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Changes in the Biomass of Vegetation in the Aral Sea Region

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ABSTRACT: Long-term changes in the plant biomass of the dried bottom of the Aral Sea and the Karakalpak part of the Ustyurt plateau were determined. Despite the drying of the Aral Sea 50 years ago, primary and intermediate stages of vegetation haloseries dominated by annual and shrub halophyte fraction remains as the main directing force of succession. The emergence and increase in the area of "zero" or arid local territories after the 1990s is observed in the central, especially southern part of the Karakalpak Ustyurt. In contrast to the formation of vegetation on the drained bottom of the Aral Sea, long-term changes in the biomass of various natural-territorial complexes of Ustyurt are characterized by a negative correlation with a reduction in the area of mirrors over the past 30 years.

KEYWORDS. NDVI, TSAVI, biomass, aridization, salt marshes, gypsum soils

INTRODUCTION

The phenomenon of desertification is diverse and the uniqueness of the causes of desertification, acting in combination against the background of initially diverse conditions, leads to various forms of land degradation that are combined under the general term “desertification” [Kust G.S. 1999:361].

The diversity of desertification forms is due not only to the different ultimate results of the interaction of natural and anthropogenic causes, but also to even more numerous intermediate options. This situation is typical for the current state of the natural complexes in the territory of the Aral Sea, among which there are current deserts in the bottom of the Aral Sea and areas with different stages of desertification of the natural complexes of the plateau Ustyurt [Kust G.S. 1999: 361].

As it is known, the Aral Sea used to be a natural thermo regulator, which indirectly led to the formation of natural vegetation and affected the dynamic processes occurring in the vegetation of Ustyurt and the Kyzylkum desert.

At the same time, the drying of the sea effectively stimulated autogenic succession of vegetation, of the drained bottom of the Aral Sea and adjacent territories, primarily the Plateau Ustyurt, which aimed to form climax vegetation [Wucherer, W., 1979: 2,66-70., Kuzmina, Zh.V., Treshkin, S.E., Bakhiev, A., Mamutov, N., 2006: 42-46].

To understand the changes in vegetation in the Aral Sea region, an important point is to assess the formation of vegetation that is resistant to modern soil and climate conditions after the sea drying. At the same time, determining the effects of the trend in the formation of plant biomass and the degree of correlation of their formation with the drying of the Sea, first of all, provides multi-faceted information about the formation of autogenous vegetation in Central Asia. Secondly, it informs about the degree of transformation of vegetation cover in various natural and territorial complexes of the Aral Sea region, including the Plateau Ustyurt, which allows predicting trends in vegetation changes due to the climate that formed after the drying of the Aral Sea.

A number researchers have studied the processes of landscape formation and trends in the development of individual components of natural-territorial complexes in the Aral Sea region [Kurochkina, L.Ya., Kuznetsov, N.T., 1986: 5, 68-74., Wucherer, W., Brekle, Z.V., 2003: 153., Kuzmina, Zh.V., Treshkin, S.E., Bakhiev, A., Mamutov, N., 2006: 42-46.]. According to L. Dimeyeva (2015) [Dimeyeva. L. 2015: 136-142] the changing vegetation of the drained bottom of the Aral Sea is accompanied by three successional areas as psammosere, halo sere and potamosere (psammosere, halo sere and potamosere), which are different in environmental conditions, patterns of dynamics, indexes of species diversity and the stages of formation, selected on the basis of a change of the dominant plant communities under changing soil conditions [Dimeyeva.L. 2015: 136-142].

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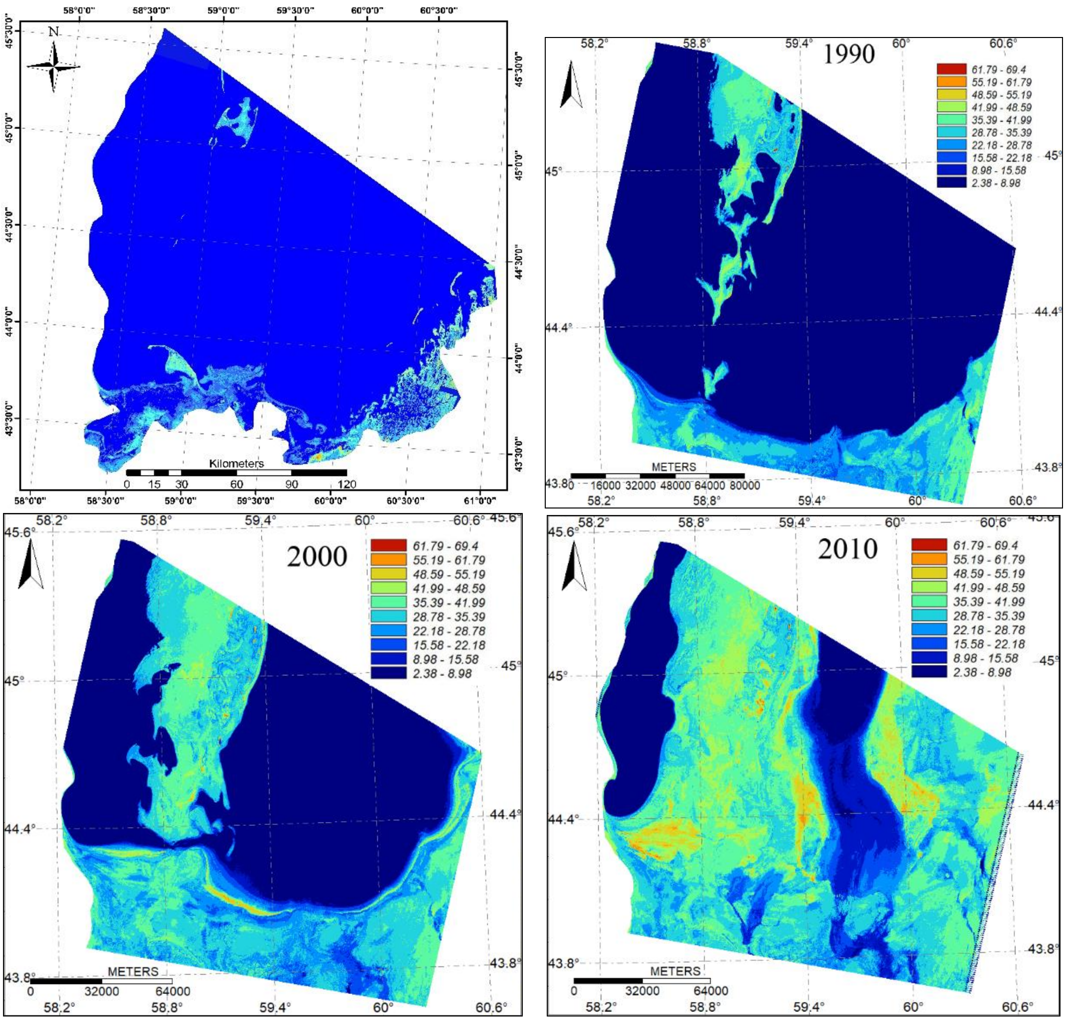
RESEARCH METHODS

To assess the appearance of autogenic vegetation in modern soil and climatic conditions, on the basis of TSAVI index the rates of formation of plant phytomass in the drained bottom of the Aral Sea were studied.

In the process, the classification of vegetation formation of the drained bottom of the Aral Sea in the period of 1990-2019 was developed. Specifically, according to TSAVI, 10 indexes are distinguished by spectral features: the territory of the Aral Sea (1), swamps (2), wet saltmarshes (3), plump saltmarshes (4), the areas vulnerable to vegetation formation (5), the area with very low (6), low (7), average (8), high (9) and very high biomass (10) (figure 1). According to this classification, the areas occupied by vegetation were determined and changes in those areas during the years of observation were identified (table 1, fig. 1).

RESULTS AND DISCUSSION

The data reveal that despite the shrinking of the Aral Sea, all NTCs are undergoing restructuring aimed at the formation of vegetation (table 1, fig. 1). The main trend is a constant increase in areas vulnerable to vegetation formation. Currently, the area of such territories is about 1 800000 thousand hectares.



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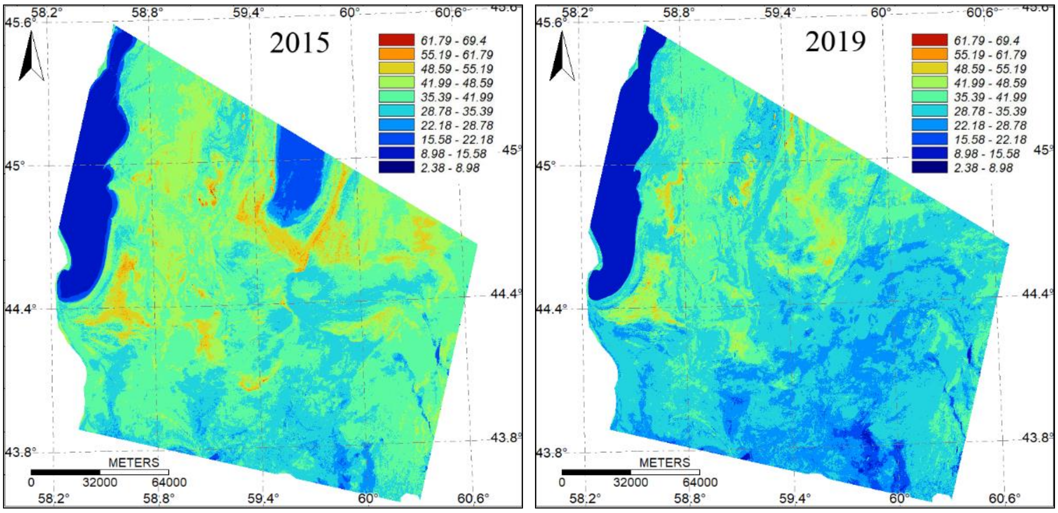


Figure 1. Dynamics of vegetation biomass formation in the drained bottom of the Aral Sea (1970-2019):
Up left: the state of the Aral Sea in the period 1970-1973; classification of the legend (from blue to red): 1 – The Aral Sea; 2 – swamps, 3 – wet saltmarshes, 4 – plump saltmarshes, 5 – areas vulnerable to vegetation formation, 6 – areas with very low, 7 – low, 8 – average, 9 – high; 10 – very high biomass

Table 1: Changes in the areas with different biomass in the drained bottom of the Aral Sea (thousand ha)

Years	Area:					
	Vulnerable to vegetation formation	With very low biomass	With low biomass	With average biomass	With high biomass	With very high biomass
1990	369477	234398	22322	1398	341	257
2000	822301	517026	48642	10687	1506	173
2010	1005706	1119994	433832	102307	7751	413
2015	1115867	1699999	773850	188361	15162	459
2019	1747504	1009852	256314	35309	1925	560
K	0.7	0.9	0.8	0.7	0.6	0.2

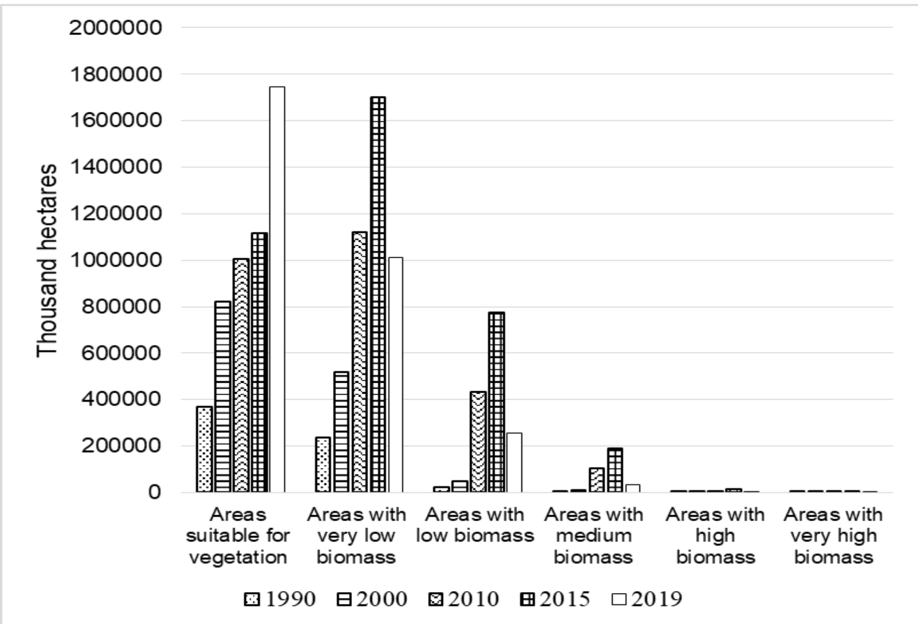


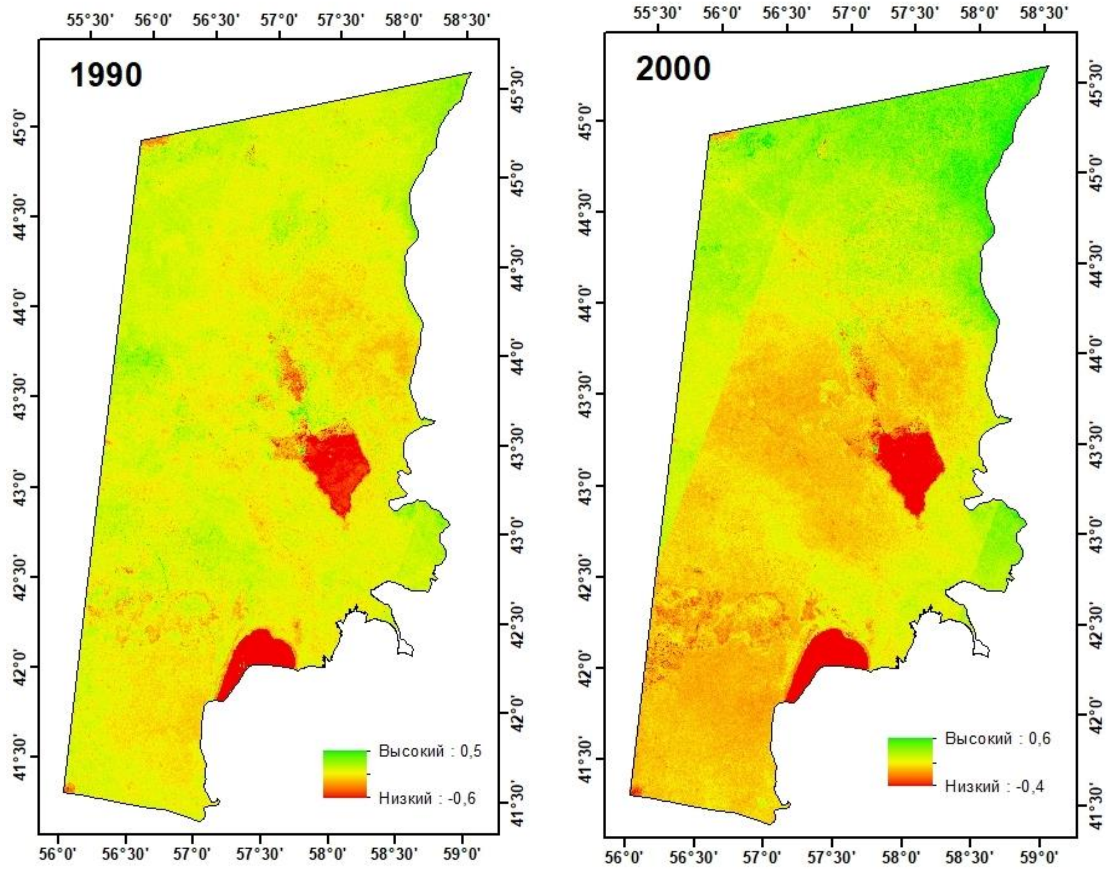
Figure 2. Dynamics of areas with different biomass in the drained bottom of the Aral Sea (thousand ha) during 1990-2019

The high correlation between the reduction of water levels and the formation of "swamps" (0.9) and its lowest value with the formation of areas with "very high biomass" (0.2) indicate the progressive nature of the dynamics of the shoreline of the Aral Sea in recent years and low progressing trends in fraction of trees and bushes in the dried bottom. (Table 1).

The main part of the territories with "very high biomass" is localized in sandy massifs, where representatives of psammophilic vegetation such as Haloxylon aphyllum, Calligonum caput-Medusa, C.eriopodum, Salsola richterii are in dominance etc.

Based on the spectral reflection of the TSAVI index, the directions of vegetation succession at the present stage are determined. Despite the drying of the sea 50 years ago, as the main guiding force, the primary and intermediate stages of the haloserium succession with the dominance of annual saltpans and the halophilic shrub fraction remain unchanged. According to L. Dimeyeva (2015), the haloserium lasts for 30-40 years and gives way to the psammoserium. However, the psammoserium rate dominates only in local areas of the Muinak Peninsula and the adjacent western and southern territories of the Renaissance Island. Today the stability of the haloserium in the vast areas of the drained bottom of the Aral Sea indicates the preservation of the role of hydrogenic succession of vegetation due to the balance between soil moisture and progressive aridity of the territory.

Based on the NDVI index, long-term changes in the biomass index of the southern and south – western parts of the Karakalpak part of the plateau Ustyurt -the Asaka-Audan and Kaplankir massifs were determined. In addition, based on the results of previous years of research (NDVI results of the northern and central parts), maps of the dynamics of the biomass of the Karakalpak Ustyurt were compiled (fig. 3).



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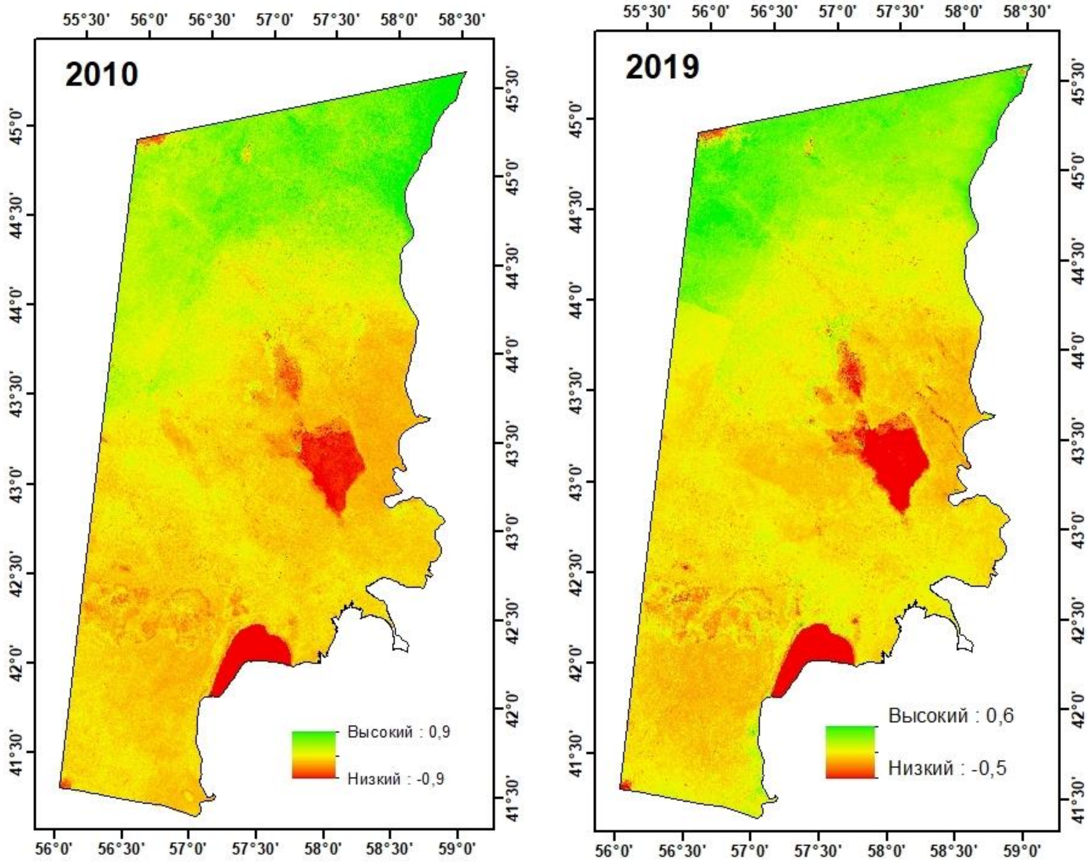

Figure 3. Change in the NDVI index of the Plateau Ustyurt in different years of observation (Karakalpak area)

In the previous year, the research revealed an increase in the $NDVI_{max}$ index of vegetation in the Central and Northern parts of Ustyurt despite the deterioration of the ecological environment accompanied by a decrease in precipitation and an increase in air temperature of the territories under research. This was explained by the occurrence of vegetation in the drained bottom of the Aral Sea and the increase in thickets of wetland plants in the south western former coastal strip of the Aral Sea basin.

Based on the introduction of special processing of satellite images of the ArcGIS software package, redundant territories were removed, including the territory of the Aral Sea, and the multi-year NDVI index of the Karakalpak Ustyurt was optimized in a single system.

The results show the occurrence and increase in the area of "zeroes" or arid local territories after 1990 in the central, especially in the southern part of Ustyurt (fig. 3). It should be noted that there is a sharp drop in the vegetation biomass of the Asaka-Audan depression, which is characterized by a variety of tree and shrub fractions. Even the peculiar mild climatic conditions of the depression did not contribute to the preservation of tree and shrub vegetation during drought in the southern territories of Ustyurt (fig. 4). This trend is observed both in the areas of Kaplankir and Shahpahti.

Figure 4. Dry bushes of white saxaul (Haloxylon aphyllum) in the area of Asaka-Audan. During the expedition (2019) completely dried-up areas of white saxaul were discovered

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Current climate data show a sharp increase in drought for the last 15 years and this affects the state of the population of The Red Book species. Specifically, it is noteworthy to emphasize the regression of the southern Ustyurt population of Malacocarpus crithmifolius and Crambe edentula (growing in Kaplankir, Sarikamish and Shorja), caused by digressions due to the natural destruction of their habitats and destabilization of climatic factors concerning drought. In addition, structural-spatial and mathematical analyses of vegetation confirms the transformation of vegetation in the Kulantakir and Assakeawdan geobotanical regions of southern Ustyurt into xerophytization and the predictive models show complete degradation of the historical territories of black saxaul in the coming years. [Tamambetova Sh, B. 2021: 4103 – 4113].

In general, despite the occurrence of arid areas, due to the increase in the biomass of the northern part of the Plateau Ustyurt, the NDVI of the surveyed territory has a low progressive trend (R^2=0.2) (fig. 5). The emergence of areas with high biomass was noted in the north-eastern outskirts of the Karakalpak Ustyurt (the formation of such sites occurred in 2000), and at the present time similar sites are occupied in the north-western part of Ustyurt (fig. 3).

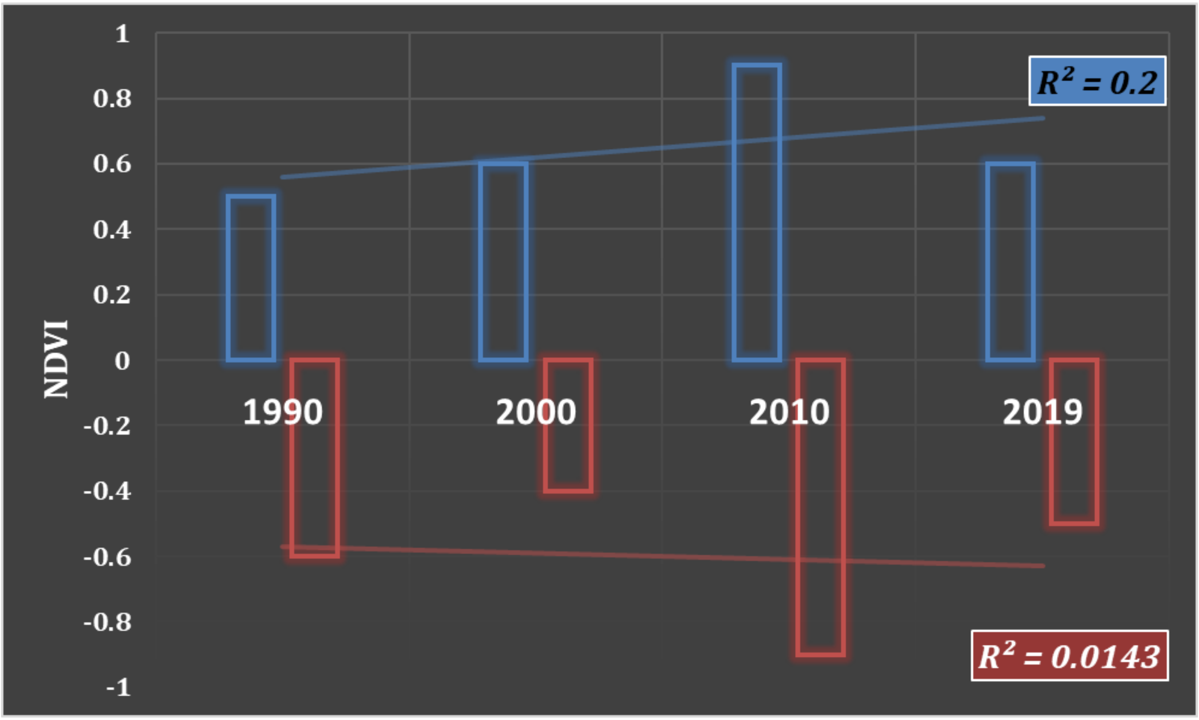


Figure 5. Changes in the trend of high and low NDVI values of the plateau Ustyurt depending on the year of observation

Reference to the vegetation map of the Ustyurt (1995) indicates the contours of salsola arbuscula along with sagebrush and biyurgun. However, field data from the field expedition (2018) show vegetation transformations due to a decrease in the proportion of sagebrush (Artemisia terrae albae) and an increase in the density of biyurgun (Anabasis salsa).

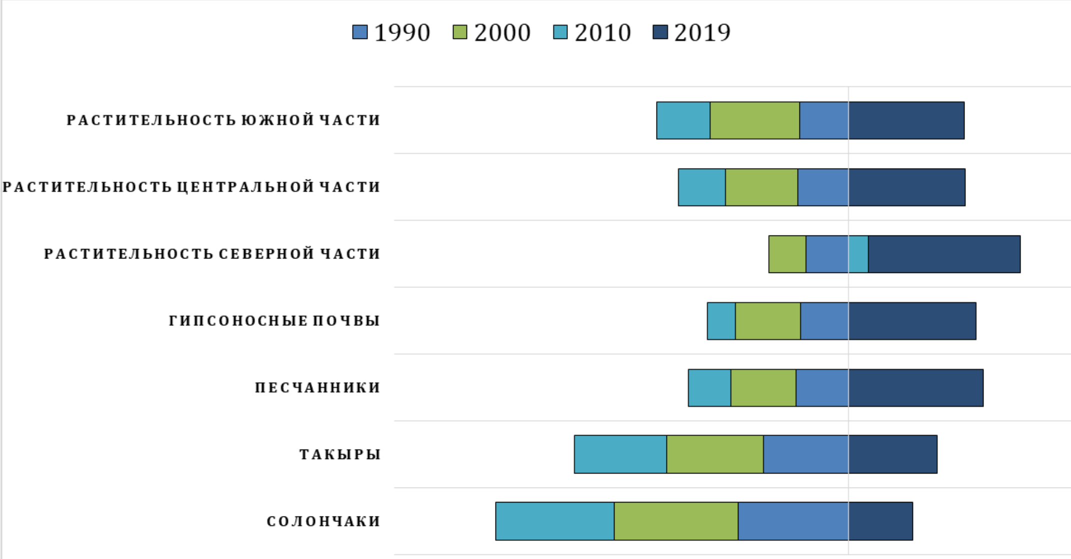
According to the data by I.F. Momotov (1953) [Momotov I.F. 1953: 133.] salsola arbuscula complex is one of the largest complexes of Ustyurt in Karakalpakstan, and it is well isolated geographically. It occupies the northern part of the Karakalpak Ustyurt. The southern border of its irregular lines runs from the collective farm Kabanbay, on the shore of the Aral Sea, to the west to the collective farm Kuanishkazgan. The total area of the salsola arbuscula complex is 2 million ha. I.F. Momotov (1953) [Momotov I.F. 1953: 133.] divides the complex into two: 1) a central one, along with the southern part to the border of biyurgun-sagebrush complex, 2) north one along the seaside area, in which salsola arbuscula and sagebrush groups quantitatively predominate over biyurgun one.

In addition, based on reconnaissance data (2018), it can be assumed that the northern variant of dissection and the dominance of the central variant of the salsola complex, characterized by the predominance of biyurgun-salsola communities, partially disappeared.

Based on NDVI data from 149 monitoring sites located on salt marshes, takyrs, sandstones and gypsum soils more vulnerable vegetation in various natural territorial complexes (NTC) of the Karakalpak Ustyurt were identified in the period 1990-2019.

In 2018 in certain NTC areas in the central and southern parts of Ustyurt some territories vulnerable to climate change were revealed. At the same time, the trends of decrease in the biomass of takyr vegetation, its stability on sandstones and dynamism on gypsum soils were determined. Accumulation of NDVI data from monitoring sites made it possible to estimate optimally the long-term change in biomass in each Ustyurt NTC as a whole. Analysis of the results reveal that the "zero" indicator of the above-mentioned NTC is located in the following: saltmarshes→takyrs→sandstones→gypsum soils, which reflects the natural order of formation of plant biomass in the deserts of Central Asia (fig. 6).

Despite the increasing drought, the preservation of minimal biomass of vegetation in takyrs, especially salt marshes, provides information about the resistance of vegetation of these NTC to unfavorable environmental factors.



	Солончаки	Такыры	Песчанники	Гипсоносные почвы	Растительность северной части	Растительность центральной части	Растительность южной части
1990	-0.07	-0.06	-0.03	-0.03	-0.03	-0.03	-0.03
2000	-0.08	-0.06	-0.04	-0.04	-0.02	-0.05	-0.06
2010	-0.08	-0.06	-0.03	-0.02	0.01	-0.03	-0.04
2019	0.04	0.06	0.09	0.08	0.10	0.08	0.08

Figure 6. Changes of the NDVI indicator in different NTC

Historical formation of vegetation is associated not only with the formation of environment-forming species that appear from among species that are more adapted to a particular environment, but also with their geographical locations in territories. According to I.F. Momotov, (1953) in the areas of the plateau from north to south, the ratio of elements in different complexes, for example, the appearance of small and large bushes Artemisia terrae albae, Anabasis salsa, Salsola arbusculaformis, and their numerical ratio is constantly changing.

The changes in the NDVI index of the gypsum desert located in the northern, central and southern parts of Ustyurt were determined. Analyses show a lower biomass of vegetation in the southern part than in the northern part, as well as a more progressive trend of its decrease during 1990-2010. This confirms the data of I.F. Momotov (1953) and supplements it with information about the vulnerability of vegetation to aridization in gypsum soils located in the southern areas of Ustyurt (fig. 6).

Despite the decrease in the NDVI until 2010, there has been an increase in biomass in all NTCs over the past 10 years. Even in the vegetation of salt marshes and takyrs, minimal positive trends were noted. This is probably due to the transformation of vegetation, which informs about the disappearance of unstable and vulnerable to aridization species and the expansion of the range of more persistent and competitive species.

Correlations (c) between the NDVI of different Ustyurt NTCs and changes in the mirror areas of the Aral Sea, air temperature, and the amount of precipitation in the territories were established. In contrast to the formation of vegetation in the drained bottom of the Aral Sea, which had a positive correlation with a decrease in Sea level, long-term changes in biomass in different Ustyurt NTC showed a negative correlation with a reduction in the area of water mirrors over the past 30 years. This indicates that there is no close relationship between the shrinking of the Aral Sea and changes in the vegetation of territories (Table 2).

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Table 2: Correlation (c) between the NDVI of different Ustyurt NTC and changes in the mirror area of the Aral Sea, air temperature, and precipitation (based on weather data between 1980-2018 , «Jasliq» weather station)

NTC	Mirror area of the Aral Sea, sq.km^2	Temperature,t^0C	Total precipitation, mm
Saltmarshes	-0,63	0,26	0,39
Takyrs	-0,62	0,33	0,34
Sandstones	-0,62	0,30	0,32
gypsum soils	-0,67	0,33	0,24
Vegetation:			
in northern part	-0,81	**0,51**	**0,05**
in central part	-0,62	0,25	0,30
in south part	-0,56	**0,19**	**0,36**

CONCLUSION

However, the results show a positive correlation between the NDVI of all NTCs and the multi-year temperature and total precipitation of Ustyurt. A more obvious correlation was noted in the vegetation of the gypsum desert located in the northern and southern parts of the research area. For vegetation in the northern part, air temperature is a decisive factor in the accumulation of biomass (k=0, 51) and this is confirmed by the increase in the NDVI index in recent years (fig. 3). Moreover, for the southern part of vegetation, the amount of atmospheric precipitation is a limiting factor (k=0, 19), which, due to a decrease in its amounts, has worsened the state of vegetation in recent years.

Thus, the shrinking of the Aral Sea is not a transformative force of vegetation in the Plateau Ustyurt. Its degradation has indirectly affected the climate of the region, which is expressed through the generation of ecosystem dynamics and the emergence of vegetation resistant to climate aridization.

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