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Trade-Off Analysis Of Land Function Transfer For Industrial Activities On Economic Growth And Environmental Sustainability In Dumai City

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Abstract

This study analyzes the trade-off between land-use conversion for industrial activities, economic growth, and environmental sustainability in Dumai City. It employs a quantitative descriptive method using secondary data for 2015–2025 from Statistics Indonesia, spatial planning documents, spatial data, and environmental agency publications. The analysis compares industrial development, land-use changes, and environmental quality indicators. The findings show that the manufacturing sector in Dumai City generally developed over the study period, although fluctuations occurred in several years. This development coincided with the expansion of built-up areas and a decline in mangrove and forest cover. Environmental pressures were also reflected in a decrease in the Air Quality Index and the continued presence of water quality monitoring points classified as slightly polluted. These findings indicate a trade-off between the economic benefits of industrial activities and the pressures they place on environmental sustainability. Therefore, industrial development needs to be accompanied by controls on land-use conversion, protection of coastal ecosystems, and stronger environmental monitoring to ensure that economic growth remains aligned with the conservation of natural resources.

Keywords: Land-Use Conversion, Industrial Activities, Economic Growth, Environmental Sustainability, Trade-Off.

INTRODUCTION

Economic development is an effort to improve public welfare by increasing production, investment, and employment opportunities. One sector that plays a role in driving economic development is the industrial sector. Industrial development can contribute to regional economic growth, both through increased production value and employment. However, industrial development also requires adequate land availability to encourage land use changes from their previous function to industrial areas.

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These land-use changes pose development challenges, particularly when the economic benefits must be weighed against their environmental impacts. Industrial development can provide economic benefits, but it also has the potential to reduce green areas, alter environmental conditions, and increase pressure on natural resources. This situation demonstrates a trade-off between the interests of economic growth and environmental sustainability.

*Trade-off*Land use conversion can be understood as a condition where the economic benefits of land use change need to be considered alongside its impacts on the environment. von Groß et al. (2024) explained that land use change in Jambi Province can create conflicts between economic interests and environmental protection. The study showed that efforts to fulfill certain ecological functions can require changes in land use that have the potential to reduce economic benefits. In line with this, Widayani et al. (2023) found that changes in land cover and use in Sleman Regency impact the value of ecosystem services. This finding indicates that land use change is not only related to economic activities but can also affect the ecological benefits provided by an area. Meanwhile, Silvian et al. (2024) found that the decision to convert land from rice farming to oil palm plantations is related to economic considerations, sustainability, and environmental conditions. Based on this research, the trade-off concept in this study is used to analyze the exchange between the economic benefits obtained from land use conversion for industrial activities and its potential consequences for environmental sustainability.

Dumai City is one of the areas in Riau Province that has growing industrial and economic activities. Industrial development requires land that can encourage changes in land use. On the one hand, industrial development has the potential to increase economic activity and create jobs. However, on the other hand, poorly managed land use conversion can cause environmental problems, such as reduced green areas, changes in water management, and declining environmental quality. The development of industrial activity in Dumai City is evident in the presence of various companies engaged in the oil and gas and palm oil processing sectors. Some of the large companies operating are PT Pertamina Hulu Rokan which is engaged in upstream oil and gas activities, PT Pertamina in oil and gas processing and distribution activities, and a number of palm oil processing companies such as PT Sari Dumai Sejati, PT Ivo Mas Tunggal, and PT Energi Unggul Persada. In addition, Dumai City also has several industrial areas, such as the Dumai Industrial Estate in Pelintung, the Lubuk Gaung Industrial Estate, Dock Yard, Bukit Kapur, and Bukit Timah. The existence of these companies and industrial areas shows that industrial activities are an important part of Dumai City's economy.

On the other hand, the development of industrial areas requires significant land use, potentially driving changes in land use from its previous use. This condition poses a

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challenge for Dumai City because land use for industrial activities requires consideration of the characteristics of the area and its ecological function. Poorly managed land conversion can lead to a reduction in green areas, disruption of swamp and peatland functions, and a decline in environmental quality. Therefore, this research is important to understand the trade-off between the need for industrial development and efforts to maintain environmental sustainability in Dumai City. The results of the study are expected to provide an overview of the impact of land conversion and become a consideration in determining development policies that still consider environmental sustainability.

RESEARCH METHODS

This study uses a quantitative descriptive approach to analyze land use changes due to industrial development, as well as their relationship to economic growth and environmental sustainability in Dumai City, Riau Province. The research object is the conversion of non-industrial land into industrial areas. Dumai City was chosen because of its role as one of the industrial and commercial areas in Riau Province.

The data used is secondary data for the 2015–2025 period, adjusted for data availability from each source. Economic data, namely Gross Regional Domestic Product (GRDP), the contribution of the manufacturing sector, and employment, were obtained from publications of the Dumai City Statistics Agency (BPS). Land use data were obtained from spatial planning documents, land use maps, and spatial data. Environmental data, such as green open space, water quality, and air quality, were obtained from publications of authorized environmental agencies.

Land use change analysis was conducted by comparing land area at the beginning and end of the period to determine the types of land that were reduced due to industrial development. Economic growth was analyzed descriptively through the development of GRDP at constant prices, the economic growth rate, and the contribution of the manufacturing sector. Environmental conditions were analyzed by comparing indicators between periods based on available data.

The results of these three analyses were then compared to examine the economic benefits of land conversion and the associated environmental pressures (trade-off analysis). This analysis is descriptive in nature and is not intended to prove a direct cause-and-effect relationship.

RESULTS & DISCUSSION

Dumai City is a region in Riau Province that plays a significant role in industrial and trade activities. Geographically, Dumai City consists of lowlands in the north and a portion of highlands in the south. The soil conditions are dominated by peat swamps with several types of soil, such as red-yellow podzolic, organosol, and gley humus. In addition

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to its potential for industrial development, Dumai City also has land resources that can be utilized for agricultural, plantation, and agro-industrial activities. This potential makes land a crucial resource in supporting economic activity and regional development. Along with regional development, the industrial sector has become a crucial part of Dumai City's economic development because it can encourage increased regional production and create employment opportunities for the community.

The development of the industrial sector is evident in the presence of various industrial areas in Dumai City. The Dumai Industrial Area is one of the largest industrial areas in Riau Province with a total land area of 1,859 hectares. Industrial activity in Dumai is not only concentrated in one location, but is spread across several areas, such as the Dumai Industrial Area (KID) in Pelintung, Lubuk Gaung, Dock Yard, Bukit Kapur, and Bukit Timah. The Dumai Industrial Area was developed with the aim of becoming a green zone and improving community welfare through the development of modern and sustainable industrial areas. In 2010, the Dumai Industrial Area was also designated as a Palm Oil Industrial Cluster by the Indonesian Government due to the large potential of palm oil-based industries. The development of these areas indicates the increasing need for land to support industrial activities and infrastructure development in Dumai City.

The increase in industrial activity also plays a role in driving the economic growth of Dumai City. One indicator used to measure regional economic development is Gross Regional Domestic Product (GRDP). The development of Dumai City's GRDP in the 2000–2005 period showed an increase, which is one illustration of the development of regional economic activity. In supporting the increase in GRDP, Dumai City's economic development is directed at maintaining the superiority of the industrial, trade, construction, and transportation sectors, while still paying attention to the agricultural sector as a provider of industrial raw materials. The development of these sectors is expected to increase regional production, expand employment opportunities, and encourage improvements in community welfare. The significant role of the industrial sector in Dumai City's economy is also evident in its contribution to Gross Regional Domestic Product (GRDP).

Table 1 Data on the growth of the processing industry in Dumai City from 2015-2025

Year	Growth of the Manufacturing Industry
2015	53.21
2016	53.96
2017	54.75
2018	56.42
2019	57.73

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2020	59.96
2021	60.82
2022	61.79
2023	61.25
2024	60.42
2025	61.79

Source: Dumai City Central Statistics Agency

Based on the table, the growth of the processing industry in Dumai City shows an increasing trend during the 2015–2025 period, although it experienced a slight decline in 2023 and 2024. The value increased from 53.21 in 2015 to 61.79 in 2022. After experiencing a decline to 61.25 in 2023 and 60.42 in 2024, growth increased again to 61.79 in 2025. Overall, this condition shows that the processing industry sector has developed quite well and plays an important role in supporting the economy of Dumai City. However, the fluctuations that occur indicate that the development of the industrial sector continues to face dynamics from year to year.

The development of industrial activity has also created changes in employment and population conditions in Dumai City. Increasing investment in the industrial sector opens up new job opportunities because the development of industrial areas requires a certain number of workers. This condition can also encourage migration from outside Dumai City to obtain employment opportunities. However, the influx of workers from outside the region sometimes causes social problems, especially when local residents feel they have fewer job opportunities than migrant workers. These problems can give rise to conflicts between local communities, migrant workers, and companies. To address these issues, the regional government is trying to regulate the proportion of local workers accepted and workers from outside the region through employment policies in Dumai City, as explained in sources discussing the labor ratio provisions of 60 percent for local workers and 30 percent for workers from outside the region.

Although industrial development contributes to economic growth and creates job opportunities, the resulting benefits are not necessarily felt equally by the entire community. The Dumai City Regional Representative Council (DPRD), Riau, is pushing for a draft Regional Regulation (Ranperda) concerning the Dumai City Industrial Development Plan for 2026–2046 to be structured, inclusive, environmentally friendly, and capable of having a real impact on the regional economy. This demonstrates that industrial development is not only directed at increasing economic activity, but also needs to pay attention to the equitable distribution of benefits and environmental sustainability. At the local level, Defriza and Tanjung (2022) show that the presence of an industrial area in Lubuk Gaung Village has a positive impact, especially on the economic sector,

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while the negative impacts are more directed at the physical environment. However, these economic benefits have not been fully felt by the local community. Arrehla (nd) explains that industry in Dumai has not had a significant economic impact on the surrounding community because economic circulation is still limited and a portion of workers' income is spent outside the city. Thus, the increase in industry's contribution to GRDP is not necessarily in line with the improvement in the welfare of the community around the industrial area.

The growth of industrial activity and coastal development in Dumai City has been accompanied by changes in land use. One ecosystem under pressure from these changes is mangrove forests. Mangroves are coastal ecosystems that play a crucial role in maintaining environmental balance, providing habitat for various marine organisms, and protecting coastal areas from abrasion. Therefore, changes in mangrove cover can be an indicator of the impact of land use changes on environmental sustainability. The increasing development of industrial areas requires land availability, which can encourage changes in land use from its previous use to industrial areas, infrastructure, and other supporting activities. These changes need to be considered because land not only has economic value but also plays an ecological role in maintaining environmental balance. One indicator that can be used to assess the condition of the urban environment is the area of Green Open Space (RTH). Based on the 2025 Dumai City Sectoral Statistics Data Book, the area of green open space in the park and green belt category increased from 132,760.98 m² in 2022 to 133,428.48 m² in 2023, then reached 139,681.98 m² in 2024.

Land cover changes in the coastal areas of Dumai City during the 2013–2024 period indicate significant changes in several land use categories. The area of mangroves decreased from 7,131.13 hectares in 2013 to 4,760.86 hectares in 2024, a decrease of approximately 2,370.27 hectares. During the same period, the area of built-up land increased from 1,836.66 hectares to 7,848.74 hectares, an increase of approximately 6,012.08 hectares. The study explains that changes in mangrove areas are related to various human activities, including the development of industrial areas and ports in coastal areas. This condition indicates that the development of economic activities and development in Dumai City is also followed by changes in land cover, especially in coastal areas. Pramesthy et al. (2026)

Land use changes in Dumai City are also evident in the development of industrial areas, infrastructure development, and the expansion of built-up areas. Research by Giofandi et al. (2025) on land use dynamics in the Dumai River Basin shows that forest cover decreased from 53.75% in 1994 to 10.87% in 2024. Conversely, built-up areas increased from 5.29% to 24.67% during the same period. These changes are related to increased human activity, the development of the oil and gas industry, and regional

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infrastructure development. Furthermore, built-up areas are seen around fuel storage facilities, petroleum processing facilities, ports, and transportation networks. This condition illustrates that the development of economic and industrial activities plays a role in driving land use changes in Dumai City.

The problem of land use change in Dumai City is evident in various forms of land use that have the potential to impact environmental conditions. One such incident occurred in Sungai Sembilan District, when the Riau Regional Police in September 2026 uncovered alleged encroachment on a 111.77-hectare mangrove area in Mekar Sari Village, Kampung Tengah, which was allegedly intended for oil palm and secondary crop plantations. Furthermore, in October 2022, there was news of an environmental lawsuit related to alleged control of 920 hectares of land in the Teluk Makmur and Bangsal Aceh areas, which were allegedly converted from Conversion Production Forest (HPK) to oil palm plantations. Both incidents demonstrate the existence of land use change issues that could threaten the existence of forest areas and coastal ecosystems in Dumai City.

Another issue relates to the conversion of agricultural land to oil palm plantations and mining areas, which is also a concern in regional development planning documents. These changes have the potential to reduce the availability of agricultural land and impact environmental functions, particularly water catchment areas. Furthermore, the development of palm oil processing or refinery activities in the Lubuk Gaung, Pelintung, and Selinsing areas has also generated complaints from peatland farmers, mangrove groups, and fishermen. According to a 2022 report by ANTARA News Riau, these complaints relate to industrial waste management and the quality of fish catches experienced by the community. These various issues demonstrate the environmental pressures resulting from changes in land use and economic development in Dumai City. Consequently, the interests of economic growth and environmental sustainability are interrelated and have the potential to create trade-offs in the regional development process.

The decline in mangrove areas in Dumai City can impact the ecological function of coastal areas. Mangroves play a crucial role as nursery and feeding grounds for various marine organisms, including fish, shrimp, and crabs. If mangrove areas continue to decline, the habitats of these organisms could be disrupted, potentially impacting fisheries productivity and the livelihoods of coastal communities. Furthermore, the reduction in mangrove areas can also reduce the coast's natural ability to withstand waves and prevent abrasion. This is evident in the coastal area in Pelintung Village, Medang Kampai District, which has experienced approximately 1,000 meters of abrasion. This condition demonstrates that changes in land use in coastal areas not only impact the physical condition of the environment but also affect the sustainability of the natural resources utilized by the community.

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Based on these various conditions, land conversion to support industrial activity and development in Dumai City is linked to both economic development and environmental changes. From an economic perspective, land use for industrial areas, ports, and supporting infrastructure can encourage increased production activity, expand investment opportunities, and create jobs for the community. The development of industrial areas can also increase trade and service activities, supporting the regional economy. Furthermore, the oil and palm oil processing industry has the potential to add value to production and strengthen linkages with other economic sectors. Therefore, the development of industrial areas is one factor that can support Dumai City's economic growth by increasing production and community economic activity.

However, this increase in economic activity is also accompanied by various consequences for environmental sustainability. The decline in mangrove and forest cover, as well as the increase in built-up areas, indicate changes in land use conditions that can affect ecosystem balance. The reduction in mangrove areas has the potential to disrupt the habitat of marine organisms, reduce the natural protection of coastal areas, and impact fisheries productivity. Meanwhile, the reduction in forest cover and the increase in built-up areas can reduce the land's ability to absorb rainwater, potentially increasing the risk of inundation and flooding. Furthermore, industrial activity also has the potential to put pressure on environmental quality through the waste it produces, especially if it is not managed optimally. These impacts are not only related to environmental conditions but can also affect the lives of communities that depend on natural resources for their livelihoods, such as fishermen and farmers.

This situation demonstrates the conflicting interests between land use to promote economic growth and land use to maintain the ecological function of the environment. On the one hand, the development of industrial areas provides economic benefits through increased production, investment, employment opportunities, and the development of other economic activities. However, on the other hand, changes in land use that reduce mangrove areas and forest cover can put pressure on the environment and disrupt the sustainability of natural resources. Thus, the increased economic benefits from industrial development have the potential to be accompanied by environmental consequences that can be felt in the long term. This situation indicates a trade-off between economic growth and environmental sustainability in the development process in Dumai City. Therefore, this study seeks to analyze the relationship between land use conversion for industrial activities, its contribution to economic growth, and its impact on environmental sustainability in Dumai City.

In addition to changes in land use, the development of industrial activity in Dumai City is also associated with various environmental issues, particularly the decline in air and water quality. This can be seen in the Dumai City Air Quality Index (IKU), which

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decreased from 92.66 in 2022 to 87.97 in 2024. Air quality issues have also been a concern for the Dumai City Environmental Agency. According to an ANTARA report on February 2, 2021, the Environmental Agency issued a warning to PT Kawasan Industri Dumai and PT Meridan Sejatisurya Plantation after their factory chimneys were observed emitting thick black smoke. This condition indicates that industrial activities need to pay attention to emission management to prevent negative impacts on surrounding air quality.

Meanwhile, water quality in Dumai City showed a different development. The Water Quality Index (IKA) increased from 45.56 in 2023 to 50.83 in 2024. However, in 2024, there were still 23 monitoring points categorized as lightly polluted. Furthermore, aquatic environmental issues also emerged in Lubuk Gaung Village. According to a tvOne report on April 17, 2025, residents protested the alleged filling or blockage of the Nerbit Kecil River by a company operating in the area. Residents complained about the river's condition, which is suspected to be related to flooding and decreased fish catches. These complaints demonstrate that changes in environmental conditions around industrial areas can also impact the activities and lives of local residents.

These issues align with several previous studies that found indications of pollution in Dumai waters. Research by Riani et al. (2015), for example, found heavy metals lead (Pb) and cadmium (Cd) in sediments in the northwest waters of Dumai City. Research by Manurung (2010) also showed that several water quality parameters, such as BOD5 and oil and grease, exceeded seawater quality standards for marine biota. Furthermore, research by Suwandono et al. (2015) identified potential lead exposure through environmental media, such as soil, fish, and air, in communities living around the Dumai oil refinery. These findings indicate that environmental issues in the Dumai industrial area are not only related to changes in land cover, but also encompass air and water quality, and potential exposure to pollutants for the community.

Based on these conditions, the development of industrial activity in Dumai City demonstrates two aspects that require attention. On the one hand, industry plays a role in driving production, investment, and regional economic growth. However, on the other hand, the expansion of industrial areas and their production activities has the potential to put pressure on the environment, such as the reduction of natural areas, deterioration of air and water quality, and disruption to the activities of surrounding communities. This situation illustrates the trade-off between the interests of economic growth and environmental sustainability.

The relationship between industrial development and environmental sustainability in Dumai City demonstrates a trade-off that can be seen from several aspects. First, there is a time difference between economic benefits and environmental impacts. Economic benefits from industrial activities can be felt in a relatively short time through increased

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GRDP, investment, and employment opportunities. Meanwhile, environmental impacts tend to occur gradually and can accumulate over the long term, such as decreased water quality and pollution due to industrial activities. Second, there is a difference in who receives the benefits and who bears the impacts. Economic benefits are mostly obtained by industrial actors and the workforce involved, while environmental impacts are felt by communities surrounding industrial areas, especially coastal communities that depend on natural resources to meet their needs. Third, environmental damage also has the potential to threaten other economic sources, such as fisheries and tourism, which can be alternative sources of income for the people of Dumai City (Arrehla, n.d.).

This situation demonstrates that industrial development and environmental sustainability are two aspects that require balanced management. In the long term, neglecting environmental sustainability can actually reduce the natural resources that support community economic activities. Therefore, industrial development in Dumai City must not only be oriented towards increasing economic growth but also consider ecological functions and community well-being. Controlling land conversion, waste management, protecting mangrove areas, and monitoring industrial activities are crucial steps to ensure that the economic benefits of industrial development go hand in hand with environmental sustainability.

CONCLUSION

Based on the research and discussion, the development of industrial activity in Dumai City shows a link to regional economic growth as well as changes in environmental conditions. The existence of various industrial areas has driven increased production activity, investment, trade, and employment opportunities. This is reflected in the development of the manufacturing industry sector during the 2015–2025 period, which generally shows an increase, although it fluctuates in some years. However, this increase in industrial activity has not been fully accompanied by equitable distribution of economic benefits to the local community, so the industry's contribution to the regional economy needs to be balanced with efforts to improve the welfare of the community around the industrial areas.

Environmentally, the development of industrial areas and infrastructure development are also linked to changes in land use in Dumai City. The decline in mangrove area from 7,131.13 hectares in 2013 to 4,760.86 hectares in 2024, along with the reduction in forest cover in the Dumai River Basin, indicate pressure on natural areas as built-up areas increase. This situation has the potential to reduce the ecological function of the land, disrupt the habitat of coastal organisms, increase vulnerability to abrasion, and impact the sustainability of the livelihoods of communities dependent on natural resources. In addition to changes in land cover, issues related to industrial waste

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management, air quality, and water conditions also demonstrate that industrial activities have environmental consequences that require attention.

These findings demonstrate a trade-off between economic growth and environmental sustainability in industrial development in Dumai City. The economic benefits generated through increased production, investment, and employment opportunities need to be considered alongside the potential long-term ecological and social losses. Therefore, industrial development needs to be directed at a balance between economic interests, environmental protection, and community welfare. The local government needs to strengthen control over land conversion, supervision of industrial activities, and protection of mangrove, forest, swamp, and peat areas. Companies also need to improve compliance with waste and emission management regulations and environmental responsibility around their operational areas. Furthermore, local community involvement and equitable distribution of economic benefits need to be part of industrial development policies. Thus, the growth of the industrial sector in Dumai City is expected to be oriented not only toward improving economic performance but also to maintain the ecological function of the environment and ensure the sustainability of regional development.

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