The Long-Term Morphodynamic of Barito Delta, Southern Kalimantan, Indonesia

Deasy Arisanty, Junun Sartohadi, Muh. Aris Marfai and Danang Sri Hadmoko
Faculty of Geography, Gadjah Mada University, Bulaksumur 55281, Yogyakarta, Indonesia

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Abstract: Barito Delta morphodynamic had contradictive role with its potency and problem. Potency in Barito Delta may support the development of Banjarmasin City, but development of Barito Delta may decrease the capacity of transportation in Barito River. Multitemporal topographic map and Landsat satellite image during the period 1862-2008 were used to analyze the long-term delta morphodynamic. The analysis consisted of delta growth, yearly growth, growth orientation, delta shape, and shoreline changes. The research showed that the Barito Delta had developed during the period 1862-2008. Barito Delta had developed to south orientation. The growth of Barito Delta during the period 1862-1946 was 27.82 km² or 0.33 km²/year. However, during the period 1946-1997, Barito Delta growth was 175.82 km² or 3.45 km²/year. Area of Barito Delta decreased during the period 1997-2004. The reduction of Barito Delta area was 4.73 km² or 0.67 km²/year. Area of Barito Delta in years 2004-2008 increased about 3.38 km² or 0.84 km²/year. Shoreline during the period 1862-2008 had changed. Accretion occurred in Kuala Lupak River during the period 1862-1997, but erosion occurred during the period 1997-2004. The delta morphodynamics were influenced by human activities in watershed and delta such as landuse change and land degradation.

Key words: Morphodynamic, Barito Delta, topography map, Landsat satellite image.

1. Introduction

The major cities in Indonesia, such as Jakarta, Banjarmasin, Pontianak, Samarinda, Makasar, etc., develop at the delta or near of the delta. These cities develop in delta or near of the delta because of deltaic deposits contained fertile soil, ground water resources, and petroleum reserves [1, 2].

Delta is a geomorphological feature that is formed in river mouth or near river mouth. Delta is coastal deposition which is formed by fluvial sediment supply and redistributed by marine processes [1-4]. The morphodynamic of delta depends on fluvial processes and marine processes (redistributed of sediment). Therefore, delta is considered as fluviomarine landform.

Development of delta are resulted by balance condition between the fluvial system, the climate, tectonic stability, and shoreline dynamics [5-7]. Some deltas have problems caused by subsidence, or sea level changes [7, 8].

Barito River is one of the big rivers in Kalimantan. Barito River has length of about 900 km and width average of about 800 m. Depth average of Barito River is 8 m [9]. Barito River flows from upper part of Muller Mountain into Java Sea. Barito Watershed covers two provinces, i.e. South Kalimantan Province and Central Kalimantan Province [10].

Forest area in Barito Watershed decreases every year. The percentages of forest surface of South Kalimantan and Central Kalimantan at 2009 were 4.15% and 38.77%, respectively. During the period 2000-2009, the area of forest in Barito Watershed decreased approximately 1,047,163.82 hectare or 16.38%. Critical land in South Kalimantan are 1,839,449 hectare or less than one third of land forest is critical condition. This condition is caused by forest degradation, illegal logging, forest fire, and mining [11].

Corresponding author: Deasy Arisanty, main research field: geomorphology. E-mail: deasyrsnt@gmail.com.
Human activities within a watershed, such as agriculture, urbanization, dam building and change in landuse may affect the sediment yield from the watershed [12-16]. Sediment from watershed is the fundamental control for delta morphodynamic.

Barito Delta is formed in the mouth of Barito River. The boundaries of Barito Delta are Barito River as the eastern boundary, Kapuas Murung River as the western boundary, Pulau Petak River as the northern boundary and Java Sea as the southern boundary. This delta is characterized by swampy land. Two canals (Tamban and Serapat) join Barito River and Kapuas Murung River and Talaran Canal joins Barito River and Pulau Petak River [17]. The morphology of Barito Delta is transition from cuspate to lobate [18]. The location of Barito Delta is presented in Fig. 1.

2. Methods and Data

2.1 The Growth of Barito Delta

The growth of Barito Delta was analyzed from topographic map and Landsat satellite image. Barito Delta maps in years 1862 and 1946 were obtained from topographic map. Barito Delta maps in years 1997, 2004 and 2008 were obtained from satellite image. Topographic map was digitized to obtain the boundaries of Barito Delta. Satellite image was processed based on composite band 543 to separate land and water. The research area was mostly covered by cloud. Hence, to minimize the effect of cloud was used the composite of band 543 to get the best result of the separation of land and water. Changing area analysis, yearly growth, growth orientation and delta

![Fig. 1 The location of Barito Delta within Indonesia (source: Google Earth).]
shape change were based on multitemporal map in years 1862, 1946, 1997, 2004 and 2008.

### 2.2 The Shoreline Change

Shoreline changes were analyzed from the satellite image in years 1997, 2004 and 2008, and from topographic map in years 1862 and 1946. Shoreline extraction from satellite image was processed based on the composite of band 543. The research area was also covered by cloud. Hence, to minimize the effect of cloud, the composite of band 543 was used to get the best extraction result. Shoreline extraction from map was identified by ArcView software. Shoreline changes could be evaluated by overlapping multitemporal shoreline. Shoreline changes were used to determine the location of erosion and accretion.

### 3. Results and Discussion

#### 3.1 The Delta Growth

According to interpretation of topographic map and satellite image during the period 1862-2008, delta was developed. The Barito Delta development was caused by both sediment supplied by fluvial processes and sediment redistributed by marine processes. Barito Delta was a lowland area developing in Sunda Shelf. Sunda Shelf had stable characteristic and non-tectonic characteristic, hence delta could develop fastly.

Based on interpretation of Barito Delta maps in years 1862 and 1946, Barito Delta had developed to south orientation. In year 1862, shape of the delta was transition from cuspatate shape to lobate shape. Then, the shape of this delta in 2008 was also transition from cuspatate shape to lobate shape. Thus, the shape of Barito Delta did not change.

In year 1862, the area of Barito Delta was 2,198.36 km$^2$. In year 1946, the area of Barito Delta was 2,226.18 km$^2$. Accretion area was 27.82 km$^2$. The delta growth per year during the period 1862-1946 was 0.33 km$^2$/year. Accretion occurred in south part of Barito Delta, such as in Kuala Lupak River. In year 1862, landuse in Barito Delta was a swampy forest, without the agriculture area. In map 1946, the irrigation channel had been formed; hence the delta was used as the agriculture area.

The area of Barito Delta in year 1997 was 2,402.05 km$^2$. The accretion rate during 1946-1997 was 175.82 km$^2$. The growth of delta during the period 1946-1997 was 3.45 km$^2$/year. During the period 1946-1997, the intensive agriculture occurred in the Barito Delta. Some area in Barito Delta was planned for transmigration area [17, 18].

The area of Barito Delta in year 2004 was 2,397.32 km$^2$. The reduction of Barito Delta area during the period 1997-2004 was 4.73 km$^2$. The reduction rate of Barito Delta area during the period 1997-2004 was 0.67 km$^2$/year. Barito River was used for transportation network, so that the river was dredged to decrease the sediment in Barito River. Hence, the sediment supply of Barito Delta was decreased due to the dredging activity.

The area of delta in year 2008 was 2,400.70 km$^2$. Barito Delta growth during the period 2004-2008 was 3.38 km$^2$. The accretion rate during the period 2004-2008 was 0.84 km$^2$/year. The development of Barito Delta during the period 1862-2008 is presented in Table 1. Multitemporal Barito Delta maps are presented in Fig. 2.

<table>
<thead>
<tr>
<th>Years</th>
<th>Area (km$^2$)</th>
<th>Increase (km$^2$)</th>
<th>Decrease (km$^2$)</th>
<th>Growth per year (km$^2$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1862</td>
<td>2,198.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1946</td>
<td>2,226.18</td>
<td>27.82</td>
<td></td>
<td>0.33</td>
</tr>
<tr>
<td>1997</td>
<td>2,402.05</td>
<td>175.82</td>
<td></td>
<td>3.45</td>
</tr>
<tr>
<td>2004</td>
<td>2,397.32</td>
<td>4.73</td>
<td></td>
<td>0.67</td>
</tr>
<tr>
<td>2008</td>
<td>2,400.70</td>
<td>3.38</td>
<td></td>
<td>0.84</td>
</tr>
</tbody>
</table>
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Fig. 2  Multitemporal Barito Delta maps.
3.2 The Shoreline Change

According to shoreline map in years 1862-1946 (Fig. 3), Barito Delta shoreline had been changed. Shoreline in year 1862 had length about 37.64 km. Shoreline length in year 1946 was about 32.78 km. Based on the interpretation, in the mouth of Kuala Lupak River, accretion occurred about 3.01 km (profile a) and accretion also occurred about 3.13 km in Barito Estuary (profile c). Erosion occurred about 1.51 km in Kapuas Murung Estuary (profile b).

Based on shoreline map in years 1946-1997 (Fig. 4), shoreline was changed in Barito Delta. Shoreline length in year 1997 was about 33.30 km. Shoreline in Kuala Lupak River mouth during the period 1997-2004 increased because sedimentation occurred in Kuala Lupak River mouth (profile a). The Sedimentation rate was about 2.51 km. Accretion also occurred during the period 1946-1997 in profile b (Kapuas Murung Estuary). Accretion occurred about 2.09 km. Erosion occurred in profile c (Barito Estuary). Erosion occurred about 2.01 km.

According to shoreline map in years 1997-2004 (Fig. 5), shoreline changes occurred in Barito Delta. Shoreline length in this area in year 1997 had 33.30 km. Shoreline length in year 2004 was about 33.72 km. Shoreline in Kuala Lupak River mouth during 1997-2004 decreased because erosion occurred in Kuala Lupak River mouth (profile a). The Erosion rate...
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Fig. 5  Shoreline changes during the period 1997-2004.

Fig. 6  Shoreline changes during the period 2004-2008.

Table 2  Shoreline changes of Barito Delta.

<table>
<thead>
<tr>
<th>Years</th>
<th>Profile a (Kuala Lupak) (km)</th>
<th>Profile b (Kapuas Murung Estuary) (km)</th>
<th>Profile c (Barito Estuary) (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1862-1946</td>
<td>+3.01</td>
<td>-1.51</td>
<td>+3.13</td>
</tr>
<tr>
<td>1946-1997</td>
<td>+2.51</td>
<td>+2.09</td>
<td>-2.01</td>
</tr>
<tr>
<td>1997-2004</td>
<td>-0.24</td>
<td>+0.30</td>
<td>0</td>
</tr>
<tr>
<td>2004-2008</td>
<td>0</td>
<td>+0.24</td>
<td>0</td>
</tr>
</tbody>
</table>

occurred about 0.24 km. Accretion occurred during the period 1997-2004 in profile b. The accretion rate was about 0.30 km. In year 1997, sedimentation process formed an island in front of the delta. In year 2004, the islands were united with the main delta.

Shoreline in year 2004 was about 33.72 km. Shoreline length in year 2008 was about 34.58 km. In profile a and c, shoreline change was 0 km, whereas the accretion rate in Kapuas Murung Estuary (profile b) was about 0.24 km. Shoreline changes in years 2004-2008 can be shown in Fig. 6. Shoreline changes of Barito Delta are presented in Table 2.

Shoreline change in Barito Delta was caused by human factor. Human activities such as landuse change, fire, forest logging and land degradation in watershed and delta. Forest was converted into agricultural and mining areas. Intensive agriculture and mining activities in watershed and delta influenced delta morphodynamic.
4. Conclusions

The multitemporal topographic map and satellite image could be used to evaluate the long-term morphodynamic of Barito Delta. Barito Delta during the period 1862-1997 had increased to south orientation. Shape of delta did not change due to transition from cuspate to lobate delta. Area of Barito Delta was decreased during the period 1997-2004. Erosion and accretion occurred in shoreline of Barito Delta. Shoreline accretion occurred during the period 1862-1997 in Kuala Lupak River mouth but erosion occurred during the period 1997-2004 in Kuala Lupak River mouth. Therefore, human activities cause delta growth and shoreline change.

References