Using the Geographical Information System (GIS) Methods in Determination of Landuse Changes at Batu Sapi, Sandakan, Sabah, Malaysia

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Abstract. The study area is in the southwestern part of the Sandakan city center bounded by latitude 05°48’ until 05°52’ N and longitude 117°58’ until 118°03’ E and covers the area of 100km². The study area comprises the Sandakan Formation which is overlain by the Quaternary Alluvium. The landuse changes is done through the Geographical Information System (GIS) method by using the ILWIS (Integrated Land and Water Information System) software. There are four main stages involved in the GIS method to produce the thematic maps. Landuse map of the year 1980 and 2010 have been used to study the changes at the study area. The results show the percentage of urban area coverage have increased, while the village area have the highest percentage of land diminution. So, with the model of the evolution of landuse, it calls for landuse planning in the study area is more sustainable in the future.

1. Introduction

The study was conducted in Sandakan, one of the districts in the eastern part of Sabah and it is the second largest city after the capital city of Sabah, Kota Kinabalu with a total area of 2,266km². The study area consists of two formations, namely Sandakan Formation and Quaternary Alluvium deposition. The Sandakan Formation is the Miocene Age of the Lower Upper Miocene [1]. The Sandakan Formation is a young formation that is deposited on the Garinono Formation separated by unconformity. In general, this formation comprises a layer between sandstone and mud pitch [2] and is dominated by sandstone and mudstone [3].

[4] classified the Sandakan Formation into five (5) major lithology namely mudstone facies, laminated and grooved sandstone, thin sandstone layer and bioturbidity mudstones, thick sandstone, medium thick sandstone with Skolithos and interlayered of sandstone and mudstones. There are four rock lithology units that have been identified by the authors while conducting field studies in the study area. Among them are thick sandstone units, thin sandstone layers and bioturbidity mudstones, interlayered of sandstone and mudstones and a not mentioned lithology units by [4], a thin to medium layer of sandstone with Ophiomorpha.

While in the aspect of the landuse changes by using the GIS method in the study area it will discuss the changes that took place from 1980 to 2010. [5], said that Land Use or Land Cover can be defined as an assessment of the spatial information of any area modified by geomorphological conditions on the face of the earth. In addition, according to [6], the use of land on the landscape shows the level of human activity on the area. In general, landuse in an area is controlled by several factors such as soil, hydrology, climate, socio-economic and political. However, geology and
geomorphology also play an important role and uncontrolled land use also can affect and change the geomorphology of an area.

2. Research Approach

2.1 Study Area

The study area is located at Batu Sapi in the southwest of Sandakan town with the longitude of 117° 58' to 118° 03' E and latitude 05° 48' to 05° 52' N. The study area covers about 100km² as shown in the Figure 1. Generally, the terrain in the study area is quite hilly in the east and with the highest topography is 220 meters. While in the western and eastern regions is much lower with less than 200 meters of topography and is comprises of lowland area and covered by alluvial deposition.

![Figure 1. Base map of the study area](image)

2.2 Data and methods

2.2.1 General Geology

There two main steps in the methodology which are the preliminary studies and the fieldwork. Preliminary study is aimed at gathering information and information related to the ongoing research. The aspects involved are the production of geological maps and literature studies where they act as important guidelines in general geology, structural geology, general stratigraphy and geology of the region.

Fieldwork was conducted to identify the study area for the purpose of recording and collecting the field data. Sampling, photo taking, observing and recording general geological data are important aspects of fieldwork. Photo taking for rock units identification, lithology and geological structures. Discontinuities data are important in stratigraphic determination of the study area while observation and recording of general geological data such as the grain size, thickness, colour, texture and trace fossils are also carried out during the general geological studies.
2.2.2 Geographical Information System (GIS) method
The use of the GIS method generally contains four main stages which including the collection of basic data / satellite images, satellite data analysis, GIS processing and the creation of thematic maps, integration of thematic data and data presentation. The GIS map produced is using ILWIS (Intergrated Land and Water Information System) computer software. Figure 2 shows a flow chart of the major stages of the GIS method and its components.

![Diagram of GIS method stages](image)

**Figure 2.** Major stages of the GIS method

a. Basic Data Collection
Data on landuse changes should be listed first. Relevant data such as drainage maps, topographic elevations and road maps were collected and analyzed. The information is derived from topographic maps and geological maps. The basic map of landuse for the years 1980 and 2010 was supplied by the Department of Agriculture Malaysia, Sabah Branch.

b. Satellite Data Analysis
Satellite data analysis is based on 'Google Earth' computer software. By using the 'Time-Lapse' application and function on Google Earth, satellite imagery for the 1980s, 1990s, 2000s, 2010 and 2016 can be retrieved and processed and can be seen in comparison with thematic maps of landuse for the years 1980 and 2010 (Figure 3 and 4).

c. GIS Processing and Thematic Map Production
The preparation of a thematic map is different because it follows the original form of data obtained and the type of parameter to be derived from the data. The creation of these thematic maps began with the conversion of the data to be used in the form of digits and data conversion was performed using a common coordinate system so that all thematic maps could be integrate with the base map.
Figure 3. Satellite image year 1980 (Google Earth) – time lapse

Figure 4. Satellite image year 2010 (Google Earth) – time lapse
d. Data Integration
Repositioning and integrating base maps and thematic maps have been given the next step in producing final maps for mapping presentations on landuse changes using the GIS method. From [7], the integration process can be created either by displaying multi-form composite visuals or with an integrated model that creates new maps from some existing maps.

Thematic maps and attribute data can be combined in one step of processing. The map combining process is known as cartography or map modeling. For example, the Boolean Logical Model, the Index Overlay model, the Fuzzy model and the Bayesian model is among the models that can be used for combining thematic maps for the purpose of integrating and analyzing appropriate data for the final map implementation in GIS.

3. Results and Discussion
Figure 5 shows the landuse map of 1980 and Figure 6 shows a landuse map of 2010. Based on Figure 4 (1980), there are seven (7) main landuse attributes which are forest, swamp forest, mining area, urban area, agriculture, bushes and water body. The seven attributes have a different area.

![Landuse thematic map of 1980](image)

**Figure 5.** Landuse thematic map of 1980

While the Figure 5 shows map of the year 2010. There are thirteen (13) landuse attributes. That is an increase of 58.85% of attributes in 30 years. The landuse attributes are urban area, aquaculture, palm oil plantation, former mining/quarry rea, agriculture, cleared land, bushes, forest, swamp forest, water body, lake/pond, estate office and grassland.

Based on the Figure 4 and 5, it can be seen that evolution of landuse changes in the study area from 1980 until 2010. Comparisons can be made until 2010 only due to limited map production. Table 1 shows the percentage of landuse changes in the study area for 30 years (1980 – 2010).
The percentage (%) of land use in the study area is calculated by using the following steps and formula:

\[ B - A = C \]  

Where \( B \) is the area of land use in 2010, and \( A \) is the area of land use in 1980. The value of \( C \) is the result of \( B \) minus \( A \). For the value of \( C \) which has been calculated positive value indicates the increase in the land use attribute, while the negative value indicates the occurrence of reduction for land use attributes.

The value of \( C \) is then equated with the value of \( D \), but the value of \( D \) is not taken into account whether it is negative or positive. Value \( D \) is the value taken from the change of area regardless of whether it increase or decrease.

\[ C = D \]  

The percentage of change (%) of the study area is then calculated according to the formula referring to [6].

\[ \frac{D}{\text{Total } D} \times 100\% = \text{Percent changes (}) \]
Table 1. The percentage of the landuse changes at the study area from the year 1980 to 2010

| Landuse                        | Width of the area (m²) | 1980 (A) | 2010 (B) | 2010-1980 (B-A=C) | Different (D) | Percent changes (%) |
|-------------------------------|------------------------|----------|----------|------------------|---------------|---------------------|
| Forest                        | 27,175,700             | 32,420,600 | +5,244,900 | 5,244,900        | 11.30%        |
| Swamp                         | 16,374,500             | 10,684,200 | -5,690,300 | 5,690,300        | 12.25%        |
| Mine/Quarry/Former Mine       | 246,700                | 249,000   | +2,300   | 2,300            | 0.005%        |
| Urban                         | 2,320,200              | 9,491,400 | +7,171,200 | 7,171,200        | 15.44%        |
| Agriculture                   | 12,857,200             | 2,384,000 | -10,503,200 | 10,503,200        | 22.61%        |
| Bushes                        | 14,882,900             | 7,827,000 | -7,055,900 | 7,055,900        | 15.19%        |
| Aquaculture                   | -                      | 19,400    | +19,400  | 19,400           | 0.042%        |
| Oil palm                      | -                      | 6,166,600 | +6,166,600 | 6,166,600        | 13.27%        |
| open space                    | -                      | 4,136,800 | +4,136,800 | 4,136,800        | 8.90%         |
| Lake                          | -                      | 6,300     | +6,300   | 6,300            | 0.014%        |
| Estate Office                 | -                      | 146,300   | +146,300 | 146,300          | 0.31%         |
| Grass                         | -                      | 317,000   | +317,000 | 317,000          | 0.682%        |
| Water body                    | 24,996,100             | 24,996,100 | 0     | 0               | 0%            |
| Total                         | 98,844,700             | 98,844,700 | 46,460,200 | 100%            |               |

Forest attributes as in Table 3 shows there has been an increased from 27,175,700 m² to 32,420,600 m² which is a change of 11.30%. These percentage changes are likely due to the increased in forest areas when the bushes are not well managed, while the area of the bushes has decreased from 14,882,900 m² to 7,827,000 m² a 15.19% changes.

Table 3 shows a decline in the percentage of mangrove forests in the study area of 12.25% and the mangrove swamp area has decreased from 16,374,500 m² to 10,684,200 m² a reduction of an area by 5,690,300 m².

Urban area is a landuse attribute that has a highest increasing in area size with a percentage change of 15.44% compared to other landuse attributes. In addition, it has grown from 2,320,200 m² to 9,491,400 m² an increase of 7,171,200 m². The area of urban that is meant here is an area that has undergone urbanization changes such as factory areas, housing, shop lots, industrial areas and so on.

The agricultural landuse attributes of cocoa and nipah plantation have experienced a decline of 22.61%. The area has decreased from 12,857,200 m² to 2,384,000 m² and reducing the total area of 10,503,200 m². Despite the drastic changes in the agricultural sectors, the oil palm plantation has been opened the past 30 years, with an area of 6,166,600 m² which is 13.27% coverage from the total landuse changes at the study area.

The aquaculture sector is a landuse attribute that not available in 1980 and this new attribute has an area of 19,400 m² and covers an area change of 0.042%. In addition, with the opening of the palm oil plantations mentioned above, the estate offices were first opened and set up around the study area and had a total area of 146,300 m² with a percentage change of 0.31%.

Landuse changes from 1980 to 2010 has shown that grassland attribute area is a wasteland area known as a weed area with a total area of 317,000 m² and a percentage change of 0.682%. Lake and
ponds or also known as water reservoir intended to store and collect water source is also a landuse attribute that existed in 2010 with an area of 6,300 m² and a percentage change of 0.014%.

4. Conclusion
The connection between landuse changes for 1980 and 2010 has been identify by using the GIS method. Based on the mapping that has been done, the study area has no significant changes within period of 30 years. The urban areas have the highest percentage of changes with 15.44% increasing, while the agriculture area has the highest reduction of 22.61%. The geomorphological aspect has also contributed to the landuse changes for the urban attributes. Urban development was carried out at the river estuary and geomorphological aspects also contributed to the existence of lakes and ponds as water reservoirs. In addition, in the event of unplanned and unsustainable development can lead to the impact and changes of geomorphology. Where it will affect the rate of erosion, flow changes and water quality. Development impact on geomorphology will also contribute to geological disasters in the study area involving flood disasters, mass movement and water pollution.

For the future study, using the high-resolution satellite images such as Ikonos, Quickbird, etc. will be a good option, since this type of satellite images have a better resolution which can give more information and a better result of the study area.

5. References
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