Urban Heat Island: Identification of Spatial Patterns of Green Open Space for Mitigation in Kendal Industrial Park, Indonesia

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Abstract. The development of industrial estates is a strategy in encouraging the growth of national industries in Indonesia. The development of industrial estates, especially in the regions, is an implementation of the 2015-2035 master Plan of National Industry Development. Kendal Industrial Park (KIP) is one of the industrial estates in Central Java which is experiencing growth and is expected to be one of the choices for investors. The development of industrial estates in the regions has an impact on changes and increases in space requirements. This condition makes land-use change green land into industrial land which is the cause of the effect of rising air temperatures in cities. This study intends to identify the need for green open spaces spatially based on the phenomenon of increasing temperature in the Kendal industrial area using the Urban Heat Island (UHI) approach. Remote Sensing via satellite imagery is used to detect UHI spatially. The location of this UHI will later be used as spatial modelling data to assess how big and where green open space is needed. The results of this study are in the form of a spatial identification of the adequacy of green open space which will mitigate the UHI phenomenon in the Kendal industrial area which is presented spatially in the form of a thematic map.

Keywords: Industry, Remote Sensing, Urban Heat Island

1. Introduction

The growth of industrial areas cannot be separated from the growth of urban areas where the process of fulfilling human needs is carried out with spatial processes and urban settlements as a focus on fulfilling economic and social facilities [1]. This condition makes the growth of non-agricultural land into industrial areas as one of the characteristics of land use change that leads to future problems in integrated urban areas [2–4]. The land has the three attributes of resource, property, and capital as well as being the carrier of the urban-rural system and offering the basis for human activity. Industry plays an important role as an internal driver for the development of the urban-rural system [5].

Growth in rural and urban areas results in changes in temperature, Gartland [6] mention heat islands because many common construction materials absorb and retain more of the sun’s heat than natural materials in less developed 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, the heat island can also be influenced by the industrial structure. The heavy industry refers to the high consumption and release of energy. the company, which can cause temperatures to rise in some areas [6–9].
The development of land change in the study sites around big cities is actually identical to Urban sprawl. According to Peirce [10], stated the problems affecting urban communities and suburban and rural areas, caused by the loss of agricultural land. This condition causes the consumption of thousands of hectares of forest and agricultural land. This policy on land use that allows sprawl is based on a complex of laws and regulations. The uneven development of urban areas, especially for industry, will increase transportation costs and increase the consumption of fossil fuels, which will have an impact on the greenhouse gas effect [11]. In the phenomenon of increasing temperature, an Urban Heat Island phenomenon is formed which is manifested as an "island" of heat surface air centered in an urban area and the temperature will decrease further on the surface which has a suburban/rural typology.

Based on the existing literature, issues related to heat islands in regional and urban development have attracted the interest of several researchers who have tried to explore the spatial patterns and mechanisms of heat islands, especially in developing countries. Most of the research focuses on the calculation of the heat island, as a result of the influence of land change, especially in industrial areas [1,12–14]. As for industrial development, some research is more related to infrastructure supporting production activities in industrial areas [15,16]. However, it is important to develop how green open space planning is developed in industrial areas as a mitigation measure from heat islands.

Identification of growth Industrial estates in Indonesia today are part of the Rencana Pembangunan Jangka Menengah Nasional IV 2020-2024: A prosperous, justice and sustainable middle-high income Indonesia, with a development agenda to strengthen economic resilience for quality growth. Achievements in the Indonesian industry in 2015-2019 built 8 Industrial Estates/Special Economic Zones already operating with an investment value of Rp179.9 trillion from Foreign Investment and Domestic Investment. In the 2020-2024 RPJMN, the target for the number of industrial estates to be facilitated outside Java is 9 priority industrial zones and 10 development industrial zones, but for industrial estates in Java, especially on the north coast of Java, they will be integrated with connectivity support, as well as an adequate supply of energy and human resources. This support is expected to reduce costs, as well as increase productivity and competitiveness of the processing industry [17].

The development of industrial estates is part of the strategy taken to achieve the vision and mission of national industrial development. The government's steps are to develop Industrial Growth Center Areas (WPPI), Industrial Designated Areas, Industrial Estates, and Industrial Centers for small and medium-sized industries. On the other hand, the government must provide affirmative steps in the form of policy formulation, strengthening institutional capacity and providing facilities to small and medium industries; and carry out the construction of industrial facilities and infrastructure [18]. In the context of accelerating the spread and even distribution of industrial development throughout the territory of the Unitary State of the Republic of Indonesia and in order to facilitate synergy and coordination in industrial development in the regions, administratively the territory of the Unitary State of the Republic of Indonesia is divided into 10 (ten) Industrial Development Areas (WPI). The Kendal Industrial Estate is included in one of the WPI areas with Semarang City and Demak Regency.

The development of the Kendal industrial area which is adjusted to the direction of the regional policy with the general provisions of the zoning regulations for the industrial designation area is prepared with provisions. Currently, the industry in Kendal Regency based on the Regional Spatial Plan has an industrial designation area of approximately 5,109 (five thousand one hundred and nine) hectares located in: part of Kaliwungu District; part of Brangsong District; part of Kendal District; and part of Patebon District. This condition is often limited by the environmental conditions of the industrial location in the area so that several development issues arise. Changes in activities and land use that occur significantly can have an impact on extreme environmental changes. One of the environmental changes that can occur in an extreme way is a change in temperature. Where the impact of existing temperature changes will form a pattern and there will be a temperature difference in the built-up land cover compared to the non-built area. This incident is commonly referred to as an urban heat island.

Research conducted in Kendal Regency, especially in industrial designation areas, is to identify and analyze green open spaces and their relation to heat islands that develop in industrial areas with mandated years starting from 2013-2020. This research is also a mitigation measure from heat islands that arise as the result of the development of industrial areas in the Pantura of Java Island, especially in Kendal Regency.
2. Data and Methods

This research departs from the initial identification of the development of industrial areas in Kendal Regency which has an impact on the increasing need for infrastructure and increasing demand for land. In accordance with the direction of the Kendal Regency Spatial Plan, the delineation of the study area is determined from the direction of the industrial development plan in Kendal Regency. The data in this study were obtained from field observations and data processing using Landsat 8 images from 2013, 2015, 2018, 2020. In this study, the images were taken between May – June where conditions in Kendal Regency were in the summer. The data processing was carried out in several stages, namely radiometric correction, geometric correction, NDVI processing, supervised classification processing, the identification used Maximum likelihood classification (MLC) for land cover classification of OLI data where MLC is the most commonly used method in classifying remote sensing data. After this identification we used surface temperature processing and UHI processing. The results of the analysis are combined and matched with the conditions of green open space both from the regional spatial plan and existing conditions.

3. Results and Discussion

3.1 Identification of Kendal Industrial Estate Land Cover

Urban growth as a result of increasing population followed by changes in the rural economy, mainly from agriculture to the non-agricultural sector, affects changes in land use and land cover [19]. Kendal Regency land use changes show that during the period 2005 to 2017 there was a growth and reduction in the area of certain types of land use, an increase in residential land of 260.65 ha and industry 54.65 ha. [1]. It was identified from the spatial pattern of land-use changes in the Kaliwingu area and the Kendal urban area (Figure 1). Changes in land and land cover have an impact on the decline in other types of land use, such as irrigated rice fields [15].

Figure 1. Land Cover in The Provision of The Kendal Industrial Area
The results of the identification use Maximum likelihood classification (MLC) for land cover classification of OLI data where MLC is the most commonly used method in classifying remote sensing data [20]. It was found that in the area of industrial designation in Kendal Regency there are many areas of pond farming. Kendal Regency is an agrarian area with a percentage of 54.57% agricultural land, the development of an industrial area will change the function of the land even though it is in accordance with the Kendal Regency Spatial Plan policy. [13]. The results of mapping changes in land cover classified into 4 groups (Vegetation, Rice Fields, Water Bodies and Built Areas) from 2013-2020 there was an increase in built-up land and ponds identified as water bodies, on the other hand there was a decrease in paddy fields. Identification in 2013 the land cover in the designated industrial area (Figure 2) is mostly rice fields, ponds and vegetation covering an area of 4960.62 Ha, in 2020 the area of open land (rice fields, ponds and vegetation) decreased to 4681.46 and rice fields switched function of being a pond. Meanwhile, the increase in built-up land from 2015 (45.2%), 2018 (18.3%) and 2020 (5.9%) was triggered by the development of industrial estates in this area.

![Figure 2. Area of Land Cover in The Provision of The Kendal Industrial Area](image)

### 3.2 Identification of Industrial Development Plans in Kendal Regency

Kendal Regency as one of the Industrial Growth Center Areas (Wilayah Pasat Pertumbuhan Industri-WPPI) in Central Java based on the 2015-2035 National Industrial Development Master Plan together with Semarang City and Demak Regency. Based on the Provincial Spatial Plan, the Industrial Estate in Kendal Regency has a fairly high development value, thus making the Industrial Estate in Kendal Regency a Special Economic Zone. In addition, the location of the Kendal Industrial Estate is very strategic, namely near national roads, airports, and ports and has a complete infrastructure which includes two export ports, two international airports, railway lines, gas pipelines, electricity, water, and telecommunications [21].

Industrial development based on changes in the RTRW (Regional Spatial Plan) 2011-2031 in 2020, the industrial designation area of approximately 5,109.34 hectares is located in part of Kalisungu Sub-District, part of Brangsong Sub-District, part of Kendal Sub-District; and part of Patebon Sub-District [22]. The results of the identification carried out by [1] Land use predictions in 2031 in East Kendal show that there are four land uses that will grow in 2031 including, industry (2017.96 Ha), settlements (1007.30 Ha), trade and services (271.39 Ha), and warehouses (18.76 Ha). The land uses that were converted into built-up land were ponds (1,593.54 Ha), irrigated rice fields (784.35 Ha), mixed gardens (362.34 Ha), moor (361.65 Ha), open land (145.5 Ha), rainfed rice fields (66.71 Ha), and production forest (1.32 Ha).
In the development of industrial areas in accordance with the direction of Kendal Regency for the development of Industrial Estates, industrial activities are permitted to utilize technology, natural resource potential, and human resources in the surrounding area with environmental management. Other policies related to the arrangement of industrial estates such as permitting the development of industrial estates with land-use patterns in industrial areas consisting of a maximum of 70% (seventy percent) industrial plots, roads, infrastructure and supporting facilities as needed, and green open space at least 10%.

3.3 Urban Heat Island in the industrial area of Kendal Regency

The pattern of changes in heat temperatures in the designation of industrial areas in Kendal Regency changed from 2013-2018, but in 2020 there was an anomaly of decreasing temperature (see Figure 3). After identifying industrial developments and land changes in the Kendal industrial area where there is an increase in land area at this stage an analysis of land surface temperature and urban heat island is carried out. The analysis was carried out over 4 years of measurement (2013, 2015, 2018, and 2020) in the industrial development direction area in the Kendal Regency. Figure 4 shows the distribution of land surface temperatures in the area designated for the development of the Kendal industrial area where the widest temperature of identification has a temperature of 26.1°C - 30°C from 2013-2020. This condition is in line with the results of a study conducted by [23,24] locations in coastal areas have warmer temperatures by considering the distance from the beach and the sampling season.

Figure 3. Area UHI in The Provision of The Kendal Industrial Area

The results of the calculation of the average temperature in this area are 26.1°C - 30°C with an average area of 4 years of observation 3,528.88 Ha. Above the average temperature identified at the location, there are the first two classes of temperatures between 30.1°C - 34°C with an average area of 631.81 Ha, while the hottest temperature class is 34.1°C - 38°C with an average area of 4 years of observation in the area. 29.22 Ha. These results were identified in spatial form based on the Kendal Regency Spatial Plan map (Figure 4), in 2013 almost all locations were in the temperature class 22.1°C - 26°C, for areas with temperatures over 30.1°C - 38°C identified from the results The field is an industrial area (Wood Processing) in the east and a residential area in the northwest.

The results of observations in the second year (2015) show that residential and industrial activities have begun to be built so that heat areas are more visible and form spatial patterns. Followed by the analysis in 2018 the heat temperature conditions in the industrial designation area relatively increased, especially at temperatures of 26.1°C - 34°C this condition was influenced by several factors, especially in the pond area, where the image of the pond area was dry so that the heat identified increased. In 2020,
it is indicated that the temperature in the industrial designation area has decreased, this is influenced by the area of ponds, rice fields, and growing vegetation. This condition is evidenced by the re-measurement of vegetation density and surface temperature in the pond areas which is relatively lower, but for industrial areas, the temperature is still high detected. The results of the survey observations identified that the north coast of Kendal Regency has government programs related to mangrove planting where this condition lowers the temperature in several locations. Meanwhile, in other places, the factors that reduce the temperature are planting and growing vegetation in open spaces.

![Figure 4. UHI in The Provision of The Kendal Industrial Area](image)

4. Conclusion

Changes in surface temperature in the industrial designation area in Kendal Regency have been identified starting from 2013 to 2020. This temperature change is dynamic where based on UHI analysis there are open areas such as rice fields, ponds, and yards experiencing temperature increases and decreases. Meanwhile, in industrial areas, starting from those identified that have not been built in 2013 until the construction of buildings, surface temperatures show an increase with an average temperature of 30.1°C - 38°C. The utilization of green open space, especially around industrial areas, has not yet sufficiently impacted the decrease in surface temperature. Meanwhile, the decrease in surface temperature was identified as coming from coastal areas that were carried out by the mangrove planting program.

The results of this study show that surface temperature through UHI analysis can change dynamically, especially if it is related to green open spaces where vegetation density can reduce surface temperature. For example, planting mangroves as vegetation can reduce surface temperatures and cope with rising sea levels. The identification results can also be used as a basis for calculating changes in surface temperature in the future, because of the area allotted for an industrial area of 5,109.34 hectares but currently, the land managed by KIK is 994.00 Ha.

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