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Analysis of Rawa Pening Lake Morphometric Changes for Identification of Land Arises

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ABSTRACT

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Rawa Pening Lake is a natural lake with the status of a critical lake in Indonesia because there is an uncontrolled population of water hyacinths, so a layer of water hyacinths covers the surface of the water. Sedimentation causes indications of the appearance of soil to arise. Based on this, it is essential to monitor the presence of surface soil. This study aimed to determine changes in the morphometry and morphology of Rawa Pening Lake, to study changes in morphology, and the spatial distribution of land arising indicative of Rawa Pening Lake. The study This data used the satellite imagery of Landsat 5 in 1989, Landsat 7 in 2002, and Landsat 8 in 2015 and 2021. The method used is NDWI (Normalized Difference Water Index) and manual interpretation to distinguish between water and non-water areas. The results showed that the use of the NDWI method was not optimal for determining the firm boundaries of the lake. The manual interpretation method shows that in 1989–2002, Rawa Pening Lake experienced a narrowing with a change in the area of 75,639 Ha and the distribution of indicative raised land of 141,146 Ha. From 2002–2015, the lake experienced an increase in the area of 159,734 Ha, and the total area of indicative arising land distribution was 99,285 Ha, and in 2015–2021 there was a change in the area of 230,192 Ha with the distribution of raised land of 18.010 Ha.

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1. INTRODUCTION

Lake is a water ecosystem rich in productive natural resources for human life and the environment. Natural resources are one of the factors in creating community economic activities to increase economic growth in a region (Fitriani et al., 2019). Rawa Pening Lake is a natural lake that has an essential role in the water ecosystem located in Central Java Province. The lake is a traffic stop and collects surface water for various human needs (Piranti et al., 2018). Rawa Pening Lake is a strategic area supporting the agriculture, tourism, and fisheries sectors (Apriliyana, 2015). However, the lake has severe problems regarding uncontrolled water hyacinth development, almost covering most of the water's surface (Utomo, 2016). Land use change causes the lake's condition to experience degradation, which was initially forest to become agricultural land on a sloped area of 25-40% (Apriliyana, 2015). The water quality of Rawa Pening Lake has decreased from 2013 to 15, so it can be said that the lake's trophic status belongs to the hypertrophic damaged group (Heriza et al., 2018). Rawa Pening Lake also experienced a decrease in the area from 1990 to 2009 due to the sedimentation that changed the lake morphometry (Hardini et al., 2012). These problems can lead to other problems, such as control and ownership of land arising. Based on these, monitoring of land arises, and lake morphometry needs to be monitored to avoid various problems. One of the methods that can monitor the presence of land arises and lake morphometry is remote sensing. Remote sensing methods have advantages in obtaining data and mapping a comprehensive area coverage.

Image data shows that the entire area of the lake is in the form of water and land, so it is necessary to process it to separate the water and land areas using the Normalized Difference Water Index (NDWI) algorithm. The NDWI algorithm can distinguish between bodies of water and land with a reasonable degree of accuracy (Prayogo, 2021). NDWI is an algorithm used to separate water and land areas by utilizing a green band channel with a wavelength that has and responds well to objects in the form of water and a Near Infrared (NIR) band channel, which has an excellent response to vegetation and soil so that both channel bands are ideal for combination (McFeeters, 1996). The Near Infrared Channel and the green channel in Landsat and Sentinel imagery produce a border with the shape of the beach with rocky, sandy, and mangrove cliff characteristics (Ginting, 2020). The separation between land and water areas is used to identify indicative relief land and lake morphometric changes using multispectral Landsat imagery data from 1989 to 2021. This research is expected to help local governments know the spatial distribution of arises land. This research aims to study the morphometric changes of Rawa Pening Lake from 1989 to 2021 and indications of land distribution arise.

2. METHOD

2.1. Location

This research is located in Rawa Pening Lake in Semarang Regency. The lake is geographically located at 7^0 04' – $7^0$30' S Latitude dan $110^0$24'46" - $110^0$49'06" E Longitude (Figure 1). Based on the Decree of the PUPR Minister No 365/KPTS/M/2020 concerning the Establishment of The Demarcation Line of Rawa Pening Lake in the Jratunseluna River area, the lake has an area of 2.507 Ha.

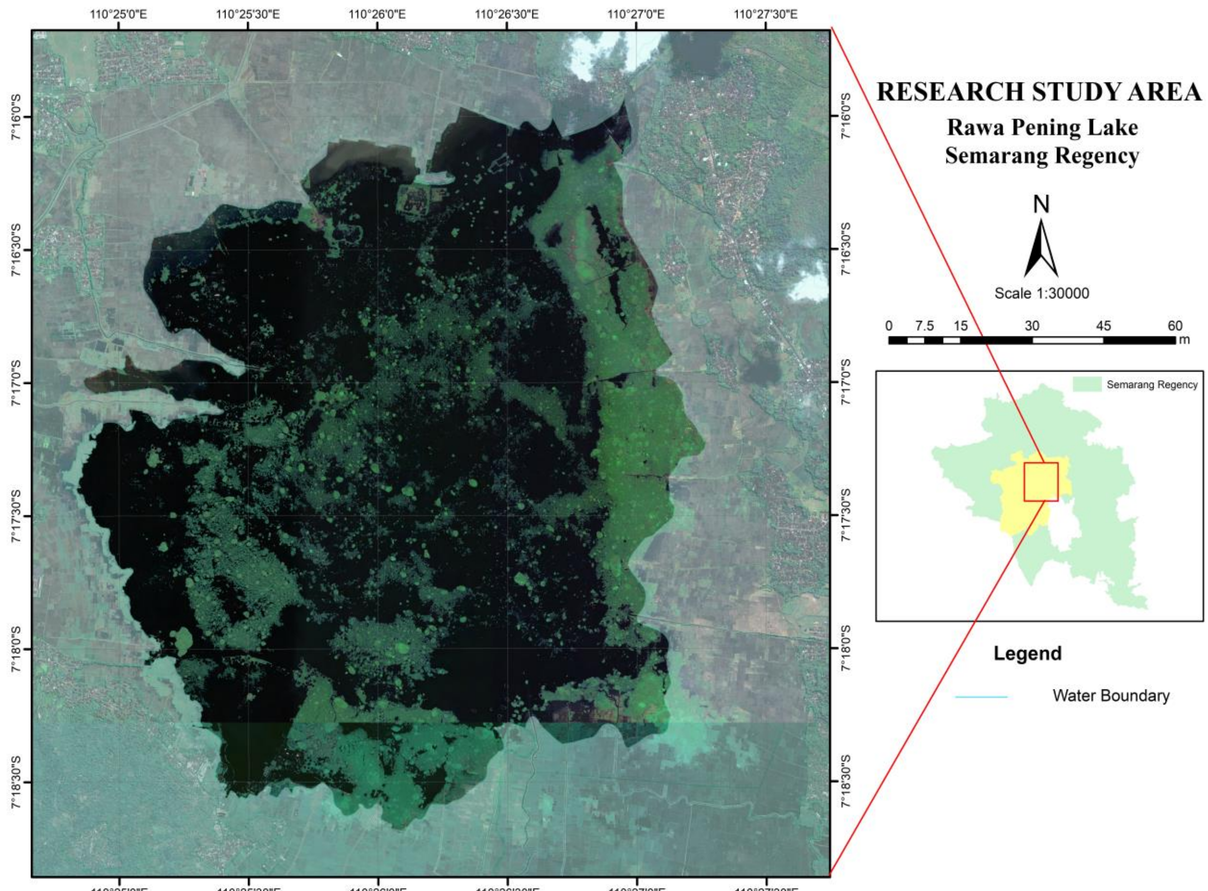

Figure 1. Research location

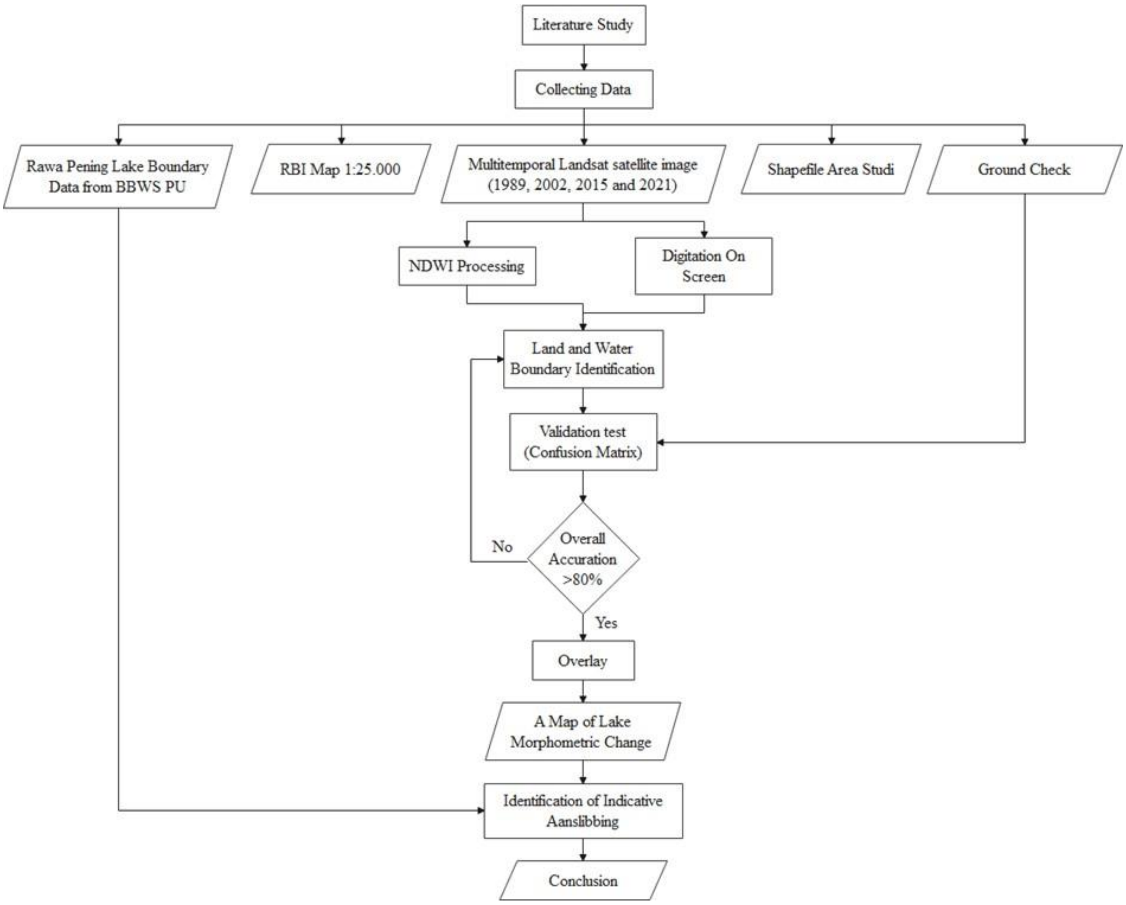

Figure 2. Research flowchart

2.2. Data

The data used in this study are as follows: Administrative map of Semarang Regency in 2020 from the PUPR Regency Office Semarang, Landsat 5 imagery 1989 from USGS, Landsat 7 imagery 2002 from USGS, Landsat 8 imagery 2015 and 2021 from USGS, Rawa Pening Lake land and water boundary data from BBWS PU Central Java. This research starts from the preparation, pre-processing, processing, and analysis stages, which can be seen in Figure 2.

2.3. Normalized Difference Water Index (NDWI)

NDWI is an algorithm used to estimate soil moisture and canopy water content (Sánchez-Ruiz et al., 2014). NDWI algorithm is also used to identify water and land areas in satellite images. The application of NDWI utilizes a combination of band channels between Near Infrared and Green channels (Anggraini et al., 2017). The results of the NDWI algorithm have a value range between -1 to 1. If the NDWI results have a value greater than zero, then the area is water, and vice versa; if the NDWI results have a value less than zero, then the area is land. (McFeeters, 1996). The NDWI formula can be seen in Equation 1.

$$\text{NDWI} = \frac{\text{Green Band} - \text{NIR Band}}{\text{Green Band} + \text{NIR Band}} \quad (1)$$

Description:
Green channel : Channel 2 reflectance Landsat 5 imagery
NIR channel : Channel 4 reflectance Landsat 5 imagery
or
Green channel : Channel 2 reflectance Landsat 7 imagery
NIR channel : Channel 4 reflectance Landsat 7 imagery
or
Green channel : Channel 3 reflectance Landsat 8 imagery
NIR channel : Channel 5 reflectance Landsat 8 imagery

2.4. Land Arises

Land arises is land that is formed naturally due to the deposition of rivers, lakes, beaches, and/or emerging islands, and its control is controlled by the state according to PMNA/KBPN number 17 of 2016 article 1. Land arises from sedimentation resulting from river erosion forming a stretch (Hidayat, 2021). The community often uses the land for agriculture or ponds because it is a natural resource with economic value. Land arises a positive impact on society but often causes various problems. Land arising creates problems in various aspects, including recognition, protection, and legal certainty of control over emerging land. Land arising in Indonesia is a serious problem because there are no strict rules regarding land-arising rights. Land arises often becomes a problem of ownership disputes because some are used as illegal settlements without IMB (Building Permits) or unilateral claims by providing land boundary markers in the form of stakes. The general public often thinks that the land's status arises; ownership is unclear so that it can be claimed first, but based on juridically, the state owns the land. The conflict cycle must understand the duration, location, pattern, focus, and time duration in implementing land/agrarian conflict resolution strategies (Hanum, 2017).

2.5. Morphometry

Morphometry is a quantitative assessment of measuring the morphological characteristics of the waterbed based on the parameters contained in a lake or watershed (Welch, 1952). Lake morphometry has shape characteristics based on underwater basins. The physical form of the lake is affected by seasonal variations, waves, and currents. Morphometric parameters include length, width, depth, area, volume, coastline circumference, and shore development (Cole, 1993). The morphometric structure of the lake can be measured based on water depth and elevation. Lake morphometry is also influenced by the topography around the lake area and land use.

3. RESULT AND DISCUSSION

3.1. Analysis of Normalized Difference Water Index (NDWI)

The NDWI used in this study utilizes the reflection of the NIR channel and the Green Channel to enhance water features and eliminate land and terrestrial vegetation features. The results of Landsat 5 image processing in 1989 are shown in Figure 3a, and each classification obtained an NDWI value range of -0.8649 to -0.5965 for non-water bodies (Land), the vegetation of -0.5965 to -0.1016 and water bodies of -0.1016 to 0.6557. Figure 3a shows the condition of Rawa Pening Lake, which is dominated by water bodies, and several non-water bodies spread around the lake.

The NDWI algorithm was applied to Landsat 7 imagery in 2002, which can be seen in Figure 3b. The results of processing the NDWI classification obtained a range of -0.6411 to -0.3841 for non-water bodies (Land), the vegetation of -0.3841 to - 0.1999, and water bodies of -0.1999 to 0.3371. The dominating part is the non-water body area for NDWI classification. One of the main factors causing non-water body areas to dominate in Landsat 7 imagery in 2002 is the uncontrolled growth of water hyacinths (blooming).

The results of applying the NDWI algorithm to Landsat 8 image data for 2015 can be seen in Figure 3c. The results of the NDWI classification processing obtained values ranging from -0.8715 to -0.6394 for non-water bodies (Land), vegetation from -0.6394 to -0.2826, and water bodies from -0.2826 to 0.5723. The results obtained in processing Landsat 8 imagery in 2015 with the NDWI method, the dominating part is the non-water body area that spreads to cover the lake body.

The NDWI processing results of Landsat 8 Image data in 2021 shown in Figure 3d have values ranging from -0.8894 to -0.6307 for non-water bodies (Land), the vegetation of -0.6307 to -0.2740 and water bodies of -0.2740 to 0.8938. The results obtained in processing Landsat 8 imagery in 2021 using the NDWI method are that the more dominant part is the water body area, but several non-water body areas spread across the surface of the lake body. The NDWI processing that has been carried out shows that the use of the NDWI method is not optimal in determining the precise boundaries of the lake because water hyacinth affects the results of NDWI processing; detected water hyacinth is considered as land. Still, visually it is shown to be close to the original conditions on Landsat 5, Landsat 7, and Landsat 8 images.

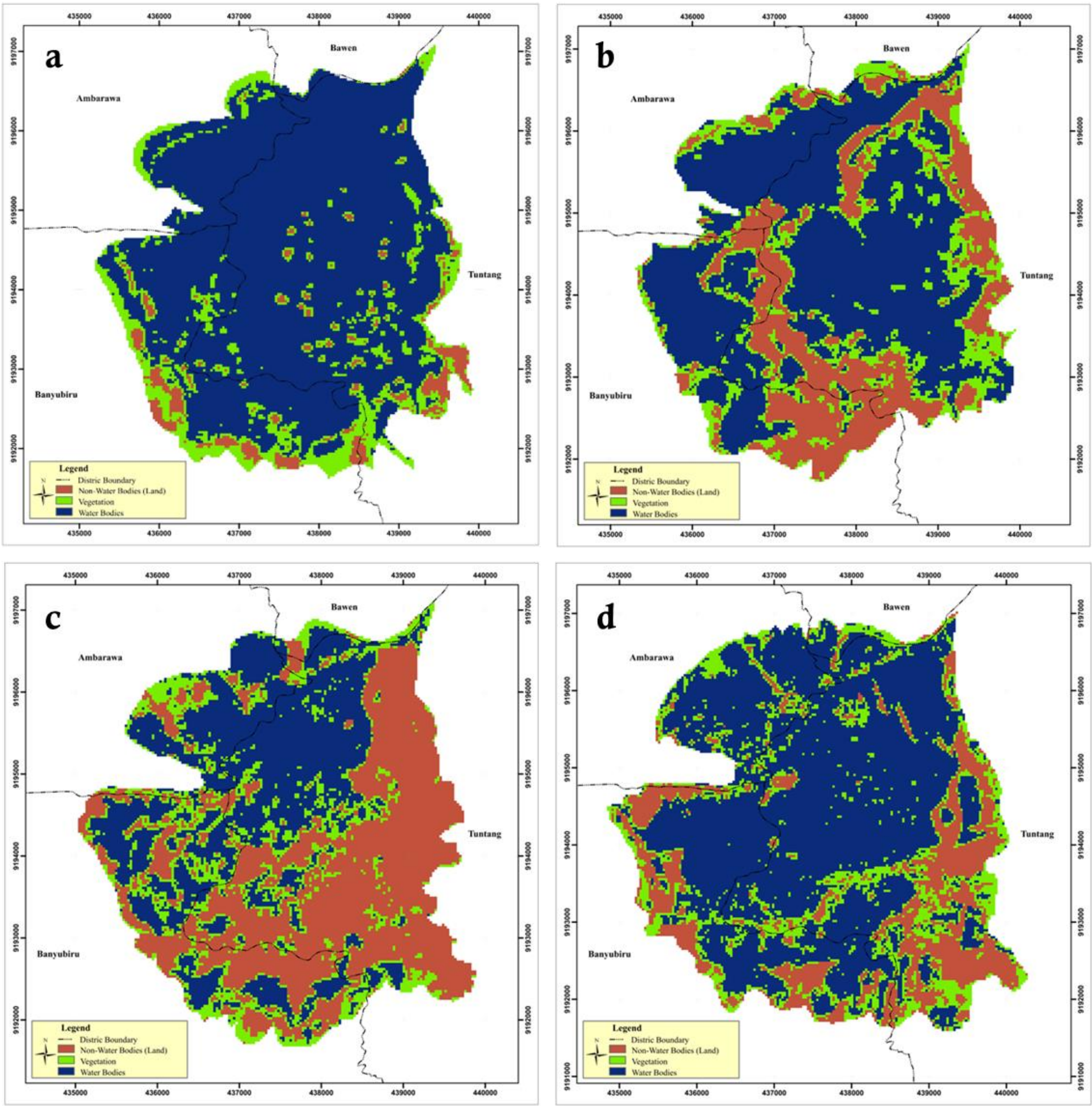

Figure 3. a) NDWI Landsat 5 imagery results 1989; b) NDWI Landsat 7 imagery results 2002; c) NDWI Landsat 8 imagery results 2015; d) NDWI Landsat 8 imagery results 2021.

Table 1. Area of Rawa Pening Lake 1989-2021

Year	Area (Ha)	Year Change	Area Change (Ha)
1989	1716,983	1989-2022	75,639 (-)
2002	1641,344		
2002	1641,344	2002-2015	159,734 (+)
2015	1801,078		
2015	1801,078	2015-2021	230,192 (+)
2021	2031,27		

Information: (+): lake experiencing widening; (-): lake experiencing narrowing

3.2. Analysis of Lake Area Changes

The digitization results of Landsat satellite imagery and colour combinations in each image yield details of the lake's total area from 1989 to 2021. Table 1 and Figure 4 show the area of Rawa Pening Lake from 1989 to 2021. The area of the lake in 1989 was 1716.983 Ha; in 2002, it was 1641.344 Ha; in 2015, it was 1801.078 Ha; and the area lake in 2021 is 2031 270 Ha. From the results obtained, it is clear that area changes have occurred in Rawa Pening Lake over the

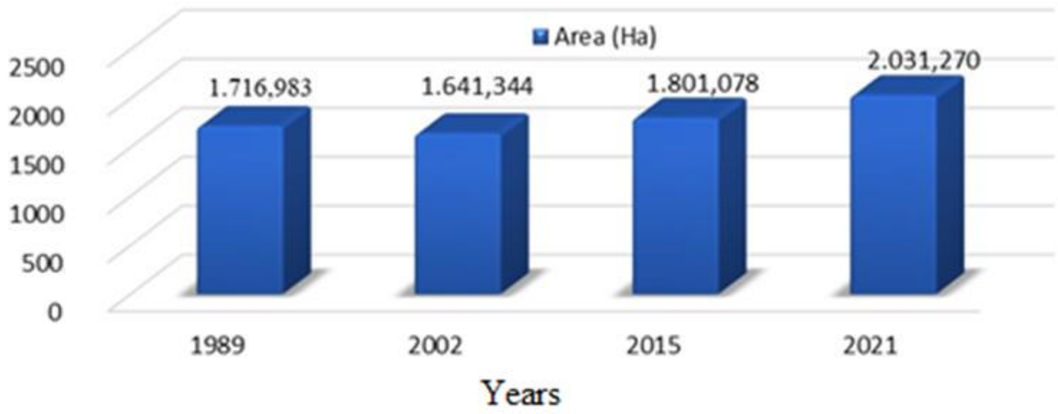

Figure 4. Changes Rawa Pening Lake area in 1989-2021

past 32 years. The lake's area narrowed from 1989 to 2002, amounting to 75.639 Ha. From 2002 to 2015, the lake widened by 159,734 Ha, and in 2021 Rawa Pening Lake widened by 230,192 Ha. Some of the NDWI processing data that has been carried out shows that in 2021 Rawa Pening Lake will experience a widening of the water body area. One of the factors causing Rawa Pening Lake to widen in 2021 is that since 2015 monitoring of water hyacinth cleaning and lake normalization has been carried out every year until now.

3.3. Changes in Lake Shape and Lake Direction

3.3.1. Lake shape changes in 1989 and 2002

Table 2 and Figure 5a show the direction of movement of the shape of Rawa Pening Lake from 1989 to 2002. Based on the results of the morphometric map, there have been changes in the lake consisting of lake expansion and lake narrowing, but the most dominant is the narrowing of the lake body. The largest lake increase occurs at an angle of 15˚, which is 217.797 m or 15˚ from the north to the northeast, and the least increase of the lake is at an angle of 300˚, which is 20.331 m or 30˚ from the west to the northwest. The biggest lake narrowing occurs at an angle of 165˚,

Table 2. Lake movement direction change in 1989-2002

Level	Lake distance change in 1989-2002 (m)	Level	Lake distance change in 1989-2002 (m)	Level	Lake distance change in 1989-2002 (m)
0°	-36,491	120°	82,240	240°	-74,732
15°	217,797	135°	-254,016	255°	-6,986
30°	23,438	150°	-86,538	270°	-106,680
45°	136,077	165°	-505,220	285°	21,639
60°	35,994	180°	-87,526	300°	20,332
75°	59,202	195°	-198,162	315°	-72,619
90°	84,984	210°	-210,126	330°	49,319
105°	189,481	225°	-290,791	345°	-141,140

Table 3. Lake movement direction change in 2002-2015

Level	Lake distance change in 2002-2015 (m)	Level	Lake distance change in 2002-2015 (m)	Level	Lake distance change in 2002-2015 (m)
0°	323,946	120°	-642,117	240°	67,391
15°	-138,010	135°	445,549	255°	68,637
30°	-13,432	150°	-62,406	270°	236,665
45°	-77,380	165°	281,774	285°	622,387
60°	-82,810	180°	170,615	300°	847,123
75°	-106,031	195°	215,257	315°	124,580
90°	-376,845	210°	18,985	330°	82,036
105°	-287,284	225°	71,581	345°	150,595

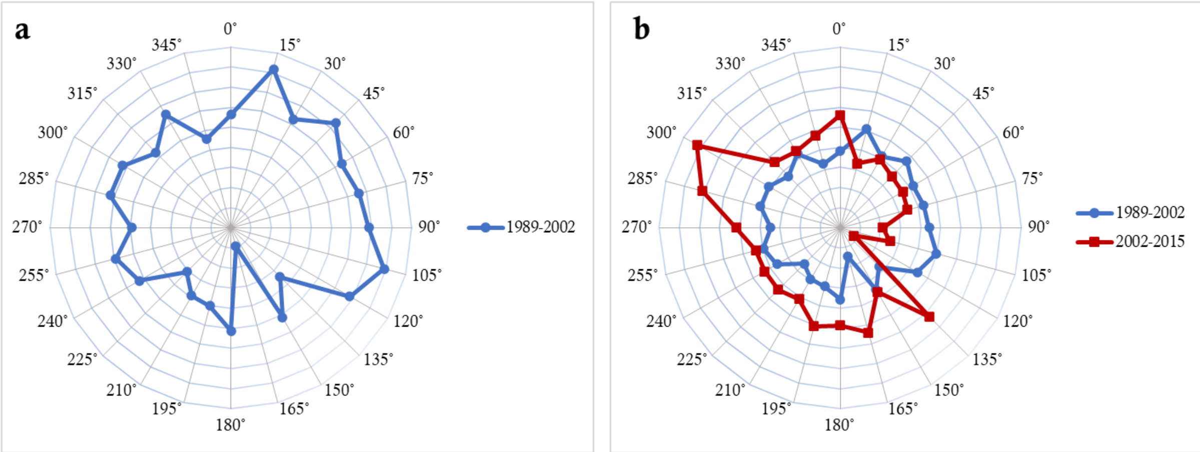

Figure 5. a) Lake direction changes in 1989-2002; b) Lake direction changes in 1989-2015

which is 505.220 m or 30˚ from the southeast towards the south, while the smallest narrowing occurs at an angle of 255˚, which is 6.985 m or 30˚ from the southwest towards the west. The changes in Rawa Pening Lake are most inclined toward the northeast, northwest, south, and west.

3.3.2. Lake shape changes in 2002-2015

Based on Table 3 and Figure 5b shows the direction of movement of the shape of Rawa Pening Lake from 2002 to 2015. Based on the results of the morphometric map, changes occurred in the lake consisting of lake additions and lake narrowing, but from 2002 to 2015, changes in shape were the most dominant in the widening of the lake body. The largest lake increase occurs at an angle of 300˚, which is 847,122 m or 30˚ from the west to the northwest, and the least increase of the lake is at an angle of 240 ˚, which is 67,390 m or 15˚ from the southwest to the west. Meanwhile, the biggest narrowing of the lake occurs at an angle of 120˚, which is 642,117 m or 30˚ from the east to the southeast, while the smallest narrowing occurs at an angle of 30˚, which is 13,432 m or 30˚ from the north to the north-east. The changes in Rawa Pening Lake are most inclined toward the northeast, southeast, northwest, south, and west.

3.3.3. Lake shape changes in 2015-2021

Based on Table 4 and Figure 6a show the direction of movement of the shape of Rawa Pening Lake from 1989 to 2021. Based on the results of the morphometric map, there has been a change in the lake, which consists of increasing the lake and narrowing the lake, and the most dominant is the widening of the lake's shape. The largest lake increase occurs at an angle of 300˚, which is 1247.934 m or 30˚ from the west to the northwest and the least increase of the lake is at an angle of 135˚, which is 12.729 m towards the southeast. Meanwhile, the biggest narrowing of the lake occurs at an angle of 195˚, which is 170.805 m, 15˚ from the south to the southwest, while the smallest narrowing occurs at an angle of 180˚, which is 21.693 m in the south. The most skewed morphometric changes were found in the east, northeast, southeast, and northwest directions. The morphometric changes that occurred from 1989-2021 led to the possibility of indications of emerging land or new land emerging. Based on Figure 6a, it can be seen that the parts that are experiencing widening and narrowing of the lake, this widening and narrowing are used for the analysis of the identification of arising land.

3.4. Changes in Lake Shape and Lake Direction

Morphometric research conducted over approximately 32 years at Rawa Pening Lake provides information that there has been a change in the lake's shape over that period. The distribution of possible land in Rawa Pening Lake is due to a narrowing in some areas. From 1989-2002 the area of land arising was 141,146 Ha; from 2002-2015, the land area was 99,285 Ha; from 2015-2021, the land area was 18,010 Ha. Figure 6b shows changes in the area of land arising from 1989-2021, land arising subsidence that occurred because, in 2015 and 2021, the lake experienced a widening in shape so that the area of the lake increased.

Table 4. Lake movement direction change in 1989-2021

Level	Lake distance change in 1989-2002 (m)	Lake distance change in 2002-2015 (m)	Lake distance change in 2015-2021 (m)
0°	-36,491	323,946	133,774
15°	217,797	-138,010	73,846
30°	23,438	-13,432	-27,105
45°	136,077	-77,380	107,045
60°	35,994	-82,810	226,677
75°	59,202	-106,031	303,961
90°	84,984	-376,845	532,766
105°	189,481	-287,284	401,857
120°	82,240	-642,117	480,711
135°	-254,016	445,549	12,729
150°	-86,538	-62,406	983,357
165°	-505,220	281,774	377,351
180°	-87,526	170,615	-21,693
195°	-198,162	215,257	-170,806
210°	-210,126	18,985	250,729
225°	-290,791	71,581	125,799
240°	-74,732	67,391	477,899
255°	-6,986	68,637	214,326
270°	-106,680	236,665	112,332
285°	21,639	622,387	129,134
300°	20,332	847,123	1.247,935
315°	-72,619	124,580	165,013
330°	49,319	82,036	424,184
345°	-141,140	150,595	89,250

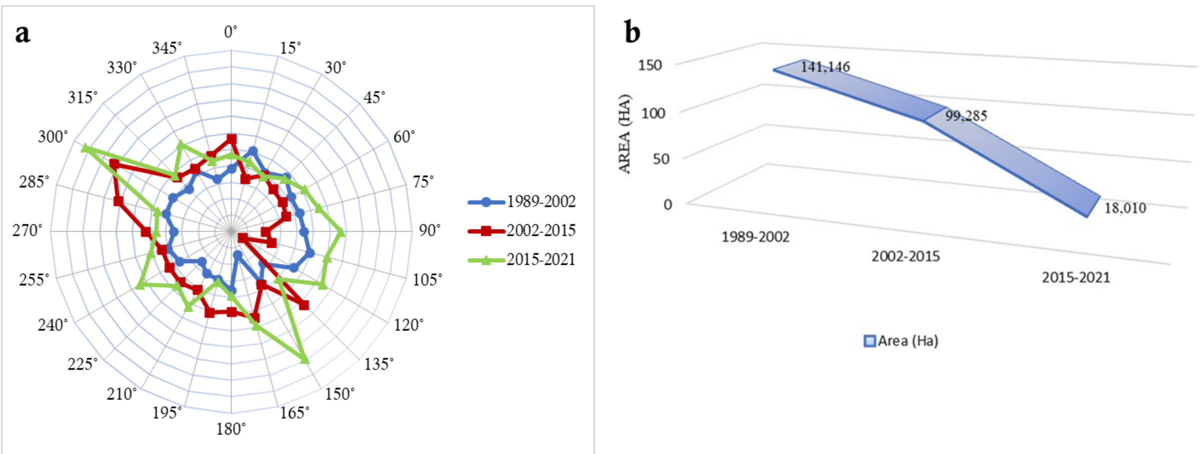

Figure 6. a) Lake direction changes in 1989-2021; b) Land arises area change in 1989-2021.

Based on the research results from 1989 to 2002, there is a distribution of 141.146 Ha of arising land. The areas of the lake that experience the biggest narrowing are at an angle of 165° which is equal to 505.220 m or 30° from the southeast towards the south, and the smallest narrowing occurs at an angle of 255° which is equal to 6.985 m in the West direction, so the areas that are experienced narrowing including the southeast, south, southwest, west, and northwest. The distribution of land from 1989 to 2002 can be seen in Figure 7a.

Figure 7b shows that from 2002 to 2015, the lake experienced a widening in size, but several areas of the lake body experienced a narrowing. The biggest narrowing occurs at an angle of 120° which is 642.116 or 30° from the east to the southeast, and the smallest narrowing occurs at an angle of 30° of 13.432 m or 30° from the north to the northeast. Based on the morphometric map, the areas experiencing narrowing include the north, northeast, east, southeast, southwest, and

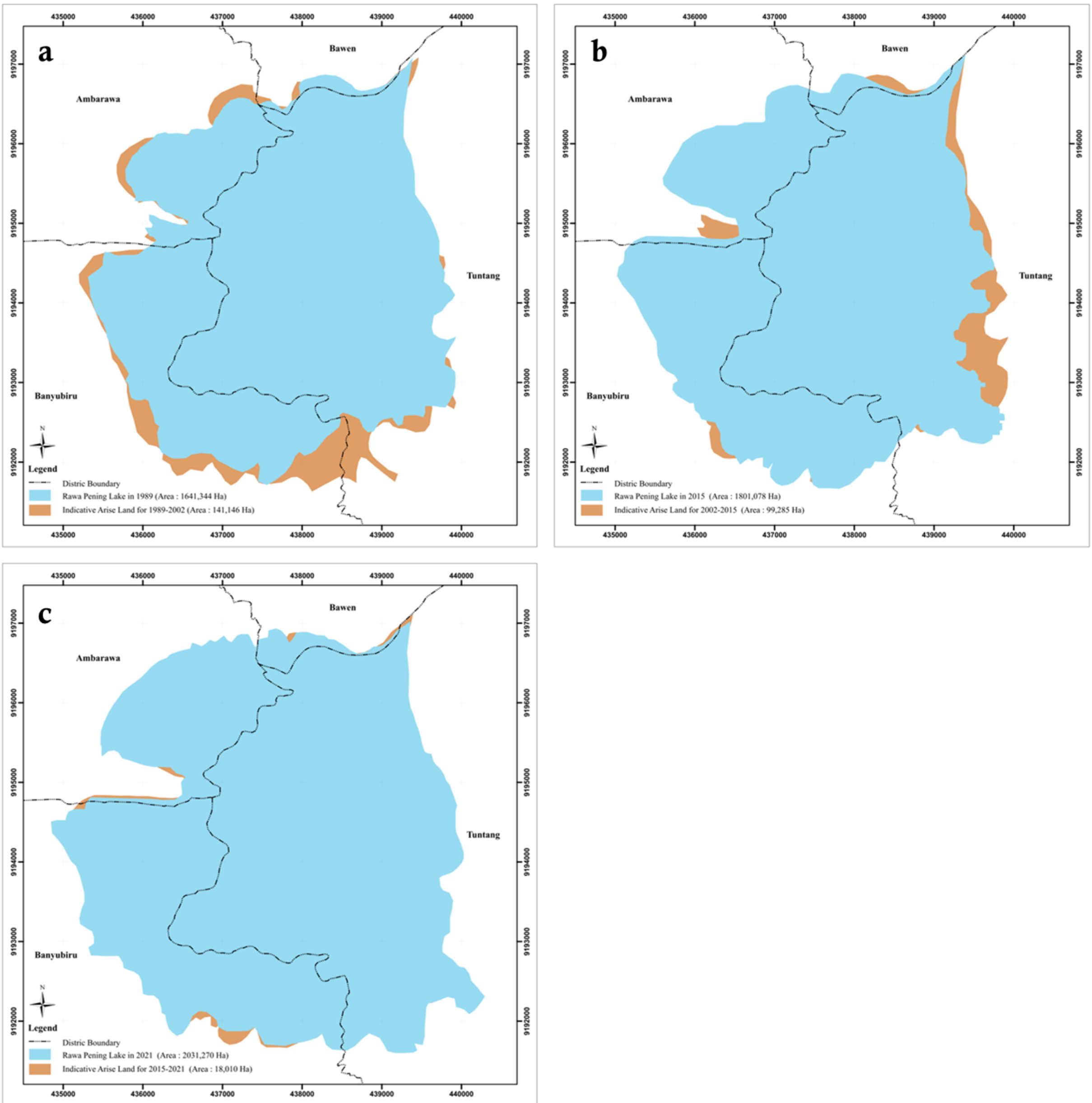

Figure 7. Map of indicative arise land distribution, a) 1989-2002; b) 2002-2015; c) 2015-2021.

northwest regions. Based on the morphometric map, the distribution area of the arising land from 2002 to 2015 was 99.285 Ha.

Based on Figure 7c shows that from 2015 to 2021, the lake also experienced a widening in size of the lake. In 2021 one of the water entrances, namely the Tuntang River DAM, was closed for the last two years, causing the lake's volume to increase and several areas to be inundated; this is indicated by the very small distribution of rising land, namely only 18,010 Ha. Based on the lake morphometry, the part of the lake that experiences the biggest narrowing occurs at an angle of 195˚ of 170.805 m or 15˚ from the south to the southwest, and the least narrowing occurs at an angle of 180˚ of 21.693 m in the south. The areas experiencing narrowing are scattered in the north, northeast, south, southwest, and northwest regions.

3.5. Validation Test

The results of the separation of water bodies and non-water bodies must be tested to show the accuracy of the processing results. This aims to provide a level of confidence in the processing results. The classification results were tested based on field data obtained from as many as 30 sample points. Table 5 compares image interpretation results with land cover conditions in the field.

Table 5. Field validation test result

Interpretation result / Field survey	Water body	Non –water body (water hyacinth)	Total	Commission (%)	Producer accuracy (%)
Waterbody	20	0	20	0	91
Non-water body	2	8	10	2	100
Total	22	8	30	2	87,5
Commission (%)	2	0	2	6,66	-
User accuracy (%)	100	80	-	-	-
Overall accuracy	-	-	93,33%	-	-
Kappa accuracy	-	-	84,21%	-	-

Table 5 shows the accuracy of the classification results obtained an overall accuracy value of 93.33%, which indicates the classification results following the actual conditions in the field, while the kappa accuracy is 84.21%. The overall accuracy value obtains a value of more than 80%; it can be said that the classification results follow the reality on the earth's surface. However, the sample has two errors due to not being careful in interpreting the image.

4. CONCLUSION

The processing results of the NDWI algorithm show the state of the lake where the visuals displayed are close to the original conditions on Landsat 5, Landsat 7, and Landsat 8 images. However, the weakness of this method is that it cannot clearly show the lake boundaries because Rawa Pening Lake is one of the critical lakes in Indonesia where growth Water weeds cover the lake body, so the limitations of NDWI to define the types of vegetation and objects that cover the surface of the lake cannot be clearly defined, so in this research, visual interpretation was used in determining the strict boundaries of the lake. The results of the interpretation of Landsat 5 satellite imagery in 1989, Landsat 7 in 2002, Landsat 8 in 2015, and Landsat 8 in 2021 obtained lake morphometry from 1989 to 2002, which experienced a narrowing of the size of the lake with an area of 75,639 Ha with the direction of change leaning towards Northeast, West Sea, South, and West. From 2002 to 2015, the lake experienced a widening in size with an area of 159.734 Ha with a change in direction leaning towards the northeast, southeast, northwest, south, and west. From 2015 to 2021, it also experienced a widening in the lake's size, with an area of 230.192 Ha, with the direction of change most inclined to the East, Northeast, Southeast, and Northwest. The land distribution arises indicative of morphometric processing from 1989 to 2002 due to the narrowing of the lake with an area of 141.146 Ha. From 2002 to 2015, the distribution of indicative land arising was 99.285 Ha, and from 2015 to 2021, the distribution of indicative land arising was 18.010 Ha.

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