# THE EFFECT OF LEAF AREA INDEX CHANGES ON LAND SURFACE TEMPERATURE IN WEST KALIMANTAN

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**Abstract.** West Kalimantan, located along the equator, is a tropical area with high surface temperatures. Decreasing forests or green spaces in this region could endanger the creatures living there, due to rising surface temperatures. Hence, analyzing the impact of Leaf Area Index changes on soil surface temperature is vital. This research employed remote sensing technology via the Terra-MODIS satellite to analyze this impact. The satellite imagery was used to determine Leaf Area Index (LAI) and Land Surface Temperature (LST), using image data from 2001 and 2021 in West Kalimantan Province. The research revealed that the region underwent changes, with wide pine forests being replaced by savanna land. The surface temperature value with the largest distribution area remained between 25$^{o}$C to 30$^{o}$C in both 2001 and 2021. LAI changes affected LST by 46% to 47%, but substantial changes require a significant number of years to observe.

Keywords: *Leaf Area Index, Land Surface Temperature, Terra-MODIS*

## 1 INTRODUCTION

West Kalimantan is one of the provinces on Kalimantan Island with an area of 14,730,700 hectares or 1.13 times the area of Java Island (Pemerintah Provinsi Kalimantan Barat, 2023). With this area, in 2001 the population in West Kalimantan was estimated at around 3.79 million people. Meanwhile, in 2021 the population in West Kalimantan will increase to 5.47 million people (BPS, 2022). The increase in population will influence changes in land use and decrease in green open space. The less green open space in an area, the more surface temperatures will increase. Urban surfaces tend to heat up more quickly than natural surfaces because urban surfaces release water more quickly than natural surfaces which can retain water (Zulkarnain, 2016).

In connection with changes in land use and its consequences on surface temperature, LAI is one of the parameters that can be used to see the correlation. Leaf Area Index (LAI) is defined as the one-sided green leaf area per unit area of land covered with vegetation in broadleaf canopies and as one-half the total needle surface area per unit area of land covered with vegetation in coniferous canopies (Zhu *et al.*, 2013). LAI is used in this research because it shows plant development and estimates fractional vegetation cover (Sari *et al.*, 2022). LAI is a crucial biophysical parameter of vegetation and is extensively used for monitoring crop growth, estimating yield, simulating land surface processes, and studying global changes. Remote sensing is the most feasible method for estimating LAI at regional and global scales (Xiao *et al.*, 2016). Several observational studies have been conducted to examine geographic patterns and seasonal changes in LAI and to evaluate their relevance in the context of local surface climate change at larger scales.

It is crucial to investigate the impact of vegetation productivity on temperature and how plant communities respond to temperature changes at regional and global scales (Huang *et al.*, 2019). An investigation into the changing trends of LAI and LST, and their interannual variability at the regional and global scales, could reveal ecological processes and biosphere-atmosphere interactions, setting the basis for monitoring vegetation and climate feedback (Rasul *et al.*, 2020). This study demonstrates the contrasting responses of regional weather and climate variability to the widespread greening pattern. It can have many implications for ecological processes, agriculture, forestry, human health, and the global economy (Peñuelas *et al.*, 2009).

Using remote sensing image technology on Google Earth Engine cloud computing, we monitored changes in LAI and LST over a 20-year period with two different sample years, namely 2001 and 2021. Our study utilized Terra-MODIS satellite imagery, which boasts a greater number of spectral wavelengths, more comprehensive land coverage, and a higher observation frequency compared to other options (Sabarati *et al.*, 2022).

The aim of this research is to determine the extent of each classification of LAI and LST and to determine the effect of changes in the LAI on LST in West Kalimantan Province.

## 2 MATERIALS AND METHODOLOGY

Geographically, West Kalimantan is crossed by the equator (0° latitude) so it is a tropical area with quite high surface temperatures. If forests or green open spaces in West Kalimantan decrease, it will endanger the living creatures in them because the air and surface temperatures will increase. Identifying the influence of LAI changes on LST in West Kalimantan is very important to analyze for the sake of survival and preservation of the surrounding environment.

### 2.1 Location and Data

Research in West Kalimantan Province, which is in the western part of Kalimantan Island and geographically located between 2°08' North Latitude to 3°05' South Latitude and 108°0' East Longitude to 114°10' East Longitude as in Figure 2-1.

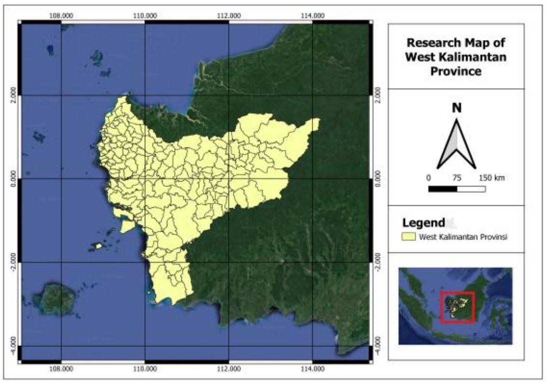


Figure 2-1: Recearch location map.

### 2.2 Standardization of data

The research utilized satellite image data from Terra-MODIS (Moderate Resolution Imaging Spectroradiometer). Analysis carried out statistically and spatially and do narration descriptive analysis to explain the effect of LAI changes on LST.

Table 2-1: Details of data used in research in 2001 and 2021.

| No | Data | Data ID in GEE | Selected Band |
|---|---|---|---|
| 1 | Terra Land Surface Temperature and Emissivity | MODIS/ 061/ MOD11 A1 | LST_Day _1km |
| 2 | MODIS Land Cover | MODIS/ 061/ MOD11 A1 | LC_Type 3 |

This research also uses the administrative boundaries of West Kalimantan District and Province.

### 2.3 Methods

LAI data processing utilizes the Google Earth Engine platform at https://code.earthengine.google.com/ using MODIS Land Cover data with data ID MODIS/061/MCD12Q1 and by entering the LC_Type3 band in the programming. LAI classification used in this study is shown in Table 2-2.

Table 2-2: Leaf Area Index legend and class definitions (Sulla-Menashe & Friedl, 2022).

| Value | Name | Description |
|---|---|---|
| 1 | Grasslands | Dominated by herbaceous annuals (<2m) including cereal croplands. |
| 2 | Shrublands | Shrub (1-2m) cover >10%. |
| 3 | Broadleaf croplands | Dominated by herbaceous annuals (<2m) that are cultivated with broadleaf crops. |
| 4 | Savannas | Between 10-60% tree cover (>2m). |
| 5 | Evergreen Broadleaf Forests | Dominated by evergreen broadleaf and palmate trees (>2m). Tree cover >60%. |
| 6 | Deciduous Broadleaf Forests | Dominated by deciduous broadleaf trees (>2m). Tree cover >60%. |
| 7 | Evergreen Needleleaf Forests | Dominated by evergreen conifer trees (>2m). Tree cover >60%. |
| 8 | Deciduous Needleleaf Forests | Dominated by deciduous needleleaf (larch) trees (>2m). Tree cover >60%. |
| 9 | Unvegetated | At least 60% of area is non-vegetated barren (sand, rock, soil) or permanent snow and ice with less than 10% vegetation. |
| 10 | Urban and Built-up Lands | At least 30% impervious surface area including building materials, asphalt, and vehicles. |

LST data processing also utilizes the Google Earth Engine platform at https://code.earthengine.google.com/ using Terra Land Surface Temperature and Emissivity data with data ID MODIS/061/MOD11A1 and by entering the LST_Day_1km band in the programming. Land Surface Temperature classification used in this study is shown in Table 2-3.

Table 2-3: Classification of Land Surface Temperature (Latue *et al.*, 2023).

| No | Land Surface Temperature Class | Information |
|---|---|---|
| 1 | Very low | $<20^{o}C$ |
| 2 | Low | $20^{o}C$ - $25^{o}C$ |
| 3 | Currently | $25^{o}C$ - $30^{o}C$ |
| 4 | High | $30^{o}C$ - $35^{o}C$ |
| 5 | Very high | $>35^{o}C$ |

Analysis coefficient correlation score statistics with state linear relationship between two variables or more. The coefficient correlation range between -1 to +1. A correlation value of positive shows the existence connection unidirectional among variables, while a correlation of negative shows a connection between variables the opposite. The equation to calculate correlation is shown in Equation 2.1

$$C = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 (\sum x)^2}\ \sqrt{n\sum y^2 (\sum y)^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

*C* = correlation coefficient, *x* = first variable, *y* = second variable (Firdaus *et al.*, 2023). The interpretation correlation score is described in Table 2-4.

Table 2-4: Interpretation correlation score (Sugiyono, 2017).

| No | Correlation Value | Interpretation |
|---|---|---|
| 1 | 0.00 – 0.19 | Very low |
| 2 | 0.20 – 0.39 | Low |
| 3 | 0.40 – 0.59 | Currently |
| 4 | 0.60 – 0.79 | Strong |

# 3 RESULTS AND DISCUSSION

## 3.1 Changes in the extent of Leaf Area Index distribution

Between 2001 and 2021, Table 3-1 shows that the largest change in the LAI in West Kalimantan Province was observed in evergreen broadleaf forests. These forests experienced a decrease in area from 10,526,131 ha (72.2853%) in 2001 to 8,804,880 ha (60.3429%) in 2021, which is a loss of 1,721,251 ha (11.9424%). The smallest change was observed in non-vegetated land, with a decrease in area from 198.55 ha (0.0014%) to 24.82 ha (0.0002%), a decrease of 173.73 ha (0.0012%). Table 3-1 also indicates that there has been a shift from evergreen broadleaf forest to savannas. Savannas has increased in area from 3,760,504 ha (25.8242%) in 2001 to 5,446,091 ha (37.324%) in 2021, an increase of 1,685,587 ha (11.4998%). This change could have occurred because most of West Kalimantan has peatlands that can easily catch fire during the dry season (Dicelebica *et al.*, 2022). In 2019, peatland fires in West Kalimantan reached 151,919 hectares, affecting their function as water retainers, sources of biodiversity, as well as agricultural production and forest commodities (Wahyunto et al., 2013). To see a visual representation of the distribution of the LAI in West Kalimantan Province in 2001 and 2021, please refer to Figure 3-1.

The increasing LAI is partly mediated by anthropogenic land use and land cover change because of agricultural expansionand wood harvest. The variations in LAI are more strongly affected by temperature changes at high latitudes. However, in tropical areas, these variations are more strongly influenced by moisture levels. LAI also presents important feedback to climate change. Increasing LAI will decrease surface albedo and air temperature for snow-free regions, increase canopy ET, and decrease ground evaporation over tropical regions (Fang *et al.*, 2019).

Table 3-1: Changes in Leaf Area Index in West Kalimantan Province in 2001 and 2021.

| No | Leaf Area Index | 2001 | | 2021 | | Change | |
|---|---|---|---|---|---|---|---|
| | | Wide (ha) | % | Wide (ha) | % | Wide (ha) | % |
| 1 | Grasslands | 239,823.1 | 1.6469 | 307,478.9 | 2.1073 | + 67,655.8 | + 0.4604 |
| 2 | Shrublands | 918.29 | 0.0063 | 99.27 | 0.0007 | - 819.02 | - 0.0056 |
| 3 | Broadleaf croplands | 18,092.83 | 0.1242 | 16,206.61 | 0.1111 | - 1,886.22 | - 0.0131 |
| 4 | Savannas | 3,760,504 | 25.8242 | 5,446,091 | 37.324 | + 1,685,587 | + 11.4998 |
| 5 | Evergreen Broadleaf Forests | 10,526,131 | 72.2853 | 8,804,880 | 60.3429 | - 1,721,251 | - 11.9424 |
| 6 | Deciduous Broadleaf Forests | 918.29 | 0.0063 | 99.27 | 0.0007 | - 819.02 | - 0.0056 |
| 7 | Evergreen Needleleaf Forests | 2,754.88 | 0.0189 | 570.83 | 0.0039 | - 2,184.05 | - 0.015 |
| 8 | Deciduous Needleleaf Forests | 49.64 | 0.0003 | 0 | 0 | - 49.64 | - 0.0003 |
| 9 | Unvegetated | 198.55 | 0.0014 | 24.82 | 0.0002 | - 173.73 | - 0.0012 |
| 10 | Urban and Built-up Lands | 12,533.44 | 0.0861 | 15,958.42 | 0.1094 | + 3,424.98 | + 0.0233 |

Note: (+) indicates an increase in area, while (-) indicates a decrease in area.

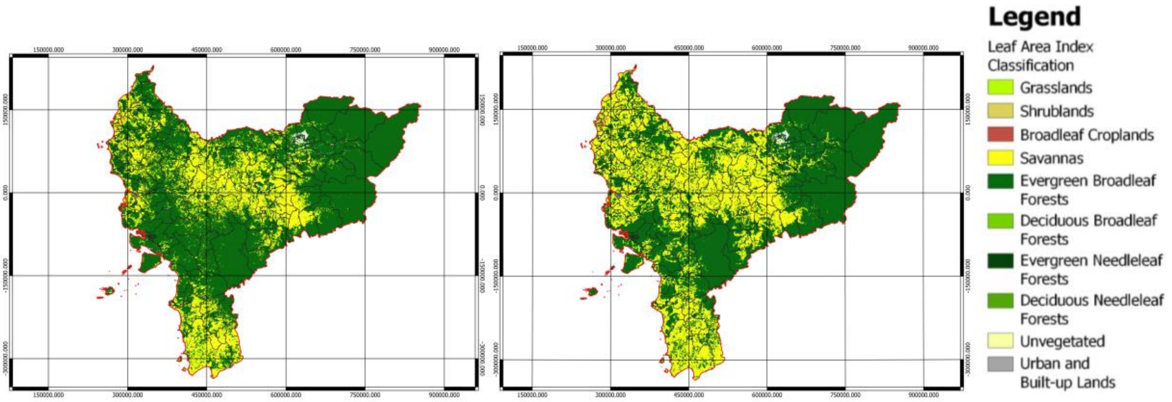


Figure 3-1: West Kalimantan Province's LAI distribution in 2001 (left) and 2021 (right).

### 3.2 Changes in the distribution of Land Surface Temperature

Table 3-2: Changes in Land Surface Temperature in West Kalimantan Province in 2001 and 2021.

| No | Land Surface Temperature | 2001 | | 2021 | | Change | |
|---|---|---|---|---|---|---|---|
| | | Wide (ha) | % | Wide (ha) | % | Wide (ha) | % |
| 1 | <20°C | 1,489.14 | 0.010 | 397.1 | 0.003 | -1,092.04 | -0.007 |
| 2 | 20°C - 25°C | 1,159,343 | 7.845 | 830,640.8 | 5.621 | -328,702.2 | -2.224 |
| 3 | 25°C - 30°C | 13,068,966 | 88.435 | 12,823,954 | 86.778 | - 245,012 | -1.657 |
| 4 | 30°C - 35°C | 546,215.5 | 3.696 | 1,115,860 | 7.551 | +569,644.5 | +3.855 |
| 5 | >35°C | 2,084.79 | 0.014 | 7,247.13 | 0.049 | +5,162.34 | +0.035 |

Note: (+) indicates an increase in area, while (-) indicates a decrease in area.

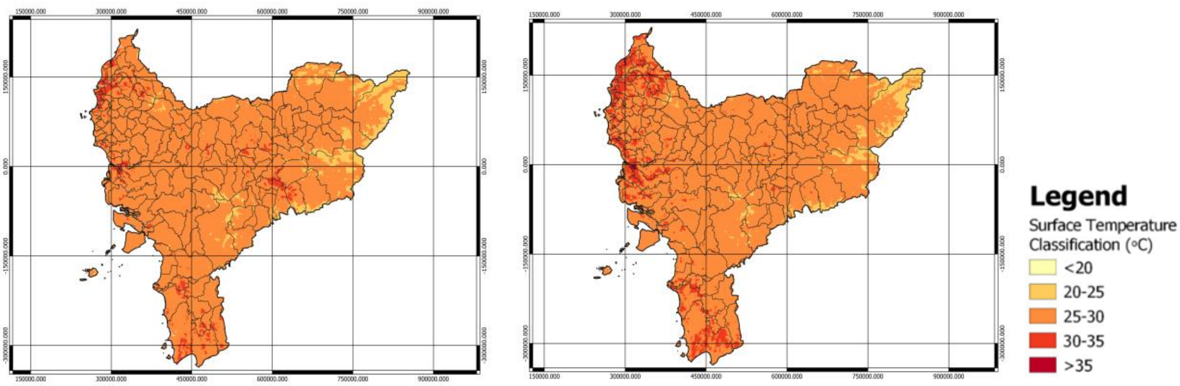


Figure 3-2: West Kalimantan Province's LST distribution in 2001 (left) and 2021 (right).

According to Table 3-2, the West Kalimantan Province experienced a significant change in LST between 2001 and 2021. The temperature range of 30°C – 35°C saw the most significant increase, with the distribution area growing from 546,215.5 ha (3.696%) in 2001 to 1,115,860 ha (7.551%) in 2021. This indicates an increase of 569,644.5 ha (3.855%). However, the temperature range of less than 20°C saw the smallest change, with the distribution area decreasing from 1,489.14 ha (0.010%) in 2001 to 397.1 ha (0.003%) in 2021, resulting in a decrease of 1,092.04 ha (0.007%). These findings show that the distribution area of high-temperature classification has increased, while the distribution area of low-temperature classification has decreased. The increase in LST mostly occurred in the northwest, west and south of West Kalimantan. Continuous development in urban areas has resulted in the occurrence of Urban Heat Islands, activities in industrial areas, and even forest fires are one of the factors causing the increase in temperature in the West Kalimantan region.

The results of this research also show that West Kalimantan Province has a dominant surface temperature in the range of 25°C - 30°C. Changes in the distribution of LST in map form in West Kalimantan Province in 2001 and 2010 can be seen in Figure 3-2.

### 3.3 Effect of changes in Leaf Area Index on Land Surface Temperature

To determine the effect of changes in the LAI on LST, the raster correlation method was used. The correlation value was searched for by taking data from sample points 5 km away. From these sample points, 5892 data were obtained. The x-axis is the first variable (LAI) and the y-axis is the second variable (LST).

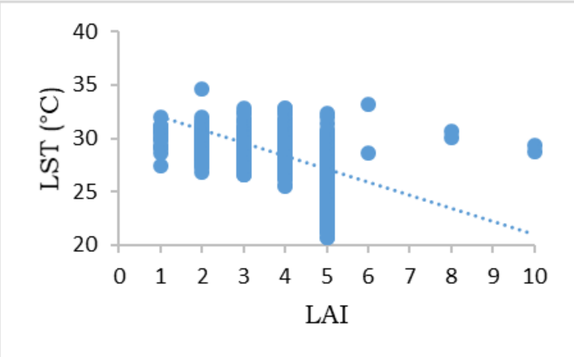


Figure 3-3: Plotting the relationship between LAI and LST in 2001.

Figure 3-3 shows that grasslands cover has surface temperature range is between 27°C-32°C, shrublands have a temperature range surface between 26°C-35°C, broadleaf croplands has a temperature range surface between 26°C-33°C, savannas has a surface temperature range between 25°C-33°C, evergreen broadleaf forests have a surface temperature range between 20°C-33°C, deciduous broadleaf forests have a temperature range between 28°C-33°C, deciduous needleleaf forests leaves have a temperature range between 30°C-31°C, as well as urban and built-up lands cover has a temperature range of 28°C-30°C.

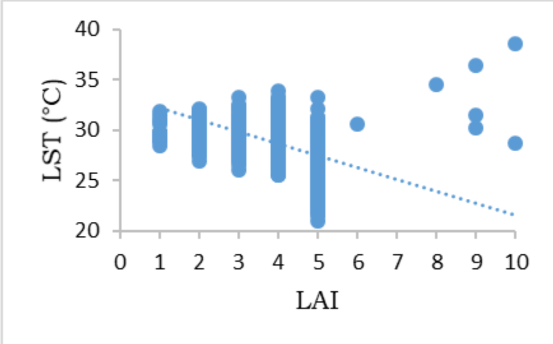


Figure 3-4: Plotting the relationship between LAI and LST in 2021.

Figure 3-4 shows that grasslands cover has a surface temperature range between 28°C-32°C, shrublands have a surface temperature range between 27°C-33°C, broadleaf croplands has a surface temperature range between 26°C-34°C, savannas has a surface temperature range between 25°C-34°C, evergreen broadleaf forests has a surface temperature range between 21°C-34°C, deciduous broadleaf forests has a temperature range between 30°C-31°C, deciduous needleleaf forest has the temperature range is between 34°C-35°C, unvegetated has a temperature range surface between 30°C-37°C, as well as urban and built-up lands cover has a temperature range of 28°C-39°C.

Table 3-3: Correlation results of LAI with LST in 2001 and 2021.

| Year | Correlation LAI vs LST |
|---|---|
| 2001 | -0.459670916 |
| 2021 | -0.469898466 |

According to equation 1 and Table 3-3, the correlation between LAI and LST in 2001 was -0.46 or 46%. This suggests that the two variables are inversely correlated, and the effect of the change is 46%. In 2021, the correlation value increased to -0.47 or 47%, indicating that the two variables continue to be inversely correlated, with the effect of the change being 47%.

The trend of increasing surface temperatures has many impacts on the environment and humans in the form of health problems, increasing electrical power consumption, disrupting the ecological balance, crop failure, and even urban heat islands. The existence of quite strong interactions between LAI and LST shows that the solution to dealing with rising temperatures appropriately can be through various reforestation programs such as restoration of green open spaces, reforestation of river borders and mangroves on the coast, as well as raising public awareness to green the surrounding yards (Dede *et al.*, 2019).

## 4 CONCLUSION

Based on the research that has been carried out, it can be concluded that in West Kalimantan Province in 2001 and 2021 there will be a change in LAI from broadleaf pine forest land to savanna land. In 2001 it was known that the area of savanna land was 25.8% and in 2021 the area of savanna land increased to 37.3%, an increase of 11.5%. Meanwhile, the surface temperature shows that the surface temperature value with the largest distribution area is in the range of 25°C - 30°C both in 2001 and 2021. With a temperature range of 25°C - 30°C that dominates, this means that West Kalimantan Province has a LST in the medium category. Meanwhile, the temperature value with the smallest distribution area is in the range <20°C both in 2001 and 2021. The correlation between changes in the LAI and the distribution of LST is quite currently, namely around 46% - 47%. These findings provide a comprehensive picture of environmental dynamics in West Kalimantan Province over the last two decades.

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## REFERENCES

BPS. (2022). *Jumlah Penduduk (Jiwa), 2020-2022*. https://kalbar.bps.go.id/indicator/12/42/1/jumlah-penduduk.html

Dede, M., Pramulatsih, G. P., Widiawaty, M. A., Ramadhan, Y. R. R., & Ati, A. (2019). Dinamika Suhu Permukaan Dan Kerapatan Vegetasi Di Kota Cirebon. *Jurnal Meteorologi Klimatologi Dan Geofisika*, *6*(1), 23–31.

Dicelebica, T. F., Akbar, A. A., & Jati, D. R. (2022). Identifikasi dan Pencegahan Daerah Rawan Bencana Kebakaran Hutan dan Lahan Gambut Di Kalimantan Barat. *Jurnal Ilmu Lingkungan*, *20*(1), 115–126. https://doi.org/10.14710/jil.20.1.115-126

Fang, H., Baret, F., Plummer, S., & Schaepman-Strub, G. (2019). An Overview of Global Leaf Area Index (LAI): Methods, Products, Validation, and Applications. *Reviews of Geophysics*, *57*(3), 739–799.

Firdaus, P., Dwi, M., Manessa, M., Tambunan, M. P., & Tambunan, R. P. (2023). Future Suitability of Tea Plants: Climate Analysis Using Remote Sensing in Java, Indonesia. *International Journal of Remote Sensing and Earth Sciences (IJReSES)*, *20*(1), 77–88.

Huang, M., Piao, S., Ciais, P., Peñuelas, J., Wang, X., Keenan, T. F., Peng, S., Berry, J. A., Wang, K., Mao, J., Alkama, R., Cescatti, A., Cuntz, M., De Deurwaerder, H., Gao, M., He, Y., Liu, Y., Luo, Y., Myneni, R. B., … Janssens, I. A. (2019). Air temperature optima of vegetation productivity across global biomes. *Nature Ecology and Evolution*, *3*(5), 772–779.

Latue, P. C., Rakuasa, H., Somae, G., & Muin, A. (2023). Analisis Perubahan Suhu Permukaan Daratan di Kabupaten Seram Bagian Barat Menggunakan Platform Berbasis Cloud Google Earth Engine. *Sudo Jurnal Teknik Informatika*, *2*(2), 45–51.

Pemerintah Provinsi Kalimantan Barat, P. P. dan D. (PPID). (2023). *Gambaran Umum Aspek Geografis Kalimantan Barat*. https://ppid.kalbarprov.go.id/?public=profil-daerah

Peñuelas, J., Rutishauser, T., & Filella, I. (2009). *Phenology Feedbacks on Climate Change*. *324*(5929), 887–888.

Rasul, A., Ibrahim, S., Onojeghuo, A. R., & Balzter, H. (2020). A trend analysis of leaf area index and land surface temperature and their relationship from global to local scale. *Land*, *9*(10), 1–17.

Sabarati, A., Aminuddin, J., & Toersilowati, L. (2022). Utilization of Terra-MODIS Satellites for Phenomenon Analysis Urban Heat Island in Kalimantan Island. *Georest*, *1*(1), 22–26.

Sari, N. M., Indra, T. L., & Kushardono, D. (2022). Urban Vegetation Quality Assessment Using Vegetation Index and Leaf Area Index from Spot 7 Data with Fuzzy Logic Algorithm. *International Journal on Advanced Science, Engineering and Information Technology*, *12*(2), 738–746. https://doi.org/10.18517/ijaseit.12.2.11719

Sugiyono. (2017). *Method Study Quantitative, Qualitative, and R&D*. Alfabeta, CV.

Sulla-Menashe, D., & Friedl, M. A. (2022). User guide to collection 6 MODIS land cover (MCD12Q1 and MCD12C1) product. *USGS: Reston, VA, USA*, *1*, 1–18.

Wahyunto, W., Supriatna, W., & Agus, F. (2013). Land Use Change And Recommendation For Sustainable Development of Peatland For Agriculture: Case Study at Kubu Raya and Pontianak Districts, West Kalimantan. *Indonesian Journal of Agricultural Science*, *11*(1), 32. https://doi.org/10.21082/ijas.v11n1.2010.p32-40

Xiao, Z., Liang, S., Wang, J., Xiang, Y., Zhao, X., & Song, J. (2016). Long-Time-Series Global Land Surface Satellite Leaf Area Index Product Derived from MODIS and AVHRR Surface Reflectance. *IEEE Transactions on Geoscience and Remote Sensing*, *54*(9), 5301–5318. https://doi.org/10.1109/TGRS.2016.2560522

Zhu, Z., Bi, J., Pan, Y., Ganguly, S., Anav, A., Xu, L., Samanta, A., Piao, S., Nemani, R. R., & Myneni, R. B. (2013). Global Data Sets of Vegetation Leaf Area Index (LAI)3g and Fraction of Photosynthetically Active Radiation (FPAR)3g Derived from Global Inventory Modeling and Mapping Studies (GIMMS) Normalized Difference Vegetation Index (NDVI3g) for the Period 1981 to 2. *Remote Sens*, *5*(2), 927–948. https://doi.org/https://doi.org/10.3390/rs5020927

Zulkarnain, R. C. (2016). Pengaruh Perubahan Tutupan Lahan Terhadap Perubahan Suhu Permukaan di Kota Surabaya. *Skripsi Institut Teknologi Sepuluh Nopember*, 1–306.