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Prediction of Land Cover and Land Surface Temperature in Kuta Selatan Sub-district, Bali Province

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Abstract— **Kuta Selatan Sub-district has experienced changes in land cover due to the development of urbanization in recent years. One of the main problems caused by the progress of this development is the Land Surface Temperature (LST), which can cause several issues such as adverse socio-economic and environmental impacts on the urban population. This study provides information for the future urban developer by considering the implications of future temperature growth for city dwellers' thermal comfort, which should assist in developing and implementing management strategies to reduce the effects of urban heat. We used Landsat 7 ETM + and Landsat 8 OLI-TIRS as data sources for spatial-temporal analysis of land cover and LST in Kuta Selatan Sub-district for 2006, 2015, 2020 and their predictions in 2033 using the CA-Markov model. The results showed that the built-up area and LST in 2033 experienced a significant increase in space and distribution in Jimbaran, Benoa, Tanjung Benoa, and the mean LST in Kuta Selatan Sub-district would increase, from 25.63°C in 2006 to 33.07°C in 2033. Built-up areas and bare soil produce higher LST than vegetation and water bodies. Thus, vegetation and water bodies play an essential role in LST mitigation. Based on these results, in the future, LST in Kuta Selatan Sub-district will be warmer compared to the present.**

Keywords— **CA-Markov; Kuta Selatan sub-district; land cover; land surface temperature; prediction.**

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I. INTRODUCTION

An administrative region will continue to experience population growth and the development process to become more advanced urban areas over time. Population growth requires built-up areas, which will increase to consume natural resources, especially vegetation and agricultural land, which leads to urbanization. These conditions will cause changes in land cover, along with urbanization growth. The area of vegetation in the Kuta Selatan Sub-district from 2013 to 2016 decreased in size from 3,614 hectares to 3,465 hectares [1]. Meanwhile, the built-up area has increased from 6,320 Ha to 6,468 Ha [1]. Urbanization is an environmental phenomenon that has become a concern in the 21st century. The growth of extensive urbanization makes it challenging to achieve a prosperous and sustainable city. This situation is made worse because urbanization is intertwined with environmental phenomena, one of which is the difference between the city's climate and the surrounding area [2].

Changes in land cover due to urbanization can affect urban climate. The urban climate will change due to loss of vegetation cover and be replaced by surfaces that can absorb heat such as asphalt, concrete, bricks, and roofs, then cause higher surface temperatures in the city center compared to the surrounding rural areas [3]. When different land covers absorb the same amount of solar radiation, the resulting temperature is also different. The temperature difference is due to differences in heat capacity that can be absorbed by land cover. Thus, an increase in the built-up area increases surface temperature values [2].

Many previous studies have conducted research on LST and land cover. Some focus on distribution patterns and their relationship to land cover using Landsat image data [4]–[6]. Several studies have examined Urban Heat Island (UHI) in urban and rural areas from LST analysis [7]–[9]. LST and land cover predicted for the future have also been carried out by several researchers involving the CA-Markov model, Multi-Layer Perception Markov, and Stochastic Markov [10]–[16]. There is even research related to Multi-Criteria Evaluation (MCE), which uses several scenarios to suit urbanization and modeling of urban growth that affect LST [17].

Urban growth's effects on the urban microclimate are projected to continue to increase as urban populations continue to expand globally [18]. Rapid urban growth can cause land cover changes, which replaces natural surfaces into surfaces that can absorb heat. The hot surface of the earth can cause an increase in temperature in the urban climate. LST has an essential role in changes in surface energy, climate, and environment [19]. If we analyzed LST in the long run, this could help monitor and reduce urban heat temperatures. This study aims to analyze the change and distribution of land cover and LST in 2006, 2015, and 2020. It also predicts land cover and LST for 2033 in Kuta Selatan Sub-district using CA-Markov.

II. Material and Methods

A. Study Area

The study was conducted in the Sub-district of Kuta Selatan, Badung District, Bali Province, with an area of 100.66 Km^2 or 10,066 Ha. Kuta Selatan Sub-district is one part of the Badung District, directly bordered by the coast (Figure 1). Geographically, Kuta Selatan Sub-district is located between 08°46'58.7" South Latitude and 115°10’41.3" East Longitude. Kuta Selatan Sub-district has six villages, namely Pecatu, Ungasan, Kutuh, Benoa, Tanjung Benoa, and Jimbaran. Kuta's sub-districts border the area of Kuta Selatan Sub-district in the north, the Indian Ocean in the south, east, and west. In 1980, Kuta Selatan Sub-district's coastal area, Nusa Dua, was built a luxury tourist area called the Bali Tourism Development Corporation (BTDC). With the development of the tourist area, it is causing increased urban growth. Kuta Selatan Sub-district experienced an increase in population density from 723.17 to 1,629 per Km2 from 2010 to 2018, then supported by the annual population growth rate data, which 4.49, and it’s the highest in Badung District [1].

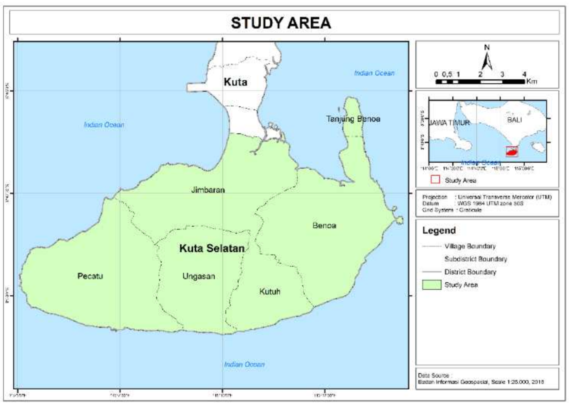


Fig. 1 Study Area

B. Raw Data

TABLE I
DATA SPECIFICATIONS USED IN THE STUDY

Type	Source	Date	Spatial Resolution
Remote Sensing	Landsat 7 ETM+	2006-06-16	30 m
	Landsat 8 OLI-TIRS	2015-04-15	30 m
	Landsat 8 OLI-TIRS	2020-02-24	30 m
Vector Dataset	DEMNAS	2018	0.27 arcsecond
	Topographic Map	2016	1: 25000
	Road Network	2016	1: 25000
	Point of Interest	2016	1: 25000
	Coastline	2016	1: 25000

This study uses three images from Landsat, and some vector data such as DEMNAS, topographic maps, road networks, coastlines, and points of interest (POI). The data specifications used in this study are in Table I. The image in 2006 was obtained from Landsat 7 ETM+, and images in 2015 and 2020 were gathered from Landsat 8 OLI-TIRS. We used Landsat data to classify land cover and derive LST. Vector data acts as a driving factor that will help in predicting future land cover.

C. Land Cover Classification

Land cover for 2006, 2015, and 2020 is processed using the maximum likelihood classification method in ENVI 5.1 software. This method can produce higher accuracy in image classification results even though it is computationally intensive and time-consuming [20]. This method approach has been adopted for monitoring and analyzing land use/cover. Each image is classified into four classifications, which are built-up area, vegetation, water bodies, and bare soil [11]. The maximum likelihood classification method results were tested for accuracy by comparing it with the Google Earth images. The accuracy assessment is performed with the overall accuracy and Kappa coefficient, then classified with the Kappa Index of Agreement (KIA) [10], [11], [21]. After obtaining proper accuracy, we calculated the area of each land cover classification.

D. Computation Land Cover Indicies

Several land cover indices were tested to compare differences in the strength of the relationship with LST and to identify the index with the most potent ability to predict LST, namely NDBI, UI, NDVI, and EVI [10]. Some of the indexes are calculated from Landsat imagery for 2006, 2015, and 2020. The results of the calculation of some of these indices are in the range of -0.1 to 0.1. The equation is shown below.

$$NDBI = \frac{SWIR1-NIR}{SWIR+NIR} \quad (1)$$

$$UI = \frac{SWIR2-NIR}{SWIR2+NIR} \quad (2)$$

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (3)$$

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (4)$$

E. LST Derivation

To get the LST value, we convert the DN value to radians. Next, we calculated the radiant brightness temperature and corrected the emissivity to finally get the surface temperature from the brightness temperature [22]. Emissivity correction is done because the surface temperature of an object can emit more radiation due to the addition of reflective radiation so that it can give a wrong perception about the transmit power or heat of a surface [23]. Brightness temperature comes from thermal radians, which are a single channel of Landsat. Specifically, to estimate temperature using the Equation 5 and 6 below [10,24,25,26]. Furthermore, LST is derived after applying Equation 6 to correct emissivity at brightness temperature. The symbol λ represents the wavelength emitted by thermal radians (10.8 µm), while ρ is equivalent to $1.438x10^{-2}$mK. K_1 and K_2 coefficients that are used in the equation are shown in Table II. After obtaining the LST value, an area calculation is performed for each year so that changes in LST can be analyzed.

$$TB = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda}+1\right)} \quad (5)$$

$$Ts = \frac{T_B}{1+\left(\frac{\lambda T_B}{\rho}\right) ln\varepsilon} \quad (6)$$

TABLE II
K_1 AND K_2 COEFFICIENT VALUES FOR LANDSAT 7 AND 8 THERMAL DATA

Sensor	K_1 [W/(m²srμm)]	K_2 [W/(m²srμm)]
Landsat 7	666.09	1282.71
Landsat 8	774.89	1321.08

F. Land Cover Prediction Using CA-Markov

Prediction of land cover distribution for 2033 uses the CA-Markov model contained in the IDRISI software. We choose the CA-Markov model because of its proven ability to predict land cover changes over time and the simplicity of its implementation [11], [25]. Before using CA-Markov analysis in actual predictions, we predict future land cover changes using the land cover transition in 2006 and 2015. Furthermore, after we carried out the potential tests, then land cover changes can be predicted for 2020. then we compared the expected land cover to the land cover obtained by using the maximum likelihood classification in 2020. We thus assess the accuracy of the model by comparing the predicted results and the actual data.

In the CA-Markov analysis, driving factors are used as factors that help determine the change from one pixel of land cover to another. To get the results of driving factors is done by scoring, fuzzy, and finally overlaying between fuzzy to produce driving factors. This study shows several driving factors such as distance from the road, distance from the coastline, distance from the POI, slope, and elevation [14]. The details of the driving factors are shown in Table III.

TABLE III
CLASSIFICATION OF DRIVING FACTORS

Driving Factors	Class	Suitability
Distance from Road	0 – 100 m	Very Suitable
	100 – 200 m	Suitable
	200 – 500 m	Quite Suitable
	500 – 1000 m	Less Suitable
	> 1000 m	Not Suitable
Distance from the Coastline	0 – 100 m	Not Suitable
	100 – 500 m	Suitable
	> 500 m	Less Suitable
Distance from the POI	0 – 500 m	Very Suitable
	500 – 1000 m	Suitable
	> 1000 m	Less Suitable
Slope	0 – 2 %	Very Suitable
	2 – 15 %	Suitable
	15 – 40 %	Less Suitable
	> 40 %	Not Suitable
Elevation	0 – 25 msl	Very Suitable
	25 – 100 msl	Suitable
	100 – 500 msl	Quite Suitable
	> 500 msl	Not Suitable

G. LST prediction using CA-Markov

We predict LST using several indices has the potential to predict future surface temperatures such as Normalized Difference Built-up Index (NDBI), Urban Index (UI), Normalized Difference Vegetation Index (NDVI), and Enhanced Vegetation Index (EVI) [10]. The index that has the strongest relationship and ability to predict LST is calculated by its transition probability matrix with the Markov Chain to map the future state of the index for 2020 and 2033 in the Cellular Automata model. After that, the linear regression calculation is done to convert the index prediction to LST for 2020 and 2033. Furthermore, validation is performed with the statistical calculation of Mean Absolute Percentage Error (MAPE) to assess the accuracy of the LST generated from the predicted model of the land cover index in 2020.

III. RESULTS AND DISCUSSION

A. Changes of Land Cover in 2006, 2015 and 2020

Land cover of Kuta Selatan Sub-district for 2006, 2015, and 2020 resulting from the maximum likelihood classification method was carried out an accuracy assessment to see the feasibility of land cover resulting from the process. Evaluation of the overall accuracy test and the kappa coefficient is shown in Table IV. This accuracy test was generated from 81 sample points spread across Kuta Selatan Sub-district. The overall accuracy of each year produces a value of more than 85%. The results of the Kappa coefficient each year show values above 0.85. Then, from the overall accuracy and kappa coefficient accuracy test results, each year produces almost perfect agreement on the Kappa Index of Agreement (KIA), which means the accuracy of land cover classification using the maximum likelihood classification is acceptable. After obtaining acceptable accuracy, the area of land cover can be calculated and analyzed to see changes in land cover.

TABLE IV
LAND COVER ACCURACY ASSESSMENT

Accuracy	2006	2015	2020
Overall Accuracy	98,1696	92,5926	88,8889
Kappa Coefficient	0,9760	0,8866	0,8517
KIA	Almost Perfect Agreement	Almost Perfect Agreement	Almost Perfect Agreement

TABLE V
LAND COVER AREA IN 2006, 2015 AND 2020

Land Cover	Year 2006		2015		2020	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Vegetation	5,389.46	53.54	4,002.48	39.76	4,853.12	48.23
Water Body	227.47	2.26	46.64	0.46	53.01	0.53
Built-up Area	1,626.37	16.16	2,279.36	22.64	3,140.79	31.21
Bare Soil	2,822.68	28.04	3,737.51	37.13	2,015.72	20.03
Total	10,066	100	10,066	100	10,066	100

Information on land cover changes in Kuta Selatan Sub-district in 2006, 2015, and 2020 are presented in Table V. In 2006, the largest area of land cover was vegetation with an area of 5,389.46 Ha, then followed by bare soil with an area of 2,822.68 Ha, built-up area 1662.37 Ha, and water bodies 227.47 Ha. In 2015, the largest area of land cover in Kuta Selatan Sub-district was vegetation with an area of 4,002.48

Ha, then followed by bare soil with an area of 3,737.51 Ha, built-up area 2,279.36 Ha, and water body 46.64 Ha. In 2020, the largest area of land cover in Kuta Selatan Sub-district was vegetation with an area of 4,853.12 Ha, then followed by built-up area 3,140.79 Ha, bare soil 2,015.72 Ha, and water body with an area of 53.01 Ha.

Figure 2 shows spatial information about changes in land cover in Kuta Selatan Sub-district from 2006 to 2020. In 2006, vegetation was concentrated in the east, southeast, southwest, and west of Kuta Selatan Sub-district. Then the water body is focused on the north and northeast of the Kuta Selatan Sub-district. Furthermore, the built-up area is concentrated in the middle, north, northeast, and east of Kuta Selatan Sub-district. Bare Soil is focused on the southern, western, and central parts that lead north of the Kuta Selatan Sub-district. In 2015, vegetation was concentrated in the southwest and west of the Kuta Selatan Sub-district. Then the water body is focused on the north and northeast of the Kuta Selatan Sub-district.

Furthermore, the built-up area is in the middle, north, northeast, and east of Kuta Selatan Sub-district. Then there is bare soil in the southeast, south, west, northwest, and the central part of the Kuta Selatan Sub-district. In 2020, vegetation is concentrated in the east, southwest, west, and northwest of the Kuta Selatan Sub-district. Then the water body is focused on the north and northeast of the Kuta Selatan Sub-district. Furthermore, the built-up area is concentrated in the middle, north, northeast, east, south, southwest, and northwest of the Kuta Selatan Sub-district. Bare soil is concentrated in the central, southeast, and south of the Kuta Selatan Sub-district.

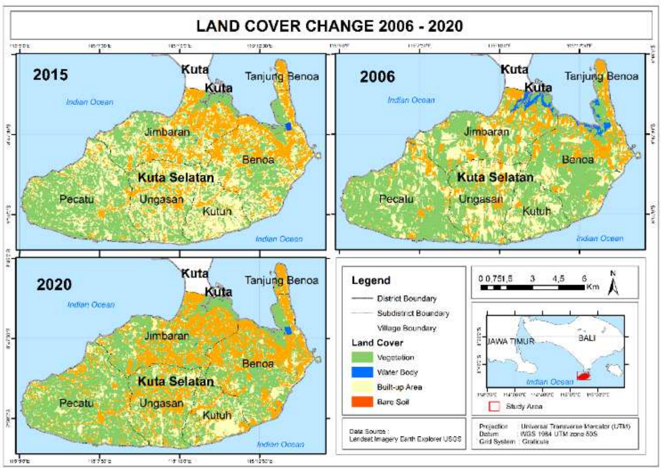


Fig. 2 Land cover change in 2006, 2015 and 2020

Table VI shows the information on the land cover that has changed into the built-up area. The land cover that experienced the most extensive area change into the built-up area was bare soil with 1,761.99 Ha from 3,058.27 Ha or 57.61% of the total area of change that occurred in Kuta Selatan Sub-district in the period 2006 - 2020. Land cover classification vegetation and water bodies also experience changes to the built-up area, but not as significant as bare soil.

Figure 3 shows a land cover that has changed into a built-up area symbolized by red color. The distribution of the built-up area is concentrated in the villages of Jimbaran, Benoa, and Tanjung Benoa. There are government buildings, hospitals, markets, and schools, so people prefer to live in places close to facilities. Then there was also an extensive development and the distribution of built-up areas in the villages of Kutuh, Ungasan, and Pecatu, whose developments followed the road infrastructure.

TABLE VI
LAND COVER CHANGES IN 2006 - 2020

Land Cover	Built-up Area	
	Ha	%
Bare Soil	1.761,99	57,61
Vegetation	1.264,73	41,35
Water Body	31,55	1,03
Total	3.058,27	100

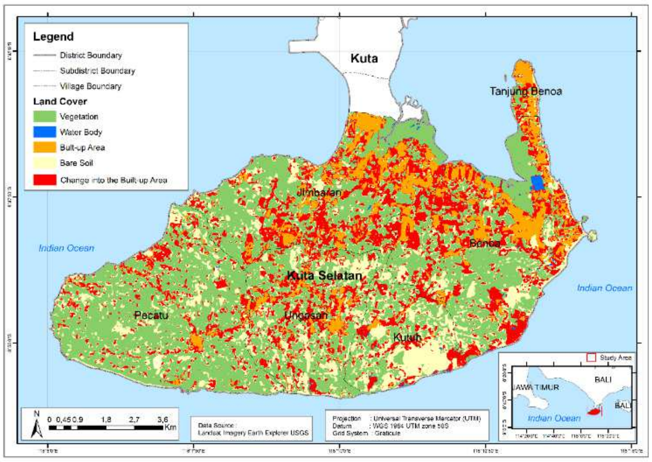


Fig. 3 Land cover changes into the built-up area in the period 2006 – 2020

B. *LST Distribution in 2006, 2015 and 2020*

TABLE VII
LST AREA IN 2006, 2015 AND 2020

LST (°C)	Year					
	2006		2015		2020	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
< 24	707.59	7.03	3,214.14	31.93	448.44	4.45
24 – 26	6,248.49	62.08	5,884.83	58.46	5,509.82	54.74
26 – 28	2,828.53	28.1	929.92	9.24	3,478.65	34.56
28 – 30	276.4	2.75	37.09	0.37	628.03	6.24
> 30	4.99	0.05	0	0	1.05	0.01
Total	10,066	100	10,066	100	10,066	100

After applying Equations (5) and (6) on the Landsat images to derive the LST value, and then the LST area is calculated, an LST change for 2006, 2015, and 2020 can be analyzed. Table VII shows information about changes in the LST area in Kuta Selatan Sub-district in 2006, 2015, and 2020. In 2006, LST 24 - 26°C with the largest area of 6,248.49 Ha, then followed consecutively by LST 26-28 ° C; < 24°C; 28 - 30°C, with a total area of 2,828.53 Ha; 707.59 Ha; 276.4 Ha. The smallest area of LST is LST > 30°C covering 4.99 Ha. In 2015 and 2020, LST 24 - 26°C is still the widest, and LST > 30°C is still the narrowest. There was a change in LST distribution in 2015 and 2020. Differences occurred in 2015 in the order of LST < 24°C; 26 - 28°C; 28 - 30°C, with an area of 3,214.14 Ha; 929.92 Ha; 37.09 Ha. In 2020 the LST broad sequence after 24 - 26°C is 26 - 28°C; 28 - 30°C; < 24°C, with an area of 3,478.65 Ha; 628.03 Ha; 448.44 Ha.

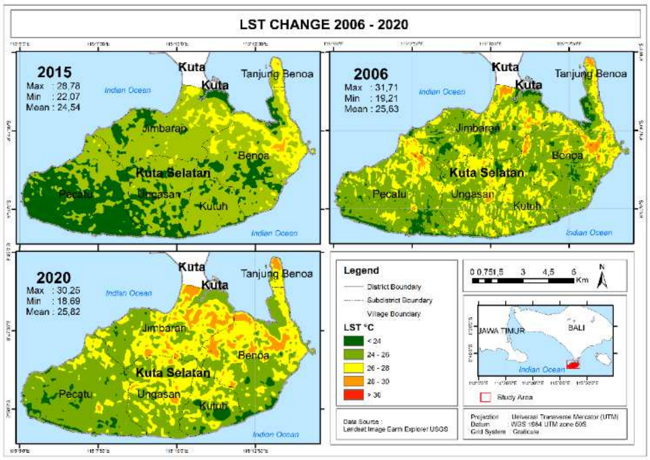


Fig. 4 LST change in 2006, 2015, 2020

Figure 4 shows spatial information about changes in the distribution of the Kuta Selatan Sub-district LST from 2006 to 2020. The LST in Kuta Selatan Sub-district in 2006 had a minimum value of 19.21°C, a maximum of 31.71°C, and a mean of 25.63°C. LST < 24°C is concentrated in the middle, north, northeast, east, southwest, and northwest of the Kuta Selatan Sub-district. As described in Table 6, the area that dominates is the 24 - 26°C classification. This classification is spread almost in the whole of Kuta Selatan Sub-district, which covers all villages. Then 26 - 28°C is also spread throughout the villages in Kuta Selatan Sub-district. Furthermore, for classification 28-30°C, found in the north, northeast, east, south, and west of Kuta Selatan Sub-district. In the LST classification > 30°C is the smallest broadest classification, the distribution is also getting smaller. LST in Kuta Selatan Sub-district in 2015 had a minimum value of 22.07°C, a maximum of 28.78°C, and a mean of 24.54°C. LST < 24°C, which is the dominant classification in Kuta Selatan Sub-district in 2015, was concentrated in the east, south, southwest, west, and northwest. Furthermore, at 24 - 26°C, this classification is spread almost in the whole of the Kuta Selatan Sub-district. Then LST 26 - 28°C is found in the north, northeast, and east of the Kuta Selatan Sub-district. Furthermore, for 28 - 30°C is located in the eastern part of the Kuta Selatan Sub-district. LST > 30°C has no spatial information because the temperature in 2015 did not reach more than 30°C. LST in Kuta Selatan Sub-district in 2020 has a minimum value of 18.69°C, a maximum of 30.25°C, and a mean of 25.82°C. In 2020, the LST classification < 24°C found in the southeast and southwest of the Kuta Selatan Sub-district. LST that dominates in 2020 is the classification of 24 - 26°C, this classification is spread throughout the Kuta Selatan Sub-district, which includes all villages. LST 26 - 28°C is also spread throughout the villages in Kuta Selatan Sub-district. Furthermore, for 28 - 30°C found in the north, northeast, east, southeast, south, and southwest of Kuta Selatan Sub-district. LST > 30°C is the smallest extent of classification, and the distribution is also getting smaller. This classification is found in the northern and eastern parts of the Kuta Selatan Sub-district.

C. Prediction of land cover in 2033

Accuracy assessments were conducted on the 2020 model and the existing 2020 land cover data to see the model's feasibility as information on the study. Accuracy assessment is performed using the validated tool contained in the IDRISI software. The resulting kappa value is shown in Kstandard of 0.7167, which leads to a substantial agreement, which means the agreement between the 2020 land cover model and the existing 2020 land cover data has good accuracy for further modeling predict land cover in 2033.

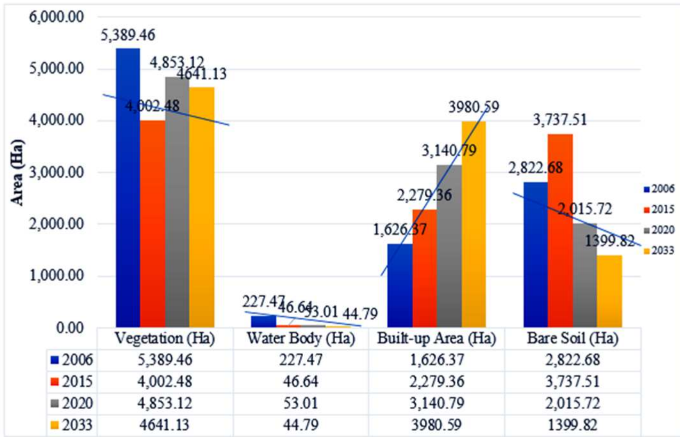


Fig. 5 Land cover changes in 2033

The land cover changes of the Kuta Selatan Sub-district in 2033 can be seen in Figure 5. Vegetation decreased significantly, which initially in 2006 had an area of 5,389.46 Ha predicted in 2033 to 4,641.13 Ha, or reduced by 7.44% since 2006. Water bodies experienced a significant decrease in 2033, which initially in 2006 had an area of 227.47 Ha. It was estimated that in 2033 it would change to 44.79 Ha or decrease by 1.81% since 2006. Empty land in 2006 has an area of 2,822, 68 hectares, and then predicted in 2033, it will change to 1,399.82 hectares, or decrease by 14.14% since 2006. Meanwhile, the construction area in 2006, has an area of 1,662. It is estimated that 37 hectares in 2033 will change to 3,980.59 hectares, or has grown by 23.39% since 2006.

In 2033 land cover experienced a decrease is vegetation, water bodies, and bare soil, while the built-up area increased. Based on the information from the table in Figure 5, it can be seen that land cover continues to experience extensive changes in the timeframe 2006 - 2033.

Figure 6 shows the spatial information comparing the existing land cover in 2020 and the land cover model in 2033. At a glance, vegetation land cover does not show significant changes, but some differences indicate the shift from vegetation to bare soil in the northwest. The distribution of vegetation is predicted to be concentrated in the east, southwest, and west of the Kuta Selatan Sub-district, which includes the villages of Benoa and Pecatu. Water bodies do not experience significant changes so that the spatial changes are not too visible. It is predicted that the distribution of water bodies will remain concentrated in the northern and northeastern areas of Kuta Selatan Sub-district, namely in the villages of Jimbaran and Benoa. Land cover is predicted in 2033 to change from vegetation and bare soil to a built-up area. The distribution of the built-up area shows an increase in area and density, which is spread in the middle, north, northeast, east, and south, while the area that is expanding is in the southwest and west of Kuta Selatan Sub-district. The urban areas that experienced expansion and densities that were increasingly dense were Jimbaran, Benoa, Tanjung Benoa, and Ungasan.

In contrast, those that experienced widespread expansion were found in the villages of Kutuh and Pecatu. The distribution of bare soil is predicted to be concentrated in the central, southeast, and northwestern areas of Kuta Selatan Sub-district, namely in the villages of Kutuh, Ungasan, Jimbaran, and Pecatu. In the southeast and northwest, it can be seen that there has been a change in land cover from vegetation to bare soil in 2033. Based on information from Figure 6, it can be seen that land cover that has increased in area and density is built-up area. Sustainable urban growth will increase warming and produce high temperatures in the future [10].

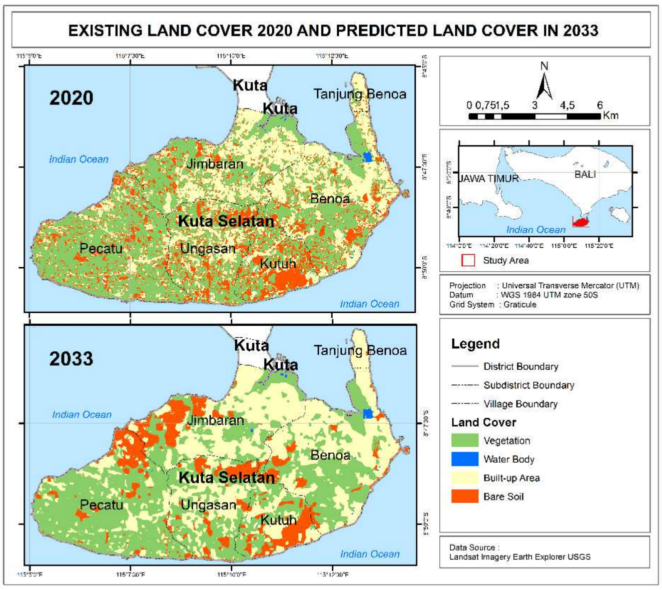


Fig. 6 Comparison of existing land cover in 2020 and the model in 2033

D. *Future LST in 2033*

LST in 2033 is predicted by first conducting the processing to produce a land cover index and correlation test. The land cover index with the highest correlation is NDBI with a value of r = 0.915308 and Y = 2.037819 + 31.3395652X. Furthermore, to obtain the LST results from the NDBI land cover index value, a linear regression statistical calculation is performed to convert the NDBI prediction model to the LST prediction model in 2020 and 2033. Regression from NDBI and LST produces the equation LST = 2.8525 + 8.0568 * NDBI and R^2 = 0.809261, which shows the strong influence between NDBI and LST. The linear regression model results between NDBI and LST 2020 were validated using the MAPE statistical test. The temperature obtained from NDBI is compared with the temperature obtained directly from Landsat 8 infrared thermal data (Figure 7). Based on 81 sample points taken, the statistical calculation yields MAPE = 4.20%, RMSE = 1.27°C, and KIA = 0.76. Based on these calculations, the NDBI land cover index is considered capable of predicting LST with fairly high accuracy. After conducting the accuracy test, proceed with modeling for 2033.

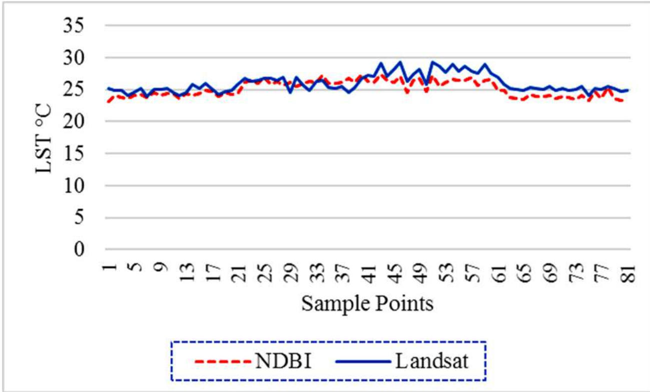


Fig. 7 LST comparison from NDBI with infrared thermal Landsat

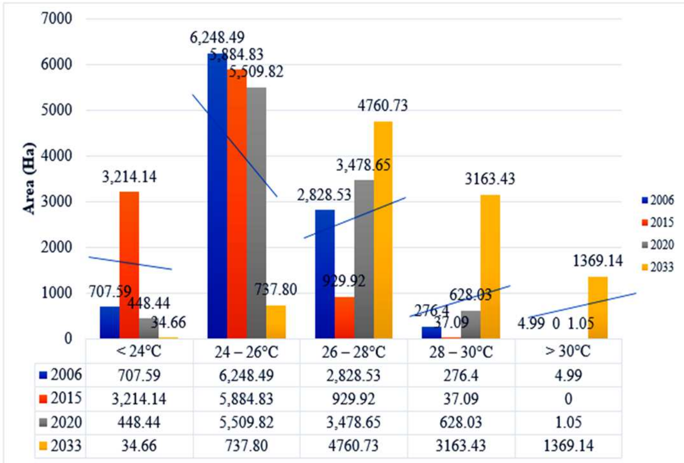


Fig. 8 LST changes in 2033

Changes in LST in 2033 are shown in Figure 8. LST < 24°C has decreased in 2033, which initially in 2006 had an area of 707.59 Ha predicted in 2033 will change to 34.66 Ha. This classification has reduced by 6.69% since 2006. LST with a grouping of 24 - 26°C experienced a significant decrease in 2033, which initially in 2006 had an area of 6,248.49 Ha and predicted in 2033 it would change to 737.80 Ha. This classification has decreased by 54.75% since 2006. LST with a classification 26 - 28°C experienced an increase in area in 2033, which initially in 2006 had an area of 2,828.53 Ha and predicted in 2033 will change to 4,760.73 Ha. This classification has increased by 19.20% since 2006. LST with a grouping of 28 - 30°C experienced an increase in area in 2033, which initially in 2006 had an area of 276.4 Ha and predicted in 2033 will change to 3,163.43 Ha. This classification has increased by 28.68% since 2006. LST with a temperature > 30°C experienced an increase in area in 2033, which initially in 2006 had an area of 4.99 Ha and predicted in 2033 will change to 1,369.14 Ha. This classification has increased by 13.55% since 2006. In 2033 LSTs that experienced a decrease were < 24°C, and 24 - 26°C, while LSTs that experienced an increase were 26 - 28°C, 28 - 30°C, and > 30°C. Based on the information in Figure 8, over time, the LST with temperatures below 26°C experienced a decrease in area, and temperatures above 26°C experienced an increase in space in the span of years 2006 - 2033.

Figure 9 shows spatial information comparing the existing LST in 2020 and the LST model in 2033. It can be seen in a very significant difference between the two. The maximum, minimum, and mean values are also different. In 2020 the maximum LST is 30.25°C, while in 2033, the maximum LST is predicted to be 43.14°C. The minimum LST value in 2020 is 18.69°C, while the maximum LST value in 2033 is 22.99°C. Then the mean LST value in 2020 is 25.82°C, while in 2033, the LST is predicted to be an average of 33.07°C. The higher the maximum, minimum, and mean LST values in 2033 shows that the temperature in Kuta Selatan Sub-district in 2033 is predicted to be much hotter than the temperature in 2020.

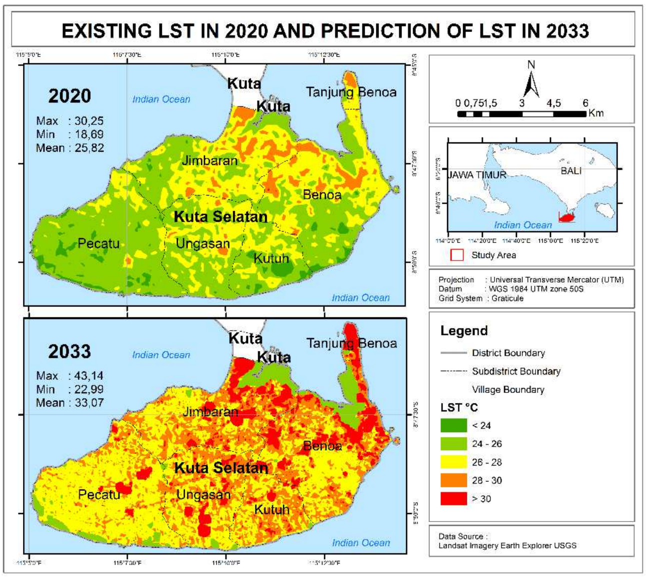
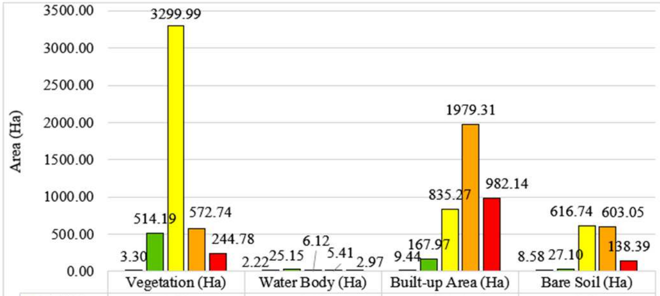


Fig. 9 Comparison of existing LST in 2020 and the model in 2033

A spatially noticeable difference in Figure 9 is the wider distribution of LST above 26°C in 2033 when compared to LST in 2020. LST with classification < 24°C shows significant changes, the extent of distribution of the classification changes to be minimal until it can hardly be seen in plain sight. However, this classification is still found on the southern coast of Kuta Selatan Sub-district. Furthermore, LST with a grouping of 24 - 26°C also experienced a significant change in the distribution area. The extent of the distribution has shrunk compared to the LST in 2020. In 2033, this classification is predicted to be spread in the north, northeast, and southwest of Kuta Selatan Sub-district, namely in the villages of Jimbaran, Benoa, and Pecatu. LST with a classification of 26 - 28°C shows an increase in changes in the distribution area. This LST class region is predicted to be the largest in 2033. Its distribution is almost in all villages of Kuta Selatan. Distribution of LST with classification 26 - 28°C covers all villages, namely, Jimbaran, Benoa, Tanjung Benoa, Kutuh, Ungasan, and Pecatu. The distribution of LST with a classification of 28 - 30°C is predicted in 2033 to be spread throughout all parts of the Kuta Selatan Sub-district, namely, Jimbaran, Benoa, Tanjung Benoa, Kutuh, Ungasan, and Pecatu. Then LST > 30°C, it is predicted that by 2033 the distribution will be concentrated in a dense area of land, namely in the central, northern, northeast, and east parts of Kuta Selatan Sub-district. It is precisely located in Jimbaran, Benoa, Tanjung Benoa, and Ungasan. Based on this information, it can be seen that in 2033 the extent and distribution of temperatures above 26°C are increasingly scattered in all parts of Kuta Selatan Sub-district compared to temperatures in 2020.



	Vegetation (Ha)	Water Body (Ha)	Built-up Area (Ha)	Bare Soil (Ha)
< 24°C	3.30	2.22	9.44	8.58
24 – 26°C	514.19	25.15	167.97	27.10
26 – 28°C	3299.99	6.12	835.27	616.74
28 – 30°C	572.74	5.41	1979.31	603.05
> 30°C	244.78	2.97	982.14	138.39

Fig. 10 Graph of LST based on Kuta Selatan Sub-district land cover in 2033

The overlay between LST and land cover in 2033 was made to make it easier to interpret changes in LST values and areas due to land cover. Figure 10 shows information about the LST area based on Kuta Selatan Sub-district land cover in 2033. Vegetation, the dominant LST classification is 26 - 28°C, with an area of 3299.99 Ha or 71.20% of the total LST area on vegetation in Kuta Selatan Sub-district. The LST classification that dominates the water body is 24-26°C, with an area of 25,15 Ha or 60.07% of the total LST area in a water body in Kuta Selatan Sub-district. Furthermore, in the built-up area, LST that dominates is the classification of 28-30°C with an area of 1979.31 Ha or 49.80% of the total LST area on the built-up area in Kuta Selatan Sub-district. On bare soil, LST classification of 26 -28°C and 28 - 30°C has almost the same area, but what dominates is 26 -28°C with 616.74 Ha 44.25% of the total area of LST on bare soil in Kuta Selatan Sub-district. Based on this information, land cover that produces the highest LST classification is a built-up area with LST classification 28 - 30°C. Then from the results obtained, in line with several studies conducted by other researchers, which stated that LSTs would experience an increase in the value and area over time caused by the urban expansion that converts natural land cover to built-up land [10]–[13], [18]. Thus, the growth in the area of land built or the expansion of the city will always be followed by an increase in LST.

In figure 11, spatial information is useful in the visual interpretation of LSTs based on the land cover of the Kuta Selatan Sub-district in 2033. LSTs with temperatures over 28°C are concentrated in the north, east, and northeast on the built-up area. The location is in the villages of Jimbaran, Benoa, and Tanjung Benoa, which are the downtown Kuta Selatan Sub-district. There are government buildings and hospitals, a trade center, and most schools in the area, so people prefer to stay in Jimbaran, Benoa, and Tanjung Benoa to fulfill their daily lives. The NDBI and LST correlation test produces a directly proportional relationship, which means more dense the built-up area, creating a high LST. Previous research also found results that an increase in urban areas will be followed by the rise in LST [12].

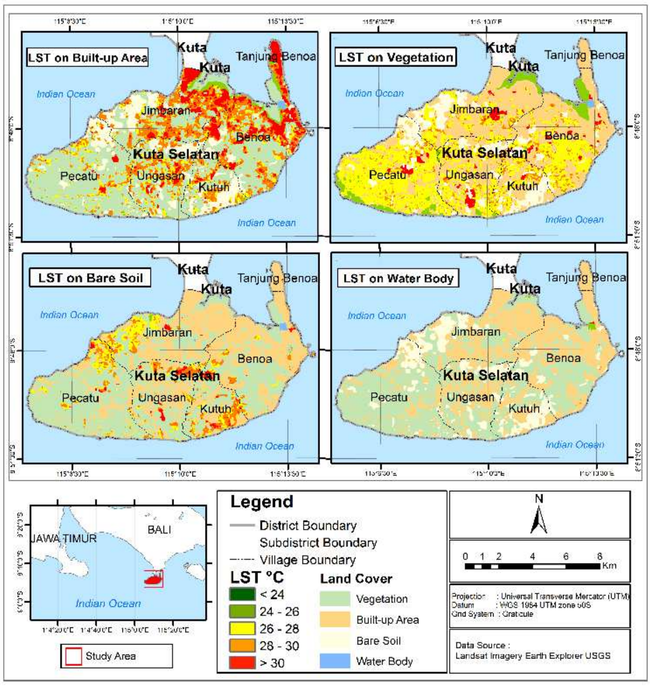


Fig. 11 LST based on Kuta Selatan land cover in 2033

Vegetation has a range of LST 24 - 30°C, which is spread in Jimbaran, Benoa, Kutuh, Pecatu, and Ungasan, but the dominant one is the LST with a classification of 26 - 28°C (Figure 11). Vegetation produces a lower LST than the built-up area and bare soil. In the north and northeast provides low LST because in that area is the conservation area of Kuta Selatan Sub-district mangrove plants. According to statistical tests, the correlation between NDVI and LST is known that the relationship is reversed, if the more vegetation in an area, the LST produced will be lower. Previous studies have shown that dense vegetation and the water-covered regions produce low LST values [5]. Thus, vegetation has an essential role in mitigating LST so that it can create a comfortable urban area for city dwellers.

Bare soil produces LST more than 28°C, but the area and distribution are not as large as the built-up area. The distribution is in Kutuh, Ungasan, Pecatu, Jimbaran, and Benoa (Figure 11). Based on these results, it is known that bare soil also produces a high LST and contributes to the increase in LST. The previous research shows bare soil produces quite high LST as well [11].

Water bodies produce LSTs ranging from 24 - 28°C found in the villages of Jimbaran and Benoa (Figure 11). Water bodies produce lower LST compared to other land covers, even though the area and distribution are not significant. Low LSTs are caused because water bodies have an inverse relationship with LSTs, which means that the more water bodies, the smaller the LSTs are produced [11]. Based on the results, it can be seen that the built-up area and bare soil provides high LST than vegetation and water bodies.

IV. Conclusions

Based on the results of research conducted, it is known that in the range of 2006 to 2020, the built-up area experienced a consistent increase in space and its distribution was concentrated in the north, northeast, and east of Kuta Selatan Sub-district, namely in Jimbaran, Benoa, and Tanjung Benoa. The most changeable land cover to the built-up area is bare soil, followed by vegetation and water bodies. At the same time, LST with a classification of 26 - 30°C experienced an increase in area, while others than that experienced a decrease in area. LST with temperatures > 28°C is spread in the north, northeast, and east of Kuta Selatan Sub-district, namely in the villages of Jimbaran, Benoa, and Tanjung Benoa. The LST is quite high because the built-up area is concentrated in these villages.

Land cover and LST Kuta Selatan Sub-district in 2033 experienced extensive changes, and the distribution is quite significant. Land cover of vegetation, water bodies, and bare soil has decreased by 7.44%, 1.81%, and 14.14%, on the other hand, the built-up area has increased by 23.39% which is concentrated in the north, northeast, and east of Kuta Selatan Sub-district, namely in the villages of Jimbaran, Benoa, and Tanjung Benoa. From 2006 to 2033, LST < 24°C and 24-26 °C experienced a broad decrease of 6.69% and 54.75%. Otherwise LST 26 - 28 ° C; 28 - 30 ° C; and > 30°C experienced an increase in the area of 19.20%; 28.68%; and 13.55%. Over time, the built-up area will increase, and at the same time, the LST shows an increase in value and area. Built-up area and bare soil contribute greatly to LST increase, while vegetation and water bodies play an important role in mitigating LST. Based on the results of the research conducted, it can be concluded that the built-up area and LST in Kuta Selatan Sub-district in 2033 experienced a significant increase in area and distribution in Jimbaran, Benoa and Tanjung Benoa villages. The average LST in Kuta Selatan Sub-district will increase, from 25.63°C in 2006 to 33.07°C in 2033 thus that it will generate warmer temperatures in the future.

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