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SPATIAL MODEL OF BUILT-IN LAND CHANGE (NDBI) IN LANGSA CITY USING CELLULAR AUTOMATA MARKOV (CA-MARKOV)

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ABSTRACT

The increasing population in Langsa City has caused changes in land use to increase, which is due to the urge to meet the need for housing and other supporting facilities. This makes research on built-up land in Langsa City very important to do, where this study aims to analyse and predict changes in built-up land in Langsa City in 2011, 2017, 2023, and 2035, to provide an overview of changes in built-up land that occur from year to year. In addition, this study also analyses the direction of built-up land policy in Langsa City. The method used in this study is a spatial-based quantitative method with the Cellular Automata Markov approach to create built-up land modelling in Langsa City, and the Analytical Hierarchy Process method to identify variables that influence changes in built-up land in Langsa City. This study produces a map of built-up land changes from 2011 to 2023, showing an increase in built-up land area of 2.417 Ha, which is caused by population growth and regional development factors. In addition, this study also produced a prediction map of built-up land in 2035, which was produced through image interpretation with a kappa index accuracy value of 0,88, which is included in the very good accuracy category. In addition, this study also produced a policy direction for built-up land in Langsa City, which shows the main criteria that are a priority, namely physical conditions with sub-criteria, namely the existence of land that must be far from disaster-prone areas.

Keywords: *Change Interval; Built-up Land Prediction; Policy Direction.*

INTRODUCTION

The high population growth rate, especially in urban areas, will undoubtedly impact the increasing changes in land use, especially in built-up land, caused by the need for housing and accessibility of the population. In addition, according to several studies that have been conducted previously, it is known that almost 43% of the world's population prefers to live in urban areas, which is what causes the increasing changes in built-up land, especially in urban areas (Hidayati and Danoedoro 2017).

As one of the cities located in Aceh province with a population based on

(Badan Pusat Statistik, 2024) data reaching around 188.878 residents, Langsa City is one of the cities that continues to experience development in terms of construction. This is one of the impacts that arise due to the increasing population, thus driving the high rate of change in built-up land in Langsa City to meet the need for housing and other supporting facilities (Lisayoana 2024). This is also supported by research conducted in 2022, which stated that there had been a significant increase in built-up land, especially in the central area of Langsa City (Urfan, Sihotang, and Arrasyid 2023). In addition, there was also a similar study in 2018 regarding agricultural and forestry land in Langsa City, which also showed that within 10 years, there had been a lot of conversion of natural land into built-up land, both for housing and for the construction of public facilities (Hanum and Wanniatie 2015).

The less relevant handling of population growth and built-up land in Langsa City will damage the city's order due to the dense and irregular distribution of buildings. Therefore, researchers feel the need to analyse changes in built-up land in Langsa City so that various regional governance plans for Langsa City can be planned as early as possible to prevent unwanted things from happening in the future (Ruslisan, Zahira, and Dharmasanti 2015). One can be done by spatial analysis using multispectral remote sensing imagery data to see changes in built-up land in Langsa City yearly. In addition to analysing changes in built-up land, analysis using this spatial approach can also provide an overview (prediction) of the condition of the built-up land area in the future. In this study, researchers set 2035 as a reference for predicting the built-up land in Langsa City (Fariz 2017). In addition to making predictions, researchers also analysed built-up land policy directions to see what factors need to be considered in determining built-up land policy directions in Langsa City (Luhukay, Sela, and Farnklin 2019).

Researchers hope that the results of this study can be used as a reference to educate the government and local communities about the importance of regional governance and development planning so that it will not have a negative impact in the future.

MATERIALS AND METHODS

This study uses a quantitative method with a spatial approach, field surveys and interviews with experts to analyse the direction of built-up land policies in Langsa City. Later, the analysis of built-up land will be processed using the AHP (Analytical Hierarchy Process) method. The tools needed in this study are a laptop, a compass, ArcGIS software version 10.8, and QGIS version 2.16. Research instruments are shown in **Table 1.**

Table 1. Research Instruments

Variable	Data
Built-up land change model for 2011, 2017, and 2023	Google Earth Imagery
Spatial prediction model of built-up land in 2035 in Langsa City	Land use maps for 2011, 2017, 2023, and Euclidean Distance data.
Langsa City Built-up Land Policy Direction	Field Observation

Built-up Land Change Analysis

The Normalised Difference Build-Up method was used to analyse changes in built-up land in Langsa City in 2011, 2017, and 2023. Where to calculate the NDBI level, this can be done using the following formula (Anissa, Rini, and Soedwiwahjono 2024):

$$NDBI= SWIR-NIR/SWIR+NIR \quad (1)$$

Where:

SWIR = Short Wave Infra Red (B6)

NIR = Near Infra Red (B5)

Apart from using the NDBI method, researchers also use the supervised classification method to classify each existing land cover.

Prediction of Built-up Land in Langsa City

The cellular automata Markov model creates a prediction map of built-up land changes. The main formula of the CA model can be stated as follows (Sheladiya and Patel 2023)

$$S (t, t+1) = f (S(t).N) \quad (2)$$

Where:

S = Discrete cell state

T = Time instant

t+1 = Future time instant

N = Cellular field

f = Cellular state transition rule in local space.

Apart from that, there are also Markov formulations, including the following (Triyatno, Ikhwan, and Febriandi 2020):

$$S(t+1) = P_{ij} \times S(t) \quad (3)$$

Where:

S(t) = Current state of the system

S(t+1) = Future state of the system

P_{ij} = Transition probability matrix of a region.

$$Pij = \begin{pmatrix} P_{11} & P_{12} & P_{1n} \\ P_{21} & P_{22} & P_{2n} \\ P_{n1} & P_{n2} & P_{nn} \end{pmatrix}$$

Given That

(0 ≤ Pij = 1< 1 dan ∑Nj= 1 Pij = 1, (I, j = 1, 2, …, n)

The method used to predict changes in built-up land in Langsa City is the artificial neural network (ANN) method with the following formula (Diana et al. 2019):

$$Zj = \sum \infty i{=}1\ W_{j1}X_1 + Wj_0 \quad (4)$$

Where:

Nk = Number of hidden units

Ni = Number of incoming inputs

To measure the accuracy level of the prediction map, data validation needs to be carried out by looking at the resulting kappa index. A prediction is accurate with a kappa index of at least 61% or 0.61. With the formulation:

$$OA = \frac{\sum B}{\sum S} X100 \quad (5)$$

Where:

OA = Overall accuracy,

∑B = Number of correct,

∑S = Total sample.

Built-up Land Policy Direction in Langsa City

To determine the direction of land development policy in Langsa City, the Analytical Hierarchy Process (AHP) method is used. After determining the criteria and sub-criteria that will be used in the assessment of the direction of built-up land policy, an assessment is carried out using the Saaty scale shown in **Table 2**:

Table 2. AHP Assessment Scale

Intensity Of Interest	Information
1	Both elements are equally important.
3	One element is slightly more important than the other elements.
5	One element is more important than the other elements.
7	One element is clearly more absolutely important than the other elements.
9	One element is clearly absolutely more important than the other elements.
2, 4, 6, 8	The value used if there are considerations.

Source: (Oktapiani et al. 2020)

In order to measure the level of accuracy in the direction of built-up land policy, data validation is carried out by looking at the consistency ratio resulting from observations of criteria or sub-criteria that have been previously assessed. The AHP assessment will be considered consistent or correct if the CR value produced is less than or equal to 0.1

(10%). (Yakin, Rustiadi, and Pribadi 2024; Yastika et al. 2024).

The following is the AHP calculation formula:

CI=λmaks-n/(n-1) (6)

Where:

CI = Consistency Index

n = Matrix Size

CR= CI/IR (7)

Where: CI = Consistency Index

IR = Index Random Consistency

The following is the IR value index according to Saaty (Kamal, Satria, and Pasha 2025), shown in **Table 3**:

Table 3. Random Consistency Index Value

Matrix Size	IR Value
1-2	0,00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

Source: (Kamal et al. 2025)

RESULTS AND DISCUSSION

General Description

This research was conducted in Langsa City, precisely located on the east coast of Aceh province. This city consists of 5 sub-districts, namely Langsa Baro, Langsa Lama, Langsa City, East Langsa, and West Langsa, with astronomical lines located between 04'35.68"-04'47.03" North Latitude, 97'14.59" - 98'42.16" East Longitude and an area of approximately 239.83 Km^2. The following researchers present the area of land use in Langsa City in **Figure 1**.

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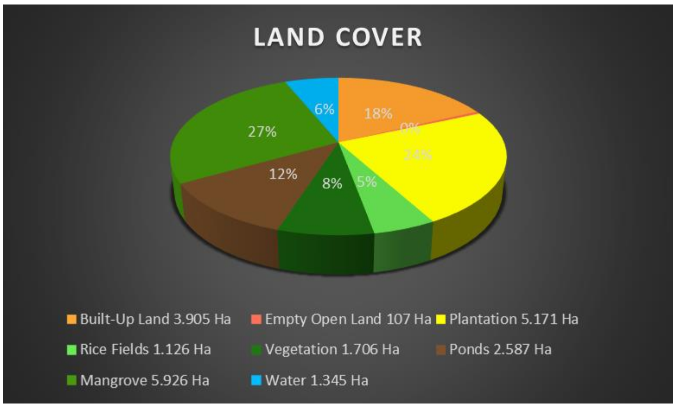

Figure 1. Land Cover Diagram of Langsa City

Based on the diagram above, it is known that the built-up land area in Langsa City has reached 18% of the total area of this city or around 3905 Ha.

Analysis of Built-up Land Changes in Langsa City

To identify changes in built-up land in Langsa City in 2011, 2017, and 2023, the area in each land cover category was calculated using Calculate Geometry in the ArcGIS 10.8 application. The time interval used to see changes in built-up land is a 6-year change from 2011 to 2023. The following researcher presents a map and area of changes in built-up land in 2011-2017 and a map of changes in built-up land in Langsa City in 2017-2023, shown in **Figure 2**.

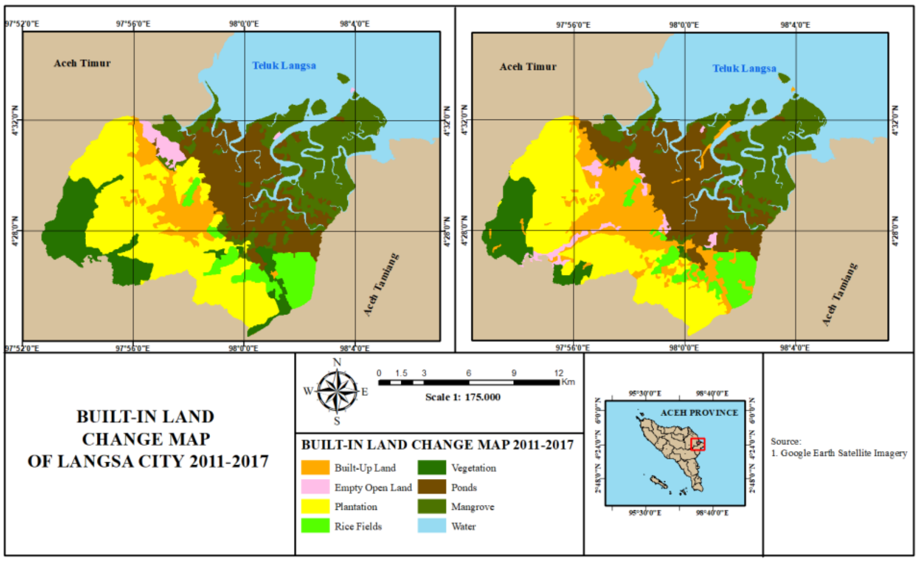

Figure 2. Map of Land Changes in Langsa City Built-up Area 2011-2017

Based on the image above, we can see that there has been a change in built-up land in Langsa City in the period of 2011-2017. To see more clearly the changes in the built-up land area in Langsa City, see **Table 4**.

Table 4. Changes in Built-up Land in Langsa City 2011-2017

Land Cover	2011 (Ha)	2017 (Ha)	Area Change
Built-up Land	1.469	3.251	+ 1.782 Ha
Empty Open Land	376	526	+ 150 Ha
Plantation	6.518	5.608	- 910 Ha
Rice Fields	1.384	1.187	-197 Ha
Vegetation	2.485	1.559	-926 Ha
Ponds	4.191	4.708	+ 517 Ha
Mangrove	4.510	3.976	-534 Ha
Water	937	1.005	+ 168 Ha

Based on the table above, it is known that there has been a change in built-up land in Langsa City in the period of 2011-2017. Based on ArcGIS calculations using Calculate Geometry, it is known that there was a very significant increase in built-up land in 2017, namely 1,782 Ha, where initially it was only 1,469 Ha in 2011, increasing to 3,251 Ha in 2017. In addition, there was also a significant decrease in vegetation land cover, namely -926 Ha, where initially it was 2,485 Ha in 2011, decreasing to 1,559 Ha in 2017. Map of land changes in langsa city built-up area 2017-2023 shown in **Figure 3**.

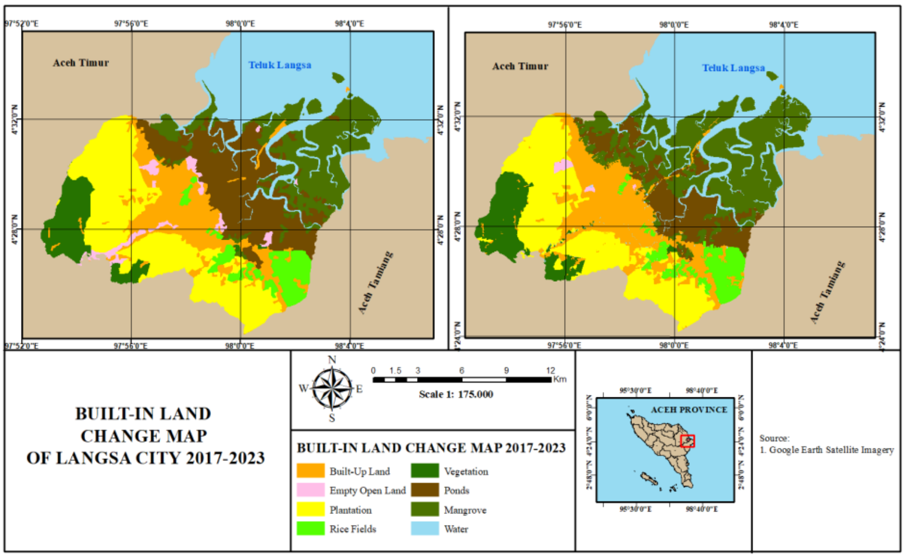

Figure 3. Map of Land Changes in Langsa City Built-up Area 2017-2023

The image above shows that there has been an increase in built-up land in Langsa City in the period 2017-2023. Based on ArcGIS calculations using Calculate Geometry, it is known that there has been an increase in built-up land of 653 Ha in 2023. To see more clearly the changes in the built-up land area in Langsa City, see **Table 5**.

Table 5. Changes in Built-up Land in Langsa City 2017-2023

Land Cover	2017 Ha	2023 Ha	Area Change
Built-up Land	3.251	3.904	+ 653 Ha
Empty Open Land	526	106	+ 420 Ha
Plantation	5.608	5.171	-438 Ha
Rice Fields	1.187	1.126	-61 Ha
Vegetation	1.559	1.705	+ 1.46 Ha
Ponds	4.708	2.587	-2.121 Ha
Mangrove	3.976	5.925	+ 1.949 Ha
Water	1.005	1.345	+ 340 Ha

Based on the table above, it is known that in addition to the increase in built-up land in the 2017-2023 period, there was also a significant decrease in pond land cover, namely -2,121 Ha.

Based on the results of image analysis, the dynamics of changes in built-up land in Langsa City are seen to continue to experience addition. Where changes in built-up land can be caused by various factors, namely population growth factors and regional development factors, the following research was previously conducted by Zahra et al. (2021). The statement regarding this is also emphasised by (Sawo, Rogi, and Lakat 2021; Umar 2019), who state that the increase in settlements (built-up land) in an area is greatly influenced by internal factors such as population growth and external factors such as regional development. Both of these things are very influential because the population growth rate will urge humans to change natural land into built-up land to meet their needs.

Based on BPS data in 2024, Langsa City continues to experience population growth every year, where in 2023 the population of Langsa City reached around 194.730 people (Lisayoana 2024). As a result of this population growth rate, the need for land as a place to live and supporting infrastructure for life is also increasing, which causes changes in built-up land in Langsa City to continue to experience a significant increase from year to year. This is following the opinion of (Citra Chintia Dewi, Pavitasari, and Pribadi 2023), which states that built-up areas can take up a proportion of two-thirds in an urban area, because the increase in population in urban areas continues to take place dynamically, where this population growth can be caused by several factors including natural births, and population migration which makes the need for space even more increasing.

In addition to population growth factors, changes in built-up land in urban areas can also be caused by regional development factors. Though Langsa City is not a large city, it is one of the fairly developed cities in Aceh. The development of the Langsa City area cannot be avoided, and it is a common phenomenon even in other urban areas in Indonesia. This follows research previously conducted by (Umar et al. 2017) which states that sustainable development in urban areas is significant to keep up with the population, which also continues to increase. This statement is also emphasised by (Iskandar, Awaluddin, and Yuwono 2016) who state that urban area development can occur due to two things, the first is due to the need to meet the needs of the population, and the second is related to the increasing demand for a better quality of life. However, because the land area on the face of the earth tends to remain constant, the development of urban areas must be closely monitored so as not to have an impact on the decline in environmental quality which could cause disasters in the future.

Prediction Model of Built-up Land Change in Langsa City

The prediction of the built-up land map of Langsa City in 2035 was produced using the CA-Markov technique with the Artificial Neutral Network (ANN) method. This prediction was made using the QGIS application version 2.16 and the Mollusca plugin. The data used as a reference in making predictions of built-up land in Langsa City in 2035 are built-up land maps from 2011 and 2017, and supporting data such as elevation data, slope data, building Euclidean distance, road Euclidean distance, and river Euclidean.

Where based on the prediction results using the mollusca plugin, it is known that this study produces a kappa value of 0.88 with a percentage of correctness of 80% which is included in the very good accuracy category and can be used to

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predict changes in built-up land in Langsa City in the future. The map of prediction and area of land use in 2035 is shown in **Figure 4**.

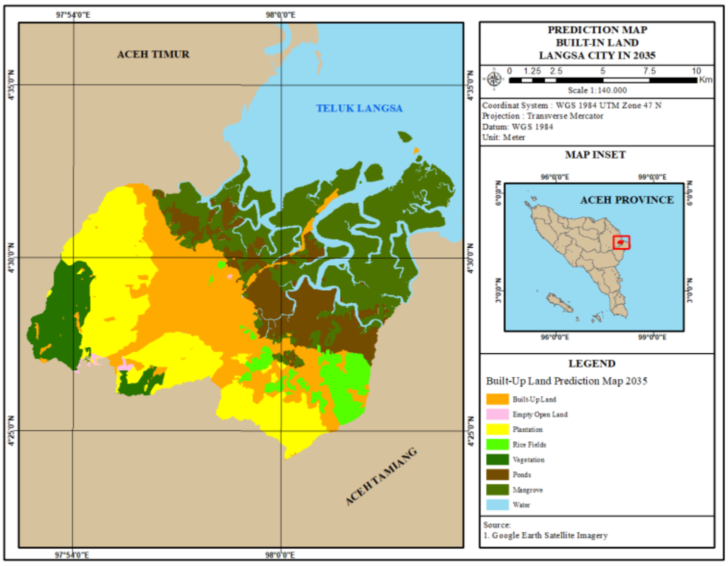

Figure 4. Map of Predicted Built-up Land in Langsa City in 2035

Map of the predicted built-up land in 2035 which is divided into eight classifications consisting of areas in blue which are water, moss green which are mangrove forests, orange which are settlements, pink which are empty open land, yellow which are plantations, light green which are rice fields, brown which are pond areas, and dark green which are vegetation. The predicted area of built-up land in 2035 is shown in **Table 6**.

Table 6. Prediction of Built-up Land in Langsa City in 2035.

Land Cover	Luas (Ha)	Percentage
Built-up Land	4.729 Ha	21,62 %
Empty Open Land	69 Ha	0,31 %
Plantation	4.888 Ha	22,34 %
Rice Fields	1.036 Ha	4,73%
Vegetation	1.447 Ha	6,61 %
Ponds	2.401 Ha	11 %
Mangrove	5.833 Ha	26,68 %
Water	1.468 Ha	6,71 %
Total	21.873 Ha	100

The predicted built-up land in 2035 which is divided into eight classifications consisting of areas in blue which are water, moss green which are mangrove forests, orange which are settlements, pink which are empty open land, yellow which are plantations, light green which are rice fields, brown which are pond areas, and dark green which are vegetation.

The results of spatial modelling of built-up land in 2011-2035 show that there have been many changes in natural land cover to built-up land in Langsa City, where the most changes occurred in plantation land cover, which was initially 6.518 Ha in 2011, reduced to 5.171 Ha in 2023. Even in 2035, this plantation land cover is predicted to decrease to 4.888 Ha. Analysis of changes in built-up land using this spatial modelling refers to previous research by Triyatno and Asri (2023), which states that spatial analysis using high-resolution imagery can produce data quite by conditions in the field. In this study, to produce spatial modelling of built-up land, researchers used Google Earth imagery, including high-resolution imagery with a resolution of 10 x 10 meters.

Built-up Land Policy Directions in Langsa.

Figure 5. Hierarchical Framework of Land Use Policy Directions

Based on the hierarchical framework in **Figure 5**, it is known that, to determine the direction of built-up land policy in Langsa City, researchers have determined three main criteria, namely policy, physical conditions, and facilities and infrastructure, where each criterion is divided into three sub-criteria.

The determination of the three main criteria in this study refers to previous research conducted by AlAli, Salih, and Hassaballa (2023), which states that government policy is an important factor in controlling built-up land that is not following its intended use. In addition, physical condition factors are also important things that must be considered so that the development of this built-up land does not cause a decline in the environmental quality of an area. Similar research was also conducted by Oktapiani et al. (2020) and Permatasari (2020), which stated that land changes are not only caused by human needs for housing but are also related to increasing demands for a better quality of life. Therefore, the main criterion used in this study is the facilities and infrastructure factor.

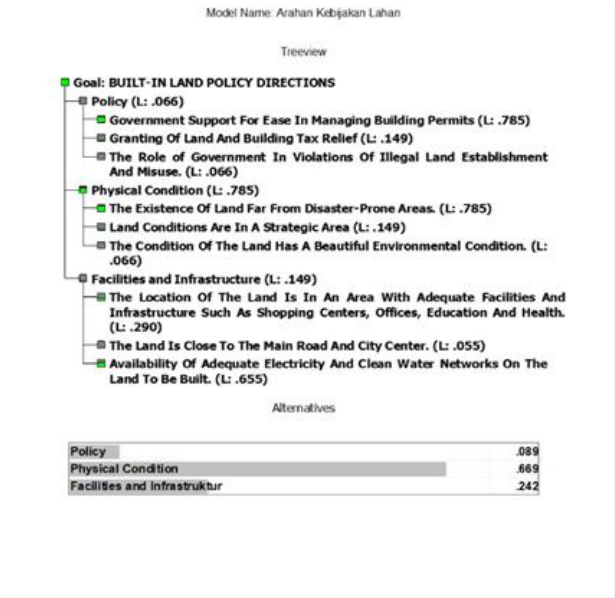

Figure 6. Consistency Value Priority Main Criteria Policy Direction Built-up Land

Based on the **Figure 6** above obtained from the recapitulation results of all respondents, it is known that the factor that most influences the direction of built-up land policy in Langsa City is its physical condition with a priority value of 0.669, followed by the criteria for facilities and infrastructure with a priority value of 0.242, and the last is the policy criteria with a priority value of 0.089.

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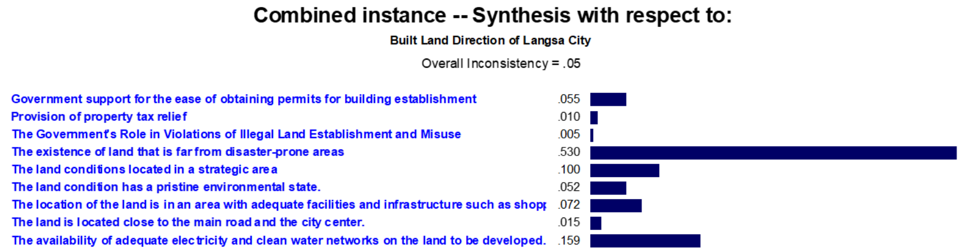

Figure 7. Consistency Value of Priority Sub-Criteria for Built-up Land Policy Direction in Langsa City

Based on the results of the analysis of the sub-criteria of built-up land in Langsa City obtained through the recapitulation of all respondents (**Figure 7**), it is known that the sub-criteria that are the most priority factors in determining the direction of built-up land policies in Langsa City are that the existence of land must be far from disaster-prone areas with a priority value of 0.530, followed by the sub-criteria of the availability of electricity and clean water networks on the land to be built with a priority value of 0.159.

Therefore it can be concluded that based on the results of the analysis of the policy direction of built-up land in Langsa City, it is known that the physical condition factor is the most important factor that needs to be considered in determining the policy direction of built-up land in Langsa City. The sub-criteria that most determine the policy direction of built-up land in Langsa City are that the existence of land must be far from disaster-prone areas. This statement is also emphasised by Law No. 26 of 2007 concerning spatial planning, which firmly states that disaster-prone areas must be considered and avoided when preparing regional spatial plans, especially for residential areas.

CONCLUSIONS

The conclusion that can be drawn based on the results of this study is the change in land use into built-up land in Langsa City in the period 2011-2023 with a spatial approach proves that analysis of this built-up land is very important to be carried out so that regional spatial planning can be carried out as early as possible to prevent damage to the city order in the future due to population growth and regional development. The level of public awareness is also very important in overcoming changes in built-up land, where the people of Langsa City are urged to be more concerned about environmental conditions in Langsa City, namely by not erecting buildings in disaster-prone areas such as riverbanks and mangrove areas or in areas that are prohibited from erecting buildings. In addition, not erecting buildings illegally ensures that the spatial planning of Langsa City remains orderly and balanced. In addition, more in-depth research is needed to find out how much impact will be caused by this built-up land, one of which is by analysing the perception and impact of built-up land for the people of Langsa City to be able to find out more precisely the impact of this built-up land on the social conditions of the people in Langsa City.

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