URBAN SPRAWL ON JENEBERANG DELTA OF MAKASSAR: A REMOTE SENSING AND GIS PERSPECTIVE

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ABSTRACT.
The city of Makassar, the capital of South Sulawesi sited on the western coast of the South Sulawesi peninsula with population of 1.25 million in 2009, and annual growth of 23%. The city laid on the northern side (downstream) of the Jeneberang River and shares the river’s floodplain with the city of Sungguminasa. The river’s watercourse has formed a delta on the coastal zone of Makassar. The delta is growing in size and the watercourse has shifted over the years. In the past, the area has been known to prone to the flood risks before a control dam was built upstream in Bilibili in 1999.

With the presence of the Bilibili flood control dam, the development of Jeneberang delta has flourished. In the last 10 years, there has been an extensive development on the delta such as the elite residential of Tanjung Bunga, the large indoor theme parks of Trans Studio and the megaproject plan of the “center point of Indonesia”.

The dynamics of the delta’s landscape has been traced using remotely-sensed data and GIS technology. The analysis shows that the conversion rate has occurred rapidly in the last 10 years. The current land use shows that the area has been converted into residential and business area with the rate of conversion around 18% and 34% during the 1999 to 2003 and 2003 to 2010 respectively. The result obtained from image analysis also indicated that mangrove and wetland area has decreased over the 20 years period with reduction rate of about 14% and 13% respectively within the two period of study year.

Keywords: River delta, remote sensing, urban sprawl

Introduction
The shifting between agricultural land and urban is now becoming a subject of controversy. The transformation of productive agricultural land to urban use under burgeoning populations has become a contentious element in debate over sustainable development and food security [1], [2]. The transformation of the productive land into urban uses happening in all cities around the world in accordance with the rapid population growth. The transformation occurs with different rates. The trends of conversion systematically reduce the ability to produce food.

The population living in urban areas exceeded half of the total world population as estimated by UN in 2006 and projected to around 60% in 2020 where the growth is taking place mostly in developing counties [3]. The accelerated progress in urban sprawl induced by rapid industrialization and urbanization, and for waterfront cities such as Makassar, constructions of harbors and embankment also contributed to the urban sprawl toward the sea shore. Severe environmental problems such as land subsidence, sea water intrusion, siltation of river channels and coastal erosion resulted from lack of sustainable coastal management [4].

Concerns on the environmental impact of urban sprawl have raised among planners and stimulated other models in town planning and urban expansion such as the concepts of “smart growth” planning [3]. The planning of urban development without proper concerns on environmental impacts often leads to the even worse damages to environment.
The specific, measureable and generally accepted definition of “Urban sprawl” is difficult to find. Definition by William Whyte 1958 referred to patterns of urban development and some defined it simply on the aggregate population density of a given urban area[5]. The of urban sprawl range from local pattern of the advancement of land use and development to the aggregate measure of per capita land consumption for given contiguous urban areas [5]. Urban sprawl has become a remarkable characteristic of urban development worldwide in the last decades. However, trajectories and rhythms of sprawl may vary in important ways according to specific geographical and historical characteristics [3].

The common negative impacts of urban sprawl are traffic congestion, loss of open space, energy consumption and increased pollutant runoff into natural waterways [5].

The use of Remote Sensing and GIS Technology
In order to determine the rate of urban advancement, remote sensing data and Geographical Information System (GIS) technology offer a sound solution. A broad view of landscapes provided by remotely-sensed data can be consistent through time, making it an important tool for monitoring and managing certain area such as protected lands [6]. Change detection on landscapes by digital images essentially comprises of quantification of temporal phenomena from multi-date imagery [7].

Land cover composition and change are important factors that affect ecosystem condition and function [8]. The advancement of the city development in water front cities usually surpasses the wetland area which playing an important role in ecological balance on either terrestrial or estuarine ecology. The concentration of people in densely populated urban areas, especially in developing countries, calls for the use of monitoring systems like remote sensing. Such systems along with spatial analysis techniques like digital image processing and geographical information system (GIS) can be used for the monitoring and planning purposes as these enable the reporting of overall sprawl at a detailed level[9].

The use of satellite-based remotely-sensed data has been extensively used to provide a cost-effective means to develop land coverage and change detection over large geographic regions [8]. In recent years, the accessibility to remotely sensed data with little or even no-cost such as Landsat Thematic Mapper and high resolution digital data such as Quick bird can be accessed on Google Earth / Google Map offering an even more accurate analysis on the land use change anywhere in the world.

This study examines the quantitative and qualitative changes in the past 20 years related to urban sprawl and its impact on the Jeneberang river delta in the southern part of Makassar city. The city of Makassar, the capital of South Sulawesi sited on the western coast of the South Sulawesi peninsula with population of 1.25 million in 2009, and annual growth of 23%. The city laid on the northern side (downstream) of the Jeneberang river and shares the river’s floodplain with the city of Sungguminasa. The river’s watercourse has formed a delta on the coastal zone of Makassar. The delta is growing in size and the watercourse has shifted over the years. In the past, the area has been known to prone to the flood risks before a control dam was built upstream in Bilibili in 1999.

Study site and method
Makassar city is a waterfront city located in the west coast of South Sulawesi (Fig.1) The land use of Jeneberang delta in 1999 dominated by rice field and swamp areas with fishpond and mangrove forest. The area of the delta is about 1100 ha, laid between 5.132953°S; 119.378509°E and 5.196874°S; 119.419927°E. The region is administratively belongs to the city of Makassar. The delta land use also consists of cultural heritage i.e. the fortress of the ancient Gowa kingdom that excavated and restored in early 1980s, and the cultural center consists of traditional houses of the four major ethnics of South Sulawesi i.e. Buginese, Torajanese, Mandarese and Makassarnese.

The development on the delta starts to accelerate since the late 1990s as the access road into the delta has been established. The access road is connecting the Losari beach and the northern shore of the delta’s “gulf” with one
bridge to provide access into the old port (fishermen port) in the eastern shore line. As the access road been established, the conversion of the delta’s land is flourished. Started from the construction of the Celebes Convention Center (CCC), the residential and shopping malls of Tanjung Bunga, construction of the indoor theme park of Trans Studio and the latest is the ongoing construction of the Center Point of Indonesia, a mega-project that has been started since the visit of the Indonesian President in March 2009.

Figure 1. Location of study (Image By Google Earth)

The method used in this study using a series of remotely-sensed data using Landsat TM imagery and the digital maps derived from Google earth. Due to the area of interest is small (15 km$^2$) the change detection from 2003 to 2010 is classified based on the available high resolution of image on Google Earth / Google Map, while the land use condition in 1999 is classified from Landsat TM imagery acquired on the 13$^{th}$ of September. The series of images used in this study presented in Fig.2.
The procedure in the study consists of the pre-processing of the Landsat TM data started from image preprocessing (dark object subtraction and geometric corrections), classification and land use change mapping (Fig. 3). The image classification based on supervised classification [10],[11] is applied to the Landsat TM imagery as well as accuracy assessment [12] of Kappa coefficient.

Image interpretations on the image derived from Google Earth. We use some raster and vector processing software on the image and map processing in this study. Training areas were selected for each of the land use types by
delimiting polygons around certain types of land use i.e. rice fields, fishponds, buildup areas, mangroves and free water body. Using the pixels from training regions the classification process is started using supervised classification with maximum likelihood method as classification method. The output is a thematic raster layer (classified image). The thematic layer was used for mapping the land use of post classification map.

**Result and discussion**

The result of image analysis performed by supervised classification on satellite image required a validity assessment to ensure the accuracy of classification. The validity of classification result is validated using reference data or ground truth. The ground truth data is obtained by visiting the specific locations on the ground as well as using visual assessment on the image from high resolution data. Table 1 shows the errors of the image classification of Landsat data in 1999 derived from error matrix [10]. In this study we only classified the image based on three land use classes i.e. Dry land farming and rice field, the wetland and the buildup and residential area.

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Dry land and RF</td>
<td>96%</td>
<td>4%</td>
<td>83%</td>
<td>17%</td>
</tr>
<tr>
<td>Wetland</td>
<td>88%</td>
<td>12%</td>
<td>92%</td>
<td>8%</td>
</tr>
<tr>
<td>Buildup</td>
<td>80%</td>
<td>20%</td>
<td>91%</td>
<td>9%</td>
</tr>
</tbody>
</table>

The user’s accuracies are the measure of commission error indicates the probability that a pixel classified into a given category actually represents that category on the ground. On the other hand, the producer’s accuracies reflecting the accuracy of a pixel that omitted from the category that a pixel should belong to. The accuracies of the pixel classification in this study range from 80 to 96 percent, with the overall accuracy of 88%.

Another measure of classification accuracy is the Kappa statistic (“$K_{\text{hat}}$”), is the measure of the difference between the actual agreement between reference data and an automated classifier and the chance agreement between the reference data and a random classifier [10]. In this study we found a $K_{\text{hat}}$ value of 0.82. The Kappa statistic is expressed as:

$$K_{\text{hat}} = \frac{\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} * x_{+i})}$$

Where $r =$ number of rows in the error matrix; $x_{ii} =$ the number of observations in the row I (major diagonal); $x_{+i} =$ the number of observation in row I; $x_{i+} =$ total observation in column and $N =$ total number of observation.

The data presented in Table 1 show that the dry land farming and rice field and wetland classes were all characterized by the highest classification accuracy. The data presented in Table 2 and Fig.4 represents the total area and spatial distribution of each land use class on each study year.
Table 2. Land use change of the study area from 1999 to 2003 and 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>1999 (ha)</th>
<th>%</th>
<th>2003 (ha)</th>
<th>%</th>
<th>2010 (ha)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryland farming and ricefield</td>
<td>381.19</td>
<td>38%</td>
<td>347.60</td>
<td>35%</td>
<td>135.37</td>
<td>14%</td>
</tr>
<tr>
<td>Wetland</td>
<td>406.67</td>
<td>41%</td>
<td>264.48</td>
<td>26%</td>
<td>136.20</td>
<td>14%</td>
</tr>
<tr>
<td>Buildup area and Residence</td>
<td>213.37</td>
<td>21%</td>
<td>389.16</td>
<td>39%</td>
<td>729.26</td>
<td>73%</td>
</tr>
<tr>
<td>Total (ha)</td>
<td>1001.24</td>
<td>100%</td>
<td>1001.24</td>
<td>100%</td>
<td>1001.24</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 4. The dynamics of land use change in the study area from 1999 to 2003 and 2010

Table 3. Percentage of land use change in Jeneberang delta 1999-2003 and 2003-2010

<table>
<thead>
<tr>
<th>Year</th>
<th>1999-2003</th>
<th>% Change</th>
<th>2003-2010</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryland farming and ricefield</td>
<td>-33.59</td>
<td>-3%</td>
<td>-212.23</td>
<td>-21%</td>
</tr>
<tr>
<td>Wetland</td>
<td>-142.19</td>
<td>-14%</td>
<td>-128.28</td>
<td>-13%</td>
</tr>
<tr>
<td>Buildup area and Residence</td>
<td>175.79</td>
<td>18%</td>
<td>340.10</td>
<td>34%</td>
</tr>
</tbody>
</table>

The rate of land use change in Jeneberang delta as shows in Table 3 suggest that during 4 years period (1999 to 2003) the natural condition of wetland area in the delta declined 14% and on subsequent seven years (2003 to 2010) the area is further reduced by 13%. The similar patterns happened to the dryland farming and rice fields. On the other hand, the buildup area increased significantly as Table 3 shows the rapid increase of 18% in the first period and further 34% in the last 7 years. This trend shows that one day the Jeneberang delta will be converted into a
massive concrete and paving area that the wetland ecosystems and farming practice will dwindle and disappear in the coming future.

**Conclusions**

The availability of no-cost Landsat TM data and data processing techniques that provide high quality continuous time series data represent a major advancement for the automated monitoring annual land cover change and vegetation condition over a certain geographic regions.

The advantages and limitations of satellite data change detection approach are substantially associated with spatial data resolution (30m). In particular, change events less than 900 m² will have a low probability of being detected. One impact of this resolution problem is potentially poorer accuracies for urban areas that tend to change at finer scale. This problem can be overcome thanks to the available data from Google which can be assessing with no cost.

The urban impact of urban sprawl over the wetland and estuary can be manage properly by utilizing the available satellite imagery for better understanding of the potential impacts both economic and environmental aspect.
Reference


