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Analysis of spatio-temporal changes of surface water within the Semipalatinsk test site based on the Google Earth Engine platform

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Abstract: The article is devoted to analyzing the dynamics of spatio-temporal changes in water bodies within the Semipalatinsk Test Site using remote sensing data based on the Google Earth Engine platform, with the aim of developing a map of surface water and irrigation systems to support landscape planning of the area. Landsat and Sentinel-2 satellite imagery, ERA5-Land climatic data, and the SRTM digital elevation model were used as the primary input datasets. Water surfaces were extracted using the Modified Normalized Difference Water Index (MNDWI) method. The results revealed that the largest extents of water surfaces were observed in years characterized by cold and snowy winters (2000 and 2010), whereas the smallest extents occurred during warm and low-snow periods (1996, 2012, and 2024). The proportion of temporary water bodies exceeds 60%, reflecting the instability of the hydrological regime and its strong dependence on climatic variability. The use of modern platforms such as Google Earth Engine for identifying spatio-temporal changes in water bodies has proven to be effective and demonstrates great potential for water resource management and dynamic assessment. The obtained results can be applied for environmental monitoring and landscape planning in the development of the former test site areas for agricultural purposes.

Keywords: water bodies; Google Earth Engine; remote sensing data; the Semipalatinsk test site (STS)

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1. Introduction

Remote sensing is a key tool for monitoring and assessing surface water bodies. The advantages of high temporal resolution and repeated observations provided by optical satellite imagery make it widely used for the mapping and monitoring of water resources (Hossain et al., 2023).

The analysis of spatio-temporal changes in water bodies using the Google Earth Engine (GEE) platform represents a significant advancement in the field of environmental monitoring and water resource management (Ngamile et al., 2025; Zhang et al., 2022). It enables comprehensive analysis of spatio-temporal datasets and provides a cloud-based solution for fast and scalable processing of remote sensing data (Li et al., 2022; Zhao & Bang, 2024).

This approach employs advanced methodologies, including time series of remote sensing data and machine learning–based classification methods, to assess the dynamics of surface water. Google Earth Engine (GEE) has proven its effectiveness in visualizing water presence and analyzing the factors influencing changes in water bodies (Zhao & Bang, 2024; Alzurqani et al., 2024; Sherjah et al, 2023). However, the use of GEE for water body analysis is associated with several challenges. The availability and quality of data remain significant constraints. Methodological limitations, such as the potential misclassification of adjacent vegetation types, may also affect the reliability of the results. Moreover, the integration of community-sourced data presents both opportunities and challenges for the validation of satellite observations, highlighting the need for collaborative efforts in data collection and analysis (Alzurqani et al., 2024; Sherjah et al, 2023).

The aim of this study is to identify the spatio-temporal changes of surface water within the Semipalatinsk Test Site using satellite data and the analytical capabilities of the Google Earth Engine platform.

2. Materials and methods

2.1. Study Area

The Semipalatinsk Test Site (STS) is located in the eastern part of Kazakhstan, at the junction of the Abai, Pavlodar, and Karaganda regions, covering an area of approximately 18300 km² (Figure 1).

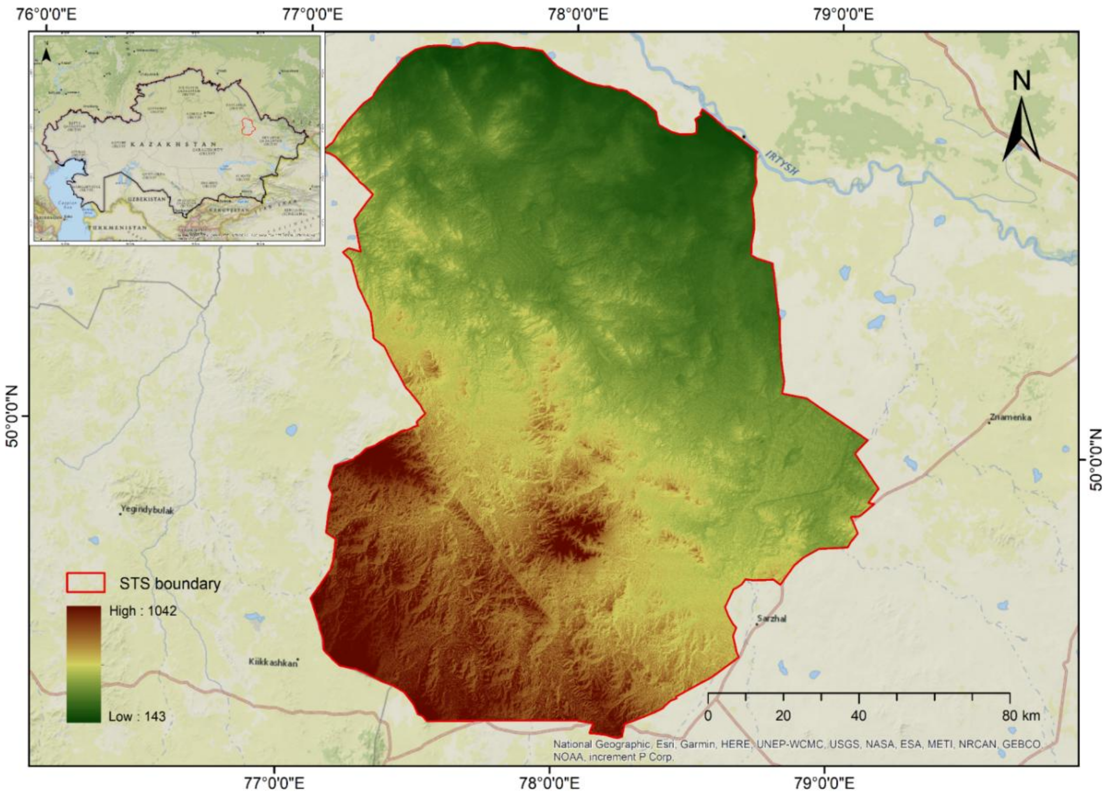

Figure 1. Study area

The territory of the test site extends from the Irtysh River valley southwestward for approximately 180 km and lies within the eastern part of the Kazakh Uplands, which are characterized by an arid, sharply continental climate. The mean annual air temperature ranges from +0.6°C to +5°C, and the annual precipitation amounts to 250–300 mm.

The hydrographic network is represented by the Shagan River with its tributary Ashchysu, as well as by small streams and lakes that become active during the spring flood period. In summer, most of the water bodies dry up, forming saline depressions. The primary source of water supply is snowmelt, which accounts for up to 95% of the annual runoff.

A distinctive feature of the study area is the complex combination of natural and anthropogenic factors resulting from the long-term use of the site for nuclear weapons testing during 1949–1989. This analyzes the spatio-temporal dynamics of water bodies crucial for assessing the current state and transformation of the region's aquatic ecosystems (Nazarbayev et al., 2016; Batyrbekov et al., 2021).

2.2. Data Sources

This study utilized all available surface imagery from Landsat (TM, ETM+, and OLI) and Sentinel-2 MSI covering the territory of the Semipalatinsk Test Site for the period 1996–2024. The analysis was performed on the Google Earth Engine (GEE) platform, followed by visualization and map composition in ArcGIS Pro.

For each image, a cloud, shadow, and snow masking function was applied to ensure high-quality scenes suitable for analyzing the dynamics of water bodies within the test site. Only images acquired during the vegetation period (May–September) were used in the analysis, which made it possible to minimize seasonal and atmospheric distortions.

A total of 90 scenes were used in the study, including 30 Landsat scenes (6 years × 5 scenes per year) and 60 Sentinel-2 scenes (2 years × 2 coverages × 15 scenes per year). In addition, the SRTM digital elevation model with a spatial resolution of 30 m was used to refine watershed boundaries and to analyze the influence of orography on the distribution of water bodies.

For the analysis of climatic factors, ERA5 reanalysis data (precipitation and air temperature) for the period 1996–2024 were used. These data made it possible to establish the relationship between changes in the extent of water bodies and the climatic conditions of the region (Gorelick et al., 2017; Drusch et al., 2012; Hersbach et al., 2020; Farr et al., 2007).

2.3. Processing Methods

The methodology applied for analyzing the spatio-temporal changes in water bodies using the Google Earth Engine (GEE) platform included several key components, such as data collection, classification methods, and accuracy assessment (Mutanga & Kumar, 2019). The workflow is illustrated in Figure 2, which shows the sequence of analysis stages. The approach is based on the integration of multitemporal satellite data from Landsat and Sentinel-2, climatic indicators from ERA5-Land, and the SRTM digital elevation model (Hansen & Loveland, 2012; Kaplan & Avdan, 2017; Yilmaz, 2023; Rodriguez et al., 2006). The use of the cloud-based GEE platform ensured consistent data processing, automation of calculations, and reproducibility of the results.

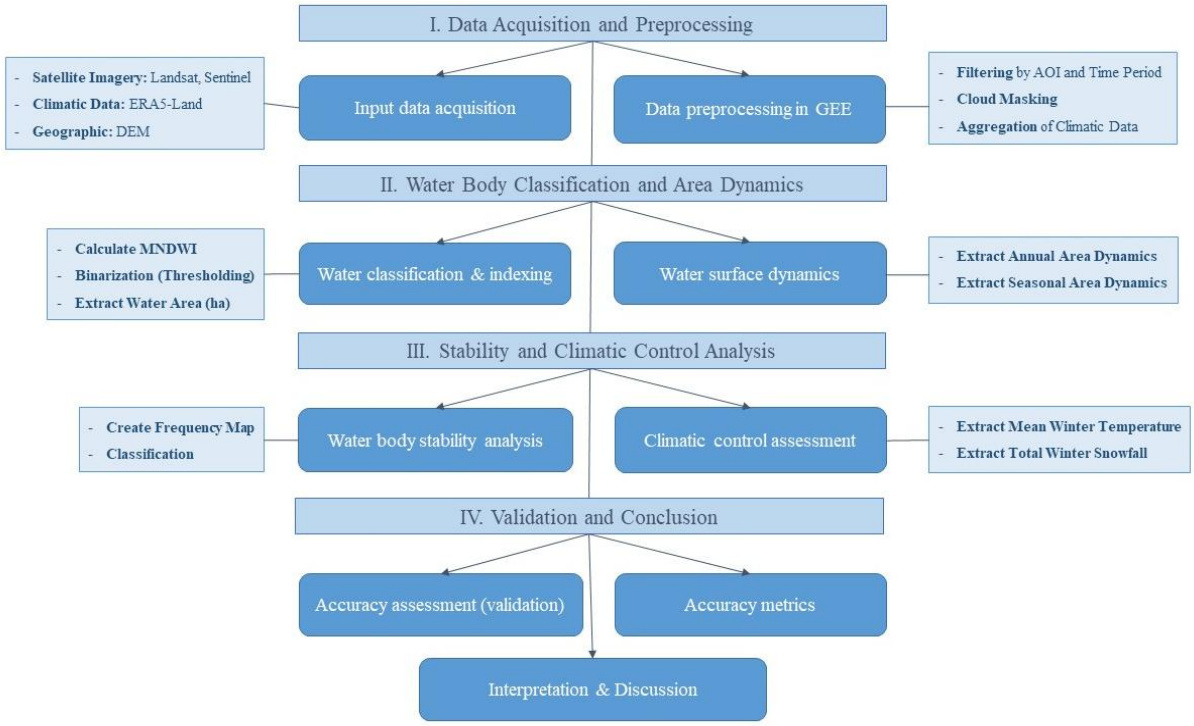

Figure 2. Workflow of the methodology for analyzing water bodies using GEE

The study covers six representative temporal snapshots – 1996, 2000, 2010, 2012, 2020, and 2024. This selection was determined both by the availability of high-quality satellite data and by the need to reflect key stages in the hydrological evolution of the region. Each of these periods characterizes a typical state of the water systems under different climatic and anthropogenic conditions. To minimize seasonal and atmospheric distortions, only images acquired during the vegetation period (May–September) were used, when water surfaces are most distinctly expressed in satellite imagery. Such a discrete observation structure made it possible to capture the stage-by-stage changes in the configuration and area of water bodies over nearly three decades and to ensure comparability between temporal intervals (Pekel et al., 2016; Xu, 2006).

Preprocessing of the data included spatial clipping to the boundaries of the test site and atmospheric noise removal using the tools available in Google Earth Engine (GEE). After masking, the reflectance values of the images were normalized to ensure the comparability of data obtained from different sensors.

Water surface extraction was performed using the Modified Normalized Difference Water Index (MNDWI) (Gorelick et al., 2017):

$$MNDWI=\frac{\rho Green\text{- }\rho SWIR1}{\rho Green+\rho SWIR1}$$

MNDWI=ρGreen+ρSWIR1ρGreen−ρSWIR1 (1)

where ρGreen and ρSWIR1 are the reflectance values in the green (0.52–0.60 μm) and shortwave infrared (1.55–1.75 μm) bands, respectively.

For the historical composites (2000 and 2010), an MNDWI threshold of > 0.30 was applied, whereas for the multiyear analysis and Sentinel-2 data, a more sensitive threshold of > 0.0 was used (Xu, 2006; Ji et al., 2009). This approach made it possible to account for both permanent and shallow or temporary water bodies.

The water frequency (WF) was calculated based on binary water masks, representing the proportion of observations in which a pixel was classified as a water surface:

$$WF=\frac{\sum N_{water}}{\sum N_{valid}} x100\%$$

WF=∑N_{valid}∑N_{water}×100% (2)

where N_{water} is the number of observations in which the pixel was classified as water, and N_{valid} is the total number of valid observations for the pixel.

Pixels with fewer than 20 valid observations were excluded from the analysis (Pekel et al., 2016; Donchyts et al., 2016). Based on the WF values, categories of water body persistence were identified: temporary (WF < 40%), semi-permanent (40–70%), and stable (≥ 70%) water bodies (Pekel et al., 2016).

To analyze the climatic influence, ERA5-Land data (European Centre for Medium-Range Weather Forecasts [ECMWF], 2021) were used, including mean winter air temperature (°C) and total snowfall (mm) for the period from November to March. These parameters were averaged within the boundaries of the Semipalatinsk Test Site and compared with the time series of water body areas. Changes in surface water extent were quantified using the dynamic coefficient K (Pekel et al., 2016):

$$K=\frac{S_b\text{-}S_a}{S_a}\ x\ \frac{1}{T}\ x\ 100\%$$

K=((S_b−S_a)/S_a)×(1/T1)×100% (3)

where $S_a$and $S_b$are the surface water areas at the beginning and end of the period, respectively, and T is the duration of the interval (in years).

To verify the classification accuracy, a quantitative assessment was conducted using reference samples from Sentinel-2 and Google Earth imagery based on a standard confusion matrix. Validation was performed using 150 randomly selected control points located within the study area. The year 2010, characterized by the maximum floodwater extent (14993.96 ha), was used as the reference period, allowing for the evaluation of the model's performance under extreme hydrological conditions.

Comparison of the "water" and "land" classes derived from MNDWI with visual interpretation of high-resolution imagery showed a high degree of consistency. The calculated accuracy metrics were as follows: overall accuracy (OA) – 94.0%, producer's accuracy (PA) for the "water" class – 75.0%, and user's accuracy (UA) – 85.7%. The obtained results confirm the reliability and reproducibility of the classification, providing a robust basis for further analysis of the spatial dynamics of water bodies and their climatic relationships (Gorelick et al., 2017; U.S. Geological Survey [USGS], 2022).

Thus, the proposed methodology integrates automated processing of multitemporal satellite data and statistical analysis of climatic factors, providing a comprehensive understanding of the spatio-temporal dynamics of water systems within the Semipalatinsk Test Site.

3. Results

3.1. Spatial distribution and long-term dynamics of water bodies

The Landsat and Sentinel-2 satellite composites (Figure 3) clearly reveal the spatial and temporal variations of water bodies within the Semipalatinsk Test Site over the period 1996–2024.

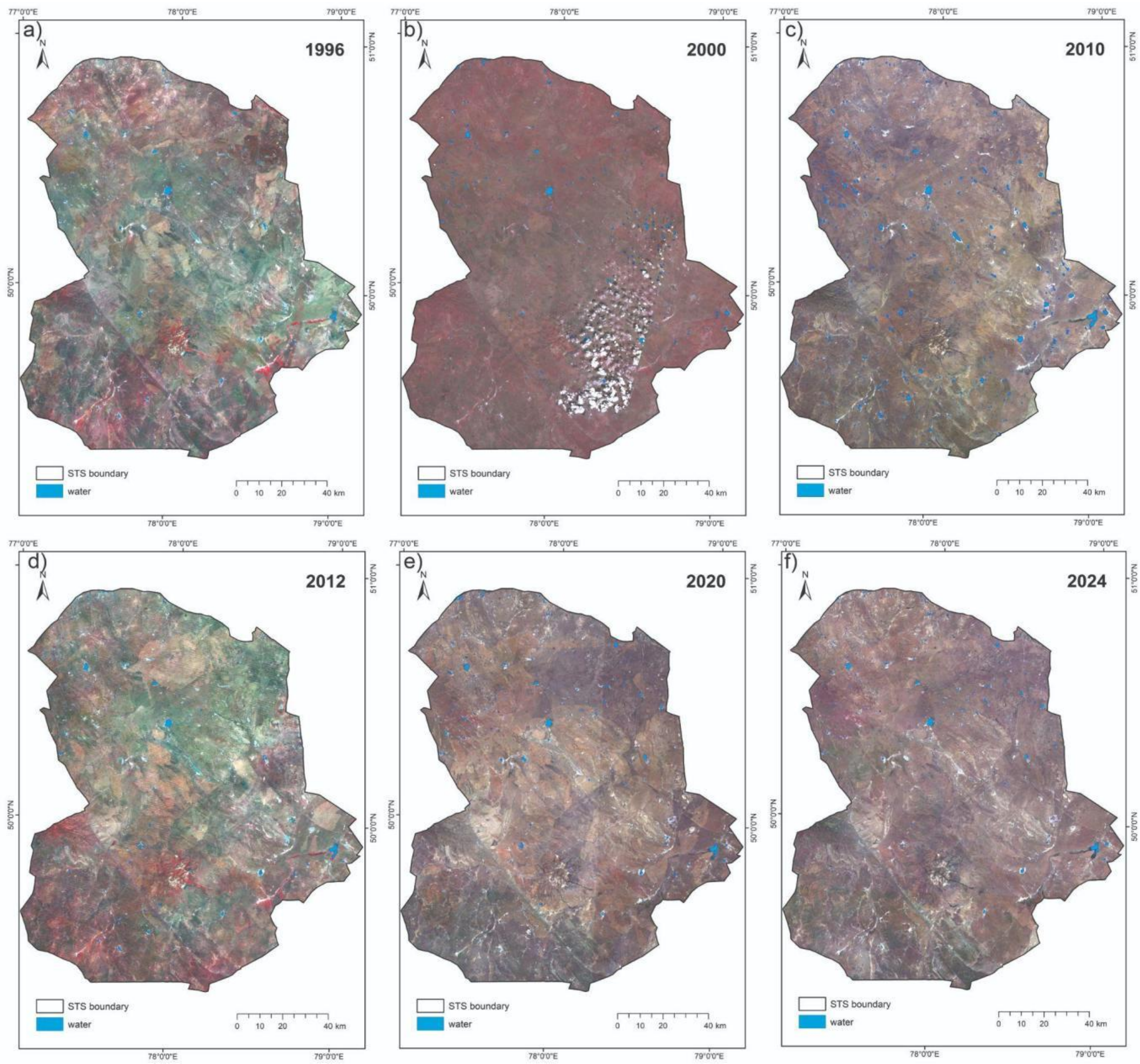

Figure 3. Spatial distribution of water bodies within the Semipalatinsk Test Site: (a) 1996; (b) 2000; (c) 2010; (d) 2012; (e) 2020; (f) 2024.

The water surfaces are mainly confined to the valleys of the Shagan and Ashchysu rivers, as well as to the closed depressions in the eastern and southeastern parts of the test site. In the early imagery (1996), water bodies were limited to small depressions, whereas by 2000 and 2010, a significant expansion of the water surface area was observed, particularly along the Shagan River channel and within the central lowlands. After 2010, a gradual reduction in the extent of water bodies was recorded, which is confirmed both visually and quantitatively.

According to Table 1, the total area of water surfaces varied from 4512.9 ha in 1996 to 14993.9 ha in 2010, accounting for 0.24% to 0.81% of the total area of the test site. The minimum values were recorded in 1996 and 2012, which corresponded to low-snow winters, while the maximum values occurred in 2000 and 2010. Thus, the amplitude of area fluctuations reached nearly a threefold difference, reflecting the extreme sensitivity of the hydrological regime to climatic variations during the winter–spring period.

Table 1. Water body areas within the Semipalatinsk Test Site area (1996-2024)

Year	Area of water bodies, ha	Share of territory, %
1996	4512.92	0.24
2000	7654.16	0.41
2010	14993.96	0.81
2012	4456.66	0.24
2020	6428.99	0.34
2024	5685.82	0.30

3.2. Spatial Structure Based on the MNDWI Index

The cartographic data derived from the MNDWI index (Figures 4 and 5) made it possible to visually assess the spatial changes in water surfaces within the test site and using Lake Ashchysu as an example.

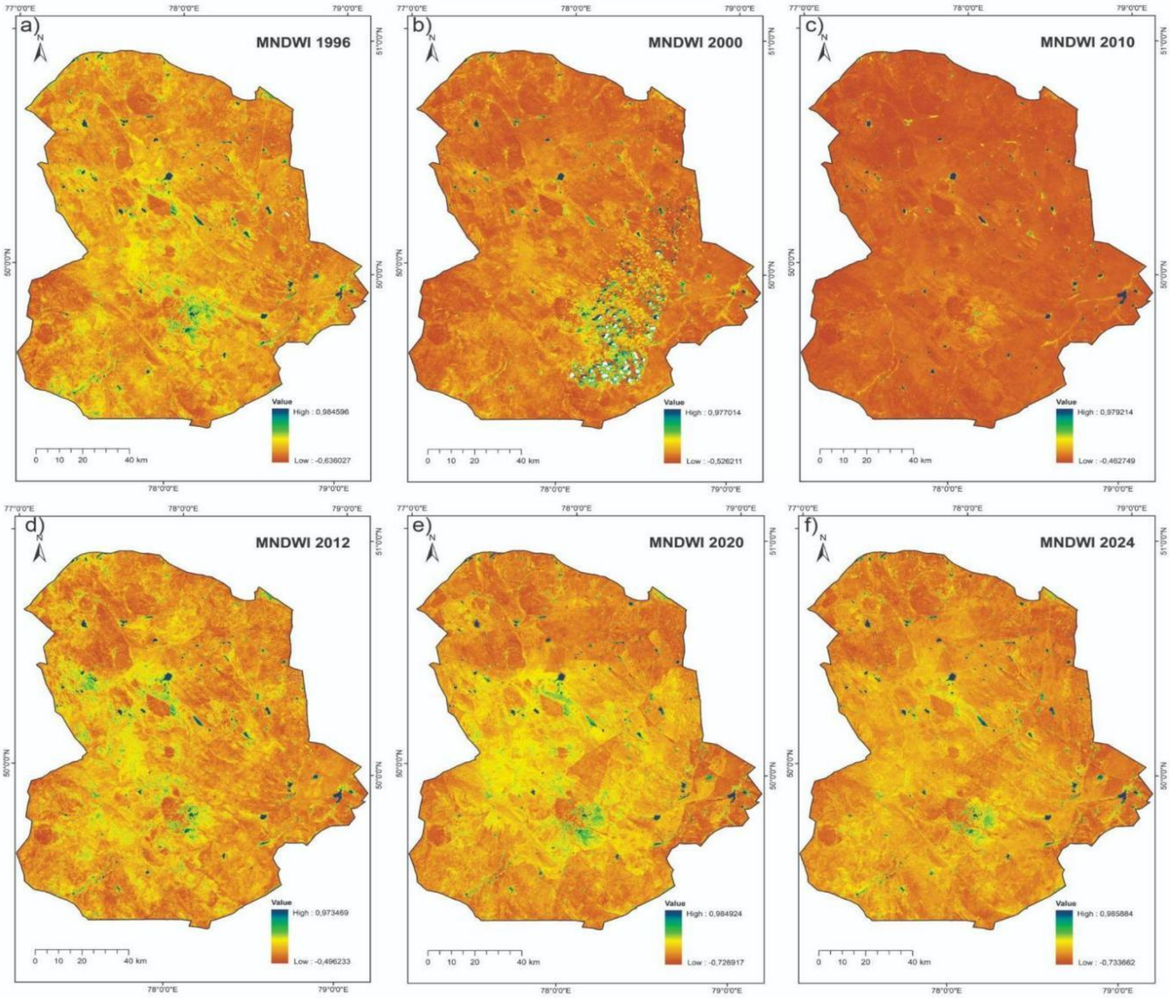

Figure 4. Spatial distribution of water bodies based on the MNDWI index: (a) 1996; (b) 2000; (c) 2010; (d) 2012; (e) 2020; (f) 2024

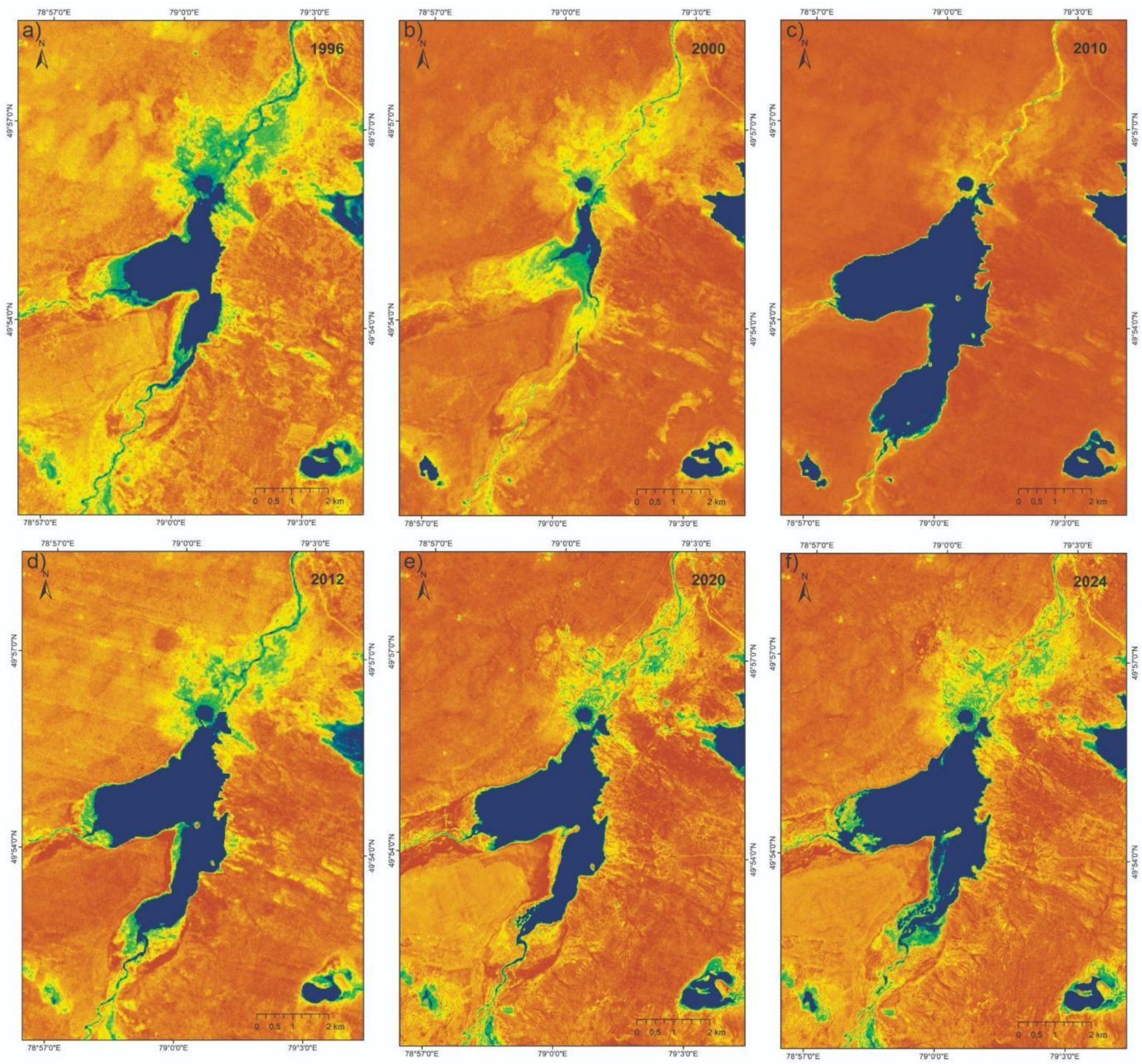

Figure 5. Dynamics of Lake Ashchysu surface area based on satellite data: (a) 1996; (b) 2000; (c) 2010; (d) 2012; (e) 2020; (f) 2024

On the MNDWI maps, zones of permanent and temporary water bodies are clearly distinguishable. The highest positive index values (above 0.3) are associated with the Shagan River valley, the depressions in the southeastern part of the test site, and the water area of Lake Ashchysu, where water persists throughout the entire vegetation period.

In the central part of the test site and in the interfluve areas, regions with moderate or negative MNDWI values are observed, corresponding to seasonal water bodies that fill during the spring flood and dry up in summer.

In 2000 and 2010, the most extensive distribution of water bodies was observed, particularly in the area of Lake Ashchysu, whereas in 2020–2024, the water surfaces became more fragmented and localized. This indicates a gradual reduction of temporary water bodies and an overall decline in the water availability of the territory over recent decades.

3.3. Interannual and Seasonal Variability

The graphs of interannual and seasonal dynamics (Figure 6) show that the area of water surfaces within the test site varies greatly from year to year. In spring, water bodies consistently occupy a significantly larger area than in summer or autumn, which is associated with the inflow of meltwater.

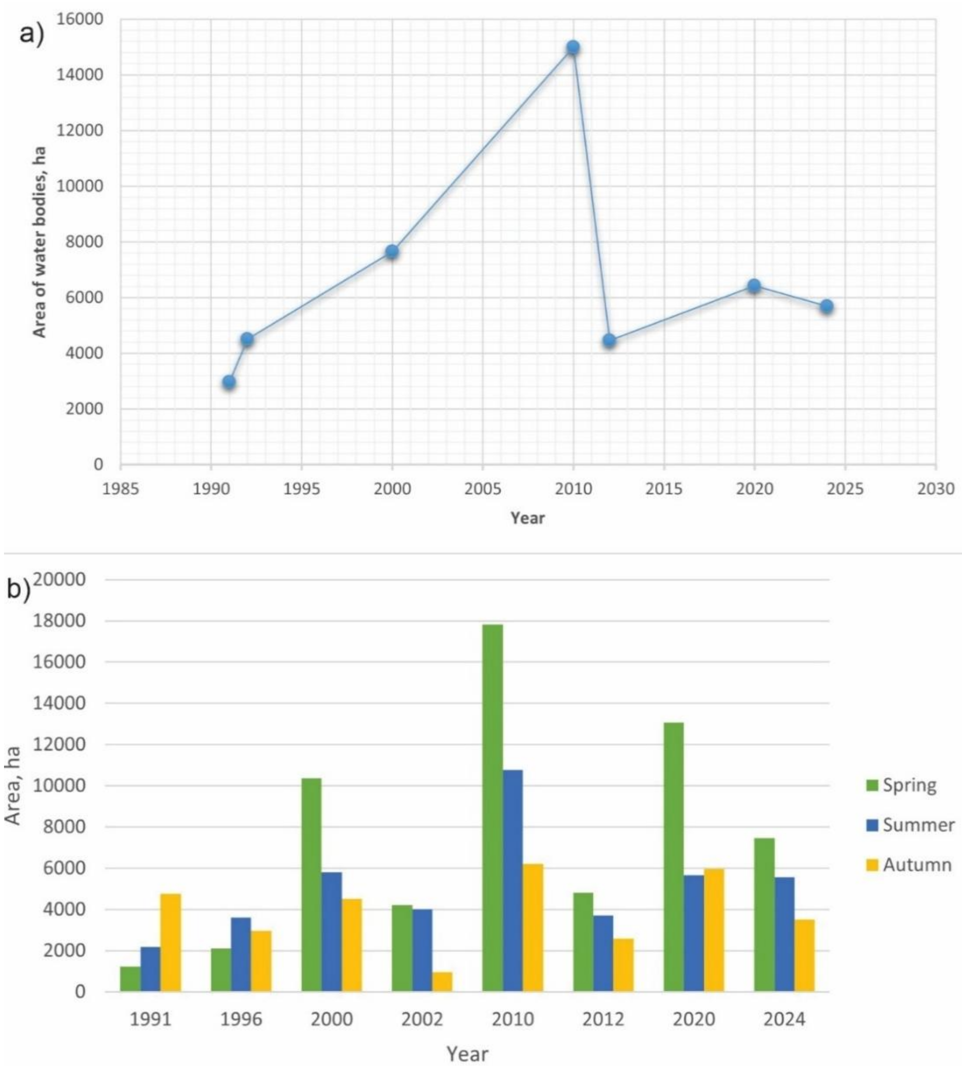

Figure 6. Changes in the surface water area within the Semipalatinsk Test Site: (a) interannual variability; (b) seasonal variability

According to Table 2, in the spring of 2010, the area of water bodies reached 17,826 ha, decreasing to 10774 ha in summer and 6202 ha in autumn. This indicates a typical spring maximum followed by a gradual reduction of water surface area throughout the summer. In dry years (1996 and 2012), the spring water area did not exceed 2–5 thousand hectares, reflecting weak floods and low snow accumulation during the winter.

In recent years (2020–2024), a trend toward faster drying of water bodies has been observed, with their areas starting to decrease as early as mid-summer. This is associated with an increase in mean air temperature and warmer winters, which cause earlier snowmelt and faster evaporation.

Since 2020, the region has shown a tendency toward an earlier peak in water availability and accelerated drying of temporary lakes by mid-summer. This corresponds to an increase in mean air temperature by 1.5–2 °C above the climatic norm, enhancing evaporation and shortening the duration of the water phase in small ponds and lakes. Such changes are particularly evident in the central part of the test site, where previously stable water bodies have gradually acquired a seasonal character.

Table 2. Seasonal dynamics of surface water area

Year	Spring, ha	Summer, ha	Autumn, ha
1996	2106.16	3605.7	2947.36
2000	10371.52	5813.7	4515.5
2002	4205.9	4020.11	949.8
2010	17826.13	10774.09	6202.42
2012	4810.16	3701.59	2582.64
2020	13072.35	5654.45	5966.43

3.4. Stability of Water Surfaces

The analysis of water surface stability (Figure 7) shows that temporary and seasonal water bodies prevail within the territory of the test site. Their share exceeds 60%, whereas permanent water bodies occupy about 30–35% of the total area (Table 3).

Table 3. Distribution of the water surface area by stability categories (1996-2024)

Category (Class)	Area, km^2	Area, ha	Share of Total Water, %	Share of territory, %
Permanent water	44.05	4405	31.91	0.24
Seasonal water	94.10	9410	68.09	0.51

The "River Network" layer data were taken from a previous study conducted by the authors. There are four large river basins located on the territory of the Semipalatinsk Test Site. These are the Saryozen river from south to north, Aschyozek and Karabulak from the center to the north, and Shagan from the south to the northeast. They are all left tributaries of the Irtysh River (Valeyev et al., 2025).

The total length of the talwegs of the rivers in the study area is 13874 km, with sixth-order watercourses accounting for about 361 km or 2% of the total length of temporary and permanent watercourses. The main length of 95% of the talwegs, considering the factors of arid climate and steppe landscapes, falls on temporary watercourses. In summer, they form a dry gully-beam network or inconspicuous depressions. They are formed mainly during floods due to meltwater flows, as well as during precipitation in the warm season (Valeyev et al., 2025).

Permanent water bodies are located in the valleys of the Shagan and Ashchysu rivers, as well as in the southeastern depressions where water persists for longer periods. Temporary and seasonal water bodies occur in the central and western parts of the test site and appear only in years with heavy snowfall. This distribution indicates that the region's hydrological system is highly dependent on weather conditions and exhibits an unstable character.

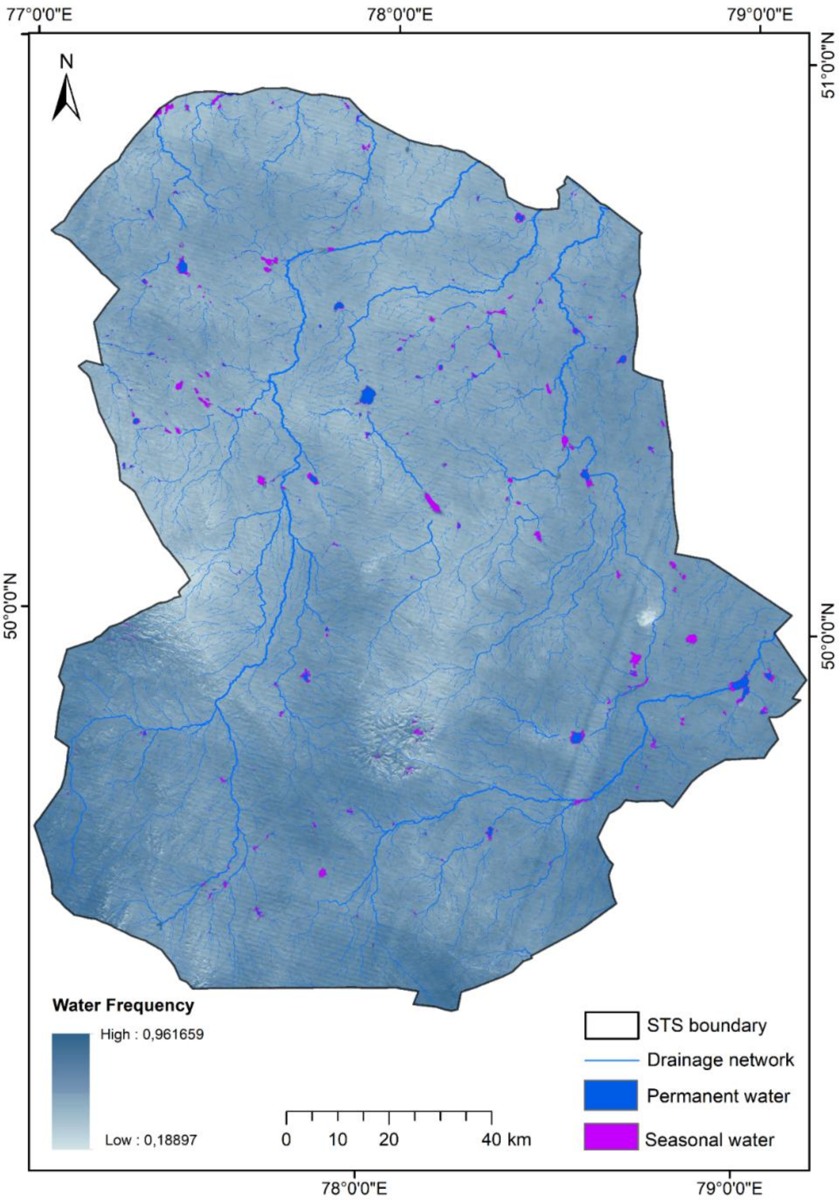

Figure 7. Surface water within the territory of the Semipalatinsk Test Site

3.5. Influence of Climatic Factors

Comparison of satellite data with ERA5-Land climatic indicators (Table 4) shows that interannual variations in the area of water bodies within the Semipalatinsk Test Site are directly related to winter season conditions - primarily to the amount of snowfall and air temperature.

In years with colder winters and higher snowfall, an expansion of water surfaces is observed, whereas warm and low-snow winters lead to a reduction in water area. For instance, in 1996, a moderately cold winter (-11 °C, 57 mm of precipitation) resulted in limited flooding and a minimum water surface area of about 4.5 thousand ha. In 2000, an increase in snow accumulation to 96 mm contributed to an expansion of the water area to 7.6 thousand ha.

The most pronounced hydrological anomaly was recorded in 2010, when the combination of the lowest air temperature (-13 °C) and record snowfall (106 mm) resulted in the maximum development of water surfaces-nearly 15 thousand ha. This situation highlights the role of the winter season as a key factor in shaping spring runoff and floodwater recharge of water bodies.

Table 4. Water Area Dynamics and Climatic Control (1996-2024)

Year	Area of water bodies, ha	Share of territory, %	Mean Winter T, Nov–Mar, ^{0}C	Snowfall, Winter, mm
1996	4512.92	0.24	-11	57.0
2000	7654.16	0.41	-10	96.0
2010	14993.96	0.81	-13	106.0
2012	4456.66	0.24	-13	65.0
2020	6428.99	0.34	-7	83.0
2024	5685.82	0.30	-6	52.0

In 2012, despite similarly low air temperatures (-13 °C), a decrease in snowfall to 65 mm led to a reduction in the water surface area to about 4.5 thousand ha. In recent years (2020 and 2024), with warmer winters (-7 °C and -6 °C) and precipitation deficits (83 mm and 52 mm), earlier snowmelt and increased evaporation have been observed, limiting the water surface area to 6.4 thousand ha and 5.7 thousand ha, respectively.

4. Discussion

The results of the analysis confirm that the hydrological regime of the region is determined by winter climatic conditions rather than by the amount of summer precipitation. The volume and persistence of water bodies depend on the accumulation and preservation of the snow cover, which forms the main spring runoff. The peak water surface areas recorded in 2000 and 2010 correspond to periods of lower air temperatures and heavy snowfall, confirming the key role of winter moisture accumulation in shaping spring flow. In contrast, years with warm and low-snow winters (1996, 2012, 2024) are characterized by a sharp reduction in the extent of water bodies, reflecting the high sensitivity of local ecosystems to climatic fluctuations. Thus, long-term variations in temperature and snow reserves act as the primary drivers of the spatio-temporal variability of water systems within the Semipalatinsk Test Site.

Comparison of satellite observations with ERA5-Land reanalysis data revealed a clear negative correlation between mean winter air temperature and the area of water surfaces. At the same time, the amount of summer precipitation has a much weaker influence on the dynamics of water bodies, which is consistent with the sharply continental climate of the region. In this climate, the main recharge of water systems is formed by snowmelt, and the stability of water bodies is primarily determined by the snow balance of the winter season.

In addition to climatic factors, anthropogenic and technogenic impacts also play an important role. The territory of the Semipalatinsk Test Site, which was subjected to long-term nuclear and engineering activities, is characterized by a disturbed structure of soil–hydrological systems, altered permeability, and redistribution of surface runoff. This partly explains the spatial fragmentation of water surfaces, particularly in the central and western parts of the test site, where the highest instability of temporary water bodies is observed. Furthermore, the degradation of irrigation systems previously used for agricultural purposes has weakened the connection between surface and groundwater, reinforcing the seasonal nature of water bodies.

Comparison of the obtained data with the results of similar studies (Pekel et al., 2016; Ji et al., 2009) shows that the identified trends of decreasing water surface area and increasing seasonality correspond to global climatic patterns observed in the arid regions of Central Asia. However, the uniqueness of the Semipalatinsk Test Site lies in the combination of natural and technogenic factors, which makes this territory a model area for assessing the consequences of climatic and anthropogenic changes.

5. Conclusion

The analysis of spatio-temporal changes in water bodies within the Semipalatinsk Test Site for the period 1996-2024 revealed a pronounced climatic dependence of the region's hydrological regime. The main factors determining the extent and persistence of water bodies are winter conditions – air temperature and snowfall amount. The largest surface water areas were observed in years with cold and snowy winters (2000 and 2010), whereas the smallest areas occurred during warm and low-snow periods (1996, 2012, and 2024).

Spatial analysis showed that permanent water bodies are concentrated in the valleys of the Shagan and Ashchysu rivers, while temporary and seasonal ones are mainly distributed in the central and western parts of the test site. The share of temporary water bodies exceeds 60%, reflecting the instability of the hydrological regime and its high dependence on climatic fluctuations.

The use of the Google Earth Engine platform and the MNDWI index made it possible to effectively assess spatio-temporal changes, classify water body types, and establish their relationship with climatic parameters. The methodology demonstrated high reliability with an overall accuracy of 94% and can be applied for the monitoring of similar arid territories in Kazakhstan and Central Asia.

The obtained results have practical value for environmental monitoring, landscape planning, and the assessment of climate change impacts on the degraded lands of the former test site. Future research should focus on the integration of optical and radar sensor data, the application of machine learning models for automated classification, and the development of predictive models of water resource dynamics under global warming conditions.

6. Supplementary Materials: No supplementary materials.

7. Author Contributions

Conceptualization - A.A.; methodology - O.T.; software – O.T., N.Zh.; data collection – A.A., K.T.; data analysis – O.T., N.Zh., A.A.; writing - original draft preparation – N.Zh., O.T., A.A.; writing - review and editing – A.A., K.T.; project administration - A.A. All authors have read and agreed to the published version of the manuscript.

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Семей полигоны аумағындағы жер беті суларының кеңістіктік-уақыттық өзгерістерін Google Earth Engine платформасы негізінде талдау

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Аңдатпа. Мақалада Семей сынақ полигоны аумағындағы су нысандарының кеңістіктік және уақыттық өзгерістерінің динамикасы талданған. Зерттеу барысында жерді қашықтықтан зондтау деректері негізінде Google Earth Engine платформасы қолданылып, ландшафттық жоспарлау кезінде жерүсті сулар мен ирригациялық жүйелер картасын құрастыру мақсат етілді. Бастапқы деректер ретінде Landsat және Sentinel-2 ғарыштық суреттері, ERA5-Land климаттық деректері және SRTM сандық бедер моделі пайдаланылды. Су айдындарын анықтау үшін модификацияланған нормаланған су индексі (MNDWI) әдісі қолданылды. Нәтижелерге сәйкес, су бетінің ең үлкен аудандары суық әрі қарлы қыстарда (2000, 2010 жж.) байқалды, ал ең аз көрсеткіштер жылы әрі қар аз түскен кезеңдерде (1996, 2012, 2024 жж.) тіркелді. Уақытша су айдындарының үлесі 60%-дан асады, бұл гидрологиялық режимнің тұрақсыздығын және климаттық ауытқуларға жоғары тәуелділігін көрсетеді. Google Earth Engine сияқты заманауи платформаларды пайдалану су нысандарының кеңістіктік-уақыттық өзгерістерін анықтауда тиімділігін және су ресурстарын басқаруда зор әлеуетін көрсетті. Алынған нәтижелер экологиялық мониторинг пен ландшафттық жоспарлау жұмыстарында, сондай-ақ бұрынғы полигон аумақтарын ауыл шаруашылығына игеру кезінде пайдаланылуы мүмкін.

Түйін сөздер: су нысандары; Google Earth Engine; ЖҚЗ деректері; Семей сынақ полигоны (ССП).

Анализ пространственно-временных изменений поверхностных вод в пределах Семипалатинского полигона на основе платформы Google Earth Engine

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Аннотация: Статья посвящена анализу динамики пространственно-временных изменений водных объектов на территории Семипалатинского полигона с применением данных дистанционного зондирования Земли на основе платформы Google Earth Engine для дальнейшего составления карты поверхностных вод и ирригационных систем при ландшафтном планировании территорий. В качестве исходных данных применялись спутниковые снимки Landsat и Sentinel-2 и климатические данные ERA5-Land и цифровой модели рельефа SRTM. Выделение водных поверхностей осуществлялось с применением метода модифицированного нормализованного водного индекса (MNDWI). Результаты показали, что наибольшие площади водных поверхностей наблюдались в годы с холодными и снежными зимами (2000, 2010 гг.), а минимальные – в тёплые и малоснежные периоды (1996, 2012, 2024 гг.), и доля временных водоёмов превышает 60%, что отражает нестабильность гидрологического режима и высокую зависимость от климатических колебаний. Применение современных платформ, как Google Earth Engine для определения пространственно-временных изменений водных объектов показал свою эффективность и огромный потенциал в управлении водными ресурсами при оценке их динамики. Полученные результаты могут использоваться для экологического мониторинга и ландшафтного планирования при освоении территорий бывшего полигона для ведения сельского хозяйства.

Ключевые слова: водные объекты; Google Earth Engine; данные ДЗЗ; СИП.