Directions of Settlement Development in Banda Aceh City based on Land Capability

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Abstract. Banda Aceh City is the center of government and economic activity of Aceh Province. Designated as central city of Aceh Province, Banda aceh often faces a problem of not considering the population growth and land availability. This research is based on the increasing need of land caused by population growth, while the potential land for development continues to decrease. The land capability analysis aims to assess the level of land capability for development based on physical aspects so that land use can be carried out optimally and sustainably. The physical aspects of land capability are then called land capability unit. From the nine units analyzed, mostly represent high land capability class, except drainage and natural disaster unit. The results of the land capability analysis dividing Banda Aceh City into two classes. Class D or area with high development capability takes the widest part or 4,394 Ha (74.4%) and the rest 1,508 Ha (25.6%) is Class C or moderate development capability. Based on this condition, the direction of settlement development could be developed is about 26% or 190.3 Ha. Therefore, appropriate direction is needed for the sustainability of settlements in the future.

1. Introduction

1.1. Background

The increasing population over time has an impact on development activities demand. Settlement facilities, infrastructure networks, and other constructions are increasing rapidly [1]. This will certainly followed by increasing need for land to accommodate the development activities. The problem is development progress grow faster while the land carrying capacity can be decrease [2]. Banda Aceh City is the capital city of Aceh Province as well as the center of government and economic activity. The population density of Banda Aceh City in 2020 is 4,122 people/km², while Lhokseumawe City is 1,042 people/km² and Langsa City is 709 people/km². In terms of the percentage Aceh province area, Banda Aceh City only occupies a 0.11% portion of the total area of Aceh Province, while Lhokseumawe City occupies a 0.31% and Langsa City occupies 0.45% portion [3]. Thus, Banda Aceh city is the most populous city in Aceh Province.
The need for space continues to increase naturally along with the complexity of the needs of social life. The most extensive land use in an area is generally occupied by settlement land uses. However, the development of settlements from each part of the city or region is not the same, depending on the natural physical conditions and facilities of the city or region, the potential resources (job opportunities) available, and the characteristics of community life in the area [4]. Settlements are unitary areas where housing is located. This allows any problems in the location of a housing area to be inseparable from the scope of the settlement itself [5]. The development of housing or settlements that are not following the proper regulations will cause development problems [6].

The negative impact of non-optimal land use can be overcome by determining the suitability of the land. Therefore, the physical aspects must be considered. The settlements development that are not following the proper land capability will affect the rate of development [6]. Based on the description above, it is necessary to optimize land use efficiently by obeying the spatial plan. So that decisions on the most profitable land use can be made [7]. Physical aspects such as hydrology, geology, and geomorphology act as important factors in determining land capability. It represents the quality of land [8]. However, the land capability with limitations cannot support the development. The limited land capability shows that not all land use can be supported by the land [9]. Therefore, the needs of settlement allocation in the city becomes important to consider according to the conditions of the existing land capabilities.

1.2. Aim
This study aimed to find out the settlement development directions in Banda Aceh City based on its land capability from the physical aspects.

2. Method

2.1. Study Area
The study area is Banda Aceh City, the Capital of Aceh Province. It is geographically located between 05°16'15"–05°36'16" North Latitude and 95°16'15"–95°22'35" East Longitude. Administratively, Banda Aceh City is divided into 9 sub-districts and 90 villages. Banda Aceh City is surrounded by the Aceh Besar Regency in the southern, western, and eastern and bordered by Malacca Strait in the northern (figure 1).

![Figure 1. Administrative Map of Banda Aceh City.](image-url)
2.2. Analysis of the Land Capability

Analysis of the Land Capability Unit refers to the Regulation of the Minister of Public Works No.20/PRT/M.2007 [10] concerning Technical Guidelines for Physical and Environmental, Economic and Socio-Cultural Analysis in the Preparation of Spatial Plans. The analysis was carried out by overlaying the various required data and their weighting to obtain nine parameters needed for settlement development. The nine parameters include: Morphology; Slope Stability; Foundation Stability; Water Availability; Disaster Vulnerability; Drainage; Waste Disposal; Erosion; Ease of Construction. Therefore, the data used in determining the nine parameters include: Morphological Map, Altitude Map, Slope Map, Soil Type Map, Rainfall Map, and Disaster Vulnerability Map. Each map is superimposed by assigning scale value of 1-5, where scale value 1 is for the lowest criteria and the scale value 5 is for the highest criteria [10]. The steps of analysis are presented in figure 2.

Figure 2. Flow chart of settlement development analysis.

2.3. Analysis of Settlement Development Capability

The analysis of the development capability for settlements is carried out from the nine parameters of land capability that have been obtained. The stages carried out in this analysis include:

1. Analyzing 9 parameters of land capability unit using the weighted overlay method, by giving a scale value of 5 for the highest value and scale value of 1 for the lowest value.
2. Multiply the values on the scale value with the weight of each parameter (table 1) using the weighted sum method.
3. Superimpose all land capability units produced by adding the multiplication of the values and weights of all land capability units.

4. Determine the value of the interval used as a divider for land capability classes for the classification of settlement development in Banda Aceh City [6,11].

| Table 1. Weighting of Land Capability Units. |
|-----------------------------------------------|
| No   | Land Capability Unit       | Weight |
|------|---------------------------|--------|
| 1    | Morphology                | 5      |
| 2    | Ease of Construction      | 1      |
| 3    | Slope Stability           | 5      |
| 4    | Foundation Stability      | 3      |
| 5    | Water Availability        | 5      |
| 6    | Erosion                   | 3      |
| 7    | Drainage                  | 5      |
| 8    | Waste Disposal            | 0      |
| 9    | Natural Disaster          | 5      |

The weight shows the level of importance of each land capability unit to determine land capability value. Land capability value is the multiplication of each land capability unit and the weight. It generates the interval value from 32 as the minimum value to 160 as the maximum value (table 2).

| Table 2. Land Capability Value of Banda Aceh City. |
|--------------------------------------------------|
| Land Capability Unit | Weight x Scale Value |
|----------------------|----------------------|
| Morphology           | 5 5 10 15 20 25      |
| Ease of Construction | 1 1 2 3 4 5           |
| Slope Stability      | 5 5 10 15 20 25      |
| Foundation Stability | 3 3 6 9 12 15        |
| Water Availability   | 5 5 10 15 20 25      |
| Drainage             | 3 3 6 9 12 15        |
| Erosion              | 5 5 10 15 20 25      |
| Disposal Waste       | 0 0 0 0 0 0          |
| Disaster Vulnerability | 5 5 10 15 20 25     |

Total value (Weighted Sum) Minimum Value = 32
Maximum Value = 160

After obtaining the land capability value, settlement development classification is carried out based on the maximum and minimum value ranges in each class with an equal interval approach. As the result, classification is determined for the settlement development area which is divided into 5 development classes (table 3).

| Table 3. Classification of Settlement Development Classification. |
|---------------------------------------------------------------|
| No   | Land Capability Class       | Settlement Development Classification |
|------|-----------------------------|--------------------------------------|
| 1    | Class A                     | Very Low Development Capability      |
| 2    | Class B                     | Low Development Capability           |
| 3    | Class C                     | Moderate Development Capability      |
| 4    | Class D                     | High Development Capability          |
| 5    | Class E                     | Very High Development Capability     |
2.4. Directions of Settlement Development in Banda Aceh City

Based on the Ministry of Works direction, proportion of built-up and unbuilt-up land determined according to land capacity. The regulation manages the difference in the allocation of space for 5 types of development areas; where very low development areas may only be used as protected areas; low development area is only used as buffer areas and/or protected areas; the development area is being used as a developed area with the proportion of built land and un-built land of 50% : 50%; the high development area is used as a developed area with various activities in the proportion of 75% : 25%; and the very high development area can be used as a developed area with various activities in the proportion of 90%: 10% [10]. The land availability is obtained by calculating the area of land that has the potential to be developed (as a settlement area) and is not a protected land such as forest and green open space. Calculations were carried out using Ms. Excel from ArcGIS attribute data. The available land includes vegetated land such as rice fields, mixed gardens and ponds whose form of use is still possible to change.

3. Result and Discussion

3.1. Land Capability Unit Analysis

The land capability analysis produces a different class in each analysis, which is divided into the range of class 1 to class 5. However, the different physical conditions of the area cause the resulting land capability unit class to vary as well. The best land capability unit class is indicated by class 5 and the closer to class 1 the land capability is getting lower or can be categorized as very bad. The overall land capability unit class for Banda Aceh City and its area is shown in table 4.

| Land Capability Unit | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Total | %  |
|----------------------|--------|--------|--------|--------|--------|-------|----|
| Morphology           | 1.753  | 4,149.9| 5.903  | 100    |
| Ease of Construction | 1.650  | 4,252.2| 5.903  | 100    |
| Slope Stability      | 1.578  | 4,324.8| 5.903  | 100    |
| Foundation Stability | 1,362.7| 4,319.2| 5.903  | 100    |
| Water Availability   | 1,152  | 3,680.8| 1,069.5| 5.903  | 100    |
| Drainage             | 4,623.9| 221.2  | 5.903  | 100    |
| Erosion              | 1,152  | 1,566.7| 3,193.3| 5.903  | 100    |
| Disposal Waste       | 1,152  | 1,566.7| 3,193.3| 5.903  | 100    |
| Disaster Vulnerability| 2,046.6| 3,856.6| 5.903  | 100    |

Table 4. Area of Land Capability Unit in Banda Aceh City.

Table 4 allows us to see that most of the land capability units are in class 4 and 5, indicating that the physical condition of Banda Aceh City is slightly suitable for development. However, there are several land capability units that have the potential to obstruct. The lowest land capability unit is indicated by class 1, namely land capability unit for drainage, followed by land capability unit of foundation stability and land capability unit of natural disaster which are in class 2 and 3. Settlement development must pay attention to all physical aspects in order to minimize losses that will occur in the future. Reflecting on the Aceh tsunami that occurred in 2004, Newton and Icely, 2007 [12] argue that tsunamis can threaten settlements and destroy coastal communities in them, so a careful plan is needed to develop settlements in disaster-prone areas. The maps of land capability unit in Banda Aceh City are presented in these following figures.
Figure 3 and figure 4 show us that land capability unit of Banda Aceh City is in the range of grade 4 and grade 5 which supports development. It has relatively flat land surface with a slope of 2-8% and an altitude ranging from -0.45 m to +1.00 m above sea level, with an average height of 0.8 m above sea level [13]. In general, Ease of construction aims to determine the level of ease of land to be excavated or matured in the development and development process in an area. Ease of Construction is in line with morphology land capability unit, the flatter the morphology of land, the easier it is for construction [14]. 73% of the area of Banda Aceh City is an area with high ease of construction while the rest is in moderate ease of work. This physical condition allows Banda Aceh City to have a high capability to be developed into various forms of land use without resorting to engineering technology. The next land capability units are presented in figure 5 and figure 6.

Land capability unit of slope stability aims to determine the level of slope stability in the development area in accepting the load of the building. The slope stability of an area is low if the area is prone to landslides or easy to move [10]. Based on the results, Banda Aceh City mostly has high slope stability (73%). This is related to the research of [15] that this city is very suitable for settlements in terms of slope class. Meanwhile, 26.7% of the city shows moderate slope stability, which is influenced by the vulnerability to earthquakes. The rock and soil conditions that make up the slopes, geological structures, and rainfall influence on the slope stability [16]. Slope stability is closely related to seismic ground motion, so it needs to be considered in civil construction for settlements [17]. This is also related to land capability unit of foundation stability and disaster vulnerability.
Settlements where people live should consider the stability of the foundation in order to minimize losses due to earthquakes [18]. Based on the results, Banda Aceh City is dominantly has moderate stability. This is closely related to the land capability of natural disasters. As already known, Banda Aceh is prone to earthquakes and tsunamis (figure 11). Disaster vulnerability is a very crucial parameter in the development of settlements. Therefore, it is very important to implement disaster-based spatial planning, especially in coastal areas that are prone to tsunamis [19]. Besides, the following figures shows the other land capability units in Banda Aceh City.

Figure 7. Land Capability Unit of Water Availability.
Figure 8. Land Capability Unit for Drainage.
Figure 9. Land Capability Unit against Erosion.
Figure 10. Land Capability Unit of Waste Disposal.
Figure 11. Land Capability Unit against Natural Disasters.
3.2. Settlement Development Capability of Banda Aceh City

Based on the results of the 9 land capability units obtained, all of the units are superimposed by using Weighted Sum method through ArcGIS software. The result represent 0 as minimum value and 160 as maximum value (table 5). This is in line with research in Tapaktuan and Bima City [6,11].

| Interval | Land Capability Class | Settlement Development Classification |
|----------|-----------------------|-------------------------------------|
| 0-32     | Class A               | Very Low Development Capability     |
| 33-64    | Class B               | Low Development Capability          |
| 65-96    | Class C               | Moderate Development Capability     |
| 97-128   | Class D               | High Development Capability         |
| 129-160  | Class E               | Very High Development Capability    |

Table 5. Classification of Settlement Development.

Based on the results, Banda Aceh City is in the interval range 89-124 that divided into 2 land capability classes, they are class C and class D (table 6). Above 4,394 Ha or 74.4% of the Banda Aceh City area is Class D or an area with a high development capability. The rest, covering 1,508 Ha or 25.6% are Class C or moderate development capability (figure 12). This is in line with the research of [20] that the land capability in Teluk Betung Selatan District, Bandar Lampung is class D and C because it is influenced by the lack of drainage conditions. The physical condition of the land that is not supported by good drainage will cause flood disasters that affect the economic, social, and environmental aspects of the community.

| No | Total Value | Land Capability Class | Development Classification | Area (Ha) |
|----|-------------|-----------------------|---------------------------|-----------|
| 1  | 89-109      | Class C               | Moderate Development Capability | 1,508    |
| 2  | 109-124     | Class D               | High Development Capability  | 4,394    |
|    | Total       |                       |                           | 5,903    |

Table 6. Land Capability Classification of Banda Aceh City

![Figure 12. Land Capability Unit for Banda Aceh City.](image)

Weighted Sum analysis shows that Banda Aceh City is in the range of 89 - 124, which is included in the moderate development (class C) and high development (class D) so that it is suitable for use as a developed area for certain activities [13]. Based on this condition, development activities are directed at moderate development locations. Meanwhile, low development areas and very low development
areas can only be designated as protected areas that function for water absorption so that disruptive or destructive activity is not allowed.

3.3. Settlement Development Directions in Banda Aceh City

Based on the land capability and settlement development analysis before, it can be directed how Banda Aceh City should be developed especially for the settlements, by considering its built land and also the un-built land. Considering that the proportion of land built in Banda Aceh City has now reached 75.7%, the actual land in the development city has a deficit or exceeds the direction of the land cover ratio. This condition can be triggered by several things, but the dominant one is the population growth rate which stimulate urbanization [21] and has a major effect on the increasing of settlement area resulting land use change [22] as happened in Marisa City [23]. Seeing the facts that happened in Banda Aceh City, the development that can still be done in this city is in the moderate capability class area. From the calculation results, it is found that for areas with high development there is no available land (table 7 and table 8).

| Table 7. Available Land Area at Moderate Development Capability. |
|---------------------------------------------------------------|
| Land Type          | Area  | %   | Available Land |
| Built-up Land      | 175.2 | 23.9| 190.3 Ha       |
| Unbuilt-up Land    | 555.8 | 76  | -              |
| Total              | 100   |     | 5,903          |

| Table 8. Available Land Area at High Development Capability. |
|-------------------------------------------------------------|
| Land Type          | Area   | %   | Available Land | Note                      |
| Built-up Land      | 3,052  | 75.7| -              | Exceeds cover ratio       |
| Unbuilt-up Land    | 981.23 | 24.3| -              | direction 0.6%            |
| Total              | 100    |     | 5,903          |

Based on the area data in tables 7 and 8, it is shown that the available land area in Banda Aceh City according to its development capability has different land cover ratio directions. With this direction, Banda Aceh City can still be designated as a settlement of around 29.7% or an area of 190.3 Ha for moderate development area and for a high development area Banda Aceh City has developed an area of 75.7% which indicates the land has been in deficit or exceeds land cover ratio direction.

4. Conclusion

Land capability of Banda Aceh City tends to be in a homogeneous class, where 74.4% is an area with high capability to develop and the rest 25.6% is an area with moderate development capability. Based on the directions of land cover ratio, it can be found that the availability of land in Banda Aceh City has a shortage of land, while the capacity is only 26%. For this reason, the development of the area can be directed to land that can still be developed in an area of 190.3 Ha, by considering the needs further. Considering the condition of the existing land capability in Banda Aceh City and the availability land, the government should start implementing development alternatives with minimal land, such as the construction of flats so that the housing needs can be met sustainably without compromising the capability of the land itself. Following this result, stakeholders should pay attention to the construction of existing buildings in this area. Earthquake resistant buildings with strong foundation structures are important to avoid collapse due to earthquakes.

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