Effect of Changes Composition and Intensity of Green Space on Surface Temperature: Case Study in Pekalongan Regency, Indonesia

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Abstract. The spatial planning document is planning guidance intended to regulate an area's spatial use and development planning. This document contains the component that regulates the composition of green space. This composition is designed to maintain the stability of the existing ecosystem quality. Pekalongan is one of the Regency in Central Java Province with environmental problems related to lack of green space area. The existence of ecological degradation makes environmental quality in Pekalongan one that needs to be considered. This study aims to determine the effect of changes in the composition and intensity of green space on surface temperature from these problems. This study will use time-series data during the initial implementation of spatial planning documents (2013) to the current year (2021) to see how changes in the composition and intensity of green space in each sub-district in Pekalongan Regency. The method used is descriptive quantitative with a GIS approach. The result of this study can be a consideration to make policies related to green space.

Keywords: Green space, surface temperature, environmental

1. Introduction

The existence of changes in a space is a process that cannot be avoided. These changes occur because of a change in an activity, such as a change from open land to built land. The action is the movement of people which causes the development of an urban area [1]. These developments destroy and fragment natural and semi natural habitats with loss of biodiversity and ecosystems [2,3]. In a plan, there is a regulation that regulates how the land is allocated and used in an area. With this regulation, it is expected to provide a balance in the ecosystem. One of the regulations is about the regulation of green space in urban areas, as stated in regional documents.

In urban green spaces where some utilities support performance, this can be seen from many points of view [4]. Green spaces have different roles, such as social spaces and areas for recreation with cultural and environmental purposes. The balance of an ecosystem must, of course, be maintained sustainably by maintaining and increasing property values due to aesthetic and functional characteristics [5]. When this green space is maintained, positive environmental benefits will emerge [5,6]. An example is countering the effects of urban heat to reduce air conditioning energy costs. Plants that grow in it can also minimize the negative impact of air pollution, water, noise and reduce the greenhouse effect through CO2 absorption [7]. Green space also has a mitigation function, namely minimizing floods and storms [8]. There are also ecological functions related to biodiversity conservation and nature conservation [9]. From a health perspective, this green space allows for physical activity and relaxation to improve the
quality of life [10]. Research in recent years has reported an association between green space and health benefits at both the individual and population levels [11,12]. When viewed as a whole, the benefits of green space are significant; therefore, we need a balance of green space and non-green space in an area.

The sustainability of the green space of an area and society has become an important issue because of the effects of global warming, which are recognized by the whole world [13]. There has been significant research in understanding urban heat and its environmental impacts in the last three decades, such as mitigation measures, policy development, and implementation programs to cool urban surface temperatures by adding vegetation to areas with high surface temperatures [14]. The increased surface temperature produced by UHI impacts public health conditions both indoors and outdoors—related to comfort and economic welfare; therefore, green space needs to be maintained from various environmental perspectives [15].

A natural-based solution supports green vegetation, thereby avoiding heat build-up by creating shadows and increasing relative humidity through evapotranspiration [16]. However, it should be noted that the types of green spaces provide different proportions of services [17,18].

Pekalongan Regency is one of the regencies crossed by the North National Road (Pantura), connecting Jakarta and Semarang City. The mobility of vehicles that pass through this route is very congested because this is the only national road that connects significant regencies/cities on the northern coast. The existence of this mobility can undoubtedly affect the green space in Pekalongan Regency. When viewed from the distribution of surface temperatures in Pekalongan Regency in 2020, those around the north coast have a higher surface temperature than the south side. Thus, there is an influence between changes in land use and surface temperature [19]. Pekalongan’s south side has a high level of forest vegetation density ranging from 43.41% and a medium category ranging from 40.72%, meaning that the overall forest vegetation density level is in a suitable variety [20]. But are other green spaces in good standing, and how are they related to the composition and intensity of green spaces?

In this research, we will examine to determine the effect of changes in the composition and intensity of green space on surface temperature. This study will use time-series data during the initial implementation of spatial planning documents (2013) to the current year (2021) to see how changes in the composition and intensity of green space in each sub-district in Pekalongan Regency. Has the plan that has been prepared been able to maintain/add green space? The result of this study can be a consideration to make policies related to green space.

2. Data and Methods

2.1 Study Area

Pekalongan Regency is one of the Regencies in Central Java Province, which is located alongside the North Java Coast and broad to the south bordering Banyumas Residency. The eastern borders are Batang Regency and Pekalongan Municipality, while the western is Pemalang Regency. Its location stretches along the equator between 6°- 7°23’ South Latitude and between 109° - 109°78’ East Longitude. The total area of Pekalongan Regency is ± 836.15 Km² and is administratively divided into 19 districts and 285 subdistricts. 11 of the 285 subdistricts are coastal, and the rest are noncoastal. Topographically, there are 66 villages/subdistricts or 23.16 percent in the up-land area, and 219 subdistricts or 76.84 percent are in the down-land area. In 2020, Pekalongan Regency averaged rainfall 737 mm, which is lower than that in 2019, 1928 mm. Meanwhile, the average number of rainy days in 2020 is 149 days, higher than that in 2019, which is 108 days.

Pekalongan Regency has 19 Districts. In 2010, it did a region broadening scheme in one of its subdistricts in Kandangserang district, Sukoharjo. As a result, Sukoharjo village is divided into three subdistricts: Sukoharjo village, Trajumas village, and Karanggondang village. As a result, the number of sub-districts turns from 270 Desa or administrative villages to 272 administrative villages, and all of them are self-supporting sub-districts. Then, the corresponding number is divided into 1.058 Dusun or administrative village regions, 1.592 RW or Community Cluster, and 4.454 neighborhood areas. In 2020, the number of people in Pekalongan Regency recorded as many as 968,821 people, consist of
491.607 male population and 477.214 female population. Growth Rate Population was 1.53 percent in 2020.

2.2 Processing Green Space & LST

The map base used is Pekalongan Regency RTRW data in 2020 – 2040, while the image used is Landsat imagery recording 14 October 2013 and 27 April 2021. The map used is a base map and land use maps in 2013 and 2020 land use sourced from the RTRW. This land-use map will be synchronized with the data from the NDVI analysis so that the distribution of green space can be measured. In the NDVI analysis, band four and band 5. The data taken in band 4 is NIR (Near Infrared Radiation), while the data for band 5 is VIS (Visible) [21,22]. After the NDVI is carried out, an LST analysis will be carried out to determine the surface temperature in 2021 [23].

Figure 1. Processing Green Space (Analysis, 2021)

3. Result and Discussion

3.1 Green Space Area in Pekalongan Regency 2013 – 2021

Based on the distribution, green space in Pekalongan Regency has a more excellent distribution in Pekalongan Regency on the south side. This is because the south side is directly adjacent to Purbalingga and Banjarnegara Regencies which have steep hillside reliefs. The development of the area is more of a protected and buffer area. The north side is crossed by the north coast route and is directly adjacent to Pekalongan City, Pemalang Regency, and Batang Regency. Therefore, when viewed from the
development side of the area more towards cultivation areas and dominant to trade and services, this causes the rate of land conversion from green space to non-green space to be high. These results indicate that human factors can cause some changes in land use/cover and, over time, will affect the temperature in the area [24]. This green space classification is based on NDVI analysis with four categories [25]. For more details, see Table 1.

Table 1. Distribution Classification of Vegetation Index

| Class       | NDVI Range | Value | Mean 2013 | Mean 2021 | Area (Ha) 2013 | Area (Ha) 2021 |
|-------------|------------|-------|-----------|-----------|---------------|---------------|
| Non Vegetation | < 0.11     |       | 1,720.88  | 3,559.26  |               |               |
| Low VGI     | 0.11-0.33  |       | 28,165.03 | 34,904.54 |               |               |
| Medium VGI  | 0.33-0.45  | 0.37  | 33,737.66 | 38,047.05 |               |               |
| High VGI    | >0.45      |       | 25,655.72 | 12,768.43 | 89,279.28     | 89,279.28     |

* using Raster Calculator ArcGIS 10.8

In period 2013 – 2021, there is a decrease in high VGI (-) 12,887.54 Ha. This result is quite significant because when viewed from the proportion of the total area, it is in the range of (-) 14.44%. A more detailed for map distribution can be seen in Figure 1.

![Figure 1](image1.png)

**Figure 2. The Map of NDVI 2013 & 2021 (Analysis, 2021)**

Based on the average over nine years, there is a decrease in high VGI (-) 1,431.95 Ha every year. An increase in other classifications accompanied the reduction in high VGI, and the largest was Low VGI (+) 6,739.51 Ha. This decrease in high VGI certainly needs to be addressed because it is related to the quality of ecosystem services, such as the quality of air filters from pollution and the benefits of the ecosystem formed there [26]. Green Space must be maintained because it will bring benefits to the microclimate through shading, evapotranspiration, and regulation of air movement [27]. A more detailed look at each sub-district can be seen in Table 2.
Table 2. Distribution Change Classification of Vegetation Index in each Sub District 2013 - 2021

| Sub District | Class NDVI (Ha) |
|--------------|----------------|
|              | Non Vegetation | Low VGI | Medium VGI | High VGI |
| Hojong       | 14.51          | -1,019.60 | 1,243.33 | -238.24 |
| Buaran       | -0.08          | 20.92    | -7.39     | -13.17  |
| Doro         | 133.06         | 829.93   | 1,343.93  | -2,306.92 |
| Kajen        | 58.34          | 1,214.71 | 1,050.28  | -2,323.33 |
| Kandangserang| 16.53          | -56.79   | 24.24     | 15.41   |
| Karanganyar  | 37.50          | 272.49   | 971.60    | -1,281.58 |
| Karangdadap  | 6.43           | -305.81  | 208.90    | 90.50   |
| Kedungwuni   | 9.43           | 34.22    | -3.13     | -40.51  |
| Kesusi       | 76.85          | 333.91   | -261.99   | -149.06 |
| Lebakbarang  | 113.63         | 1,344.15 | 153.47    | -1,611.01 |
| Paninggaran  | 139.60         | 1,768.33 | -458.06   | -1,449.97 |
| Petungkriono | 455.23         | 3,011.88 | -1,353.83 | -2,112.65 |
| Siwalan      | 328.21         | -270.87  | -47.89    | 9.19    |
| Sragi        | -27.47         | -521.20  | 569.95    | -21.45  |
| Talun        | 1.14           | 379.23   | 1,058.47  | -1,439.81 |
| Tirto        | 107.10         | 229.81   | -292.39   | -44.45  |
| Wiradesa     | 9.29           | -128.68  | 131.49    | -12.10  |
| Wonokerto    | 356.18         | -265.99  | -82.68    | -7.13   |
| Wonopringgo  | 2.90           | -131.13  | 61.10     | 67.13   |
| Total        | 1,838.38       | 6,739.51 | 4,309.39  | -12,887.54 |

*Using Calcula Geometry ArcGIS 10.8*

Table 2 describes that the most significant change occurred in the high VGI classification of (-) 12,887.54 Ha. If viewed by sub-district, the most significant change is in Kajen District (-2,323.33 Ha). This is because Kajen District is the central government in Pekalongan Regency; therefore, the conversion rate there is quite large. This is normal because it is a central government, so there are concentrated various kinds of activities, but what needs to be considered is the creation of a large and evenly distributed park to support the missing green space area. This is evidenced in research [28] that city parks contribute significantly to lowering environmental temperatures in urban zones; besides that, they can also cover noise, filter pollutants, prevent erosion, stabilize soil, and relax visitors. On the other hand, Sragi Subdistrict has a reduced non-vegetation change (-27.47 Ha), meaning that the green space area has increased in the past nine years. Furthermore, Table 3 will intersect with non-green space data (built area). This non-green space data is taken from land-use data built-in 2013 and 2021, sourced from the RTRW planning document.
Table 3. Composition and Intensity Change Green Space Area in each Sub District 2013 - 2021

| Sub District | Class NDVI (Ha) | Non Vegetation | Low VGI | Medium VGI | High VGI |
|--------------|----------------|----------------|---------|------------|----------|
| Bojong       |                | 13.74          | 1,251.37| 1,414.45   | -208.28  |
| Buaran       | -1.51          | 56.02          | 43.66   | -8.12      |
| Doro         | 132.70         | 741.12         | 1,395.50| -2,208.81  |
| Kajen        | 56.05          | 920.31         | 1,130.16| -2,292.75  |
| Kandangserang| 7.46           | -158.41        | -66.03  | -15.67     |
| Karanganyar  | 38.24          | 174.70         | 1,007.57| -1,228.25  |
| Karangdadap  | 6.41           | -318.55        | 305.87  | 103.65     |
| Kedungwuni   | 0.85           | -51.84         | 158.16  | 0.06       |
| Kesisi       | 61.42          | 54.68          | -97.85  | -108.45    |
| Lebakbarang  | 112.96         | 1,314.41       | 106.88  | -1,615.28  |
| Paninggaran  | 133.36         | 1,703.97       | -462.28 | -1,441.85  |
| Petungkrono  | 441.39         | 2,937.20       | -1,352.58| -2,109.01  |
| Siwalan      | 265.28         | -405.21        | 137.44  | -4.90      |
| Sragi        | -25.22         | -772.83        | 775.18  | -9.58      |
| Talun        | 1.62           | 288.02         | 1,071.94| -1,342.42  |
| Tirto        | -160.29        | 72.22          | -85.71  | -28.93     |
| Wiradesa     | -2.00          | -242.07        | 232.87  | -6.82      |
| Wonokerto    | 15.95          | -201.06        | -43.99  | -5.72      |
| Wonopringgo  | 6.69           | -167.75        | 118.26  | 87.87      |
| Total        | 1,105.12       | 4,581.53       | 5,789.51| -12,443.27 |

*Using Calculate Geometry ArcGIS 10.8

Green space changes occur the most in the High VGI and Low VGI classifications because these two classifications are very susceptible to change. High VGI classification is prone to change towards medium or low VGI, while low VGI is prone to change to non-vegetation. A more detailed for map distribution can be seen in Figure 2.

Figure 3. The Map of Green Space Area 2013 & 2021 (Analysis, 2021)
3.2 The Effect of Change Green Space on Land Surface Temperature

In this analysis, it will be known how the distribution of LST in Pekalongan Regency in 2021. Furthermore, this will reveal how this LST effect on the green space area is following the 4 NDVI classifications.

Table 2. Composition and Intensity Change Green Space Pekalongan Sub District 2021

| Sub District | Class NDVI | Area (Ha) | Percentage (%) |
|--------------|------------|-----------|----------------|
| 5.92 – 10.91 | 697.35     | 0.91      |
| 10.91 – 13.88| 1,881.54   | 2.47      |
| 13.88 – 15.98| 4,400.91   | 5.77      |
| 15.98 – 17.90| 6,056.29   | 7.95      |
| 17.90 – 19.48| 9,060.27   | 11.89     |
| 19.48 – 20.96| 14,602.25  | 19.16     |
| 20.96 – 22.45| 19,898.84  | 26.11     |
| 22.45 – 23.93| 17,029.76  | 22.34     |
| 23.93 – 28.31| 2,589.03   | 3.40      |
| Total        | 76,216.24  | 100.00    |

*Using Calculate Geometry ArcGIS 10.8

The data distribution in Table 2, for Pekalongan Regency in April, the average surface temperature is 19.48 – 23.930°C. This temperature is in the middle category (15.9 – 22.9°C) and high (22.9 – 29.9°C) [24]. If it is synchronized with the average rainfall data https://en.climate-data.org/, the average temperature range in Table 2 corresponds to 23 - 240°C (see Figure 4).

Figure 4. Temperature Data in Pekalongan Regency (Analysis, 2021)

The distribution of surface temperatures in Table 3 illustrates that the temperature is affected by the elevation of an area. In the high VGI distribution, the majority are on the south side of Pekalongan, which has a height above Pekalongan on the north side. This is under a study that observed elevation temperatures in the highlands [29]. It also strengthens the evidence that the rate of warming is amplified with the region’s altitude [30].
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### Table 3. Effect of Change LST Green Space in Pekalongan Sub District 2021

| Sub District | Class NDVI (Ha) | Non Vegetation | Low VGI | Medium VGI | High VGI |
|--------------|----------------|---------------|---------|------------|----------|
|              |                |               |         |            |          |
| 5.92 – 10.91 | 11.56          | 121.15        | 219.19  | 345.47     |
| 10.91 – 13.88| 77.63          | 568.23        | 721.64  | 514.04     |
| 13.88 – 15.98| 169.89         | 1,254.06      | 1,940.58| 1,036.38   |
| 15.98 – 17.90| 245.12         | 1,961.16      | 2,779.28| 1,070.73   |
| 17.90 – 19.48| 235.51         | 3,126.93      | 4,244.22| 1,453.60   |
| 19.48 – 20.96| 101.63         | 3,252.36      | 8,429.70| 2,818.56   |
| 20.96 – 22.45| 766.52         | 4,246.86      | 9,984.12| 4,901.34   |
| 22.45 – 23.93| 223.21         | 9,974.62      | 6,525.31| 306.61     |
| 23.93 – 28.31| 18.56          | 1,705.55      | 856.19  | 8.72       |
| Total        | 1,849.63       | 26,210.92     | 35,700.23| 12,455.45 |

*Using Calculate Geometry ArcGIS 10.8

The distribution of green space areas at high temperatures is minimal because of the ability of vegetation to survive in a hot climate. The majority of Green Space in the Pekalongan Sub District lives well in low (8.9 – 15.9°C) to middle (15.9 – 22.9°C) climatic conditions [24]. A more detailed for map distribution can be seen in Figure 3.

![Figure 5. Map of LST 2021 (Analysis, 2021)](image)

### 4. Conclusion

The conclusion that can be drawn from this research is that green space needs to be maintained because it is related to the sustainability of the ecosystem quality of an area. If green space is maintained and added, many positive benefits will be obtained. In addition, for urban areas with a high level of activity, it is expected to create a city park so that the temperature around it can be maintained. The effect of temperature changes from a change in green space needs to be carried out with a mitigation-based plan that can later reduce the impact of the temperature change. This is indeed difficult to avoid, but mitigation-based planning, as outlined in the planning document, can undoubtedly help overcome this.
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