DETECTION OF WATER OBJECTS USING NDWI WITH GOOGLE EARTH ENGINE (CASE STUDY OF THE KHOREZM REGION)

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Abstract: In this study, the spatial and temporal changes of water bodies in the Khorezm region were analyzed based on remote sensing data. The study was conducted on the Google Earth Engine platform, and the NDWI (Normalized Difference Water Index) was calculated using Landsat 5 and Sentinel-2 satellite images from 2010, 2018, and 2025. The obtained results showed a significant variability of the water bodies. In particular, between 2010 and 2018, the water area decreased from 214.53 km² to 140.16 km², it partially recovered to 164.17 km² in 2018–2025. Overall, a decreasing trend in water surface area was observed during the 2010–2025 period. Spatial analysis showed that water bodies are primarily associated with the Amu Darya and irrigation canals. The study's findings confirm the significant impact of climate change and anthropogenic factors on water resources. The application of the NDWI index has proven to be an effective and rapid method for identifying water bodies. This approach is of great importance for monitoring and sustainable management of water resources in arid regions.

Key words: NDWI, remote sensing, Google Earth Engine, water monitoring, Sentinel-2, spectral index, Khorezm.

Introduction. Globally, the issue of dwindling water resources and their effective management is becoming increasingly urgent. In arid regions such as Uzbekistan's Khorezm region, water resources are a key factor in agricultural and economic stability. Therefore, the need for regular monitoring of water bodies is growing. Since traditional monitoring methods are complex and resource-intensive for covering large areas, remote sensing technologies are widely used as an effective alternative. One of the most common methods for detecting water bodies from satellite data is the NDWI index. This index is based on the spectral properties of water, distinguishing it from other land cover types. Modern cloud platforms, particularly Google Earth Engine, enable the rapid processing and analysis of large volumes of geospatial data. This study aims to identify water bodies and analyze their spatial distribution in the Khorezm region using NDWI, based on Landsat 5 data for 2010, Sentinel-2 for 2018, and Sentinel-2 for 2025.

Materials and Methods. The Khorezm region was selected as the study area. The region has a dry climate, and its water resources are primarily managed through artificial irrigation systems. The region's hydrographic network consists of the Amu Darya river and numerous irrigation canals and collector-drainage systems. In the Khorezm region, agriculture, especially the cultivation of cotton and grain, is directly dependent on water resources, making the identification and monitoring of water bodies of great importance. Administratively, the region is divided into several districts, and the distribution of water resources among them exhibits regional variations. These characteristics make the study area a relevant and important target for detecting water bodies based on remote sensing.

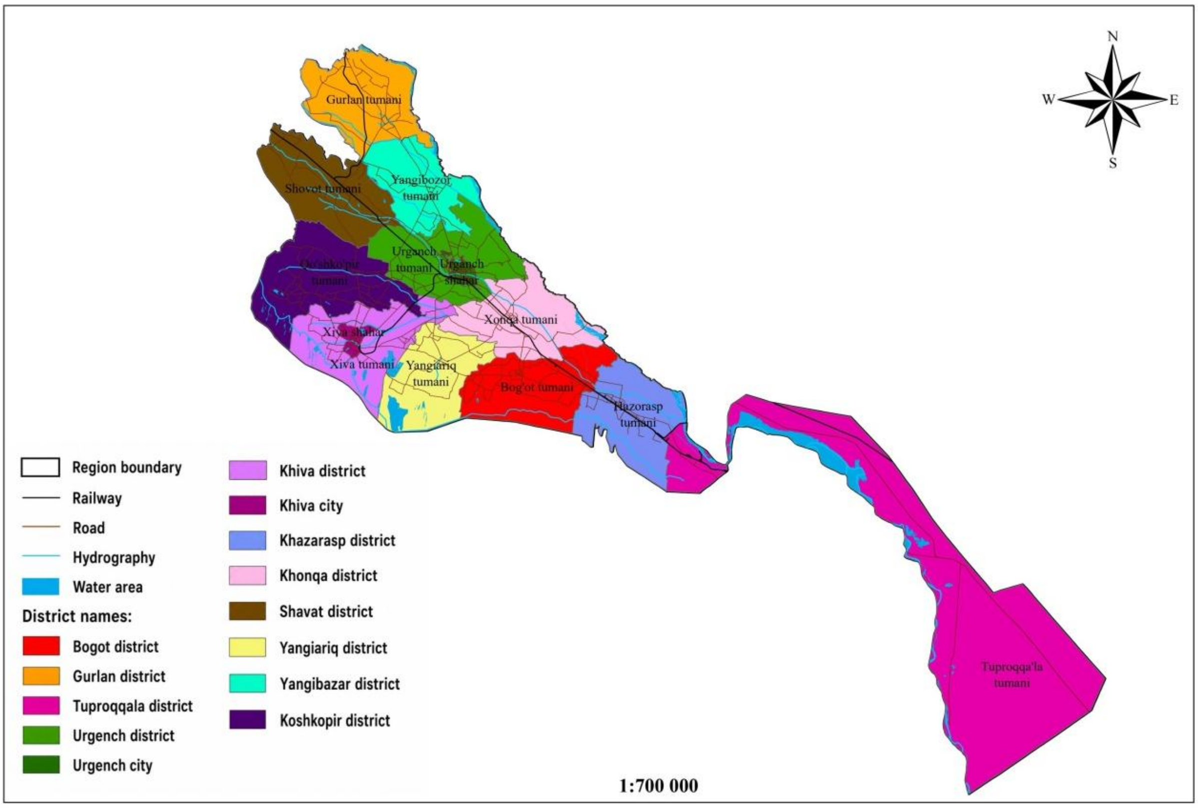


Figure 1. Map of the research area of Khorezm Province (with administrative boundaries, hydrografy, and transportation networks)

In this study, remote sensing data and a cloud-based geospatial computing environment—the Google Earth Engine platform—were used to identify water bodies. Sentinel-2 satellite imagery was selected as the primary data source. These data have a 10-meter spatial resolution, providing sufficiently high accuracy for detecting water bodies.

For the study, images from the period 2010–2025 were selected, and scenes with low cloud cover (≤10%) were filtered. The median composite method was applied to enhance image quality. Additionally, a Region of Interest (ROI) was defined based on the boundaries of the Khorezm region as the study area.

The Normalized Difference Water Index (NDWI) was calculated to detect water bodies. This index is determined based on the Green (B3) and Near-Infrared (NIR, B8) spectral bands using the following formula:

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

Based on the calculated NDWI values, the threshold method was applied, and pixels with NDWI > 0 were classified as water bodies. To improve the results, the threshold value was examined through visual inspection and histogram analysis. The data processing and analysis workflow was carried out entirely on the GEE platform. This approach enabled rapid and efficient processing of large volumes of satellite data, enhancing the accuracy and reliability of the study.

The process of identifying water bodies on the Google Earth Engine platform included the following steps:

1. Research Area Identification (ROI): The boundaries of the Khorezm region were uploaded to the platform as a vector shapefile and designated as the analysis area.

2. Data Selection: Sentinel-2 Level-2A (surface reflectance) images were selected. These data have a 10 m spatial resolution, which is optimal for detecting water bodies.

3. Cloud and shadow filtering: To improve image quality, scenes with a cloud cover level of ≤10% were selected, and clouds and shadows were masked using the SCL (Scene Classification Layer).

4. Compositing: A median composite was created from the selected images to reduce temporal noise and random errors.

5. NDWI Calculation: The NDWI index was calculated based on the green (B3) and near-infrared (B8) channels.

6. Threshold-based classification: Pixels with NDWI > 0 were classified as water bodies.

7. Visualization and export: The results were visualized in a map view and exported for further analysis.

The Google Earth Engine algorithm we used is attached below:

```javascript
// 1. ROI (your assets)
var roi = ee.FeatureCollection("projects/ee-jonizarifov/assets/xorazm");

// 2. Center map
Map.centerObject(roi, 8);
Map.addLayer(roi, {color: 'red'}, 'ROI');

// 3. Landsat 5 collection (2010)
var collection = ee.ImageCollection("LANDSAT/LT05/C02/T1_L2")
  .filterBounds(roi)
  .filterDate('2010-01-01', '2010-12-31')
  .filter(ee.Filter.lt('CLOUD_COVER', 20));

// 4. Cloud mask + scaling
function maskL5(image) {
  var qa = image.select('QA_PIXEL');

  var mask = qa.bitwiseAnd(1 << 3).eq(0) // cloud
    .and(qa.bitwiseAnd(1 << 4).eq(0));   // cloud shadow

  // scale factor (important)
  var scaled = image.select(['SR_B2', 'SR_B4'])
    .multiply(0.0000275)
    .add(-0.2);

  return scaled.updateMask(mask);
}

// 5. Cleaning + composite
var clean = collection.map(maskL5).median().clip(roi);

// 6. NDWI (for Landsat 5)
var ndwi = clean.normalizedDifference(['SR_B2', 'SR_B4']).rename('NDWI');

// 7. Extract water
var water = ndwi.gt(0).selfMask();

// 8. Visualization
Map.addLayer(ndwi, {min: -1, max: 1, palette: ['brown', 'white', 'blue']}, 'NDWI 2010');
Map.addLayer(water, {palette: ['blue']}, 'Water 2010');

// 9. Export (optional)
Export.image.toDrive({
  image: water,
  description: 'Xorazm_Water_2010',
  region: roi,
  scale: 30,
  maxPixels: 1e13
});
```

Figure 2. Algorithm for calculating the NDWI index for 2010 and separating water bodies based on Landsat 5 data on the Google Earth Engine platform. The code employs cloud masking (QA_PIXEL), radiometric calibration (scale factor), and median compositing processes.

JavaScript

```javascript
var roi = ee.FeatureCollection("projects/ee-jonizarifov/assets/xorazm");

Map.centerObject(roi, 8);
Map.addLayer(roi, {color:'red'}, 'ROI');

var collection = ee.ImageCollection("COPERNICUS/S2_SR")
  .filterBounds(roi)
  .filterDate('2018-01-01', '2018-12-31')
  .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 20));

function maskS2(image) {
  var scl = image.select('SCL');
  var mask = scl.neq(3)
    .and(scl.neq(8))
    .and(scl.neq(9))
    .and(scl.neq(10))
    .and(scl.neq(11));
  return image.updateMask(mask).divide(10000);
}

var clean = collection
  .map(maskS2)
  .select(['B2','B3','B4','B8'])
  .median()
  .clip(roi);

Map.addLayer(clean, {
  bands:['B4','B3','B2'],
  min:0,
  max:0.3
}, 'RGB 2018');

var ndwi = clean.normalizedDifference(['B3','B8']).rename('NDWI');

var water = ndwi.gt(0).selfMask();

Map.addLayer(ndwi, {
  min:-1,
  max:1,
  palette:['brown','white','blue']
}, 'NDWI 2018');

Map.addLayer(water, {palette:['blue']}, 'Water 2018');

Export.image.toDrive({
  image: water,
  description: 'Xorazm_Water_2018',
  region: roi.geometry(),
  scale: 10,
  maxPixels: 1e13
});
```

Figure 3. Code for calculating NDWI and detecting water bodies based on Sentinel-2 data in Google Earth Engine (2018).

JavaScript

```javascript
var roi = ee.FeatureCollection("projects/ee-jonizarifov/assets/xorazm");

Map.centerObject(roi, 8);
Map.addLayer(roi, {color:'red'}, 'ROI');

var collection = ee.ImageCollection("COPERNICUS/S2")
  .filterBounds(roi)
  .filterDate('2025-01-01', '2025-12-31')
  .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 20));

var image = collection.median().clip(roi);

Map.addLayer(image, {
  bands:['B4','B3','B2'],
  min:0,
  max:3000
}, 'RGB 2025');

var ndwi = image.normalizedDifference(['B3','B8']).rename('NDWI');

var water = ndwi.gt(0).selfMask();

Map.addLayer(ndwi, {
  min:-1,
  max:1,
  palette:['brown','white','blue']
}, 'NDWI 2025');

Map.addLayer(water, {palette:['blue']}, 'Water 2025');

Export.image.toDrive({
  image: water,
  description: 'Xorazm_Water_2025',
  region: roi,
  scale: 10,
  maxPixels: 1e13
});
```

Figure 4. An algorithm for calculating the NDWI index for 2025 and detecting water bodies based on Sentinel-2 data on the Google Earth Engine platform. In the script, images are filtered by cloud cover level, a final image is generated via median compositing, and water bodies are extracted using the NDWI index.

Algorithm for calculating water object areas. This script was implemented in the Google Earth Engine environment, and the sum of pixel areas was calculated using the water mask extracted from the NDWI. During the calculation, the actual area of each pixel was determined using the pixelArea() function, and the total water surface area was converted to square kilometers (km²).

Figure 5. The algorithm for calculating water bodies on the Google Earth Engine platform is attached below:

JavaScript

```
// ================================
// 9. CALCULATING WATER AREA
// ================================

// Pixel area (m²)
var pixelArea = ee.Image.pixelArea();

// Mask only for water areas
var waterAreaImage = pixelArea.updateMask(water);

// Total area (m²)
var waterArea = waterAreaImage.reduceRegion({
  reducer: ee.Reducer.sum(),
  geometry: roi,
  scale: 10,
  maxPixels: 1e13
});

// Convert m² to km²
var waterAreaKm2 = ee.Number(waterArea.get('area')).divide(1e6);

// Print result
print('Water area in 2026 (km²):', waterAreaKm2);
```

Results. Analyses based on NDWI revealed the precise spatial distribution of water bodies in the Khorezm region. Maps for 2010, 2018, and 2025 confirm that water bodies are primarily located along the Amu Darya River, its tributaries, and irrigation canals.

In 2010, water bodies cover a relatively large area and are observed at high density, especially in the eastern and southern parts of the region. In 2018, however, a significant reduction and fragmentation of water bodies is observed. In 2025, a recovery of water bodies and an expansion in some areas was observed. The area of water bodies for each year, calculated in Google Earth Engine, was as follows:

2010 water area (km²):

214.52585242542358

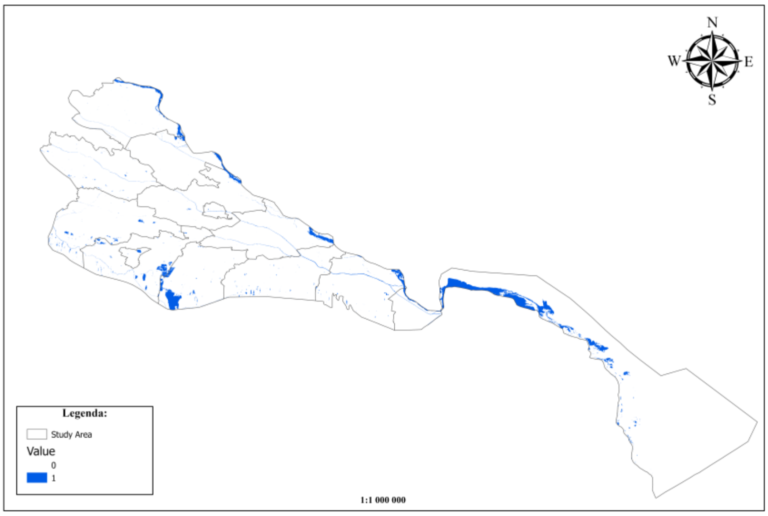
2018 water area (km²):

140.1589164121072

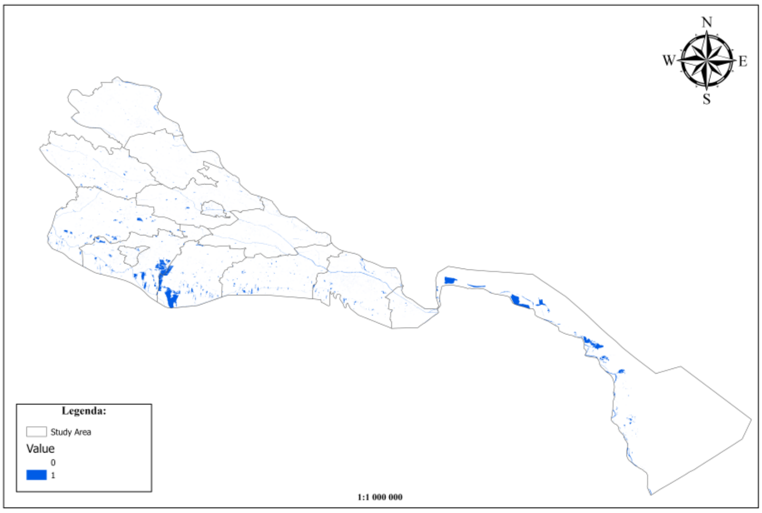
2025 water area (km²):

164.16784451425525

2010-YEAR KHOREZM REGION NDWI INDEX



2018-YEAR KHOREZM REGION NDWI INDEX



2025-YEAR KHOREZM REGION NDWI INDEX

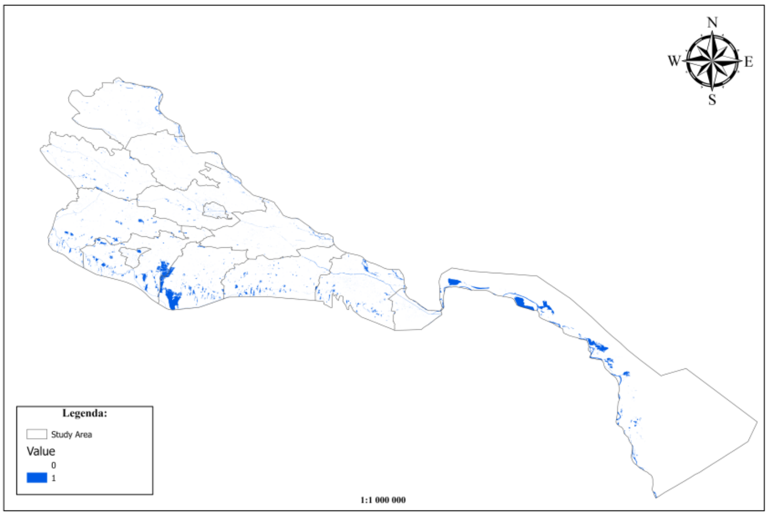


Figure 6. Temporal changes in water surface distribution in the Khorezm region based on NDWI analysis for the years 2010, 2018, and 2025.

Results show that:

Between 2010 and 2018, the water area decreased sharply

decrease: ~74.37 km² (≈34.6%)

A partial recovery was observed between 2018–2025

increase: ~24.01 km² (≈17.1%)

2010–2025 overall trend:

total decrease: ~50.36 km² (≈23.5%)

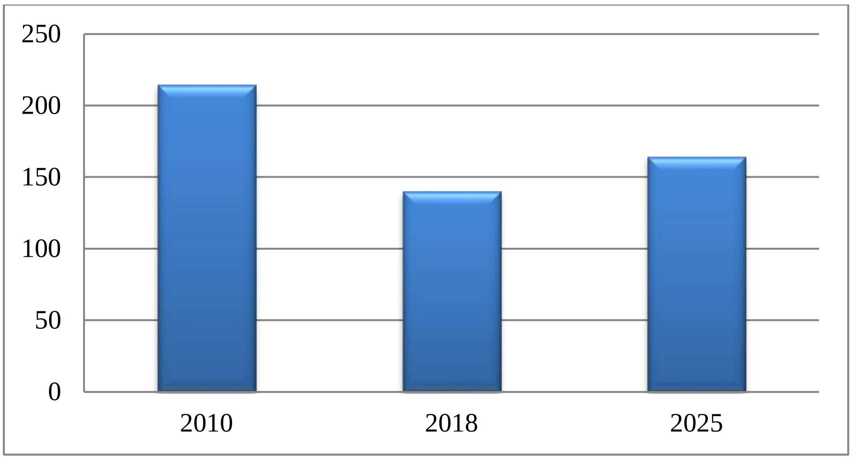


Figure 7. Water Surface Area Change in Khorezm Region(2010-2025) km2

Discussion. The results obtained show that the spatiotemporal dynamics of water resources in the Khorezm region are significantly variable. The change in water surfaces identified based on NDWI between 2010 and 2025 confirms that it is a complex process linked to natural and anthropogenic factors. The high water area recorded in 2010 (214.53 km²) is explained by the relatively stable water flow in the Amu Darya basin. By 2018, the sharp decrease in the water area (140.16 km²) indicates increased pressure on the region's water resources. This situation is linked to climate change, intensive water use, and losses in the irrigation system. The partial recovery of the water area (164.17 km²) between 2018 and 2025 is explained by positive changes in water resource management or improvements in hydrological conditions. However, the 2025 figure did not reach the 2010 level, and the overall downward trend persists. Spatial analysis showed that water bodies are mainly located along the Amu Darya and irrigation canals, indicating a high degree of dependence on the region's water system. The observed fragmentation in some areas suggests an uneven distribution of water resources.

Methodologically, NDWI proved effective in detecting water bodies, but there is a potential for confusion with wet soils. Therefore, its future use in conjunction with indices such as MNDWI is advisable.

Conclusion. In this study, water bodies in the Khorezm region were analyzed using the Google Earth Engine platform based on the NDWI index for the years 2010, 2018, and 2025. The results showed that water resources are significantly variable. It was found that between 2010 and 2018 the water surface area decreased sharply (from 214.53 km² to 140.16 km²), which can be explained by climatic factors and intensive water use. However, between 2018 and 2025, a partial recovery of the water area (to 164.17 km²) was observed, which is attributed to positive changes in water resource management or improved hydrological conditions.

Spatial analysis confirmed that water bodies are primarily associated with the Amu Darya and irrigation networks. This indicates that the region's water resources are highly dependent on the river system. Methodologically, the NDWI index proved to be an effective tool for identifying water bodies. At the same time, it is recommended to use additional spectral indices in the future to increase accuracy. Overall, the study's results reveal a trend of decline and partial recovery of water resources in the Khorezm region, highlighting the need for their sustainable management. This study highlights the importance of continuous monitoring and sustainable management of water resources in arid regions under increasing climatic and anthropogenic pressure.

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