Economic Impact of Climate Change in the Midland of Russia

V N Ozherelev¹, M V Ozhereleva², A V Dyachenko¹

¹Bryansk State Agrarian University, 243365, Bryansk region, v. Kokino, st Sovyetskaya, 2a, RF
²Bryansk State Technical University, 241035, Bryansk, st. 50 let Oktyabrya, 7, RF

E-mail: marinavo@inbox.ru, vicoz@bk.ru

Abstract. The article discusses the global climate warming impact on the most important agro-climatic parameters of the southern half of the Russian Federation European part. It has been established that in recent years a stable zone of moisture deficiency, stretching as a strip from Bryansk to the border of the Chelyabinsk region with Kazakhstan, has formed. At the same time, the most stable moisture deficit in summer is observed in the Bryansk region. For 2014-2016 the amount of moisture deficit according to the Bryansk State Agrarian University meteorological station was 47%. Due to the increasing climate aridity, the Bryansk region is approaching in agroclimatic parameters to traditionally grain regions. The increase in the amount of active temperatures turns its territory into an agro-climatic analogue of the northwestern part of the United States Corn Belt. A significant warming of winter, as well as a reduction in stable snow cover period, increases the beef cattle breeding competitiveness. At the same time, the cultivation of berries, raspberries in particular, becomes impossible without artificial irrigation.

1. Introduction

The Earth's climate is a self-regulating dynamic system that functions according to certain laws and algorithms. This algorithm is initially based on variability, the frequency of which is due to the precession of the planet's rotation axis. As a result, the amount of solar energy absorbed by its surface changes which causes the most serious changes, up to the occurrence of ice ages [1].

It is generally accepted that the complete revolution duration of the rotation axis around the precession center is 22 thousand years, however, within this longest period there are also less scale periodicity. So, in addition to the actual ice ages, it is customary to single out small ice ages, which mankind has already been able to record in written sources.

It should be borne in mind that the processes occurring on the planet surface are significantly influenced by geological processes in its depths. In particular, during large volcanic eruptions, the amount of ash emitted into the atmosphere is so great that it becomes a noticeable obstacle to sunlight. As a result, the climate changes towards a cold snap, which can last for several decades.

In the last hundred years, human activity has taken on a geological scale. Emissions from industrial enterprises have become comparable in negative consequences with the results of volcanic activity. Most scientists have a negative attitude to atmospheric pollution with carbon dioxide, attributing to this phenomenon a noticeable warming of the planet's climate, characteristic of the last 70 years. On the other hand, there is a version that the anthropogenic impact on the climate will allow the Earth to bypass the next Little Ice Age, which the planet was supposed to enter at the turn of the century [1].
At present, it is difficult to assess the balance of positive and negative from the fact that the Little Ice Age may not happen. The negative should be attributed to the fact that with the current climate trend some territories will be flooded, since by 2050 the world ocean level will have risen by 0.3 m. In an alternative scenario, Canada, Southern Siberia and Northern Kazakhstan would have to turn into a barren forest-tundra for several centuries.

Global problems and transformations have a significant impact on our lives. Most likely, we will not be able to predict the situation for a century ahead, but it seems to be a real scientific task to track the emerging climatic trends and assess their consequences for economic activity, in particular, for the specialization of agriculture in the framework of the coming decades.

2. Problem statement
The strategy for the agricultural production location is based on traditional ideas about the regional climate parameters, formed as a result of long-term observations [2-4]. Meanwhile, the situation is changing so radically that the once exclusively "potato" Bryansk region in the last decades has acquired a significant grain specialization.

The problem of climate transformation is being monitored by many scientists, both from the point of view of regional aspects and sectoral ones. Thus, the scientists of Voronezh State Agrarian University studied in detail the climatic processes characteristic of the Voronezh Region and the Central Chernozemic Region as a whole. They identify the increasing water shortage as the main problem [5].

It should be noted that the deficit of water resources at the beginning of 2020 in the southern half of the Central Federal District and in the Southern Federal District has noticeably increased. So, on the Desna River (in the Chernigov section) at the end of May, the water level turned out to be the minimum for 140 years [6]. The Seversky Donets which is the only source of fresh water for Belgorod, Kharkov and Donbass practically dried up in the upper reaches. The water level in the Tsimlyansk reservoir is at a critical point, the reserves of which may not be enough to ensure sustainable navigation on the lower Don and Volgodonsk canal.

This problem is not accidental for the region under consideration. Tracking the moisture degree in the territory of the main grain-producing regions (since 1936), scientists from the Institute of Geography of the Russian Academy of Sciences revealed that after 1990 the trend of this most important agro-climatic parameter became steadily downward [7]. In this regard, it is expedient to assess the prospects for the Bryansk region agro-industrial complex transformation under the moisture deficit influence, as one of the main factors of farmland productivity.

3. Material and methods
Long-term data from the Bryansk State Agrarian University meteorological station, personal observations of the author, and data from annual reports of Roshydromet were used in the study. The data was processed according to standard programs.

4. Results and Discussion
In order to unambiguously assess the situation, one should first consider separately the trends in temperature and precipitation. For the agricultural sector of the economy, the most important indicator is the amount of active temperatures, which, to a large extent, determines the specialization of agriculture in the region. It was found that the growth rate of the amount of active temperatures in the European part of Russia in recent years is 1.03 [8, 9]. As a result, over the past 30 years there have been significant changes that have caused a noticeable drift of the traditional boundaries of climatic zones in the northern direction (Table 1).
Table 1. Change in the amount of active temperatures in Ukraine, Belarus and the European part of Russia.

| Regions                                      | Amount of active temperatures, °C |
|----------------------------------------------|-----------------------------------|
|                                             | Perennial | Average | Current |
| St. Petersburg, Berezni, Vologda, Cherepovets| 1650       | 2100    | 2200    | 1800    |
| Perm, Glazov, Krasnokamsk, Kirov             | 1700       | 2000    | 2300    | 1900    |
| Kalyazin, Uglich, Yaroslav, Kostroma         | 1850       | 2100    | 2400    | 2000    |
| Yekaterinburg, Izhevsk, Ivanovo, N.-Novgorod| 1900       | 2300    | 2500    | 2100    |
| Moscow, Kazan, Chelyabinsk                   | 2000       | 2400    | 2600    | 2200    |
| Alatyr, Smolensk, Ryazan, Kaluga             | 2100       | 2500    | 2700    | 2300    |
| Bryansk, Penza, Samara, Bobruisk, Syzran     | 2200       | 2600    | 3000    | 2400    |
| Michurinsk, Oryol, Tambov, Lipetsk, Yelets, Gomel | 2300       | 2700    | 3000    | 2500    |
| Voronezh, Saratov, Kursk, St. Oskol, Chernigov| 2500       | 2800    | 3100    | 2600    |
| Belgorod, Kamyshin, Lviv, Kiev, Sumy         | 2600       | 2900    | 3100    | 2700    |
| Kantemirovka, Poltava, Cherkasy, Vinnytsia   | 2800       | 3000    | 3200    | 2800    |
| Volgograd, Lugansk, Dnepropetrovsk           | 3000       | 3100    | 3500    | 2900    |
| Rostov-on-Don, Nikopol, Chisinau             | 3150       | 3300    | 3600    | 3100    |
| Kherson, Nikolaev, Melitopol                 | 3300       | 3400    | 3700    | 3200    |
| Kerch, Tikhoretsk, Stavropol                 | 3400       | 3600    | 3800    | 3300    |

An increase in the amount of active temperatures correlates with an increase in average daily temperatures. So, in Bryansk for 20 years (from 1991 to 2010) the average annual temperature increased from + 5.8°C to + 7.3°C. An inevitable consequence of climate warming is an increase in moisture evaporation, therefore, in order to maintain a constant degree of moisture, the amount of precipitation must also increase in parallel with the temperature. The analysis of the situation in the zone under consideration over the past seven years indicates that both annual and summer precipitation as a rule do not even reach the traditional (long-term) level (Table 2). Thus, the annual amount of precipitation in the Central Federal District for four years out of seven was significantly lower than the multi-year level, and the amount of summer precipitation - for five years out of seven.

When considering climatic problems, it should be borne in mind that federal districts in Russia were formed without taking into account the natural boundaries of climatic zones. Thus, in the Southern Federal District and the North Caucasus Federal District, the degree of interregional climatic differentiation is significantly distorted by the Caucasus Mountains, as rainstorm are possible there, while the steppe part of the territory suffers from drought. The situation is similar in the Central Federal District. In recent years, the strip of rains (the trajectory of cyclones) runs, as a rule, to the north of the “Smolensk-Kaluga” line. Thus, the Bryansk region falls into a zone of stable moisture deficit, especially in summer [10-17]. Over the course of several years, this arid strip has formed along the corresponding parallel to the border of the Chelyabinsk region with Kazakhstan [16, 17]. In some years, it reached only the western foothills of the Ural or Voronezh, but almost every year in the Bryansk region as a whole or in a significant part of it in the summer there is a steady deficit of moisture.
Table 2. Precipitation in the southern half of the European part of Russia in 2013 - 2019. [10-17].

| Years, federal district | The amount of precipitation, % of long-term values | Per year | Summer |
|-------------------------|--------------------------------------------------|---------|--------|
|                         |                                                  |         |        |
| CFD                     | 112                                               | 89      |        |
| SFD                     | 110                                               | 109     |        |
| NCFD                    | 109                                               | 102     |        |
| CFD                     | 80                                                | 66*     |        |
|                         |                                                  |         |        |
| SFD                     | н/д                                              | н/д     |        |
| NCFD                    | н/д                                              | н/д     |        |
| CFD                     | 95                                                | 90      |        |
|                         |                                                  |         |        |
| SFD                     | 93                                                | 73      |        |
| NCFD                    | 97                                                | 84      |        |
| CFD                     | 112                                               | 132     |        |
|                         |                                                  |         |        |
| SFD                     | 117                                               | 103     |        |
| NCFD                    | 114                                               | 108     |        |
| CFD                     | 116                                               | 108     |        |
|                         |                                                  |         |        |
| SFD                     | 100                                               | 79      |        |
| NCFD                    | 106                                               | 100     |        |
| CFD                     | 94                                                | 85      |        |
|                         |                                                  |         |        |
| SFD                     | 98                                                | 81      |        |
| NCFD                    | 100                                               | 85      |        |
| CFD                     | 97                                                | 92      |        |
|                         |                                                  |         |        |
| SFD                     | 92                                                | 93      |        |
| NCFD                    | 84                                                | 69      |        |

* - Moscow

Table 3. Variation of climatic indicators in the village of Kokino (Bryansk region) for 2014 – 2016.

| Years | Months | Climate indicators | Average monthly temperature, °C | Relative to the average long-term level, % | Monthly precipitation, mm | Relative to the average long-term level, % |
|-------|--------|--------------------|---------------------------------|-------------------------------------------|--------------------------|-------------------------------------------|
| 2014  | June   | Average value for nine months | 103                             | -                                         | 54                       | -                                         |
|       | July   | Average long-term value     | 17,1                            | -                                         | 54                       | -                                         |
|       | August |                     | 18,9                            | -                                         | 87                       | -                                         |
| 2015  | June   |                     | 17,4                            | 97                                        | 82,7                     | 95                                        |
|       | July   |                     | 18,2                            | 96                                        | 82,7                     | 95                                        |
|       | August |                     | 18                              | 103                                       | 8,4                      | 12                                        |
| 2016  | June   |                     | 17,7                            | 104                                       | 53,7                     | 67                                        |
|       | July   |                     | 19,9                            | 105                                       | 59                       | 68                                        |
|       | August |                     | 18,7                            | 107                                       | 28,4                     | 41                                        |
In connection with the presence of such a negative phenomenon, the data of the meteorological station of the Bryansk GAU (the village of Kokino, Vygonichsky region) were analyzed in detail. At the same time, the analysis (Table 3) was carried out in relation to the needs of the production of raspberries, which are most sensitive even to a short-term moisture deficit [18-20].

The data given in Table 3 indicate that, for example, during three (relatively favorable in terms of weather conditions) years (2014-2016), nevertheless, the deficit in the monthly amount of precipitation in summer amounted to 46% on average from their long-term level. At the same time, the mean value of the average monthly temperature in the summer months increased by 3%, which causes a proportional increase in moisture evaporation. In extreme weather years (for example, in 2010) and even in some months of 2014-2016 moisture deficit on raspberry plantations could increase up to 60 - 70%. In this regard, efficient production of raspberries without a system of a plantation artificial irrigation in the Bryansk region is impossible [19].

5. Conclusions
1. Climate warming has a stable, systemic character therefore it is necessary to make appropriate adjustments to the agricultural production location and specialization. In particular, it should be borne in mind that in terms of the territory moistening degree, the Bryansk region approached the indicators of traditionally grain regions, and in terms of the amount of active temperatures - the northwestern part of the Corn Belt of America.
2. A significant winter warming, as well as a decrease in the snow cover height and the duration of the period of its stable occurrence, improves the conditions for beef cattle winter grazing, which brings this direction of cattle breeding closer to dairy specialization of animal husbandry, traditional for the Bryansk region [21].
3. In the conditions of increasing climate aridity, commercial berry growing (strawberries, raspberries) is only possible if artificial irrigation is available.

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