Google earth engine and landsat data for detecting inundation changes in Limboto lake

To cite this article: R J Lahay and S Koem 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **739** 012087

Google earth engine and landsat data for detecting inundation changes in Limboto lake

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Abstract. Limboto Lake has environmental degradation due to the high sedimentation rate. Based on that fact, monitoring of inundation change is needed for upcoming lake management. The dynamics of Limboto lake inundation can be detected by utilizing remote sensing data. The emergence of cloud computing-based geospatial technology allows its users to automatize remote sensing data preparation and processing procedures. The study attempted to investigate the dynamics of Limboto lake inundation within the time frame of 2001-2019. The detection was conducted by incorporating the Landsat data and water index method through Google Earth Engine (hence, GEE) interface. The observation year was chosen to start from 2001 due to the Landsat 7 ETM + images were completely available for a year (11 months). The results displayed that the lake's inundation area's dynamics during the observed time frame tended to show a trend of shrinkage in size. The shrinkage mostly took place at the west and northwest part of Limboto lake. The shrinkage that occurred at the lake inundation area is to be treated as a warning sign for decision-makers to formulate a decision to handle the potential negative impacts of the lake inundation shrinkage.

1. Introduction

Limboto lake is one of some largest lakes in Sulawesi Island. It is included in the 15 lakes in Indonesia with degrading environment [1]. Environmental changes in drainage basin area have caused the high rate of sedimentation that enters the lake, thus leading to the shrinkage of lake surface area [2]. Such an alarming phenomenon demands serious concerns to anticipate the potential negative impacts of flooding to the lake's environment. Therefore, time-extensive historical data that record the shrinkage phenomenon are of utmost importance in the effort of analyzing its causes and preventing further damages from environmental instability.

Remote sensing technology is capable of yielding spectral, spatial, and temporal satellite data in continuous manner [3]. This study incorporates data from Landsat satellite, as it is proven to show a high temporal resolution. From the existing literature, several past studies have addressed the incorporation of Landsat satellite data and water index method in detecting and monitoring the changes in surface water [4–8]. The satellite image data are continuously available for a long period. Manual methods of preparation, pre-processing, processing, and data analysis generally demand longer processing time and greater resources. The current advancements of cloud computing-based geospatial technology have emerged as the alternative to tackle the limitation of such conventional methods [3].

As a cloud-based platform, GEE features a high computing performance to process and analyze large-sized geospatial data [9]. The present study lays its basis on the argument that the GEE interface is applicable to conduct the whole procedure of preparation, pre-processing, processing, and analysis automatically. The platform features web-based interface environment that facilitates its user to develop an algorithm to carry out the tasks as previously mentioned [10]. In addition, past works on the implementation of this technology in monitoring environmental changes by using satellite data are limited, thereby leaving a huge challenge to explore on [11].

The present research aims to investigate the difference in changes that occur on Limboto lake surface within 19 years by incorporating Landsat data and water index method in the GEE interface. It utilizes all the available data from Landsat 7 ETM+ in 2001 and Landsat 8 OLI in 2019 in the study area. The observation year was chosen to start from 2001 due to the Landsat 7 ETM + images were completely available for a year (11 months). In addition, Landsat 7 ETM + products since May 31, 2003 have experienced a Scan Line Corrector (SLC) failure. Therefore, the second data chosen to complete the analysis were the Landsat 8 OLI images. To perform such conducts efficiently, the automatization of the procedure as mentioned earlier through GEE web interface is deemed to be necessary.

2. Material and Method

2.1. Study area

This study was conducted in the area of Limboto lake, with geographical coordinate borders of 0°31’54.02” N to 0°37’52.43” N latitude and 122°55’29.19” E to 123° 2’0.99” E longitude; the area map is displayed in Figure 1. Administratively, the site is located under the area of Gorontalo regency, province of Gorontalo. The study area covered the Limboto lake drainage basin and the estuary of five big rivers: Marisa, Melupo, Biyonga, Rintenga, and Alupohu. The lake outlet is located at the southeast part of the lake that passes through Tapodu river to the Tomini bay [12].

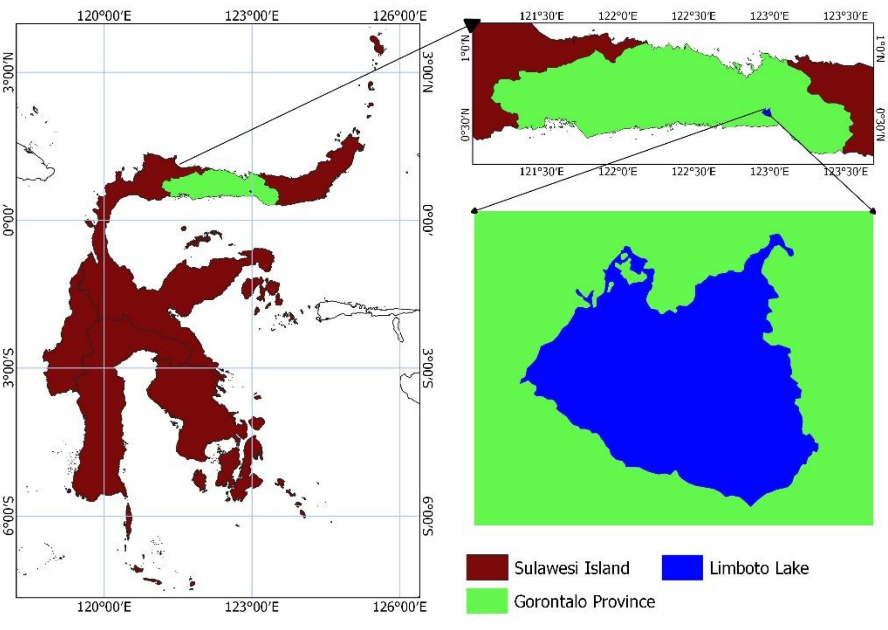

Figure 1. Study area location

2.2. Dataset

The GEE is featured with archive catalogue of satellite image from Landsat 1 to Landsat 8 that is accessible for free. The present study involved all the available data from Landsat 7 ETM+ in 2001 and Landsat 8 OLI in 2019 in the GEE catalogue. The detailed data are displayed in Table 1.

2.3. Methods

The research used GEE web interface to conduct the whole procedure of pre-processing, processing, and analysis. The pre-processing step consisted of accessing and displaying the satellite data from the

GEE catalogue, running the cloud masking function, and calculating the water index by applying the formula in Table 2. It applied the normalized difference water index (NDWI) method [13].

Table 1. Details of Landsat data involved.

No	Dataset and Acquisition Date	
	Landsat 7 ETM+	Landsat 8 OLI
1.	21 January 2001	31 January 2019
2.	11 April 2001	16 February 2019
3.	13 May 2001	04 March 2019
4.	29 May 2001	20 March 2019
5.	14 June 2001	05 April 2019
6.	30 June 2001	21 April 2019
7.	16 July 2001	07 May 2019
8.	01 August 2001	23 May 2019
9.	02 September 2001	08 June 2019
10.	18 September 2001	24 June 2019
11.	04 October 2001	26 July 2019
12.	05 November 2001	11 August 2019
13.	21 November 2001	27 August 2019
14.	07 December 2001	12 September 2019
15.		28 September 2019
16.		14 October 2019
17.		30 October 2019
18.		15 November 2019
19.		01 December 2019
20		17 December 2019

Table 2. NDWI formula applied in the study.

Formula	Reference
$NDWI = \frac{(Green_{band} - NIR_{band})}{(Green_{band} + NIR_{band})}$	[13]

The output of pre-processing stage was the collection of images with NDWI bands. The image collection was then composed with composite image function to produce a single image that represents each of the observation years, 2001 and 2019. Moreover, the water pixel value of each image was extracted by referring to the threshold value calculated by Otsu method [14]. Each pixel was classified as water feature if it fulfilled the "NDWI > threshold value" rule. Both images were then juxtaposed to detect the changes in inundation area for each observation year; a comparison map was formulated based on the comparison results.

3. Results and discussion

Implementation of NDWI composite function for Landsat 7 (14 images) and Landsat 8 OLI (20 images) make 2001 and 2019 NDWI maps (see Figure 2). Detection of changes in Limboto lake inundation area from 2001 to 2019 is derived from comparison of both years images (see Figure 3). Figure 3 also illustrates spatially distribution of the change (shown in four classes) within 2001-2019. The changes in inundation area are mostly dominated by decreased class which is 1,235.46 ha. The area is displayed by green color in figure 3 and located at the west and northwest part of the lake. According to [12], the phenomenon is caused by land use changes in the Limboto watershed. The people around the lake will be threatened if the shrinkage of this lake area is ignored.

The results display that the water feature is extractable from the satellite images by applying water index method. The procedure of data preparation and processing is automatized by using GEE platform to spend less processing time. In spite of that, there are several features that commit classification error (displayed in Figure 3). The yellow area at the far northwest side from the lake is classified as water. A threshold value is required to separate of water and non-water features by water index method. The standard threshold value of NDWI is zero (0) [13]. However, the present research incorporates a threshold value (0.11) obtained by Otsu method [14] calculated by using the GEE platform.

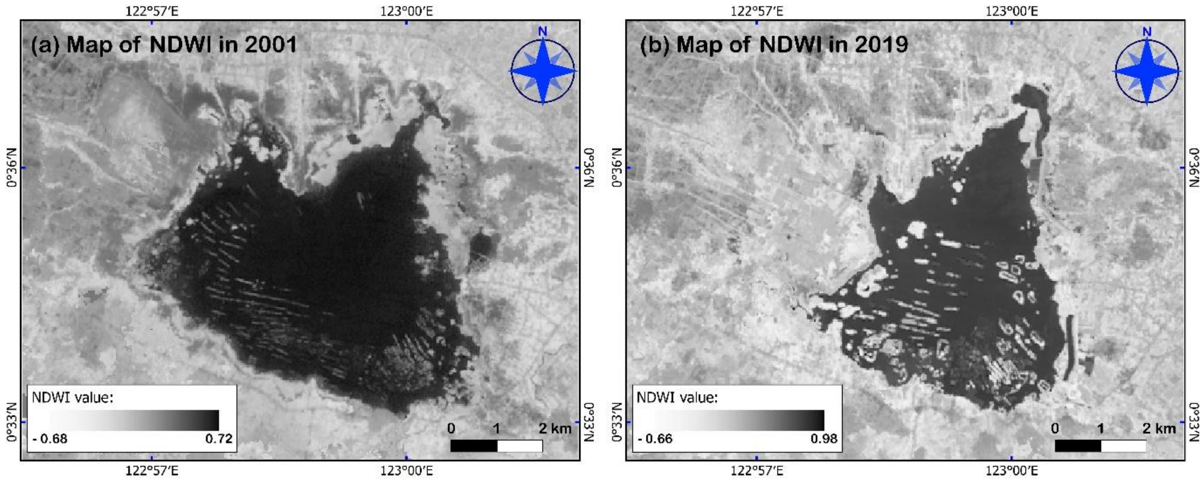

Figure 2. The NDWI map in 2001 (a) and 2019 (b) resulted from NDWI composite function

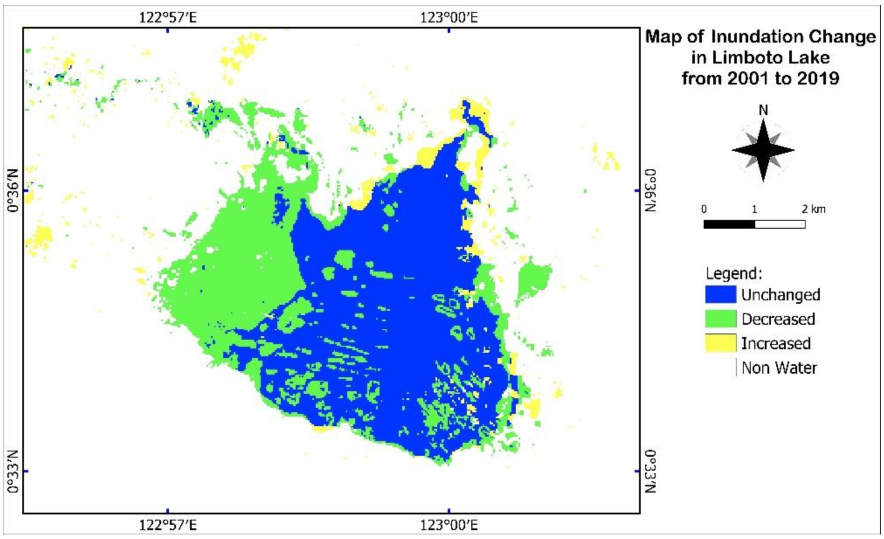

Figure 3. Map of changes in Limboto lake inundation area 2001 to 2019.

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IOP Conf. Series: Earth and Environmental Science **739** (2021) 012087 doi:10.1088/1755-1315/739/1/012087

The presence of water vegetation that covers the lake surface area is an impactful factor on the separation of water and non-water features. That said, the study does not take into account the water vegetation during classification. On top of that, further studies might require to incorporate several water index methods to compare the results.

4. Conclusion

The combination of Landsat satellite data and water index method is applicable to detect changes in the inundation area of Limboto lake from 2001-2019. Thanks to the emergence of cloud-based geospatial technology, the detection process's automatization are now practically viable. The investigation result in the form of a map of dynamics in Limboto lake's inundation area is considered applicable as the supporting reference for Limboto lake management policies. The 1,235.46 ha shrinkage of the inundation area is seen as the indication of a change that has taken place in the drainage basin area nearby the lake.

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