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PHYSICAL GEOGRAPHY

Coastal processes

**TRANSFORMATION AND DYNAMICS
OF STRUCTURAL-GENETIC FEATURES
OF THE LANDSCAPES OF THE CASPIAN COAST
PLAINS (ON THE EXAMPLE OF THE SALYAN,
SOUTH-EAST SHIRVAN AND LANKARAN PLAINS)**

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Abstract

The study is centred on a comparative analysis of the distribution areas and structural-genetic features of the landscapes of the coastal plains over the period of the last transgressions and regressions of the Caspian Sea level, which makes it possible to predict the process of transformation of geosystems in the future, depending on further changes in sea level. Global climate change, especially climate warming, has accelerated the sharp decline in the level of the Caspian Sea in recent years. In the course of the study, the main factors influencing the dynamics and functioning of natural processes and the development of landscapes of the coastal territory were identified: 1. sea level fluctuations; 2. neotectonic processes; 3. anthropogenic transformations. Depending on the degree of influence of the Caspian Sea, the following groups of landscapes are distinguished: 1. fundamentally changed; 2. landscapes subject to different levels of flooding. The following main typical flooded landscapes were studied: strongly, moderately, and slightly flooded landscapes.

Key words: dynamics, transformation, sea level changes, semi-desert landscape, meadow-marsh landscapes, long-term precipitation dynamics, coastlines, humid and arid climatic periods

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Introduction. During the years changes in the level of the Caspian Sea, fundamentally influenced the structural, genetic, and functional features of the development of natural and anthropogenic coastal ecosystems. Over the past 45 years (1977–2022), two significant stages have been observed in Caspian sea-level fluctuations: the first is the rising of the level (1977–1995); the second is the retreating of the level of the sea (from 1995 to the present day). Many years of field research, the study of fund materials, as well as the analysis of satellite images of different periods, made it possible to compare the processes of landscape transformation taking place on the coastal plains, which occur sequentially during periods of rise and decrease in the level of the Caspian Sea. This kind of research makes it possible to predict the process of transformation of geosystems depending on the change in the level of the Caspian Sea.

Recently, global change, mainly climate warming, has accelerated a sharp decline in the level of the Caspian Sea (over the past 27 years – by more than 2 m). Today, in the studied coastal plains, there is a shortage of fresh water [10]. In addition, exacerbation of extreme landscape changes is expected under the influence of global climate change [1, 5, 11, 12].

Materials and methods. The object of the comparative landscape analysis was the anthropogenic landscapes of the South-Eastern, Shirvan, Salyan, and Lankaran plains located on the coast of the Azerbaijani part of the Caspian Sea. The study area is located between 39°52'32" and 38°23'46" north latitude. The main landscape types here replace each other in the north from semi-desert and dry steppe to meadow forest in the south. On this territory, there are national parks with virgin nature (Shirvan and Gyzytagadzh national parks), as well as landscapes subject to dense rural settlement and the development of industrial and technogenic systems.

The scientific materials and statistical data on the levels of the Caspian Sea used in the work cover the entire period of instrumental observations from 1837 to 2022 [2]. In this research, special attention was paid to the last two periods. During these periods, changes occurring in coastal ecosystems were studied on the basis of fund materials, literary sources [3, 7, 10], as well as field research over the past 20 years.

Dynamic changes in the coastal ecosystems were studied using multi-spectral satellite images Landsat 5 and Landsat 8. Climatic instrumental observations have been carried out for a long time (from 1878 to the present day) from the Lankaran meteorological station. Due to the lack of indications of the amount of precipitation for some years, the average long-term indications of the amount of precipitation were established by the comparison method [6]. The method of the index of annual radial growth of wood [4] was used to study the relationship between climate change and the productivity of forest ecosystems. For choosing a model tree, the optimal role of atmospheric precipitation during its growth was clarified.

Results and discussion. As a result of the analysis of the long-term and current dynamics of the development of natural processes, the study of their direction, intensity, as well as the features of the functioning of landscapes of the coastal territory of the Caspian Sea, the following groups of main factors that determine landscape transformation can be distinguished: 1. fluctuations in the level of the Caspian Sea, global climate change, river water content, the intensity of hydromorphization or aridification of landscapes; 2. neotectonic processes; 3. anthropogenization of natural landscapes.



Fig. 1. Interannual changes in the level of the Caspian Sea since the beginning of instrumental measurements at the post in Baku [2]

One of the main natural sources of influence on the dynamics and transformation of coastal lowland landscapes is changes in the level of the Caspian Sea (Fig. 1). When analyzing graphs reflecting fluctuations in the level of the Caspian Sea (from 1977 to the present day), two periods are clearly distinguished: the first 1977–1995, the period of increase; the second – from 1995 to the present day – a period of decline. If fluctuations in the level of the Caspian Sea were directly related to climate change, then the level should have corresponded to the latest global and regional climate changes. However, the sharp rise and fall of the level within the limits of 1977–2022 suggests that other factors also affect the sea level. In our opinion, it is necessary to take into account the tectonic factor in this case. A comparative study of the transformation and dynamics of the landscape-ecological conditions of the Caspian plains was carried out on the basis of data from both periods.

In the period 1977–1995, the rise in the level of the Caspian Sea led to a rise in the level of groundwater and, in general, a complex change in the landscape

and ecological situation in the natural-territorial complexes. By 1995 the sea level had risen by more than 2.0 m. In this regard, over the previous 20 years, the direction and formation of landscapes have changed fundamentally.

The period of the rise in the level of the Caspian Sea affected the surrounding geosystems in different ways. First of all, narrow coastal geosystems remained underwater and switched to the underwater mode of development. The rise in the level of the Caspian Sea was manifested most often in the flooding of low coasts and the development of a number of processes associated with the groundwater and raising their level. This caused flooding, where in order to determine this phenomenon, it is necessary to select: firstly, the object of the flooding; secondly, the reasons for the rise in the level of groundwater, which is not included in the definition of flooding itself [8]. From this, it follows that the flooding of any object is that this object, which was above the groundwater level as a result of the rise of the latter, is completely or partially in an environment flooded with groundwater [9].

On the Caspian coast of the Kura-Araz and Lankaran lowlands, residential and natural landscapes, and other technical systems performed as such objects of flooding. With regard to agricultural landscapes, it makes sense to speak of a flood zone in which groundwater comes close to the surface, being at a depth of 0–3.0 m.

Within the Salyan, South-East Shirvan and Lankaran plains were divided into the following types of landscapes according to the degree of change under the influence of the Caspian Sea: 1. fundamentally changed; 2. landscapes subject to different levels of flooding.

The first type of the geosystem covers the narrow coastal strips of the studied plains. The hydromorphic landscapes located here are gradually replaced by a semi-desert type of landscape, which mainly covers the coast of the Caspian Sea, and in the territory of the Salyan and Neftchala districts, its borders gradually stretch to the central part of the lowland from the northwest to the southeast. The width of the territory of this landscape varies depending on the geomorphological structure of the coasts.

We have compiled graphs of changes in annual precipitation values for the long-term period 1870–2020, using data from weather stations in the study area (Lankaran), as well as data obtained from annual tree rings (Fig. 2). Analysis of the graph shows that there is a certain relationship between the dynamics of perennial precipitation and the growth rings of the model tree. However, the correlation of these indicators with fluctuations in the level of the Caspian Sea is rather weak. This is due to the multi-parameter fluctuations in the Caspian Sea level.

Despite the annual deviations of atmospheric precipitation values from the norm, in the long-term course, one can trace a tendency towards their decrease, especially after 1990. The decline in productivity and the weakening of natural

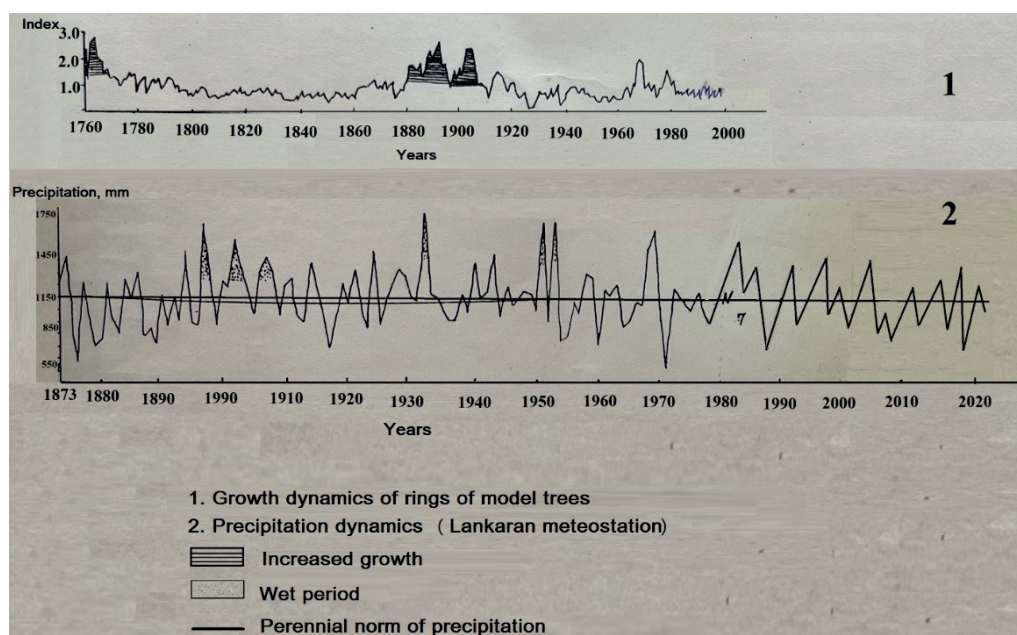


Fig. 2. Dynamics of growth of annual rings of model trees and atmospheric precipitation

reforestation processes in the forests of the Lankaran lowland is explained not only by a decrease in the amount of atmospheric precipitation but also by a change in the nature of the underlying surface as a result of cutting down lowland forests, eliminating old artificial reservoirs, draining swamps, reducing water area and increasing land area (until 1977).

Semi-desert landscapes are represented mainly on slightly dissected and sloping plains, in local depressions, and sandy ridges. These relief forms determine the typological and morphological differentiation of natural landscapes. In the area between the mouths of Boradigah and Viravulchay rivers in the coastal strip, due to the greatest terracing, a wavy-stepped relief was formed.

Due to the rise in the level of the Caspian Sea, the aquatic landscape from 200–300 m on the southern coast to 2000–2500 m in the northern part of the coast has moved inland. Even in the area of Gyzylagaj Bay, 4–5 km of the coastline moved inland, where the former coastline was formed. According to our calculations, during this period, 80–100 km² of the semi-desert landscape was flooded by sea waters.

The following main typical flooded territories were distinguished on the studied plain: a) landscapes subjected to severe flooding; b) landscapes subjected to moderate flooding; c) landscapes subjected to weak flooding. Within landscapes subjected to severe flooding, the groundwater level was close to the surface and amounted to 0–0.5 m. This zone mainly covered the narrow modern coastal strips confined to the modern marine accumulative plain. Swamp-lagoon and swamp

complexes were formed here, which completely transformed the anthropogenic covers of the landscape. The width of the landscape zone of strong flooding on the Lankaran coast was 100–200 m, in the Neftchala region 500–2000 m, and in the Gyzylagaj region, part of the coast reached about 4–6 km from the newly formed shores.

On the Salyan and Lankaran plains, landscapes of medium flooding mainly covered coastal meadows, ephemeral-saltwort, and inter-ridge depressions with saltwort-ephemeral and partially primal-meadow landscapes. Here the groundwater level was at a depth of 0.5 m to 1.5 m. The technogenic and agricultural covers of this landscape were partially destroyed.

The external part of the strip of flooded landscapes is occupied by complexes of weak flooding, where groundwater occurs at a depth of up to 3.5 m. This complex stretches along the coast, leaving tongues and patches inland of ancient dry and modern valleys. Field observations showed that along the river valleys, seawater moved inland in the areas of the Kura River 30–35 km, Lankaranchay up to 1.5 km, etc.

The rise in the level of the Caspian Sea and the associated process of flooding of the landscapes of the Salyan, Southeast Shirvan, and Lankaran plains to a large extent determined the modern dynamics of change and the economic use of the coastal lowlands. Landscapes differ greatly in their susceptibility to various natural and anthropogenic processes. On the coastal plain of the Western Caspian Lowland, local processes (fluctuations in the level of the Caspian Sea) play an important role in the differentiation of landscapes. The variants of landscapes are formed that differ to some extent from the zonal type. The latter processes are more variable and, accordingly, less resistant to various natural-anthropogenic and natural influences. And the stronger this or that local factor acts, the more dynamic and unstable the studied landscape is. Thus, the landscape structure of a given territory is presented in the form of a series of geosystems according to the degree of their deviation from the primary type and dynamism for each local differentiation factor operating in the given territory.

Depending on the degree of stability of a given territory, weakly stable and stable landscapes are identified. On the studied plain, weakly stable landscapes cover the coastal strips: sandy undivided marine accumulative plains with rare ephemera; alluvial-marine plains with wormwood-ephemeral shrub vegetation on gray-brown solonchak soils; coastal sea-eolian plain and undulating eolian dunes with ephemera, tamarix, camelthorns on sandy sierozem-alkaline soils; transportable eolian dunes with rare sedge, hogweed, forbs on sandy alkaline soils.

The above strongly flooded landscapes are highly transformed hydromorphic landscapes. These are geosystems that function under the constant and excessive impact of sea or groundwater. Landscapes slightly transformed of the hydromorphic type, also function with an undoubtedly increased influence of the hydrological factor but do not experience excessive or constant moisture. This

type of landscape of the modern marine accumulative plain includes moderately and slightly flooded modern river valleys. Background semi-desert Khvalynsk alluvial-marine plains are classified as primary landscapes.

Conducted field observations in the Salyan district show that the general trend in the development of landscapes is as follows: with a prolonged rise in the level of the Caspian Sea, and consequently an increase in the hydromorphization of landscapes, psammorphic landscapes become more stable; the process of overgrowth of dune ridges is intensifying, the eolian process is weakening, and unstable and stable landscapes are shifting. Hydromorphization processes create a different direction of dynamics: landscapes are destroyed and change their structure, i.e. due to flooding by sea waters, they pass into aquatic natural complexes.

A purely natural component was not singled out in the transformation-dynamic structure of the landscapes of the coastal plain of the study area. The anthropogenic factor turned out to be, as it were, integrated into it, while it can give the most multidirectional trends in the development of landscapes. On the aeolian-marine plain, overgrazing leads to an increase in the unsustainability of landscapes. In the Lankaran lowland, unregulated felling led to increased aridization of lowland forests and accelerated the formation of steppe landscapes.

The conducted long-term monitoring established that the drop in the level of the Caspian Sea only over the past 26 years (1995–2021) by 2 m was the reason for the decrease in the base of erosion, the acceleration of deep erosion in river valleys, and the change in the level and regime of groundwater. During this time, significant areas of the coastal zone of the Salyan, South-East Shirvan and Lankaran plains were freed from seawater and switched to a continental development regime (Fig. 3).

As a result, the groundwater level in coastal hydromorphic (marsh, marsh-lagoon, marsh-meadow) complexes decreased, and the water regime of soils changed, which contributed to the development of zonal semi-desert and dry-steppe plant groups.

The sharp drop in the groundwater level in the key monitoring wells located in the ephemeral-dry-steppe marine and alluvial-marine complexes of the Salyan and South-East Shirvan plains is directly related to the drop in the level of the Caspian Sea after 1995.

During the drop in the level of the Caspian Sea, the groundwater level within the landscapes of the coastal Salyan and South-East Shirvan plains decreased by 0.28–0.72 m. The decrease in the level of groundwater has led to a reduction in biomass and soil moisture, a change in the area and morphological structure of landscapes in the coastal zone. As a result of the regression of the sea, hygrophytic and halophytic plant associations of the coastal zone degraded, and instead of them, psammophytic and ephemeral vegetation adapted to arid conditions began to develop (Fig. 4).

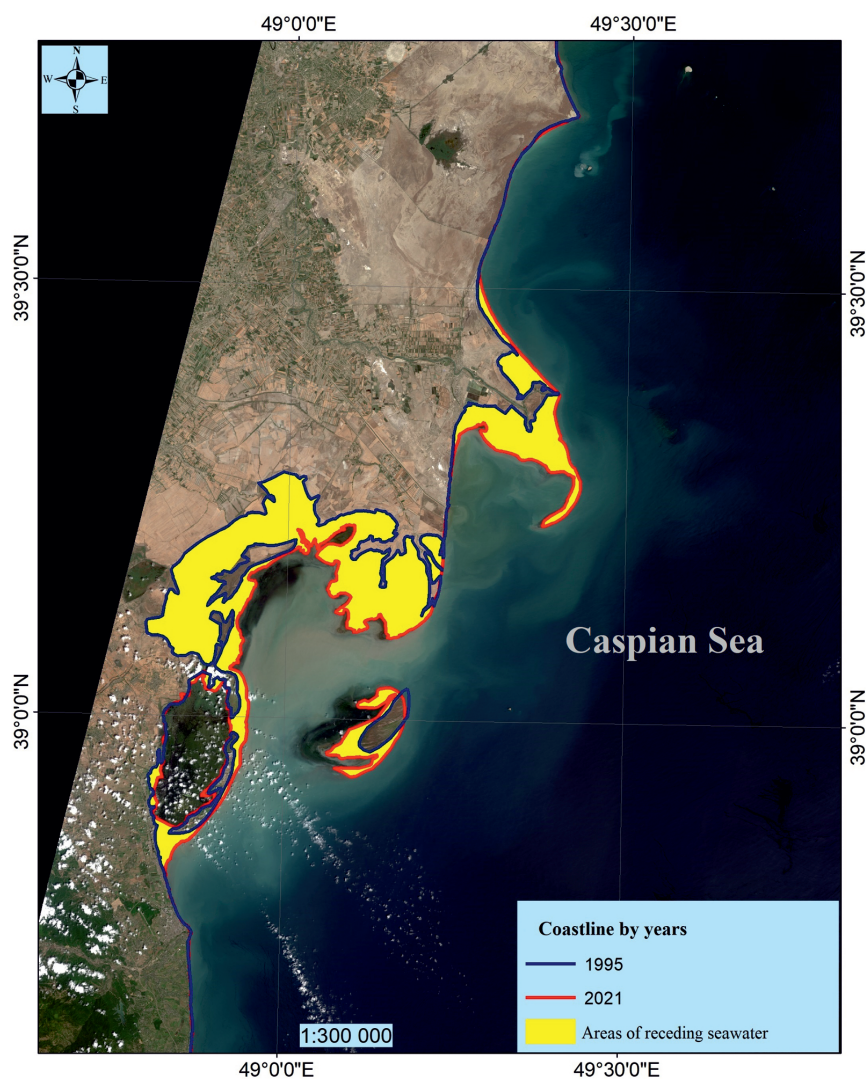


Fig. 3. Dynamics of the coastlines of the Caspian Sea for the period from 1995 to 2021

As a result of field and camera studies, it was revealed that as the distance from the sea increases, the effect of its level drop on the depth of groundwater becomes weaker. Thus, during the studies, the width of the strip of intense fall in the groundwater level in the coastal zone of the Salyan and East Shirvan plains was 0.5–1 km.

Landscape studies show that after 1995, for 25 years, the Caspian Sea receded by almost 4 km, and therefore large areas of the Gyzylagaj Bay, the coastal shallow shelf adjacent to the Lankaran and Salyan plains found themselves in continental conditions of development (Fig. 4). The analysis of climate data shows

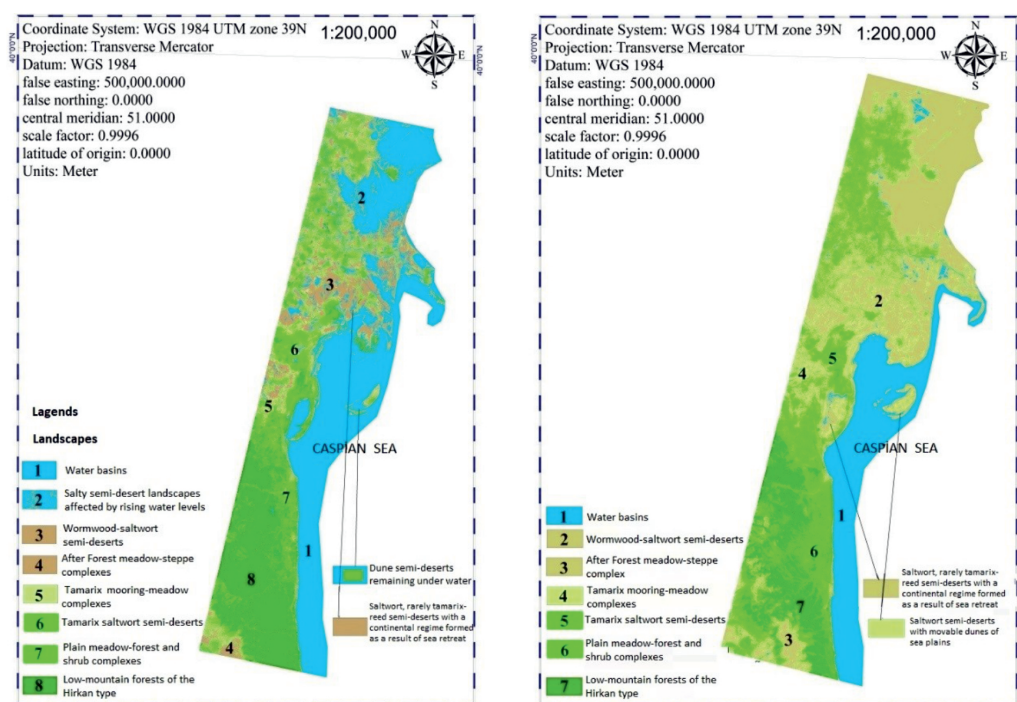


Fig. 4. Space-landscape maps of the coastline of the transgression and regression period of the Caspian Sea

that during the period of the drop in the level of the Caspian Sea by 2.0 m, the annual evaporation rate increased by 10–11% in comparison with the long-term norm for 1978–2020 in the Kura delta. The decrease in the water area of the Caspian Sea as a result of a decrease in its level, as well as global climatic changes, increased the continentality of the climate, which in turn accelerated the process of desertification of the landscape of the western coast of the Caspian Sea and caused the replacement of degraded hygrophytic and mesophytic plant groups by xerophytic ones. The transformation and dynamics of the landscapes of the South-East Shirvan, Salyan, and Lankaran plains took place and are taking place in a certain sequence, consisting in the transformation of the primary type of landscape into another, more complex one, due to the lowering of the level of the Caspian Sea, its regression and changes in soil moisture conditions. Primary is the meadow-marsh type of landscape, which was formed along the ancient coastlines of the sea. As the sea retreats, the meadow-marsh landscape formed in the first stage gradually transforms into a solonchak-semi-desert, and later into a dry-steppe and semi-desert landscape, far removed from the sea coast, with insufficient soil moisture.

Conclusion. Thus, natural and anthropogenic factors can be unidirectional. During the rise in the level of the Caspian Sea – this is an increase in hydromor-

phism – and then the process accelerates, which is observed in many irrigation systems on the coast of the Caspian Sea of the studied plains. If the effects on natural processes in various directions have not decreased, then it is necessary to mitigate the negative effects of human activity. In the conditions of increased hydromorphism in the flood zone of landscapes, the fixing of dune ridges should take place as a natural process.

The fall in sea level over the last period by more than 2 m consistently affects the dynamics and transformation of the primary type of landscape into another. The primary meadow-marsh type of landscape is gradually replaced by a solonchak-semi-desert, and then a dry-steppe and semi-desert landscape.

As a result of fluctuations in the level of the Caspian Sea, the natural and economic structures of the coast undergo significant, although not always negative changes in human activity.

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