Conference Paper

Effect of Climate Variability on Agro-climatic Potential of Landscapes of the Chechen Republic

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Abstract

The paper analyzes variability of the agro-climatic parameters of landscapes in the Chechen Republic, which are actively involved in agricultural production. The paper employs statistical and mathematical research methods. Due to climate aridization, agro-climatic conditions were found to deteriorate in 1965--2015 in the plain semi-desert and desert landscapes. Despite the improved thermal and moisture conditions in the plain steppe landscapes, the number of dangerous meteorological phenomena was observed to increase, including those detrimental to agriculture. Owing to the increased period of active vegetation of plants, agro-climatic conditions in the mountain-valley shrub-steppe landscapes of the republic improved compared to those observed in 1931--1960.

1. Introduction

Natural and climatic resources of the Chechen Republic are the most important factor affecting the agricultural specialization of the region. Variability of the climatic resources of individual regions can be attributed to global climate change. Despite a great number of studies on climate change in the Chechen Republic and the North Caucasus [1--10], the consequences of these changes for agriculture of the region are neglected. Therefore, we focused on the assessment of current agro-climatic conditions in the Chechen Republic.

2. Materials and Methods

Climate change results in variability of such climatic parameters as temperature and precipitation. The changes of these parameters are mainly analyzed for individual years, seasons and/or months. For agricultural assessment of thermal resources, air temperature (minimum, average and maximum) is analyzed. G.T. Selyaninov proposed to use the sum of temperatures above 10 °C, that is active temperatures that serve as an indicator of the heat supply during the period of active vegetation of agricultural crops. The sum of effective temperatures is also used to show the need of plants for heat, which is the sum of average daily temperatures calculated on the biological minimum required for the given crop (variety, hybrid) to develop. For example, when calculating the sum of effective temperatures above 10 °C ($\Sigma t > 10°$), 10 °C is subtracted from the average daily temperature per each day, and the residuals are added together. The conditionally accepted vegetation threshold for cold-resistant crops is + 5 °C, for crops of the moderate band + 10 °C, and for thermophilic crops + 15 °C. For natural vegetation of temperate latitudes, air temperature of 5 °C is considered to be the onset of spring development. The sum of effective temperatures in the growing season can be less than 1500° for cold-resistant plants and more than 2000° for thermophilic plants (2000--3000° for cotton and 3500--4000° for rice). The sum of effective temperatures is a practically valuable indicator that differs from the real one. In fact, photosynthesis even in tropical plants occurs at 5--7 °C, and in plants of the temperate zone it can be observed at temperatures below 0 °C.

In addition to the amount of precipitation, various coefficients and indices are used to assess the moisture parameter. The most common coefficients are the hydrothermal coefficient introduced by G.T. Selyaninov and the moisture coefficient proposed by N.N. Ivanova. Hazardous hydrometeorological processes and phenomena affecting agriculture (atmospheric drought, high intensity precipitation, hail, significant wind speeds, etc.) are also analyzed.

The Chechen Republic exhibits different landscapes that are actively involved in agricultural production and cover the North Caucasus: plain semi-desert and desert, plain steppe, and mountain-valley shrub-steppe. Variability of agro-climatic conditions in these landscapes was assessed over the period of 1965--2015. Climate variability analysis was based on data from Naurskaya, Grozny, Gudermes and Shatoi meteorological stations. Indicators of variability of agro-climatic conditions calculated based on data from Naurskaya station are representative for semi-desert and desert landscapes, those obtained from Grozny and Gudermes stations are characteristic of steppe landscapes, and indicators calculated based on data from Shatoi station are characteristic of mountain-valley shrub-steppe landscapes of the republic.

3. Results

Analysis of annual and average monthly air temperature over the period of 1965--2015 based on data from all the stations shows the increased temperature compared to that observed in 1931--1960 (Table 1). Thus, in semi-desert and desert landscapes the annual air temperature increased by 0.4 °C, in steppe landscapes it increased by 0.5 °C, and in mountain-valley shrub-steppe landscapes the temperature rises by 0.3 °C. In the study period, an increase in the average temperature was observed in all months except April as compared to the norm. In April, the difference from the norm is negative and amounts to --0.2 °C in semi-desert and desert landscapes, --0.1 °C in steppe landscapes, and --0.3 °C in mountain-valley shrub-steppe landscapes. Cold months -- November, December, January, February and March -- significantly contributed to the temperature increase.

Analysis of the variability of the sum of active temperatures in 1965--2015 shows that the average value of the sum of active temperatures in semi-desert and desert and steppe landscapes is less than the norm, whereas in mountain-valley shrub-steppe landscapes this value is higher than the norm (Table 2). Thus, the growing period in semi-desert and desert and steppe landscapes shortened by 3 and 2 days, respectively, which can be due to the fact that April (onset of the growing season) exhibited temperature lower than a long-term annual average temperature value. In contrast, the growing season in mountain-valley shrub-steppe landscapes lengthened by 10 days, which can be due to the fact that the maximum air temperature increased in the cold period and lengthened the growing season.

Analysis of critical temperatures over the period of 2005--2015 shows that the maximum temperature in summer has an adverse effect on crops. According to observations of agrometeorologists, since 2010, July and August have been characterized by unfavorable agro-climatic conditions due to dry and hot weather, lack of moisture in soil, and frequent dry winds.

A tendency to the shift of seasons can be observed across all the stations, when the hottest month is not July but August. In 2010 the hottest day was registered on September 1 at all the stations, when air temperature reached 40.0 °C in semi-desert and desert landscapes, 40.0 °C (Grozny) and 41.0 °C (Gudermes) in steppe landscapes, and 37.0 °C in mountain-valley shrub-steppe landscapes. Analysis of the minimum air temperature in 2005--2015 shows that extremely low temperatures "fit" in the calendar winter months. According to agrometeorological observations, damage to crops caused by low temperatures in winter was not observed during the study period. All the stations registered frosts in April, but there were no data on damage to agricultural crops.

Analysis of the variability of precipitation shows an uneven change in that the amount of precipitation in the territory of the Chechen Republic. The amount of precipitation in plain steppe and mountain-valley shrub-steppe landscapes increased by 30 and 24 mm, respectively (Table 3). In plain semi-desert and desert landscapes, the amount of precipitation increased by 7 mm only. The maximum increase in the amount of precipitation was observed in June across all the stations.

In general, the hydrothermal coefficient and the moisture coefficient (Tables 4 and 5) indicate the stability of moisture conditions in the study area. Despite the changed amount of precipitation, the moisture indicators remained virtually unchanged. Thus, the hydrothermal coefficient increased on average by 0.05 in plain steppe landscapes and by 0.03 in mountain-valley shrub-steppe landscapes. In plain semi-desert and desert landscapes, this indicator remained unchanged. The moisture coefficient increased by 0.01 in semi-desert and desert landscapes, by 0.03 in steppe landscapes, whereas in mountain-valley shrub-steppe landscapes this coefficient decreased by 0.02. This can be due to the increased evaporation as a result of the increased sum of active temperatures.

In 2010--2015, 52 hazardous hydrometeorological phenomena were observed in the territory of the Chechen Republic. In 2010--2011, damage to agriculture crops was caused by prolonged dry weather that affected the harvest of spring, tilled and industrial crops. In 2012, frequent intense rains delayed crop harvesting for 12--17 days, which resulted in partial blackening of the ear axes, grain shedding, lodging, and germination of grain in the ear (Table 6).

4. Conclusions

Thus, the study showed various changes in the agro-climatic potential of plain semi-desert and desert, steppe and mountain-valley shrub-steppe landscapes in the territory of the Chechen Republic. Steppe landscapes exhibit a significant increase in air temperature by 0.5 °C and an increase in the amount of precipitation by 10 % in Grozny and by 3.4 % in Gudermes. As a result, the improved thermal and moisture supply in steppe landscapes increased the crop yield. In semi-desert and desert landscapes,

TABLE 1: Air temperature variability in 1965--2015 across the stations[a].

Naurskaya (semi-desert and desert landscapes)													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Min	--12,7	--8,6	--2,2	7,4	14,7	19,3	20,4	20,9	15,3	6,1	--4,8	--8,6	9,3
Max	3,0	4,0	8,8	14,8	20,2	24,9	27,1	28,0	22,2	15,1	8,0	4,7	13,0
Average	--2,1	--1,2	4,1	11,2	17,2	21,8	24,3	23,7	18,5	11,3	5,1	0,3	11,2
Norm	--2,4	--1,9	3,6	11,4	16,8	21,7	24,2	23,3	18,2	10,9	4,5	--0,2	10,8
Difference	0,3	0,7	0,5	--0,2	0,4	0,1	0,1	0,4	0,3	0,4	0,6	0,5	0,4
Grozny (steppe landscapes)													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Min	--12,7	--12,0	--1,8	7,1	14,1	18,8	21,6	20,3	15,3	6,4	--4,6	--7,1	8,6
Max	2,7	4,1	8,8	14,6	21,1	25,0	26,1	28,9	21,4	14,7	7,5	4,3	12,6
Average	--2,3	--1,8	4,0	11,0	16,9	21,4	24,0	23,5	18,4	11,1	4,9	--0,2	10,9
Norm	--3,1	--2,4	3,3	11,1	16,4	20,9	23,9	22,8	18,1	10,6	4,2	--0,6	10,4
Difference	0,8	0,6	0,7	--0,1	0,5	0,5	0,1	0,7	0,3	0,5	0,7	0,4	0,5
Gudermes (steppe landscapes)													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Min	--12,5	--7,6	--1,5	7,2	14,4	19,2	21,8	21,3	15,8	6,7	--4,2	--6,9	9,2
Max	3,1	5,0	9,2	15,4	20,2	25,0	27,9	28,0	22,8	16,2	8,7	5,0	13,3
Average	--1,9	--1,0	4,4	11,3	17,2	22,0	24,8	24,1	19,0	11,8	5,6	0,4	11,5
Norm	--2,3	--1,4	4,0	11,4	16,7	21,7	24,6	23,6	18,7	11,4	4,8	--0,1	11,1
Difference	0,4	0,4	0,4	--0,1	0,5	0,3	0,2	0,5	0,3	0,4	0,8	0,5	0,4
Shatoi (mountain-valley shrub-steppe landscapes)													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Min	--12,4	--8,5	--2,6	6,4	12,0	15,6	16,9	17,2	12,2	4,9	--5,1	--7,2	7,2
Max	1,4	2,5	8,7	14,3	16,8	21,2	23,4	24,7	18,3	17,7	7,3	4,0	11,0
Average	--3,1	--2,1	2,7	9,6	14,4	18,0	20,3	20,0	15,4	9,4	3,5	--1,3	8,9
Norm	--3,6	--2,7	2,1	9,9	14,1	17,8	20,1	19,5	15,1	8,9	3,0	--1,6	8,6
Difference	0,5	0,6	0,6	--0,3	0,3	0,2	0,2	0,5	0,3	0,5	0,5	0,3	0,3

[a]Hereinafter, min is the minimum temperature in 1965--2015; max is the maximum temperature in 1965--2015; average is the average temperature in 1965--2015; norm is the long-term annual average temperature values (reference data); difference is the difference between average and norm values.

TABLE 2: Variability of the period of active vegetation of crops in the Chechen Republic.

	Naurskaya	Grozny	Gudermes	Shatoi
Min	3050	2934	3126	2469
Max	4333	4337	4439	3671
Average	3760	3692	3868	2949
Norm	3854	3772	3903	2647
Difference	-94	--80	--35	301
Vegetation period deviation (days)	--3	--3	--1	+10

the increased air temperature (by 0.4 °C) and the reduced amount of precipitation led

Table 3: Variability of the amount of precipitation in 1965--2015 across the stations.

Naurskaya													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Min	3	4	5	4	8	1	0	1	1	0	5	4	249
Max	81	93	95	120	98	149	224	122	168	106	87	128	686
Average	28	26	28	32	48	55	46	39	34	33	32	34	439
Norm	24	28	30	33	49	48	48	34	33	35	37	33	432
Difference	4	--2	--2	--1	--1	7	--2	5	1	--2	--5	1	7
Grozny													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Min	1	5	3	4	17	1	5	0	4	0	5	5	253
Max	63	56	56	107	122	185	175	159	190	152	104	94	784
Average	22	21	24	37	57	75	57	46	38	38	30	27	472
Norm	21	23	21	32	55	66	57	37	31	29	31	26	429
Difference	1	--2	3	5	2	9	0	9	7	9	--1	1	43
Gudermes													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Min	1	5	4	2	5	2	4	4	2	0	3	5	204
Max	87	79	61	130	196	154	146	158	265	112	114	98	835
Average	29	28	29	38	60	65	47	41	40	40	35	32	485
Norm	26	30	27	35	63	55	46	39	37	38	41	32	469
Difference	3	--2	2	3	--3	10	1	2	3	2	--6	0	16
Shatoi													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Min	2	5	3	8	27	25	17	18	11	0	4	2	466
Max	136	54	114	136	181	198	198	184	186	141	140	129	944
Average	25	23	39	64	102	108	89	77	62	46	32	30	698
Norm	28	24	35	60	99	101	89	76	59	39	32	32	674
Difference	--3	--1	4	4	3	7	0	1	3	7	0	--2	24

Table 4: Variability of the hydrothermal coefficient over the period of 1965--2015.

	Naurskaya	Grozny	Gudermes	Shatoi
Min	0,28	0,32	0,32	0,94
Max	1,37	1,67	1,65	2,77
Average	0,73	0,89	0,83	1,63
Norm	0,73	0,81	0,80	1,60
Difference	0,00	0,08	0,03	0,03

to climate aridization. In mountain-valley shrub-steppe landscapes, the agro-climatic conditions improved compared to those observed in 1931--1960, which was due to an increase in air temperature by 0.3 °C and an increase in the amount of precipitation

Table 5: Variability of the moistening coefficient over the period of 1965--2015.

	Naurskaya	Grozny	Gudermes	Shatoi
Min	0,22	0,23	0,17	0,45
Max	0,70	0,80	0,87	1,16
Average	0,41	0,45	0,45	0,78
Norm	0,40	0,40	0,43	0,81
Difference	0,01	0,05	0,02	-0,02

Table 6: Damage to the agriculture of the Chechen Republic caused by hazardous phenomena (HP) and complex of meteorological phenomena (MPC) in 2010--2015.

Date	Region	Characteristics of HP and MPC	Damage
5.08--21.08.2010	Steppe zones of the republic	MPC (prolonged dry weather), no rains were observed for 16--20 days. The maximum air temperature reached 35--39 °C. The phenomenon lasted 16 days. There was a shortage of soil moisture.	Adverse effect of prolonged dry weather on the harvest of spring, tilled and industrial crops.
1.08--5.08.2011	Northern regions of the republic (semi-desert and desert landscapes)	Atmospheric drought in the northern regions of the Chechen Republic lasted 4 days.	Adverse effect of atmospheric drought on the harvest of late tilled crops.
9.07--16.07.2012	Chechen Republic	The combination of intense, long-lasting rains and overmoistening of soil delayed crop harvesting (MPC). The phenomenon lasted 16 days. The amount of precipitation was 200--380 % of the decade rate and led to overmoistening.	12--17-day delay of crop harvesting caused by frequent intense rain. Partial blackening of the ear axes, grain shedding, lodging, and germination of grain in the ear.

by 24 mm (3.6 %) that led to a 10-day increase in the period of active vegetation of agricultural crops.

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