Dynamics of Lake Beratan Area Changes Due to Sedimentation Using Remote Sensing Imagery

Dewa Made Atmaja[1], I Gede Yudi Wisnawa[2], Wayan Damar Windu Kurniawan[3], I Gst Ngr Yoga Jayantara[4]

{made.atmaja@undiksha.ac.id[1]}

Universitas Pendidikan Ganesha, Indonesia, [1,2,3,4]

Abstract. The dynamics of the area of Lake Beratan is important to know the impact of population development and changes in land use changes that occur around the lake. In addition, sedimentation originating from river flows and household waste is a concern which can cause silting and pollution of Lake Berata water. Therefore, the aim of this research is to monitor the area of Lake Beratan periodically using a fast and efficient method. The method used to support this is remote sensing technology, especially through visual interpretation by paying attention to the key elements of interpretation and digitizing it on screen. The results show that there are differences in areas from 1990, 2000, 2010 and 2020. The largest area obtained when digitized in 2010 was 377.42 hectares and the smallest area in 2020 was 363.98 ha. The entire digitization process cannot be separated from knowledge of interpretation in digitization and recognizing the conditions of the Beratan Lake area. Based on this, it is possible for remote sensing imagery to be used in monitoring lake area manually and to obtain more accurate results of course combined with color composite analysis.

Keywords: Landsat, Visual Interpretation, Digitizing, Lake Beratan Area

1 Introduction

Indonesia has 840 large lakes and 735 small lakes which contain 25% of the world's germplasm, and supply 72% of surface water and provide water for agriculture, community raw water sources, hydroelectric power plants and tourism. Currently, most of the lake ecosystems in Indonesia have experienced degradation (decreased quality) due to population growth, forest land conversion, pollution and erosion that occurred in the lake water catchment areas. The 1st Indonesian National Lakes Conference (KNDI I) in Bali in 2009 and the 2nd (KNKD II) in Semarang in 2011 resulted in an agreement on sustainable lake management, where management and saving of lake ecosystems will be carried out periodically based on the severity of the level of damage and its impact on community life. One of the damages caused is the emergence of sedimentation which occurs and flows into the lake.

Sedimentation is a very important thing to pay attention to, especially in lake or reservoir areas [1,2]. Especially in the Indonesian region itself which has two dominant climates to cause lake sedimentation to increase quickly [2,3]. The higher the shallowing is caused by the faster surface water enters the river directly with all the material carried to the estuary in the form of a lake, reservoir or sea [4]. The impact of sedimentation in a short period of time is difficult to know just like that, but if it occurs over a certain period of time and occurs continuously then shallowing of the lake or pollution due to shallowing is possible to occur [1,2,5]. Problems related to sedimentation do not only come from climate but also from

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changes in land around lakes or reservoirs in a river basin (DAS) [5]. Sedimentation resulting from human and natural activities influences changes in the surface area of a lake or reservoir itself [2,6,7]. Detecting sedimentation that is tracked through indications of changes in lake surface area can also be done using remote sensing [6,8].

Remote sensing is a suitable method for observing sedimentation which results in changes in lake area dynamics using remote sensing images [1,2]. Measurements via remote sensing imagery cannot be done at one time but must be done multi-temporally to emphasize changes in sedimentation which result in changes in lake area and changes in lake surface temperature [9-12]. The results of remote sensing image analysis with multi-temporal data can identify the dynamics of changes in lake area due to sedimentation [2,11,12]. Problems that arise related to changes in lake ecosystems are increased sedimentation and changes in lake areas. Therefore, efforts need to be made to monitor sedimentation and lake area temporally to overcome this problem. The most appropriate location to optimize monitoring of sedimentation and lake area is Lake Beratan. This is because Lake Beratan has experienced dynamic changes, especially due to the growth of tourism, which has affected water quality conditions and light pollution has also been identified.

The causes of damage to the function of Lake Beratan are sedimentation, water quality, changes in land use and increased water use. The impacts resulting from factors influencing the function of the lake are the reduction in lake volume, the extinction of the tin head fish (Aplocheilid panchax), the extinction of green algae (charophyte), not suitable for drinking, tourist attractions around the lake, if the skin comes into contact with the water, it will cause itching, the ecosystem in the rainwater catchment area will be disturbed, water runoff will increase so that more sediment will be transported into the body of the lake. Based on this explanation, it is important that research be carried out on Lake Beratan to determine changes in area and analyze these changes.

2 Study Area and Data

2.1 Study Area

The location of this research is focused on the Beratan Lake (Figure 1) area which is located in the caldera of the Bedugul plateau, which is one of the tourist attractions on the island of Bali, located approximately 50 kilometers to the north of the city of Denpasar and approximately 43 kilometers to the northeast of the city of Tabanan.

Obtaining the area of Lake Beratan was carried out by visual interpretation of remote sensing images because Lake Beratan objects can be seen clearly. In addition, the identified area is obtained through onscreen digitization with changes in color composites that are sensitive to distinguishing water and land.

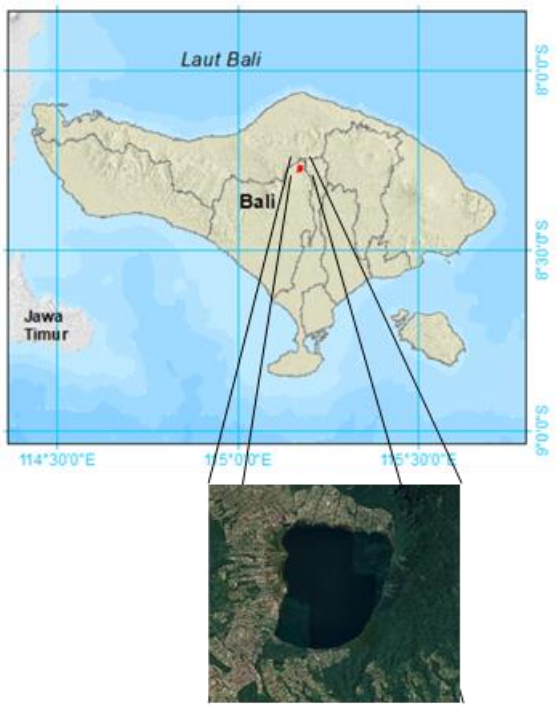

Fig.1. Research Location

2.2 Remote Sensing Data

This research uses Landsat 8 OLI/TIRS imagery and can be obtained for free on the official USGS website http://earthexplorer.usgs.gov. Landsat image processing stages are carried out starting from radiometric correction, such as changing the Digital Number (DN) to Reflectance and then correction Top of Atmospheric (TOA) and ends with a correction Dark Object Subtraction (DOS) [13,14]. No changes were made to the Geometric correction because Landsat 8 already has a level of accuracy according to the position of the earth's surface and this has been stated in the metadata and also the image level, namely level 1T [15].

3 Method

3.1 Visual Interpretation

The method used in this study is simple and detailed, namely manual interpretation. Manual interpretation was chosen because it is closely related to the remote sensing imagery, namely High spatial resolution. The high-resolution imagery used comes from Google Earth imagery which can be obtained for free. In addition, manual interpretation uses an interpretation key as a basis for drawing lines and boundaries from Lake Beratan. This certainly has weaknesses that are entirely focused on the interpreter. Manual interpretation

was carried out on images from 1990-2020 as a basis for determining the dynamics of changes in Lake Beratan.

4 Result and Discussion

The broad dynamics of Lake Beratan cannot be separated from the impact of increasing population density and land conversion. Lake Beratan is indirectly a source of daily water needs for residents around the lake. Atmaja [16] said that the water balance in Lake Beratan is in the critical category. This is also proven by the change in Lake Beratan which is decreasing from 1990 to 2020. Apart from that, the rate of sedimentation in Lake Beratan is relatively large, namely 0.56 tons/ha/year, thus allowing for shallowing of the lake and a reduction in the area it has [17]. Continuous changes in the area of the lake due to water use or sedimentation will trigger other disaster impacts such as land subsidence [18].

Measurements from the results of visual interpretation of the Landsat 8 OLI image and then validation of the position using the high-resolution image approach owned by Google Earth showed that the geometric position was appropriate to the location and had not experienced a significant shift (Figure 2). Apart from that, the use of spectral patterns with color composites in different channels is very helpful in distinguishing the outer boundaries of water and land in Lake Beratan. In Landsat 8 OLI the composites used to distinguish between water and land are composites 567 and 564. These two composites are sensitive in distinguishing water and land reflection patterns. In addition, the color composite was chosen to differentiate water and land objects better based on changes in Lake Beratan compared to vegetation indices such as NDVI because the area of Lake Beratan is clearly defined between water and land. Then the area of Lake Beratan in remote sensing images is still better recognized with clear boundaries so that using NDVI will require more time and treatment to obtain the area of Lake Beratan [19]. In addition, changes in lake dynamics are the same as changes in coastline dynamics, where all are influenced by human activities and changes in land use, which will have negative impacts such as droughts on water needs [20,21].

Changes in Lake Beratan in 1990 and 2000 had a similar pattern and the location decreased or increased (Figures 3a, 3b). This is caused by community activities on the edge of the lake which is used as a tourist attraction. Meanwhile, changes from 2000 to 2010 and 2020 saw a shift in position but had the same pattern (Figures 3c, 3d). This is a result of the different geometric correction processes carried out on each remote sensing image. The wide differences that occurred between 1990 and 2020 were mostly in the north, west and south of Lake Beratan. The dynamics of change tend to be influenced by increased development or human activity on the edge of the lake. Even though it enters the lake body, it is not significant, but it will be a differentiator when digitized. Then, the boat parking and water rides on the lake look like building covers so that makes a difference when digitizing. Knowing this, it can be confirmed that there was an error on the part of the interpreter in carrying out the digitization and this resulted in additions or deletions in the identification of Lake Beratan. However, this should not cause large differences because the digitization scale used is the same, around 5 (five) times zoom in. The difference in curves during digitization

becomes a problem and the digitized data is not smoothed as provided by the spatial data processing application, namely ArcGIS. This is because it can reduce the area directly carried out when this digitization is carried out. It looks good/smoother but in the case of the lake it becomes not good to use so it will look rougher every turn/bend it takes in the digitization.

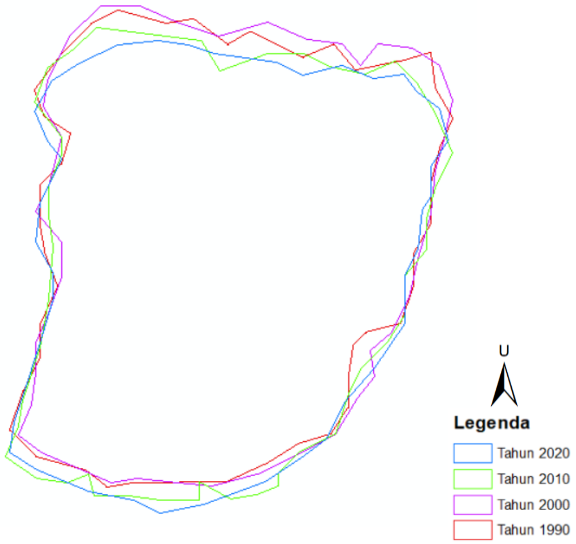

Fig. 2. Lake Beratan Digitization Results 1990 to 2020

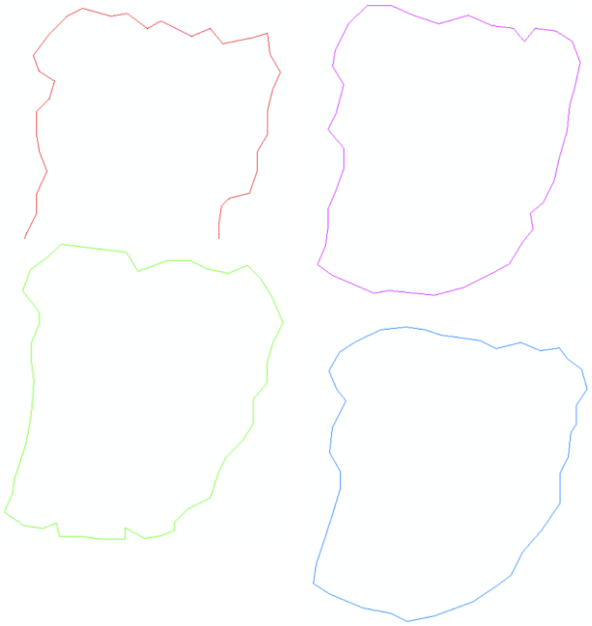

Fig. 3. Lake Beratan Digitization Results; a) 1990, b) 2000, c) 2010, and d) 2020

The difference in area between 1990, 2000, 2010 and 2020 (Figure 4) shows a significant increase but also a continuous decline. From 1990 to 2000 there was an increase in the area of Lake Beratan by 9.62 hectares. This is possible due to increased development in the Beratan Lake area as an economic support. Apart from that, from 2000 to 2010 there was a significant decrease with almost the same area as the increase of 9.22 hectares. Furthermore, from 2010 to 2020 there was a decline again of 4.23 hectares. Monitoring using visual interpretation and on-screen digitization is different from the classification method used by Koto et al. [9] used a classification method on remote sensing images to determine area and the result was that remote sensing images could provide different area results and dynamics like digitization results. Apart from that, Trisakti et al. [10] who used two different Landsat and SPOT images and compared them with color composites, showed that color composites were more optimally used to distinguish clear boundaries of water and land compared to certain formulas.

Based on this, remote sensing images will provide area information which will certainly differ from processing by various methods. Moreover, different remote sensing image recording times can contribute to differences in lake areas due to the influence of human activities or seasonal changes, especially in the dry season. Apart from that, lake identification through remote sensing image data is one method that can be an option for quickly obtaining information on broad dynamics over time.

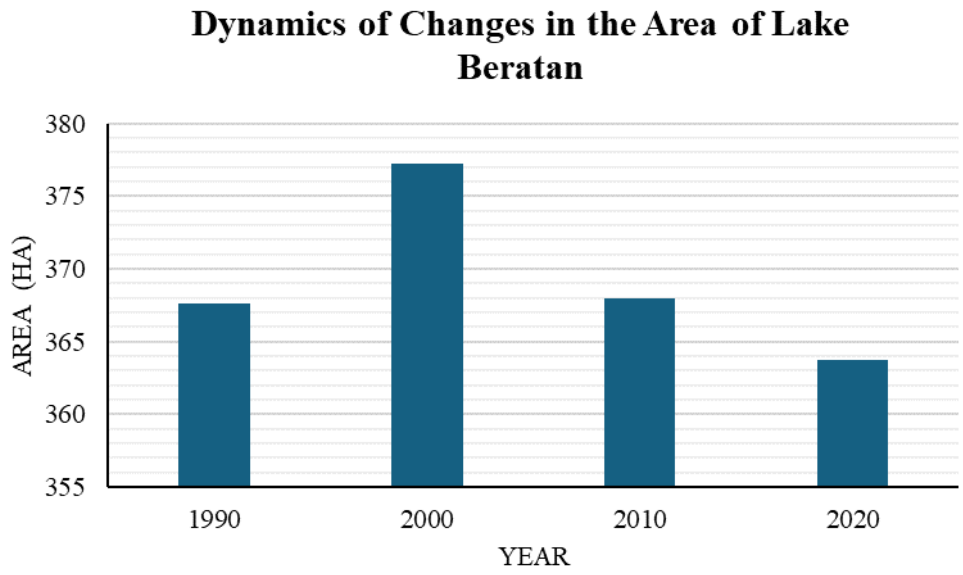

Fig. 3. Total Suspended Solid result (a) TSS Landsat 2015 and (b) TSS Landsat 2021

5 Conclusion

Remote sensing imagery can be used to monitor changes in lake dynamics, especially Lake Beratan. The largest area of use of onscreen digitization was in 2000 and the smallest area was in 2020. Changes in the dynamics of the area of Lake Beratan were influenced by occupation activities and as a tourist location, resulting in shallowing of sediment and the closure of several lake boundaries with buildings.

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