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Spatial Temporal Analysis of Development in Adiwerna Sub-district, Indonesia due to the Impact of Pejagan-Pemalang Toll Road Development

Heinrich Rakuasa[1,*], Viktor Vladimirovich Budnikov[1], Benson Joshua[2], Philia Christi Latue[3]

[1]Department of Geography, Faculty of Geology and Geography, Tomsk State University,
Ulitsa Arkadiya Ivanova, 49, Tomsk, Tomsk Oblast, 634028, Russian Federation
[2]Department of Bioinformatics, Schools of Advanced Engineering Studies, Tomsk State University,
пл. Новособорная, 1, Tomsk, Tomsk Oblast, 634029, Russian Federation
[3]Department of Biology, Faculty of Teacher Training and Education, Pattimura University,
Jalan Ir. M. Putuhena, Ambon, 97233, Indonesia.

Corresponding author*
heinrich.rakuasa@stud.tsu.ru

Abstract: The development of transportation infrastructure, particularly the Pejagan-Pemalang Toll Road, has had a significant impact on the development of areas in Adiwerna Sub-district, Central Java, Indonesia. This study uses spatial temporal analysis with high-resolution satellite image data from 2013, 2018, and 2023 to evaluate land cover change and settlement development patterns. The results showed that the settlement area increased from 942.76 hectares in 2013 to 1308.90 hectares in 2023, with the growth rate increasing significantly after the toll road is fully operational. This settlement development not only increases accessibility and economic activity, but also leads to conversion of agricultural land, potentially threatening the sustainability of food production. While this infrastructure development brings economic benefits, a sustainable planning strategy is needed to manage the impacts of urbanization and maintain a balance between development and environmental preservation.

Keywords: Adiwerna, Built-up land, Pejagan-Pemalang Toll Road.

Introduction

The development of transportation infrastructure, especially toll roads, has a significant impact on the development of the surrounding area (Irawan et al. 2019). One of the major infrastructure projects that has changed the landscape of the Central Java region is the construction of the Pejagan-Pemalang Toll Road. This project, which is part of the Trans Java Toll Road network, has had a diverse impact on the areas it passes through, including Adiwerna Sub-district in Tegal Regency (Ahmad 2022). Adiwerna Sub-district, as one of the areas directly affected by the construction of the Pejagan-Pemalang Toll Road, experienced significant changes in land use patterns and settlement development (BPS 2023). Increased accessibility due to the presence of the toll road has driven economic growth and attracted investment interest in the region(Saraswati et al. 2022). This in turn triggers changes in land function from agricultural areas to residential and commercial areas (Shofy and Wibowo 2023).

Spatial-temporal analysis is an important instrument in understanding the dynamics of land use change and settlement development patterns. Using data from 2013, 2018, and 2023, this study aims to comprehensively examine how the construction of the Pejagan-Pemalang Toll Road has affected settlement development in Adiwerna Sub-district over the past decade. Rapid settlement development can have both positive and negative consequences for the local community and environment (Shofy and Wibowo 2023). On the one hand, this growth can increase economic activity and improve local infrastructure (Shafizadeh

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Moghadam and Helbich 2013). But on the other hand, uncontrolled settlement expansion has the potential to threaten the availability of productive agricultural land and cause environmental problems such as flooding and pollution (Zhou et al. 2021)

The use of remote sensing technology and Geographic Information Systems (GIS) in this study allows for a more accurate and comprehensive analysis of land cover change and settlement development patterns (Rana and Sarkar 2021). These methods allow for the visualization and quantification of spatial changes over time, providing a more in-depth understanding of trends and patterns of area development (Fallati et al. 2017). The results of this study are expected to make a significant contribution to the understanding of the impact of large infrastructure development on the spatial dynamics of the region. The findings obtained can be valuable input for policy makers in formulating more sustainable regional planning and management strategies, especially in the context of transportation infrastructure development. Furthermore, this study is also expected to be a reference for similar studies in the future, especially in the context of evaluating the long-term impact of large infrastructure projects on regional development. By understanding the patterns and dynamics of spatial changes due to toll road development, it is hoped that future development planning can better consider aspects of sustainability and balance between economic development and environmental preservation.

Materials and Methods

This research was conducted in Adiwerna Sub-district, Tegal Regency, Central Java Province, Indonesia, with the aim of analyzing the development of settlements due to the impact of the Pejagan-Pemalang Toll Road construction. The data used in this study included high-resolution satellite images, namely Worldview-2 for 2013 and 2023, and Geoeye-1 for 2018, obtained from Maxar Technologies (Figure 1). These satellite images were used to identify and map land use change, particularly settlement development in Adiwerna Sub-district.

Figure 1. Worldview-2 Satellite Imagery in 2013 and 2023 and Geoeye-1 in 2018.

Spatial-temporal analysis of settlement development was conducted using a process of visual interpretation and digitization of satellite images. This process involved identifying new settlement areas as well as changes in settlement area from 2013, 2018, to 2023. In addition, area analysis was conducted using ArcGIS 10.8 software, which allows for accurate measurement and mapping. The population data of Adiwerna Sub-district for 2013, 2018, and 2023, obtained from the Indonesian Central Bureau of Statistics, was also analyzed to see the relationship between settlement growth and population increase. By this method, a clear picture of the impact of toll road construction on settlement development in Adiwerna Sub-district is expected.

Results and Discussion

Settlement Development in Adiwerna Sub-district

The results showed that there was a significant increase in the area of settlements in Adiwerna Sub-district from 2013 to 2023. In 2013, the settlement area reached 942.76 hectares. Five years later, in 2018, there was an increase of 106.82 hectares to 1049.58 hectares. In 2023, the settlement area further increased to 1308.90 hectares, an increase of 259.32 hectares compared to 2018 (Figure 2). In total, over a 10-year period, settlements increased by 366.14 hectares. The construction of the Pejagan-Pemalang toll road that crosses this area plays an important role in accelerating settlement development in Adiwerna Sub-district. The construction of this toll road infrastructure triggered increased accessibility and mobility, thus attracting investment, construction of commercial, residential and industrial facilities. This has been one of the main factors in the expansion of settlements and other land uses in the area.

During the period 2013 to 2018, the growth of settlements showed a moderate pace with an addition of about 2.27% per year. However, in the following five years (2018-2023), the growth rate increases to about 4.94% per year. This faster increase reflects the direct effect of the full operation of the toll road which has led to faster economic growth and development in the region. Settlements are mainly expanding around toll gate accesses and along main routes that connect with new residential areas and centers of economic activity. This development pattern illustrates that the construction of toll roads increases the attractiveness for the development of surrounding areas, especially in the property and commercial sectors.

One of the main impacts of the increase in settlements is the conversion of agricultural land. The increase in settlements from 942.76 hectares to 1308.90 hectares within 10 years indicates that most of the converted land came from productive agricultural land. This raises concerns about the sustainability of local food production and the degradation of environmental quality in the area. The rapid growth of settlements has an impact on the social and economic changes of local communities. Communities living near toll roads tend to experience an increase in the value of their land and assets. However, this can also lead to social problems such as uncontrolled urbanization, increased living costs, and pressure on city infrastructure. As built-up land increases, environmental quality in Adiwerna Sub-district may suffer, such as reduced green open space, increased surface temperatures, and changes in water flow patterns. Massive development in this area has the potential to increase flood risk and degrade groundwater quality due to reduced infiltration areas.

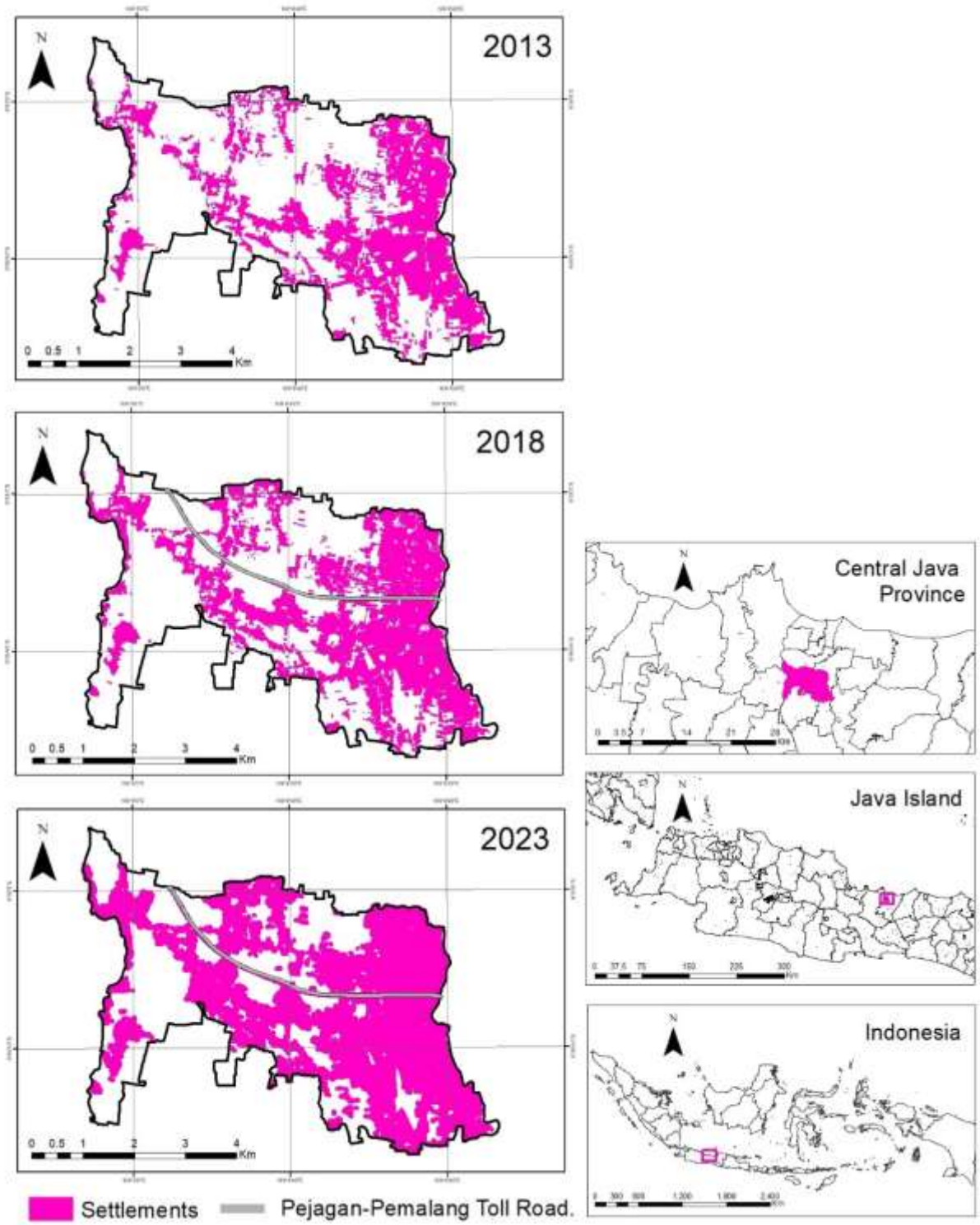

Figure 2. Settlement Development in Adiwerna Sub-district in 2013, 2018 and 2023.

Population Growth

Based on population data obtained from the Indonesian Central Bureau of Statistics, there has been a significant increase in population in Adiwerna Subdistrict within 10 years, from 2013 to 2023. In 2013, the total population was recorded at 120,350 people, and continued to increase until it reached 139,028 people in 2023 (BPS 2013; BPS 2023). This represents a growth of 18,678 people or about 15.5% in a decade. This growth was influenced by several factors, including infrastructure development such as the Pejagan-

Pemalang toll road, which improved the accessibility of the region and attracted more people to live in the area. This increase also shows that Adiwerna Sub-district is becoming a more densely populated area due to urbanization and economic development. In terms of gender, both male and female populations have increased consistently from year to year. In 2013, the male population was 60,860 people, while women reached 59,490 people. In 2018, the male population increased to 65,270 and the female population to 62,525 (BPS 2018). This figure continues to grow until 2023, where men reach 71,179 people and women 67,849 people. This faster increase in the male population than the female population is likely related to economic changes in the region, especially the growth of the industrial and service sectors that attract more male workers, as well as migration from other regions.

Population growth in Adiwerna Sub-district has a direct correlation with the development of built-up land. As the population increases, the need for housing, public facilities, and supporting infrastructure such as schools, hospitals, and shopping centers also increases (Rakuasa and Nurul Achmadi 2024). This encourages the expansion of built-up land, as seen from the significant increase in built-up land area during the period 2013 to 2023. In 2013, the built-up land area in Adiwerna Sub-district reached 942.76 hectares, and increased to 1049.58 hectares in 2018 and 1308.90 hectares in 2023. This increase indicates that population growth drives the need for conversion of non-residential land into built-up areas to accommodate the needs of the population. The Pejagan-Pemalang toll road that crosses this area has a significant impact on population growth. With easier and faster access, the area has become more attractive to newcomers, especially those seeking employment and business opportunities in the trade, service and industrial sectors. The toll infrastructure also facilitates better mobility for local residents, thereby increasing the attractiveness of Adiwerna Sub-district as a place to live. The toll road serves as connection that accelerates the flow of urbanization and increases the attractiveness of investment in the property sector, which also influences population growth in the area.

The rapid population growth over the past 10 years in Adiwerna Sub-district brings a number of challenges, including the need for good land management to address environmental issues, uncontrolled urbanization, and the potential for increased congestion and pressure on infrastructure. Increased demand for basic amenities such as clean water, electricity and sanitation must also be anticipated by local government. In addition, there is a risk of deteriorating quality of life in the absence of adequate planning, especially in terms of the provision of decent housing, public facilities, and efficient transportation. Population growth of 15.5% over the past 10 years demands better and more sustainable infrastructure development. The development of education, health, transportation, and public space facilities must be adapted to the needs of the growing community. If not managed properly, this population growth can exacerbate social problems such as poverty, unemployment, and traffic congestion (Lisanyoto, Supriatna, and Sumadio 2019). Population growth in Adiwerna Subdistrict also contributes to changes in socioeconomic dynamics. An increase in population is usually followed by the development of informal sectors such as small trade, food stalls, and other service businesses. However, this economic development needs to be accompanied by an increase in employment opportunities and the provision of suitable land for businesses, so that there is no imbalance between population growth and economic welfare (Supriatna et al. 2016).

The population increase of nearly 20,000 people over the past decade has certainly increased the need for housing land. This has resulted in the conversion of land, especially agricultural land, into housing and commercial areas. The government must ensure that the development of built-up land does not harm the sustainability of natural resources and still pay attention to environmental aspects. With an increasing population growth rate, Adiwerna Sub-district is projected to become an increasingly urbanized area in the future. This urbanization must be balanced

with careful planning to avoid uneven population distribution and the creation of slums due to inadequate housing. Local governments must also prepare strategies to manage the impact of urbanization to keep it under control.

Conclusions

The results of this study show that the construction of the Pejagan-Pemalang Toll Road has significantly affected settlement development in Adiwerna Sub-district, with the conversion of agricultural land into residential and commercial areas increasing from 942.76 hectares to 1308.90 hectares within a decade. While this growth drives economic activity and attracts investment, negative impacts such as a decrease in the availability of productive agricultural land and environmental issues such as flooding and pollution are major concerns. Therefore, it is important for policy makers to develop sustainable planning strategies, so that the impacts of urbanization can be well managed and the balance between economic development and environmental preservation is maintained.

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