Assessment of Rapid Urban Development Impact for a Small-Sized Transit City Using Remote Sensing: A Case Study of Salatiga, Indonesia

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Abstract. Salatiga is the connecting city between Semarang City and Surakarta, which makes it one of the small-sized transit cities in Central Java. Its strategic location has led to various developments being carried out in Salatiga in the last ten years. This study aimed to assess the impact of the rapid development of Salatiga as a transit city. This study utilized remote sensing to analyze land cover changes and changes in land surface temperature (LST). The results showed that Salatiga experienced more significant growth in the built-up area than the population growth. The rapid development in Salatiga creates various new activities, such as trade and services and industries. This development changed the land cover and affected the land surface temperature in Salatiga. In the last ten years, Salatiga experienced an average temperature increase of 0.23°C. Mitigation efforts are needed to suppress environmental changes in the future.

Keywords: urban development, land surface temperature, transit city

1. Introduction

Regional development in various parts of the world has various development systems, such as decentralization which gives local governments the authority to regulate their regions. The granting of authority to each region is due to the diversity of potential resources, such as Indonesia. Indonesia has implemented a decentralized system since the late 1990s. Since then, the power and authority of the government have shifted from the central government to local governments. However, the granting of authority to local governments to carry out their regional development raised new problems such as disparities between regions which can be seen from the significant differences in per capita income and poverty levels between regions [1]. In Indonesia, disparities occurred between development on Java Island and other parts of Indonesia, affecting the balance of regional development [2–5].

Through decentralization, local governments are expected to manage revenues adapted to the regional development needs [5]. However, in reality, each region has various resource potential and various resource manager's capacities, thus allowing disparities to occur [6]. In this case, managing resources will affect the economic condition and environmental sustainability in the future.

In Central Java, some areas with the most significant urban growth among other regions are Semarang, Sragen, and Surakarta [7–11]. Salatiga became the connecting city, making it a transit city in Central Java. As a transit city, Salatiga has a strategic location and has higher economic growth than the surrounding areas [7]. However, based on Central Java Provincial Statistics Agency [12], Salatiga has the lowest GRDP contribution in Central Java due to its small-sized characteristics and limited natural resources availability. These conditions then become a challenge to improve its economy through various developments to accelerate regional growth and become the highest income contributor in Central Java.
In recent years, Salatiga has undergone various developments, such as the construction of the Southern Ring Road of Salatiga (2013), the construction of the Salatiga-Kartasura Toll Road (2018), the construction of Campus III of IAIN Salatiga (2019), and other infrastructure developments. Through these various developments, of course, changed the composition of land cover in Salatiga. The rapid development of Salatiga will also affect the characteristics of activities in the future. One of the impacts of these developments is the development of new trade corridors in several locations. In addition, connections between regions will also change according to the linkages between developing activity centers, thus creating new public transport routes. In the end, changes in activity characteristics affect the employment types and economic growth of Salatiga in the future.

Previous studies have proven that infrastructure development can change the characteristics of community socio-economic activities [13]. In addition, the existence of infrastructure development is also inseparable from the impact on the environment, such as an increase in surface temperature [14,15]. Compared to the surrounding cities (such as Semarang, Sragen, or Surakarta), which have a high average surface temperature [16,17], Salatiga is well-known as ‘the cold city’. This is because of its location at the foot of Mount Merbabu. In this case, the various developments that are carried out will undoubtedly impact the environmental conditions, identical to ‘the cold city’.

Meanwhile, with the development of remote sensing technology, it can be used as a tool in assessing the changes that occurred due to the various developments that have been carried out [15,18,19]. In this case, remote sensing technology can be applied for various things, for example, to monitor temperature changes [15,20,21], vegetation density [22,23], as well as the relationship between the two [14,24]. No study has reviewed the impact of various developments in Salatiga, especially related to environmental changes. This is very important to study considering the existence of Salatiga, which is a small-sized city with limited natural resources and as a transit city with high development demands. Therefore, this study aims to determine the effect of accelerated development on environmental changes in Salatiga as a transit city. This research is expected to explore the relationship between urban development and environmental change in Salatiga. In addition, through this research, mitigation efforts can be identified that can be optimized as a driver for creating sustainable development in the future.

2. Data and Methods

Salatiga is located at coordinates 110°27'56.81" - 110°32'4.64" East Longitude and 007°17' - 007°17'23" South Latitude. Salatiga is a small-sized city with a total area of 5,678 ha. Administratively, Salatiga is directly adjacent to Semarang Regency, or more precisely surrounded by Semarang Regency area (Figure 1). In addition, Salatiga consists of 4 districts divided into 23 sub-districts with 192,323 people based on Central Bureau of Statistics Data [12]. In addition, Salatiga is also traversed by several alternative routes such as the Southern Ring Road (SRR) and the Salatiga-Kartasura Toll Road, which heighten the accessibility.

This study used a quantitative approach using secondary data. The data used include Landsat 5 TM imagery in 2010 and Landsat 8 OLI imagery in 2020. Then, based on the data obtained, the study used several analytical methods, including land cover changes and land surface temperature (LST) analysis.

Land cover change detection was carried out using Landsat 5 TM imagery in 2010 and Landsat 8 OLI imagery in 2020 (path 120 and row 65). Land cover change analysis was performed using machine learning algorithms and cross-tabulation in QGIS 3.12. This analysis aimed to determine how the land cover changes pattern due to various developments to affect environmental changes. Here, the analysis of the environmental changes is carried out by calculating the change in surface temperature of Salatiga using the thermal band (band 6 for Landsat 5 TM and band 10 for Landsat 8 OLI). According to Parvez et al. (2021), LST is one of the indicators to assess the impact of urban development. Changes in surface temperature can be done by calculating Eq. 1 as follows,

\[ T = \frac{TB}{1 + (\lambda \times TB/c2) \times \ln(e)} \]  

where, \( T \) is the result of the surface temperature conversion in Celcius (°C), \( TB \) is the atmospheric temperature in Celcius (°C), while \( \lambda \) is the wavelength (11.45 for Landsat 5 Band 6 and 10.8 for Landsat 8 Band 10), \( c2 \) is a constant (14.388 µmK), and \( e \) is the emissivity.
3. Results and Discussion

3.1. Rapid Urban Development Impact on Land Use/Land Cover (LULC) Change

In 2010-2020, Salatiga experienced a significant change in land cover (Table 1 and Figure 2). In 2010, the forest cover composition was still quite large, covering 2,011.01 ha or 35% of the total area. Then, the built-up area in 2010 had an area of 1,810.55 or 32%. Meanwhile, agricultural land has a proportion of 33% (1,851.41 ha). In addition, in 2010, there were also bare land areas of 5.04 ha or only 0.1% of the total area.

Then, in 2020, significant land cover changes occurred in the reduction of forest land cover and an increase in the built-up area (Table 1 and Figure 2). The reduction in forest cover occurred due to the conversion of forest cover into agricultural land of 736.96 ha or 36% of the total forest cover area. This left a forest area of 946.43 ha or the remaining 44% of the forest land area in 2010. Meanwhile, the increase in built-up land in 2020 mostly comes from the agricultural land conversion into the built-up area, 756.62 Ha. In other words, there is a 40% conversion of the agricultural land into built-up land. In addition, in 2020, there will also be an increase in bare land originating from forest and agricultural land conversion, amounting to 45.03 ha and 22.66 ha, respectively.

Table 1. The Land Use/Land Cover (LULC) Change
Transition of Salatiga in 2010-2020 (ha) (Analysis, 2021)

| LULC Class 2010 | LULC 2010-2020 | LULC Class 2020 | LULC Composition 2010 |
|-----------------|----------------|-----------------|-----------------------|
| Built-up        | 1,474.51       | 321.90          | 1,810.55              |
| Bare land       | 3.29           | 1.65            | 0                     |
| Agriculture     | 756.62         | 993.88          | 1,851.41              |
| Forest          | 364.41         | 736.96          | 2,011.01              |
| LULC Composition| 2,598.83       | 2,054.39        | 5,678.00              |
Spatially, the built-up area growth is almost evenly distributed throughout the region (Figure 3). However, Sidorejo District experienced the most significant increase in the built area compared to other Districts. Apart from being due to the construction of the SRR, this is also due to the development of the IAIN educational area, Islamic boarding schools, and several other supporting facilities. The development
carried out can trigger the growth of the trade area along the southern ring road. In this case, the growth of the trade area is undoubtedly one factor for the conversion of the non-built-up into built-up areas. Not only trade and service areas, but the construction of the southern ring road has also triggered the growth of industries such as a shoe factory in Argomulyo District. This is due to the increasing accessibility and strategic location.

3.2. Spatio-temporal Impact of the Pervious-Surface Degradation on Land Surface Temperature in Salatiga

Various developments in Salatiga have changed the land cover, which was previously a non-built area, into a built-up area. The development of the built-up area is certainly in line with the more impervious areas in Salatiga and the fewer green areas in it. This turned out to impact changes in surface temperature in Salatiga. The most significant changes in surface temperature were in Argomulyo District (Figure 4), where there was the development of a shoe industrial area that was previously a forest cover. Then, an increase in surface temperature also occurred in the southern part of Tingkir District, which is an area close to the Bawen-Salatiga toll gate construction, where there was also an increase in other activities such as commercial activities. This is in line with what was stated by Yamashita et al. [25], that the increasing intensity of activity and development affects changes in surface temperature in urban areas.

Based on the results obtained, in 2010, Salatiga had an average surface temperature of 24.35°C with a maximum temperature of 32.46°C. Meanwhile, in 2020, Salatiga has an average surface temperature of 24.58°C with a maximum temperature of 35.17°C. In this case, there is an increase in the surface temperature of Salatiga by 0.23°C. Furthermore, the highest surface temperature increase was in Argomulyo District of 10°C, where industrial development converted the forest and agricultural land cover. If the rapid and uncontrolled development continues, of course, the average surface temperature in Salatiga will continue to rise.

![Figure 4. The Land Surface Temperature of Salatiga (analysis, 2021)](image-url)
3.3. Discussion

Salatiga is a city with a small-sized category. In this case, the growth of small and large cities each has different characteristics. Small-sized cities tend to expand the built-up area, which is smaller than the increase in population/density [26]. However, in this study, it was found that in the period 2010–2020, Salatiga experienced a more significant increase in built-up areas compared to the increase in population (Table 2). This is due to several things, and the first is related to the construction of the southern ring road and the freeway on the east and west sides of Salatiga. Then, this development can trigger a significant growth of built-up areas and increase the types and intensity of existing urban activities—for example, the growth of trades, street vendors, and restaurants. The growth of the built-up areas and regional activities, and new activity centers can change the population movement system and connect routes between regions. On the other hand, the more negligible population growth of Salatiga is due to the existence of Salatiga as a transit city, where some residents are only temporary and not permanent. Some are students from other areas, and so it is not recorded statistically.

Table 2. Changes in Population (P) and Built-up Area (BU) (analysis, 2021)

| No | District   | Area (ha) | P 2010 | P 2020 | ΔP  | ΔP (%) | BU 2010 | BU 2020 | ΔBU  | ΔBU (%) |
|----|------------|-----------|--------|--------|-----|--------|---------|---------|------|--------|
| 1  | Argomulyo  | 1.852     | 42.638 | 49.295 | 6.657| 15.61  | 408     | 593     | 185  | 45.34  |
| 2  | Tingkir    | 1.054     | 42.054 | 45.971 | 3.917| 9.31   | 346     | 439     | 93   | 26.88  |
| 3  | Sidomukti  | 1.145     | 36.611 | 44.237 | 7.626| 20.83  | 392     | 589     | 197  | 50.26  |
| 4  | Sidorejo   | 1.624     | 50.024 | 52.819 | 2.795| 5.59   | 535     | 790     | 255  | 47.66  |

Furthermore, Khorev (1974) mentions that one characteristic of a small city is the limited management of natural resources and employment opportunities. In this case, the construction of the southern ring road and freeway in Salatiga can be economically profitable. According to Khumya & Kusakabe (2015), it can increase the potential for new jobs and increase labor migration from outside the city. In this case, the increase in employment opportunities in Salatiga can be seen from the growth of the trading area along the ring road route to the emergence of a weekly trading area commonly known as the ‘New Street Market (Pasar JB)’. In addition, IAIN Salatiga campus educational facilities were also built on the edge of the ring road, which supports the growth of boarding houses for students, modern cafes, and workplaces.

Meanwhile, from an environmental perspective, the conversion of forest and agricultural land cover into bare land and built-up areas has proven to influence changes in surface temperature in Salatiga. This is in line with the research of Yang et al. [15], which proves that the built area indicates a high surface temperature. In this case, the more development carried out, the more significant the average increase in surface temperature in Salatiga.

Efforts to examine the spatiotemporal characteristics of urban area development expansion are essential in creating sustainable urban development [28–31]. In this case, remote sensing has proven to help see the spatial pattern of urban growth. Here, this showed an urbanization and industrialization phenomenon in Salatiga (Figure 3). Statistically, based on data sources from the Salatiga City Office of Industry and Employment, the number of industries in Salatiga in 2020 was 1,981 units with a total workforce of 15,762 people. Meanwhile, in 2010 there were 1,875 industrial units with total employment of 6,581 people. This shows a significant increase in the number of industries by 106 units (5.6%) with a rise in employment of 9181 people (139%). Judging from the socio-economic aspect, of course, this will be very beneficial, such as reducing unemployment and increasing income. However, rapid urbanization will worsen natural resource availability and lead to environmental degradation [32–36]. In fact, in this case, Salatiga has the characteristics of a small city with minimal availability of natural resources. Without special attention from the government, the environmental sustainability of Salatiga will be threatened.

Based on case studies in several other urban areas, Salatiga is not the only city experiencing environmental changes due to urban development [4,10,16,17,37]. Various efforts to mitigate the increase in surface temperature due to urban development have been carried out in various regions in various ways according to the characteristics of each region. Semarang City, with the existence of industrial areas and dense settlements, undertakes mitigation efforts through the use of reflective roofs, reflective walls, greening parking lots, and planting trees around buildings [38]. Meanwhile, in Surakarta, Kurnianti (2019) stated that the government carried out the mitigation efforts by selecting vegetation quality, greening parking lots, green walls, and green roofs. In this case, among the various scenarios and mitigation efforts that have been carried
out, other studies have proven that the parking area canopy plays an essential role in achieving an air temperature reduction, especially in dense urban areas with limited land [40]. Based on its characteristics, the Salatiga City Government can encourage the community to increase the vegetation canopy, plant trees along road/pavement corridors, and plant trees on vacant land. In addition, land-use monitoring and controlling needs to be carried out more intensively to suppress development discrepancies with spatial planning policies. In this case, spatial planning is crucial as a controller and guide in realizing sustainable urban development in the future.

4. Conclusion

Rapid urban development in Salatiga affects the environmental changes, wherein 2010-2020 Salatiga experienced an average surface temperature increase of 0.23°C. In contrast with other small cities, Salatiga underwent urban growth in 2010-2020 that is more significant than its population growth. This phenomenon was caused by the development of the southern ring road and Salatiga-Bawen Toll Road that promoted rapid urban activities growth. In this case, the highest surface temperature increase was in Argomulyo District by 10°C, where industrial development converted the forest and agricultural land cover. Mitigation efforts need to be done to minimize the ecological pressure in the future. Also, urban growth in Salatiga needs to follow spatial planning to promote sustainable development.

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