Identifying Potential New Residential Areas Based on Physical Conditions Using the Weighted Overlay Method on Batam Island, Batam City

Prama Ridho Ramadhana[1] and Oktavianto Gustin[1]

[1]Geomatics Technology Study Program, Politeknik Negeri Batam,
Jl. Ahmad Yani Tlk. Tering, Batam City, Indonesia

pramaridho1011@gmail.com

Abstract. The population growth on Batam Island has led to an increased need for new residential areas. Therefore, it is necessary to identify areas with suitable physical conditions for housing development planning. This study uses the Weighted Overlay method in a Geographic Information System (GIS) to identify potential new residential areas based on physical conditions. The parameters used include slope, soil type, and rainfall. Each parameter was reclassified based on suitability scores, weighted, and overlaid to produce four classes of suitability: unsuitable, less suitable, suitable, and highly suitable. The analysis results show that the "suitable" class is the largest at 17,175.07 hectares, followed by the "somewhat suitable" class at 16,297.09 hectares, the "highly suitable" class at 2,980.28 hectares, and the "unsuitable" class at 1,374.14 hectares. Next, we validated the Weighted Overlay results by overlaying them with Regional Spatial Plan (RTRW) data for residential areas only. The validation results show that residential areas in the RTRW fall into all four classes: 159 ha (unsuitable), 602 ha (less suitable), 497 ha (suitable), and 644 ha (highly suitable). This indicates that most of the planned residential areas in the RTRW are in areas with good suitability levels based on physical conditions. Thus, the Weighted Overlay method can be used to identify potential new residential areas on Batam Island.

Keywords: Geographic Information System, Weighted Overlay, Land Suitability, Housing, RTRW, Batam Island.

1 Introduction

The ever-increasing population growth has led to a growing demand for housing. This situation has spurred the development of new housing estates in various regions, including on the island of Batam. As one of Indonesia's cities experiencing rapid growth in industry, trade and services, Batam has become a destination for people migrating from various regions. This increase in population is directly proportional to the rising demand for land for housing development [1].

On the other hand, the availability of land that can be used for housing development is becoming increasingly limited. Not all land is suitable for use as a residential area. If development is carried out without taking the physical characteristics of the land into account, various problems may arise, such as high construction costs, environmental damage, and an increased risk of disasters, such as erosion and flooding. Therefore, a study is required to identify land with physical conditions suitable for housing development [2].

One approach that can be used is land suitability analysis based on a Geographic Information System (GIS). GIS enables various spatial data to be analysed simultaneously, thereby providing information on the suitability of a particular area. In this study, the analysis focused on the physical conditions of the land, including slope gradient, soil type and rainfall. These three parameters were selected because they influence the suitability of an area for housing development. Slope gradient relates to the ease of construction and land stability; soil type affects the load-bearing capacity of buildings; whilst rainfall is associated with the potential for waterlogging, erosion and drainage systems [1].

The Weighted Overlay method was chosen because it allows several parameters to be combined into a single analysis by assigning weights according to the degree of influence of each parameter. The result of this method is a land potential map showing the suitability of each location based on its physical conditions. Consequently, the process of identifying land suitable for housing development can be carried out more systematically [3].

This study aims to identify the potential for new residential land based on physical conditions using the Weighted Overlay method on Batam Island. The results of the study are expected to provide spatial information regarding the level of potential of land suitable for housing development and to serve as a basis for consideration in planning more targeted and sustainable regional development.

2 Methodology

2.1 Research Areas

The research area is centred on Batam Island, Batam City, Riau Islands Province.

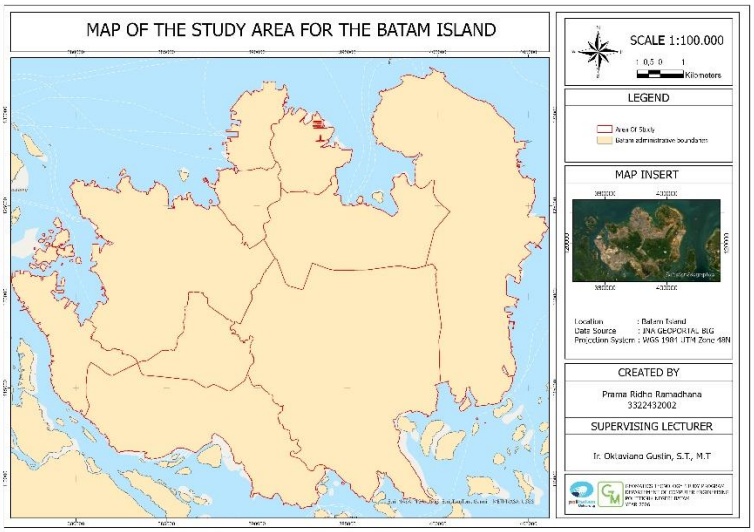

Figure 1. Research Location Map

2.2 Tools, Equipment and Data Sources

In this study, ArcMAP was used as the primary software for processing and analysing spatial data. The main data sources used in this modelling were secondary data from Demnas, BMKG and Bappeda.

Table 1. Research Data

Data	Type	Source
Slope Gradient	Raster	Demnas
Soil Type	Vector	Bappeda
Rainfall	Point/Raster	BMKG
Administrative Boundaries of Batam	Vector	BIG
Batam City Regional Spatial Plan (RTRW)	Vector	ATR/BPN Batam

ArcMAP was used to carry out data pre-processing, slope analysis, parameter reclassification, scoring and weighting, and a weighted overlay process to produce a map of residential land potential. In addition, this software was also used to validate the results through an overlay with the Batam City Regional Spatial Plan (RTRW) and to compile the analysis results into a map. Microsoft Excel is used to manage attribute data, compile scoring and weighting tables, and perform simple calculations to support the analysis.

2.3 Weighted Overlay

Weighted Overlay is a raster-based spatial analysis technique used to solve multi-criteria problems by integrating several geospatial parameter maps [4]. Mathematically, this method normalises the varying class intervals of each parameter into a single, uniform standardised value (score or rating). Each criterion is then multiplied by its percentage weighting, and all raster layers are summed to obtain a total suitability value for each spatial unit pixel, based on the mathematical formula in Equation (1):

$$S = \sum_{i=1}^{n}(W_i \times X_i) \quad (1)$$

Where S is the total final land suitability score, W_i denotes the percentage weighting of the i-th parameter, and X_i represents the score or rating assigned to the i-th criterion class [4].

3 Result and Discussion

3.1 Analysis of the Slope Map of Batam Island

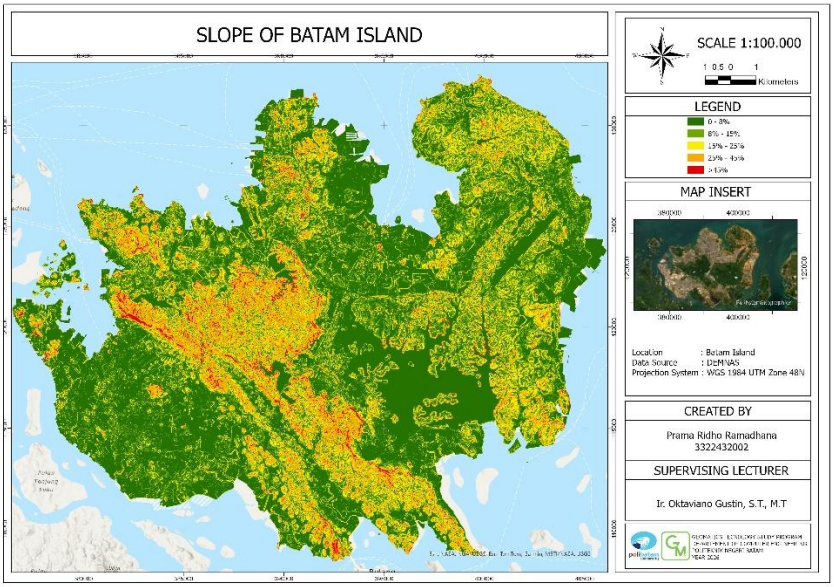

Figure 2. Slope of Batam Island

Slope gradient is one of the physical parameters used in this study as it influences the ease of developing residential areas. The flatter an area is, the easier the development process will be, both in terms of construction work and land preparation costs. Conversely, areas with steep slopes require more extensive earthworks, such as cutting and filling, and are therefore less suitable for residential development. Based on the results of DEMNAS data processing, slope gradients on Batam Island are divided into five classes: flat (0–8 per cent), gentle (8–15 per cent), moderately steep (15–25 per cent), steep (25–45 per cent) and very steep (>45 per cent). The mapping results show that the majority of Batam Island is dominated by flat to gentle slope classes. This indicates that, physically, Batam Island has many areas suitable for the development of residential estates.

Meanwhile, areas classified as moderately steep, steep and very steep are scattered across the hilly regions in several parts of Batam Island. These areas are subject to development constraints as they require higher construction costs and present a greater level of risk compared to flat areas. In this study, the slope gradient parameter was assigned a weighting of 40 per cent, making it the most influential parameter in the Weighted Overlay process. The gentler the slope of an area, the higher its suitability score in determining the potential for new housing developments based on the physical conditions of the land.

3.2 Analysis of the Soil Type Map of Batam Island

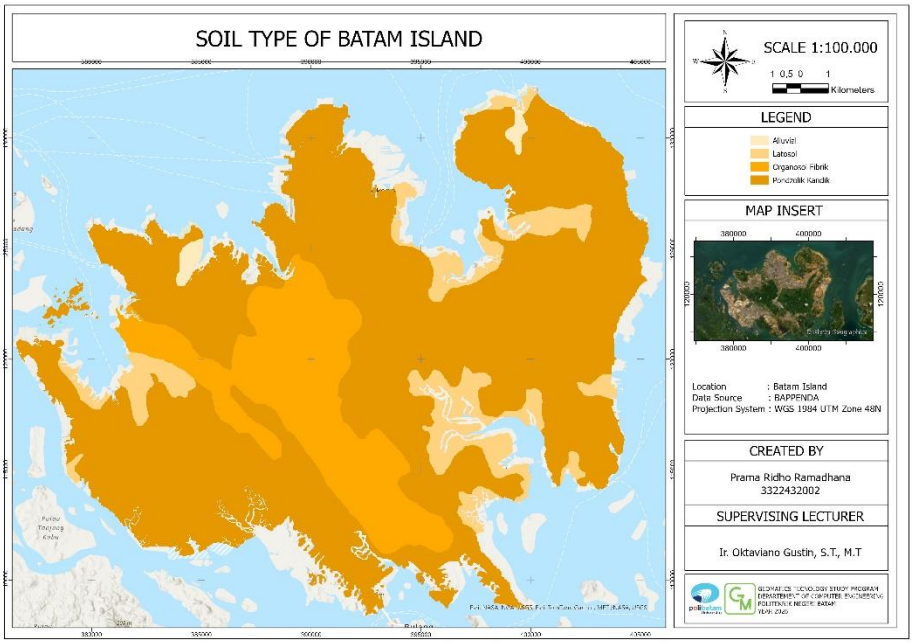

Figure 3. Soil Type of Batam Island

Soil type is a physical parameter used to determine a site's suitability for residential development. Each soil type has distinct characteristics, such as bearing capacity, stability, and water permeability. These differences in characteristics influence the site's suitability for development. Based on the Batam Island Soil Type Map, the study area comprises four soil types, namely Alluvial, Latosol, Fibrous Organosol and Kandik Podzol. The most common soil type is Latosol, which is found across almost the entire area of Batam Island, whilst Fibrous Organosol and Kandik Podzol are only found in certain locations.

In this study, the soil type parameter was assigned a weighting of 35 per cent. This weighting indicates that soil type is an important factor, second only to slope gradient, in determining land suitability. Soil types with more stable characteristics receive a higher score, whilst those with limitations for development receive a lower score. Consequently, information on soil type forms one of the bases for identifying the potential of new residential areas based on the physical conditions of the land on Batam Island.

3.3 Rainfall Map of Batam Island

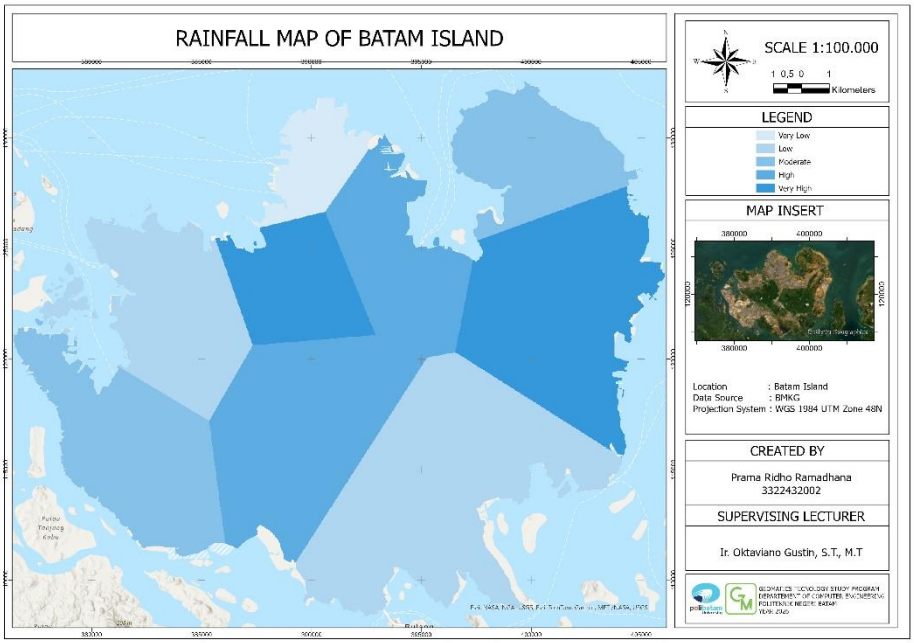

Figure 4. Rainfall Map of Batam Island

Rainfall is one of the physical parameters used because it influences the environmental conditions of an area, particularly in relation to the potential for flooding and the need for drainage systems in residential areas. Rainfall data for this study were obtained from the BMKG and processed using the Thiessen Polygon method. This method divides the area into several polygons based on the shortest distance to each rainfall

station, so that each area is considered to have the same rainfall value as the station representing it.

The mapping results show that Batam Island has rainfall variations divided into five categories: very low, low, moderate, high and very high. These differences in rainfall indicate variations in the physical conditions of the area, which may influence the suitability of the land for residential development. In this study, the rainfall parameter was weighted at 25 per cent. Areas with lower rainfall receive a higher suitability score as they have a relatively lower potential for flooding. Conversely, areas with high rainfall receive a lower score, meaning their suitability for residential development is also lower.

Table 2. weights of the main parameters and parameter scores
Source : Adapted from Rizki N. S., Affan, and Rusdi (2023) [1]

Parameters	Weight (%)	Criteria Class	Score
Slope Gradient	40%	0-8% Flat	20
		8-15% Gentle	40
		15-25% Quite Steep	60
		25-45% Steep	80
		>45% Very Steep	100
Soil Type	35%	Alluvial	15
		Latosol	30
		Organosol Fibrik	45
		Podzolik Kandik	60
Rainfall	25%	Very Low	10
		Low	20
		Medium	30
		High	40

3.4 Analysis of Land Suitability Maps

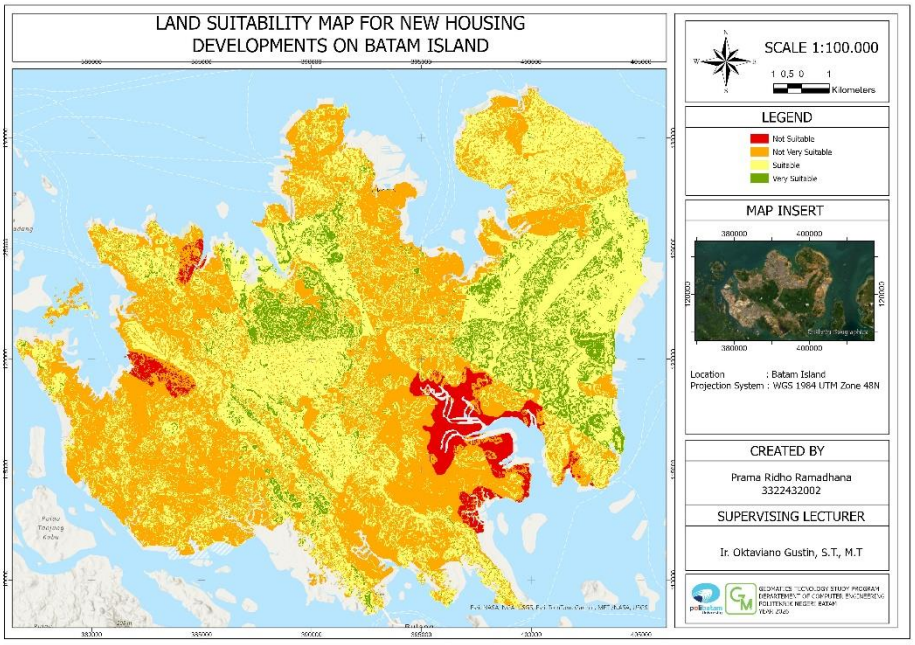

Figure 5. Land Suitability Map for New Housing on Batam Island

The land suitability map was derived from the results of a Weighted Overlay analysis, combining three physical parameters: slope, soil type and rainfall. Each parameter was classified, scored according to its level of suitability, and then combined on the basis of weightings to produce four land suitability classes: unsuitable, less suitable, suitable and highly suitable.

Based on the results of the analysis in Figure 5, it can be seen that the 'Suitable' class covers the largest area, namely 17,175.07 ha or 45.40 per cent of the total study area. This indicates that almost half of Batam Island has physical conditions that are sufficiently favourable for the development of residential areas. Areas in this class generally have a combination of relatively gentle slopes, soil types suitable for construction, and rainfall conditions that remain within the 'Suitable' category. The 'Less Suitable' class ranks second, covering an area of 16,297.09 ha or 43.08 per cent. This substantial area indicates that there are still many areas with development potential; however, one or more physical factors act as constraints, necessitating further consideration during the development process.

Furthermore, the 'Highly Suitable' class covers an area of 2,980.28 ha, or 7.88 per cent. Although its area is relatively small, this region exhibits the best combination of physical conditions based on the weighted results. Consequently, this area has greater potential for new housing development than the other classes. Meanwhile, the 'Unsuitable' class covers the smallest area, namely 1,374.14 ha or 3.63 per cent. Areas in this

class have physical conditions that are less favourable based on the analysis of the three parameters and are therefore not recommended as sites for housing development.

Overall, the results of the Weighted Overlay analysis show that 53.28 per cent of Batam Island falls into the 'Suitable' and 'Highly Suitable' categories. This indicates that more than half of the study area possesses physical conditions conducive to the development of new residential areas. However, these results cannot yet serve as a direct basis for determining development locations, as they still need to be compared with the Batam City Regional Spatial Plan (RTRW) to ensure compliance with the applicable spatial utilisation guidelines.

3.5 Validation Analysis using the Regional Spatial Plan (RTRW)

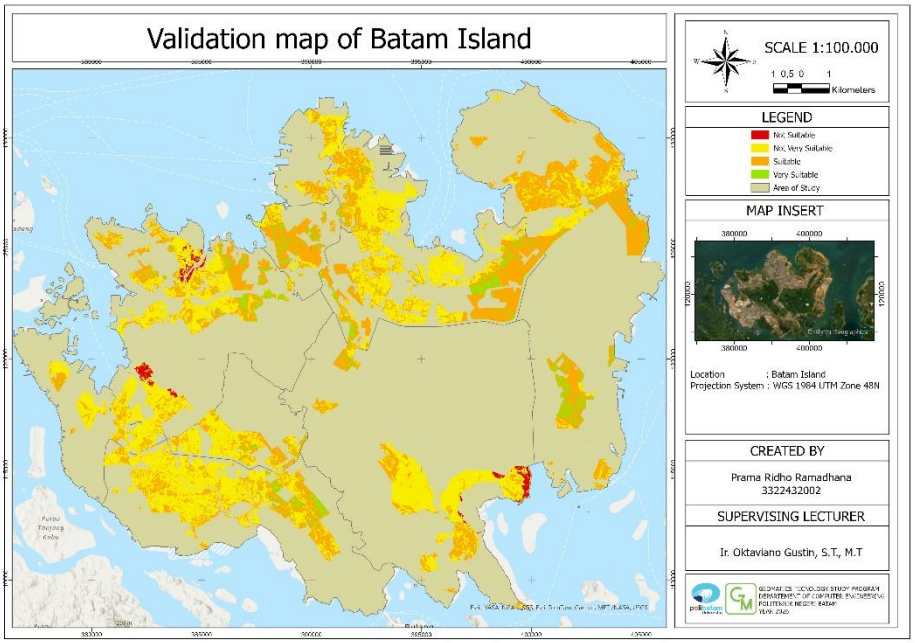

Figure 6. Validation map of Batam Island

Validation was carried out by comparing the results of the Weighted Overlay with the Batam City Spatial Master Plan (RTRW) using the Intersect function in ArcGIS. Subsequently, only residential areas were selected to ensure that the analysis was in line with the research objective, namely to identify potential new residential areas.

Based on the validation results, the total area of residential zones corresponding to the Weighted Overlay results was found to be 1,902 hectares. Of this total, the 'Highly Suitable' class covered the largest area, at 644 hectares, followed by the 'Less Suitable' class at 602 hectares, the 'Suitable' class at 497 hectares, and the 'Unsuitable' class at 159 hectares. These results indicate that some of the areas designated as residential areas in the RTRW also have favourable physical conditions based on the Weighted

Overlay analysis. However, there are still several residential areas classified as ‘Less Suitable’ and ‘Unsuitable’. This indicates that, although these areas have been designated as residential areas in the RTRW, their physical conditions still present certain limitations based on parameters such as slope gradient, soil type and rainfall.

Validation was carried out using RTRW data selected on the basis of residential/settlement area attributes. Other attributes contained in the RTRW data, such as built-up land, were not used in the validation process as the study focused on the consistency of the Weighted Overlay results with areas designated for residential use. Consequently, the Intersect process only displays the parts of the RTRW settlement areas that overlap with each class of the Weighted Overlay results. The selection of residential area attributes was carried out to ensure consistency between the validation data and the research objective, namely to identify potential housing areas based on physical conditions. Consequently, the presence of the ‘built-up land’ attribute was not used as a basis for validation, as it indicates land-use conditions, whereas this study focuses on the designation of housing areas within the RTRW and the physical conditions of the land.

Overall, the validation results indicate that the Weighted Overlay analysis is consistent with the land-use guidelines set out in the Batam City Spatial Plan (RTRW). Consequently, the findings of this study can be used as supporting information when identifying potential sites for the development of new residential areas.

4 Conclusion

Based on the results of the research conducted, the Weighted Overlay method can be used to identify potential new residential areas on Batam Island based on the physical conditions of the region. The analysis was carried out using three parameters—slope gradient, soil type and rainfall—which were weighted and scored according to their level of influence on housing development. The analysis resulted in four land suitability classes: unsuitable, less suitable, suitable and highly suitable.

The results of the Weighted Overlay analysis show that the ‘suitable’ class has the largest area, namely 17,175.07 ha, followed by the ‘less suitable’ class covering 16,297.09 ha, the ‘highly suitable’ class covering 2,980.28 ha, and the ‘unsuitable’ class covering 1,374.14 ha. This indicates that the majority of Batam Island possesses physical conditions that are sufficiently favourable for the development of new residential areas, particularly in areas with relatively gentle slopes, suitable soil types, and rainfall levels that do not pose a major obstacle to development.

Validation was carried out by overlaying the results of the Weighted Overlay onto the Regional Spatial Plan (RTRW) data selected for the residential area. The validation results show that the residential areas within the RTRW fall across all suitability classes, with 159 ha in the ‘unsuitable’ class, 602 ha in the ‘less suitable’ class, 497 ha in the ‘suitable’ class, and 644 ha in the ‘highly suitable’ class. These results indicate that the majority of residential areas planned within the RTRW are situated on land with a good level of suitability based on physical conditions. Consequently, the Weighted

Overlay method can be used as an effective approach for identifying potential new residential areas and can serve as supporting information for the planning and development of residential areas on Batam Island.

References

[1] N. S. Rizki, M. Affan, and M. Rusdi, "Pemetaan Wilayah Peri-Urban Yang Berpotensi Sebagai Lahan Permukiman di Kota Banda Aceh dengan Metode Weighted Overlay," vol. VIII, no. 2, pp. 6034–6042, 2023.

[2] G. Laia, Z. Nasution, and A. S. Thoha, "Analisis Kesesuaian Lahan Permukiman Menggunakan Sistem Informasi Geografis Di Kota Binjai," vol. V, no. 2, pp. 921–932, 2020.

[3] P. Peta, P. Lahan, and B. Kondisi, "Jurnal Geodesi Undip April 2016 Jurnal Geodesi Undip April 2016," vol. 5, no. April, pp. 136–146, 2016.

[4] W. Aqli, "ANALISA BUFFER DALAM SISTEM INFORMASI GEOGRAFIS," vol. VI, no. 2, pp. 192–201, 2010.

[5] P. Name *et al.*, "KAJIAN DAYA DUKUNG LAHAN PERMUK Fadlia Djalil 3409 Words 20729 Characters 12 Pages Aug 18 , 2023 2 : 35 PM GMT + 8 23 % Overall Similarity The combined total of all matches , including overlapping sources , for each database . Crossref database 17 % Submitted Works database 10 % Publications database Crossref Posted Content database Excluded from Similarity Report Bibliographic material Small Matches (Less then 8 words)," 2023.

[6] A. Handayani, A. Wibowo, and A. N. Zain, "Sebaran Kesesuaian Lahan Permukiman di Kecamatan Alam Barajo Kota Jambi Provinsi dengan Spatial Multi Criteria Analisis (SMCA)," vol. 11, no. 2, pp. 114–122, 2023.

[7] M. Ilmiah, "Geomedia," vol. 21, no. 2, pp. 125–134, 2023.