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ASSESSMENT OF CLIMATE CHANGE IN NATURAL AREAS OF THE TURKESTAN REGION OF THE REPUBLIC OF KAZAKHSTAN FOR THE PURPOSES OF SUSTAINABLE AGRICULTURAL AND RECREATIONAL NATURE MANAGEMENT

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Abstract: The article presents the scientific results of a study for assessing climate change trends in natural areas of the Turkestan region of the Republic of Kazakhstan based on the use of long-term climate data (1940-2020) of sixteen meteorological stations located in the region. In the course of the study, tested domestic, international and proprietary methodology for assessing climate change in natural areas were used based on plotting a fixed time series of climatic indicators and the resulting equations of linear trends. The results of the study showed that the average annual air temperature in all natural areas of the Turkestan region tend to increase, and the amount of annual precipitation to decrease, this has a negative impact on the development of recreational and agricultural nature management. On the basis of the developed mathematical models of changes in climatic indicators that characterize the coefficient of coincidence of the growth rates of average annual air temperature and annual precipitation, their quantitative values were determined in the territories of the natural areas of the region, which influence the formation of the environment-forming functions of the natural system. The results of the study enable economic entities, especially farms, to organize sustainable agricultural environmental management, and management bodies to develop plans for the development of recreational tourism in the Turkestan region.

Key words: climate, air temperature, precipitation, climate model, natural system, agricultural and recreational nature management

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INTRODUCTION

The study of climate change, as the most important environmental factor involved in the implementation of the laws of nature, providing the environment-forming and ecological functions of the natural system, is the object of research in the field of geography, climatology, geoecology, agriculture and recreation (Karl and Trenberth, 2003). Timely identification and assessment of trends in spatio-temporal dynamics and patterns of climate change makes it possible to take them into account in various types of nature management (Chen et al., 2011). Analysis of the state of the modern climate, identification of facts of detection of climate change and development of strategic measures to adapt various types of nature management to a changing climate are extremely important tasks for sustainable development (Kharlamova, 2011). Conducted studies on climate change over the past decades state that in many regions of the world and, in particular, in Central Asia and Kazakhstan, there is a trend towards an increase in average annual air temperatures and a decrease in annual precipitation, which leads to an increase in the daily expenditure item of the water balance surfaces (Tursunova et

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al., 2022). As an arid region, the development of society and economy in Central Asia and Kazakhstan in particular is more sensitive to climate change than in the humid regions (Huang et al., 2016; Huang et al., 2017). Changes in surface temperature and rainfall erosion have the most direct effect on soil ecosystem services (ESs) (Li et al., 2015; Li et al., 2020; Zhang et al., 2010, 2017a). During the past 30 years, the temperature rise in Central Asia has been reported to be higher than the global average (Zhang et al., 2010; Hu et al., 2017), which has accelerated evaporation losses (Lioubimtseva and Henebry, 2009) and caused a shortage of water consumption of agricultural land.

Climate change, population growth, over-exploitation of water resources and inappropriate land management are considered to be responsible for environmental degradation in Central Asia (Agadjanian et al., 2013; Demin, 2016; Kuzmina and Treshkin, 2016), this, in turn, exacerbates the risk of land degradation and desertification in the near future in developing countries. Dryland climate change is also increasing the challenges related to food security and water supply in these regions (Asseng and Pannell, 2013; Zinyengere et al., 2014), as water supply is an important part of the climate system (Confortola et al., 2013). Climate change will certainly cause the change of hydrological information (water level, flow, groundwater level, etc.) in time and space (Wang et al., 2022).

Precipitation events, especially following extreme drought, can sharply alter soil moisture, which plays a vital role in soil biological activity (Banerjee et al., 2016; Slessarev et al., 2021) and agricultural food production. Agricultural food products (Hou et al., 2022) remain in perpetual demand because of the increasing population, rapid urbanization and urban growth, declining productivity of the agricultural land, and climate change (Aldazhanova et al., 2022). Drought resilient vegetation species in areas with increasing air temperature and precipitation deficiency are outcompeting other species in natural vegetation such as grasslands, and being more frequently sown in arable lands (Móricz et al., 2021). Vegetation types and types of crops grown can greatly influence the amount of rainfall that can reach the soil surface, as dense vegetation canopy intercepts raindrops, which might not reach the ground, especially for smaller precipitation events, or, the non-evenly distributed, rainwater might result in heterogeneous soil water content (Horel et al., 2022).

Climate change, whether natural or human-caused, will have an impact on human life, including recreation and tourism among other things (Endler and Matzarakis, 2011). The local ecosystem gives services of recreation and tourism that can fundamentally provide support for greater incomes (Reyers et al., 2013; Malhi et al., 2020). Climate change is affecting the ecosystem services of tourism and recreation internationally, not because of their unique characteristics and specific to certain regions but are not viable to the society who created them (Bakure et al., 2022). In addition, tourism is a highly climate-sensitive sector that is also strongly influenced by numerous factors including the state of the natural environment (Scott et al., 2012), the average annual precipitation, seasonal temperature, etc. In this regard, the Turkestan region has an important place in the development of tourism in the country in recent years. The region is assigned an important role in the historical, cultural, spiritual and tourist life not only of Kazakhstan, but of the entire Central Asian region. The landscapes of the mountainous territories of the Turkestan region are the object of assessment of recreational attractiveness (Mukayev et al., 2022). Thanks to the continuous development of the sphere of natural and sacred tourism in the region, by 2025 it is planned to increase the flow of tourists and the number of visitors by 2.5 million people (The concept of the master plan for the development of the city of Turkistan, 2018). Economic and social destinations in the tourism industry create favorable conditions for effective use of tourist and recreational potential of the country in the context of the concept of balanced development and increase the positive impact of the industry on socio-economic development of the regions (Kyrylov et al., 2022). Therefore, climate change will pose an increasing barrier to tourism contributions to the Sustainable Development Goals (Scott et al., 2019).Taking into account the above, there is a need to test the hypothesis of an increase in the intensity of average annual air temperatures and a decrease in the amount of annual precipitation over several decades in various natural zones of Kazakhstan (Medeu, 2010).

Figure 1. Location of natural zones on the territory of the Turkestan region (Source: personal original data)

The object of our study is the territory of the Turkestan region of the Republic of Kazakhstan, the geographical coordinates of the region: 41-46° N. and 65-74° E. where four natural zones are located: a forest-meadow steppe zone of mid-mountains; a steppe zone of low-hill terrain and midlands; a semi-arid zone of foothills; arid zone of foothills, lowland and high plains, characterized by a variety of climatic conditions (Kuderin et al., 2019) (Figure 1). The length of the region from north to south is more than 550 km, and from west to east - about 470 km (Medeu, 2010). The relief of the territory is mostly flat with a general slope to the southwest. In the north, the territory of the region is located within the elevated Betpakdala plateau. To the south of the Shu River lies the Moyinkum sandy massif. In the central part of the region, the Karatau Range extends from the northwest to the southeast. In the southeast there are mountains Talas Alatau, Karzhantau, Ugam ridge. The sands of Kyzylkum go to the south-west of the region with their marginal part, and in the very south there is the marginal part of the flat plain Hungry Steppe. The purpose of the study is to assess the trends in climate indicators (average annual air temperatures and annual precipitation) in natural areas and, on their basis, develop models of climate change and growth rates of climate indicators to ensure sustainable agricultural and recreational nature management.

MATERIALS AND METHODS

Research on the assessment of climate change in the natural areas of the Turkestan region of the Republic of Kazakhstan was based on the methods of mathematical statistics. Theoretical and methodological basis of the study included: creation of an information and analytical database of research, assessment of changes in climatic indicators on a spatio-temporal scale, development of models: 1) climate change; 2) growth rates of climatic indicators (Figure 2). An analysis of annual temperatures and the period of precipitation is a necessary condition for organizing regional recreational and agricultural activities (Kotlyarova, 2020). To assess climate change trends in the territory of the Turkestan region for 1940-2020, we used a verified time series of average annual air temperatures and annual precipitation at sixteen meteorological stations (Table 1) located in various natural zones of the region. Climatic studies were carried out on the basis of long-term information and analytical materials of the Republican State Enterprise "Kazgidromet" (http://www.kazhydromet.kz), World Meteorological Organization (https:// public.wmo.int/en) and information and reference portal "Weather and climate" (http://www.pogodaiklimat.ru/). One of the main methods for studying changes in climate parameters, according to time series of observations, the climatic indicators we are considering (average annual air temperature and annual precipitation), is the assessment of trends in the average statistical value, that is, trend coefficients that characterize the average rate of change in the level of the series for a certain duration of time (Otnes and Enoxon, 1982). To determine the patterns of change in the average annual air temperature and the amount of annual precipitation for 1940-2020, the linear trend method was used, that is, the method of statistical mathematics, which is widely used to assess the trend in climate indicators, and is calculated using the linear regression formula 1 (Ivchenko et al., 2015: 46):

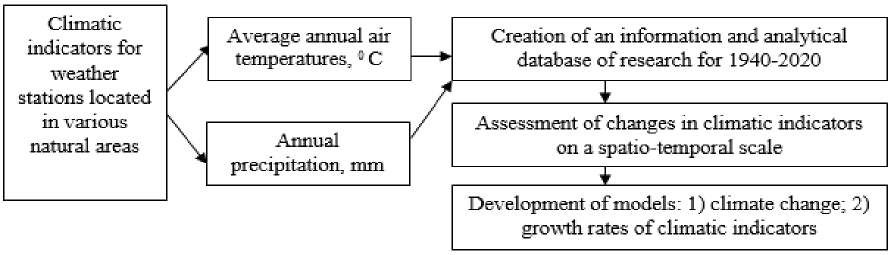

Figure 2. Flowchart of the theoretical and methodological basis of the study on the assessment of climate change in the natural areas of the Turkestan region (Source: compiled by the authors)

Table 1. Geographical coordinates of meteorological stations located in the natural zones of the Turkestan region (Source: personal original data)

Natural zones	Meteorological station	Geographic coordinates		Height above sea level, m
		longitude	latitude	
1. Forest-meadow steppe zone of mid-mountains	Shuyldak	42.30	70.43	1984.0
	Tassaryk	42.23	70.15	1122.0
2. Steppe zone of low-hill terrain and midlands	Achisai	43.55	68.90	822.0
	T. Ryskulov	42.48	70.30	808.0
3. Semi-arid zone of foothills	Shymkent	42.32	69.70	604.0
	Kazygurt	41.76	69.36	566.0
4. Arid zone of foothills, lowland and high plains	Sholakkorgan	43.77	69.18	481.0
	Shayan	4303	69.37	365.0
	Shardara	41.37	68.00	275.0
	Bugen	42.74	68.98	250.0
	Arys	42.43	68.80	240.0
	Bayirkum	42.12	68.15	215.0
	Turkestan	43.27	68.22	207.0
	Tasty	44.80	69.12	190.0
	Kyzylkum	42.80	67.42	185.0
	Akkum	43.72	67.42	174.0

$$y(n) = a_o + a_i \cdot n, \quad (1)$$

where $y(n)$ – is the calculated value of the observation index; n – is the ordinal number of the observed quantity; a_o and a_i – are regression coefficients.

Climate change is a long-term statistical series of the state of the natural environment, characteristic for each natural area, which depends on the growth rate of climatic indicators and has an impact on the development of recreational and agricultural nature management. The assessment of the growth rates of climatic indicators was also carried out on the basis of the equation of linear trends of the time series (Ivchenko et al., 2015), which characterizes the average annual air temperatures and the amount of annual precipitation, allowing us to determine their current and base values within the time period we are considering. Thus, the growth rate of climatic indicators was calculated as the ratio of the difference between the current and basic values of climatic indicators to the current value of the time series, expressed as a percentage, according to formula 2 (Developed by the authors):

$$\Delta T_t = [(t_m - t_v)/t_v] \cdot 100; \qquad \Delta T_{Oc} = [(O_{cm} - O_{cv})/O_{cv}] \cdot 100, \qquad (2)$$

where ΔT_t – growth rate of mean annual air temperatures; ΔT_{Oc} – growth rate of annual atmospheric precipitation; t_m – current values of mean annual air temperature; O_{cm} – current value of annual precipitation; t_v – base value of average annual air temperatures; O_{cv} is the base value of annual precipitation.

At the same time, the ratio of the growth rate of average annual air temperatures to the growth rate of annual precipitation characterizes the coefficient of coincidence of climatic indicators for the period under review for all fixed meteorological stations, which was determined by formula 3 (Developed by the authors):

$$m_{tOc} = \Delta T_t^{min}/\Delta T_{Oc}^{min} \div \Delta T_t^{max}/\Delta T_{Oc}^{max}, \qquad (3)$$

where ΔT_t^{min} – is the minimum value of the growth rate of average annual air temperatures for the period under consideration; ΔT_{Oc}^{min} – the minimum value of the growth rate of annual precipitation for the period under review; ΔT_t^{max} – the maximum value of the growth rate of average annual air temperatures for the period under consideration; ΔT_{Oc}^{max} – the maximum value of the growth rate of annual precipitation for the period under consideration.

RESULTS AND DISCUSSION

The climate of the Turkestan region is characterized by extreme heterogeneity, which is due to the inland position of the territory, orographic conditions, a significant latitudinal strike and openness of the territory's topography from the north. The region belongs to areas of insufficient moisture, and is characterized by low rainfall and high evaporation rates (Kuderin et al., 2019). In the distribution of precipitation over the territory of the region, there is a large unevenness due to a significant latitudinal strike and the presence of mountain systems. The general pattern of climate formation in the region is the interaction of air temperature, precipitation, solar radiation and evaporation from the underlying surface. The average annual air temperature is the energy resource basis for climate formation and the development of ongoing physical and geographical processes, and annual precipitation is the most important source that ensures the flow of chemical, physicochemical and biological processes in all natural zones of the region (Zheleznova et al., 2021).

Based on the created information and analytical database (1940-2020) on the climatic indicators of the Turkestan region, graphs were built (using the Microsoft program Excel 2010) showing the changes in the average annual air temperature and the amount of annual precipitation with their linear trends (Figure 3-6), which made it possible to obtain a climate model in the form of systems of linear equations presented in Table 2.

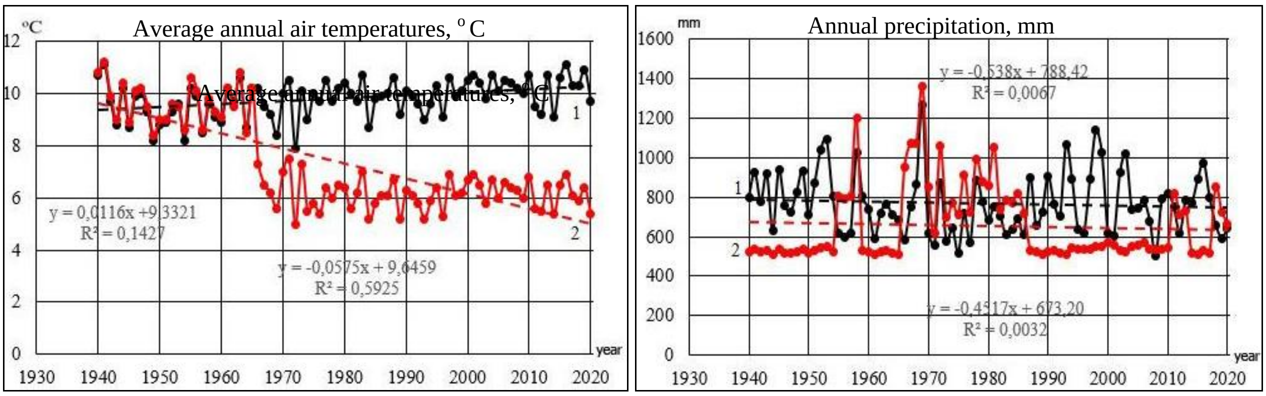

Figure 3. The trend of climate change in the forest-steppe and meadow steppe zone of the middle mountain of the Turkestan region (according to meteorological stations: 1. Tassaryk and 2. Shuyldak)

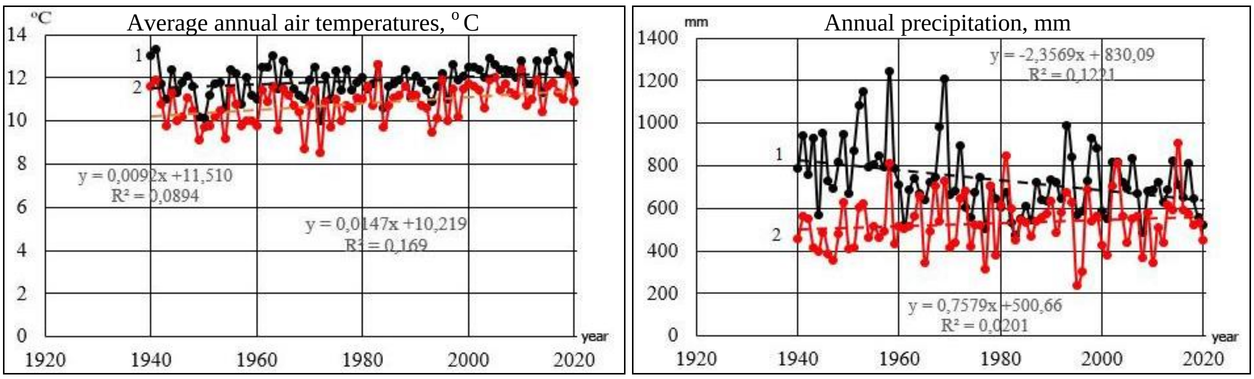

Figure 4. The trend of climate change in the steppe zone of low and middle mountains of the Turkestan region (according to meteorological stations: 1. T. Ryskulov and 2. Achisai)

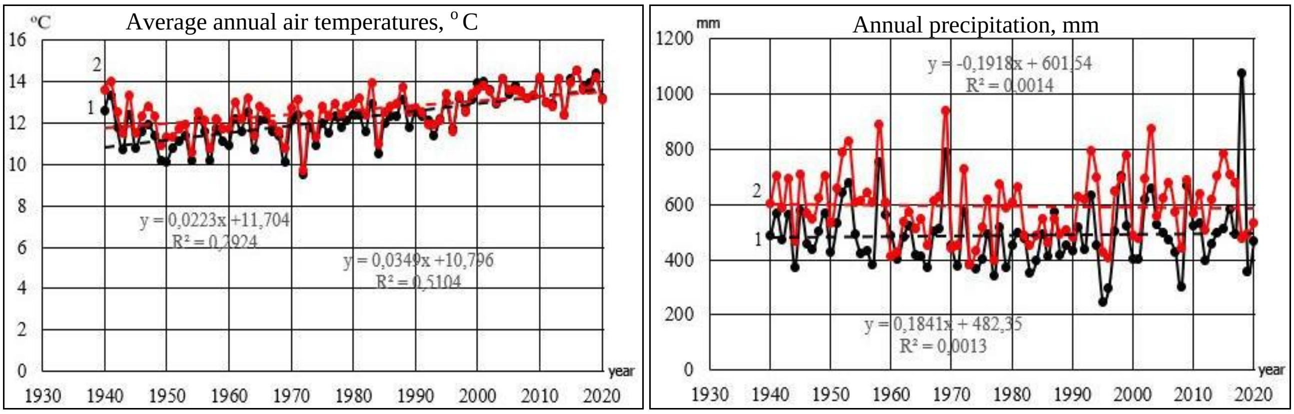

Figure 5. The trend of climate change in the semi-arid zone of foothills of the Turkestan region (according to meteorological stations: 1. Kazygurt and 2. Shymkent)

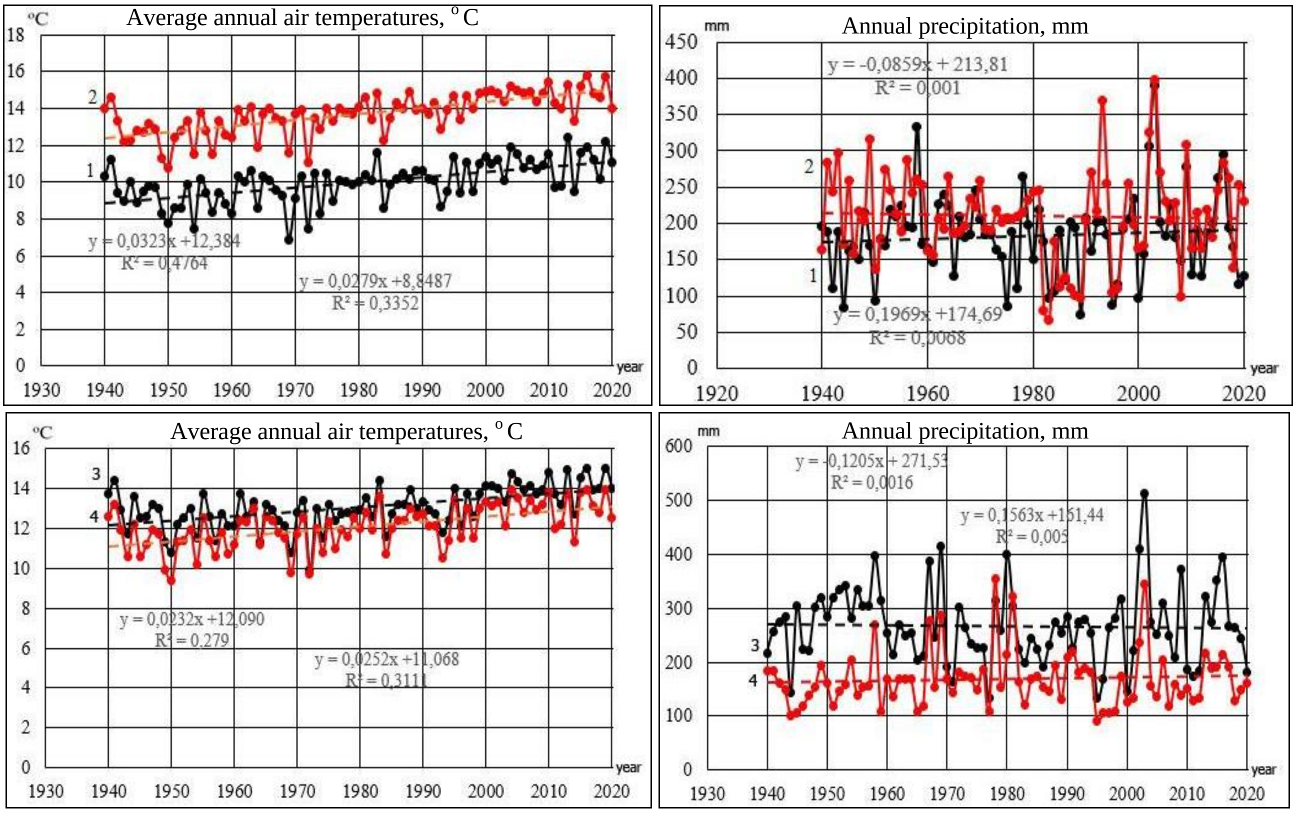

Figure 6. The trend of climate change in the arid zone of foothills, low and high plains of the Turkestan region (according to meteorological stations: 1. Sholakkorgan and 2. Shardara); (according to meteorological stations: 3. Arys and 4. Akkum)

An analysis of the dynamics of changes in climatic indicators (average annual air temperatures and annual precipitation) in the natural zones of the Turkestan region (for sixteen meteorological stations) showed that, despite their significant variability over the years, common patterns of climate change are observed in all natural zones. The most pronounced increase in air temperature, and the observed decrease in the amount of precipitation is noted at the meteorological stations Tassaryk, T. Ryskulov, Shymkent, Shardara, Bugen, Arys, Bayirkum and Tasty (Table 2).

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– in the forest-meadow steppe zone of mid-mountains, where the meteorological stations Shuyldak and Tassaryk are located, the changes in the average annual air temperatures were -4.64 and 0.93° C with an intensity of -0.057 and 0.011° C/year, and the change in the amount of annual precipitation was observed on the order of -43.04 mm with an intensity of -0.53 mm/year;

– in the steppe zone of low-hill terrain and midlands (meteorological stations Achisai and T. Ryskulov), the change in the average annual values of annual air temperatures was about 1.18 and 0.74° C with an intensity of 0.015 and 0.009° C/year, and the change in the amount of annual precipitation about 61.63 and -188.56 mm with an intensity of 0.760 and -2.327 mm/year;

– in the semi-arid zone of foothills (meteorological stations Shymkent and Kazygurt), the change in the average annual values of annual air temperatures was observed 1.86 and 2.79° C with an intensity of 0.023 and 0.034° C/year, and the change in the amount of annual precipitation was -15.36 and 14.72 mm with an intensity of -0.19 and 0.18 mm/year;

– in the arid zone of foothills, lowland and high plains (the territory of the location of 10 meteorological stations: Sholakkorgan, Shayan, Shardara, Bugen, Arys, Bayirkum, Turkestan, Tasty, Kyzylkum and Akkum), the change in the average annual values of annual air temperatures ranged from 1.86 to 2.63° C with an intensity of 0.023-0.032° C/year.

Table 2. Regression model of climate change on a spatio-temporal scale in the context of natural zones of the Turkestan region for 1940-2020 (Source: personal original data) (Note: -4.64 is a decrease rate)

Natural area	Weather station	Indicators	Linear trend equation	Change indicators	Growth rate
Forest-meadow steppe zone of mid-mountains	1. Shuyldak	t_i, °C	$t_i = -0.058 \cdot n_i + 9.646$	-4.64	-93.8
		O_{ci}, mm	$O_{ci} = -0.538 \cdot n_i + 673.2$	-43.04	-6.84
	2. Tassaryk	t_i, °C	$t_i = 0.0116 \cdot n_i + 9.3321$	0.93	9.03
		O_{ci}, mm	$O_{ci} = -0.538 \cdot n_i + 788.4$	-43.04	-5.78
Steppe zone of low-hill terrain and midlands	3. Achisai	t_i, °C	$t_i = 0.0147 \cdot n_i + 10.219$	1.18	10.31
		O_{ci}, mm	$O_{ci} = 0.7579 \cdot n_i + 500.66$	61.63	10.97
	4. T. Ryskulov	t_i, °C	$t_i = 0.0092 \cdot n_i + 11.510$	0.74	6.00
		O_{ci}, mm	$O_{ci} = -2.357 \cdot n_i + 830.1$	-188.56	-29.50
Semi-arid zone of foothills	5. Shymkent	t_i, °C	$t_i = 0.0233 \cdot n_i + 11.7040$	1.86	13.71
		O_{ci}, mm	$O_{ci} = -0.192 \cdot n_i + 601.5$	-15.36	-2.62
	6. Kazygurt	t_i, °C	$t_i = 0.0349 \cdot n_i + 10.796$	2.79	20.49
		O_{ci}, mm	$O_{ci} = 0.184 \cdot n_i + 482.35$	14.72	2.96
Arid zone of foothills, lowland and high plains	7. Sholakkorgan	t_i, °C	$t_i = 0.0279 \cdot n_i + 8.8487$	2.23	20.10
		O_{ci}, mm	$O_{ci} = 0.1969 \cdot n_i + 174.69$	15.75	8.26
	8. Shayan	t_i, °C	$t_i = 0.0243 \cdot n_i + 11.4140$	1.94	14.52
		O_{ci}, mm	$O_{ci} = 0.1667 \cdot n_i + 342.87$	13.34	3.74
	9. Shardara	t_i, °C	$t_i = 0.0323 \cdot n_i + 12.3840$	2.58	17.23
		O_{ci}, mm	$O_{ci} = -0.086 \cdot n_i + 213.81$	-6.88	-3.33
	10. Bugen	t_i, °C	$t_i = 0.0273 \cdot n_i + 11.5380$	2.18	15.88
		O_{ci}, mm	$O_{ci} = -0.109 \cdot n_i + 291.5$	-8.72	-3.08
	11. Arys	t_i, °C	$t_i = 0.0232 \cdot n_i + 8.2529$	1.86	18.32
		O_{ci}, mm	$O_{ci} = -0.121 \cdot n_i + 271.5$	-9.68	-3.70
	12. Bayirkum	t_i, °C	$t_i = 0.0276 \cdot n_i + 11.539$	2.21	16.03
		O_{ci}, mm	$O_{ci} = -0.1016 \cdot n_i + 256.1$	-8.13	-3.28
	13. Turkestan	t_i, °C	$t_i = 0.0286 \cdot n_i + 11.402$	2.29	16.68
		O_{ci}, mm	$O_{ci} = 0.1470 \cdot n_i + 201.52$	11.76	5.51
	14. Tasty	t_i, °C	$t_i = 0.0329 \cdot n_i + 8.3778$	2.63	23.83
		O_{ci}, mm	$O_{ci} = -0.330 \cdot n_i + 179.3$	-26.40	-17.30
	15. Kyzylkum	t_i, °C	$t_i = 0.0241 \cdot n_i + 11.870$	1.93	13.95
		O_{ci}, mm	$O_{ci} = 0.0814 \cdot n_i + 172.3$	6.51	3.64
	16. Akkum	t_i, °C	$t_i = 0.0252 \cdot n_i + 11.0480$	2.02	15.40
		O_{ci}, mm	$O_{ci} = 0.1563 \cdot n_i + 161.44$	12.50	7.18

The trend of change in the amount of annual atmospheric precipitation in the areas where the meteorological stations Sholakkorgan, Shayan, Kyzylkum and Akkum are located was positive in the range from 6.51 to 15.75 mm with an intensity of 0.080 to 0.194 mm/year. In the areas where the meteorological stations Shardara, Bugen, Arys, Bayirkum and Tasty are located, a negative trend was observed in the change in the amount of annual precipitation from -6.88 to -26.40 mm with an intensity of -0.085 to -0.326 mm/year.The analysis of changes in climatic indicators in the natural zones of the Turkestan region showed that for 1940-2020 the growth rate of average annual air temperatures compared to the growth rate of annual precipitation is much higher (Table 2), which influences the formation of the environment-forming functions of natural systems. In the natural zones of the region, changes in climatic indicators can be observed, differing from each other in intensity, growth rates and direction, which affect the formation of the qualitative and quantitative state of all components of the natural system. Below is the mathematical model of the growth rates of climatic indicators developed by the authors, where ΔT_t – growth rate of mean annual air temperatures; ΔT_{Oc} – growth rate of annual atmospheric precipitation, m_{tOc} – coefficient of coincidence of climatic indicators:

1) if $(-\Delta T_t)/(-\Delta T_{Oc}) = m_{tOc}$, then in the forest-meadow steppe zone of mid-mountains, simultaneous decreases in the average annual air temperatures and annual precipitation will be observed, which will reduce its runoff-forming functions;

2) if $(-\Delta T_t)/\Delta T_{Oc} = -m_{tOc}$, then in the forest-meadow steppe zone of mid-mountains, the steppe zone of low-hill terrain and midlands, there will be a decrease in average annual air temperatures and an increase in the amount of annual precipitation, which will increase their runoff-forming functions and water supply;

3) if $\Delta T_t/(-\Delta T_{Oc}) = -m_{tOc}$, then in the forest-meadow steppe zone of mid-mountains, the steppe zone of low-hill terrain and midlands, there will be an increase in average annual air temperatures and a decrease in the amount of annual precipitation, which will affect the increase in runoff-forming functions and a decrease in water supply;

4) if $\Delta T_t/\Delta T_{oc} = m_{tOc}$ =1.0, then in the steppe zone of low-hill terrain and midlands there will be a balanced increase or decrease in average annual air temperatures and the amount of annual precipitation, which will ensure the optimal flow of soil-forming processes in the natural system;

5) if $\Delta T_t/\Delta T_{oc} = m_{tOc}$ >1.0, then in the forest-meadow steppe zone of mid-mountains, the steppe zone of low-hill terrain and midlands, there will be a decrease in average annual air temperatures and an increase in annual precipitation, which will provide a balanced combination of physicochemical and biochemical processes, which will contribute to accumulation of biological substances, and will allow organic and reliable integration with the components of the natural system;

6) if $\Delta T_t/\Delta T_{oc} = m_{tOc}$ <1.0, then in the semi-arid zone of the foothills and the arid zone of foothills, lowland and high plains, an increase in average annual air temperatures and a decrease in precipitation will be observed, which will lead to a decrease in the ecological productivity of the vegetation cover and the intensity of the soil-forming process due to a decrease in natural water supply, which cause degradation of the natural system.

Thus, the climatic model of the natural system developed by us and the mathematical model of the growth rates of climatic indicators (average annual air temperatures and annual precipitation) in the natural zones of the Turkestan region have scientific and practical significance for recreational and agricultural nature management. The scientific significance of the developed climatic model of the natural system of the region, obtained on the basis of the equations of linear trends and the model of the growth rates of climatic indicators, lies in the ability to trace the causal relationship between the formation of various states of the natural systems in accordance with the laws of nature.

CONCLUSION

Assessing the trend climate change (average annual air temperatures and annual precipitation) for 1940-2020, in the context of the natural zones of the Turkestan region, it was carried out on the basis of long-term information and analytical data on sixteen meteorological stations of the Kazgidromet RSE, which made it possible to perform all statistical calculations and build graphs of changes in climate indicators using a linear trend in the Microsoft program Excel 2010.

It is established that in all natural zones of the Turkestan region, there is an increase in average annual air temperatures. Average annual air temperatures in the region as a whole over the period under consideration (81 years) increased in all natural zones. The range of increase was from 0.736^{o} C (steppe zone of low-hill terrain and midlands) to 2.792^{o} C (semi-arid zone of foothills). There is also a decrease in annual precipitation at 9 meteorological stations out of 16 located in all natural zones of the Turkestan region. The range of decrease is from -6.88 (arid zone of foothills, lowland and high plains) to -188.56 mm (steppe zone of low-hill terrain and midlands).

It should be noted that the obtained climatic model of the natural system and the mathematical model of the growth rate of average annual air temperatures and the amount of annual precipitation in the context of the natural zones of the Turkestan region do not coincide in the direction and intensity of their development, which has a negative impact on the ecological and economic functions of the natural system of the Turkestan areas. The obtained results of the study enable economic entities, especially farms, to organize sustainable agricultural environmental management, and management bodies to develop plans for the development of recreational tourism in the Turkestan region of the Republic of Kazakhstan.

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