# Quantifying Water Bodies with Sentinel-2 Imagery and NDWI: A Remote Sensing Approach

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**Abstract.** This paper presents a comparative analysis of surface water dynamics using Sentinel-2 satellite imagery and the Normalized Difference Water Index (NDWI) obtained through the Google Earth Engine (GEE) platform. The study focuses on assessing changes in surface water area and water ratio in the area between the winter and summer seasons of 2017 and 2023. Our results indicate a notable fluctuation in water area over the study period, with the reservoir exhibiting varying extents of surface water coverage across different seasons and years. Specifically, in the summer of 2023, the water area was measured at 14.35 km², compared to 14.98 km² in 2017. Conversely, during the winter months, the water area decreased to 12.54 km² in 2023, while it was 14.68 km² in 2017. The findings suggest a shift in surface water dynamics over time, potentially influenced by climatic and environmental factors. Furthermore, the study highlights the efficiency of utilizing GEE and remote sensing techniques for surface water mapping and monitoring. Remote sensing provides a cost-effective and reliable means of monitoring surface water resources, enabling timely assessments and informed decision-making for water resource management and conservation efforts. This research underscores the importance of leveraging remote sensing technologies for effective resource management and environmental stewardship in the face of changing climatic conditions.

## 1 Introduction

Surface water plays a vital role in various ecological, agricultural, and socio-economic processes, making its accurate monitoring and assessment essential for effective resource management and environmental conservation [1], [2]. Traditional methods of surface water mapping and monitoring often rely on manual data collection and interpretation, which can

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be time-consuming, labor-intensive, and costly [3], [4]. However, advancements in remote sensing technology [5], [6], [7] and the availability of satellite imagery have revolutionized the way surface water is observed and analyzed [8], [9], [10]. This study aims to utilize the capabilities of the Google Earth Engine (GEE) platform and Sentinel-2 satellite data to assess surface water dynamics in a selected region across different seasons and years. By leveraging the spectral information provided by Sentinel-2 imagery, particularly the Normalized Difference Water Index (NDWI), this research seeks to quantify changes in surface water area and analyze seasonal variations over time [11], [12], [13]. Comparative analysis of surface water dynamics between the winter and summer seasons of 2017 and 2023 reveals notable fluctuations in water extent. The automated processing of Sentinel-2 data through GEE facilitates the efficient calculation of water area and ratio, enabling comprehensive assessments of temporal changes in surface water coverage. The findings indicate a decrease in water area during the winter of 2023 compared to 2017, suggesting potential impacts of climate variability or human interventions on water resources [14], [15]. Furthermore, the study underscores the advantages of remote sensing-based approaches, emphasizing the ease and accuracy of surface water mapping achieved through GEE automation [16], [17], [18]. By replacing traditional manual methods with remote sensing techniques, this research highlights the efficiency and cost-effectiveness of remote sensing for large-scale environmental monitoring [19], [20] and resource management [21], [22], [23]. As climate change continues to exert pressure on water resources, the integration of remote sensing technologies into monitoring frameworks becomes increasingly crucial for informed decision-making and sustainable water resource management [24], [25], [26]. Overall, this study contributes to advancing our understanding of surface water dynamics and underscores the importance of leveraging remote sensing and automated processing tools for effective environmental monitoring and conservation.

# 2 Study area and Methods

## 2.1 Study area

The study area encompasses the Tuyabogiz reservoir, situated in the northern foothills of the Tashkent region, Uzbekistan (Figure 1). Covering an area of 20 km², with an average depth of 12.5 meters, the reservoir has a total volume of 250 million cubic meters, of which 224 million cubic meters are utilizable [1][27], [28]. It serves as a vital source of water for irrigation, primarily for agricultural activities in the surrounding areas, including the towns of Ohangaron and Chirchiq. Constructed in 1962, the reservoir comprises a complex system of intake and discharge channels, as well as regulating structures. The dam, spanning a length of 2.4 kilometers, is constructed from compacted earth embankments with reinforced concrete elements. Its central section functions as a spillway, designed to accommodate the flow of the Ohangaron river during periods of high-water levels. The dam is fortified with prefabricated reinforced concrete slabs and monolithic elements to withstand hydraulic pressures and ensure structural stability. Additionally, the Tashkent-Bekobod highway traverses the reservoir, facilitating transportation and connectivity across the region.

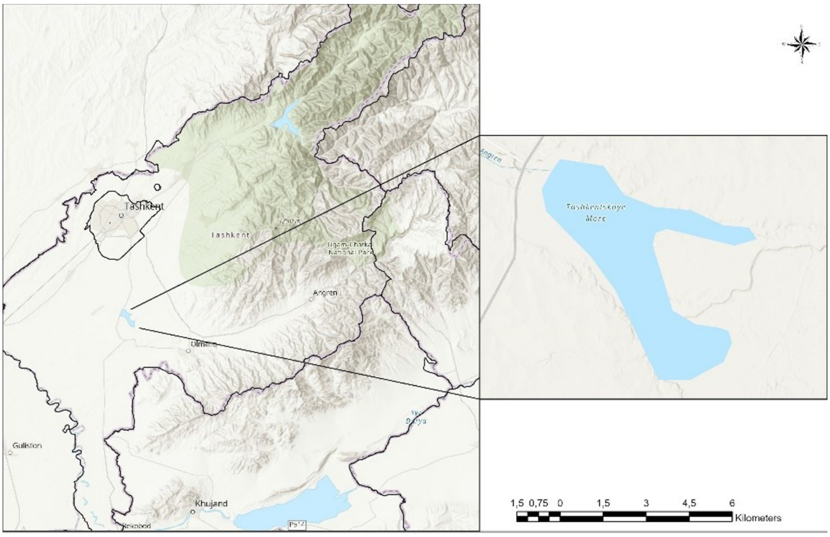



**Fig. 1.** Location of the Tuyabuguz reservoir.

The Tuyabogiz reservoir plays a crucial role in water resource management and agricultural development, supporting the socio-economic needs of the local communities. Its strategic location and significance in the regional water infrastructure make it an essential area of study for assessing water availability, utilization, and sustainability in the Tashkent region.

## 2.2 Methods

Sentinel-2 satellite imagery was obtained from the Copernicus Open Access Hub via the Google Earth Engine (GEE) platform (Figure 2). The study area was delineated, and coordinates were specified to define the region of interest (ROI) for analysis. Imagery for the winter and summer seasons of 2017 and 2023 was selected based on predefined dates to ensure temporal consistency and comparability. Preprocessing of Sentinel-2 imagery included cloud masking and atmospheric correction to minimize the effects of atmospheric interference and cloud cover. The Normalized Difference Water Index (NDWI) was calculated using the near-infrared (NIR) and short-wave infrared (SWIR) bands of the Sentinel-2 imagery to delineate surface water bodies [16].

For Sentinel-2 satellite imagery, the NDWI formula can be expressed as:

$$NDWI = \frac{(NIR - SWIR)}{(NIR + SWIR)} \quad (1)$$

Where: NIR is the near-infrared band (e.g., Band 8 for Sentinel-2 imagery)

SWIR is the short-wave infrared band (e.g., Band 11 or Band 12 for Sentinel-2 imagery) [16], [18]

The NDWI thresholding technique was applied to generate binary water masks, distinguishing water pixels from land pixels based on NDWI values. The area of surface water was calculated by summing the pixel areas identified as water within the study area. Descriptive statistics were computed to analyze the surface water area and water ratio for each season and year [20]. Comparative analysis was conducted to examine seasonal variations in surface water dynamics between the winter and summer seasons of 2017 and 2023.

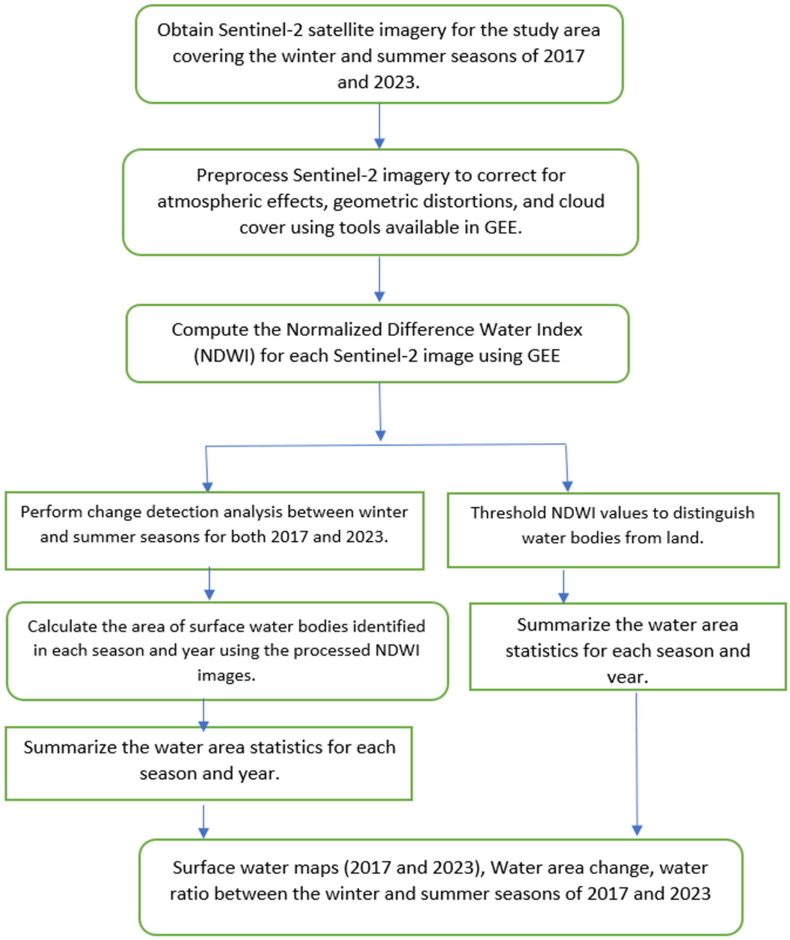
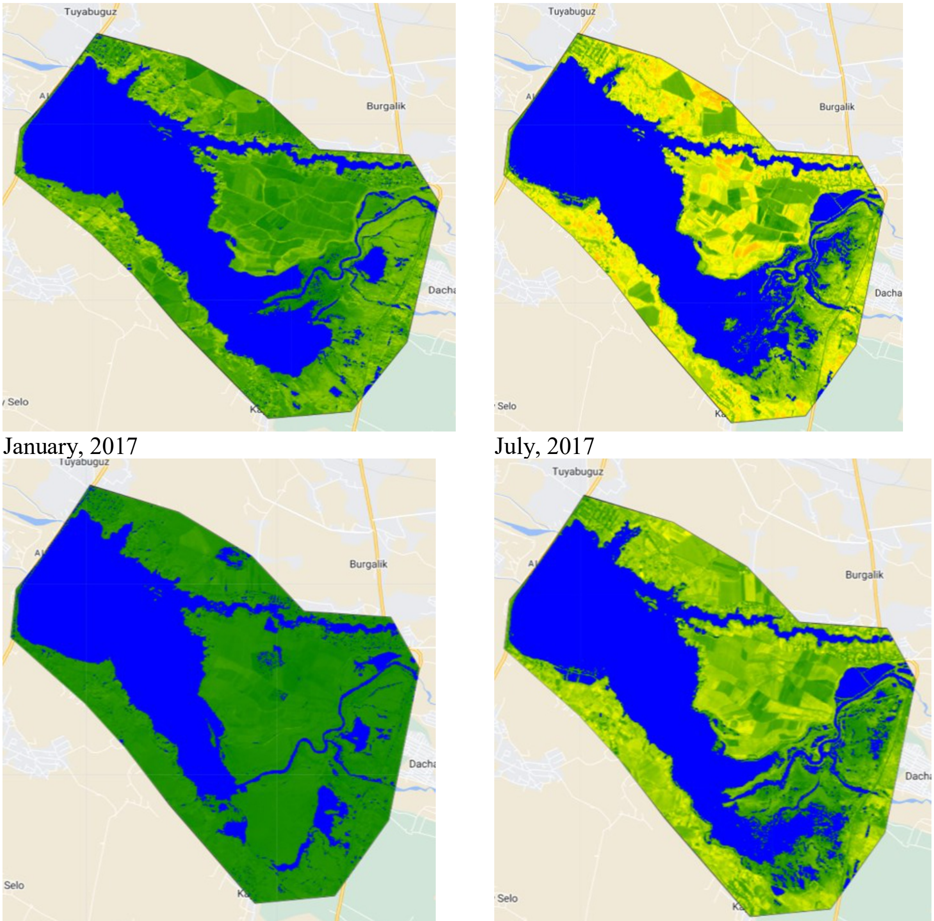



**Fig. 2.** Methodological flowchart of the research.

## 3 Results

The analysis of surface water dynamics in the Tuyabogiz reservoir area revealed significant variations in water extent and seasonal patterns between different years (Figure 4). Comparing the winter and summer seasons of 2017 and 2023, notable changes were observed in the water area of the reservoir. In the summer of 2017, the water area was measured at 14.9779 km², whereas in 2023, it decreased to 14.3494 km². Similarly, during the winter months, the water area decreased from 14.6778 km² in 2017 to 12.5365 km² in 2023 (Figure3).




January, 2017 July, 2017

January, 2023 July, 2023

Legends

Water body

Mostly wetland (Grass)

Vegetation (Grass)

Dry vegetation

**Fig. 3.** Spatial distribution of water area in the Tuyabogiz reservoir during summer and winter seasons of 2017 and 2023.

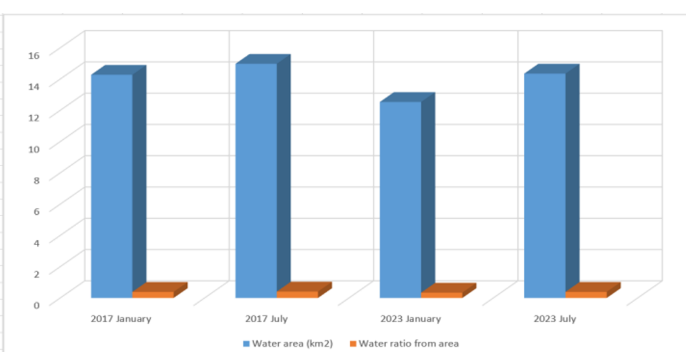



**Fig. 4**. Comparison of surface water area (km²) and water ratio between winter and summer seasons in 2017 and 2023

## 4 Discussion

The observed fluctuations in the water area of the Tuyabogiz reservoir can be attributed to various factors, including changes in precipitation patterns, land use dynamics, and human activities within the watershed. The decrease in water area between 2017 and 2023, particularly during the summer season, may indicate alterations in hydrological regimes and water availability due to climatic variability or anthropogenic influences [22]. The discrepancy in water area between winter and summer seasons underscores the seasonal variability in surface water dynamics, with higher water levels typically observed during the winter months compared to the drier summer period [23]. This seasonal pattern reflects the influence of precipitation patterns, snowmelt, and runoff on water accumulation within the reservoir. The findings highlight the importance of continuous monitoring and assessment of surface water resources using remote sensing techniques and geospatial analysis. The utilization of Sentinel-2 satellite imagery and Google Earth Engine platform enabled the efficient retrieval and analysis of multi-temporal satellite data, facilitating the evaluation of surface water dynamics at a regional scale.

## 5 Conclusion

However, to the conclusions, remote sensing technologies have the ability to assist efficient water resource management plans and offer insightful information on hydrological processes. Significant differences in water extent and seasonal patterns across years were found when the surface water dynamics in the Tuyabogiz reservoir region were analyzed. These changes were most evident when comparing the winter and summer seasons of 2017 and 2023: the water area was 14.9779 $km^2$ in the summer of 2017 and dropped to 14.3494 $km^2$ in 2023. Likewise, the water area decreased from 14.6778 $km^2$ in 2017 to 12.5365 $km^2$ in 2023 over the winter. These results highlight the value of automated processing and analysis tools provided by Google Earth Engine and other platforms, which improve surface water mapping's accuracy and efficiency. This makes it possible to allocate resources and make decisions quickly for sustainable water management techniques. All things considered, the study highlights the value of using remote sensing techniques to track surface water dynamics and the necessity of more research and monitoring to fully comprehend the causes and effects of hydrological changes in the studied region and elsewhere.

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