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ESTIMATED IMPACT OF TSUNAMI HAZARDS DUE TO URBANIZATION IN THE AEROTROPOLIS AREA OF YOGYAKARTA INTERNATIONAL AIRPORT, INDONESIA

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ABSTRACT: This research aims to determine the urbanization in the aerotropolis area, determine the danger of tsunamis, and estimate the impact of tsunami disasters that are likely to occur. The method used in this research is spatial analysis using geographic information systems and remote sensing. Urbanization is known through analysis of changes in land use in the year before the airport, namely 2017, and after the airport in 2023. The tsunami hazard calculation uses mathematical calculations developed by Berryman (2006), which considers the loss of tsunami height per 1 m inundation distance (inundation height) based on distance to slope and surface roughness. Furthermore, the hazard results are overlapped with land use and building mapping. The findings show a significant increase in land use, especially in the residential sector, increasing by 3.5%, new residential areas increasing by 1,589%, and hotel hotels increasing by 31%, reflecting the progress made by government plans in urbanization. However, it should be noted that this area has a high risk of tsunami hazards, exacerbated by the flat topography and low surface roughness coefficient. Estimates of the economic and social impact of the hazard include severe damage to thousands of housing units, with significant financial losses. Sustainable regional development planning must be implemented by considering the risk of natural disasters and balancing urban growth and environmental sustainability. Involving local communities in planning processes, public education campaigns, and economic impact evaluations is crucial in creating a safe and sustainable environment in the region.

Keywords: Urbanization, Loss estimation, Aerotropolis, Tsunami, Hazard

1. INTRODUCTION

Indonesia is one of the countries undertaking massive economic development through the Masterplan for the Acceleration and Expansion of Indonesian Economic Development (MP3EI) to turn Indonesia into one of the most developed countries in the world by 2025. One of the MP3EI projects is the construction of the New Yogyakarta International Airport (YIA) as one of the international air transportation infrastructure; the Indonesian Government then followed up through Presidential Regulation (PERPRES) Number 98 of 2017 concerning the Acceleration of Development and Operation of New Airports in Kulonprogo Regency, Yogyakarta Special Region Province. This infrastructure development has a crucial role in the growth and development of a country because it will trigger economic flows with open access [1] and free market dynamics [2]. The development of Yogyakarta International Airport is also supported by the construction of a southern highway and freeway, which aims to connect with the city areas on the outskirts and can accelerate the dynamics of the city [3]. The impact of the development of Yogyakarta International Airport is the growth of economic activities, such as hotels, restaurants, housing, rentals, and boarding houses [4,5].

Yogyakarta International Airport was built in the southern coastal region of Java Island, precisely in Temon District, Kulonprogo Regency, Yogyakarta Special Region Province (DIY). This airport was constructed on productive land owned by residents and on land belonging to the Duchy of Surakarta, also known as Paku Alam Ground (PAG), totaling more than 1.5 million square meters spread across various villages [6]. The construction of this airport causes the change of rural areas into aerotropolis areas or what is known as urbanization [7] which is indicated by changes in urban land use, economics, and population dynamics [8].

In response to these dynamics, the Kulonprogo Regency government prepared an aerotropolis city master plan through the issuance of Kulon Progo Regent Regulation Number 47 of 2023 concerning Detailed Spatial Plans for the Area Around Yogyakarta International Airport for 2023-2043. The regulation states that the aerotropolis area which is part of Kapanewon Kokap, part of Kapanewon Pengasih, part of Kapanewon Temon, part of Kapanewon Wates. The use of aerotropolis space is divided into Protected Zones and Cultivation Zones. Within the Protected Zone, there are river borders, springs, and reservoirs. Meanwhile, the Cultivation Zone consists of a Financial center, Mosque, upper-middle-class housing, Museum library, mixed CBD,

Campus, market, Health center, and Aerotropolis center [9].

The dynamics of the metropolis urban area around Yogyakarta International Airport are shown by changes in land use and an increase in population in the Temon sub-district. The use of residential land and buildings increased from 2017 to 2019 by 86.01% [10] and increased the population by 7.8%, namely from 26,960 people in 2017 to 29,067 people in 2021 [11,12]. Changes in land use and population growth are predicted to continue to increase. As the city grows, the aerotropolis has the potential to encroach or damage dunes, foredunes, and estuaries, which can increase the potential risk of disasters [13], disrupt local ecosystems, and increase the vulnerability of local communities [14–19]. The potential danger of disasters in the aerotropolis around Yogyakarta International Airport is geological disasters in the form of megathrust earthquakes and tsunamis. The physical condition of the Yogyakarta International Airport area is made worse. It is located between two large rivers, namely the Serang River and the Bogowonto River, which are large rivers whose flow direction is perpendicular to the Indian Ocean, so they become entry points when a tsunami hits the coast and increases the tsunami danger level [20].

The chance of a tsunami occurring due to an earthquake in the aerotropolis around Yogyakarta International Airport is very high, considering that the area is on the southern coast of Java, where the megathrust route passes. Historically, several tsunami events occurred on the south coast of the island of Java, namely in 1994 and 2006, tsunamigenic earthquakes measuring < 8 occurred near Banyuwangi (Mw 7.8), East Java [21] and Pangandaran (Mw 7.7), Middle Java [22], which killed a total of nearly a thousand people [23]. Historically, a tsunami disaster can potentially occur in the Yogyakarta International Airport aerotropolis area and cause losses and casualties. The significant impact of disasters is caused by urbanization, characterized by the large number of people concentrated in this area and the large amount of built-up land.

So this research aims to determine the urbanization that has occurred in the aerotropolis area, determine the danger of tsunamis and estimate the impact of tsunami disasters that are likely to happen in the future in areas experiencing urbanization due to the development of the aerotropolis area.

2. RESEARCH SIGNIFICANCE

This research highlights the impact of disasters on areas experiencing rapid development due to the presence of airports. On the other hand, this area is prone to megathrust tsunami disasters. Even though disaster-based regional planning has been carried out, it cannot be denied that a tsunami could destroy the city. This research is important because it examines the urbanization that is occurring, the level of danger and its impacts. The main objective of this research is the usefulness of the research results which can be used to make decisions regarding tsunami disaster mitigation.

3. METHODS

3.1 Research Location

The research location at the Yogyakarta International Airport aerotropolis is the area around Yogyakarta International Airport determined based on administrative and functional aspects [24]. Yogyakarta International Airport Aerotropolis boundaries are based on boundaries determined by the government through Kulon Progo Regent's regulation Number 47 of 2023 concerning Detailed Spatial Plans for the Area Around Yogyakarta International Airport for 2023-2043. This area's location is partly in Kapanewon Kokap, partly in Kapanewon Pengasih, partly in Kapanewon Temon, and partly in Kapanewon Wates. The use of aerotropolis space is divided into Protected Zones and Cultivation Zones. Within the Protected Zone, there are river borders, springs, and reservoirs. Meanwhile, the Cultivation Zone consists of a Financial centre, Mosque, upper-middle-class housing, Museum library, Mix use CBD, Campus, market, Health centre and Aerotropolis centre.

3.2 Research Procedures And Analysis Techniques

The process of analyzing the estimated impact of the tsunami disaster on areas experiencing urbanization due to the development of the Yogyakarta International Airport aerotropolis area goes through several stages as follows:

3.2.1 Spatial Urbanization Analysis

Urbanization analysis is known through land use change analysis analyzed by temporal land use mapping extracted from high-resolution images with GIS [8,25]. The high-resolution images used are Ikonos Images from 2017 and 2023. The selection of 2017 and 2023 was due to a moment in that year; in 2017, The Indonesian government began planning for airport development in the area through Presidential Regulation (PERPRES) Number 98 of 2017 concerning the Acceleration of Construction and Operation of the New Airport in Kulonprogo Regency, Special Region of Yogyakarta Province, and in 2023 as the existing condition after the airport

has been operational since August 28 2020. The images obtained are in the form of pieces that must be combined by mosaicking to form one single image and converted from a coordinate system geographic (latitude/longitude) to a projected coordinate system (north/east) using the Universal Transverse Mercator (UTM) projection in Arc GIS 10 [26]. Next, image interpretation is carried out visually using on-screen digitization by recognizing the characteristics of the object based on the elements of interpretation. The land use classes used are settlements and buildings, greenbelt, tourism area, airport area, rice fields, gardens, moorland, ponds, water bodies, and forest/mangrove. The class determination is based on spectral signs and spatial characteristics [27]. The image interpretation results were checked in the field; then, a validity test was carried out. Validity tests are carried out by calculating accuracy assessments using Microsoft Excel software by comparing image interpretation with field checks [28]. The United States Geological Survey has established a more than 85% data accuracy rate. The classification results are then analyzed for the area values in the attribute table [29]. The flow of the data analysis process is shown in Figure 1 below:

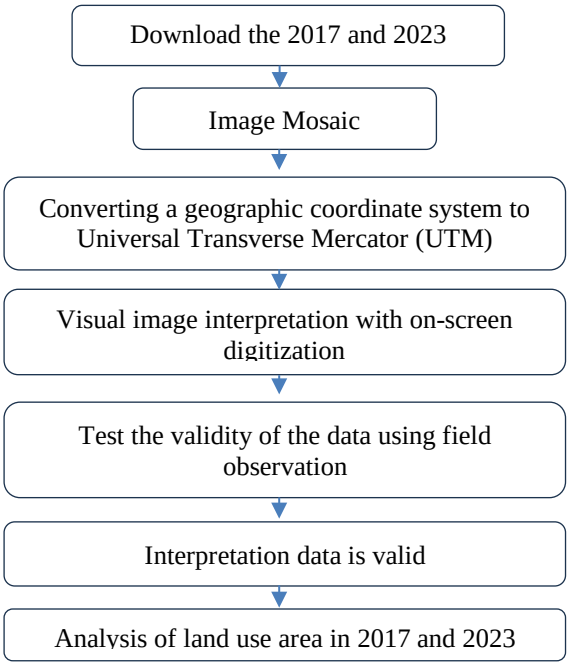

Fig. 1 Flow diagram of spatial urbanization analysis

3.2.2 Tsunami Hazard Analysis

Geographic Information Systems (GIS) is used to capture, store, manipulate, analyze, manage and visualize geographic data for tsunami hazard analysis [30]. Mathematical formulas are entered into the GIS system to obtain the collected data. The calculation of the tsunami area distribution uses mathematical calculations developed by [31,32] which consider the loss of tsunami height per 1 m inundation distance (inundation height) based on the distance to the slope and surface roughness.

$$H_{loss} = \left(\frac{167\, n^2}{H_0^{1/3}}\right) + 5 \sin S \quad (1)$$

Where:

Hloss : tsunami height loss per 1 m inundation distance
N : surface roughness coefficient
H0 : Tsunami wave height on the coastline (m)
S : surface slope (degrees)

The surface roughness coefficient values are shown in Table 1.

Table 1 Roughness coefficient values

Land Cover	Roughness Coefficient
Lake/Situ	0,007
Building/Building	0,055
Jungle	0,070
Plantation/Garden	0,035
Moorland/Field	0,015
Ricefield	0,025
Shrubs	0,040
River	0,007
Empty/bare land	0,015
Settlements and Places of Activity	0,045

Source :[33]

The tsunami hazard index is measured based on the inundation value, which reflects the estimated tsunami inundation height map/tsunami hazard map. There are three tsunami hazard classes or indices: the low index class if the inundation height is less than 1 meter, the medium index class if the inundation height is between 1-3 meters, and the high index class if the inundation height is >3 meters [34].

3.2.3 Analysis of Tsunami Hazard Impact Estimates

The estimated impact of tsunami hazards is analysed using regional hazard/damage mapping efforts based on tsunami hazard propagation modelling [35]. Estimates of the impact of tsunami hazards can be known through mapping objects likely to be hit by a tsunami, such as buildings and productive land. In addition, estimates of impact losses are also known through population exposure [36,37]. Population exposure is known through the proportion of the population living in tsunami hazard areas. The value and number of impacts caused are calculated based on the hazard class of the runway that has been calculated previously. This value estimates the market value of buildings and material assets per hectare for each land use class [38]. By overlaying the tsunami hazard map on the land-use map, we estimate the total area affected in each land-use class as well as the total value of assets exposed (damage exposure) per land-use class. The market

assessment was carried out based on interviews conducted for this study (for uniform and non-uniform residential land use categories) and based on existing literature and statistics for other land use types (such as value data provided at https://bhumi.atrbpn.go. id/map).

4. RESULTS AND DISCUSSION

4.1 Urbanization in the Yogyakarta International Airport Aerotropolis Area

Yogyakarta International Airport (YIA) has a terminal area of 210,000 square meters with a capacity of 20 million passengers annually. Its use was only inaugurated on August 28 2020 [10]. The existence of this new airport in Kulonprogo Regency is an urban catalyst that will have a positive impact and increase the impact of the urban economy to improve the community's quality of life [39]. The development of Yogyakarta International Airport will impact land conversion of up to tens of thousands of hectares in several areas around the airport [40]. This land use change is known through mapping land use changes using high-resolution imagery obtained via Google Earth. Land conversion in the Yogyakarta International Airport aerotropolis area tends towards increasing built-up land, including residential areas, homestays, or accommodations [41]. During the construction of YIA, the number of buildings increased, not only permanent buildings but also semi-permanent buildings, such as buildings used by the community to open food businesses to meet the needs of airport workers and visitors [5]. The increase in buildings in this area shows an urbanization process that is turning this area into an urban area as planned by the government as an airport city area or aerotropolis.

The results of spatial analysis in the Yogyakarta International Airport aerotropolis area show that land use, which is very characteristic of urban areas, has increased from 2017 to 2023, such as the use of residential land and buildings increasing by 3.5%, new residential areas increasing by 1589%, and hotel areas increasing by 31% (See Table 2). In 2017, the airport had not yet been built, so the dominant land use was productive land use, namely moorland, rice fields and ponds. The extent of productive land shows that most people work as farmers who rely heavily on productive land. After Presidential Regulation (PERPRES) Number 98 of 2017 was issued concerning the Acceleration of the Development and Operation of New Airports in Kulonprogo Regency, Yogyakarta Special Region Province, a lot of land acquisition was carried out to accelerate airport development. Land acquisition uses a buying and selling system called Profit Change [42]. After the sale of their land, farmers must be able to adapt to work in other fields. Another consequence of the construction of Yogyakarta International Airport is that there is a spatial transformation of productive land use, which has decreased from 2017 to 2023, such as gardens experiencing a decrease in area of 25%, fish ponds decreasing by 54%, rice fields decreasing by 66%, empty land experiencing a decrease of 62% and dry fields experienced a decline of 14%.

Table 2. Land Use Area of Yogyakarta International Airport Aerotropolis Area

Land Use	Ha		Extent of Change	
	2017	2023	Ha	%
Moor	3014,9	2580,7	-434,2	-14%
Settlements and Buildings	1914,24	1980,58	+66,34	+3,5%
Empty land	12,98	4,93	-8,05	-62%
Garden	155,07	115,56	-39,51	-25%
Water body	75,9	75,55	-0,35	-0.5%
Pond	293,01	136,23	-156,78	-54%
New Residential Area	0,73	12,38	+11,65	+1596%
Hotel Area	4,05	5,31	+1,26	+31%
Beach Tourism Area	23,49	23,49	0	0%
Mangroves	9,43	9,43	0	0%
Ricefield	136,75	47,04	-89,71	-66%
Airport Green Belt Area	0	78,37	78,37	It cannot be a percentage because land use in the 2017 base year was non-existent or 0 Ha
Airport	0	570,99	570,99	It cannot be a percentage because land use in the 2017 base year was non-existent or 0 Ha
Total	5640,57	5640,57		

Note: (-) decreases (+) increases

The spatial transformation of 570.99 Ha into Yogyakarta International Airport (See Figure 2) resulted in 419 housing units being relocated. The relocation was done in 5 villages designated as airport development areas, including Jangkaran Village,

Sindutan Village, Palihan Village, Kebonrejo Village and Glagah Village (See Figures 2 and 3). The positive impact of this airport development is increasing investment in Kulon Progo Regency, a reasonably large sector investing or capital investment, namely the tourism sector, especially from hotels [43]. Throughout 2021, construction of six hotels has begun, namely Cordia Hotel, Daffam Hotel, IBIS Hotel, Novotel Hotel, Grand Progo Hotel, and Swiss-Bel Hotel in Kulon Progo. One is already operational, namely the Cordia Hotel [44]. This statement aligns with the spatial analysis, namely increasing the hotel land area by 31% built around airports, tourism areas and along the South Ring National Road.

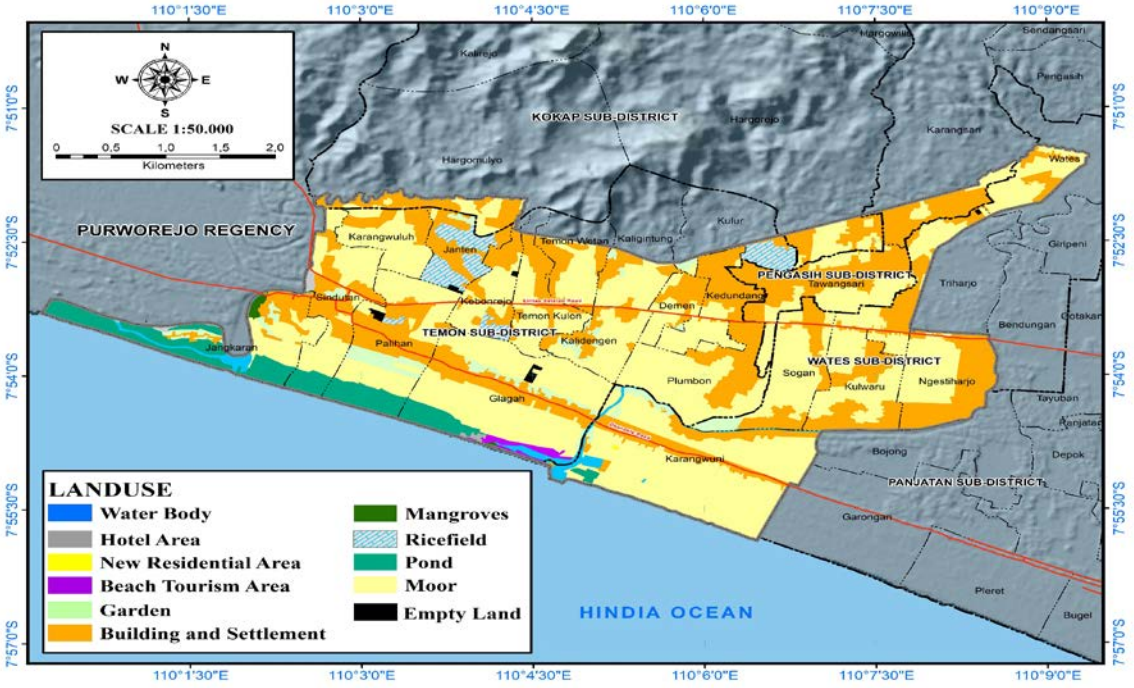

Fig.2 Land Use in 2017

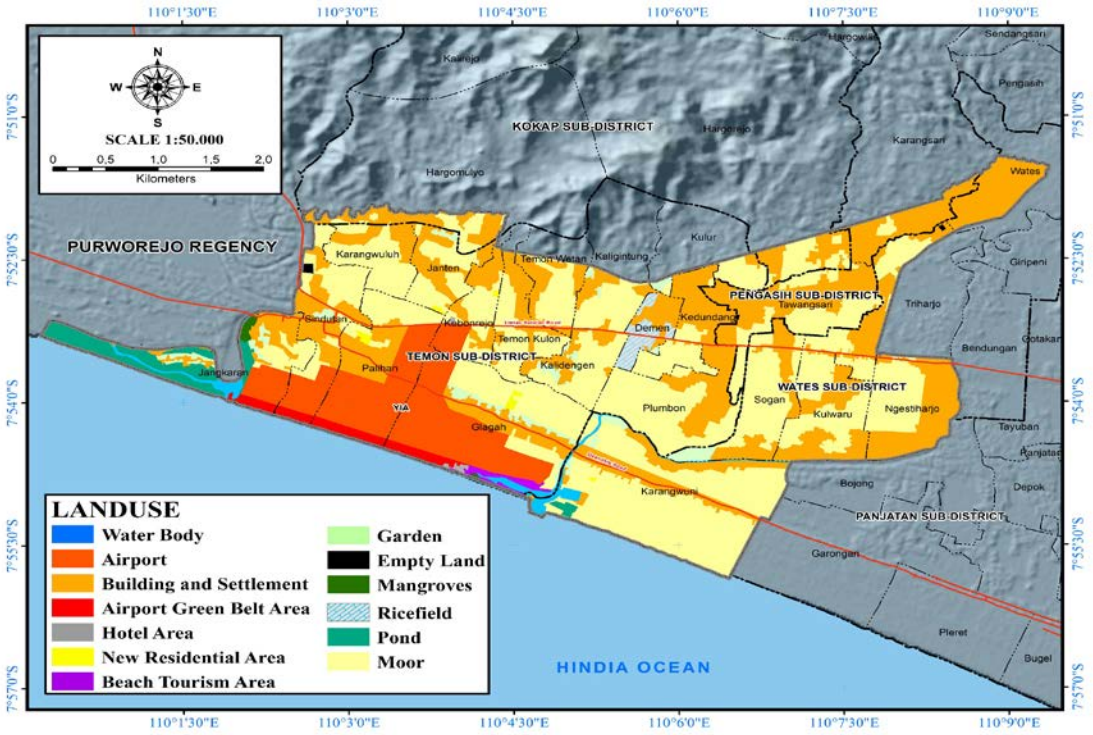

Fig.3 Land Use in 2023

It can be seen in Figure 3 that urbanization occurs mainly in the area around the airport and the area around the Southern Ring Road, as shown in the use of residential land and hotels centred in these areas. The Southern Ring Road is a connecting access road between surrounding cities and the airport and a link between leading tourism destinations around Central Java and the Special Region of Yogyakarta and the airport. The leading tourist destinations include Borobudur, Prambanan, Yogyakarta City, Menoreh Mountains and Parangtritis. International access to Central Java Province and the Special Region of Yogyakarta Province via Yogyakarta International Airport makes this area a new urban centre. This interests investors in developing their businesses in this area, such as office businesses, hotels and housing contractors. The area around the airport will have the opportunity to attract a large population because of the many job vacancies due to the many new business and industrial developments. On the other hand, population movement in the airport area will increase residential land as a place to live; new housing increased in 2017 from 0.73 Ha to 12.38 Ha. Orderly building objects and high density characterize this new housing complex. Usually, new housing has a more modern house design than local community houses, narrow yards, and distance between close houses. The increase in built-up land can result from the rise in population and economic activity in the Yogyakarta International Airport aerotropolis area [45,46].

Due to the opportunity for very rapid urbanization, the local government issued Kulon Progo Regent Regulation Number 47 of 2023 concerning Detailed Spatial Plans for the Area Around Yogyakarta International Airport for 2023-2043. This regulation regulates land use to remain by its intended purpose. The development of the aerotropolis area in Yogyakarta will focus on urban areas and the agricultural sector, which will later be supported by the international market [47]. The regulation states that there are 270.54 Ha of Sustainable Food Agriculture Areas (KP2B) where conversion of area functions is permitted. Sustainable Food Agriculture Areas (KP2B) include Sustainable Food Agriculture Reserve Land (LCP2B) and Sustainable Food Farming Land [24]. So, despite rapid urbanization, several agricultural areas are still maintained to meet local food needs.

On the other hand, Yogyakarta International Airport was built on a coastal area bordering the Indian Ocean with the potential for megathrust earthquakes. During its construction, disaster mitigation area planning was carried out as a coastal protected area as a greenbelt between the beach and the airport, covering an area of 78.37 hectares. Before the airport existed, this greenbelt was productive land in the form of ponds, but after the airport was built, it was transformed into a greenbelt area planted with mangrove trees and pine shrimp. Urbanization cannot be avoided and will continue to grow along with the opening of international access to the site. However, efforts to monitor land use according to its intended use are still carried out through official regional planning regulations. It cannot be denied that the possibility of a megathrust earthquake and tsunami remains, with estimates that losses will be more significant as the aerotropolis city develops.

4.2 Tsunami Hazards

The Yogyakarta International Airport Aerotropolis area has the potential for a tsunami disaster from the South Java Tunnel Zone between the Indian Ocean Tectonic Plate and the Asian Continent Tectonic Plate [48]. The history of earthquakes and tsunamis and the potential for earthquakes in the southern island of Java, which, according to several studies, has a reasonably high tsunami danger due to the seismic gap [23]. Historically, several tsunami events occurred on the southern coast of the island of Java, namely in 1994 and 2006. Tsunamigenic earthquakes measuring < 8 occurred near Banyuwangi (Mw 7.8), East Java [21] and Pangandaran (Mw 7.7), Java Middle [22]. History records that the danger of a tsunami could potentially occur in the southern coastal area of Java Island, including the area around Yogyakarta International Airport. Tsunami hazard mapping needs to be carried out with the assistance of a geographic information system (GIS). Tsunami hazard mapping around Yogyakarta International Airport is based on the inundation distance (inundation height), based on the distance to the slope and surface roughness. With the construction of an airport, of course, the danger class will be higher because the airport area is dominated by asphalt, empty land and grassland, which have a low level of surface roughness coefficient; in other words, the smoother the ground surface, the lower the surface roughness coefficient which is one of the factors of high tsunami danger.

The Yogyakarta International Airport Aerotropolis area is dominated by high hazards with an area of 2417,915 Ha. The extent of the high tsunami hazard is due to the area's flat topography and is supported by a small surface roughness coefficient. Apart from airports, moorland and rice fields also contribute to the high tsunami hazard, with a value of 0.015 for moorland and 0.025 for rice fields. Apart from topography and roughness of the land surface, another factor is the distance from the beach; the closer the distance is to the beach, the higher the danger. The high tsunami hazard class is also exacerbated by the airport's location between two large rivers, namely the Serang River and the Bogowonto River, whose flow is perpendicular to the Indian Ocean, so it becomes an entry point when a tsunami hits. Meanwhile, the medium danger class

has an area of 2025.15 Ha, and the low danger class has 499.53 Ha (See Figure 4).

Land use can determine the tsunami hazard class in the Yogyakarta Aerotropolis International Airport area, so many buildings and open land will increase the danger. The land use factor is an indicator that can be controlled more than other indicators, such as topographic indicators and distance from the beach. The situation cannot be changed because it is a geographical condition of the region. Changes in land use due to the development of the airport city area will worsen the tsunami hazard conditions because the land surface coefficient will be lower due to the lack of vegetation. Coastal vegetation can reduce tsunami waves and protect coastlines from damage [49]. As a form of tsunami disaster mitigation, the Kulonprogo government has designed a local protected route in the coastal and river border areas. For example, the greenbelt area near the airport is planted with pine trees, and land development is limited and can only be used for protected areas.

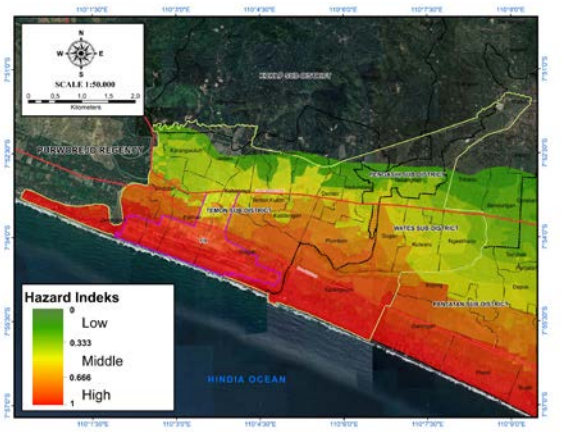

Fig.4 Tsunami Hazard Map

4.3 Tsunami Impact Estimation

Urbanization around the Yogyakarta International Airport area takes the form of an increase in settlements and buildings. Settlements are a land use that is very vulnerable to disasters because most human activities involve this land use. The more buildings and settlements there are, the higher the potential for people to be exposed to disasters. After mapping was carried out using high-resolution imagery, it was obtained that the number of buildings/houses in the aerotropolis area was 12,473 units, which were spread across three hazard classes, including 5720 units in the high tsunami hazard class, 4571 units in the moderate tsunami hazard area and 2182 units in the low tsunami danger (See Figure 5). The number of building units can be used as a reference in calculating estimates of the exposed population. This calculation is based on the reference that the average number of residents in a house is five people [50], and multiplied by the number of housing units. The results of these calculations are shown in Table 3.

Table 3. Estimated Population Exposure

Hazard Class	Number of Buildings	Total population exposed
High	5,720 Units	28,600 People
Middle	4,571 Units	22,855 People
Low	2,182 Units	10,910 Souls
Total	12,473 Units	62,365 People

The large number of people living in tsunami hazard areas means that the government must act to reduce the risk of tsunami disasters through both structural and non-structural disaster mitigation. Structural mitigation can take the form of standardizing buildings for tsunamis, while non-structural mitigation can take the form of socializing increased preparedness, disaster simulations, planting protective vegetation and so on.

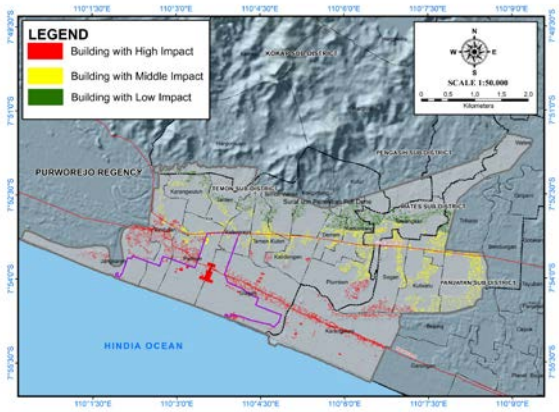

Fig.5 Building distribution map based on tsunami hazard class

Impact estimates are not only carried out on exposed residents but also estimates of economic losses due to damage to residential and agricultural productive land. This loss is based on the price assessment for each land use sourced from Regional Land Agency data, the value of which can be accessed online via https://bhumi.atrbpn.go.id/. Low Hazard ~ no loss; Medium Hazard ~ 50% total loss of productive land; and High Danger ~ 100% total loss of productive land [51]. The results of the analysis show that based on the existing conditions of the Yogyakarta International Airport Aerotropolis if a tsunami disaster with a height of 10 m occurred, the resulting loss would be IDR 48,245,093,608,152 or USD 3.097.692.023 (See Table 4). The high losses are due to the large area of productive land, many buildings, and other essential facilities.

Along with the urbanization process through increasing built-up land, the losses incurred will be higher. High losses are based on the value of land. Land in the airport area continues to experience land increases due to its strategic location. Based on research [52] the changes in land prices around Yogyakarta International Airport from before to after

the airport construction were above IDR 1,000,000.00 per m^2 (high-very high class) distributed to land located close to the airport area and close to primary road access. The increase in land prices is a form of change in perspective on land values from rural to urban areas. The tsunami's impact is seen in economic losses and environmental damage, which can potentially disrupt the ecosystem. The estimated environmental damage is based on the current condition of the existing aerotropolis, namely damage to mangrove forests covering an area of 9.43 Ha and damage to coastal greenbelt vegetation covering an area of 78.37 Ha. Both are located in highly disaster-prone areas, so the water will hit and damage the vegetation in its path if a tsunami occurs.

Table 4. Estimated Economic Losses

Land Use	Hazard Class	Area (m^2)	Estimated Loss (In IDR)
Garden	Low	115569	0
Empty land	Low	4383	0
Settlements and Buildings	Low	3820440	0
Ricefield	Low	30076	0
Moor	Low	1024855	0
Airport	Middle	864491	2.161.228.590.158
Hotel Area	Middle	12585	12.585.313.806
New Residential Area	Middle	57406	57.405.631.751
Garden	Middle	121110	30.277.409.285
Empty land	Middle	36609	9.152.163.494
Settlements and Buildings	Middle	6565203	4.923.902.018.685
Ricefield	Middle	419566	104.891.389.603
Moor	Middle	12161982	3.040.495.608.300
Airport	High	4845431	24.227.152.786.100
Hotel Area	High	40513	81.025.829.754
New Residential Area	High	66438	132.875.894.850
Garden	High	863628	431.814.163.267
Settlements and Buildings	High	4755651	7.133.475.974.055
Ricefield	High	20770	10.385.216.185
Pond	High	1356255	678.127.654.260
Moor	High	10420596	5.210.297.964.600
		Total	48.245.093.608.152

5. CONCLUSIONS

The results of the spatial analysis of the Yogyakarta International Airport Aerotropolis Area show a significant increase in land use, especially in the residential, new housing and hotel categories from 2017 to 2023. This reflects the urbanization process by the government's plan to develop this area into an urban area or aerotropolis. However, in its development, it should be noted that this area has a high tsunami risk due to the flat topography and small surface roughness coefficient. Land use changes that reduce vegetation can exacerbate the impact of this tsunami hazard.

The tsunami's estimated economic and social impact includes heavy damage to 5,720 housing units, with losses reaching IDR 48,245,093,608,152 or USD 3,097,692,023. Therefore, serious mitigation efforts need to be carried out. The government and related authorities should implement coastal protection strategies and spatial planning that consider geological risk factors. Vegetation planting and green land maintenance programs must be strengthened to reduce vulnerability to tsunami hazards. In addition, sustainable regional development planning needs to be implemented, considering the risk of natural disasters and maintaining a balance between urban growth and environmental sustainability. Involving local communities in the planning and decision-making and holding public education campaigns regarding safety measures and preparations for dealing with tsunami hazards are also essential steps. Evaluation of the economic impact of disaster risk also needs to be carried out to allocate resources wisely and consider compensation schemes that support the economic recovery of affected communities. With these steps, it is hoped that we can achieve a balance between urban development and disaster risk mitigation and actively involve the community in efforts to create a safe and sustainable environment.

6. ACKNOWLEDGMENTS

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