fluxes in Casangkuy Watershed

Sensible heat flux (H) is the energy used to move heat from the surface to the air due to the temperature difference between the two, usually it will feel like an increase or decrease in temperature in the atmosphere. The lowest value in H calculation using satellite imagery is found at the river point in Pamengpeuk with a value of 105.045 W/m² and the highest point is found in the cornfields in Banjaran with a value of 254.777 W/m². Formula H shows that there are two factors that influence the calculation of H, namely surface temperatures (Ts) and air temperatures (Ta). This is because in this measurement the Ts value is higher than other factors, so it can be estimated that Ts is directly proportional to H, it can be seen at the highest value of Ts and H calculations at the same point.

Figure 2 shows that the sub-watershed area of Cisangkuy is dominated by the value of H with a moderate value, which is marked in yellow. The highest and lowest values for H are only spread in several regions in each district. The widest area with a high distribution of air flux values is found in Baleendah and Pamengpeuk districts, which are marked in red. Clouds found in some sub-districts make lower values due to cloud-covered surfaces, so that the digital value of the image becomes lower or can be a minus, this is marked in blue.
3.4. Distribution evapotranspiration in Cisangkuy sub watershed

The process of evaporation of water in evapotranspiration is carried out using latent heating flux (LE), which is the energy used to evaporate some water from the soil surface to the atmosphere. LE can be converted to evapotranspiration by multiplying by the conversion factor of evapotranspiration value. The calculation results show that the most ET value in satellite imagery is located in mixed forest in Pangalengan with a value of 4.190 mm/day, while the lowest value in this calculation is 1.113 mm/day in paddy field. The highest ET value point with the highest radiation point Rn is located at the same point, i.e. mixed forest, so that it means that net radiation is directly proportional to evapotranspiration.

![Figure 2. Sensible Heat Fluxes Spatial Distributions (A) and Evapotranspiration Spatial Distributions (B).](image)

The results showed that mixed forests (Pangalengan) had the highest evapotranspiration values, because the Rn value at that point was higher among other sample points, but the values of G and H were low when compared to other sample points. The use of paddy fields in Banjaran has the lowest evapotranspiration value compared to the net radiation values of other samples, but the value of G and air heating flux (H) are high compared to other sample points. Land use with different cover can also be a cause of high or low evapotranspiration values. The value of land use in industry and urban areas has a lower evapotranspiration value than other land uses[8].

| Table 1. Evapotranspiration in region area distribution |
|-------------------------------------------------------|
| Number | Region       | Evapotranspiration (mm/day) |
|--------|--------------|-----------------------------|
| 1      | Baleendah    | 0.17 – 5.5                  |
| 2      | Banjaran     | 0.55 – 4.88                 |
| 3      | Cimaung      | 0.89 – 4.94                 |
| 4      | Pamengpeuk   | 0.47-4.78                   |
| 5      | Arjasari     | 0.44-4.88                   |
| 6      | Pangalegan   | 1.29-5.77                   |

The Cisangkuy watershed on average experiences evapotranspiration with high values, indicated by the green color in most of the sub-districts on the map, while the regions that experience lower
evapotranspiration are marked in blue in Figure 4. The image shows the blue color usually caused by the existence of clouds covering the land, so that the reading by the image becomes less accurate. Of the 6 sub-districts, Pangalengan experienced the highest evapotranspiration with a range of 1.2680 - 5.7663 mm / day. The spatial distribution of average evapotranspiration value per district can be seen in Table 1.

4. Conclusion
The spatial distribution of Cisangkuy sub DAS evapotranspiration values using satellite images of LANDSAT 8 OLI / TIRS showed that the highest evapotranspiration values occurred in mixed forest land in Pangalengan with a value of 8.380 mm /day and the lowest evapotranspiration values in paddy fields in Banjara with a value of 2.23 mm /day. High Evapotranspiration values occur because the value of net radiation (Rn) is higher among other sample points, but the value of soil heating flux (G) and air (H) heating flux is lower than other sample points. LANDSAT 8 OLI / TIRS satellite imagery is able to estimate the distribution of evapotranspiration in the Cisangkuy sub DAS, West Java with a test value of RMS Error 1,794. This value is accurate because the value of the RMS Error does not exceed the average value of the squared difference between the calculation of satellite imagery and the field. Based on the results of satellite images, the Pangalengan area has the highest daily evapotranspiration with a value of 1,268 - 5,766 mm / day.

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