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Evaluation of changes in ecological conditions of wetlands in the Teniz-Korgalzhin depression (Kazakhstan)

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The article presents the results of a study of the long-term dynamics of the state of ecosystems of the Teniz-Korgalzhyn depression, carried out using data from the Earth remote sensing (ERS). Based on the analysis of space images, the formation factors of modern environmental conditions are established. In the study area, such factors are positional and barrier factors, as well as the confinement of individual surface sections to different-height layers of the Earth's surface. An analysis of the Landsat series of space images taken at different time, made it possible to establish spatial differences in the intensity of phytomass accumulation in areas located in different landscape locations. The spatio-temporal variability of the ecological conditions of the Teniz-Korgalzhin depression wetlands is accompanied by a change in the amount of food supply and the number of living organisms. Monitoring of these changes on the basis of Earth remote sensing data will allow to prove measures to preserve the biodiversity of the Teniz-Korgalzhin depression wetlands timely.

Keywords: Ecosystems; Wetlands; Teniz-Korgalzhin depression; The earth remote sensing

Introduction

The ecological conditions of the wetlands of Teniz - Korgalzhin depression are favorable for the habitat of many species of birds, including, listed in the Red Book of Kazakhstan - curly pelican (Pelecanus crispus), small (Egretta garzetta) and great white (Egretta alba), grey heron (Ardea cinerea) and others. This is one of the northernmost habitats of the Pink Flamingo (Phoenicopterus roseus). Antelope (Saiga tatarica) and many other typical steppe animals inhabit the steppe ecosystems. To preserve the animal population of this territory, the Korgalzhinsky State Reserve was established in 1968, which since 1974 has been included in the Ramsar list of wetlands of international importance. The wetlands of the Teniz-Korgalzhin depression are valuable ecosystems, as they are of great importance to keep the biological diversity and water balance of the landscapes of the Korgalzhin depression. In 2008, the territory became part of the UNESCO World Heritage Saryarka - Steppes and Lakes of Northern Kazakhstan. The core of this territory is Teniz Lake, into which the rivers Nura, Kulanutpes, Kon and others flow. Their level, as well as other water bodies of arid zones, is subject to significant seasonal and long-term fluctuations, which inevitably affects the changing living conditions of the animal population of the territory. Organization of monitoring the environmental conditions of the Teniz - Korgalzhin depression is important for developing a strategy for the conservation of its biodiversity. The authors of the article set the task to explore the possibilities of assessing the variability of the ecological conditions of the territory based on the data of the Earth remote sensing (ERS).

Material and Methods

We selected the sites located in different landscape conditions: in the basin of Teniz Lake, in Nura River basin, and near the Muzbel hill. At the initial stage of the work, field observations were carried out (Project ..., 2008). Earth Remote sensing was used as the most important source of information, because based on the analysis of time series of space images, according to Yu. F. Knizhnikov and V. I. Kravtsova (1991) you can obtain information on the dynamics of objects. The choice of a series of images for solving the tasks was determined by the spectral properties of the images, their spatial and temporal coverage, resolution and free access to the database. At the next stage, the automated interpretation of Landsat images (resolution 15-30 m), compiling and analysis of land cover maps, and removal of metric characteristics from them were carried out.

Teniz - Korgalzhin depression is located in the peripheral part of the Kazakh small hills and is functionally interconnected with it. This circumstance influenced the choice of model sites for a detailed analysis of remote sensing data. As criteria for the selection of keys - geographical location, absolute height above sea level, the presence of aquatic systems was applied. One of the model plots is located in the basin of Teniz Lake, which is the largest body of water in the study area and represents the main habitat of the Pink Flamingo (Phoenicopterus roseus) and many representatives of waterfowl. The second key site is located in the Nura River basin and includes watershed surfaces, slopes of the valley and the floodplain of this river. The third key site is located in barrier conditions (Maksyutov, 1981) in the Muzbel highlands (spurs of the Kazakh small hills). Such a selection of key sites allows the study to cover the maximum diversity of ecosystems and ensures representativeness of selection with continuous research within the “keys” themselves. In the process of automated decoding of Landsat images in the study area, differences were found in the quantitative indicators of vegetation indices for different types of covers: the water surface of lakes and ponds; swamps; swampy meadows; fescue-feather grass steppes; thickened wormwood and grass steppes and surfaces devoid of vegetation.

To determine the structural changes within the selected keys, a detailed analysis of the calculated indices of soil and vegetation indexes obtained on the basis of multizone space imagery from 1975 to 2018 was carried out. The calculation of the vegetation indices PVI and TVI made it possible to clarify the location and condition of groundwater, which in the conditions of the continental sector of Eurasia determines the potential for the formation of phytomass. In the process of thematic processing of images, calculations of the NDVI (Normalized Difference Vegetation Index) indices with the construction of index maps for the entire study area were used. These indicators characterize the moisture content in the soil and the amount of photosynthetically active biomass on the earth's surface. To calculate the indices, the spectral brightness values in the green (Green) and near infrared (NIR) spectral ranges were used:

$$NDWI=(Green-NIR)/(Green+NIR)$$

where Green–reflection in green area, NI –reflection in the near infrared area of the spectrum.

For its calculation, the values of spectral brightness in the red and near infrared ranges of the spectrum are used:
NDVI=(NIR-Red) /(NIR+Red), where NIR is the reflection in the near infrared region, Red is the reflection in the red area of the spectrum. Further, a classification of images by remote sensing data was developed (Linke et al., 2009) of several time slices. This algorithm included marking all the pixels in the image in the characteristics of the vegetation and soil cover for each time slice (Figures 1-3).

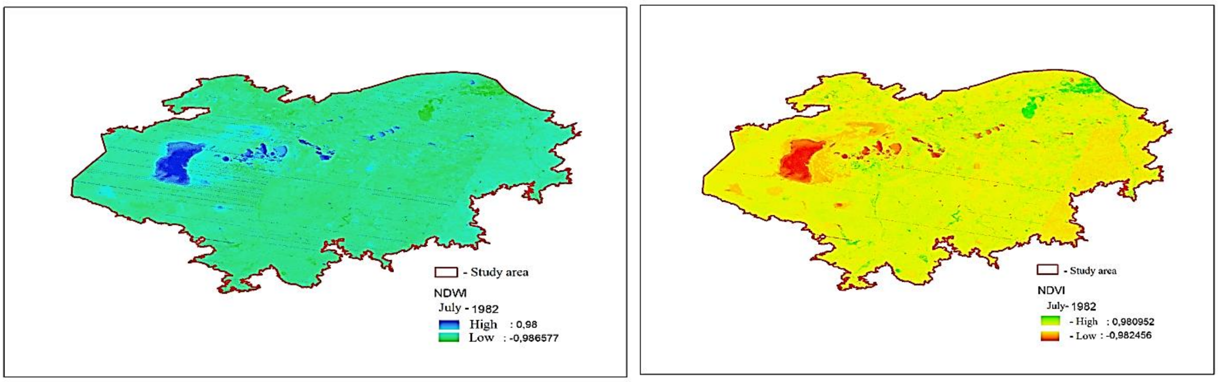

Figure 1. Soil moisture and vegetation intensity for the vegetation period of 1982, calculated by NDVI values.

Figure 1 illustrates the state of the ecosystems of the study area at the end of the period from 1940 to 1982, when the study showed an increase in summer air temperatures and a natural decrease in lake levels in the Teniz - Korgalzhin depression. Figure 2 shows a growth trend in the general wetting of the territory, perhaps this is partly due to the creation between 1986 and 1998 on the rivers flowing along the hollow of cascades of artificial ponds. On the one hand, this provoked additional moisture loss due to evaporation, on the other hand, an increase in moisture in the barrier conditions of the Kazakh Shoal.

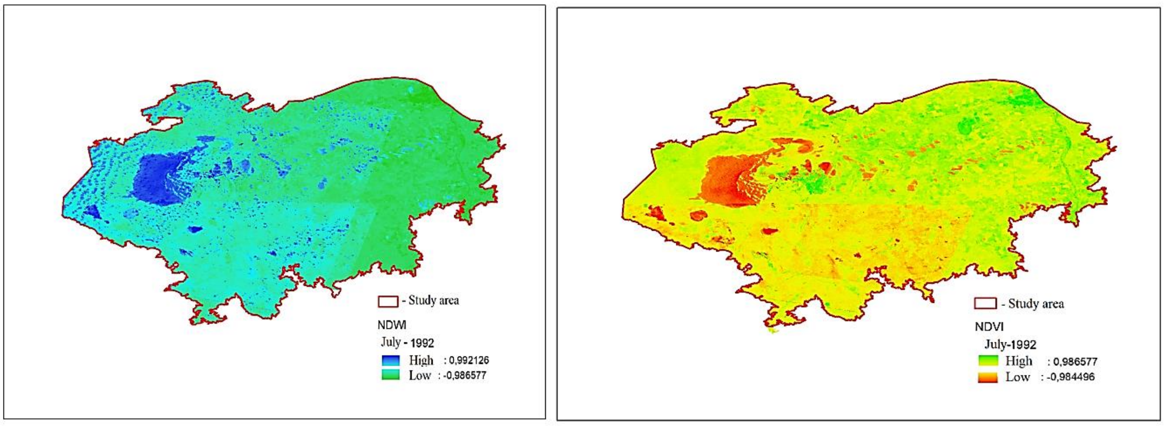

Figure 2. Soil moisture and vegetation intensity for the 1992 growing season, calculated from NDVI values.

Figure 3 demonstrates the increase in moisture in the ecosystems of the bottom of the Teniz – Korgalzhin depression and in the barrier conditions of the Kazakh Shoal and its decrease on elevated watershed surfaces, which may indicate the beginning of a new climate cycle similar to the period 1940-1982.
After obtaining the cartographic basis for the analysis of the spatiotemporal variability of vegetation index values, other landscape metrics were also studied (O'Neil et al., 1988; Li & Wu., 2004), which are traditionally divided into two groups - metrics of composition and metrics of sizes and shapes (configuration) (Li & Reynolds, 1993) (Table 1).
The table shows that against the background of a general increase in the moisture content of the territory from 1982 to 2018, against the background of an increase in the general moisture content of the ecosystems of the study area, there was a reduction in the area of existing lakes and wetlands and the emergence of new, but smaller new objects. This allows us to conclude that moisture is redistributed within the Teniz - Korgalzhin system - slopes of the Kazakh Shoal.

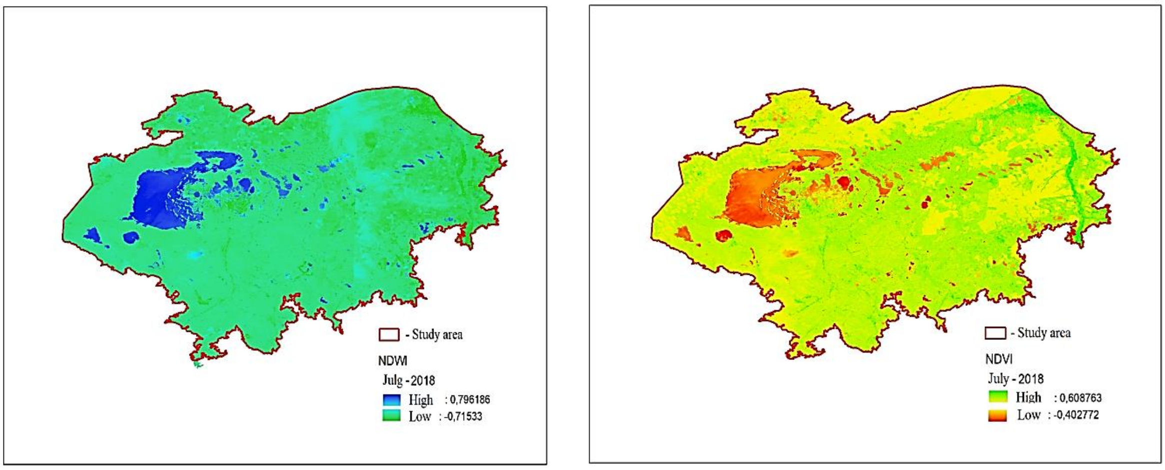

Figure 3. Soil moisture and vegetation intensity for the vegetation period of 2018, calculated by NDVI values.

Table 1. Characteristics of wetland ecosystems in Teniz-Korgalzhin depression.

Soil cover	**1982 Area, (%)**	**Number of habitats**	**Square, km²**	**2005 Area, (%)**	**Number of habitats**	**Square, km²**	**2018 Area, (%)**	**Number of habitats**	**Square, km²**
Lakes and ponds	1.43	22	0.23	1.23	20	0.23	1.33	25	20
Water meadows, swamps, and wetlands	8.75	655	0.05	7.39	469	0.06	6.07	808	0.03

Results

At the stage of interpretation of Earth remote sensing data, it was required to establish the consistency of spatiotemporal variability of the values of vegetation indices. The landscape approach made it possible to use the potential of fundamental natural sciences, including landscape science, to establish such consistencies. In all periods of observation, the maximum values of the indices were observed under hydromorphic and semi-hydromorphic conditions, which is associated with the occurrence of a groundwater level close to the surface. Such sites, as a rule, are confined to the valleys of small rivers and streams with well-developed bottoms covered with mixed grass and sedge-grass meadows on meadow and marsh-meadow alluvial soils and low lake terraces with grass-mixed shrub and sedge-grass swampy meadows on meadow-bog and primitive-layered soils. Semi-hydromorphic habitats also correspond to flat lowland areas with relatively close occurrence of groundwater, the periodic rise of which (usually in spring) creates additional ground moisture, but these ground waters are highly mineralized. Under such environmental conditions, the halophytic-semi-shrubby communities will formed on meadow-steppe alkali (desert and desert-steppe complexes with a predominance of kokpechnic vegetation) and shrubbery on meadow-chestnut soils. Semi-hydromorphic habitats include depressions and depressions on watersheds, which are moistened due to accumulation of snow in the winter and rainfall in the summer. The sections of meadow steppes are confined to them. Hydromorphic habitats, which are inhabited by waterfowl and near-water birds, during all periods of observation, were characterized by the highest values of vegetation indices, except for coastal shallows deprived of vegetation cover. In conditions of intensive evaporation under hydromorphic conditions, juicy-solyanky communities form on meadow alkali and tree-shrub communities on meadow soils or swamps and meadows on swamp and meadow-swamp soils. The automorphic watershed surfaces used for arable land or occupied by wormwood and thyrs plant groups and with xerophyte-forbs-fescue-feather grass steppes on chestnut and dark chestnut soils are least moistened.

The use of remote sensing allowed not only to subdivide accurately the terrestrial ecosystems of the study area into automorphic, semihydromorphic and hydromorphic, but also to trace the functional relationship between the ecosystems of Teniz - Korgalzhin depression and the Kazakh Shoal. An analysis of a series of space images of different times allowed us to establish that in automorphic locations the greatest amount of phytomass is formed under the barrier conditions of the Kazakh Shoal, which is incomplete, according to the classification of F.A. Maksyutova (1981), a barrier when the air masses that he detained moisturize the windward slopes, overwhelm the advanced hills and give moisture also to the upper part of the leeward slope. Minimum humidification values were observed within the watershed surfaces of interfluves beyond the influence of shallow barriers. The influence of the barrier effect created by the Kazakh small hills determines the unique environmental conditions and the redistribution of moisture in different periods of the climatic cycle. The anticipation of the air masses accumulating in front of the Kazakh Shoal barrier begins at a distance of about 100 km to it; as a result, an increase in precipitation occurs on the vast area of the Teniz-Korgalzhin depression adjacent to this upwind from the windward side.

Conclusion

Modern methods and software tools have made it possible to analyze the spatial changes in ecosystem productivity, depending on the depth of groundwater and the exposure of the slopes. Based on their application, it was found that the greatest amount of phytomass is formed in the barrier conditions of the Kazakh Shoal and in lowlands confined to lake basins, the minimum - within the watershed surfaces of interfluves. The barrier effect of the Kazakh Shoal is manifested to varying degrees throughout the territory of the Teniz-Korgalzhyn depression. The analysis of factors (zonal-sector-altitude position of individual sections and barriers) operating in the study area made it possible to interpret remote sensing data most accurately to assess changes in the environmental conditions of the Teniz-Korgalzhin depression wetlands. The use of remote sensing data allows using modern hightech methods for the analysis and interpretation of evidence, which expands the possibilities of monitoring studies of spatiotemporal changes in the environmental conditions of the territory and assessing the risks of reducing its biodiversity.

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