Utilization of DSM and DTM for Spatial Information in Lake Border

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Abstract. Lake is one part of inland waters and plays an important role in human life and the surrounding environment. Lakes need to be preserved, especially in the lake area and its border. One way to preserve the lake is to map the potential of spatial information in the lake and its surroundings. Digital Terrain Model (DTM) and Digital Surface Model (DSM) can be used to obtain spatial information in the lake border. DTM and DSM can be extracted from terrestrial and non-terrestrial mapping such as remote sensing satellites. The study area in this study is Lake Oeduli on Rote Island. This study aims to inform the potential utilization of DSM and DTM for the spatial border of lakes. The potential is in the form of determining the lakeside line, lake border area, and vegetation height. All of these potentials can be extracted from DSM and DTM. This DSM and DTM can also be dynamic and non-dynamic. The results of this study can be utilized as a method for spatial information extraction of lake borders in support of national inland waters.

Keywords: DSM, DTM, spatial information, lake border, Rote Island

1. Introduction

Lake is one part of inland waters and plays an important role in human life and the surrounding environment. Geologically, the formation of lakes is divided into tectonic, volcanic, technological, and flood exposure lakes. The type of lake depends on the distribution of the location of plates, faults, volcanoes, and basins at lower elevations over large areas. One of the unique lakes in Indonesia is lakes with very high salinity. These lakes are located in the area of the dead sea lake of the Rote Island which are generally tectonic lakes, see figure 1.
One of the problems of lakes today is the determination of lake borders. Lake needs to be preserved, especially in the lake area and its border. This lake boundary is used to determine the lake border. The area can be used for conservation and lake space planning [2]. One way to preserve the lake is to map the potential of spatial information in the lake and its surroundings. Spatial information can be obtained by terrestrial, aerial, and satellite surveys [3]. The spatial information needed for determining the boundary of a lake is the Digital Terrain Model (DTM) and Digital Surface Model (DSM). DSM and DTM can be used to obtain spatial information in the lake border. DTM and DSM can be extracted from terrestrial and non-terrestrial mapping such as remote sensing satellites [4].

DEM optical data uses optical satellite image data, aerial photography, video. DEM can also be defined as a digital model that provides information about the shape of the Earth's surface (topography) in the form of raster data, vectors or other forms of data [5]. DEM can be made by several methods such as stereo, interferometry, DEM integration, DEM fusion, and others. In optical data, high model extraction uses a stereo model, videogrammetry, and perceptive depth cue. DEM can be extracted from Synthetic Aperture Radar (SAR) satellite imagery data, Interferometry Synthetic Aperture Radar (IFSAR), Light Detection and Ranging (LiDAR) [6]. The height model extraction method uses stereo, interferometry, and perceptive depth cue models. DEMs created with sonar can use data from Interferometry Synthetic Aperture Sonar (IFSAS) [7].

DSM and DTM are involved in various mapping survey applications. Ground-level has a role in modulating atmospheric, geomorphic, hydrological, and ecological processes that operate on or near the Earth's surface [8]; [9]. An understanding of the character of this land surface can directly inform understanding of the nature and magnitude of the processes which mentioned previously [10]. Applications that exploit this knowledge rely on DEM to represent surfaces and various sophisticated and increasingly sophisticated techniques for topographic analysis and visualization [11]. There are several methods for making DEM, namely TIN, stereo, interferometry, LiDAR, videogrammetry, DEM combination [12]. This study aims to inform the potential utilization of DSM and DTM for the spatial border of lakes.

2. Methods
The method used in this research was geomodeling (DSM and DTM). DEM is a representation of an array of quadratic cells (pixels) with elevation values associated with each pixel. [13], [14]. DEM can be obtained from contour lines, topographic maps, field surveys, photogrammetric techniques, radar interferometry, and laser altimetry [13]. Different interpolation methods applied to the same data source can produce different results, therefore it needed to evaluate the comparative suitability of this technique.

DSM is an elevation model that includes of the roof of buildings, trees, and other objects, usually as a canopy model [15]. Meanwhile, DTM is a model of bare earth elevation or surface autocorrelation without vegetation, buildings and other objects [16]. In this research, DSM and DTM research uses the DEM integration method which created dynamically using the ALOS PALSAR, Sentinel, and Planet.
imagery. This method used the DEM integration reference [12], while DSM ALOS PALSAR's image is a Japanese SAR image. This image has a spatial resolution of 6.25 m and extracted by the IFSAR method which resulting a vertical accuracy of 2-3 m for the territory of Indonesia [12]; [17]. Sentinel Image is a SAR image of the European Space Agency (ESA) which has a spatial resolution of 10 m [18]. PlanetScope is satellite imagery obtained from the planet.com which has a spatial resolution of 3 m. This image has a temporal resolution of 1 day and is an optical image. Image Planet is very useful in dynamics applications. DTM integration with satellite multi-data can produce a maximum vertical accuracy of ~ 80 cm [19].

There are several potential things in determining the boundary of a lake. The potential is in the form of determining the lakeside line, lake border area, vegetation height, vegetation volume, vertical deformation, and geological structure. The research focus is the lake border and the vegetation height. These potentials can be extracted from DSM and DTM. Those geomodelling data were obtained by remote sensing satellite image data sources both in the dynamic and non-dynamic forms.

2.1. Data and study area
Research area in this study located on Rote Dead Sea Lake Region, Rote Island (figure 2). Rote Island has many lakes that have unique characteristics. Lake Oemasapoka is the largest lake in the whole Rote Island, with an estimated total area of 1005 ha [20]. In the eastern part of Rote Island, several saltwater lakes have very similar ecosystems to the sea, such as Lake Oemasapoka, Lake Oeinalaen, Lake Oeduli, Lake Oeapa, Lake Bisaolifoe, Lake Bisafoh, Lake Oeina, Lake Tutui, Lake Oekukura, and others. These lakes are also saltwater, meaning that the salinity of this lake is higher than a normal freshwater lake, or even higher than sea-saltiness [20]. These lakes have higher salt content than seawater and are inhabited. The data used is a combination of ALOS PALSAR and Planet. DSM and DTM extraction are the latest conditions in July 2019.

![Figure 2. Lake Oeduli [1].](image)

Lake Oeduli is one of the saltwater lakes in the Rote Dead Sea Region. Salinity in this lake exceeds the salinity of seawater. Its area is ~416,800 m². Based on the measurement of salinity in Lake Oeduli, the salinity of Lake Oeduli water is 50-60 ppt. The measurements were carried out in 2019. The normal salinity of seawater was 34 ppt. The salinity conditions at Lake Oeduli can be seen in figure 3. In this area, there are found many sponges (soft corals) and salt foam from the evaporation of water due to very heavy winds in this lake.
Figure 3. (a) Sponges and (b) salt foam in Lake Oeduli

Figure 3 is a photo of a field on Lake Oeduli. Figure 3 (a) shows lot of sponges on the Lake Oeduli boundary, while figure 3 (b) shows a salt foam located on the boundary of a lake. The parameters of this sponge and salt foam can cause an error in the prediction of the boundary of the lake by using DTM. This prediction error can be minimized by using a tolerance of $1.96 \sigma$ (95%) according to the class 2 mapping standard [21].

3. Results and Discussion

The results of this study are the spatial information of Lake Oeduli's boundary using DSM and DTM. In addition to the margins, initial results are also obtained in the form of DSM, DTM, and vegetation height. DSM is made with the integration of ALOS PALSAR with Sentinel and Planet. The integration of DEM on ALOS PALSAR DSM results and dynamics in Sentinel and Planet imagery will result in DSM. The DSM obtained is done high error correction to meet the tolerance of 95%. The height reference field used is EGM 2008. Figure 4 represents the DSM of Lake Oeduli created using the DEM Integration method.

Figure 4. DSM in Rote Dead Sea Lake region.

After obtained the data of DSM, then it reduced to DTM. The vegetation and building information on the DSM is filtered so that the DTM is obtained. This DTM is a terrain visualization and can be used for a variety of applications, such as determining lake boundaries as shown in figure 5.
The results of DTM still have a high error but have met the tolerance of 95%. DTM became free of height error if it meets the tolerance of mapping of 95% as seen on figure 6. Because of this height errors are generally spread on the boundary of the lake on the north-west side (figure 6), there is a light blue-white color. In this area, there are may found many sponges and salt foams. Those abundance of sponge and salts forms might be caused by the strong winds that blow from the northeast to the northwest. In this study, the DTM only describes the topographic conditions and has not been integrated with bathymetry data. Several locations in the south experience height errors, especially on the southern part. The cause of this height error probably due to higher vegetation height on that part than the surrounding area. This vegetation height can be seen in figure 7. In figure 7, higher vegetation height is found on the east to the south side. Vegetation height is obtained from the reduction of DSM with DTM. This vegetation height can be used for other applications such as carbon counts, changes in vegetation height, changes in building height, and others. After obtaining the DTM and vegetation height, then the lake boundary can be determined. Determination of the lake boundary is done if it has met the tolerance of 95% of the DTM used. Then masking the DTM in the elevation plane 0 m or <0 m. The results obtained are the prediction of the Lake Oeduli boundary, see figure 8.
In Figure 8, the Lake Oeduli boundary is overlaying with other imagery which obtained from Planet imagery. The Lake Oeduli boundary looks less smooth due to masking factors and resampling of DTM spatial resolution of 5 m to 20 m. This was done to speed up the data processing. The lake also show the results of bathymetry prediction at depths of -2 m to 0 m. Deeper values are visualized in dark blue. The use of DTM to determine the boundary of this lake can also be used in other lakes in Indonesia. DTM will be more effectively used in tectonic, volcanic and techno-volcanic lakes. It is caused by the dynamics changes in lake boundary in tectonic, volcanic and tectonic-vulcanic regions do not change drastically and rapidly. This condition will be different from the floodplain lake which poses higher dynamics.

4. Conclusions
This study concluded that the lake boundary can be predicted using DTM. This DTM is obtained from the DSM derivative results. The DSM was obtained from the integration of DEM from ALOS PALSAR with both of Sentinel and Planet imageries. The Lake Oeduli boundary in this study can be predicted with a tolerance of 95%. One of the causes of high errors in some borders of Lake Oeduli is caused by the occurrence of many sponges (soft corals) and salt foam.
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