

MORPHOMETRY OF LAKE PANDAN IN TAPANULI TENGAH DISTRICT, NORTH SUMATERA PROVINCE

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ABSTRACT: Lake Pandan is one of the lakes located in Tapanuli Tengah district. Morphometry can explain the biological and chemical processes of the lake, regulate nutrient load, productivity and the influence of input loads from the surrounding area. Therefore, the morphometry of lake was needed as a basis for lake utilization and management. This is what underlies the morphometric research of Lake Pandan, where there has been no research on this topic. The purpose of this study was to determine the morphometry of Lake Pandan. This research was conducted on April 2019. The results of measurements of lake surface dimensions obtained that Lake Pandan has an area of ± 103 Ha with a maximum length of 2,034.60 m, a maximum width of 1,033.38 m, and a length of around the lake of 5,395 m. With an edge (Sl) of 5.395 m so that the Lake Development Index (LDI) was obtained at 0.302. The LDI value of 0.302 illustrates that the lake has an irregular shape. LDI can be used to describe the level of productivity of water if the value is greater, the waters are more fertile. The subsurface dimension found that the average depth (Z) of Lake Pandan was 0.21 m with maximum depth (Zmax) 1.7 m. The morphometric parameters of lake influence the physical, chemical and biological processes in the waters of Lake Pandan, such as depth. Based on depth, Lake Pandan has low stability and easy to experience stirring.

Keywords: Bathymetry, Lake Pandan, Morphology, Tapanuli Tengah

1. INTRODUCTION

Lakes that form a body of stagnant water throughout the year can be built with natural well-made. Naturally, it can be formed due to tectonic, volcanic, glacial, weathering mountain (karst lake), flooding, meteor lake falling, etc [1,2]. Lakes have unique morphology and structure and are determined by the shape of the basin, physical, chemical, and biological interactions, and their interactions with the environment [3,4]. Morphologically, shape and shape of a lake can be determined by morphometry [5,6]. The physical structure of a lake was determined by the distribution of light, heat, waves, currents, and variations of change. The chemical structure was the result of the distribution of nutrients and dissolved oxygen composition. While biological interactions are related to internal habitat interactions, either by chemical factors or between species [3,4].

Morphometry is a branch of limnology that discusses the measurement of the appearance of a watershed. The waters are said to be lake-type if the waters have an area ranging from $<1 \text{ km}^2$ - 1 million km^2 . Public awareness about the importance of lake water resources can affect the quality of the lake waters considering various pollution due to human activities [7].

Information about Lake Pandan morphometry was needed in determining the lake layer and can

also find out how much the ability of the lake in the use by humans, to determine the occurrence of siltation and several indexes of water fertility, provide information in the form of water depth, lake shape, light penetration, and volume development lake [8].

Lake morphometry was measured based on its structure, such as depth and elevation. In other words, lake morphometry was a form of lake water body which includes surface area (A), volume (V), average depth (Z). The topography of the area around the lake also affects its morphometry. The basic structure of a lake can be arranged to form a baseline relief, called bathymetry [9].

Lake Pandan was located in Sumatra, North Sumatra, located in Central Tapanuli Regency, Pinangsori District, Pandan Village. Lake Pandan has 32.3 km from the city of Pandan if using public transportation can be reached within ± 1 hour 19 minutes from Pandan City and ± 2 hours 30 minutes by boat via the Aek Kemuning River. The Lake Pandan has a river that provides water input (inlet) for the lake, the Aek Lobu River. Lake Pandan was upstream from the Aek Kemuning River and the water flows towards the Kemuning River in the North of Lake Pandan. Besides the river, Lake Pandan was also flowed by ditches from oil palm plantations around Lake Pandan. The location of Lake Pandan was presented in Figure 1.

Research on lake morphometry was needed, to get a picture of the physical condition of lake waters both vertically (subsurface dimensions) and horizontally (surface dimensions) [5]. Lake morphometry regulates nutrient loading, primary production, and secondary production of zooplankton, zoobenthos, and fish [6]. Lake morphometry plays a role in the factors that cause changes in the biological and chemical processes of the lake [3]. Morphometry can also illustrate the potential for biological production, as well as determine the level of sensitivity to the influence

of material loads from the surrounding area [3,4].

2. MATERIAL AND METHODOLOGY

2.1. Place and Time

This research was conducted in the waters of Lake Pandan, Pandan Village, Central Tapanuli Regency, North Sumatra Province on May 2019. Geographically, Lake Pandan were located at $98^{\circ} 50' 55''$ - $98^{\circ} 51' 53''$ East longitude dan $1^{\circ} 30' 20''$ - $1^{\circ} 31' 25''$ South latitude (Figure 1).

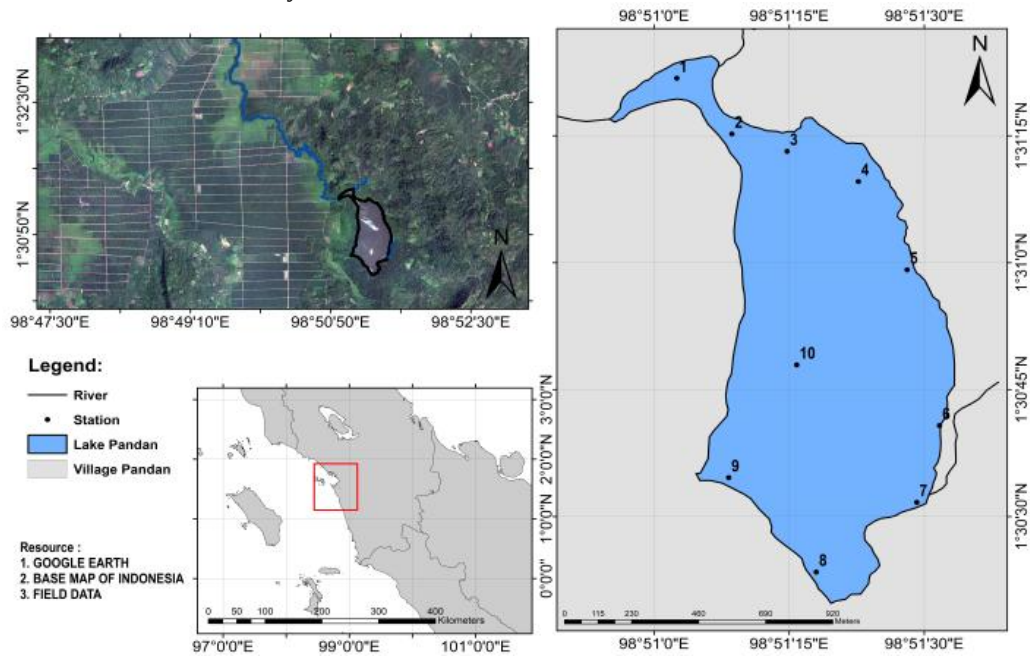


Fig. 1. Location map of research

2.2. Tools and Materials

The tools used in this study were Garmin GPS, Sonar Systems, small boats, Windows operating system laptops equipped with software such as ArcGIS 10.2.2 to create research locations and bathymetry maps. The material used in this research was Lake Pandan depth data (bathymetry).

2.3. Morphometric Measurements of Lake Pandan

2.3.1. Surface Dimension

Measurement of surface dimensions was done by going around the lake (track) using the Global Positioning System (GPS). Measurement of lake surface dimensions refers to Hakanson [5] as follows:

1. The maximum length (L_{max} expressed in meters) is obtained by measuring the distance between the two furthest points on the lake's

edge surface through the islands and land on the lake.

2. The maximum effective length (L_e expressed in meters) is obtained by measuring the farthest distance between two points on the edge of the lake's surface cannot pass through the islands or land on the lake. $L_{max} = L_e$ if there is no island or land on the lake.
3. The maximum width (W_{max} expressed in meters) is obtained by measuring the distance of the two furthest points on the edge of the lake's surface that are drawn a perpendicular to L_{max} .
4. The maximum effective width (W_e expressed in meters) is obtained by measuring the distance of the two furthest points on the edge of the lake surface drawn a perpendicular to L_e .
5. The surface area (A_o is expressed in H_a , km^2 or m^2) is the surface area of the lake, its value will vary depending on the season. Surface area measurements from bathymetry maps calculate polygon area using the Arc Map program. Measurement using the rectangular area formula:

$$A_o = L_{max} \times W_{max}$$

Explanation:

L_{max} = Maximum Length

W_{max} = Maximum Wide

6. Average width (W expressed in meters) is the ratio between lake surface area (A_o in m^2) and maximum length (L_{max} in meters). The calculation of the average width value (W) of the lake refers to Hakanson [5]:

$$w = \frac{A_o}{L_{max}}$$

7. The edge development index (LDI, without units) uses the relationship between SL and surface area. Calculation of LDI values is obtained through equations Hakanson [5]

$$LDI = \frac{SL}{\sqrt{\frac{22}{7} A_o}}$$

Keterangan:

$LDI > 1$: irregular water body shape

$LDI \leq 1$: regular water body shape

8. The length of the circumference of the lake (expressed in meters) can be measured from a bathymetry map using the Arc Map Software. Measurements can use measurement tools by drawing a line from the edge of the bathymetry map along the lake's perimeter to form polygons. The length value of the perimeter will be seen in the length column with the units specified.

2.3.2. Subsurface Dimension

Measurement of subsurface dimensions was done by measuring the depth using the Sonar System and GPS was assisted by a small boat. Mapping is done by making 10 stations. The station was expected to represent the entire waters of Lake Pandan (Figure 1). At this station, the depth data were recorded according to the number of stations that have been designed. The measurement data were then arranged in tabular form. Rows of data in the form of measurement stations, while data columns in the form of data identity (ID), time of data retrieval, coordinates, and water depth. Then, the data table was converted into spatial form and processed using a Geographic Information System (GIS) program such as ArcGIS 10.2.2 which is equipped with the 3D Analyst extension. Basic map using the 2012 Indonesian Fine Arts Map.

3. RESULT AND DISCUSSION

3.1. Map of Bathymetry

Bathymetry mapping results show that the deepest area was found in the western part of Lake Pandan with a range of 1.5 m - 1.7 m depth. The deepest locations found at the 10th station were marked in blue (Figure 2a). The most shallow location (0 m - 1 m) were in the southern part of Lake Pandan. This shallower location was station 7-8. Based on the depth based on the observation station that the higher the center (west) of Lake Pandan the higher the depth.

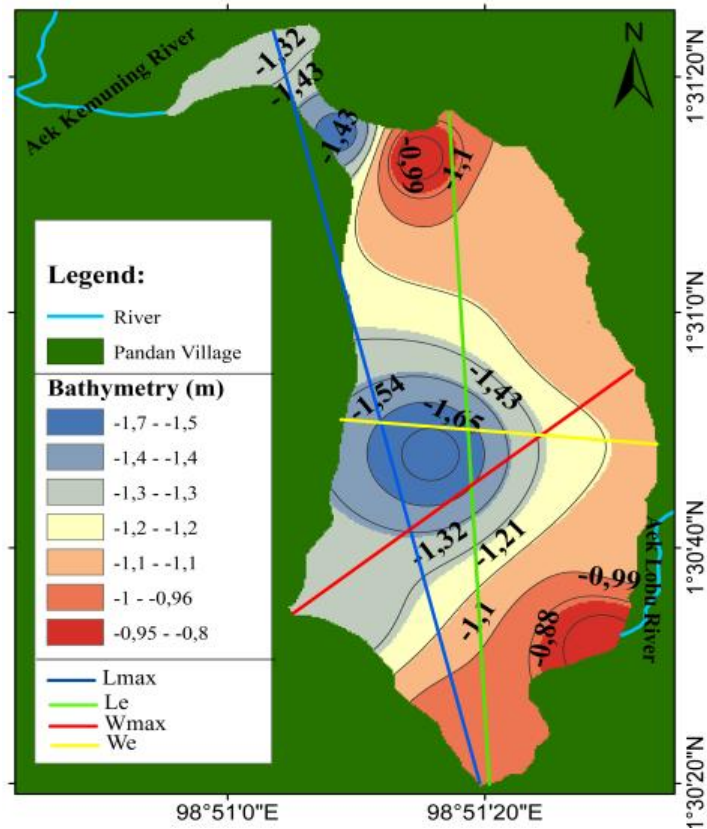
Based on the Lake Pandan contour layout which was processed using ArcGIS Software makes it clear that in the western part of Lake Pandan is the deepest location. This can be seen clearly from the increasingly tight contours at these locations (Figure 2b). The closer the contours show the deeper. And vice versa the less contour the deeper the shallower depth. In the northeast, east and south, the contours are very rare because the location was shallow with a depth of only 1 m.

This condition was increasingly visible based on the bathymetry depth layout map (Figure 2) even in this picture clearly visible the shape of the lake floor relief. At the edges, it looks flat and gentle, especially in the north to south. In the western part of Lake Pandan, the depth of the lake was clearly steep. In Figure 2 it looks like a hill because the depth had 0 to 1 m which explains that the area or location is very shallow.

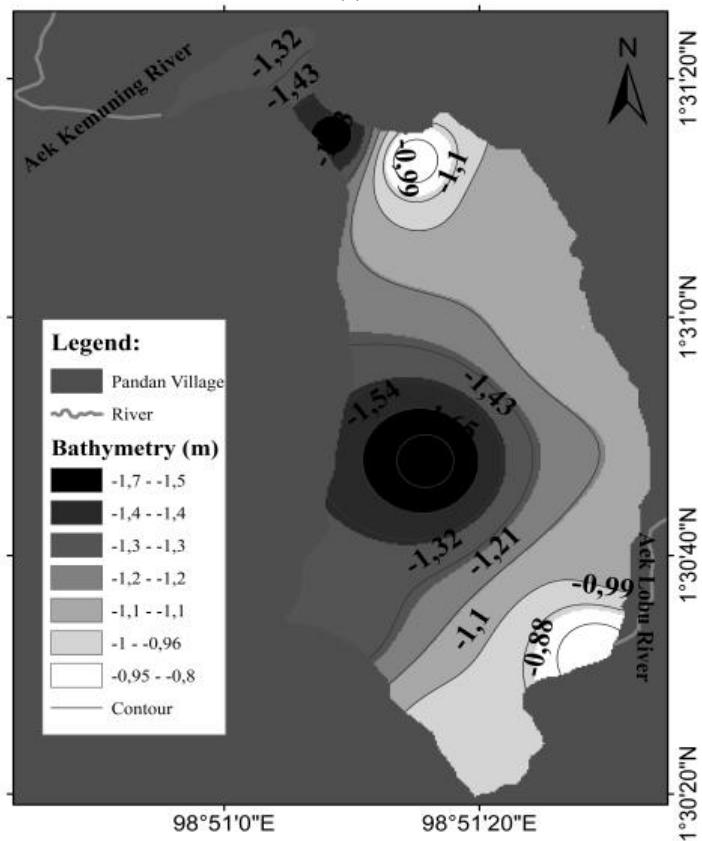
3.2. Surface Dimension

The results of measurements in the field were directly obtained that Lake Pandan has an area of ± 103 Ha, with a maximum length of 2,034.60 m, Maximum Width of 1,033.38 m, and Lake Length of 5,395 m. More complete data can be seen in Table 1. Morphometric measurements show Lake Pandan has a different L_{max} and L_e . The length and width of Lake Pandan were also different so that there is flexibility in the movement of winds above the surface of the water which will affect the movement of the water mass and indicate the contours of the lake floor which is relatively flat (Figure 2b).

The difference in value between L_{max} and W_{max} that do not differ greatly indicate Lake Pandan was a lake with a relatively flat bottom contour. This value illustrates that the waters were relatively flat with large littoral areas. Waters with large littoral areas have high biological productivity potential [10-11]. This is due to the fact that the littoral region has rooted plants which contribute to organic matter at the base; decomposed organic material into a source of nutrients for phytoplankton and aquatic plants; and layers of organic matter in the accumulated water base will be utilized for benthic growth [4, 12,13].



(a)



(b)

Fig.2. Bathymetry map (a) and Contour map (b)

Based on the results of Lake Pandan morphometry measurements using ArcMap Software obtained surface area (A_o) of 103 Ha with an outline (SI) of 5,395 m in order to obtain Lake Development Index (LDI) of 0.302. Lake Development Index (LDI) value of 0.302 illustrates that the lake has an irregular shape. Based on the area of the lake, it can be said that Lake Pandan was included in a large lake.

The subsurface dimensions (Figure 1) found that the average depth (Z) of Lake Pandan has 0.21 m with a maximum depth (Z_{max}) of 1.7 m.

Pujiastuti [14] and Barroso [4] state that shallow waters usually have high biological productivity potential because the epilimnion layer was thicker than the hypolimnion layer. This is supported by the Lake Pandan Z value. A low Z value indicates that Lake Pandan has a low level of stability of stratification, making it easy to experience stirring.

3.3. Subsurface Dimension

The Lake Pandan Bathymetry map layout processed using the Arc Map Software could be seen in Figure 1. The Lake Pandan contour line layout map that was processed using the Arc Map Software can be seen in Figure 2b and Lake Pandan without contour line can be seen in Figure 2a.

Wetzel [15] reported that the mass of water with low Z will easily undergo stirring, so the water layer tends to be homogeneous and the nutrients resulting from decomposition from the decomposition zone will be distributed to the epilimnion layer. Aldama *et al.* (2013) and Barroso *et al.* (2014) state the depth of the lake has a very big effect on water quality. The morphometric parameters of the lake influence the physical, chemical and biological processes in the waters of Lake Pandan, such as depth.

Table 1. The Data Surface Dimension of Lake Pandan

No.	Parameters	Values	Unit
1.	Maximum Length (L_{max})	2.034,60	m
2.	Effective Maximum Length (L_e)	1.751,57	m
3.	Maximum Width (W_{max})	1.033,38	m
4.	Effective Maximum Width (W_e)	762,72	m
5.	Surface area (A_o)	103	m ²
6.	Average Width (W)	50,62	m
7.	Lake Development Index (LDI)	0,302	m
8.	Long Lake Round (SI)	5.395	m

4. CONCLUSION

Bathymetry mapping results show that the deepest area was found in the western part of Lake Pandan with a range of 1.5 m - 1.7 m depth. The deepest location found at the 10th station was marked in blue. The most shallow location (0 m -1 m) were in the southern part of Lake Pandan. The results of measurements in the field were directly obtained that Lake Pandan has an area of $\pm$ 103 Ha, with a maximum length of 2,034.60 m, Maximum Width of 1,033.38 m, and Lake Length of 5,395 m. More complete data.

Morphometric measurements show Lake Pandan has a different L_{max} and L_e . The length and width of Lake Pandan were also different so that there is freedom of movement of the wind above the surface of the water which will affect the movement of the water mass and indicate the contours of the lake's bottom which is relatively flat. This value illustrates that the waters were relatively flat with large littoral areas. Waters with large littoral areas have high biological productivity potential. Wetzel reports that the mass of water with a low Z will be easily mixed, so the water layer tends to be homogeneous and the decomposed nutrients from the decomposition

zone will be distributed to the epilimnion layer. Aldama *et al.* and Barroso *et al.* state the depth of the lake have a very big effect on water quality. The morphometric parameters of the lake influence the physical, chemical and biological processes in the waters of Lake Pandan, such as depth.

5. ACKNOWLEDGEMENTS

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