ANALISIS SPASIAL KONDISI EKOLOGI PERKOTAAN DI KOTA DENPASAR, INDONESIA MENGGUNAKAN CITRA LANDSAT 9

SPATIAL ANALYSIS OF URBAN ECOLOGICAL CONDITION IN DENPASAR CITY, INDONESIA USING LANDSAT 9 IMAGERY

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Abstrak

Kota Depansar merupakan Ibukota Provinsi Bali dimana aktivitas antropogenik paling intensif di pulau ini. Studi kondisi ekologi perkotaan sangat penting untuk perencanaan dan pemantauan kondisi ideal permukiman ramah lingkungan di Kota Denpasar. Penelitian ini bertujuan untuk 1) mengkaji kondisi ekologi kota skala mikro terkait suhu berdasarkan nilai *urban thermal field variance index* (UTFVI) dan 2) mengkaji pola sebaran NDVI dan LST di Kota Denpasar yang diperoleh dari data satelit Landsat 8. Suhu permukaan lahan (LST) dan *normalized difference vegetation index* (NDVI) keduanya diturunkan dengan menggunakan data dari Landsat 9, yang juga digunakan (NDVI). Setelah itu, UTFVI dikategorikan menggunakan LST. Hasil penelitian menunjukkan bahwa semakin besar nilai UTFVI, semakin buruk keadaan degradasi ekologi perkotaan dan semakin besar intensitas UHI dan sebaliknya. Nilai UTFVI yang rendah kurang dari 0,005 secara spasial terdistribusi di selutuh kabupaten dan dicirikan sebagai daerah dengan kualitas ekologi perkotaan yang baik hingga sangat baik. Kategori ini mendominasi di Kecamatan Denpasar Selatan dan Timur, wilayah utara Kecamatan Denpasar Utara, dan wilayah selatan Kecamatan Denpasar Barat.

Kata kunci: Denpasar, LST, NDVI, UHI, UTFVI.

Abstract

Denpasar City is the capital of the province of Bali where anthropogenic activities are most intensive on the island. The study of urban ecological conditions is vital for planning and monitoring the ideal condition of environmentally friendly settlements in the city of Denpasar. This research aims to 1) examine the temperature-related ecological conditions of micro-scale cities based on urban thermal field variance index (UTFVI) values and 2) assess the distribution pattern of NDVI and LST in the city of Denpasar derived from Landsat 8 satellite data. The land surface temperature (LST) and the normalized difference vegetation index (NDVI) were both derived using data from Landsat 9, which was also utilized (NDVI). Following that, UTFVI was categorized using LST. The results show that the greater the UTFVI value, the worse the state of urban ecological degradation and the greater the intensity of UHI, and vice versa. A low UTFVI value of less than 0.005 is spatially distributed throughout all districts and is characterized as an area with good to very good urban ecological quality. This category predominates in the South and East Denpasar Districts, the northern region of the North Denpasar District, and the southern region of the West Denpasar District.

Keywords: Denpasar, LST, NDVI, UHI, UTFVI.

1. INTRODUCTION

Urbanization has caused natural land surfaces to be turned into various impermeable surfaces such as highways, buildings, and so on, which has a substantial impact on the habitability of a city region (Alberti & Marzluff, 2004). Urbanization due to land cover change degrades an area's climatic features by increasing air temperature, decreasing rainfall, increasing relative humidity, and increasing energy consumption, resulting in the Surface Urban Heat Island phenomenon (Zhao, Cai, Qiao, & Xu, 2016). The term "surface urban heat island" refers to the phenomenon in which cities or metropolitan areas experience temperatures that are noticeably higher than those of their surrounding rural areas as a direct result of the anthropogenic change of land surfaces (Gago, Roldan, Pacheco-Torres, & Ordóñez, 2013). Land surface transformation from undeveloped to developed happened. To accommodate for human needs, expanding built-up area and diminishing vegetation cover have resulted in ecological degradation over time (Singh, Kikon, & Verma, 2017). Changes in the natural environment and land usage contribute to the phenomena of an urban heat island (UHI), along with ecological degradation.

The province of Bali is a popular tourist destination in Indonesia, even on a global scale. Denpasar City is the capital of the province of Bali where anthropogenic activities are most intensive on the island. The study of urban ecological conditions is vital for planning and monitoring the ideal condition of environmentally friendly settlements in the city of Denpasar.

Previous studies have investigated the fluctuating patterns of temperature that occur in the city from time to time (Nugraha, Sidiq, & Hanafi, 2016). However, it has yet to be examined further in terms of the comfortable features of temperature-related effects of declining urban ecological circumstances.

Previous research has demonstrated that remote sensing technology is capable of assessing urban ecological conditions as well as the intensity of UHI (Singh et al., 2017). Remote sensing data can be an effective alternative for mapping urban ecological conditions. With the help of remote sensing, it is possible to gather information about the state of the Earth's surface, such as mapping the distribution of vegetation cover using the normalized difference vegetation index (NDVI).

In order to provide a more accurate description of the Urban Heat Island effect, the UTFVI has become an increasingly used indicator (Kafy et al., 2021). The urban thermal field variance index (UTFVI) is a measure of urban ecological conditions that is generated from LST retrieved from satellite data (Liou, Nguyen, & Li, 2017). The findings of research on urban ecological condition variations using the UTFVI value approach hopefully can be used by stakeholders and environmental engineers to establish which areas should be prioritized for addressing UHI effects and environmental degradation in achieving sustainable urban goals. Investigations regarding the ecological condition of Denpasar city are still limited. This research aims to 1) examine the temperature-related ecological conditions of micro-scale cities based on urban thermal field variance index (UTFVI) values and 2) assess the distribution pattern of NDVI and LST in the city of Denpasar derived from Landsat 9 satellite data.

2. METHOD

Denpasar is one of the coastal cities in Indonesia and can be found in the southern region of the island of Bali. It is located in close proximity to the Indian Ocean in both the east and the south. In addition to serving as the headquarters of the province of Denpasar, Denpasar is the most populous city on the island of Bali. Denpasar has a population density of 5686 persons per square kilometer despite its relatively small size of 127.78 km^2 overall. North Denpasar, East Denpasar, West Denpasar, and North Denpasar are the names of the city's four sub-districts, which are located within Denpasar City. According to the area map shown in figure 1, the parts of Denpasar city that are located in the center, south, and east have the highest concentration of built-up area.

Several phases were taken to obtain the variables from the data, including NDVI, LST, and UTFVI extraction. NDVI is derived from the Landsat 9 reflection channel, where the

value represents reflection on the earth's surface (at-surface reflectance). The earth's surface reflection product indicates that the data has been radio metrically and atmospherically adjusted. The formula used in Robinson et al. (2017) previous study was used to calculate the NDVI formula.

LST is calculated using Landsat 9 band 10 (thermal) data. The pixel value of band 10 is translated into radiance unit that are recorded on the sensor at this point (at-sensor radiance). The at-sensor radiance data from band 10 then translated to the sensor's brightness temperature (at-sensor brightness temperature). By integrating the emissivity value, the LST value was calculated from the brightness temperature recorded on the sensor (Meng, Cheng, & Liang, 2017). The UTFVI was computed by the equation below (Singh et al., 2017), then was classified into classes based on the index shown by table 1.

UTFVI = (LST – Mean LST)/Mean LST

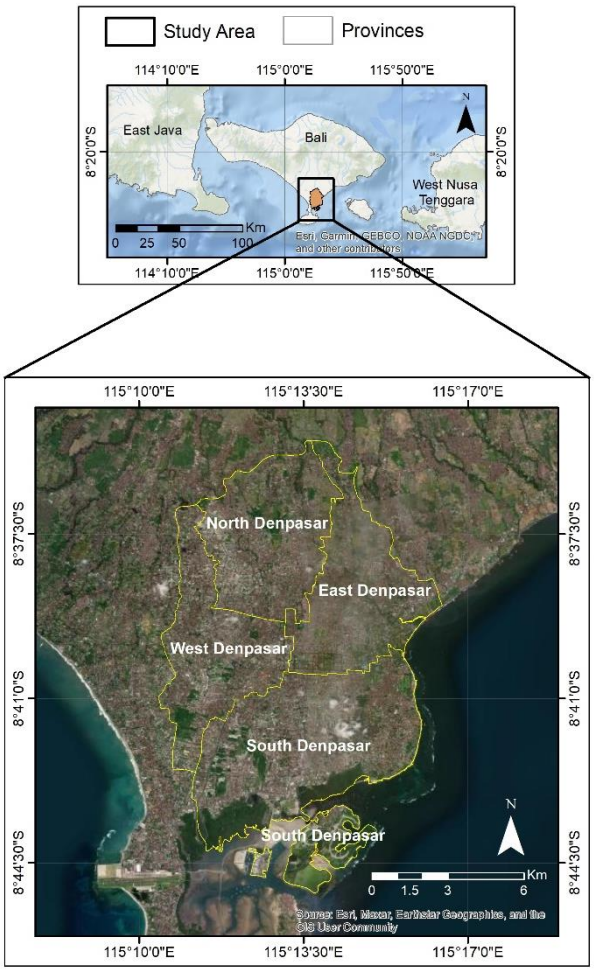

Figure 1. Denpasar City as Study Area

The spatial variability of NDVI and LST was observed in all study areas to conduct NDVI and LST analysis. For several reasons, NDVI and LST values was analyzed prior to assessing the distribution of UTFVI values. NDVI depicts the spatial dispersion of vegetation in the study area and has a statistically significant correlation with LST (Karnieli et al., 2019), and LST is the value that underpins UTFVI distribution in specific locations. Following an examination of the dispersion of NDVI and LST, investigating the ecological conditions of micro-scale cities in terms of LST using the value of the urban thermal field variance index (UTFVI) as an indicator (Table 1) was done, which refers to previous studies by Singh et al. (2017). Areas that need high priority treatment due to the negative impacts of the city's ecological circumstances was also studied in order to identify unfavorable places that demand immediate care.

Table 1. The threshold of ecological evaluation index

UTFVI	UHI Phenomenon	Ecological Evaluation Index
< 0.000	None	Excellent
0.000 - 0.005	Weak	Good
0.005 - 0.010	Middle	Normal
0.010 - 0.015	Strong	Bad
0.015 - 0.020	Stronger	Worse
> 0.020	Strongest	Worst

Source: Singh et al. (2017)

3. RESULTS AND DISCUSSION

The spatial variability of NDVI as a proxy for defining vegetation cover or land cover categories in general is depicted in Figure 1. Based on the previous research, the NDVI threshold value approach mostly less than -0.18 is chosen as a reference for aquatic bodies (Zhang, Wang, & Li, 2006), while Ndossi and Avdan (2016) believed that a threshold of -0.185 was appropriate enough. Relatively low NDVI values (-0.18) indicate bodies of water in the southern section of Denpasar, which is directly near to the Indian Ocean. The majority of Denpasar is covered by intermediate NDVI values (0.157 - 0.727). High NDVI values (> 0.727) indicate plant cover, which is typically

found in Denpasar's southern and northern outskirts. The following map (Figure 2) illustrates the NDVI's spatial distribution in the city of Denpasar.

In most cases, a high percentage of vegetation cover is indicated by an NDVI value that is relatively close to one. In contrast, the presence of built-up land, grass, and bare land is typically indicated by an NDVI value that is closer to zero. On the other hand, if the NDVI value is significantly lower than zero, it most likely indicates the presence of water (Jensen, 2015). The NDVI and the LST value have a relationship that can be described as being inversely proportional to one another, that the NDVI value will be lower when the LST value is higher Karnieli et al. (2019). However, this does not completely relate, especially when it comes to bodies of water. The NDVI values will typically be very low in water body objects, while the LST values will typically be low. Both of these trends are to be expected. Take, for instance, a body of water that is immediately adjacent to the Indian Ocean in the southern part of the city of Denpasar, where the NDVI value is less than -0.18 but the area has a low LST that is less than 294 K.

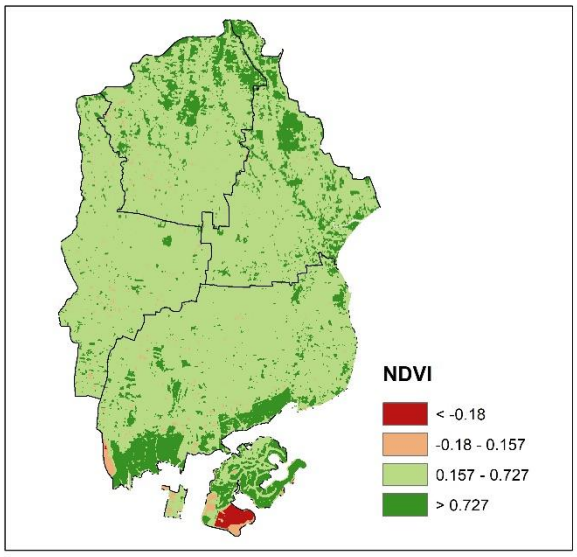

Figure 2. Spatial distribution of NDVI

The spatial variability of LST is depicted in Figure 3. LST with low values ranging below 294 K are usually found in the southern part of the south Denpasar sub-district, where bodies of water in coastal areas directly next to the Indian ocean have relatively low temperatures ranging between 291-294 K. LST with an intermediate value generally range from 294-297 K are distributed throughout almost the entire study area. The exception of the southern part of North Denpasar as well as northern part of West Denpasar sub-districts, which have comparatively high LSTs of about 291-300 K and even higher in comparison to other areas.

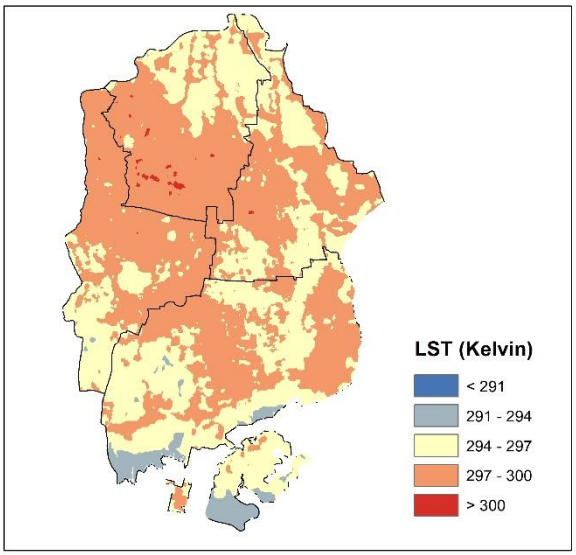

Figure 3. Spatial distribution of LST

Figure 4 illustrates the spatial distribution of UTFVI, which represents urban ecological conditions in relation to land surface temperature. The level of UTFVI is significantly higher where the temperature is significantly higher than the rural areas that are located nearby (H. Wang, Zhang, Tsou, & Li, 2017). The greater the UTFVI value, the worse the state of urban ecological degradation and the greater the intensity of UHI, and vice versa. A low UTFVI value of less than 0.005 is spatially distributed throughout all districts and is characterized as an area with good to very good urban ecological quality. This category predominates in the South and East Denpasar Districts, the northern region of the North Denpasar District, and the southern region of the West Denpasar District. The UHI intensity value there is also weak, if not non-existent.

The intermediate category UTFVI values representing normal urban ecological conditions are also widely distributed across all districts. In particular, few areas in this category can be found in the South Denpasar and East Denpasar sub-districts, some in the northern part of West Denpasar sub-district, and many in the southern part of the North Denpasar sub-district. Furthermore, ecologically stressed areas where the UTFVI value is in the bad classification are relatively

few in the city of Denpasar. Those are located in the southern part of the northern Denpasar sub-district and very few in the area to the west of east Denpasar sub-district and the northern area of west Denpasar sub-district. In comparison to other areas, the area has a relatively higher UHI level.

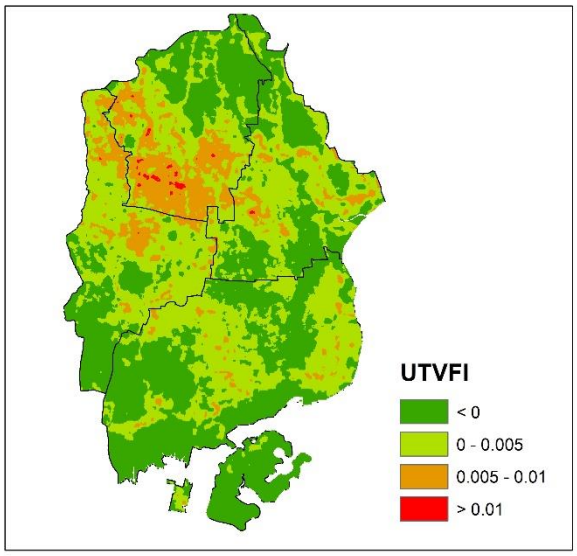

Figure 4. Spatial distribution of UTFVI values

Table 2. Area based on the ecological evaluation index in hectares

Sub-district	Area in Hectares			
	Excellent	Good	Normal	Bad
West Denpasar	644679	1219374	322137	891
South Denpasar	2594754	1683099	93474	0
East Denpasar	1016226	1150929	163458	1539
North Denpasar	773 550	867 834	716364	26730

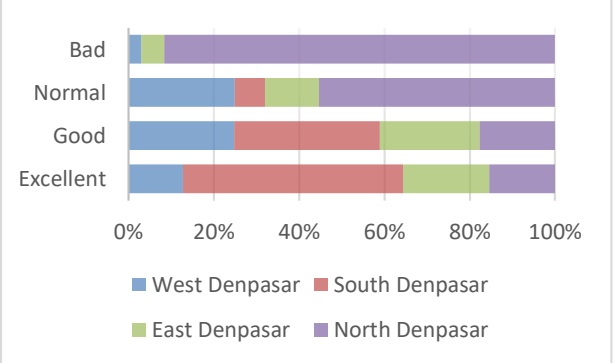

Figure 5. Graph of the percentage of area based on the Ecological Evaluation Index category

Table 2 provides a comprehensive analysis of the area as determined by the ecological evaluation index. Figure 5 presents a bar chart that illustrates the percentage distribution of the area. The North Denpasar District is at the top of the list of municipalities that need to give ecological restoration a higher priority, based on the criteria that were discussed earlier (26 730 ha). East Denpasar, which encompasses 1,539 hectares, and West Denpasar, which also encompasses 1,539 hectares, are, on the other hand, the sub districts that have the smallest area in terms of ecological restoration priority locations (891 ha). Previous research has looked at a variety of approaches to reducing UHI and has presented its findings. According to Y. Wang, Berardi, and Akbari (2016), one of the many ways that UHI can be mitigated in ecological restoration efforts is by planting trees in critical areas. Another method is to add a coating to roads or building roofs so that these objects can reflect solar radiation as effectively as possible. Both of these strategies are included in the list of potential methods. It is possible for future research to place an emphasis on UHI mitigation methods and ecological restoration strategies that are suitable for each of the sub districts.

The evaluation of urban ecological conditions in regarded to aspects of land surface temperature based on UTFVI values reveals that there is a fairly clear pattern. If a region is ecologically depressed, then that region will have an LST that is higher than average. This is due to the fact that the UTFVI value provides a description of the urban ecological condition index derived from LST (Liou et al., 2017). In addition to this, the UTFVI can be used as an indicator to determine the intensity of the UHI as well as the level of thermal comfort in a given region (Singh et al., 2017). The value of the UTFVI can be used as a foundation for prioritizing how to address urban areas with degraded ecological conditions and determining whether or not to mandate mitigation of the unfavorable effects of UHI. This is done so that environmental engineers or other stakeholders can make ecological restoration efforts that are accurate to their intended targets.

4. CONCLUSION

Relatively low NDVI values (-0.18) indicate

bodies of water in the southern section of Denpasar, which is directly near to the Indian Ocean. The majority of Denpasar is covered by intermediate NDVI values (0.157 - 0.727). LSTs with low values ranging below 294 K are usually found in the southern part of the south Denpasar sub district, where bodies of water in coastal areas directly next to the Indonesian ocean have relatively low temperatures ranging between 291-294 K. The greater the UTFVI value, the worse the state of urban ecological degradation and the greater the intensity of UHI, and vice versa. The intermediate category UTFVI values representing normal urban ecological conditions are also widely distributed across all districts. The NDVI values will typically be very low in water body objects, while the LST values will typically be low. The evaluation of urban ecological conditions in regard to aspects of land surface temperature based on UTFVI values reveals that there is a fairly clear pattern.

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