Understanding Spatial Planning Policies in Responding to Urban Heat Island Using GIS Analysis in The Kendal Industrial Area

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Abstract. The formulation of spatial planning strategies in an area is strongly influenced by the development of issues and problems in the area. Spatial planning policies contained in a regional regulation must be able to be aware of and deal with all current and future problems. Urban Heat Island (UHI) is currently a very growing issue in various regions in Indonesia which is influenced by many factors, one of which is the increase in built-up land. The issue of the Urban Heat Island is important because its effects are starting to be felt, including natural degradation, health, economic losses to excessive energy use. One of the most dominant areas in contributing to hot temperatures in urban areas is the industrial area. Kendal Regency is one of the regions in Indonesia with a fairly dominant industrial estate development. Industrial areas that are synonymous with built-up land, air pollution and the lack of green open spaces are one of the triggers for an increase in temperature. In contrast to the negative effects caused, the development of industrial estates in Kendal Regency is one of the drivers of the regional economy so that its existence is considered important. This study aims to understand spatial planning policies in response to the Urban Heat Island in the Kendal Regency industrial area. The research method used is spatial analysis using Landsat 8 imagery with supervised classification to see the UHI phenomenon in the Kendal industrial area, the results of which are used as a basis for evaluating spatial policies in response to UHI. The spatial policy of Kendal Regency in the designation of industrial areas has not fully responded to the UHI phenomenon in industrial areas, although 13 of the 14 clauses indicate the potential for an increase in surface temperature. UHI in the Kendal Regency spatial policy has not been seen as a threat to urban areas. Mitigation efforts against UHI mentioned are only in the form of providing green open space and waste management. It is hoped that this research can be input in improving spatial planning policies in the Kendal Regency industrial area, especially to suppress the increase in temperature.

Keywords: GIS, urban heat island, spatial policy

1. Introduction

Indonesia began to develop Industrial Parks for the first time in the 1970s through BUMN as a reaction to the need for land to develop industries [1]. The development of industrial estates is undeniably one of the sectors that play a very important role in the regional economy, both to reduce poverty, absorb labor and increase regional income. One of the prominent industrial estate developments in Central Java is the industrial area in Kendal Regency which is experiencing growth. Kendal Regency which is included in the Kedungsepur metropolitan area (Kendal, Demak, Ungaran, Semarang, and
Purwodadi) tends to experience significant industrial sector development. This makes the need for industrial land tends to increase in line with the launching of government programs related to the development of the Kendal Industrial Estate (Kendal Industrial Park) in 2016 covering an area of 2,700 hectares [2]. Until January 2018, inaugurated an integrated region since November 2016, attract 39 investors from Indonesia, Singapore, Malaysia, China, and Japan [16]. Kendal Regency is included in one of the government policies, namely Presidential Regulation (PERPRES) 79 of 2019 concerning the Acceleration of Economic Development in the Kendal - Semarang - Salatiga - Demak - Grobogan area, Purworejo - Wonosobo - Magelang - Temanggung, and Brebes - Tegal - Pemalang areas. This economic acceleration is correlated with increased investment in each region, one of which is the development of industrial estates. Large-scale industrial development will have an impact on increasing the development of massive built-up land with various infrastructure provisions and increasing energy needs [3].

The growth of an area accompanied by a rapid increase in built-up land has various impacts, one of which is the emergence of the urban heat island phenomenon. The results of Bernama Gartland's research (2012) revealed that heat islands are triggered by the presence of construction materials that have the property of absorbing and retaining more solar heat than natural materials found in rural areas. In addition, the number and density of the population, as well as the current urban area, are the main factors that contribute to the intensity of the heat island. In the context of the industrial structure of the hot island, it can also be influenced by the industrial structure. The heavy industry refers to high energy consumption and release that can cause temperatures to rise in some areas [4–7]. Urban heat island is a phenomenon of higher temperature/surface temperature in urban areas compared to buffer areas or rural areas due to an urbanization process [8]. In this phenomenon, it can have an impact on the accumulation of heat, the change in ozone formation, and in severe problems it can cause health problems for city residents [9].

Urban heat islands have grown and become a worldwide concern for both policy makers and urban planners because of their associated natural degradation, health risks, and economic losses [10]. In relation to strategies for mitigating the negative impacts of UHI, various actions have been taken by policymakers and urban planners, including urban design, non-heat absorbing materials, green roofs, green facades, tree shade, and vegetation [3,11–13]. The role of stakeholders is very necessary for developing a UHI mitigation strategy, of which there are at least three stakeholders that are most relevant to reducing the impact of UHI including (a) the government, including politicians acting at the local or national level, (b) city administrations, including urban planners and public health officials; and (c) residents, as individuals or as groups of people living in urban areas [5]. The private sector also plays an important role, as most buildings are privately owned, and many UHI mitigation solutions are implemented in industrial estates. Various methods of UHI mitigation are used in the analysis, one of which is using satellite imagery to analyze temperature patterns [14].

Kendal Regency through Regional Regulation Number 1 of 2020 concerning the Spatial Planning of the Kendal Regency of 2011-2031 has planned an industrial designation area of approximately 5,109 hectares located in several sub-districts including Kalikungu, Brangsong, Kendal, and Patebon. In connection with the UHI phenomenon, industrial estate planning needs to be carried out carefully so as not to increase urban heat temperatures. One way of mitigation that can be done is by monitoring land cover. Since the industrial era, land cover and land cover change have played an important role in contributing to regional and global climate change by promoting energy recycling and the exchange of materials at ground level [15]. This study looks at the extent to which Kendal Regency's spatial policies respond to the UHI phenomenon. The analysis is carried out by looking at the articles in the regional regulations governing industrial areas, whether the mitigation aspects of UHI have been included in the clause. This analysis is also based on the results of UHI in the Kendal Regency industrial area in 2013-2020 as a basis for consideration.

2. Data and Methods

This study uses a spatial approach with data processing using Landsat 8 imagery with recordings in 2013, 2015, 2018 and 2020. Data processing is carried out to determine the Urban Heat Island phenomenon using the results of Land Surface Temperature. In this study, the shooting was carried out
between May – June where conditions in Kendal Regency were in the summer. Data processing is carried out in several stages, namely radiometric correction, geometric correction, NDVI processing, supervised classification processing, identification using Maximum Likelihood Classification (MLC) for land cover classification of OLI data where MLC is the most commonly used method in classifying remote sensing data. The results of the map processing will be the basis for the analysis of the policy on the spatial pattern of the Kendal Regency Industrial Estate. Figure 1 will explain the stages in processing Landsat imagery to produce Land Surface Temperature to understanding the Kendal Regency spatial planning policy in response to UHI.

### Figure 1.
The stage of processing image data into land surface temperature (Source: Research Team, 2021)

3. **Results and Discussion**

3.1 *The Role of Industrial Estates on the Development of the Kendal Regency Region*

The development of the Kendal Industrial Estate has had a tremendous economic impact on the Kendal Regency government. Kendal Industrial Estate (KIK) has been able to attract 50 investors with an investment target of IDR 6.5 trillion and employment of 5,000 people until the end of 2019 since it started operating in 2016. Development of other industrial areas in Indonesia. The development of KIK is planned in three stages with a total land area of 2,700 hectares to become an integrated industrial area supported by the development of industrial zones, ports, fashion cities, and settlements [15].
Gross Regional Domestic Product (GRDP) data shows that the industrial sector ranks first in contributing to the economy in Kendal Regency. This shows that the industrial sector does have a very important role. Figure 2 shows 17 (seventeen) sectors that contribute to GRDP. The industrial sector continued to increase from 2015-2019 and slightly decreased in 2020 due to the effects of the pandemic. These results indicate that the existence of industry is quite important in increasing regional competitiveness.

3.2 Urban Heat Island Developments in Industrial Estate Kendal

The development of Urban Heat Island in the study area is focused on the area that will be planned to become an industrial area based on Regional Regulation No. 1 of 2020 concerning the Kendal Regency Spatial Plan for the Year 2011-2031. The development of land use will be analyzed and become the basis for consideration in observing the development of air temperature in the study area. Figure 3 shows the development of land use by recording satellite images carried out in December 2013, 2015, 2018, and 2020.
The boundaries of the industrial designation area are approximately 5,109.34 Ha wherein the existing conditions there are land uses in the form of water bodies, paddy fields, built-up land, and also the vegetation. Based on the appearance of the image and data processing, there is an increase in area, especially on built-up land. The addition of built-up land continues to increase until 2020. The increase also occurs in the aspect of water bodies which continues to increase until 2020. This increase is certainly one indicator in observing the development of surface temperature in the study area. Figure 4 shows the increase in built-up land and water bodies from 2013-2020 in the industrial plan area.

Figure 4. Land use development in the study area (Source: Research Team, 2021)
Changes in land use in the study area turned out to have an impact on the level of Land Surface Temperature which gave rise to UHI. Based on image data processing, it can be seen that in 2013-2018 the surface temperature of industrial areas increased, but decreased again in 2020. The lowest temperature ranges from 22.1 - 26°C and the highest temperature ranges from 34.1 - 38°C.

![Image](image.png)

**Figure 5.** The development of urban heat islands in the study area (Source: Research Team, 2021)

Changes in temperature in an area are influenced by several factors. Figure 5 shows that the surface temperature in the study area tends to decrease even though the built-up area increases. Based on secondary data collection and field observations, several things happened in the study area in the 2018-2020 period. Some of the things that happened include an increase in the area of water bodies, reduced vegetation and rice fields, high rainfall, and reduced community activities due to the pandemic. But on the other hand, during the period 2013-2018 surface temperature increased along with the increase in the area of built-up land and water bodies as well as reduced vegetation. The explanations and facts that occur conclude that the increase in the area of built-up land and water bodies, as well as the decrease in vegetation, can result in an increase in surface temperature. Table 1 shows the dynamics of changes in surface temperature as indicated by the area in each temperature classification.

**Table 1.** Changes in Surface Temperature Based on Area (Hectares)

| No | Temperature (°C) | Area (Hectares) |
|----|----------------|-----------------|
|    |                | 2013 | 2015 | 2018 | 2020 |
| 1  | <22            | -    | -    | -    | -    |
| 2  | 22.1 - 26      | 728.81| 2.102.75| 110.63| 684.85|
| 3  | 26.1 - 30      | 4.327.60| 1.877.12| 3.877.36| 4.033.45|
| 4  | 30.1 - 34      | 37.56 | 1.094.97| 1.028.47| 366.25|
| 5  | 34.1 - 38      | 5.20  | 17.43 | 81.14 | 13.10 |
3.3 Understanding of Spatial Policy for Industrial Estate Designation (Regional Spatial Plan) of Kendal Regency in Responding to UHI

An analysis of the development of UHI in Kendal Regency during the period 2013-2018 shows that surface temperatures may increase due to an increase in built-up land. The use of heat-absorbing materials also contributes to an increase in surface temperature. UHI is a phenomenon that has a negative impact and is considered important because it has an impact on natural degradation, health risks, and economic losses (Estrada, Botzen, & Tol, 2017). The government as a stakeholder has an important role in UHI mitigation efforts through policy formulation. Mitigation efforts that can be done in reducing the negative impact of UHI on industrial areas are to include UHI mitigation clauses in the spatial plan. The spatial policy that will be studied is the Kendal Regency Regional Regulation No. 1 of 2020 concerning Amendments to Kendal Regency Regional Regulation Number 20 of 2011 concerning Kendal Regency Spatial Planning for 2011-2031.

Table 2. Spatial Policy Analysis in Responding to UHI

| No | Clause | Potential For UHI | Analysis |
|----|--------|-------------------|----------|
| a. | industrial activities that utilize technology, natural resource potential, and human resources in the surrounding area are permitted | v | Allowing industrial activities by considering the potential of natural resources and human resources that utilize technology can affect the increase in anthropogenic greenhouse gases in the atmosphere (UHI). |
| b. | permitted for the construction of infrastructure and facilities to support industrial activities, including: housing, education and training, research and development, health, fire fighting, waste disposal sites, management offices, religious facilities, sports facilities, recreational facilities, commercial facilities and services, green open space, public facilities and social facilities | v | Allowing the construction of infrastructure and facilities to support industrial activities has the potential to change the shape of the landscape and leave only a small area of land for green open space. This can inhibit air circulation and urban heat release, so that urban air temperatures experience a sharp increase due to the dominance of pavement materials that cannot absorb UV rays of sunlight well. |
| c. | permitted with conditions for the development of industrial activities that use large amounts of water | v | The use of raw water in the development of industrial activities is one of the main elements to assist the production process, such as the use of water for engine cooling systems. The use of large amounts of water also has the potential to increase the volume of waste. Based on Presidential Regulation Number 28 of 2008 concerning National Industrial Policy, the characteristics of environmentally friendly industries are by using low water intensity, so that industrial activities are allowed to use large amounts of water with conditional permits. |
| d. | The activities permitted in the designated industrial area are the activities of small, medium and large industries | v | The granting of permits for each type of industrial area needs to take into account the area of the designated area. Increased built-up land and increased pollution can trigger an increase in surface temperature. |
| e. | permitted to develop industrial estates with land use patterns in industrial areas consisting of a maximum of 70% | v | The greater the percentage of industrial plots and other built-up land to green open space tends to increase urban heat temperatures. In fact, green open space has a significant mitigating effect on increasing urban heat temperatures. |
| No | Clause | Potential For UHI | Analysis |
|----|--------|-------------------|----------|
|    | (seventy percent) industrial plots, roads, infrastructure and supporting facilities as needed, and green open space of at least 10% (ten percent) | islands. Steps that can be taken to reduce urban heat islands are the selection of appropriate plant species, plant growth and development, design of garden forms, and the location of green open spaces. The addition of industrial and residential land area results in a decrease in the area of green open space. The addition of industrial and residential land area also has the potential to increase surface temperature. | |
| f. | prohibited the development of industries that are not environmentally friendly | Based on Presidential Decree No. 28 of 2008 concerning National Industrial Policy, environmentally friendly industries or known as green industries are industries which in their production processes prioritize the efficiency and effectiveness of sustainable use of resources, so as to be able to harmonize industrial development with the preservation of environmental functions and can provide benefits to society. The characteristics of environmentally friendly or green industries are using environmentally friendly chemicals, applying reduce, reuse, recycle, and recovery in the production process, using low energy intensity, using low water intensity, using competent human resources, minimizing waste, and using technology, low carbon. These are some of the mitigation efforts against UHI. | h. Industrial Estate Management is carried out by Industrial Estate Companies | Management of industrial estates is only related to administration, not to changes in land use. | i. Industrial companies that will run the industry must be located in the Industrial Estate | The grouping of industrial estates with the provision of infrastructure has a positive impact on land efficiency. The designation of built-up land for the benefit of industrial land must be in accordance with applicable regulations by prioritizing environmentally friendly areas with limitations on the provision of sufficient green open space, good waste management, and materials that do not absorb heat. | j. The obligation to be located in an Industrial Estate is excluded if: 1. does not yet have an Industrial Estate; or 2. already has an Industrial Estate but all of the Industrial lots in its Industrial Estate have been exhausted. | v. The exception to the obligation to be located in an Industrial Estate also applies to: |
1. small and medium-sized industries that do not have the potential to cause environmental pollution with a wide impact; or
2. Industries that use special raw materials and/or their production processes require a special location.

| No | Clause | Potential For UHI | Analysis |
|----|--------|-------------------|----------|
| 1. | Exempted Industrial Companies and medium-sized Industrial Companies must be located in Industrial Designated Areas | V | |
| m. | Industrial Estate Companies are required to provide land for small and medium-sized Industry activities | V | |
| n. | The land can be designated as a center for small and medium industries by the Government or Local Government | V | |

Source: Research Team, 2021

Analysis of the spatial planning policy in Regional Regulation No. 1 of 2020, refers to article 83 related to the general provisions of the zoning regulations for industrial designated areas. Table 2 shows that of the 14 clauses mentioned, 13 of them have the potential to increase UHI. The general provisions mentioned also do not clearly refer to UHI mitigation efforts. The Regional Spatial Plan which in this case is a spatial plan that is still macro in nature, but can still be regulated on provisions that refer to UHI mitigation efforts. In this policy, it seems that UHI has not been seen as a “disaster” that can have a big impact. Mitigation can be carried out by regulating the area of green open space, the materials used, and other provisions that can trigger an increase in surface temperature. In other policies in Kendal Regency, Regional Regulation No. 2 of 2019 concerning the Management of Green Open Spaces in Kendal Regency has been issued, wherein industrial areas, it is regulated about the provision of green open space such as:

a. Provisions for the provision of green space for industrial and warehousing business functions must have a Green Basic Coefficient of at least 15% (fifteen percent).

b. Provisions for the provision of green space for industrial and warehousing business functions with a plot size of more than 1,000 (one thousand) square meters, protective trees must be planted with at least a multiple of 50 (fifty) square meters of land designated for landscaping/greening/rainwater absorption areas and planted plants in the form of shrubs, ornamental shrubs, and ground cover/grass in sufficient quantities.

c. Provisions for the provision of RTH for Industrial and Warehousing Business Functions with a plot of less than or equal to 1,000 (one thousand) square meters must be planted with at least 3 (three) protective trees and planted with plants in the form of shrubs, ornamental shrubs, and ground/grass cover with an amount of sufficient.
4. Conclusion

Understanding spatial planning policies in industrial estates is carried out by analyzing regulations on regional spatial planning. Based on the results of the analysis carried out, the spatial policy of Kendal Regency in the designation of industrial areas has not fully responded to the UHI phenomenon even though 13 of the 14 clauses show the potential for an increase in surface temperature. Environmentally friendly industrial estate arrangements are still mentioned in general without emphasizing efforts to mitigate UHI. Mitigation efforts against UHI mentioned are only in the form of providing green open space and waste management. However, there are differences between Regional Regulation No. 1 of 2020 which states that the minimum area for providing green open space in industrial areas is 10%, while Regional Regulation No. 2 of 2019 states that green open space in industrial business functions must be provided at least 15%. In waste management, it is not stated that the waste produced must be treated until there is no content that can trigger an increase in surface temperature.

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