Land surface temperature analysis based on land cover variations using satellite imagery

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Abstract. The remote sensing satellite sensor can not only record the visual appearance of the earth’s surface characteristics but also can capture phenomena that cannot be seen by a human, such as the earth’s surface temperature. Bandung is located at a basin-shaped area and has a variety of land cover, natural and man-made. The diversity of land cover is indicated to have an effect on the characteristics of the land surface temperature recorded by satellite sensing sensor. This assumption then examined by considering the land cover type and the value of land surface temperature as its parameters. This research aims to: 1) Estimating the land surface temperature with digital image processing, 2) Visual interpreting of land cover type based on land surface temperature similarity, and 3) Analyze the level of land surface temperature with a variation of land cover type in the south-western part of Bandung Basin. The visual interpretation method was used to obtain a land cover type with high-resolution image. Whereas the transformation of the Landsat 8 thermal band index is used to acquire the land surface temperature. An analysis was carried out to observe the results of land surface temperature estimation and land cover based on land surface temperature resemblance. Then it is expected to be a consideration in terms of determining policies regarding conversion of land cover from natural to artificial forms indicated as a contributing factor to rising land surface temperatures.

1. Introduction

Uncontrolled urban development including changes in natural land to artificial land causes an increase in temperature. These changes will affect how broad the distribution of solar radiation. As a result, urban temperatures are hotter than rural areas where there is still a lot of vegetation [1-3]. Climate is a component that affects solar radiation, while topography, land cover, and vegetation are factors that affect the amount of energy that reaches the earth surface [4]. One of the environmental problems related to temperature is a result of changes in land cover, especially in urban areas. Research on rapid land-cover change has appeared in the last few decades with the awareness that landcover change shown varying impacts on the atmospheric dynamics and also climate change. The increase in built-up area which is a conversion from green areas has resulted in a drastic increase in temperature [2, 5, 6]. Earth’s surface temperature can detected with observing an emissivity of vegetation and soils, named as land surface temperature (LST).

Thermal infra red channel of remote sensing can be used to determine the temperature distribution. Also to monitor temperature change locally and global, used in climate change modelling, and monitor the surface temperature. Remote sensing data extract into LST presents information on variations in surface
temperature spatially and is useful for climate change, urban studies, forestry, agriculture, and hydrology [7-9].

Based on previous studies, land surface temperature rised in areas with more anthropogenic activities also in the build-up areas. Whereas low-temperature values appear at vegetated areas. Analysis of land surface temperature is expected to provide valuable input for ecological restoration efforts [10]. Land cover as one of the factors that influence LST can also be observed through remote sensing imagery. Unlike the case with LST obtained from thermal bands, land cover is interpreted visually using high-resolution satellite images. The difference in approach to obtaining information from remote sensing images is termed hybrid interpretation, a combination of visual interpretation techniques (based on spatial characteristics of objects) and digital processing (according to the spectral characteristics of objects). The hybrid approach is expected to minimize the lack of each interpretation technique [11].

Results of the other similar studies show different land use has a different temperature category [10]. Rural areas and forest cover area had the lowest temperature, cropland has a moderate temperature. Meanwhile, urban areas had a wider temperature variation. The lack of heat transfer capabilities and the limited ability of the evaporative cooling mechanism cause the built-up area and bare land class has a hotter temperature[1, 5]. This clarifies linkage of soil surface temperature and type of land cover which later became the basis of research in the Bandung Basin that has variations in land cover and topographic features.

Bandung basin consists of urban and mountainous areas and it affect the variations of land surface temperature. Based on background described previously, this research aims to: 1) Estimating the land surface temperature with digital image processing, 2) Visual interpretation of land cover type based on land surface temperature similarity, and 3) Analyze the level of land surface temperature with a variation of land cover type in south-western part of Bandung Basin.

2. Study Area
Bandung is the capital of West Java Province, located in the area that forms the basin that consists of other administrative regions, such as Cimahi City, West Bandung Regency, and Bandung Regency. The uniqueness of the study area is its diverse topography. The city of Bandung is the province capital city which is experiencing rapid growth, including in terms of land changes and temperature changes [12].

Figure 1. South-western Bandung Basin
This research was carried out in the south-western Bandung Basin, consisting of Bandung Regency and West Bandung Regency which, although not as dense as Bandung City, had a growing urban area. Bandung Basin has an average temperature of 25.7°C [13].

3. Methods

Hybrid Interpretation is a remote sensing image interpretation that consists of a visual approach and digital approach. Visual or manual image interpretation is the acquisition of spatial data from remote sensing images that are based on the spatial characteristics of objects in the image, which are identified using elements of interpretation. Digital interpretation is a quantitative analysis of the spectral patterns of objects represented by pixel values [14]. Classification of land cover with satellite image beneficial for inventories or environmental modeling, also in planning and management activities. Remote sensing data is popularly used for land cover studies [15].

Land cover classification is obtained by manual interpretation of satellite images to recognize the spatial characteristics of objects based on land cover types in the south-western parts of Bandung Basin. While the digital interpretation of thermal infrared band that records the earth surface reflectance (10.6 - 12.51) µm is done to get the land surface temperature.

3.1. Digital Interpretation

The remote sensing sensor records the land surface temperature (LST) per pixel which generally consists of temperature and soil moisture and vegetation cover. LST is the result of digital processing of thermal infrared channels as owned by Landsat 8 satellites [8, 16]. Land surface temperature studies are also used to observe the influence of land cover types on variations in land surface temperature, as was done in this study.

Consideration of emissivity in extraction of LST is the method of this study. The emissivity value is obtained from the Normalized Difference Vegetation Index (NDVI). It is easy to apply this method and it does not require detailed atmospheric correction [17]. Dense forests have positive NDVI values, in contrast to open land with negative NDVI values with high emissivity [18]. Each object has a different emissivity value according to its NDVI range.

The NDVI value adjusts the type of land cover. Built-up and bare soil areas have lower NDVI values than vegetation. The emissivity for the built-up area and open ground is 0.97, while for vegetation it is 0.99. For object emissivity other than built-up area, bare soil, and calculated using the formula:
### 3.2. Visual Interpretation

Natural and artificial land cover obtained from satellite images classified based on pixel value that signifies a characteristic of object. Land cover information obtained using textures, shapes, patterns, site, and tones characteristics. Classification of land cover has a different perspective and adapts to observed regional conditions. The common land cover classification, dividing land cover into: perennial snow, rangeland, forest land, barren land, built-up land, wetland, agricultural land, water, and tundra [3, 19].

However, the scheme is not suitable for Indonesia’s tropical climate. So this study uses the classification of land cover according to Standard Nasional Indonesia (SNI 7645:2010) which consists of rice fields, fields, plantations, forests, bushes, grasslands, open land, settlements, built-up land, industrial buildings, road networks, reservoirs, rivers, and irrigation channels [20]. Land cover was observed by considering spatial characters so that it can be analyzed how the influence of land cover types on the range of temperature values.

### 3.3. Variation of Land Surface Temperature, Land Cover Type and Domination

Visual interpretation of satellite image results in the classification of south-western parts of Bandung Basin, whereas digital interpretation generates a value of land surface temperature for each pixel. Spatial and spectral processing results were then observed by determining a sample area of 60 m x 60 m. Each sample was chosen by similarity of land surface temperature value in Celsius degrees. After that, it is detected whether the area covered in the sample area has homogeneous land cover or consists of several types of land cover. Sample area with several land cover categories is then identified to determine which land cover dominates and how it affects the value of land surface temperature.

### 4. Result and Discussions

Administratively, South-western area of Bandung Basin located in Bandung Regency and West Bandung Regency. As a division of the city of Bandung, this region grew as a center for new economic growth which also had implications for massive physical development.
This research shows land surface temperature in South-western area of Bandung Basin range between 17.9°C to 35.1°C. Land surface temperature results are displayed with color symbols which are divided into 6 levels to facilitate the delivery of information. Dark green represents lower LST values than light green, yellow, orange, and red symbols. The western part of the study area has a lower temperature than the east. The reason is that the west side has more vegetation cover, while the east has an artificial land cover (settlements, built land) which is more dominant than vegetation cover.

![Figure 2. Land Surface Temperature in the south-western area of Bandung Basin](image)

South-western area of Bandung Basin has several types of land cover such as: rice fields, fields, plantations, forests, bushes, grasslands, open land, settlements, built-up area (non settlements), road networks, reservoirs, and rivers. Land cover type in the south-western area of Bandung Basin affected by topographic features that varied from flat to mountainous area.

Urban land cover is found in flat areas (city areas), while natural land covers are found in flat to mountainous areas. Samples were taken by considering variations in land cover at different altitudes. South-western parts of Bandung Basin has altitude between 600 and 1300 m. Most samples are at altitudes below 700 m. At these heights are relatively flat areas and there are varied areas of land cover. Based on 168 sample areas, settlements and forests are the most observed objects. Both types of land cover are the most dominant categories in the research area.
Figure 3. LST range based on land cover type

Each land cover in the south-western parts of Bandung Basin has a different range of land surface temperature. The narrowest range is fields and reservoirs between 27°C to 29°C. Both of them only take one sample plot, so that it affects the LST values that are less diverse. Forests have LST ranges between 18°C to 32°C. 18°C is the lowest land surface temperature between all land cover and due to the presence of forest in the shadow of the hill. 35°C as the highest LST consists of roads, open fields, grassland, settlements, and rice fields. The range of LST roads is 30-35°C, the highest among all land cover.

The built-up area has an LST range from 27°C to 32°C, the minimum temperature is hotter than other types of land cover (forest, plantations, bushes). River has LST between 27°C to 32°C while bushes are lower, ie between 24°C to 29°C. Plantations as vegetated land have a wide LST range between 21°C to 32°C.

The area with poor vegetation covers such as build-up areas, also sun-exposed ridges, sand sheets or sand dunes experience an increase in temperature. Opposite with agricultural, dense vegetation (forest), and sparse vegetation categories with low temperature (4,10). This is in accordance with the forest which has the lowest LST, and bushes with a fairly low LST. However, plantations in the research area tend to have LSTs from quite low (21°C) to high (32°C). This is because there are plant variations and canopy cover that are not uniform so that not only is the temperature of the plant recorded by the sensor but also the surrounding soil.
Figure 4. sample observation of LST according to land cover

Figure 5. sample A

Figure 6. sample B

Heterogeneity can affect the range of temperature values in each class (5). For example, sample A consists of rice fields, settlement, and forest. Sample A is dominated by rice fields and affects LST which is quite low (between 26-29°C). Sample B also consists of several land covers, dominated by settlements and there are rice fields and roads too. Although the dominant ones are settlements, sample B has an LST similar to sample A which is dominated by rice fields (26-29°C).

Figure 7. Sample C
The C sample is dominated by settlements and there are also roads. Most sample C is man-made land cover, with LST> 32°C. So that it can be concluded that samples with heterogeneity and dominated by man-made land cover have higher LST than samples with a dominance of natural land cover or vegetation.

5. CONCLUSION

Hybrid interpretation can be used to examine the influence of land cover types to land surface temperature (LST). Based on processing results, LST in the south-western Bandung Basin range between 17.9°C to 35.1°C. The land cover that has been identified are: rice fields, fields, plantations, forests, bushes, grasslands, open land, settlements, built-up area (non settlements), road networks, reservoirs, and rivers.

The highest LST (35°C) are roads, open fields, grassland, settlements, and rice fields. The range of LST roads is 30-35°C, the highest among all land cover. Meanwhile 18°C is the lowest land surface temperature between all land cover and due to the presence of forest in the shadow of the hill. Samples with heterogeneous objects that have vegetation cover have low tendencies of LST (26-29°C) compared to heterogeneous objects but are predominantly man-made land cover (32°C).

Results of the study recommending to preserve vegetated land cover along development urban development in the south-western Bandung Basin to prevent an increase in land surface temperature.

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