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Zh. S. Mustafayev, A. T. Kozykeyeva, A. M. Kamaliyev

Kazakh national agrarian university, Almaty, Kazakhstan.
E-mail: z-mustafa@rambler.ru, aliya.kt@yandex.ru,kamaliev_1972@mail.ru

CLIMATIC CHANGES IN THE BASIN OF THE TRANSBOUNDARY SHU RIVER

Abstract. On the basis of multi-year information and analytical materials «Kyrgyzhydromet» (Kyrgyz Republic) and «Kazhydromet» (Republic of Kazakhstan), that is, meteorological stations located in the catchment area of the transboundary river Shu, covering the years 1930-2017, climate change was estimated landscape catenas in the catchment area of the Shu river basin, which showed that in the period of instrumental observations (1981–2017) in comparison with the baseline (1941–1960) in the mountain class of landscapes (eluvial facies i) (Theo-Ashuu meteorological station) there was a decrease in average monthly and annual air temperatures, which led to a cooling of the climate, and an increase in precipitation increases the natural moisture content of the natural system. At the same time, starting from the piedmont class of landscapes (transeluvial facies) to the flat subclass of landscapes (subaccarpal facies), an increase in mean monthly and annual air temperatures and a decrease in precipitation led to an increase in the duration of the biological active period and aridization of the climate, which must be taken into account in the complex arrangement of the catchment Shu river basin.

Keywords: climate, catchment, river, basin, change, analysis, assessment, air temperature, precipitation, landscape.

Relevance. Climate is the most important continuously operating environment-forming factor in the natural system, affecting the conditions of habitat formation and human activity. The climatic conditions of the natural system are constantly changing, that is, continuously changing, subject to the complex laws of evolution of the climate system.

The main climate-forming factors of the catchment of river basins are natural zones, which are expressed by meteorological indicators, that is, mainly air temperature and precipitation, which are among the most important geographical characteristics of the natural system, strictly obeying the law of geography - the law of geographical zonality [1, 2].

Purpose of the study is to assess the current climate change in the catchment area of the Shu river basin and its dependence on long-term changes in average annual air temperatures and precipitation as environmental factors.

Objectofstudy – the Shu river originating from Teskey Ala To’o and the Kyrgyz range. The Shu River flows through the territories of Kyrgyzstan and Kazakhstan. The length of the river is 1186 km, of which within Kazakhstan is 800 km. Catchment area is 67 500 km². Main tributaries: right –Chong-Kemin, Yrgayty, Kakpatas; on the left - Alamedin, Aksu, Kuragaty. In the lower reaches, the river flows through the Kazakh territory, forming the northern border of the Moyynkum desert, dries out in the sands only during the flood, falling into the drainless saline lake Akzhaykyn among the extensive salt marshes of the Achykol depression [1, 2].

Materials and research methods. In the work, the long-term information-analytical materials of the «Kyrgyzhydromet» of the Kyrgyz Republic and «Kazgidromet» of the Republic of Kazakhstan on air temperature and precipitation were used, that is, the climatic characteristics were determined according to 5 meteorological stations located in the drainage basin of the Shu river basin covering the formation and storage areas of the hydrological drain [3, 4]. Analysis of climatic characteristics produced using catenary approach which involves geomorphological schematization landscape catenas catchment river Shu basins, characterized in zone mountain class landscapes (eluvial facies), piedmont landscapes subclass (transeluvial facies), piedmont plains subclass (transaccumulative facies) and plain class landscapes (superaquial and subacquial facies) [5, 6].

Research methods were formed on the basis of the level of issues to be solved, that is, to identify and coordinate changes in the studied climatic characteristics, the estimated parameters of linear trends were used [7].

Research results. Forecasting and assessment of climate change in the catchment area of the Shu river basin was carried out on the basis of perennial information and analytical materials from the «Kyrgyzhydromet» of the Kyrgyz Republic and «Kazgidromet«of the Republic of Kazakhstan on air temperature and precipitation in the period 1940-2017, with four stages every 20 years old.The change in air temperature and precipitation for individual periods in comparison with the base period was determined as the difference between the climatic index of the i -th period and the baseline observation period, that is: $\Delta t_i = t_i - t_б$ and $\Delta O_{ci} = O_{ci} - O_{cб}$, where Δt_i, ΔO_{ci} - change in air temperature and precipitation for individual periods; t_i, O_{ci} – air temperature and precipitation of the i-th period; $t_б$, $O_{cб}$ – air temperature and precipitation of the base period.From this position, a statistical description of the state of the climate system and the variability of the characteristics of its components in different periods of time within the framework of the geomorphological schematization of landscape catenas in the catchment area of the Shu river basin, based on the variability of monthly and annual assessments of climatic characteristics (table).

Air temperature change (t_i, °C) and precipitation (O_{ci}, mm) in the drainage basin of the river Shu

Months	Average for 1941-1960 years (base)	Average Climatic indicators during the observation period					
		1961-1980		1981-2000		2001-2017	
		t_i	Δt_i	t_i	Δt_i	t_i	Δt_i
1	2	3	4	5	6	7	8
Average monthly air temperature, °C							
Mountain landscape class (eluvial facies) - Theo-Ashuu weather station							
January	-11,6	-11,6	0,0	-10,9	0,7	-14,7	-3,1
February	-10,8	-10,9	-0,1	-10,7	0,1	-13,7	-2,9
March	-6,8	-6,6	0,2	-7,2	-0,4	-7,8	-1,0
April	-1,5	-1,1	0,4	-1,0	0,4	-2,7	-1,2
May	2,3	2,6	0,3	2,7	0,4	1,7	-0,6
June	6,1	6,3	0,2	6,0	-0,1	5,2	-0,9
July	8,6	8,6	0,0	9,0	0,4	7,4	-1,2
August	8,1	8,7	0,6	9,0	0,6	7,4	-0,7
September	4,5	4,3	-0,2	4,2	-0,3	4,2	-0,3
October	-1,0	-1,2	-0,1	-2,5	-1,5	-2,0	-1,0
November	-6,2	-5,9	0,3	-7,2	-1,0	-7,8	-1,6
December	-9,0	-8,8	0,2	-10,7	-1,7	-12,9	-3,9
Average	-1,4	-1,3	0,1	-1,6	-0,2	-3,0	-1,6
Foothill subclass of landscapes (transeluvial facies) - Baitik weather station							
January	-4,2	-5,5	-1,3	-3,8	0,4	-5,5	-1,3
February	-3,5	-4,9	-1,4	-4,1	-0,6	-5,0	-1,5
March	0,6	0,5	-0,1	-0,3	0,9	2,0	1,4
April	6,3	7,7	1,4	6,7	0,4	7,8	1,5

Continuation of table

1	2	3	4	5	6	7	8
May	11,4	12,2	0,6	11,2	0,2	13,0	1,6
June	15,1	16,7	1,6	15,7	0,6	16,9	1,8
July	18,1	19,5	1,4	18,3	0,2	18,6	0,5
August	17,2	18,1	0,9	17,5	0,3	17,8	0,6
September	12,6	12,9	0,3	12,6	0,0	13,5	0,9
October	6,6	6,7	0,1	6,2	0,4	6,5	-0,1
November	0,4	1,7	1,3	1,5	1,1	1,1	0,7
December	-3,3	-2,4	0,9	-1,9	1,4	-4,4	-1,1
Average	6,4	6,9	0,5	6,6	0,2	6,9	0,5
Foothill plain subclass of landscapes (transaccumulative facies) - Bishkek meteorological station							
January	-3,8	-4,3	-0,5	-3,1	0,7	-2,3	1,5
February	-2,5	-2,9	-0,4	-1,5	1,0	-0,4	2,1
March	3,8	4,6	0,8	4,0	0,2	7,0	3,2
April	11,5	12,8	1,3	12,1	0,6	12,9	1,4
May	17,0	17,0	0,0	16,9	-0,1	18,4	1,4
June	21,0	21,9	0,9	22,2	1,2	23,3	2,3
July	24,2	22,9	-1,3	23,7	-0,5	25,4	1,3
August	22,8	22,9	0,1	24,9	2,1	24,3	1,5
September	17,5	17,6	0,1	18,3	0,8	19,0	1,5
October	10,5	10,6	0,1	10,6	0,1	11,8	1,3
November	1,5	3,8	2,3	3,2	1,7	4,9	3,4
December	-4,0	-1,7	2,3	-0,5	3,5	-1,6	2,4
Average	10,0	10,6	0,6	11,0	1,0	10,6	0,6
Plain subclass of landscapes (superaquial facies) - Tole bi weather station							
January	-9,4	-9,4	0,0	-6,1	3,3	-6,8	1,6
February	-6,3	-4,0	2,3	-4,0	2,3	-3,6	2,7
March	0,4	3,3	2,9	3,3	2,9	6,2	5,8
April	11,1	13,0	1,9	12,7	1,6	13,1	2,0
May	17,3	18,1	0,8	17,9	0,6	19,0	1,7
June	22,1	24,3	1,2	23,3	1,2	24,0	1,9
July	25,0	25,6	0,6	25,5	0,5	25,4	0,4
August	23,5	23,0	0,5	23,8	0,3	23,9	0,4
September	17,9	16,9	-1,0	18,0	0,1	18,0	0,1
October	9,0	9,3	0,3	9,6	0,6	11,7	2,7
November	-1,8	-1,6	0,2	2,0	3,8	2,9	4,7
December	-8,0	-4,5	3,5	-2,4	5,6	-5,1	2,9
Average	8,4	9,5	1,1	10,3	1,9	10,7	2,3
Plain subclass of landscapes (superaquial facies) –Ulanbel weather station							
January	-9,8	-10,6	-0,8	-7,5	2,3	-7,8	2,0
February	-7,5	-9,0	-1,5	-7,2	0,3	-4,9	2,6
March	0,6	0,7	0,1	0,9	0,3	4,0	3,4
April	11,1	12,2	1,1	13,1	2,0	13,0	1,8
May	18,2	19,2	1,0	18,9	0,7	20,1	1,9

Continuation of table

1	2	3	4	5	6	7	8
June	23,3	24,4	1,1	26,1	2,4	25,5	2,2
July	25,8	25,3	-0,5	27,3	1,5	26,9	1,1
August	23,7	23,7	0,0	24,8	1,1	25,4	1,7
September	17,6	17,1	-0,5	17,5	-0,1	17,0	-0,6
October	7,8	8,0	0,2	8,3	0,5	9,8	2,0
November	-2,0	0,4	2,4	0,2	2,2	1,1	3,1
December	-7,2	-6,0	1,2	-5,6	1,6	-6,7	0,5
Average	8,5	8,8	0,3	9,7	1,2	10,3	1,8
Atmospheric precipitation (O_{ci}), mm							
Mountain landscape class (eluvial facies) - Theo-Ashuu weather station							
January	25,0	32,0	7,0	27,0	2,0	23,0	-2,0
February	56,0	38,0	-18,0	21,0	-35,0	40,0	-16,0
March	87,0	59,0	-26,0	45,0	-42,0	54,0	-33,0
April	41,0	72,0	31,0	61,0	20,0	59,0	18,0
May	90,0	87,0	-3,0	85,0	-5,0	81,0	-9,0
June	60,0	88,0	28,0	84,0	24,0	118,0	58,0
July	64,0	67,0	3,0	64,0	0,0	92,0	28,0
August	35,0	45,0	10,0	45,0	10,0	56,0	21,0
September	50,0	43,0	-7,0	54,0	4,0	55,0	-5,0
October	44,0	66,0	22,0	71,0	27,0	63,0	19,0
November	46,0	50,0	4,0	55,0	9,0	49,0	3,0
December	30,0	37,0	7,0	32,0	2,0	51,0	21,0
Annual	628,0	684,0	56,0	644,0	16,0	741,0	113,0
Foothill subclass of landscapes (transeluvial facies) - Baitik weather station							
January	19,0	19,0	0,0	22,0	3,0	24,0	5,0
February	21,0	25,0	4,0	25,0	4,0	28,0	7,0
March	54,0	48,0	-6,0	43,0	-11,0	46,0	-8,0
April	75,0	84,0	9,0	64,0	-11,0	60,0	-15,0
May	84,0	93,0	9,0	65,0	-19,0	62,0	22,0
June	86,0	75,0	-11,0	43,0	-43,0	40,0	-46,0
July	48,0	52,0	4,0	25,0	-23,0	24,0	-24,0
August	29,0	31,0	2,0	15,0	-14,0	16,0	-13,0
September	21,0	26,0	5,0	12,0	-19,0	11,0	-10,0
October	34,0	39,0	5,0	33,0	-1,0	32,0	-2,0
November	33,0	35,0	2,0	33,0	0,0	35,0	2,0
December	21,0	21,0	0,0	25,0	4,0	30,0	9,0
Annual	525,0	548,0	23,0	405,0	20,0	408,0	-117,0
Foothill plain subclass of landscapes (transaccumulative facies) - Bishkek meteorological station							
January	23,0	26,0	3,0	25,0	2,0	32,0	9,0
February	27,0	33,0	6,0	30,0	3,0	40,0	13,0
March	56,0	48,0	-6,0	45,0	-9,0	51,0	5,0
April	69,0	81,0	12,0	66,0	-3,0	77,0	8,0
May	58,0	63,0	5,0	62,0	4,0	65,0	7,0

End of table

1	2	3	4	5	6	7	8
June	43,0	36,0	-7,0	34,0	-9,0	34,0	-9,0
July	16,0	16,0	0,0	21,0	5,0	19,0	3,0
August	9,0	14,0	5,0	13,0	4,0	12,0	3,0
September	14,0	17,0	3,0	20,0	6,0	16,0	2,0
October	31,0	38,0	7,0	41,0	10,0	46,0	15,0
November	35,0	43,0	8,0	44,0	9,0	47,0	12,0
December	27,0	28,0	1,0	32,0	5,0	39,0	12,0
Annual	408,0	443,0	35,0	433,0	25,0	478,0	70,0
Plain subclass of landscapes (superaquial facies) - Tole bi weather station							
January	49,0	19,0	-30,0	21,0	-28,0	29,0	-20,0
February	20,0	17,0	-3,0	21,0	1,0	28,0	8,0
March	63,0	26,0	-37,0	24,0	-39,0	34,0	-29,0
April	42,0	29,0	-17,0	25,0	-17,0	38,0	-4,0
May	50,0	25,0	-25,0	24,0	-26,0	33,0	-17,0
June	22,0	15,0	-7,0	24,0	2,0	23,0	1,0
July	12,0	12,0	0,0	10,0	-2,0	17,0	5,0
August	12,0	9,0	-3,0	5,0	-7,0	10,0	2,0
September	6,0	10,0	4,0	10,0	4,0	9,0	3,0
October	21,0	36,0	15,0	27,0	6,0	39,0	18,0
November	36,0	28,0	-6,0	38,0	2,0	38,0	2,0
December	41,0	42,0	1,0	36,0	-5,0	30,0	-11,0
Annual	374,0	268,0	-106,0	265,0	109,0	328,0	-46,0
Plain subclass of landscapes (superaquial facies) –Ulanbel weather station							
January	13,0	17,0	4,0	19,0	6,0	13,0	0,0
February	13,0	15,0	2,0	19,0	6,0	14,0	1,0
March	26,0	23,0	-3,0	22,0	-4,0	18,0	-8,0
April	22,0	30,0	8,0	25,0	3,0	21,0	-1,0
May	19,0	22,0	3,0	24,0	5,0	26,0	7,0
June	14,0	9,0	-5,0	9,0	-5,0	10,0	-4,0
July	5,0	5,0	0,0	7,0	2,0	3,0	-2,0
August	7,0	3,0	-4,0	2,0	-5,0	6,0	-1,0
September	1,0	4,0	3,0	4,0	3,0	1,0	0,0
October	10,0	19,0	9,0	14,0	4,0	11,0	1,0
November	14,0	24,0	10,0	22,0	8,0	16,0	2,0
December	14,0	24,0	10,0	22,0	8,0	13,0	-1,0
Annual	158,0	195,0	37,0	189,0	31,0	162,0	4,0

Evaluation of seasonal changes was made relative to the base period (1941-1960) according to the weather station Teo-Ashu, located in the mountainous area of the catchment basin of the Shu river basin, and showed that in the period 1961-1980,1981-2000 and 2001-2017 there was a decrease monthly air temperatures up to -1,6°C and a reduction in the duration of the biological active period ($t_i > +5^oC$) (figure 2). At the same time, an increase in precipitation to 113 mm is observed (table).

When assessing the change in the climatic characteristics of the foothill (transeluvial) zone of transformation of the geo-drainage of the Shu river basin's catchment area, long-term information and analytical materials of the Baitik weather station covering the years 1915-2017, which is the Kyrgyz-hydrometstationary network of the Kyrgyz Republic, located in the foothill zone Teskey Ala- Too and Kyrgyz Range, at an altitude of 1590 m (table and figure 2).

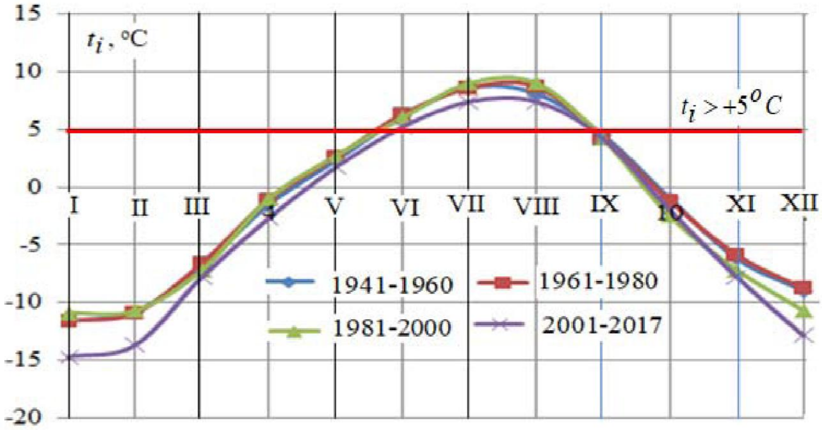

Figure 1 – Comparative seasonal changes in mean monthly air temperature and an estimate of the change in the duration of the biological active period (mountain landscape class (eluvial facies) – Theo-Ashu weather station)

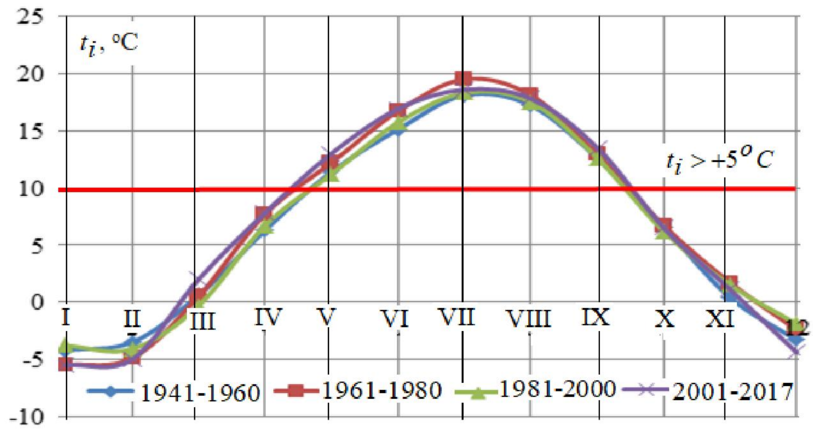

Figure 2 – Comparative seasonal changes in mean monthly air temperature and an estimate of the change in the duration of the biological active period (foothill landscape class (transeluvial facies) – Baitik meteorological station)

Comparison of the average monthly air temperatures for the base period of 1941–1960 over the years 1961–1980, 1981–2000, and 2001–2017 in the piedmont (transeluvial) zone of the Shu river basin, based on information and analytical materials from the Baitik weather station, showed that the largest temperature increase (at all altitudes) was observed in the warmer months -April, May, June, July, August, and September, whereas in the cold period the air temperature drops, and in annual terms the air temperature rises by 0.0-0.5 °C.

At the same time, there is a clear tendency for a decrease in precipitation, that is, in comparison with the base period (525 mm), it decreases to 117.0 mm and there is an increase in the duration of the biological active period 1961-1980 and 1981-2000, however, in the period 2001-2017, a significant reduction in the duration biological active period.

The climatic characteristic of the foothill plain (transaccumulative) catchment area of the Shu river basin, which passes through the Kochkars and Ortogay depressions, which enter the Shuys depression through the Bo'om gorge, is characterized by average annual air temperatures and atmospheric precipitation of the Bishkek weather station, located at an altitude of 756 m (table and figure 3).

Evaluation of seasonal and annual air temperature changes made relative to the base period (1941-1960) based on long-term information and analytical materials of the Bishkek weather station located in the foothill flat landscape subclass (transaccumulative facies) showed that 1961-1980, 1981-2000 and 2001-2017 years, the average monthly and annual air temperature increases by 0.6-1.0 ° C and

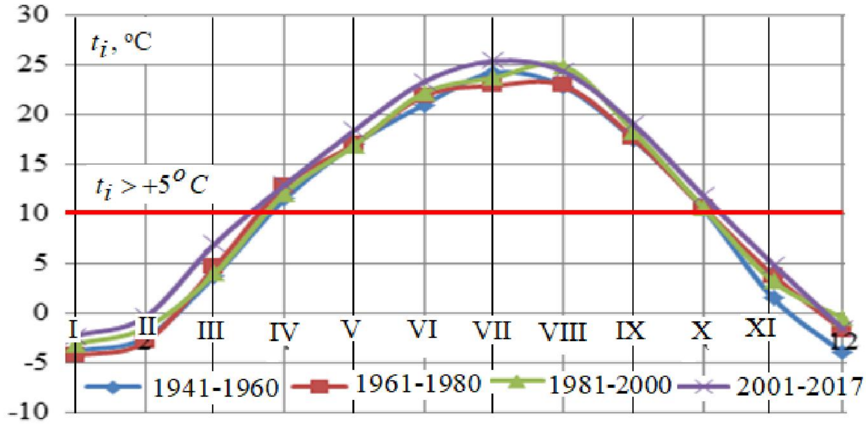

Figure 3 – Comparative seasonal changes in mean monthly air temperature and assessment of changes in the duration of the biological active period (piedmont plain landscape subclass (transaccumulative facies) - Bishkek meteorological station)

precipitation by 25-70 mm are constantly observed. At the same time, a significant increase in the average duration of the biological active period, which leads to arid climate.

The assessment of changes in climatic indicators of a flat (superaqual) zone with a reduced transformation of the geosk of the catchment area of the Shu River basin is represented by the Tole Bi meteorological station located at an altitude of 456 m (table and figure 4).

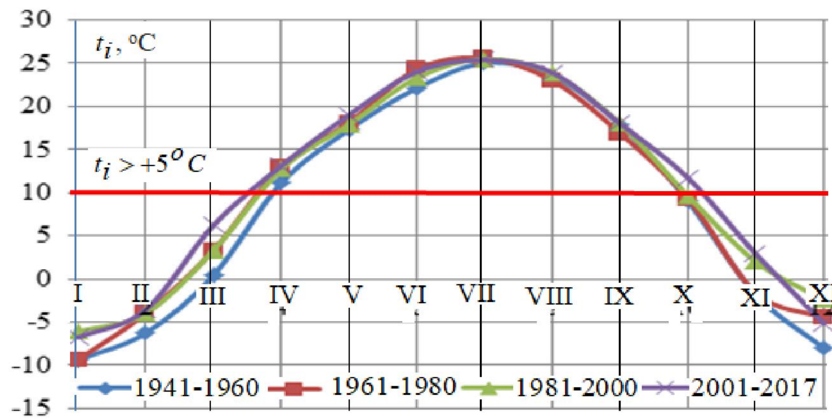

Figure 4 – Comparative seasonal changes in mean monthly air temperature and an estimate of the change in the duration of the biological active period (plain landscape subclass (supersquivic facies) – Tole bi meteorological station)

As can be seen from table 1 and figure 4, a comparative assessment of changes in air temperature made relative to the base period (1941-1960) based on long-term information and analytical materials from the Tole bi weather station showed that 1961-1980, 1981-2000 and 2001-2017 there is significant increase in average monthly air temperatures to 5.0 °C and per annum by 1.1-2.3 °C. At the same time, in comparison with the base period (1941-1960) of precipitation, a period of decrease by 45-106 mm and an increase in the duration of the biological active period are observed.

The climatic characteristic of the flat (subaqual) zone is the accumulation of the geostok of the catchment area of the Shu river basin, which is an intercontinental delta, that is, Gulyaevs (with a total length of about 140-150 km and a width of 50-60 km), Ulanbels (a length of 100 km and a width of 6-8 km) and Kamkalins (about 150 km long and up to 3-25 km wide) are represented by long-term archival materials of the Ulanbel weather station, located at 266.0 m of the land surface (table and figure 5).

As can be seen from Table 1 and Figure 5, there is a significant increase in average annual and monthly air temperatures in comparison with the baseline observation period (1941-1960), however, a sharp decrease in precipitation is not observed, that is, a decrease of 4-35 mm is observed in the period, which led to an increase in the duration of the biological active period.

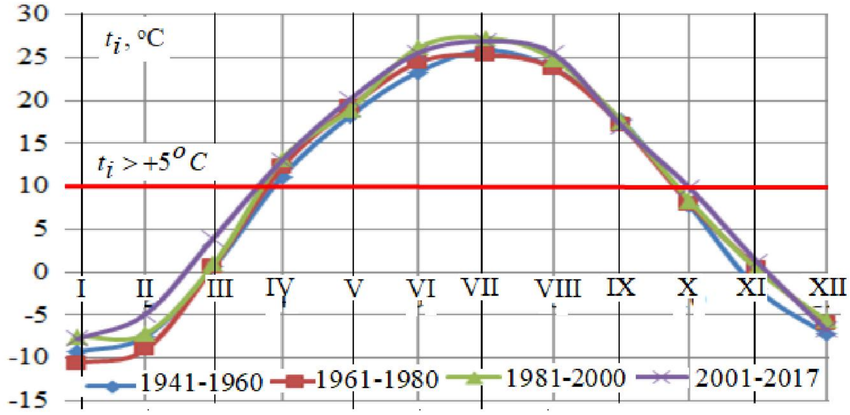

Figure 5 – Comparative seasonal changes in mean monthly air temperature and an estimate of the change in the duration of the biological active period (plainlandscape subclass (superaqual facies) – Ulanbelmeteorological station)

Conclusions. Thus, on average, in the catchment area of the Shu river basin during the instrumental observations (1981-2017) compared with the baseline (1941-1960) in the mountain landscape class (eluvial facies) (Teo-Ashu weather station), there was a decrease in monthly and annual air temperatures, which led to a cooling of the climate and an increase in precipitation is observed, increasing the natural moisture content of the natural system. At the same time, starting from the piedmont class of landscapes (transeluvial facies) to the flat subclass of landscapes (subaccarpal facies), an increase in mean monthly and annual air temperatures and a decrease in precipitation led to an increase in the duration of the biological active period and aridization of the climate, which must be taken into account in the complex arrangement of the catchment Shu river basin.

Ж. С. Мұстафаев, Ә. Т. Қозыкеева, А. М. Камалиев

Қазақ ұлттық аграрлық университеті, Алматы, Қазақстан

ШЕКАРА АРАЛЫҚ ШУ ӨЗЕНІНІҢ АЛАБЫНЫҢ КЛИМАТЫНЫҢ ӨЗГЕРУІ

Аннотация. Шекара аралық Шу өзенінің сужинау алабына орналасқан, метеорологиялық бекттердің, яғни «Қырғызгидромет» (Қырғыз Республикасы) және «Қазгидромет» (Республика Қазақстан) ұжымдары-ның 1930-2017 жылдарды қамтитын көпжылдық ақпараттық-талдау мәліметтері бойынша Шу өзенінің сужинау алабының ландшафттық катендерін геоморфологиялық желілеудің негізінде, климаттың өзгеруіне бағалау жүргізілген, ал ол көрсеткендей, базалық бақалау кезеңін (1941-1960 жж.) қазіргі бақалау кезеңімен (1981-2017 жж.) салыстырған кезде таулы аймақтық ландшафттық (элювиальдық фация) топта (Тео-Ашуу метеорологиялық бекеті) орташа айлық және жылдық ауаның температурасының төмендегені байқалады және бұл климаттың салқындауына әкелді, ал жауын-шашынның көбеюі табиғи жүйенің табиғи ылғал-дылығын арттырады. Сонымен қатар тау етегіндегі ландшафттық (трансэлювиальдық фация) топтардан бастап жазықтық аймақтың ландшафттық (субаквиальдық фация) топтарда орташа айлық және жылдық ауаның температурасының жоғарылауы және жауын-шашынның азаюы, биологиялық белсенді кезеңінің ұзақтығының ұлғайуына және климаттық құрғақшылыққа әкелетін болғандықтан, Шу өзенінің сужинау алабын кешенді үйлестәру кезінде, оны ескеру қажет.

Түйін сөздер: климат, сужинау, өзен, алабы, өзгеру, талдау, бағалау, ауа температурасы, атмосфералық жауын-шашын, ландшафт.

Ж. С. Мустафаев , А. Т. Козыкеева , А.М. Камалиев

Казахский национальный аграрный университет, Алматы, Казахстан

КЛИМАТИЧЕСКИЕ ИЗМЕНЕНИЯ БАССЕЙНА ТРАНСГРАНИЧНОЙ РЕК ИШУ

Аннотация. На основе многолетних информационно-аналитических материалов «Кыргызгидромет» (Кыргызской Республики) и «Казгидромет» (Республики Казахстан), то есть метеорологических станций, расположенных в водосборе бассейна трансграничной реки Шу, охватывающих 1930-2017 годы произведена оценка изменения климата, на основе геоморфологической схематизации ландшафтных катен водосбора речного бассейна Шу, которая показала, что в период инструментальных наблюдений (1981-2017 гг.) в сравнении с базовым (1941-1960 гг.) в горном классе ландшафтов (элювиальная фация) (метеостанция Тео-Ашуу) происходило снижение среднемесячных и годовых температур воздуха, которые приводили к похолоданию климата, и наблюдается увеличение атмосферных осадков повышающие естественную влагообеспеченность природной системы. При этом начиная с предгорного класса ландшафтов (трансэлювиальная фация) до равнинного подкласса ландшафтов (субаквиальная фация) наблюдается повышение среднемесячных и годовых температур воздуха и снижение атмосферных осадков, которые привели к увеличению длительности биологического активного периода и аридизации климата, что необходимо учитывать при комплексном обустройстве водосбора бассейна реки Шу.

Ключевые слова: климат, водосбор, река, бассейн, изменение, анализ, оценка, температура воздуха, атмосферныеосадки, ландшафт.

Information about authors:

Mustafaev Zh. S., Doctor of Technical Sciences, Professor, Kazakh national agrarian university, Almaty, Kazakhstan; z-mustafa@rambler.ru; https://orcid.org/0000-0003-2425-8148

Kozykeeva A. T., Doctor of Technical Sciences, Professor, Kazakh national agrarian university, Almaty, Kazakhstan; aliya.kt@yandex.ru; https://orcid.org/0000-0003-0581-0881

Kamaliyev A. M., PhD student, Kazakh national agrarian university, Almaty, Kazakhstan; kamaliev_1972@mail.ru

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