Dynamics of the main climatic indicators in the Trans-Ural steppe

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Abstract. The paper deals with the impact of climate change on the environment and natural processes in the Trans-Ural steppe zone within the Republic of Bashkortostan. Grade changes in climatic conditions were based on climatology in the traditional trend-analysis of fixed temperature and humidity parameters, application parameters hydrothermal: moisturizing factor GN Vysotsky - N.N. Ivanov, atmospheric moisture index (or dryness index) D.A. Pedia for the period from 1966 to 2015. Long-term observations of the network of meteorological stations were used as data for the analysis. Trends in the increase in air temperature with a slight decrease in the amount of atmospheric precipitation were found. A comprehensive analysis of indicators of heat supply and moisture supply indicates an increase in climate aridity, especially in summer; in winter, the severity of the climate decreases. The revealed tendencies of the main climatic indicators will influence the nature of natural processes in the steppe zone of the Bashkir Trans-Urals. In particular, examples of the influence of changes in climatic conditions on soil erosion processes are considered. It was found that climate changes and the existing system of farming in the steppe zone of the Trans-Urals lead to a decrease in soil resistance to air and water erosion.

1. Introduction

Studies on the problems of global and regional climate change are included in the priority research areas as well as the effects of climate change concern many natural processes and certain sectors of the economy.

Problems of global and regional climate changes are reflected in the 5 'assessment report' prepared by Intergovernmental Panel on Climate Change [1] and the two "Roshydromet assessment report on climate change and their impact on the territory of the Russian Federation" [2].

Regional climatic changes in some cases can be more pronounced than global ones as a whole. In addition, within the period of instrumental hydrometeorological observations, shorter periods of time are possible, in which the trends of climatic values will have a multidirectional course or speed.

Climate variability affects the natural environment and natural processes. In particular, in this study, the authors consider changes in climatic conditions and aspects of the impact of their changes on erosion processes in the steppe zone of the Trans-Urals within the territory of the Republic of Bashkortostan.
2. Statement of the problem
Steppe zone of the Bashkir Trans-Urals (SBZ) is not only an arid region, but its degree of aridity, and the shift of its borders further north (when compared with the steppe Urals) depends on the influence of the leeward position of the eastern slopes of the Southern Urals. Because of this, in terms of climate SBZ begin to appear sharply continental features.

The present study comes to the assessment of current climate change in SBZ as a whole, and in some seasons of the year.

As a consequence of the impact of climate change, the authors examine some soil processes, in particular, the main feature of erosion under such conditions is the prevalence of the air above the water erosion due to the increase of the intensity of evaporation of moisture from the soil surface and its withers. Changes in the regional climate will undoubtedly have an impact on the increase in the area of eroded land and the intensification of erosion processes [3].

3. Materials and Methods
As a database, we used long-term observations at meteorological stations of the network of the Bashkir Directorate for Hydrometeorology and Environmental Monitoring in the period from 1966 to 2015. (Baymak and Akyar).

When analyzing the temporal variability of climatic values, their basic characteristics were calculated: the average for meteorological stations and for the region as a whole (climatic norms for the periods 1966-2015 and 1981-2010), standard deviation (SD); revealed the maximum and minimum values of the quantities.

The assessment of regional climate changes in the SBZ was carried out using trend analysis. The value of the coefficient of determination $R^2$ was used to assess the contribution of the linear trend to the variability of indicators. The reliability of the results was assessed using Fisher's and Student's tests.

For assessing the state of any particular year or period, an indicator - an anomaly, which was calculated for the air temperature and the amount of precipitation, has a good degree of information content. In the calculations of anomalies, the base rate of the period 1981-2010 was used.

The widely used methods were used as applied hydrothermal indicators - the Vysotsky-Ivanov moisture coefficient and the atmospheric moisture (or dryness) index of D.A. Pedya [4].

The analysis of the impact on erosion processes is based on changes in the morphological, agrophysical and agrochemical properties of soils.

4. Results and Discussion
Climatic characteristics presented in Tables 1 and 2 show that continental climate conditions are formed in the SBZ.

The average annual air temperature is 2.9°C for the period 1966-2015, and 3.2°C for the period 1981-2010. Stable statistically significant trends were revealed in both periods: the slope coefficients of linear trends (CLT) were 0.47°C/10 years and 0.43°C/10 years, respectively (Figure 1). The highest average annual temperatures in the region were observed in 2001 at the Baimak meteorological station (5.3°C) and in 2015 at the Akyar meteorological station (5.5°C).

The average air temperatures increased in the central months of the cold and warm periods - January and July (table 1). The highest rate of temperature rise was found in January for the entire period under consideration (0.69°C/10 years). In the baseline operational period, negative trends in January temperature (-0.34°C/10 years) were revealed. This is explained by the fact that in the 1980s an active phase of global warming began [5,6].

The temperature growth has a smaller rate in July: 0.26°C/10 years period 1966-2015. Insignificant temperature trends this month are found in the period 1981-2010.

Temporal variability, which is characterized through the values of the standard deviation, is greatest in winter, which is explained by the greatest variation in January temperature. Differences between maximum and minimum temperatures are also related to this. In January, the difference between these indicators is 18.5°C, in July - 7.7°C. It was revealed that the value of the standard deviation for the base operational period decreased.
Table 1. Main indicators of the temperature regime and its changes.

| Meteorological quantity | Meteorological station | 1966-2015 Norm | SD | CLT | 1966-2015 Norm | SD | CLT | Maximum | Minimum |
|-------------------------|------------------------|----------------|----|----|----------------|----|----|---------|---------|
| January temperature     | Baimak                | -14.5          | 3.6 | 0.67 | -13.2          | 3.0 | -0.28 | -6.7    | -24.0   |
|                         | Akyar                  | -14.7          | 4.0 | 0.72 | -13.3          | 3.5 | -0.40 | -5.4    | -25.3   |
|                         | Average               | -14.6          | 3.8 | 0.69 | -13.3          | 3.2 | -0.34 | -6.1    | -24.7   |
| July temperature        | Baimak                | 18.9           | 1.9 | 0.31 | 19.0           | 1.9 | -0.03 | 22.5    | 15.0    |
|                         | Akyar                  | 20.2           | 1.9 | 0.25 | 20.4           | 1.9 | -0.03 | 24.2    | 16.0    |
|                         | Average               | 19.6           | 1.9 | 0.26 | 19.7           | 1.9 | -0.03 | 23.2    | 15.5    |
| Average annual temperature | Baimak           | 2.5            | 1.1 | 0.43 b | 2.8            | 0.9 | 0.43 b | 5.3     | -0.01   |
|                         | Akyar                  | 3.3            | 1.1 | 0.47 b | 3.5            | 1.0 | 0.41 b | 5.5     | 0.7     |
|                         | Average               | 2.9            | 1.1 | 0.47 b | 3.2            | 0.9 | 0.42 b | 5.5     | 0.3     |

a °C/10 years.

b a statistically significant trend at the 95% confidence level.

The annual amount of atmospheric precipitation is 274 mm/year. Over the entire studied period, it has a slight tendency to decrease (figure 1), and a more significant negative trend (-12.5 mm/10 years) was found in the base operational period. In the last period, trends with a similar sign in both cold and warm seasons were revealed in the SBZ region (table 2).

Figure 1. Long-term variation of the average annual air temperature and the amount of precipitation

Figure 2. Long-term variation of the moisture coefficient and the Pedya aridity index
When comparing rates of change rainfall amounts of warm and cold periods in the latter they changed substantially (-10.5 mm/10 years).

Table 2. Main indicators of the humidification regime and its changes.

| Meteorological quantity | Meteorological station | 1966-2015 | 1981-2010 | Maxima | Minima |
|-------------------------|------------------------|-----------|-----------|--------|--------|
|                         | Norm | SD | CLT<sup>a</sup> | Norm | SD | CLT<sup>a</sup> |        |        |
| The amount of precipitation during the cold period | Baimak | 95 | 26 | 1.8 | 95 | 21 | 2.8 | 156 | 41 |
| | Akyar | 104 | 30 | 2.8 | 107 | 26 | -6.7 | 166 | 39 |
| | Average | 141 | 35 | 2.6 | 144 | 30 | -2.0 | 206 | 56 |
| The amount of precipitation during the warm period | Baimak | 248 | 78 | -0.2 | 247 | 81 | -16.0 | 441 | 88 |
| | Akyar | 104 | 27 | 3.6 | 108 | 27 | -51.0 | 160 | 39 |
| | Average | 233 | 59 | -1.1 | 236 | 62 | -10.5 | 395 | 105 |
| Annual precipitation | Baimak | 344 | 89 | 1.6 | 342 | 89 | -13.2 | 557 | 166 |
| | Akyar | 209 | 50 | 6.5 | 214 | 48 | -11.8 | 322 | 109 |
| | Average | 274 | 56 | 1.5 | 278 | 54 | -12.5 | 602 | 216 |
| Humidification coefficient (HC) | Baimak | 0.54 | 0.17 | -0.01 | 0.54 | 0.18 | -0.01 | 1.08 | 0.24 |
| | Akyar | 0.46 | 0.17 | -0.02 | 0.47 | 0.20 | -0.01 | 1.15 | 0.13 |
| | Average | 0.49 | 0.14 | -0.02 | 0.51 | 0.15 | -0.04 | 0.92 | 0.24 |
| Dryness index | Baimak | - | 1.48 | 0.38<sup>b</sup> | - | 1.43 | 0.53 | 3.07 | -3.40 |
| Pedya (S) | Akyar | - | 1.51 | 0.48<sup>b</sup> | - | 1.39 | 0.64 | 3.71 | -3.29 |
| | Average | - | 1.45 | 0.45<sup>b</sup> | - | 1.36 | 0.59 | 3.39 | -3.35 |

<sup>a</sup> mm/10 years for atmospheric precipitation and unit/10 years for the moisture coefficient, the Pedya index.

<sup>b</sup> a statistically significant trend at the 95% confidence level.

It was revealed that the temporal variability of the amount of precipitation during the cold period has decreased, in a warm and annual periods - increased. The amount of the warm season rainfall makes the greatest contribution to "annual" trend. Consequently, summer precipitation becomes more erratic.

Derived applied indicators of heat supply and moisture supply are the Vysotsky-Ivanov moisture coefficient and the atmospheric moisture (or dryness) index of D.A. Pedia.

The moisture coefficient was 0.49 and 0.51 for different analyzed periods, which refers the region to semi-dry (semiarid) conditions. The trends of this indicator are negative (figure 2).

The Pedya index tends to increase, which indicates an increase in drier conditions. The lowest value of the Pedya index was noted in the cold 1969 and amounted to -3.35 (cold and dry conditions, winters with little snow), the highest in 1975, 3.39 (severe drought conditions).

Changes in climatic conditions informative show hydrothermal anomaly values. The calculated data characterizing the structure of years with varying degrees of anomalies are presented in table 3.

The biggest change in the structure of age was found in mean annual air temperature. In the period 1981-2010, the significantly reduced number of years, relating to the criteria of "very cold" and "cold"; the years of the criterion "Very warm" also decreased.

The structure of the anomalies of annual precipitation shows that there is a decrease of abnormal years by increasing the years with values within normal limits.

The revealed tendencies of the main climatic indicators will influence the nature of erosion processes in the SBZ. Against the backdrop of land use systems and a high degree of tilled areas, the use of moldboard plowing, and reducing the share of organic fertilizers resulted in deterioration of basic soil properties. First of all, agronomically valuable soil aggregates are destroyed, the content of
organic matter and nutrients decreases, which ultimately contributes to an increase in the intensity of moisture evaporation from the soil surface, its drying and a decrease in resistance to erosion processes.

Table 3. Structure of anomalous years according to the main hydrothermal indicators.

| Anomaly                  | 1966-2015 | 1981-2010 |
|--------------------------|-----------|-----------|
| Average annual air       | 30        | 23        |
| temperature              |           |           |
| Very cold year           | 8         | 3         |
| Cold year                |           |           |
| Within normal limits     | 16        | 40        |
| Warm year                | 18        | 17        |
| Very warm year           | 28        | 17        |
| The amount of precipitation |       |           |
| Dry year                 | 18        | 17        |
| Within normal limits     | 68        | 70        |
| Humidified year          | 14        | 13        |
| Dryness index            | 8         | 10        |
| Cold and dry year        |           |           |
| Within normal limits     | 80        | 80        |
| Warm and humid year      | 12        | 10        |

*data are given as a percentage of the number of years in the period.

The above mechanisms occurring in the soil cover of the SBZ were studied in detail in the early studies of the authors of this work [9, 10], and in the grant scientific project funded by the Volkswagen Foundation (a comprehensive study "Consequences of land use and climate change for landscape water, soil degradation and rehabilitation in the forest steppe zone of Bashkortostan" in 2010-2012) [3].

5. Conclusion

In the course of this study, the changes in the climatic conditions of the studied region were confirmed, presented in a number of works [3, 5, 6, 7, 8].

In the thermal regime, significant warming is recorded in all seasons. The average annual air temperature has a statistically significant trend. The amount of atmospheric precipitation has a certain tendency to decrease, the highest rate of decrease was found in the warm (summer) period. Comprehensive indicators of heat supply and moisture supply indicate an increase in aridity, especially in the warm season.

These changes in the desert climate within Bashkir Trans-Urals resulted in farming system emergence and lead to a decrease in soil resistance to air and water erosion.

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