Biophysical Aspects that Influence the Increase of Slum Area in the Sigli Region, Aceh, Indonesia

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Abstract. The location with a high level of accessibility and affordability has a high development of built-up land, which in turn causes slum settlements. There are some biophysical factors, which can cause slum settlements, including road networks and city service centres. Pidie District is one of the districts in Aceh Province which has a slum prevalence of more than 50 hectares, where mostly are located in the District of Sigli City. For that reason, this current study aimed to identify the growth patterns of slum settlements in the Sigli City between 2008 and 2018 based on biophysical aspects. The approach used was spatial-based quantitative, where data on growth patterns of slum settlements were processed using ArcGIS 10.6 software. Driving factors included distance to roads, distance to river, distance to coastline, and distance to city service centre. The results showed that the change in land use into settlements was 101.33 Ha, of which 51.41 Ha were slum settlements. From this number, 26.84 Ha of slum settlements grew adjacent to the road, 14.66 Ha adjacent to the river, 5.49 Ha adjacent to the coastline, and 26.84 Ha adjacent to the city service centre.

1. Introduction
Law No.1 of 2011 on Housing and Residential Areas states that the basic physical facilities of a residence must meet the standards for adequate, healthy, safe, and comfortable housing, so that it can support the implementation and development of social, cultural, and economic life. If these criteria not fulfilled, there will be a decline in the quality of the residential function, which result in building irregularities, high building density, as well as inadequate infrastructure and building quality. This condition then called as slum settlement or slum area [1].

Globally one in eight people lived in slums, so in total about one billion people lived in slum conditions, especially in developing countries. This data estimated that around 30% of the urban population lived in slum areas between 2000 and 2014, and this prevalence projected to grow rapidly where the poverty issues will be the main impact of this phenomenon later on [2].

Indonesia is one of the developing countries in the Asia-Pacific region, which has an area of approximately 191,686,200 Ha [3]. Furthermore, according to Presidential Regulation No. 2 of 2015 on National Medium-Term Development Plan 2015-2019, it mentioned that slum area in Indonesia reached 38,431 Ha. Meanwhile, in Aceh Province itself, the area of slums is estimated to be approximately 5,266.49 Ha. Pidie Regency is one of the districts in Aceh Province, which has a slum...
prevalence of over 50 Ha. The identification from Pidie Regency Government found that the largest slum area was in the Sigli Region with an area of 51.41 Ha.

The presence of slums can be caused by several factors. Population growth and increasing urbanization can have implications for activities related to community life, both economy and social of local communities, resulting in the emergence of slum settlements [4]. Therefore, the problem of slum settlements cannot be identify from just one perspective, but needs to be reviewed holistically because the implementation of the housing sector will have implications for various aspects of life, including political aspects, economic aspects, socio-cultural aspects, and of course the physical aspects of nature (biophysics) [5].

Biophysical aspects consist of some driving factors, involving distance to green open spaces, historical sites, rivers, roads, coastal areas, economic and service centres, city facilities, utilities, and slopes; and inhibiting factors including spatial planning and protected area policies [6, 7, 8, 9]. The biophysical aspect that causes the development of slum settlements in Sigli City is the distance of these settlements to rivers, roads, coastlines, and city service centres. For that reason, this current study aimed to identify the growth patterns of slum settlements in the Sigli Region between 2008 and 2018 based on biophysical aspects.

1.1. Slum Settlement
Law No. 1 of 2011 on Housing and Residential Areas states that settlements are part of a residential environment consisting of more than one housing unit which has infrastructure, facilities, public utilities, and has supporting activities for other functions in urban areas or rural areas. Meanwhile, slum settlements are settlements that are not suitable for habitation due to the irregularity of the buildings and the high level of building density. Besides, the quality of the buildings, facilities, and infrastructure in slum settlements do not meet the requirements [1].

Slum settlements are houses located close each other, where the population can be characterized as having inadequate housing and basic services [10]. Slum settlements can be identified based on the physical characteristics of buildings and the settlement environment, as well as socio-economic and cultural characteristics [11]. Slum settlements also defined as settlements with very bad houses and residential conditions, where houses and existing infrastructure are not in accordance with applicable standards [12].

1.2. Biophysical
Natural or physical is a factor that comes from natural conditions and reflected in the landscape in the form of topography and rivers, while biophysics is a factor that comes from human interaction with physical conditions as seen from the transportation network, road network, economic centre, and infrastructure [13]. Biophysical factors are very important in land use planning, in addition to economic and social factors [14].

Land use change consists of driving factors, including: distance to slope inclination, distance to disaster-prone, distance to river, and distance to city centre [8]. Besides, there is also another perspective in regards to driving factors for urban growth, namely social-economic factors (population density and distance to business centre) and biophysical factors (distance to green open space, distance to historical place, distance to river, distance to road, and distance to coastal areas) [6].

2. Methods
2.1. Data Collection Method
Data collection was carried out through field observations and agency surveys. Field observations were performed to test the interpretation of land changes due to the development of slum settlements. Primary data collection was done by multispectral from satellite imagery in 2008 and 2018. Meanwhile, secondary data is obtained from previous studies, articles from both print and electronic media, literature searches, and official documents from related agencies, such as Regional Development Agency of Pidie Regency.
Land use change was carried out by using the land use map overlay method in 2008 and 2018. The overlay method used ESRI ArcGis 10.6 for determining whether there were changes in land use. The results of this overlay analysis were in the form of a land use change map and a land change matrix. In order to determine the biophysical aspect variables affected land use change and the growth of slum settlements, previous studies that have similar conditions to this study area were elaborated.

2.2. Data Analysis

The approach used in this study was spatial-based quantitative, where data on growth patterns of slum settlements were processed using ArcGis 10.6 software, with driving factors including distance to roads, distance to river, distance to coastline, and distance to city service center.

Biophysical distance affects a spatial dynamic because the distance factor can represent the level of accessibility and affordability of a location. This biophysical distance factor is abstracted spatially using euclidean distance analysis, which is a measurement of horizontal distances using raster data. The calculation is performed by the distance of one pixel center past the center of another pixel to the specified object or phenomenon. The distance is determined by the distance of two pixels in the areas of center point [14].

Figure 1. Research Location
3. Results and Discussion

3.1. Land Use in 2008

Land use in 2008 could be investigated from the land use map for that year, which was derived from high-resolution satellite imagery, namely Quickbird. The method used was digitizing on screen interpretation, so the type of land use in 2008 could be obtained (figure 2).

From the results, the classification of land use in 2008 consisted: roads of 30.56 Ha, graves of 0.36 Ha, sports fields of 2.94 Ha, sea sands of 12.60 Ha, education places of 0.71 Ha, trade and services of 21.76 Ha, worship places of 1.02 Ha, offices and other buildings of 6.77 Ha, plantations of 75.50 Ha, settlements of 94.58 Ha, green open spaces of 0.79 Ha, paddy fields of 43.74 Ha, rivers of 26.91 Ha, fishponds of 234.78 Ha, unused land of 81.23 Ha, and open lands of 28.36 Ha. The total number of land uses in 2008 in the Sigli Region area was 662.61 Ha.

3.2. Land Use in 2018

Land use in 2018 could be investigated from the land use map for that year, which was derived from high-resolution satellite imagery, namely Quickbird. The method used was digitizing on screen interpretation, so the type of land use in 2018 could be obtained (figure 3).
From the results, the classification of land use in 2008 consisted of: roads of 34.32 Ha, graves of 0.79 Ha, sports fields of 2.70 Ha, sea sands of 4.28 Ha, education places of 3.55 Ha, trade and services of 19.72 Ha, worship places of 3.54 Ha, offices and other buildings of 9.12 Ha, plantations of 65.19 Ha, settlements of 144.09 Ha, green open spaces of 1.42 Ha, paddy fields of 29.82 Ha, rivers of 28.72 Ha, fishponds of 211 Ha, unused land of 36.24 Ha, open lands of 16.01 Ha, slums of 51.78 Ha, and tourism sites of 0.32 Ha. The total number of land uses in 2018 in the Sigli Region area was 662.61 Ha.

Figure 3. Land Use in 2018

3.3. Transition of Land Use between 2008 and 2018
The results of the analysis showed that there was a growth of land use in Sigli Region from 2008 to 2018, especially settlement areas. However, a land reduction was also found within those growing areas. The highest land growth occurred in settlements, which increased by 101.29 Ha; followed by
roads of 3.76 Ha, education places of 2.84 Ha, offices and other buildings of 2.35 Ha. Meanwhile, the largest land reduction occurred on unused lands of 44.99 Ha, and then followed by fishponds of 23.78 hectares. With an increase in the residential land growth by 101.29 Ha, 51.78 Ha of which were slum settlements. The transition of land use in 2008 and 2018 can be seen in table 1 below.

3.4. Slum Growth Pattern
The growth pattern of slum settlements in the Sigli Region was obtained through the analysis and identification of the distance between slum settlements and biophysical aspects, included distance to the road, distance to the river, distance to the coastline, and distance to the city service center.

The area of the slum that had been identified was 51.78 Ha, where 27.96 Ha was adjacent to the road, 13.75 Ha was adjacent to the river, 4.27 Ha was adjacent to the coastline, and 5.80 Ha was adjacent to the city service center. Figure 4 below describe the growth pattern of slum settlement in Sigli Region.

Figure 4. Slum Growth Pattern
### Table 1. Land Use Change between 2008 and 2018.

| Land Use Changes | Land Use 2018 (Ha) | Land Use 2008 (Ha) | TOTAL 2018 % 2008 |
|------------------|--------------------|--------------------|-------------------|
| LU 1 (Roads)     | 30.49              | 30.56              | 0.07              |
| LU 2 (Graves)    | 0.56               | 0.36               | 0.19              |
| LU 3 (Sports Fields) | 2.70             | 2.94               | 12.60             |
| LU 4 (Sea Sands) | 4.28               | 4.61%              | 0.42%             |
| LU 5 (Education Places) | 0.13          | 0.24               | 0.05%             |
| LU 6 (Trade and Services) | 0.07         | 0.24               | 0.05%             |
| LU 7 (Worship Places) | 1.47             | 2.02               | 1.40%             |
| LU 8 (Offices and Other Buildings) | 3.51       | 3.71               | 0.56%             |
| LU 9 (Plantations) | 0.04              | 0.00               | 0.00%             |
| LU 10 (Settlements) | 0.13             | 0.20               | 0.17%             |
| LU 11 (Green Open Areas) | 0.51       | 0.71               | 0.22%             |
| LU 12 (Paddy Fields) | 0.07            | 0.00               | 0.00%             |
| LU 13 (Rivers)   | 0.07               | 0.12               | 0.06%             |
| LU 14 (Fishponds) | 0.31              | 0.49               | 0.21%             |
| LU 15 (Unused Lands) | 0.26            | 0.32               | 0.28%             |
| LU 16 (Open Lands) | 2.21              | 2.26               | 0.70%             |
| LU 17 (Slum Areas) | 1.50              | 1.76               | 0.50%             |
| LU 18 (Tourist Sites) | 0.04            | 0.00               | 0.00%             |
| TOTAL 2018      | 34.32 (0.70)      | 34.35 (0.69)       | 1.57%             |

Note: LU 1 (Roads), LU 2 (Graves), LU 3 (Sports Fields), LU 4 (Sea Sands), LU 5 (Education Places), LU 6 (Trade and Services), LU 7 (Worship Places), LU 8 (Offices and Other Buildings), LU 9 (Plantations), LU 10 (Settlements), LU 11 (Green Open Spaces), LU 12 (Paddy Fields), LU 13 (Rivers), LU 14 (Fishponds), LU 15 (Unused Lands), LU 16 (Open Lands), LU 17 (Slum Areas), LU 18 (Tourist Sites).
4. Conclusions
Based on the research findings, it could be concluded that the growth of slum settlements in the Sigli Region was 51.78 Ha. The entire slum areas fulfill the criteria for biophysical aspects –adjacent to roads, rivers, coastlines, and city service centers. The distance of slum settlements adjacent to the road greatly influenced the growth pattern of slum settlements with amount of 54%, followed by slum settlements adjacent to rivers (as much as 26.55%), adjacent to the coastline (as much as 8.26%), and adjacent to city service centers (as much as 11.20%).

This study gave several recommendations, especially for stakeholders in Pidie Regency. As the growth pattern of slum settlements can accurately represent the growth phenomenon of slum settlements, so it is necessary to have a spatial policy taken by stakeholders in Pidie Regency to solve the slum settlement issues. One of the proactive approaches that can be performed is developing strict regulations in issuing building permits within the identified slum areas. Furthermore, with the existence of biophysical factors, the potential growth of slum settlements must be accommodated in the Pidie Regency Spatial Pattern Plan, especially in the Sigli Region. Hence, the sporadic slum settlement developments do not occur which can result in decreasing the quality of residential functions.

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