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SPATIAL RELATIONSHIP BETWEEN CITY CENTER AND ECONOMIC ACTIVITY CENTER ON URBAN GROWTH IN TSUNAMI-PRONE CITY: THE CASE OF BANDA ACEH, INDONESIA

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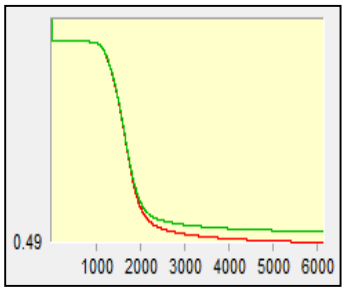
Graphical abstract



Abstract

The main purpose of this study is to examine the impacts of the distance to city center (CIC) and distance to economic activity center (EAC) on urban growth. Land use/cover (LUC) map of 2005 and 2009 are used to analyze the variables. The variables were tested using Multi-Layer Perceptron (MLP) Neural Network in IDRISI®Selva. The result of MLP process shows that the distance to CIC and the distance to EAC contributed to the urban growth in Banda Aceh between 2005 to 2009. The distance to CIC more influential than the distance to EAC on urban growth.

Keywords: Urban growth, city center, economic activity center, MLP, Banda Aceh

1.0 INTRODUCTION

In order to achieve sustainable urban development, urban growth and land use/cover (LUC) analysis have become a widely studied topic in the academic research [1, 2]. The occurrence of the urban growth is generally caused by socio-economic and bio-physical factors [3, 4] to accommodate the population growth and human activities [5, 6]. In this paper, the urban growth is defined as a process of land transformation from non built-up area to built-up area [7].

The technology development and the availability of spatial data allow a simulation activity to predict the urban growth, therefore, it can be used as a consideration in making appropriate policies that would not degrade the environment quality. Several simulation models which are widely used by planners, researchers, and geographer are agent-based

method, cellular automata, and logistic regression [8, 9].

The characters of urban growth need to be examined for the preparation of spatial plans. Indonesian cities have their own growth character, due to the geographical influence, including coastal areas and the islands. This results in a diverse community character, especially social and cultural interaction. Similarly, in terms of its formation history, the cities are originated either from the trade center, the plantation center, administration center, or mining center. They generally develop in areas adjacent to coastal areas when these sites are highly vulnerable to flooding and tsunamis, particularly in the cities lies in south west coast of Sumatra and Java. These cities are influenced by Indonesian cultural societies which is adjacent to the coastal areas, not only in terms of primary activities such as collecting seafood, but also tertiary activities such as trading and service activities (port services), the center of economic transactions across regions, as well as the central administration at the district, province, and country. Banda Aceh is one of capital city in Indonesia that is geographically located in the coastal region. In December 2004, this city has been hit by a tsunami from which a huge destruction over the city.

In the areas affected by the tsunami, the growth should also be controlled [10]. Results of previous studies show that the tsunami of 2004 added more than two million poor people in the five most affected countries, namely Indonesia, India, Sri Lanka, Maldives, and Thailand. The economic impact on the local and community levels also occur, especially an increase in the number of poor people [11].

Rehabilitation and reconstruction process allows people to regain their homes, livelihoods, education, health care, and national infrastructure development. Thus, it becomes clear that the state of the recovery process made some significant progress in certain sectors affected by the tsunami [12]. So, an appropriate policy should be implemented to control the growth of the city to achieve sustainable urban planning.

Although growth factors have been identified by many researchers, a city experiencing such a tremendous disaster, like a tsunami, has nothing much can be done. The studies were only limited to management planning and some basic principles to reduce risk and anticipate the tsunami [13, 14].

The focus of disaster mitigation is done through land use, development policy, building design, and site planning [13]. Spatial planning based on disasters has the ability to reduce disaster risk by allocating spatial allotment (zoning), however, it still needs integration with other disaster risk reduction tools [15]. Studies related to location planning for public facilities in tsunami-prone areas are also conducted [16]. In relation to the environment, natural methods are sufficient to reduce the tsunami wave energy and maintain coastal vegetation [17].

This study focuses on the aspects of location as driving factors of the urban growth. Location theory is a theoretical explanation associated with the layout of the economic activity. This layout always relates to the geographical allocation of limited resources which has an impact on both locations of various economic and social activities [18]. In the region affected by the tsunami in Banda Aceh, the built-up area was growing up doubled between 2005 to 2009 [9, 19].

In relation to the location, further review should be performed to determine the effect of distance to the city center (CIC) and to economic activity center (EAC) in the process of land use change in the city which has been hit by the tsunami. Based on Qanun no. 4 of 2009 about spatial planning of Banda Aceh 2009-2029, the coastal area is an area with a very low density and limited growth area (restricted area). This study focuses on the relationship between distance to CIC and EAC on the urban growth and land use/cover (LUC) changes in Banda Aceh.

2.0 MATERIAL AND METHOD

2.1 Study Area

The study was conducted on the administrative area of Banda Aceh (Figure 1), which is geographically located near an active fault Semangko [20]. It is between 5 ° 16'15 "N - 05 ° 36 '16" N and 95 ° 16 '15 "E - 95 ° 22' 35" longitude. The area covers around 6,000 ha with an average height of 0.80 m above sea level. Population in 2011 was 228.560. Banda Aceh consists of nine districts, 70 villages and 20 urban villages. The position of Banda Aceh city which is very close to the subduction zone, makes this city very vulnerable to earthquakes and tsunamis. Historically, most of the earthquake off the coast of Sumatra is a trigger to the mega thrust, as occurred in Aceh on December 26, 2004; the Nias earthquake on March 28, 2005, and later on September 2007 [21].

Economic activities in Banda Aceh have encountered an advanced and rapid development. Efforts to accelerate the city development, implemented by the government with the positive support by all elements of the societies and business communities, have contributed a significant impact on economic progress in Banda Aceh. It can be observed by the fact that the development of regional gross domestic product (GDP) is likely to increase. The tertiary sectors have provided a great contribution to increase the GDP value in Banda Aceh. More than half or nearly 86.21 percent of GDP is contributed by the added value of the tertiary sector (2011).

2.2 Methods

The urban growth and LUC were identified using satellite imagery of 2005 and 2009. Classification of land use/cover each year was analyzed by Geographic Information System (GIS). It is quite effective to facilitate and speed up the analysis of urban growth. Land use classification uses supervised

classification methods which are available in ArcGIS® 10.1 [9]. Land category was classified into two categories, namely the built-up and non-built-up area [7, 9, 22]. The built-up area includes concrete structure, such as pavement, buildings/housing, roads, bridges, etc. [22], while the non-built-up area includes trees, grasses, and water saturated soil (pond). On the other hand, the other category includes a body of water (sea, rivers, lake) and other uses [9].

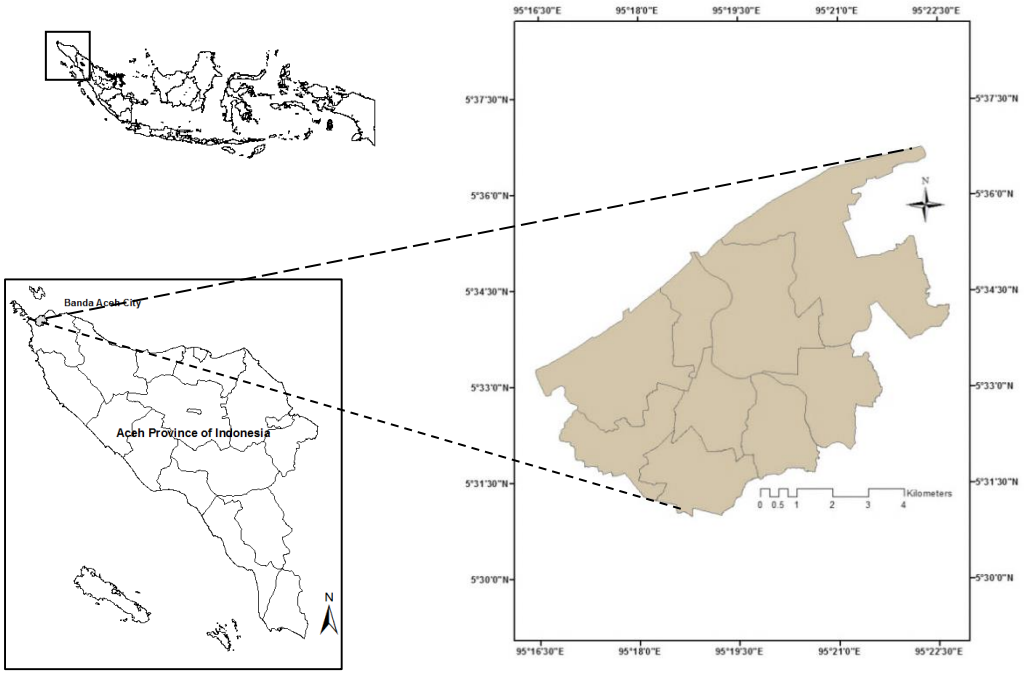
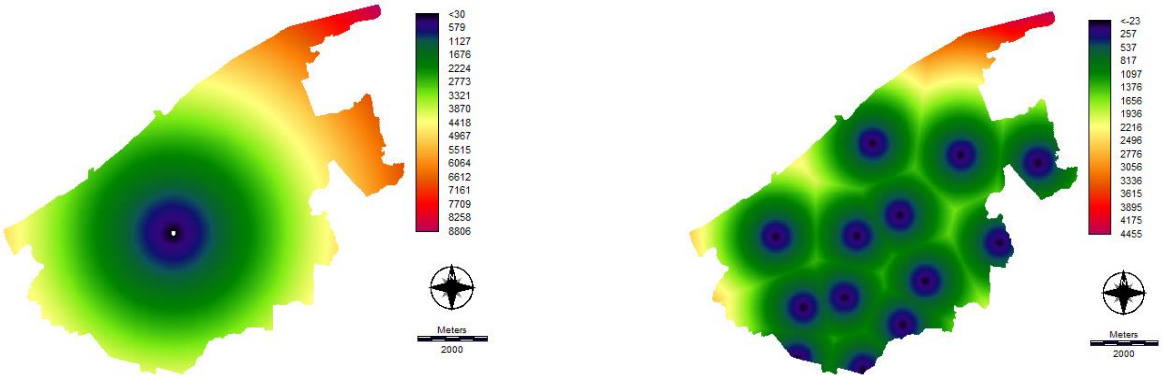


Figure 1 Study area of Banda Aceh, Indonesia

Urban growth probability or change is the dependent prepared by LUC 2005 and LUC 2009 using IDRISI® Selva. The independent variable is a dichotomous data, if there is growth, a value of 1 is given and if growth does not occur the value of 0 is given. Meanwhile, distance to CIC and distance to EAC are continuous variables. These variables were identified using a shape file in order to determine the distance to CIC and the distance to EAC. They were transformed to raster data and used to identify CIC and EAC using the Euclidean distance in ArcGIS® 10.1. CIC is the location of the Mesjid Raya Baiturrahman, while the EAC is as specified in the Qanun no. 4 of 2009 on Banda Aceh Spatial Planning 2009-2029. Furthermore, these variables were exported to IDRISI® Selva and used together to form a model of the MLP Neural Network through the Land Use Change Moduler (LCM). The sample used in this study was 10,000 pixels from satellite image. The identified variables can be seen in Figure 2.



(a) Distance to CIC (b) Distance to EAC

Figure 2 Distance to city center (CIC) and to economic activity center (EAC) [9]

Neural network gain weight value of a particular learning algorithm. These weights are used in transforming the value of the input node to the output node. The learning algorithm is a stage adaptation of the weights that have been formed at random. Renewal of the weights is generally formulated as follows [23].

$$w_{ij}(n+1) = w_{ij}(n) + \Delta w_{ij}(n) \quad \text{..... (1)}$$

where $\Delta w_{ij}(n)$ is calculated by the learning algorithm and $w_{ij}(n)$ is the initial weight is determined randomly at initialization stage. Every relationship of unit i to unit j has a weight w_{ij} which indicates the strength of the connection. The number of weighting, a_j for an input x_{ij} and weights w_{ij} are defined as follows:

$$a_j = \sum_{i=1}^{n} w_{ij} x_{ij} \quad \text{..... (2)}$$

where the value n is the number of inputs to a neuron. Activation function used the logistic sigmoid activation function:

$$g(a) = \frac{1}{1+e^{-a}} \quad \text{..... (3)}$$

Error value, $E_j(n)$, the actual output $y_j(n)$ and the output value of the neuron $d_j(n)$ is calculated by the formula:

$$E_j(n) = d_j(n) - y_j(n) \quad \text{..... (4)}$$

Formula with back-propagation learning is:

$$\Delta wij = \eta xi + a\Delta wij = \eta xi - a\frac{\delta E_j}{\delta w_{ij}} \quad \text{..... (5)}$$

3.0 RESULTS AND DISCUSSION

3.1 Land use/cover (LUC) Change

The analysis of the results toward the land use in 2005 and 2009 showed that the built-up area had a twofold increase in four years (Table 1). While non-built-up area had decreased about 200 ha. The built-up area is estimated to increase in line with the population development on the average of 6.4% per year between 2005 and 2009. The growth of the built-up area is a change of non-built-up areas and others. In the area near the beach, some parts of land, previously built-up areas, have transformed into non built-up area and others or water body due to the force of a tsunami.

Although many houses or new buildings are constructed in the area around the beach, by applying realignment or land consolidation in some villages, many built-up land areas have turned into a non-built-up one. Government through the Qanun no. 4 of 2009 stipulates that the region around the coast includes the areas of restricted growth (restricted area). This is an effort to minimize casualties and damage when the tsunami occurs. Generally, downtown area did not face any changes (persistence), and remains dominated by the built-up area, as well as the addition of new built-up area. Changes in land use for each year can be seen in Figure 3 [9, 19].

Table 1 Land use change based on class [9, 19]

Land category	2005		2009	
	ha	%	ha	%
Built-up area	1,118.89	43.46	2,134.90	47.22
Non built-up area	3,432.04	53.35	3.199.84	49.58
Others	1,446.96	3.20	663.16	3.20

Significant growth of the built-up area is due to the high demand housing, especially those displaced by the tsunami. The provision of housings is part of the post-tsunami rehabilitation and reconstruction, in which the building is built on land that is also used for completion before the tsunami. The increase of the built-up area is also due to the increasing development of city infrastructure, such as roads, ports, bridges, office buildings, and markets. Further growth is used to accommodate rapid growth of the population between 2005 and 2009. This suggests that Banda Aceh is an attractive destination for migrants, both to work and enjoy the education, although its primary function is acting as the central government of Aceh Province.

3.2 Urban Growth

Data inputs to the LCM in IDRISI® Selva generate distance to the CIC, which has a greater influence than that of the center of economic activity to the urban growth with an overall accuracy rate of 59.32%. Learning MLP in the study was conducted over 10,000 samples per class and resulted in a momentum factor of 0.5. This suggests that the control of the variables tend to produce the same effects.

The number of absorbed units is set as shown in Figure 4. The yield curve produces the performance of 0.49. Classification of a pattern to the number of neurons in the input layer of the MLP is determined by the number of features selected to represent the relevant patterns in the feature space. Neurons in the input layer act as a sensory unit to compute the function. Each neuron in the hidden layer and the output calculate the sigmoidal function of the number of products, the input value and the weight value of the variable relationships [24]. The weight analysis of the neuronal layer can be seen in Table 2. Sigmoid constantly result in value of 0 to 1 or it can be calculated using the same gradient forms between -1 to 1. Sigmoid constant obtained from the growth of Banda Aceh is 1.

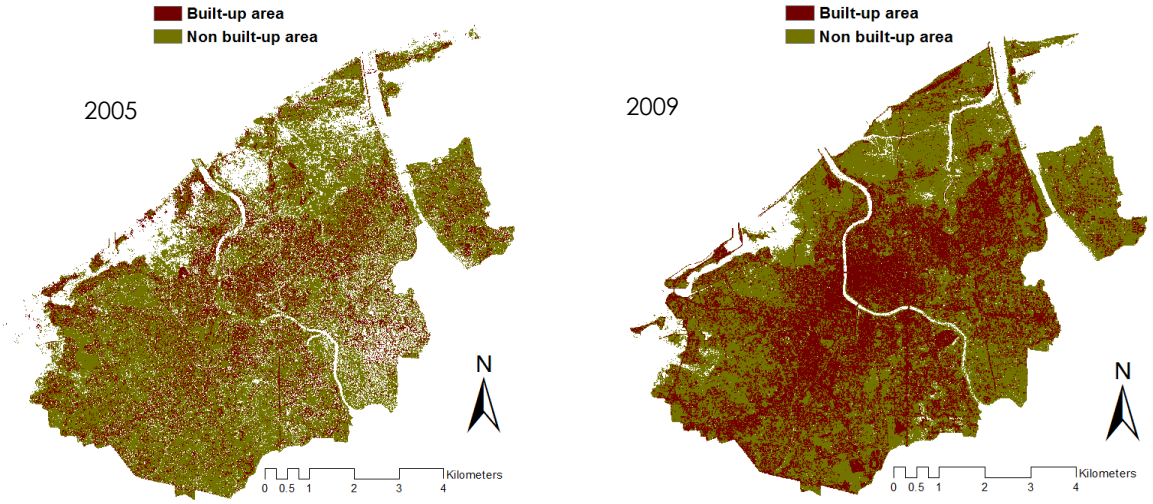


Figure 3 LUC 2005 and LUC 2009 [9, 19]

The urban growth of Banda Aceh affected by the distance to the CIC (an accuracy of 59.19 %). The closer to the CIC, the higher the probability of growth, like the theories i.e Von Thunen, [25]. Distance to EAC based on spatial planning of Banda Aceh was less impact of the urban growth.

Distance to the road has a positive effect on urban land conversion [9, 25]. The farther from the CIC, the transition potential decreases, like in the eastern part of the city and the suburbs. Developments which occurred in Banda Aceh has a special character as a city which ever hit by the tsunami. Here can be seen that the transition potential because of the distance to CIC and distance to economic activity created growth or development does not occur in all regions, but it's limited to certain places with different variable intensity and unbalanced, based on theories i.e. Perraux and Hirchman. Spatial economics cannot be separated from the spatial geographical [25].

To achieve sustainable development, the growth should be controlled. There should be parts of the region are planned and optimized as parks and urban forest, which can improve the environmental quality of urban area. The use of urban space is preferred if the environment surrounding the thermal comfort for the good of society. Thermal comfort in the external environment will also have a positive effect for the urban space, which will make the use of energy becomes smaller [26]. It needs a minimum level of environmental capital to be maintained to ensure the stability and resilience environment [27].

Table 2 Weight of neuron with layers

Input layer and hidden neuron			**Hidden layer and output neuron**		
Neuron	Hidden -1	Hidden-2	Neuron	Output-1	Output-2
Input-1	-5,8329	2,7237	Hidden -1	8,3603	-8,3598
Input-2	2,9610	-5,600	Hidden-2	-1,5554	1,5553

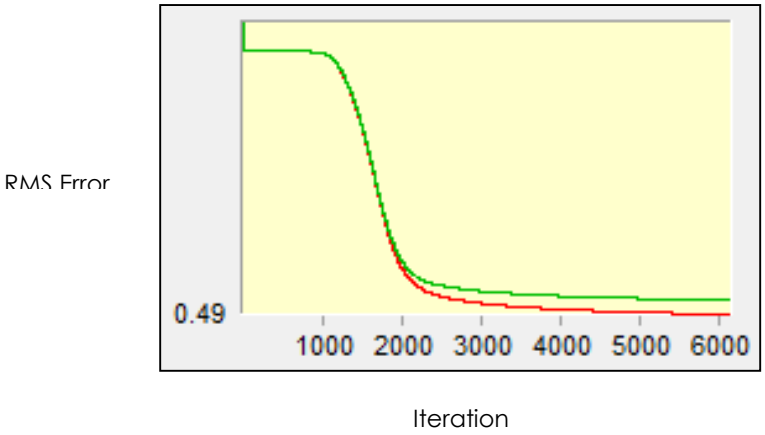


Figure 4 RMS error vs. iteration

4.0 CONCLUSION

The rapid change of the land use/cover has occurred in Banda Aceh after the tsunami, in the period of 2005 and 2009. The change from the non built-up area to the built-up area nearly doubled. It is to accommodate the needs and population increase, with the construction of housing, roads, and other municipal facilities. Uneven growth occurs. The distance to CIC still has a high probability toward the urban growth, while the northeastern part of the city is in the lowest probability of growth [9]. With the growth of built-up area in Banda Aceh, in relation with location theory, the distance to the CIC has a greater influence than that of the distance to the EAC, yet, these variables affect the urban growth. The determination of locations in the center of economic activity by the government has contributed less to the probability of the city growth. Spatial planning should consider mitigation and sustainable development. The urban growth should be controlled. Therefore, there will be remaining areas maintained as a non-built-up area, such as parks and urban forest. Further study should be performed to examine the aspects of disasters and sustainable development toward the occurring urban growth.

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