Climatic Resources of Organic Farming in Siberia (From Wheat Data)

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Abstract. The study assesses an impact of climate on the development of organic farming (wheat) in Siberian regions over the short and medium terms. To verify the results obtained, a comparative data analysis is carried out for six grain-producing regions in the Asian and European parts of Russia. A correlation analysis of eleven climatic factors influencing grain production efficiency has confirmed the premise about climate change. The variation range in the number of days when an air temperature exceeds 15°C is 43 and 48 for the Omsk and Rostov regions accordingly. The “0–5°C temperature range” is the most risk-related of the considered indicators as it has a detrimental effect on crop plants during the growing season. Its maximum was reached in Rostov (348 days); no cold winter season was observed in Krasnodar during the study period; the extremes in the Asian part of Russia (Tyumen and Omsk) were 202 and 226 days; while the values for Voronezh and Belgorod were approximately the same, ranging 228–302 days. The earliest date of permanent snow cover destruction was recorded on February, 20 (Belgorod and Voronezh), the latest – on April, 18 (Tyumen). Similarly, the earliest formation of permanent snow cover was recorded on October, 14 (Omsk), and the latest – on December, 13 (Voronezh). Overall, Siberian regions have the least favorable climatic situation: in view of the local climate pattern and the weather conditions for every spring, additional, short-term (3-5 years) and medium-term (5-10 years) investments are necessary to get new varieties of spring grains, replenish the seed fund of winter crops, renew sowing and harvesting equipment, and cover the cost of fuel and other consumables.

INTRODUCTION

Nowadays, sustainable development of organic farming tightly depends on climate change factors [1; 2]. For instance, FAO concludes [3] that temperate zones (which certainly include Siberia) will become the optimal regions for grain production in the future.

Numerous studies show that the impact and consequences of climate change are characterized by specific features across regions [4; 5; 6]. It will be necessary to adapt to the prevailing conditions in order to grow crops in different parts of the world. In more arid regions of the Earth, the amount of precipitation will decrease and the average air temperature will increase, as a consequence, diminishing grain crop yields. Conversely, climate change may have a beneficial effect on the growing season of crops in temperate countries. It should be noted separately that a number of preventive nationwide measures may be required to increase grain production capacity in a changing climate [7; 8; 9].
Predictive-and-scenario studies based on Russian domestic data also foresee declining trends for the grain-producing areas of the European part of Russia and an improved performance in the Asian part of Russia [2; 4; 10].

The study focuses on assessing the impact of climate on the development of organic farming (wheat) in Siberia in the short and medium terms. To verify the obtained results, a comparative analysis of data from regions in the Asian and European parts of Russia is carried out.

**MATERIALS AND METHODS**

The research methodology includes a retrospective assessment of natural-and-climatic factors influencing grain crops production. The data sources are weather stations of the Russian Federal Service on Hydrometeorology and Monitoring of the Environment (Roshydromet) in the European and Asian parts of Russia. For a comparative analysis of the dynamics of climatic conditions in the European and Asian parts of Russia, the following grain-producing regions were considered: Tyumen, Omsk, Voronezh, Belgorod, Rostov-on-Don, and Krasnodar.

Tendencies and trends were identified with nonlinear dynamics. Graphical Microsoft Excel tools were used. The study period is 2016–2020. The so-called sparklines (infolines) displaying changes in the analyzed data range were used for convenient visualization.

**RESULTS AND DISCUSSION**

Let’s introduce notations for the following characteristics of climatic conditions for grain production $a_i$:

- $a_1$ – effective heat sum (> 10°C);
- $a_2$ – period duration (number of days > 0°C);
- $a_3$ – period duration (number of days > 5°C);
- $a_4$ – period duration (number of days > 10°C);
- $a_5$ – period duration (number of days > 15°C);
- $a_6$ – total precipitation, mm (over V-IX);
- $a_7$ – hydrothermal factor (over V-IX);
- $a_8$ – mean air temperature in July, °C;
- $a_9$ – mean air temperature in January, °C;
- $a_{10}$ – date of permanent snow cover destruction;
- $a_{11}$ – date of permanent snow cover formation.

Figure 1 gives cumulative data on natural-and-climatic factors $a_1$–$a_9$. “Sparkline” graphically demonstrates the changes in climatic patterns throughout 2016 - 2020 where the maximum sample values are shown in green and the minimum markers – in red.

In 2018, the minimum $a_1$ for grain-producing areas was observed in Omsk and Tyumen, and the maximum – in Krasnodar, Voronezh and Rostov-on-Don.
The minimum $a_9$ for all areas was registered in 2016. The maximum value (mean air temperature in January, °C) was reached in 2020 for all areas except Belgorod (2019).

Figure 2 presents $a_2$–$a_5$ trends

During the study period, the maximum number of warm days recorded for regions in different parts of Russia was in 2020. The coldest years are 2018 for the Omsk region and 2016 for the Rostov region. The climate change premise is demonstrated and confirmed by both graphs (an increase in the number of warm days influencing the economic indicators of grain production). The variation range in the number of days with an air temperature exceeding 15°C is 43 and 48 for the Omsk and Rostov regions accordingly.
Correlation analysis of natural-and-climatic factors $a_1$–$a_9$, influencing the economic indicators of grain production, is of practical interest (Fig. 3).

Regardless, the indicators $a_1$–$a_5$, $a_8$–$a_9$ are closely related since they belong to the temperature profile group, as evidenced by a high dependence therebetween. Studying $a_6$, $a_7$ factors – a group of precipitation indicators, is of practical interest. Fig. 3b demonstrates a weak relation between this group and $a_3$ – period duration (number of days $>5^\circ C$). A moderate dependence is also observed in Voronezh, against a high dependence in Belgorod and a very high dependence in Krasnodar. This group of indicators has no relations with the temperature regime in Tyumen and Omsk.

Weak relations (the correlation coefficient ranges 0.1–0.3) in the Omsk grain-producing area are observed between $a_1$–$a_8$ and $a_5$–$a_8$.

$a_2$ (0–5$^\circ C$ temperature range) is the most risk-related of all analyzed indicators as it has a detrimental effect on crop plants during the growing season. The maximum is achieved in Rostov (348 days). $a_2$ has zero values in the given period in Krasnodar as suggested by the absence of cold winter seasons. The extremes in the Asian part of Russia (Tyumen and Omsk) were 202 and 226 days; while the values for Voronezh and Belgorod were approximately the same, ranging 228–302 days.

The dates for formation and destruction of permanent snow cover are important indicators affecting grain production capacity. The earliest date of permanent snow cover destruction was recorded on February, 20 (Belgorod and Voronezh), the latest – on April, 18 (Tyumen). Similarly, the earliest formation of permanent snow cover was recorded on October, 14 (Omsk), and the latest on December, 13 (Voronezh).

CONCLUSION

Knowing the specifics of each natural-and-climatic zone in terms of heat and moisture supply, it is important to determine the optimal sowing time for early spring crops, taking into account their biological characteristics. In Western Siberia, the soil reaches a high-plastic state, depending on weather conditions, approximately a month after the destruction of permanent snow cover: in late April - early May. At that time, the farms begin spring planting. In the European part of Russia, spring field works start in March.

Plants require sufficient amount of moisture during seed germination - seedlings - the 3rd leaf expansion - formation of nodal roots. Moisture deficiency in this period leads to a decrease in tillering intensity. This critical period is observed, depending on the sowing time, from the second half of May to the beginning of June, the weather conditions in the study years were rather ambiguous, with shortage of precipitation and soil moisture reduction in particular years. In the European part of Russia, the growing season takes place a month earlier, in milder conditions.

Heading (formation of reproductive organs) is the critical stage in terms of moisture. Lack of moisture during this period increases barrenness of spikelets, and its shortfall during grain formation and filling decreases grain weight, which leads to a significant reduction in yield. Experience has shown that when spring moisture reserves in the meter-deep soil layer are less than 100 mm, it creates unfavorable conditions for the growth and development of spring wheat, and if moisture reserves decrease below 60 mm, even a satisfactory grain yield is impossible. It is worth noting that subsequent abundant precipitation cannot improve the situation, and the output yield reduces sharply.

Thus, despite the upward trend, Western Siberia is in less comfortable climatic conditions than the European regions of Russia at close values of the hydrothermal coefficient in all selected points. Destruction of permanent snow cover occurs in the first half of April, followed by a long period of soil thawing and drying to a high-plastic state (physical ripeness), directly affect the time-frame of spring field work. It means that additional, short-term (3-5 years)
and medium-term (5-10 years) capital investments are necessary to get new varieties of spring grains, replenish the seed fund of winter crops, renew sowing and harvesting equipment, and cover the cost of fuel and other consumables.

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