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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
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АКАДЕМИЯСЫ» РҚБ

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ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

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ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
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USE OF WATER INDICES FOR WATERBODIES IN THE ESIL WATER MANAGEMENT BASIN

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Abstract. According to the historical information, there are more than 48 thousand large and small lakes in Kazakhstan, a significant part of which are located in the north of the republic. However, limnological studies of most lakes in Kazakhstan are still quite weak. This study examined the applicability of Landsat (8,9) and Sentinel-2 satellite images for the detection of surface water bodies in the Esil water management basin (WMB) using water indices: NDVI, AWEI, AWEIsh, WRI, NDWI, MNDWI, NDMI, NDTI, NDSI. The MNDWI and AWEI indices were found to be the best for water distribution in the two test lakes of this study. NDTI showed the worst results. There are 831 lakes in the Esil River basin, of which only 455 lakes have a surface area of more than 1 km 2 and 71 lakes have a surface area of more than 10 km 2. According to an analysis based on various indices, in 2023, 770 lakes were discovered in the Esil River basin, of which only 452 lakes have a surface area of more than 1 km 2 and 70 lakes have a surface area of more than 10 km 2. Thus, there was a decrease in the number of 149 lakes with a surface area of more than 1 km 2 and 27 lakes with a surface area of more than 10 km 2 by compared to the data file.

Keywords: Water indices, Remote sensing, Esil water management basin, GIS; lakes, water surfaces

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ЕСІЛ СУ ШАРУАШЫЛЫҒЫ БАССЕЙНІНДЕГІ СУ ОБЪЕКТІЛЕРІ ҮШІН СУ ИНДЕКСТЕРІН ПАЙДАЛАНУ

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Аннотация. Мұрағаттық деректер бойынша Қазақстан Республикасы аймағында 48 мыңнан астам үлкен және кіші көлдер орналасқан және олардың айтарлықтай бөлігі республиканың трансшекаралық солтүстік бөлігінде орналасқан. Дегенмен, еліміздің көптеген көлдерінің лимнологиялық зерттелуі әлі де әлсіз. Бұл еңбектегі зерттеу NDVI, AWEI, AWEIsh, WRI, NDWI, MNDWI, NDMI, NDTI, NDSI су индекстерін Landsat (8,9) және Sentinel-2 ғарыштық суреттеріне қолданыла отырып, Есіл су шаруашылығы бассейніндегі жер үсті су объектілерін анықтау үшін жүргізілді. Осы зерттеу бойынша қарастырылған көлдерде су бетін анықтау үшін қолданылған индекстерге қарағанда MNDWI және AWEI индекстері жақсы нәтиже беретіні анықталды, ал ең қолайсыз индекс болып төмен нәтижелі NDTI болды. Бұрынғы

зерттеу мәліметтерде көсетілгендей, 2013 жылы Есіл су шаруашылығы бассейнінде 831 көл болған, оның тек 455 көлінің ауданы 1 км^2-ден асады және 71 көл – ауданы 10 км^2-ден асқан. Әр түрлі индекстер комбинациясы негізінде талдау бойынша 2023 жылы зерттеу аумағында 770 көл идентификацияланды, оның ішінде: ауданы 1 км^2-ден асатын 452 көл және ауданы 10 км^2-ден асатын 70 көл анықталды. Осылайша, мұрағаттық деректермен салыстырғанда, жалпы ауданы 1 км^2-ден асатын көлдер 149 көлге, ал ауданы 10 км^2-ден асатын объектілер саны бойынша 27 көлге азайды.

Түйін сөздер: су индекстері, ЖҚЗ, Есіл су шаруашылық бассейні, ГАЖ, көлдер, су беті

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ИСПОЛЬЗОВАНИЕ ВОДНЫХ ИНДЕКСОВ ДЛЯ ВОДНЫХ ОБЪЕКТОВ В ЕСИЛЬСКОМ ВОДОХОЗЯЙСТВЕННОМ БАССЕЙНЕ

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Аннотация. По архивным данным, на территории Казахстан насчитывается более 48 тысяч больших и малых озер, их основная часть находится в северной части республики. При этом большинство озер Казахстана по лимнологическим показателям слабо изучено. В этом исследовании изучалась применимость водных индексов: NDVI, AWEI, AWEIsh, WRI, NDWI, MNDWI, NDMI, NDTI, NDSI для снимков со спутников Landsat (8,9) и Sentinel-2 по обнаружению поверхностных водных объектов в Есильском водохозяйственном бассейне (ВХБ). Было обнаружено,

что для выделения воды на тестовых озерах данного исследования индексы MNDWI и AWEI подходят лучше, чем остальные. В то же время индекс NDTI показал наихудшие результаты. По архивным данным, в 2013 г. в Есильском ВХБ было 831 озеро, из которых 455 озер имело площадь более 1 км^2 и 71 озеро были с площадью больше 10 км^2. На основе комбинации различных индексов на территории Есильского ВХБ за 2023 год обнаружено 770 озеро. По анализу было обнаружено с площадью более 1 км^2 452 озер и 70 озеро – свыше 10 км^2. Таким образом, по сравнению с архивными данными, произошло сокращение на 149 озеро с площадью свыше 1 км^2 и на 27 озер с площадью более 10 км^2.

Ключевые слова: водные индексы, ДЗЗ, Есильский водохозяйственный бассейн, ГИС, озера, водная поверхность

Introduction

In modern conditions, considering the growing global shortage of natural water, the issue of rational use, protection, and restoration of lake resources becomes especially relevant. Inefficient use and improper management of water reserves often lead to the depletion of water resources and the reduction of the inland lakes area.

Desertification and salinization in arid areas significantly contribute to the reduction of lake areas. The size of water bodies affects the climate of adjacent regions, influencing air humidity levels and, consequently, the nature of precipitation in the lake basin.

In Kazakhstan, according to archival data, there are more than 48,000 large and small lakes, a significant part of which are located in the territory of interest. Kazakhstan possesses a total of 48,262 lakes, with 45,248 being categorized as small lakes covering an area less than 1 km^2, 296 classified as large lakes spanning over 10 km^2, and 21 exceeding 100 km^2 in size. The latter group represents 60 % of the total water surface area of lakes in Kazakhstan (Frumin & Krashanovskaya, 2010).

Lake water is used in various industries, but its use is currently not well-organized (Imanaliyev et al., 2022). Therefore, a comprehensive assessment and inventory of the lake fund's current state in Kazakhstan is necessary, using modern methodologies and combining all available data in a cartographic format.

The limnological study of most lakes in Kazakhstan, their condition, and water quality and quantity is still quite weak. Studies of the lakes of Kazakhstan, initiated in the 1950s by the Geography Sector of the Academy of Sciences of the Kazakh SSR, were discontinued in the 1990s. Thus, there has been a break of more than 25 years in lake monitoring. During this time, due to changes in natural character and anthropogenic factors, many lakes have changed their hydrological, morphometric, and hydrochemical characteristics (Yang et al., 2015).

Such alterations in the presence of surface water structures have a profound impact on both agricultural and industrial productivity (Sharma et al., 2015; Anderson et al., 2012), in addition to affecting environmental and ecological security (Palmer et al., 2015; Yamazaki et al., 2015; Du et al., 2016; Liu et al., 2015).

Data on the lake locations, their volumes, and water quality, as well as conditions and possibilities for their rational use, are outdated and cannot objectively address water security issues in the Republic.

Remote sensing is an expeditiously advancing technology that can offer cheap and dependable information regarding environmental modifications at local, regional, and global levels due to the prolonged accumulation of repetitive data (Lee et al., 2018). For instance, Pekel et al. (2016) utilized all Landsat images to identify alterations in surface water reservoirs over the previous three decades on a worldwide scale. Several techniques for water extraction have been devised and implemented for images acquired through remote sensing.

McFeeters formulated the most rudimentary spectral index for water detection, known as the NDWI (McFeeters et al., 1996), by utilizing the green and NIR bands of the Landsat (TM) image to optimize the identification of water. Furthermore, McFeeters proposed that setting a threshold of 0 enables the differentiation between water and the surrounding background using NDWI (9).

Xu substituted the NIR band within McFeeters' NDWI with the SWIR band and developed a modified NDWI (MNDWI) (Xu et al., 2006). Water distribution in urban regions was delineated based on the MNDWI index utilizing Landsat (ETM+) imagery, revealing that MNDWI outperforms NDWI in discerning water from shadows.

Feyisa et al. (2014) introduced the Automatic Water Extraction Index (AWEI) for the identification of water bodies, featuring two components: AWEIsh is tailored to eliminate shadow pixels, while AWEInsh is targeted towards regions with urban characteristics. Furthermore, a multitude of other indices have been developed in various research endeavors for diverse sensors and locations, each exhibiting varying levels of accuracy (Malahlela et al., 2016; Fisher et al., 2013).

Study area. According to the our country's Water Code, the basin principle of water resource management is in effect. There are 8 water management basins: Zhaiyk-Caspian, Aral-Syr Darya, Tobol-Turgay, Esil, Nura-Sarysu, Chu-Talas, Balkhash-Alakol, and Irtysh. The water resources within each basin are hydrologically connected, so it is expedient to consider the water management situation in the country in terms of river basins. The Yesil Water Basin, located in the northern and central regions of Kazakhstan, covers a vast area spanning the Akmola, Kostanay, and North Kazakhstan regions (Figure 1). Fed primarily by the Yesil River, the basin receives its water from numerous significant tributaries originating in the Kokshetau Hills in the north and the Ulytau Ranges in the south. The region's largely flat topography, combined with the presence of various closed basins, creates favorable conditions for surface water retention and the development of lake reservoirs. The basin covers an area of approximately 176,000 square kilometers and has experienced declining water runoff for many years, during which much of the meltwater is used to fill basins and floodplains in the river channels. As a result, runoff volumes decrease, primarily due to snow accumulation in the river bed, resulting in a reduction in the area of the active catchment basin. Such hydrological patterns are usually characterized by dry conditions similar to those of a desert. Conversely, in years of high water levels, the relief exceeds its capacity, which facilitates the diversion of water into the main river bed and leads to a significant expansion of the active area of the catchment basin. The rapid onset of spring facilitates the unimpeded flow of meltwater into river channels, minimizing water losses and leading to high floods even with small snow reserves.

This determines the specific hydrological conditions of this region, characterized by extreme unevenness of runoff both in the long-term perspective and throughout the year.

In the Esil Water Management Basin, there are numerous lakes that are extremely important in the ecosystem of the region.

The lakes of the Esil Water Management Basin face a range of environmental problems. Climate change and unsustainable water use contribute to increased salinity and decreased water levels in lakes, threatening biodiversity and the sustainability of ecosystems.

The adverse impact on lake water quality caused by agricultural practices and industrial discharges leads to pollution and further deterioration of plant and animal habitats. Extensive irrigation methods, leading to decreased water levels in lakes, have a detrimental effect on the ecological state of these water bodies.

The climate of the Esil Water Management Basin is continental, characterized by sharp seasonal and daily temperature fluctuations, low precipitation, and significant evaporation. Typical January temperatures range from -15 °C to -20 °C. The winter season is characterized by low temperatures and long snowfalls. The average July temperature ranges from +18 °C to +22 °C. The summer months are characterized by high temperatures and dry weather, with occasional precipitation. Annual precipitation ranges from 300 to 400 mm. Snow cover is established in November and lasts until March-April. Snowmelt is an important source of water replenishment in the spring. Significant daily and seasonal temperature fluctuations are a characteristic feature of the region›s climate.

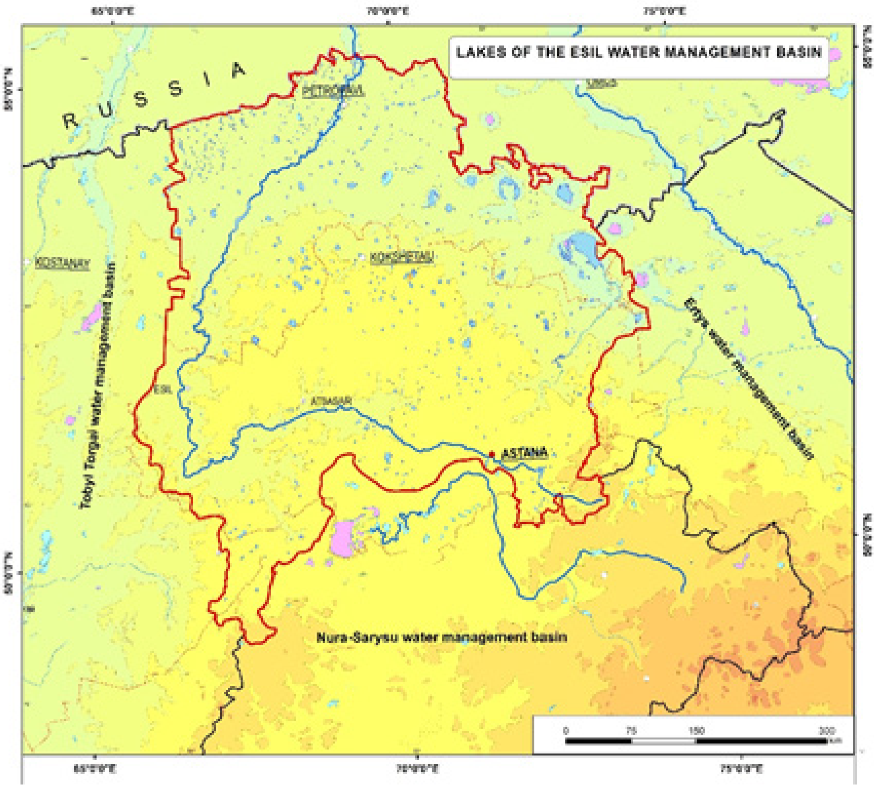


Figure 1 – Esil Water Management Basin (Esil WMB) Territory

The average air humidity throughout the year varies, reaching its lowest values in the summer and highest in the winter. High evaporation rates, especially in the summer months, contribute to the drying up of water bodies and decreased groundwater levels.

The climate conditions of the Esil Water Management Basin are the main factors of the formation and distribution of lakes in the region. Spring flooding, caused by snowmelt, is the main source of replenishment for rivers and lakes. Summer droughts and high evaporation lead to decreased water levels in water bodies and increased salinity.

Materials and methodology

The National Aeronautics and Space Administration (NASA, Washington, D.C., USA) launched the first Landsat satellite in 1972, and since then we have successfully launched Landsat 8–9 satellites are equipped with Operational Land Imager (OLI) or Operational Land Imager-2 (OLI-2) sensors, which increase the spectral resolution of the TM group by adding deep blue and cirrus bands. We analyzed and downloaded Landsat images to obtain water data from the website USGS Earthexplorer.

Sentinel-2 MSI images were downloaded from the Copernicus browser website, which serves as a repository for Earth observation satellite imagery from the European Space Agency. The image consists of 13 Sentinel-2A spectral bands, each with a different spatial resolution. Specifically, there are three visible bands and one near-infrared band with 10 m spatial resolution, a quad band dedicated to vegetation analysis, two short-wave near-infrared bands with 20 m resolution, and three thermal infrared bands with 60 m resolution . However, this study only focused on the use of blue (10 m), green (10 m), near-infrared (10 m), and short-wave infrared (20 m) due to their effectiveness in trapping water. data. We performed spatial sampling to compensate for the 10 m spatial resolution, taking into account the difference in spatial resolution between the SWIR and green/NIR bands. For the analysis, satellite images were used from September-October, a period without snow and when cloudiness did not exceed 10 %.

Data preprocessing stages included cropping of the study area, radiometric correction, and atmospheric correction. Landsat image values are stored as digital numbers representing electromagnetic radiation detected by the satellite's corresponding sensors. The purpose of radiometric correction is to convert the brightness value of a gray image into a bright glow of something comparable to the values of images that have undergone the same level of temporal or sensory correction. Atmospheric correction assumes that the overall brightness of an object on the ground measured by the sensor is not the true surface brightness, which includes error in the amount of radiation caused by atmospheric absorption, especially dispersion. Atmospheric correction is the process of eliminating errors caused by radiation from weather effects and ensuring the true surface brightness of objects on the ground.

Methodology of calculation of auxiliary indices.

To develop an algorithm for water surface extraction from LANDSAT (8,9) and Sentinel-2 satellite data, different spectral indices selected from the analyses of world experience were tested:

The first step was to calculate the Normalized Difference Vegetation Index to determine the boundaries of the lake:

$$\begin{gathered} NDVI = (NIR - RED)/(NIR + RED) \\ Landsat = (B5\text{-}B4)/(B5\text{+}B4) \\ Sentinel\ 2 = (B8\text{-}B4)/(B8\text{+}B4) \end{gathered} \tag{1}$$

NDVI is defined by values from -1.0 to 1.0; here negative values occur mainly for clouds, water and snow.

AutomatedWaterExtractionIndex is calculated using the following formula, and water has a for this index positive value:

$$AWEI = 4 * (Green - SWIR2) - (0.25 * NIR + 2.75 * SWIR1)$$
$$Landsat = 4*(B3-B7)-(0.25*B5+2.75*B6) \quad (2)$$
$$Sentinel\ 2= 4*(B3-B12)-(0.25*B8+2.75*B11)$$

The AWEI (Automated Water Extraction Index) index is specifically designed to mask non-aquatic pixels in urban environments. It is most effective on images with less than 15 % cloud cover and a modified AWEIsh index, designed to more accurately identify water in shaded areas and other dark surfaces. However, errors may occur on the classification screen in areas with highly reflective surfaces such as ice and snow.

$$AWEIsh = Blue + 2.5 *Green -1.5* (NIR + SWIR1) - 0.25 *SWIR2$$
$$Landsat = B2 + 2.5 * B3 - 1.5 * (B5+B6) - 0.25 * B7) \quad (3)$$
$$Sentinel\ 2 = B2 + 2.5 * B3 - 1.5 * (B8+B11) - 0.25 * B12$$

Water Ratio Index (WRI) is used to determine the moisture content of vegetation and is calculated as follows:

$$WRI= (GREEN + RED) / (NIR + SWIR2)$$
$$Landsat = (B3 + B4)/(B5+B7) \quad (4):$$
$$Sentinel\ 2 = (B3 + B4)/(B8+B12)$$

In the process of determining the indices, we obtain raster data about the water surface, where the pixel values will be 0 or higher; and values from 1 indicate bodies of water or objects containing moisture. This approach makes it possible to identify water systems in the study area.

The Normalized Difference Moisture Index (NDWI) is a relative index used to estimate the moisture content of vegetation, particularly in relation to the absorption of solar radiation. Thanks to its algorithm, this indicator facilitates a qualitative assessment of the level of humidity in the crown of plants. In contrast to the normalized vegetation index Differential (NDVI), NDWI index is sensitive to fluctuations in humidity and is also less sensitive to weather conditions. It is used to determine surface water in wetlands and to measure the availability of surface water. The typical range for lush vegetation is 0.1 to 0.4. This indicator is especially useful when the mid-infrared channel is not available.

The NDWI index is calculated as follows:

$$NDWI = (NIR – SWIR2)/(NIR + SWIR2)$$
$$Landsat = (B5 - B7)/(B5 + B7) \quad (5)$$
$$Sentinel\ 2 = (B8 - B12)/(B8 + B12)$$

ModifiedNormalizedDifferenceWaterindex (MNDWI) is used in various situations to improve the identification and monitoring of water bodies using remote sensing data. The index provides effective attenuation and eventual elimination of spectral interference from surfaces, soil and vegetation. It outperforms NDWI results, especially in scenarios where the studied coastline is very close to a man-made structure. As a result, determining the boundaries of water bodies in such cases provides higher accuracy without taking into account negative factors that interfere with work. MNDWI is particularly useful for accurately identifying water bodies in the context of landscape and plant systems. His formula:

$$MNDWI = (Green - SWIR2) / (Green + SWIR2)$$
$$Landsat = (B3 - B7)/(B3 + B7) \quad (6)$$
$$Sentinel\ 2 = (B3 - B12)/(B3 + B12)$$

The Normalized Differential Moisture Index (NDMI) is designed to monitor drought conditions and estimate fuel moisture content in wildfire-prone areas. The use of near-infrared (NIR) and short-wave infrared (SWIR) spectral bands provides connectivity while reducing the effects of interference and weather conditions, and improves the display of humidity levels using near-infrared (NIR) and short-wave bands. Spectral bands of infrared waves (SWIR), which are assigned a positive numerical value to the water content and measured using a special mathematical expression:

$$NDMI = (NIR – SWIR\ 1)/(NIR + SWIR\ 1)$$
$$Landsat = (B5 - B6)/(B5 + B6) \quad (7)$$
$$Sentinel\ 2 = (B8 - B11)/(B8 + B11)$$

Standard algorithm (NDTI): index based on water turbidity. This indicator characterizes a decrease in water transparency due to impurities of inorganic and organic substances in suspension, as well as the development of plankton in the lake.

NDTI is calculated:

$$NDTI = (RED-GREEN)/(RED+GREEN)$$
$$Landsat = (B4 - B3)/(B4 + B3) \quad (8)$$
$$Sentinel\ 2 = (B4 - B3)/(B4 + B3)$$

This index is suitable for identifying objects with actual humidity. To calculate the NDVI and NDTI indices, the characteristic quality of vegetation is determined; This demonstrates a pattern: the higher the NDVI, the greater the NDTI. The indices are useful for drought forecasting.

The Standardized Difference Snow Index (NDSI) was developed to detect the neutral layer of snow in clouds in Landsat TM images (bands 2 and 5). The index serves to reduce the impact of atmospheric conditions. In the case of snow, the NDSI value is usually greater than 0.4 and its calculation is based on:

$$NDSI = (GREEN — SWIR1) / (GREEN + SWIR1)$$
$$Landsat = (B3 - B6)/(B3 + B6) \quad (9)$$
$$Sentinel\ 2 = (B3 - B11)/(B3 + B11)$$

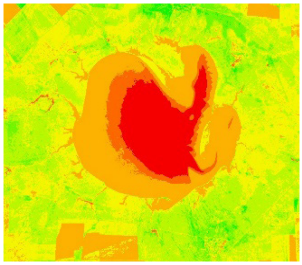
The brightness of the snow layer makes it difficult to distinguish snow from clouds in images. Snow not only reflects light well in the visible part of the electromagnetic spectrum, but also absorbs it well in the near-infrared and short-wave parts of the spectrum. When exposed to solar radiation with a wavelength of 1.6 microns, snow becomes darker in color than clouds.

Results and discussion

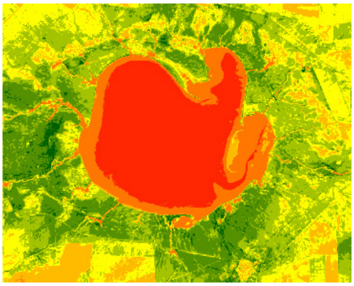
The study evaluates the performance of water-dominated indices: NDVI, AWEI, AWEISH, WRI, NDWI, MNDWI, NDMI, NDTI, Landsat (8.9) NDSI satellite imagery and Sentinel-2 for the Yesil Basin . The analysis includes an examination of standards and ideal thresholds for defining surface waters specific to grasslands and forests. In conclusion, we implemented and evaluated a new approach that integrates indices and cross-sections of a study area as a function of elevation to improve the detection of surface water across the entire area. Figures 2 and 3 show an example of the results of calculating various water surface indices.

Sentinel-2 image for October 19, 2023

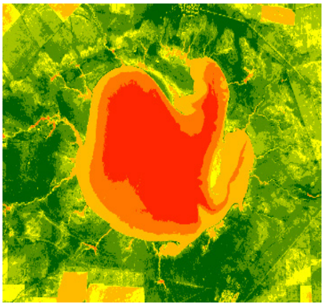
PlanetScope image for October 27, 2023.



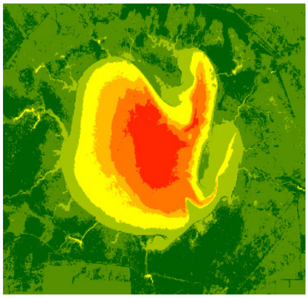
NDVI Index



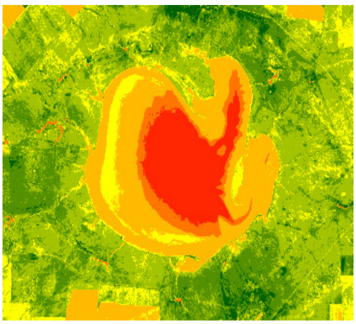
AWEI Index



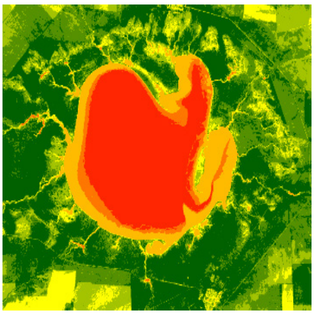
AWEIsh Index



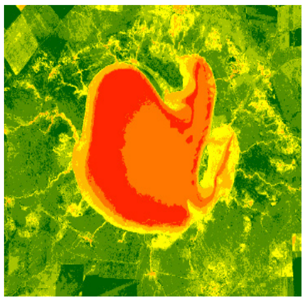
WRI Index



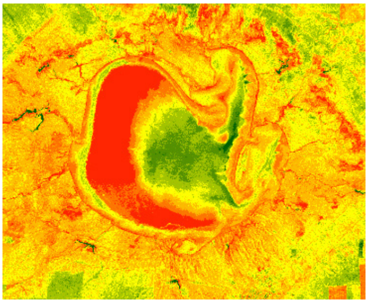
NDWI Index



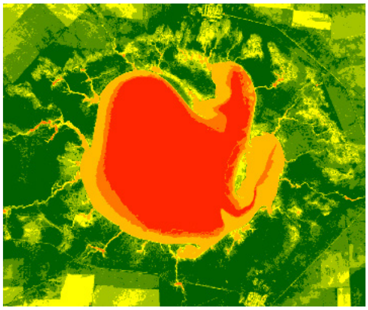
MNDWI Index



NDMI Index



NDTI Index



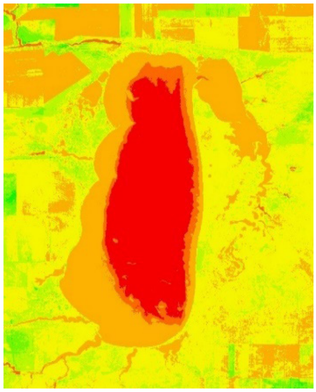
NDSI Index

Figure 2 – Calculation of different water surface definition indices at Lake Kishi Karaoi

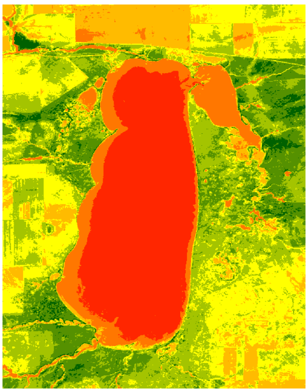
The study found that MNDWI and AWEI were better at identifying the water surface, while NDTI performed poorest results.

Sentinel-2 image for October 19, 2023

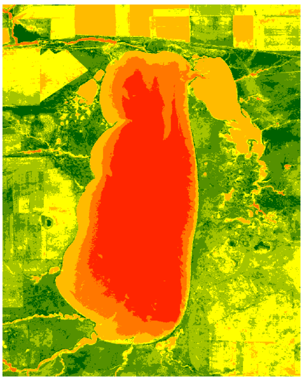
PlanetScope image for October 27, 2023.



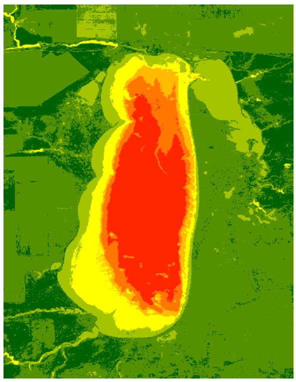
NDVI Index



AWEI Index



AWEIsh Index



WRI Index

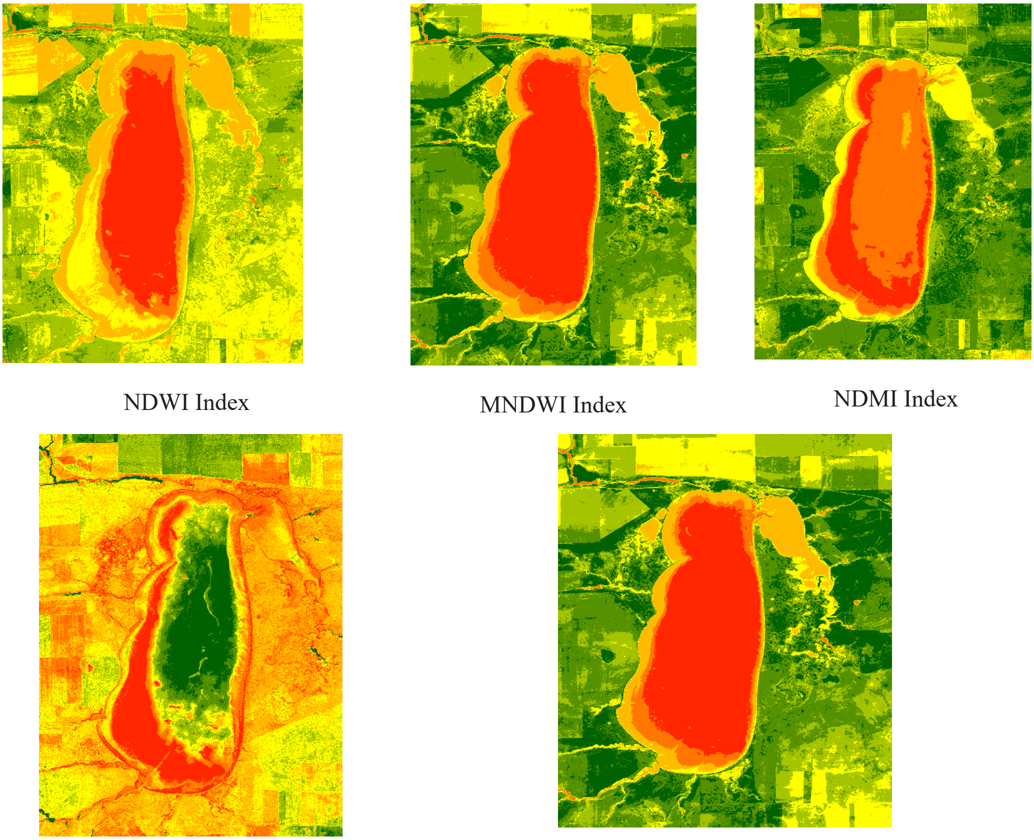


Figure 3 – Calculation of different indices of water surface definition at Lake Qalibek

Each of these indices has its own advantages and disadvantages. Using the NDVI index, you can clearly identify an area with cloudless, clear water that contrasts well with the background of clouds, ice and snow. This index typically identifies water, very wet soil, recently burned areas, and cloud shadows. The water surface with shallow water and vegetation is little differentiated. NDSI is mostly fully developed in winter or early spring, but is also useful for eliminating water surface class cloud shadows during snow-free periods.

Using archival data, the Esil Basin was found to have 9,812 lakes (Filonets et al., 1974), with 601 lakes larger than 1 km^2 and 97 lakes larger than 10 km^2. Satellite data processing in 2013 identified 831 lakes in the Esil Basin, with 455 lakes larger than 1 km^2 and 71 lakes larger than 10 km^2. Analysis in 2023 identified 770 lakes, with 452 lakes larger than 1 km^2 and 70 lakes larger than 10 km^2. This represents a reduction of 149 lakes larger than 1 km^2 and 27 lakes larger than 10 km^2 compared to archival data.

As a result of a study in which all the indices discussed above were used, according to the file, there are 9812 lakes in the Esil WMB (Filonets et al., 1974), of which 601 have an area of 1 $km^{2,}$ and the surface area of 97 lakes is more than 10 km^2. According to the processing of satellite data, in 2013, 831 lakes were digitized in the Esil WMB, of which only 455 have a mirror area of more than 1 km^2 and 71 of which have a mirror area of more than 10 km^2. According to an analysis based on various indicators, in 2023, 770 lakes were discovered on the territory of the Esil naval base, of which only 452 have a surface area of more than 1 km^2, and the surface of 70 lakes. Thus, according to the data of the array, there are 149 lakes with a surface area of more than 1 km^2, and there has been a decrease in 27 lakes with a surface area of more than 10 km^2.

The number of small lakes (up to 1 km^2) is variable for the lowland regions of central, western and northern Kazakhstan, depending on the annual humidity in a particular region. The number of lakes in river deltas also varies.

The methodology was based on methods used to solve similar problems around the world. Numerous authors (Pekel et al., 2016) have used satellite and multispectral data to detect and monitor changes in water bodies, demonstrating the successful use of remote sensing in water resource management. The study was carried out using satellite altimetry, but the accuracy of the measurements depends on the size of the reservoir, surrounding topography, surface waves and winter ice cover. This method has performed poorly in most lakes larger than 10 km^2 (Busker, 2019; Smith et al., 2015).

Conclusion

This study examined the applicability of Landsat (8,9) and Sentinel-2 image indices to detect surface water bodies in steppe and forested areas using different water levels and compared the results.

By comparing the results of different water release rates under different conditions, we found that MNDWI and AWEI performed better than others in terms of water release, while NDTI performed worse in the two lakes presented in this study. The results also show that Landsat imagery (8,9) in combination with data from other Landsat sensors and other medium-resolution satellites generally allows for the study of changes in water regimes over long periods of time.

According to the results, it was revealed that the number of lakes from 1 to 10 km^2 varies quite a bit from year to year. Given the aridity of the study area, the response to climate change was observed mainly in lakes of small area. Warming will lead not only to an increase in air temperature, but also in the temperature of surface waters, which will increase the flow of moisture from the surface of the lake into the atmosphere. Analysis of the results confirms the high degree of variability of surface waters; This does not allow us to accurately define a group of lakes classified by surface.

This data set of lake volumes helps improve our current understanding of lake behavior, their representation in hydrologic models, and hence river basin modeling. It will also improve projections of river basin development in terms of climate change under different management scenarios and improve estimates of evaporation from open water bodies.

The Esil water management basin plays an important role in providing water and protecting the region's ecosystems. The lakes of the basin are important natural objects that require constant care and protection. Joint efforts by the state, the scientific community and the public can help protect and restore these unique water bodies, ensuring sustainable development and environmental stability.

REFERENCES

Anderson M.C., Allen R.G., Morse A., Kustas W.P. (2012). Use of Landsat thermal imagery in monitoring evapotranspiration and managing water resources, Remote Sens of Environment. — 122:50–65. DOI: 10.1016/j.rse.2011.08.025 (in Eng.)

Busker T., de Roo A., Gelati E., Schwatke C., Adamovic M., Bisselink B., Pekel J.-F., Cottam A. (2019). A global lake and lake volume analysis using a surface water dataset and satellite altimetry, Hydrology and Earth System Sciences. —23:669–690. DOI:10.5194/hess-23-669-2019 (in Eng.)

Du У., Zhang У., Ling F., Wang Q., Li W., Li X. (2016 a). Water Bodies' Mapping from Sentinel-2 Imagery with Modified Normalized Difference Water Index at 10-m Spatial Resolution Produced by Sharpening the SWIR Band, Remote Sensing, — 8:354. DOI: 10.3390/rs8040354 (in Eng.)

Feyisa G.L., Meilby H., Fensholt R., Proud S.R. (2014). Automated water extraction index: A new technique for surface water mapping using Landsat imagery, Remote Sensing of Environment, — 140:23–35. DOI: 10.1016/j.rse.2013.08.029 (in Eng.)

Filonets P.P., Omarov T.R. (1974). Lakes of Northern, Western and Eastern Kazakhstan. Gidrometeoizdat, Russia.

Fisher A., Danaher T.A. (2013). A water index for SPOT 5 HRG satellite imagery, New South Wales, Australia, determined by linear discriminant analysis, Remote Sensing, — 5:5907. DOI: 10.3390/rs5115907 (in Eng.)

Frumin G.T., Krashanovskaya Уu.V. (2014). Trophic status of lakes in Kazakhstan [Trophicheskiy status ozer Kazakhstana], Terra Humana, — 3:32 (in Russ.)

Imanaliyev T., Koybakov S., Karlykhanov O., Amanbayeva B. & Bakiyev M. (2022). Prospects for the development of water resources management in the south of Kazakhstan, News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. — 6(456):80–95. DOI:10.32014/2518-170X.240 (in Eng.)

Lee J.K., Acharya T.D., Lee D.H. (2018). Exploring land cover classification accuracy of Landsat 8 image using spectral index layer stacking in hilly region of South Korea, Sensors and Materials, — 30:1–15. DOI: 10.18494/SAM.2018.1934 (in Eng.)

Liu J., Zhang У., Уuan D., Song X. (2015). Empirical Estimation of Total Nitrogen and Total Phosphorus Concentration of Urban Water Bodies in China Using High Resolution IKONOS Multispectral Imagery, Water. — 7:6551–6573. DOI: 10.3390/w7116551 (in Eng.)

Malahlela O.E. (2016). Inland waterbody mapping: Towards improving discrimination and extraction of inland surface water features, International Journal of Remote Sensing. — 37:4574–4589. DOI: 10.1080/01431161.2016.1217441 (in Eng.)

McFeeters S.K. (1996). The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features, International Journal of Remote Sensing. — 17:1425–1432. DOI: 10.1080/01431169608948714 (in Eng.)

Palmer S.C.J., Kutser T., Hunter P.D. (2015). Remote sensing of inland waters: Challenges, progress and future directions, Remote Sensing of Environment, — 157:1–8. DOI: 10.1016/j.rse.2014.09.021 (in Eng.)

Pekel J.F., Cottam A., Gorelick N., Belward A.S. (2016). High-resolution mapping of global surface water and its long-term changes, Nature. — 540:418–422. DOI: 10.1038/nature20584 (in Eng.)

Sharma R., Tateishi R., Hara K., Nguyen L. (2015). Developing Superfine Water Index (SWI) for Global Water Cover Mapping Using MODIS Data, Remote Sensing, — 7:13807–13841. DOI: 10.3390/rs71013807 (in Eng.)

Smith L.C., Pavelsky T.M. (2015). Monitoring global surface water changes using multi-source satellite data, Remote Sensing of Environment. — 157:112–123. DOI:10.1016/j.rse.2014.06.008 (in Eng.)

Xu H. (2006) Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery, International Journal of Remote Sensing, 27:3025-3033. DOI: 10.1080/01431160600589179 (in Eng.)

Уamazaki D., Trigg M.A., Ikeshima, D. (2015) Development of a global ~90m water body map using multi-temporal Landsat images, Remote Sensing of Environment, 171:337-351. DOI: 10.1016/j.rse.2015.10.014 (in Eng.)

Уang У., Liu У., Zhou M., Zhang S., Zhan W., Sun C., Duan У. (2015). Landsat 8 OLI image based terrestrial water extraction from heterogeneous backgrounds using a reflectance homogenization approach, Remote Sensing of Environment. — 171:14–32. DOI: 10.1016/j.rse.2015.10.005 (in Eng.)

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