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Dynamics of *Medicageta sativae* formation on the Ustyurt plateau under climate change and drying of the Aral Sea

Umida Sh. Saitjanova* **& Khabibullo F. Shomurodov**

Laboratory of Geobotany, Institute of Botany Academy of Sciences of Republic Uzbekistan, 100125 Tashkent, Uzbekistan

*Email: spring_girl93@mail.ru

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Abstract

The article presents a brief analysis of 20-year changes in climatic parameters of the Aktumsuk region of the Eastern Cliff of Ustyurt and their impact on the species composition of the *Medicageta sativae* formation. From the obtained analysis of the daily indicators of 2 sources (NASA POWER and the Aktumsuk meteorological station), long-term trends of changes in average, average maximum and average minimum air temperatures, as well as annual precipitation have been established. Data from 2000-2020 were taken for analysis. The warm and cold seasons of the year have been established, which affected the amplitude of the parameters. Basically, the decrease in minimum air temperature occurs in the cold half-year (November-December, January-March), which explains the increase in precipitation during these periods. The most significant warming in the territory of the Aktumsuk region was noted in warm seasons (April, June, July and August). The obtained data comparing the average annual air temperatures for the 2 above-mentioned sources of the 20-year period indicates that the climate of the Aktumsuk region is sharply continental, here we can observe sharp changes in the temperature regime in the direction of warming, which could lead to the transformation of the *Medicageta sativae* formation. The appearance of xerophytes in this type of vegetation in recent years provides information about the xerophytization of flora due to an increase in drought in the Eastern Cliff. Climate aridization, reduction in the number of mesophytes in the species composition, as well as their projective coverage, a sharp increase in xerophytes and halophytes in the species composition, communities may indicate significant changes in communities of this type of vegetation due to climate change.

Keywords

Medicago sativa, precipitation, trend, Aktumsuk, air temperature, coefficient of change

Introduction

Climate change is now recognized as the main cause of the decline in biological diversity. Currently, a definition of climate change has been adopted, which includes both natural and anthropogenic causes of such a change (1, 2). Global climate change is expressed primarily in an increase in average temperature of air, an increase in the number and intensity of adverse hydrometeorological phenomena, such as particularly hot days, droughts, heavy precipitation, sharp thaws and frosts, floods, mudslides, snow avalanches. The increasing variability of the climate leads to negative consequences for the development of the country. Weather and climate-related natural disasters are causing a reduction in food production, water pollution and other economic losses (3). According to the Intergovernmental Panel on Climate Change (IPCC), if current trends in the burning of fossil fuels continue, the average temperature on the planet would increase by 6 degrees or more by the year 2100. Melting of glaciers and permafrost, extreme weather events, rising sea levels and its oxidation will have a devastating effect on the habitat of living organisms (4).

The Eastern cliff of Ustyurt is an arid rocky desert divided into terraces. Along the entire length from Cape Ak -Tumsuk to Sarykamysh, the cliff is significantly dissected by ravines, sometimes cutting far into the plateau. The height of the cliff also varies significantly. The highest elevations are observed at Cape Ak-Tumsuk (220 m) (5). The Ustyurt plateau currently directly borders with Kyzylkum and the Aral deserts are joined not only along the eastern, but also along the western shore of the Eastern Aral (6).

The climate of the Eastern Cliff is considered sharply continental; summers are hot and winters are relatively cold, there is low precipitation. The Aral Sea, which washes the Eastern Cliff, has a considerable impact. Fogs, high humidity and more precipitation are a frequent phenomenon than in areas of the plateau remote from the sea (5).

The Aral Sea region is characterized by the climate of the inland deserts of the temperate zone (7). Some researchers (8) distinguish it under the name of the Aral type climate. Its features include exceptionally large annual air temperature amplitudes (up to 78 °C), cold winters (average January temperature up to -14 °C) and hot summers (average July temperature up to +26.3 °C), low precipitation (average 95 mm per year) and conversely, huge evaporation from the sea mirror, equivalent to a water layer of about 90 cm, as well as complete cloudlessness and the absence of fogs in summer.

The Aral Sea itself has a certain impact on the climate of the surrounding areas. The action of the Aral Sea is manifested in the softening of the climatic conditions of the coast, where it is noticeably pronounced that the temperature increases in winter and decreases in summer (up to 2 °C).

The Aktumsuk region includes a wide ledge of the coast formed by the capes of Aktumsuk and Tau, and the shores of the Karakuduk and Kassarma adjacent to it on both sides, which are alternating segments of accumulative and abrasive shores, which explains their small-scale dismemberment. The site is characterized by sea terraces (in some concavities up to 3 levels). The coast is composed mainly of red and brown clays (9). Meadow vegetation is well developed in these areas.

According to one report, *Medicageta sativae* formation belongs to the type of meadow vegetation (*Lugophyta*), which is concentrated mainly in intermountain depressions with close groundwater standing (5). It is distributed from the first to the second terrace of the Eastern Cliff and occupies the territory between the capes of Urga and Baigubekmurun, as well as in the vicinity of Kabanbai, the fortress of Korgansha, Cape Aktumsuk. The floral composition of this type of vegetation is very diverse and rich. This formation in the South-Primorsky subdistrict is spread in spots along the hollows. In the Central Primorsky and North Primorsky subdistricts of the Eastern Cliff, the formation occurs on the northern, north-eastern and eastern slopes of cliffs. Along the bottoms of the cliffs the formation forms dense thickets. The subedifiers of the *Medicageta sativae* formation are wheatgrass (*Agropyron repens*), blackroot (*Cynoglossum viridiflorum*), bindweed (*Convolvulus arvensis*) and motley grass. On the Eastern Cliff, in combination with alfalfa, 4 associations are formed – *Medicagetum sativae mixtoherbosum, Medicagetum sativae fragile agropyrosum, Medicagetum sativae viridiflori cynoglosetum, Medicagetum sativae arvensi convolvulosum* (5).

In 1970-1980, the under-cliff zone was covered with *Medicago sativa* undergrowth on an area of 3-4 ha. The Aral Sea disaster and the increase in drought caused the reduction of alfalfa thickets, and today they have partially preserved only in the upper part of the under cliff. In view of this tendency, the territories of these alfalfa associations are inevitable from the onset and capture by xerophytic species in the future (17).

The purpose of research is to analyze long-term climatic changes of the Aktumsuk region in application to the assessment and forecast of the dynamics of changes in alfalfa communities in different periods of the year, which, under the influence of anthropogenic factors that caused climate change, may change to other communities. Currently, this is an extremely important task that needs to be solved in order to preserve natural ecosystems.

Materials and Methods

The object of the research is the *Medicageta sativae* formation. Vegetation of communities was studied using generally accepted methods (19). The degree of projective coverage was determined by the eye - measuring method (20). The study areas are Karakuduk (44.461605°, 58.187548°), Kabanbai (44.225999°, 58.311715°), Aktumsuk (45.034270°, 58.27752387°), Kassarma (44.858343°, 58.185513°). The presented study analyzed the daily values of such sources as NASA POWER and Aktumsuk meteorological station for the period from 2000-2020. For comparative characteristics, graphs were constructed and linear trends of average, average maximum, average minimum temperatures and annual precipitation were established. The coordinates of both meteorological sources are the same (latitude 45.135952°, longitude 58.292707°) (11).

Average air temperatures indicators for different periods were calculated by averaging daily temperatures. Considering the daily indicators, the average maximum and minimum temperatures for the period from 2000-2020 were established. Also, warm and cold half-years were set for certain periods. The annual precipitation amount was calculated by summing the daily precipitation figures for the required time periods.

For the long-term period data series, graphs were constructed using the MS Excel 2010 program, clearly reflecting the trend of changes in indicators, and correlation coefficients between the actual data and their linear trends were calculated. For the analysis, those correlation coefficients were taken that ranged from 90% to 99.9% (12).

To adequately assess the magnitude of the long-term dynamics of air temperature (as well as precipitation), the relative coefficient of change was calculated, which is estimated as the ratio of the modulus of change in trend values of temperature (or precipitation) over a long-term period to the modulus of the amplitude of fluctuations of the actual (measured) values of this parameter in the long-term aspect (10).

Results and Discussion

In the process of our research, we analyzed climatic factors (average, average maximum, average minimum air temperature, precipitation amount) and correlation coefficients of two sources: NASA POWER and the Aktumsuk station) for the period from 2000-2020. For a comparative assessment, data from both sources were taken.

Each source uses a specific methodology to measure climate indicators. If we consider NASA, then this source considers space images and analyzes meteorological data using data from the World Meteorological Organization. The Aktumsuk station performs calculations using special meteorological instruments (Table 1).

Based on the data taken from both sources, there is a significant increase in precipitation over the year in the Aktumsuk region has been revealed. Precipitation, depending on the changing temperature regime and circulation conditions, is subject to significant fluctuations (13). Precipitation is a source of water resources in the region, largely determining the nature of natural landscapes and water availability of agricultural production (3).

The correlation coefficient for the total amount of atmospheric precipitation according to NASA data r= 0.26, according to the Aktumsuk station r = 0.71 (Fig. 1). Both trends are considered positive. The primary reasons for a significant increase in the trend according to the Aktumsuk station are 3 points (2015, 2016, 2019), during which heavy precipitation was observed, the values of which range from 152.8-164.4 mm. This phenomenon occurs both in the cold half-year (in early spring in March with precipitation from 26.2-50.0 mm) and in the warm season (April with precipitation of 35.7-44.6 mm, November - 16.1-35 mm). The amplitude of changes (K_{chang}) of the precipitation is from 7% (NASA) to 27% (Aktumsuk).

Positive trends were revealed for the indicators of average air temperatures (NASA Power r=0.34, Aktumsuk r=0.30) (Fig. 2). The interval of average air temperature values of both sources is from 9.02-14.6 °C and from 8.72-11.9 °C. On average, the air temperature in the period from 2000-2020 increases in the range from 3.2 to 5.5 °C. Taking into account the presented indicators, we can say that the average annual temperature increases due to a stable increase in temperature in the warm half-year and a not too

Table 1. Climatic data of Aktumsuk meteorological station in 2000-2020

Years	Air temperature, t °C			Total precipitation, mm
	Average	Average maximum	Average minimum	
2000	10,1	14,9	5,5	30,7
2001	9,69	14,9	5,3	30,6
2002	9,9	15,5	5,01	29,5
2003	8,8	13,3	4,09	38,4
2004	10,7	16,1	5,2	63
2005	10,2	15,6	4,8	36,6
2006	11,1	16,6	6,2	29
2007	10,5	15,6	5,6	4,6
2008	9,5	14,8	4,3	31,1
2009	9,3	14,1	4,4	19,5
2010	10,1	14,9	5,2	81,3
2011	8,7	13,8	3,5	84,7
2012	9,5	14,7	4,3	55,3
2013	11,7	15,8	5,7	105,8
2014	10,2	14,5	4,05	71,8
2015	11,3	15	5,6	164,4
2016	11,9	15,7	6,2	152,8
2017	10,3	15,5	5,2	82,8
2018	9,85	14	3,9	86,1
2019	10,3	15,5	5,5	155,2
2020	10,5	16,2	5,18	74,8

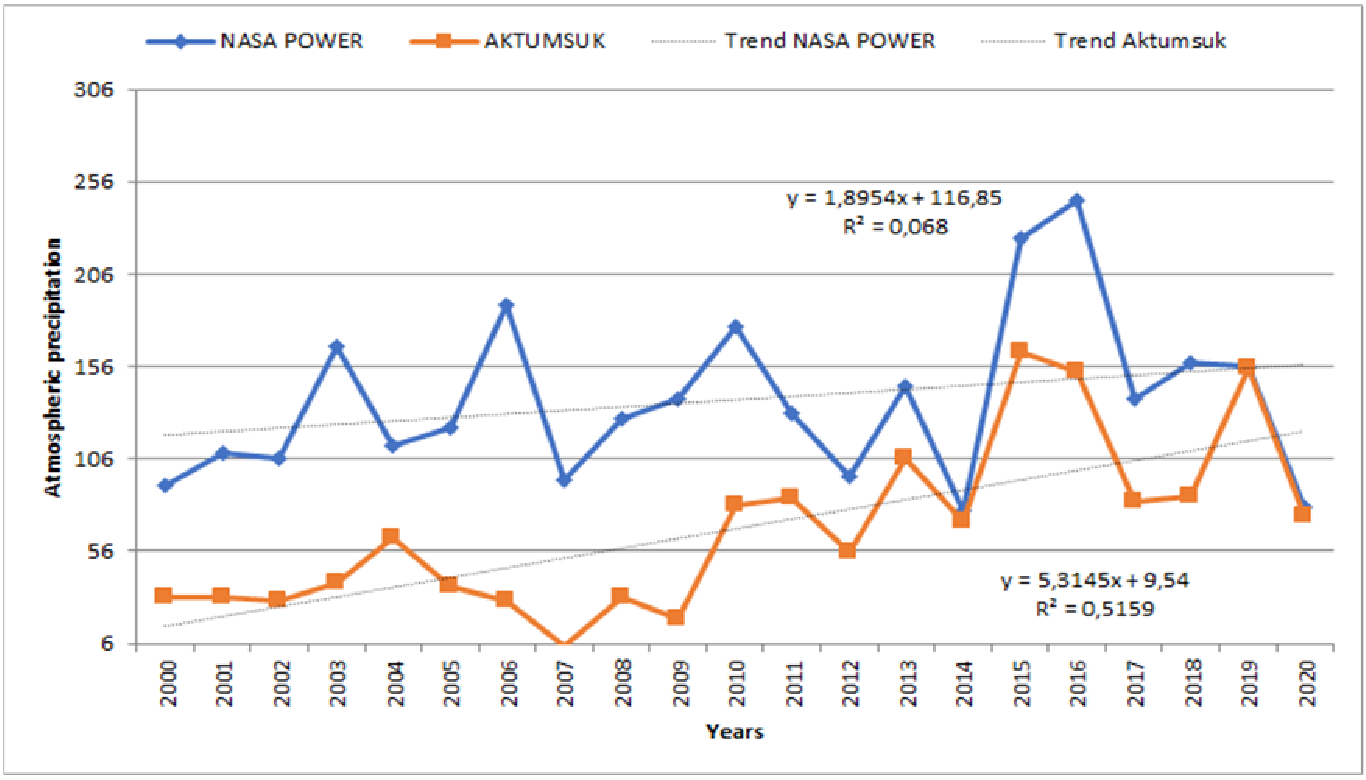

Fig. 1. The trend of precipitation of the Aktumsuk region.

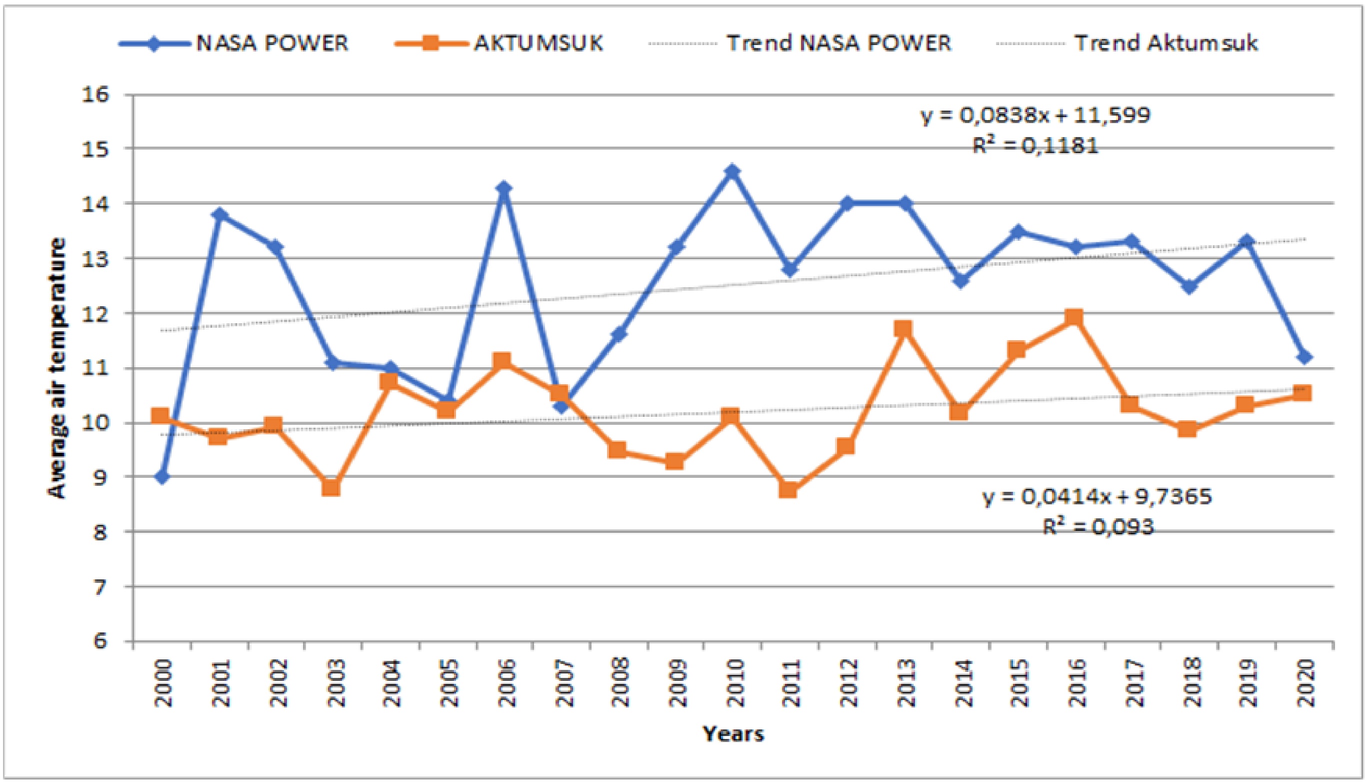

Fig. 2. The trend of change in the average air temperature of the Aktumsuk region.

sharp decrease in the cold half-year. The amplitude of changes (K_{chang}) of the average air temperature is from 12% (Aktumsuk) to 39% (NASA).

It is known from literary sources (14) that an increase in the number of city residents leads to a warming of the city's air environment. Additional sources of heat in the city are industrial facilities, large arrays of buildings that accumulate heat, asphalt and concrete coatings and etc. As a result, the microclimate of the city is formed, which is different from the surrounding territories. In comparison with the Aktumsuk region with no industrial facilities, the average air temperature values in settlements will be higher.

In 20-year dynamics of the average maximum air temperatures on the territory of the Aktumsuk region, significant trends of different directions have been identified. According to NASA Power, a negative trend r = -0.39 was detected, which indicates that the average maximum temperature does not reach high values, but on the contrary decreases and the trend was recognized as unreliable according to the Dmitriev's table (2009). As for the Aktumsuk station, here we observe a positive trend r = 0.07 (Fig. 3). In this case, there is a slight increase in air temperature. The increase in values reaches from 13.3 to 15.8 °C. The amplitude of changes (K_{chang}) of the average maximum air temperature is 39% (Aktumsuk).

Basically, the decrease in minimum air temperatures occurs in the cold half-year (November-December, January-March), which explains the increase in precipitation during these periods. The decrease in average minimum temperatures is from 0.14°C to -5.4°C (NASA Power) and from 6.2°C to 3.1°C (Aktumsuk) for 20 years. The amplitude of changes

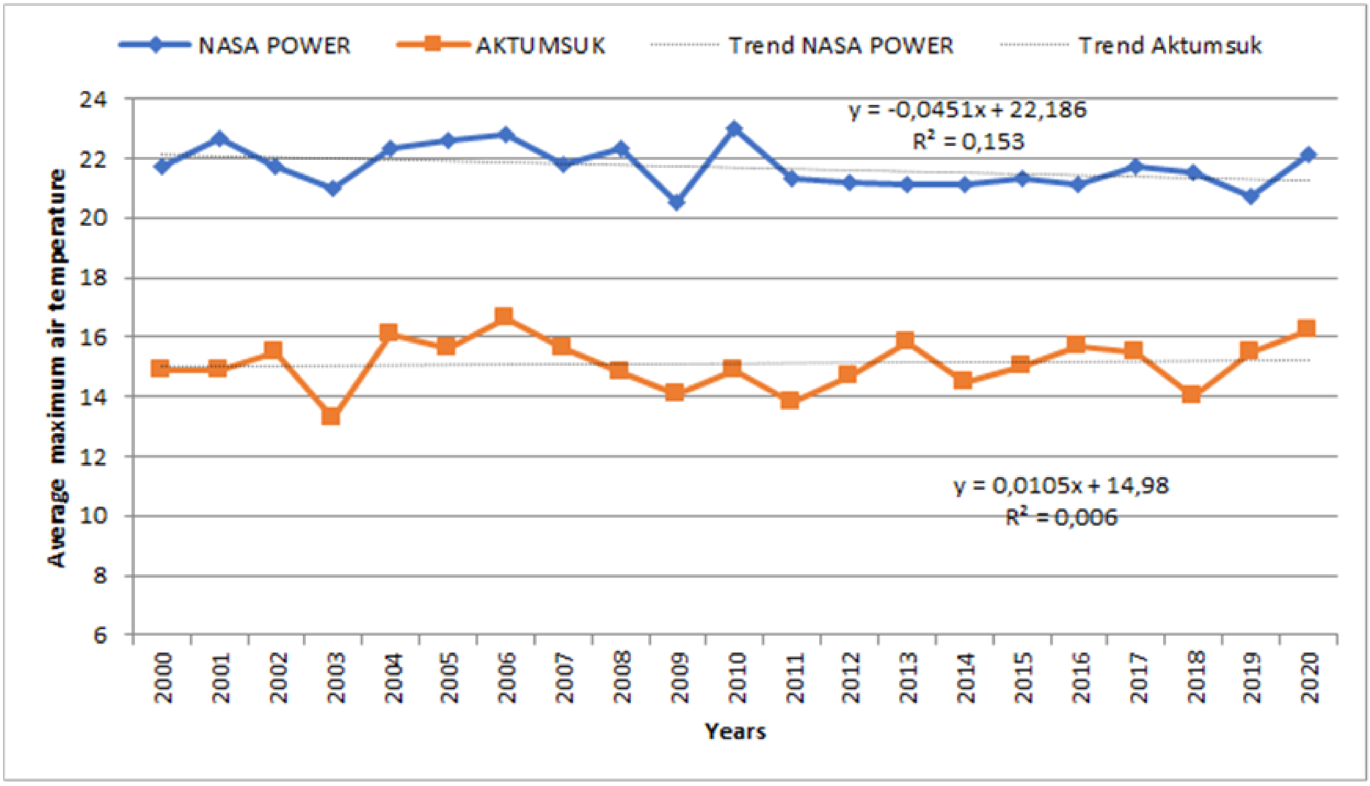

Fig. 3. Changes in the average maximum temperatures for sources NASA Power and Aktumsuk.

If we consider the change in the average minimum values of air temperature, we see a negative trend of NASA Power (r=-0.34), Aktumsuk (r=-0.05) from 2 sources (Fig. 4).

(K_{chang}) of the average minimum air temperature is from 12% (Aktumsuk) to 37% (NASA).

It should be noted that in the alfalfa formation there

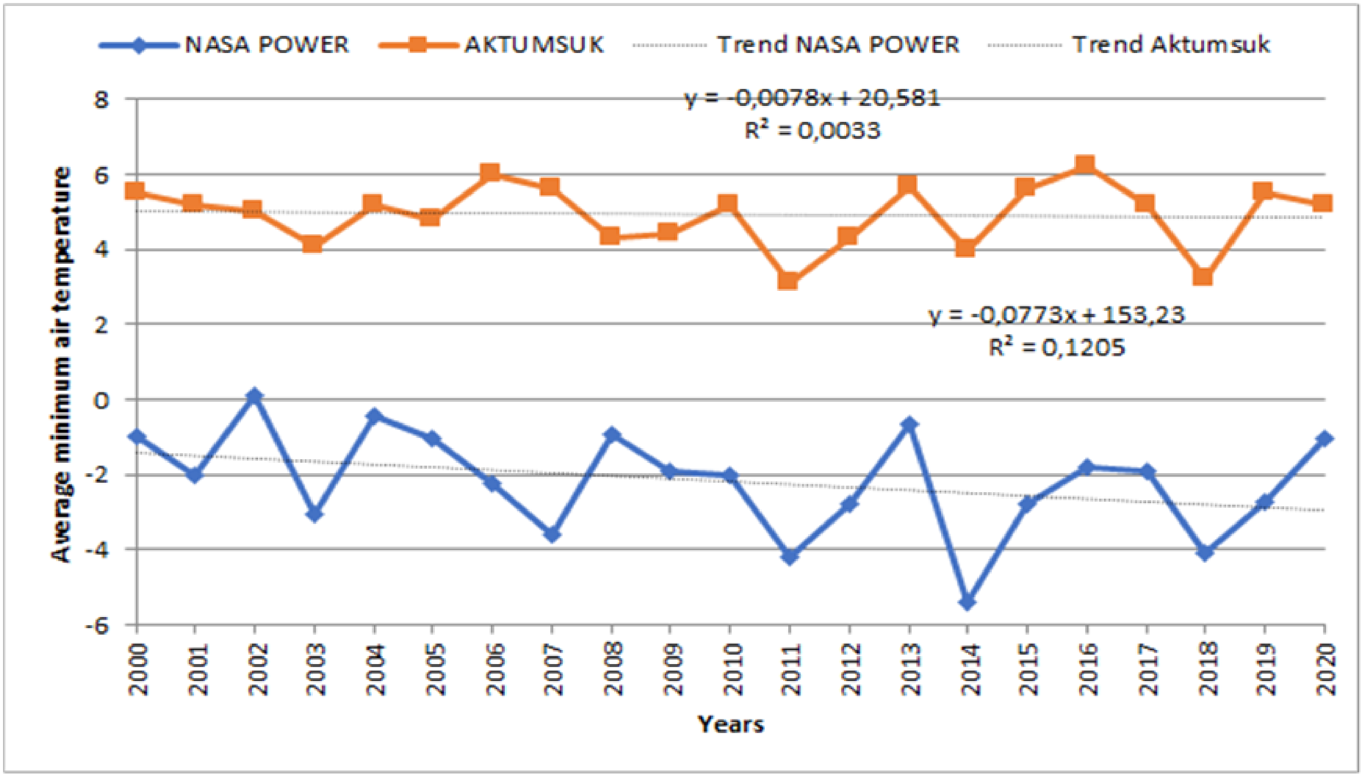

Fig. 4. The trend of change in the average minimum temperatures.

is a decrease in species composition and projective coverage compared to the 80s of the last century, xerophytic species (*Atraphaxis spinosa*, *Artemisia terrae-albae*) appear in the cover (Table 2).

Table 2. Characteristics of the species composition of *Medicageta sativae* communities

№	Species	Communities		
		Medicagetum sativae viridiflori cynoglosetum	***Medicagetum sativae mixtoherbosum***	***Medicagetum sativae artemisiaso-mixtoherbosum***
		Projective coverage, %		
		50-55%	70-80%	75-80%
	Shurbs			
1.	*Atraphaxis spinosa* L.	+	+	3
2.	*Lycium ruthenicum* Murr.	+	-	-
3.	*Hulthemia persica* (Michx. ex Juss.) Bornm.	-	+	-
	Semi - shrubbery			
1.	*Artemisia diffusa* Krasch. ex Poljakov	-	-	10
2.	*Artemisia terrae-albae* Krasch.	+	3	-
	Perennial herbs			
1.	*Agropyron fragile* (Roth) P. Candargy	7	5	+
2.	*Asparagus inderiensis* Blum ex Pacz.	+	+	-
3.	*Acroptilon repens* (L.) DC.	-	1	5
4.	*Biebersteinia multifida* DC.	+	-	-
5.	*Medicago sativa* L.	40	60	60
6.	*Cardaria pubescens* (C.A. Mey.) Jarm.	-	8	+
7.	*Centaurea apiculata* Ledeb.	+	-	+
8.	*Cynoglossum viridiflorum* Pall. ex Lehm.	8	-	-
9.	*Convolvulus arvensis* L.	-	+	-
10.	*Echinops meyeri* (DC.) Iljin	-	1	+
11.	*Ferula syreitschikovii* K. Pol.	-	3	-
12.	*Galium pamiro-alaicum* Pobed.	+	-	-
13.	*Glycyrrhiza aspera* Pall.	-	+	-
14.	*Rheum tataricum* L.	+	-	-
15.	*Rindera tetraspis* Bunge	-	+	-
16.	*Peganum harmala* L.	-	+	-
17.	*Potentilla supina* L.	-	+	-
18.	*Lactuca tatarica* (L.) C.A. Mey.	-	-	+
19.	*Limonium suffruticosum* (L.) O. Kuntze	+	-	-
20.	*Seseli glabratum* Willd. ex Spreng.	-	-	+
21.	*Silene nemoralis* Waldst. & Kit.	+	-	-
22.	*Thalictrum isopyroides* C.A. Mey.	+	-	-
23.	*Tanacetum santolina* C. Winkl.	-	-	+

Medicagetum sativae mixtoherbosum community is characterized by a high species diversity compared to other alfalfa communities. In addition to alfalfa the following mesophytes grow here: *Asparagus inderiensis, Potentilla supina, Rindera tetraspis, Glycyrrhiza aspera, Ferula syreitschikovii, Convolvulus arvensis*. In addition, the appearance of indicators of xerophytization – *Artemisia terrae-albae, Atraphaxis spinosa and Hulthemia persica* - is expressed in the same association (17).

For the meadow type of vegetation of the Eastern Cliff, the presence of xerophytes and halophytes species or their weak expression in the vegetation cover is not particularly noticeable (5). However, the appearance of xerophytes in this type of vegetation in recent years provides information about its reconstruction by the xerophytization of flora due to an increase in drought in the Eastern Cliff. If on the above two communities (*Medicagetum sativae viridiflori cynoglosetum, Medicagetum sativae mixto-*

herbosum) the numbers of xerophytic species were insignificant, then in the *Medicagetum sativae artemisiaso-mixtoherbosum* community their share reaches 13%. At the same time, *Artemisia terrae-albae* surpasses (3%) in the grass-alfalfa community in the onset of xerophytic species, while *Artemisia diffusa* (10%) is the "invader" of the territories of the *Medicagetum sativae artemisiaso-mixtoherbosum* community (17, 18).

The analysis of the comparison of the average annual air temperatures for the two above-mentioned sources of the 20-year period indicates a large number of significant changes in the direction of warming. The most significant warming in the territory of the Aktumsuk region was observed during the warm period of the year (April, June, July and August). In addition, there is a slight increase in the maximum values of air temperature and a tendency to lower the minimum values in the cold half-year.

According to one study (16), environmental conditions on the Ustyurt plateau have been changing negatively for vegetation growth in recent decades due to the drying up of the Aral Sea and the development of the oil and gas industry.

Global change, including a changing climate, is one of the most critical issues facing our future today as terrestrial and aquatic ecosystems which sustain life on Earth, are being increasingly affected by it. While the global population continues to rise, productive land resource, necessary for food production, shrinks. Uncertainties of climate change only magnify the challenge of increasing agricultural production to feed the expanding population (15).

Conclusion

Thus, to date, all research related to changes in the state of ecosystems must be linked to changes in climatic parameters, because climate is one of the main factors shaping ecosystems, which undergoes drastic shifts. The rapid increase in air temperature observed at most stations in Uzbekistan has slowed down in recent years, and even a decrease in some of its indicators has been registered at some stations. The main trend in the change in average air temperatures is a gradual increase in average values in both the cold and warm half-year. The maximum values are increasing, but only slightly. There are no positive trends in average minimum air temperatures, which may have been the first reason for the increase in the amount of annual precipitation in certain years, and the influence of the Aral Sea on climate change in nearby areas is also of no small importance. Taking into account all the analyzed values, it can be concluded that the climate of the Aktumsuk region is sharply continental, here we can observe sharp changes in the temperature regime, which could lead to the transformation of the *Medicageta sativae* formation. In addition to such an important reason as climate aridization, a reduction in the number of mesophytes in the species composition, as well as their projective coverage, a sharp increase in xerophytes and halophytes in the species composition may indicate changes in communities of this type of vegetation due to climate change.

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Authors contributions

The work was a part of Ph.D thesis work of the first author, which was supervised by second authors. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

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