OBSTRUCTION ZONE MODELING AT HALIM PERDANAKUSUMA AIRPORT USING REMOTE SENSING DATA

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Received: 15.06.2023; Revised: 23.06.2023.; Approved: . 23.06.2023

Abstract. Flight safety plays a critical role in both the national economy and military defense. According to the National Transportation Safety Board (NTSB), the highest number of aircraft accidents between 2013 and 2018 occurred during take-off (24%) and landing (40%). To model the obstruction zone based on building density and its impact on flight safety, this study utilizes remote sensing data from Sentinel 2A in 2022. The data is analysed using the Normalized Difference Built-up Index (NDBI) algorithm, which serves as the basis for modelling potential aircraft accident zones. Specifically, the study focuses on the growth of buildings within a 15 km extended runway area during take-off and landing. The findings reveal that the aircraft take-off approach area in the Flight Operation Safety Zone (KKOP) at Halim Perdanakusuma Airport exhibits the highest building density. This area demonstrates a moderate level of building density, with a prevailing growth pattern and density that extend predominantly eastward, toward Bekasi city. Furthermore, the study highlights that nearly the entire region falls under the classification of "built-up areas." Consequently, establishing urban planning policies for development around landing and take-off corridors becomes imperative while considering aviation safety factors. This research provides valuable insights to aviation authorities and decision-makers involved in infrastructure development and urban planning. By considering building density and the growth of surrounding areas along flight paths, appropriate measures can be implemented to ensure optimal flight safety and mitigate the risk of future aircraft accidents.

Keywords*: Sentinel-2, NDBI, Obstruction Zone, KKOP, Halim Perdanakusuma*

1 INTRODUCTION

Public safety is one of the objectives of non-military defense to maintain and protect state sovereignty, the territorial integrity of the Republic of Indonesia, and the safety of the entire nation from non-military threats as stated in Ministry of Defense Regulation No. 57 of 2014 (Defense, 2014). Public safety, part of the nonmilitary threats discussed in this study, focuses on air transport. Air transportation is a means of supporting the mobility of people and goods effectively with sufficient capacity (Baiq Setiani, 2015). The role of air transportation is crucial as a support for air cargo (Yusmar &; Mora, 2017). In addition, air transportation is a link to the economy of the outer islands in Indonesia (Suryawan &; Fatchoelqorib, 2018). The demand for air transportation is increasing along with Indonesia's population growth (Sefrus et al., 2017). This is important to ensure flight safety for residents as air transportation users. Aviation safety is very important for the national economy and as one of the security aspects in non-military defense (Kemhan, 2015).

According to NTSB (2019) the largest aircraft accidents between 2013 – 2018 were at take-off 24% and landing 40% (Boeing Commercial Airplanes, 2022). According to the same source, data on commercial aircraft accidents in the world from 1959 – 2021 reached 2,105 with details of 1,466 non-fatal accidents and 639 fatal accidents. This is shown in the presentation of commercial aircraft accidents in 2012-2021 is 18% during take-off and 33% when landing. Data on fatal aircraft accidents and aircraft facilities from the flight phase can be seen in Figure 1.

Based on the picture above, the most crucial phase in a plane crash occurs in the take-off and landing phases of the aircraft. This is a strong basis for determining the safety zone of the runway several kilometres ahead parallel to the runway outside the airport. Indonesian aviation safety has been regulated in the Flight Operational Safety Area (KKOP) with a radius of 15 km from the runway. This makes KKOP an important aspect that must be considered in the development of residential areas and buildings in areas that have airports in their areas as operational areas (Iqbal &; Partono, 2018). The most high-risk Aviation Operational Safety Area is the airport area surrounded by mountains and located in densely populated cities with tall buildings as barriers. The first step that can be done as an effort to fly safety policy is to observe the area around the airport. The technology suitable for making these observations is Remote Sensing technology. The use of Remote Sensing technology can help observation without having to conduct field surveys, thus saving time and costs.

Remote Sensing Technology can analyse all objects in an area based on KKOP and visualize obstructions or obstructions. Airport obstruction hazard modelling can be done using Remote Sensing technology to aid analysis. Topographic analysis was conducted to determine the suitability of KKOP to the topography of DKI Jakarta (Zahra et al., 2017). Remote Sensing can be used to analyse building densities in urban areas. Building density can be done by the *Normalize Difference Built-up Index* (NDBI) method (He et al., 2010, Andriani et al., 2018, Hidayati et al., 2018, Azhari, 2020). NDBI is an effective method to map built-up areas with Landsat 8 Operational Land Imager (OLI) imagery in urban areas including settlements, factories, buildings and other buildings (Bhatti &; Tripathi, 2014, Rasul & Ibrahim, 2017, Dolean et al., 2020). Remote Sensing Landsat 8 OLI imagery can interpret building density with an accuracy of more than 80% using the *Normalize Difference Built-up Index* (NDBI) method (Muhaimin et al., 2022). Based on this, NDBI is an important aspect as a risk measurement parameter in public safety for people living in the KKOP area.

DKI Jakarta Province is one of the areas that has an airport, namely Halim Perdanakusuma airport with a strategic location near the city centre, precisely in East Jakarta City so that it can be accessed easily. However, DKI Jakarta as the capital of the country is a densely populated city with high density so it is important to map KKOP. In addition, the high flight frequency of around 154 flights a day means that the risk of aircraft accidents triggered by the buildup of Rubber Deposit on the Runway is also higher (Cahyo Maulana et al., 2022).

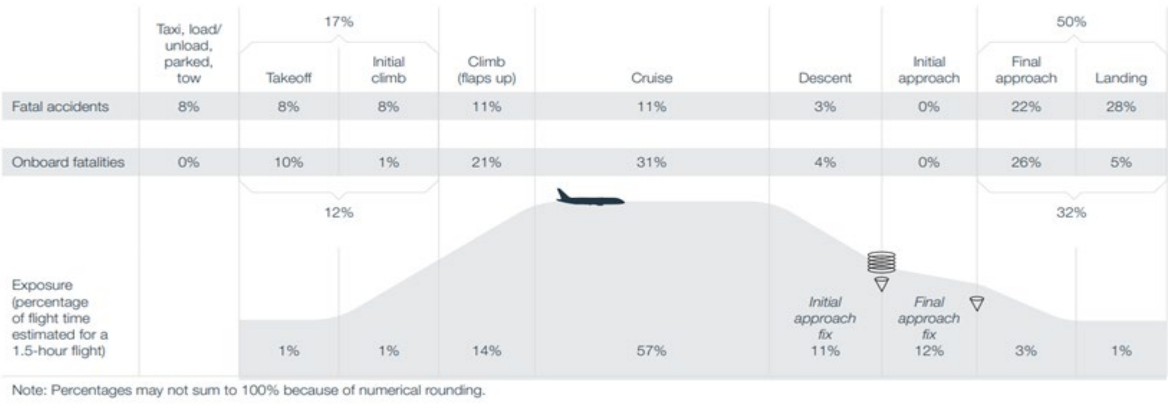


Figure 1 Percentage of fatal accidents and deaths on board 2012 to 2021

Community activities that can be an obstacle in aviation must be minimized (Putra, 2019). The legal basis of KKOP around the airport that has not been fulfilled with the existence of buildings exceeding the maximum height limit and surrounded by housing can reduce airport security (Sugito, 2010). The more obstructions, the flight readiness will be disrupted (Ulul Azmi et al., 2018). This is why it is important to model airport obstruction for aviation safety as a non-military defense. Research with data processing related to obstruction needs to be carried out to determine the potential accident zone at KKOP in DKI Jakarta.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

DKI Jakarta is located between 10648' East Longitude and 612' South Latitude with an area of 662.33 km2. The population of DKI Jakarta is 10,609,681 people and the population density reaches 15,978 people / km2. DKI Jakarta has a population growth rate of 0.57% per year. DKI Jakarta is a lowland located at an altitude of +7 m above sea level (BPS DKI Jakarta, 2022). This study took Halim Perdanakusuma airport located in DKI Jakarta, precisely in the city of East Jakarta with consideration of barriers or obstructions in the form of built land and tall buildings.

2.2 Data Uses

This research was conducted by identifying obstructions or obstructions around Halim Perdanakusuma airport. The study was conducted by conducting building density analysis on NDBI multispectral imagery. The results of the data processing are combined to determine the potential zone of building density in the KKOP area. A brief research flow chart can be seen in the figure below:

This study used one type of data, namely secondary data. Secondary data are taken from official institutions or agencies, including Sentinel 2A imagery data and extracted land cover information. Details about the data and data sources can be seen in table 1.

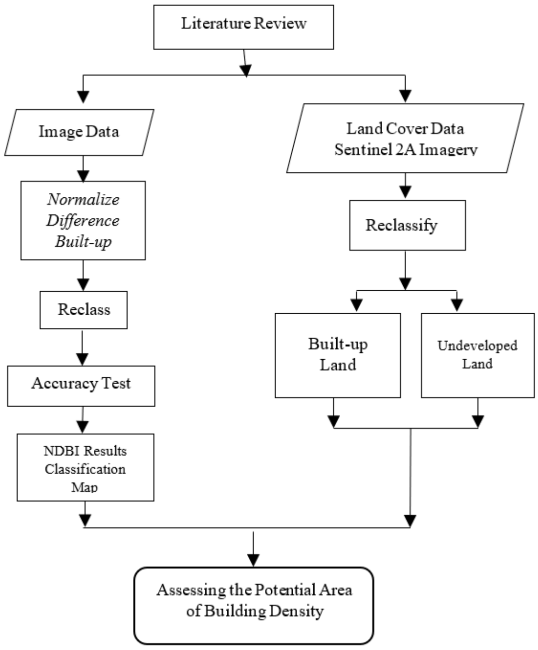


Figure 1. Research Workflow

Table 1. Data Used

No	Data	Data Criteria	Time	Software
1	Sentinel 2A Imagery	Jakarta Greater Area	2022	Copernicus (GEE)

2.3 Methods

The 6S (Second Simulation of Satellite Signal method in the Solar Spectrum) algorithm was developed by Vermote et al. based on the 5S model. It considers the atmospheric effects of the entire radiative transfer process and can better eliminate the influence of Rayleigh scattering and aerosols, which has been widely used in applications (Vermote & Kotchenova, 2008)

The research data analysis method was carried out according to the research flow chart using Google Earth Engine. The data processing to be analysed is divided into two stages, namely:

1) Normalize Difference Built-up Index (NDBI)

Building density calculation method with NDBI which is a transformation of the Normalize Different Vegetation Index (NDVI). The difference is that the Normalize Different Building Index (NDBI) uses the middle infrared (SWIR 1) and near infrared (NIR) bands that can detect the density or density of urban buildings. Research with NDBI can identify more Built-up objects with

Table 2. Built-up Density Index

Class	Density Classification	Building Density Index
1	Non-Built-up	-1 - 0
2	Low	0 - 0,1
3	Medium	0,1 - 0,2
4	High	0,2 - 0, 3
5	Very High	0,8 - 1

Source: Awaliyan & Sulistyoadi, 2018

The results of NDVI processing pass the accuracy test on the existing classification results. The accuracy value uses *confusion matrix* or error matrix. This matrix is used to describe the performance of the classification model on the test data. Accuracy test assessment is carried out by slamming between the total correct sample and the sample in the matrix (Banko, 1998). Here is the *confusion matrix* formula used in the study:

$$Overall\ Accuracy = \frac{True\ Sample}{Sample\ amount} \times 100\% \quad (2)$$

2) Land Cover Classification

At this stage, existing land cover data is classified into 2 classes with the division of undeveloped classes and Built-up classes. The classification in detail can be seen in the following table:

Table 3. Land Cover Classification

Class	Land Cover Classification
0	Non-Built-up
1	Built-up

3. Results and Discussion

The results of NDBI research are the results of data processing processed using Google Earth Engine. The 2022 Sentinel 2A image in the B8 (NIR) and B11 (SWIR) bands is the main data for building density index transformation. Processing involves CLOUDY_PIXEL_PERCENTAGE to minimize cloud noise in the image. The resulting building density index image was cut according to the study area of the Halim Perdanakusuma Airport KKOP using ArcGIS 10.8 software.

The classification of building density index is carried out by following the parameters of previous studies. The classification divides 5 density classes that are processed on ArcMap using the reclassify tool to enter the building density index value. The classification results are given contrasting colours to facilitate image interpretation and see the distribution of building density distribution in the Halim Perdanakusuma Airport KKOP study area.

Based on the results of the analysis that has been carried out in this study, it can be shown that visually the image from the sentinel 2A satellite that has been processed using the NDBI method can be recognized well in the analysis of the distribution pattern of building density around the airport area. This will also affect the impact of aviation safety risks that occur in the Aviation Operational Safety Area (KKOP) area in urban areas.

This is given that several studies have shown a positive relationship between building density and population density. For example, a study from Ehrlich et al., (2018) introduced two important social variables (ESV) – global built-up areas and global population density. Both ESVs are the building blocks of many environmental and social models and are critical to addressing the impacts of climate hazards. Another study conducted by (Mao et al., 2022) proposed a method for the spatialization of the population at the building scale based on the residential population index.

Analysis of settlement mapping conducted using remote sensing satellite images such as Landsat 8 and Sentinel-2, and then processed using the NDBI method has been shown to provide a significant degree of accuracy. In several studies, NDBI has been used to map urban areas with 92.6% accuracy (Zha et al., 2003). In addition, NDBI has been used to identify residential areas on volcanic land with an accuracy of 61.74% (Suwarsono &; Khomarudin, 2014). In addition, combining NDBI with the BAEM index—which is a combination of NDBI, NDWI, and MNDWI—also improves accuracy (Bhatti & Tripathi, 2014b).

This research utilizes Google Street View to conduct field validation. The validation took 2 samples in each building density classification. Here is a list of sample points along with the Google Street View screenshot obtained.

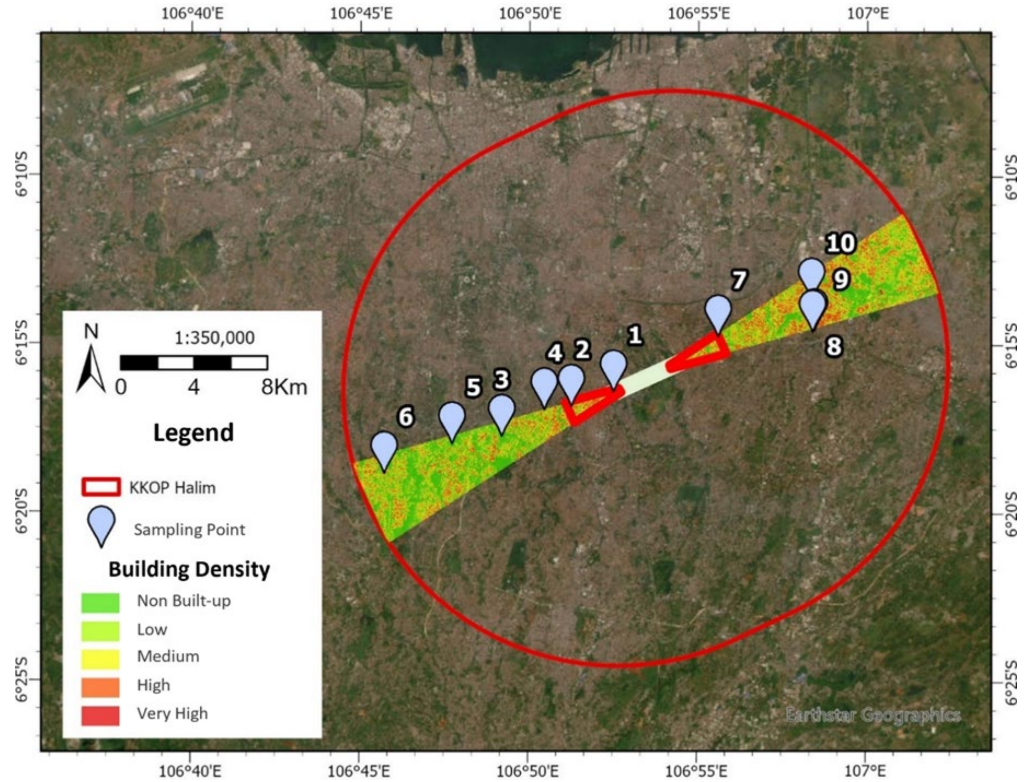


Figure 2. NDBI Analysis Results and Location of sample points

Table 4. List of Validation Coordinate Points Using Google Street View

No	Coordinates		Class	Field Evidence
	x	y		
1	-6.299385	106.795565	Non Built-up	
2	-6.282385	106.841073	Low	
3	-6.295649	106.820136	Medium	

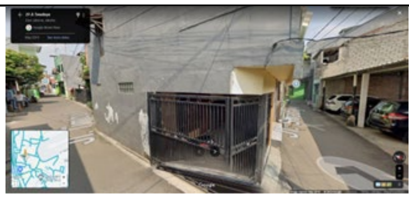
4	-6.28068	106.854442	High	
5	-6.273458	106.875235	Very High	
6	-6.227634	106.972853	Non Built-up	
7	-6.242826	106.974238	Low	
8	-6.243522	106.973381	Medium	
9	-6.246059	106.926735	High	
10	-6.57457	106.908756	Very High	

Table 5. Overall Accuracy

		Field Check Results					
		Non-Built-up	Low	Keep	Tall	Very High	**Sum**
Research Results	Non-Built-up	2					**2**
	Low		2				**2**
	Keep			2			**2**
	Tall				2		**2**
	Very High					2	**2**
	Sum	**2**	**2**	**2**	**2**	**2**	**10**

The sample points taken represent the level of building density in the study area in the KKOP area to support the validation of NDBI results. The sample that has been taken will be a comparison material in the data accuracy test matrix. The accuracy test using the confusion matrix method in this study obtained a truth result of 100%. Samples in each classification are taken 2 different places, so the total sample used is 10 samples. The results of accuracy calculations in matrix form can be seen in the following table 5.

This study only examines the airport take-off canal area as an area prone to aircraft accidents during *landing* and take-*off* in the Halim Perdanakusuma Airport KKOP Area. The process of image data to obtain NDBI classification is a way to represent the density of buildings in the study area. NDBI visualization in the form of a thematic map can be seen in the picture below:

Table 6. Building Density Classification Area

Class	Value	Area (m2)	Spacious (Ha)
Non-Built-up	1	21751600	2175.16
Low	2	15911600	1591.16
Medium	3	23769800	2376.98
High	4	13571200	1357.12
Very High	5	5915	59.15

Based on the map, there are five classification classes that will be used as material for building density analysis on general safety from the danger of potential aircraft accidents. On the map, the KKOP area of Halim Perdanakusuma Airport reaches three provinces, namely Jakarta Province, West Java Province and Banten Province. The administrative areas included in the runway take-off canal area are East Jakarata City, South Jakarta City, Depok City, Bekasi City, Bekasi and South Tangerang City. The classification map of NDBI results in the take-off canal area shows that East Jakarta, Bekasi. The Bekasi Greater area have a higher building density than building densities in South Jakarta, Depok and South Tangerang. The calculation of the area of each classification of data processing results in detail can be seen in the figure and table.

Based on the graph above, the most dominant building density area in the aircraft take-off canal area at the Halim Perdanakusuma Airport KKOP is a class with a medium building density. The area of the second highest class is the non-Built-up class. This is supported by the existence of Ragunan as a recreation area as well as Green Open Space (RTH), Golf Courses, and the Cisadane River ecosystem. In the graph, the growth and density of buildings are heading west, precisely towards Bekasi City.

The land cover of this research area was then grouped into 2 groups of land cover; The area is Built-up and not Built-up. The type of land cover of the built-up area has the highest area in the study area, considering the location of the Flight Operational Safety Area from Halim Perdanakusuma Airport covering the central population area around the Greater Jakarta area. Land cover map showing built-up areas (figure 3-5) shows that almost all these areas are built-up areas.

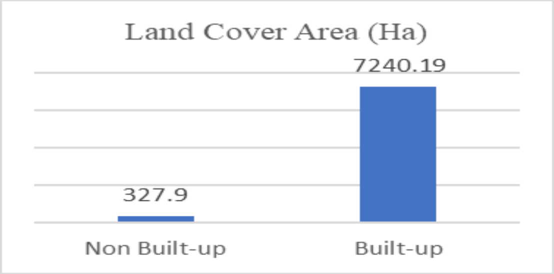


Figure 3 Calculated Build-up and no-Build-up area

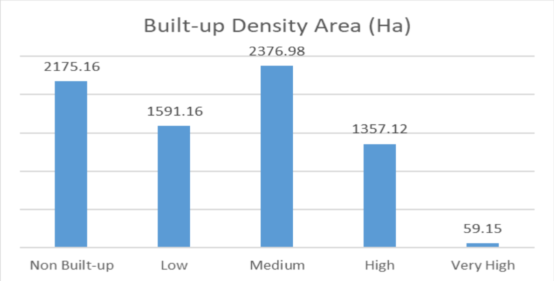


Figure 4 Calculated of the density in Build-up area

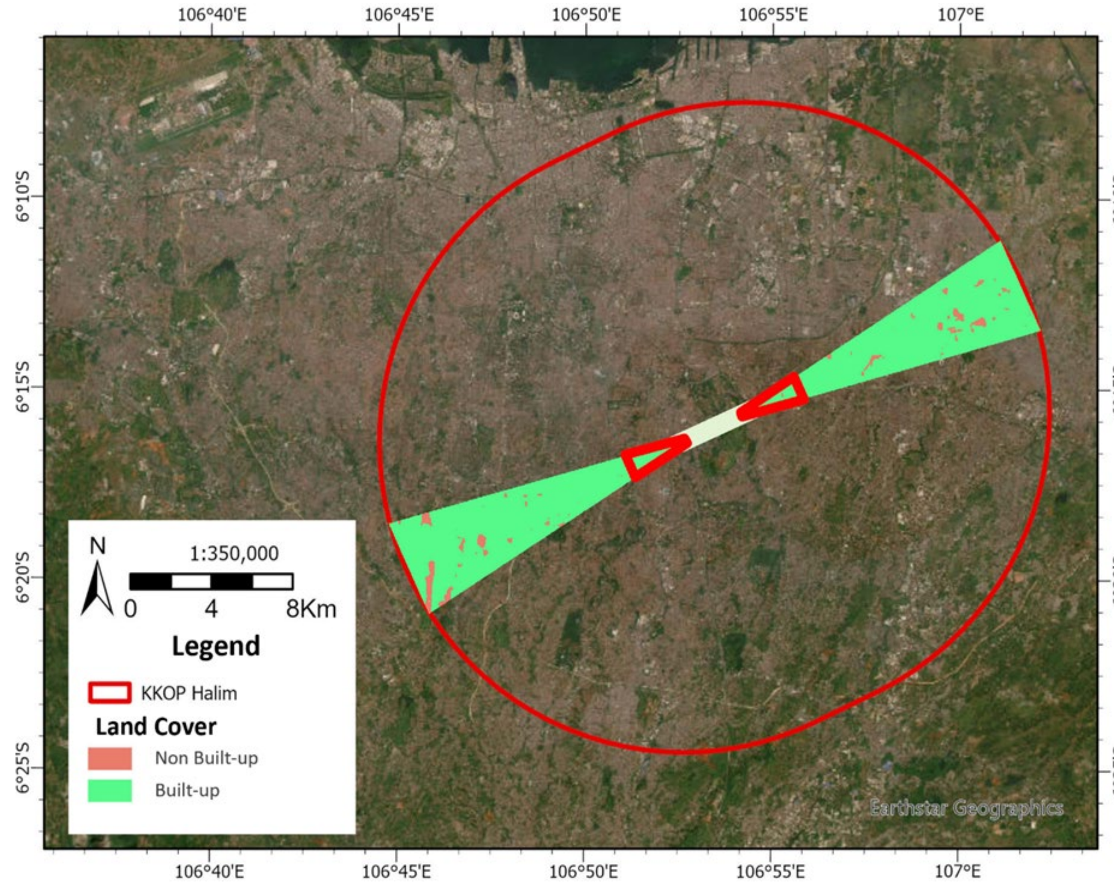


Figure 5. Land Cover of Halim Perdanakusuma take-off area

When viewed from the comparison of area between data from land cover and building density index data, it will get a value that is quite different between the two data. The built-up area obtained from the land cover map in the take-off area of Halim Perdanakusuma airport (Figure 4) is 7240.19 Ha. While the area with building density (Figure 5) both low to very high is 5384.41 Ha. This significant difference when used in risk analysis will cause a very significant difference in value as well and will have a major effect on policy determination.

So that if the determination of spatial planning policies in the KKOP area uses only land cover data, it will produce a suboptimal analysis in assessing flight safety risks in the KKOP take-off area. This greatly affects other variables in determining spatial policies in the airport take-off area at KKOP.

The policy will have a significant influence on various aspects, both related to aviation safety risks and regional and economic spatial policies. First, spatial policies that do not pay attention to aviation safety aspects can increase the risk of accidents or incidents at KKOP airport. For example, if the airport is located too close to residential areas or other important objects, such as power plants or industrial installations that have the potential to interfere with aircraft navigation. Therefore, a spatial policy that considers aviation safety risks is needed to protect the safety of passengers and the public.

Second, spatial policy in the take-off area of KKOP airport also has an impact on overall regional spatial policy. A strategic airport can encourage the development of supporting infrastructure such as highways, railways, and bus terminals to facilitate accessibility to the airport. In addition, spatial policies must consider the development of nearby areas that support airport operations, such as hotels, restaurants, and shopping centres. Thus, spatial policies in the KKOP airport area have a broad impact and must be considered in planning a comprehensive regional spatial plan.

Third, spatial policy in the take-off area of KKOP airport also affects economic policy. This airport has an important role in encouraging regional economic growth. Spatial policies that support airport development with adequate supporting infrastructure can increase investment and tourism attractiveness. The construction of industrial or tourism areas around the airport can create new jobs and increase the income of local people. In addition, spatial planning policies must also consider connectivity between the airport and the surrounding area to increase the potential for regional economic growth.

In conclusion, spatial policies around take-off and landing of aircraft at airports in KKOP have a broad impact and must consider aspects of aviation safety risks, regional spatial policies, and regional economic growth. It is important to conduct a thorough analysis to formulate policies that are sustainable and provide maximum benefits to society and the economy.

4 CONCLUSIONS

Overall, the classification results generated by the Sentinel-2 images Based on the results of the analysis that has been done, visually the results of NDBI can identify the distribution of building density in an area is very good. so that the use of this analysis in aviation safety risk analysis, especially in the Aviation Operational Safety Area (KKOP) area will be very helpful in making aviation safety policies and regional spatial planning around the airport area.

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