Mapping the water body area by using Sentinel 1 – SAR in dry season of 2023: A case study in Tri An reservoir

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Abstract. Monitoring water surface areas plays an extremely important role, especially for river and reservoir, lake systems that are significant for irrigation, hydropower and ecosystems etc. In the Tri An reservoir area, the main water source for Dong Nai province, and also where many people live in 4 districts of Vinh Cuu, Dinh Quan, Thong Nhat and Trang Bom. However, in the dry season of 2023, the weather became hot and dry with little rain due to the influence of the El Nino phenomenon. The water level of Tri An Lake has dropped to a record low in the past 12 years. Based on Sentinel 1 images and threshold method, this study conducted water surface extraction from January - May 2023 of Tri An lake. The results showed that, from January to May 2023, the water surface area decreased from 26,270.97 hectares to 10,059.87 hectares. The most obvious decrease in water surface area was in Phu Ly and Ma Da communes (Vinh Cuu district) and the La Nga bridge section. This study has been a demonstration of the impact of global climate change on water resources, providing a basis for environmental resource management.

Keywords: Tri An reservoir, Sentinel 1, water area, dry season

1 Introduction

Tri An Lake originates from Lam Vien and Bi Doup mountains on the Lang Biang plateau (in the South Truong Son range) at an altitude of over 2000 m above sea level. The basin area of Dong Nai river up to Tri An lake is 1,012,831 ha. Compared with some river basins in Vietnam and the world, the surface water resources of the Dong Nai river system basin are quite abundant [1]. Adjacent to Ma Da forest, which still preserves many characteristics of tropical forest ecosystem. This lake not only brings value in terms of hydro-power, fishing and aquaculture, but Tri An Lake is also an attractive tourist destination today.

But, at the end of the dry season in 2023, from mid-April, the water level of Tri An lake bottom dropped deeply, gradually reaching the dead water level (about 50 m), and many areas were almost dry. This was the lowest water level measured at Tri An lake over the past 12 years. The year 2023 is a period affected by the hot phase of El Nino, causing the increase of temperatures nationwide, and the decrease of rainfall, and many widespread heat waves. The El Nino phenomenon was likely to appear in the second half of summer 2023 and maintain until 2024 with a probability of about 70-80 %. For that reason, the water level of Tri An Lake continuously decreased from late March to around May, due to lack of water supply from rainwater, increased evaporation in the lake, etc.

Optical remote sensing images are usually used to calculate surface water indices and determine pixels with and without water [2]. Remote sensing image data has many advantages in observing the earth's surface, from surface water to land use cover,... over a large and continuous space. There are many ways to extract water surface, we can use photos taken from airplanes, optical images, or radar images, etc. For optical images, there are many studies using indicators related to water, such as NDWI [3], MNDWI [4], AWEI [5],... or use spectral reflectance but are easily misclassified with urban land, mountain shadows,... [6]. Another way to extract the water surface for optical remote sensing is image classification, but it requires the survey verification sample [7]. To overcome the limitations of optical remote sensing images, many studies used radar remote sensing with synthetic aperture - SAR (Synthetic Aperture Radar), because radar images have long wavelengths and can receive reflected signals from the Earth's surface in all weather conditions, as well as day and night [8]. Radar waves strongly absorb water surface objects (ponds, lakes, rivers, etc.) and water objects on the radar
image polarizes are usually black, so they are easy to identify with surrounding objects [9]. Furthermore, due to water's strong absorption of radar waves, water objects are often black when displayed on SAR images, so water surface areas can be clearly identified and separated [10]. Some studies applying radar images in extraction use the following popular methods: histogram graph [11], Ostu method [12], distance-based classification methods [13]… From the above studies, in this article, we used sentinel 1 images, with the threshold method to extract water surface in the dry season of 2023, from January to May to evaluate water surface areas under the influence of El Nino’s hot phase.

2 Study area

In the study, temperature data from January to May 2023 was collected from www.accuweather.com. Temperature values at Tri An were recorded by Gia Kiem station, the location of which was shown in Figure 1.

![Fig. 1. The location of Gia Kiem (red area).](image)

The weather in 2023 has been many unusual developments, especially severe heat coming earlier than usual and tending to increase compared to the average of many years ago. Under El Nino conditions, average monthly temperatures in regions across the country have been forecast to tend to be higher than normal; the heat may be more frequent and more intense; the possibility of many records of the absolute highest temperatures occurring. In the early days of May, some localities in the province such as Bien Hoa city and Tri An lake were approximately 38 – 39°C. The highest and lowest values were recorded as follows:

![Fig. 2. The temperature (°C) in dry season of 2023, orange bar is temperature in daytime, the blue bar is temperature in night-time, and the two lines show the maximum, the minimum of temperature.](image)

The temperature in January mostly ranged from 32-33 °C, however at the end of January, a maximum value of 35 °C appeared. February was the time when the average temperature began to increase, the threshold value was always at 33-34 °C, with a few days of temperature > 35 °C alternating. By March, the temperature value increased continuously, the number of days with temperature 34-35 °C was up to 19 days, including 3-5 days with temperature > 36 °C. April was the time when the most extreme values appeared so many times, temperatures could reach 39-40 °C and last for many days continuously. In the early days of May, the temperature remained high, from 35 to 37 °C, however in the middle and end of May, due to the activity of the Southwest monsoon, there were a few scattered rains, so the temperature was decreased. Temperature at this time tended to decrease, only fluctuating at 32-33 °C.
3 Materials and Methods

3.1 Data base

The data used in this study was Sentinel 1 with VV. The images were collected mainly in the dry season, from January to May, with good image quality, cloud cover < 10%. Details of the technical specifications were shown in Table 1.

Table 1. Technical details of satellite images used in this article

<table>
<thead>
<tr>
<th>Information technology</th>
<th>Sentinel 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition time</td>
<td>11/01/2013; 05/02/2023; 11/03/2023, 05/04/2023; 12/05/2023</td>
</tr>
<tr>
<td>Acquisition mode over land</td>
<td>IW-Interferometric Wide Swath</td>
</tr>
<tr>
<td>Polarization</td>
<td>VV and VH</td>
</tr>
<tr>
<td>Processing level</td>
<td>Level 1, processed and converted to ground value</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>10 m</td>
</tr>
</tbody>
</table>

3.2 Pre-processing Sentinel 1 images

Radar image pre-processing steps were performed in SNAP 9.0 software. SNAP stands for Sentinel Application Platform and is a tool for processing and analyzing remote sensing data from the Sentinel satellites of the European Space Agency, image processing steps included:
- Step 1 (Creating a subset): The purpose of clipping the study area was to reduce image size and eliminate unnecessary areas.
- Step 2 (Noise Removal): In addition to speckle noise, SAR images are also affected by thermal noise, especially when the backscatter power is low. Thermal noise removal is used to reduce the noise effect in the texture between sub-bands, in particular, to normalize the signal of backscatter in the entire radar image [14]. At the same time, eliminating thermal noise reduces sub-band discontinuities for every scene in multi-region acquisition modes. ESA (European Space Agency) provides thermal noise information for each image in an XML format file [15].
- Step 3 (Calibration): Calibration is the procedure that converts digital pixel values to radiometrically calibrated SAR backscatter. The information required to apply the calibration equation is included within the Sentinel-1 GRD product, specifically a calibration vector included as an annotation in the product allows simple conversion of image intensity values into sigma-naught values.
- Step 4 (Speckle filtering): SAR images always contain spots with no data (empty data) and they degrade image quality and make image analysis difficult. These spots are completely random because the sensor does not receive a response (scattered) signal from the object due to the strongly scattered signal [16]. Using filters to remove these spots on radar images helps increase image quality and improve the accuracy of image analysis.
- Step 5 (Range Doppler Terrain Correction): Geometric correction is intended to correct errors due to the influence of the tilt configuration of the radar system, terrain elevation difference to the point location and convert the coordinates of pixels to the same coordinate system [14]. To correct geometry, use the Terrain Correction function in the Geometric tab of SNAP software. The selected coordinate system is WGS/UTM zone 48 of the Northern hemisphere, geometrically calibrated using the STRM 30 m digital elevation model.

3.3 Threshold water surface values from Sentinel 1 images

With Sentinel-1 images, each image in the set had its own water surface extract-ed by using a threshold on the VV polarization. The histogram chart in Figure 4 built on VV polarization after processing, it showed that the curve of each graph had two peaks, the lower peak corresponding to the water surface object and the higher sharp peak corresponding to other surface objects.

With Sentinel images, the study applied the usual threshold formula [2]:

\[ 255 \times (\text{Sigma}_0_{\text{VV}} < \text{DN}) \text{, with DN} = 0.1. \]
Each time the image was acquired, there would be a different threshold decibel (db) value for the standing water surface object, but it would range from [-18 to -14db]. This is an easy and quick method to distinguish water from non-water features and widely used in this study. This study did not use VH polarization because after water extraction, it was easy to be confused with other objects.

**Fig. 4.** Histogram showed the distribution of decibel values for water surface extraction.

### 4 Results

From the extraction results, it was seen that the area of Tri An lake showed signs of narrowing in the section of Phu Ly commune (Vinh Cuu district), the section belonging to the 6th hamlet in Ma Da commune (Vinh Cuu district) in March.

By April, the lake surface area continued to gradually narrow until Thanh Son commune (Dinh Quan district) and some sections of Dong Nai river. This was the time when the entire South was experiencing heat waves, approximately 40°C and influenced by the Northeast Trade winds, causing the weather to become hotter, dry, and with very little rainfall. In May, more than 1/3 of the lake's surface in the north and the section of Hieu Liem commune were almost completely dry. It could be seen that the soil at the bottom of the lake on satellite images taken at this time. The area belonging to the La Nga river and the households using the water source of the lake in Dinh Quan district had almost shrunk, even disappeared completely.

In just the first 4 months of the year, the lake surface area decreased at an alarming rate, statistics of the area from January to May in 2023 were as follows:
5 Conclusion

For radar images, the water surface was extracted on VV polarization, achieving the following results, such as: Outstanding advantages include removing non-water objects better than optical images. The calculation results have given us the most general overview of the impact of climate change, especially during the period when the whole country entered the hot phase of El Nino with low rainfall and many heat waves, which has a negative affected impact on water surface resources. Research results showed that, when the temperature increased, the water surface area was significantly decreased. The area that has shrunk the most was in the north of the lake and the section of La Nga bridge. The lake's area in January is 26,270.97 hectares. In April and May, the area decreased the most, more than 10,000 hectares, coinciding with times when the temperature was > 40 oC.
This was a practical application in zoning areas lacking water, supporting the management and monitoring of water resources in Tri An lake and along the Dong Nai and La Nga river basins. To achieve better results, research needs actual measured data of the lake, combined with the Otsu method to determine the threshold for extracting water surface more accurately.

Acknowledgement

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Table 2. Statistics of Tri An lake surface area from Sentinel 1 image

<table>
<thead>
<tr>
<th>Time</th>
<th>Area (hectares)</th>
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<tbody>
<tr>
<td>January</td>
<td>26,270.97</td>
</tr>
<tr>
<td>February</td>
<td>25,362.67</td>
</tr>
<tr>
<td>March</td>
<td>24,607.33</td>
</tr>
<tr>
<td>April</td>
<td>21,908.60</td>
</tr>
<tr>
<td>May</td>
<td>10,059.87</td>
</tr>
</tbody>
</table>

References