

Influence of regional agrometeorological conditions on the yield of potatoes in the Leningrad region

Victor N. Abannikov^{1*}, *Visal P. Ganewatte*¹, *Aaed I. N. Mkhanna*¹, *Eduard V. Podgaiskii*¹, and *Svetlana V. Morozova*²

¹ Russian State Hydrometeorological University (RSHU), 79, Voronezhskaya str, St. Petersburg, 192007, Russia

² Saratov State University, 83, Astrakhanskaya str., Saratov, 410012, Russia

Abstract. Potato production is one of the main branches of crop production in the Russian Federation. The Leningrad region is the leading potato-growing region in the northwest of Russia. The sustainability of potato production depends on many factors, such as the level of agricultural technology, seed quality, soil characteristics, weather, climatic conditions, etc. Among weather and climatic factors, air temperature and precipitation are the main meteorological variables. The article analyzes the relationship between regional agrometeorological conditions and potato yields over the past 15 years. Based on the results of the study, it is possible to identify favorable weather conditions for the production of potatoes and increase its yield in the region, in order to optimize the decisions made on the sustainable provision of the population of the region with potatoes.

1 Introduction

According to the final report on the efficiency of the crop production sectors of the Russian Federation in 2017, prepared based on the results of the implementation of the food security doctrine, it was noted that potato production is 3% below the established 100% threshold [1]. Against the background of the predicted decrease in the sown areas, there is a threat of failure to achieve the target values for the gross potato harvest as part of the program to ensure food security. Currently, the parameters of food security in crop production are met only for grain and sugar production [2].

To achieve control parameters for potato production, it is necessary to solve the problem of intensifying the gross potato harvest. The solution to this problem is possible with the use of modern agricultural technology, organic and other fertilizers, modern methods of combating diseases and pests, as well as taking into account regional agro-climatic resources. Accounting for regional agrometeorological resources is due to the need to establish a homogeneous nature of the formation of agrometeorological conditions.

* Corresponding author: abvik@mail.ru

2 Materials and methods

In the course of the study, data were used on the gross potato harvest in the Leningrad Region and the potato yield indicator in the period from 2004 to 2019, which were provided by the Federal State Statistics Service of the Russian Federation [3].

Three meteorological stations on the territory of the Leningrad region were chosen for the study: Tikhvin, in the east of the region, 183 km from St. Petersburg; Belogorka, 66 km south of St. Petersburg; St. Petersburg (western part of the region).

Meteorological data at 3 meteorological stations from 2004 to 2019 were taken from the website of the All-Russian Scientific Research Institute of Hydrometeorological Information - World Data Center (VNIIGMI-WDC), which provides data for scientific research and technical services [4].

To determine agrometeorological resources and meteorological calculations, data on average monthly air temperature and average monthly precipitation over 15 years were used. In the process of analyzing a large amount of actual meteorological data and calculating agrometeorological characteristics, methods of statistical analysis, graphical visualization of data and calculated characteristics used to study the effect of agrometeorological parameters on potato yields were used.

3 Results and Discussion

According to official statistics, the potato yield in the Leningrad region as a whole increased from 2004 to 2019. In 2015, it reached its peak, and in 2016 the potato yield decreased, and then began to grow again until 2019. Potato yield dynamics from 2004 to 2019 is presented in Figure 1.

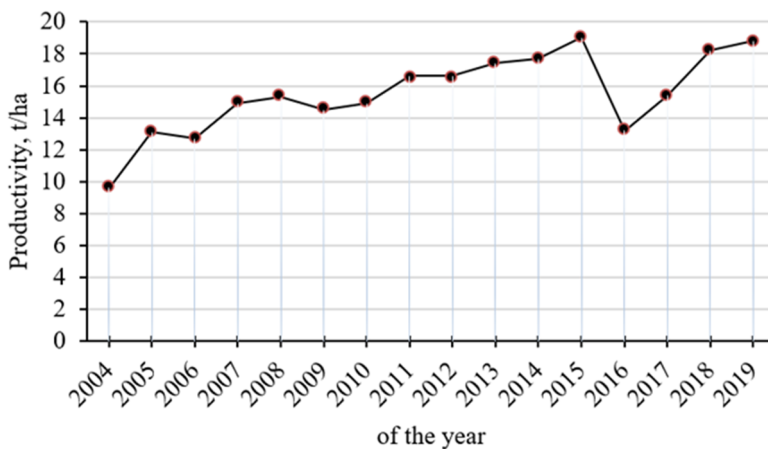


Figure 1. Potato yield in the Leningrad region for 2004-2019.

According to the report on the implementation of the program of the Leningrad Region "Development of Agriculture in the Leningrad Region" of the Committee for Agro-Industrial and Fisheries, this development occurred primarily due to increased investment in the introduction of new agricultural practices, the purchase of fertilizers, the development of land in the region and the development of agribusiness infrastructure [5-6]

Despite the fact that the potato is a perennial plant, it is cultivated during one growing season, so its yield depends significantly on the temperature regime and precipitation during the growing season.

Intensive potato growth begins at temperatures above +10°C, and the sum of active temperatures (SAT) is used to calculate its growing season [7]. To determine the SAT, a graph of the annual course of the average monthly air temperature is used to determine the date of a stable transition of the average daily air temperature through +10°C in spring and autumn. An approximate graph of the annual temperature at the Tikhvin meteorological station is shown in Figure 2, which also shows a scheme for determining the date of a stable temperature transition through +10°C.

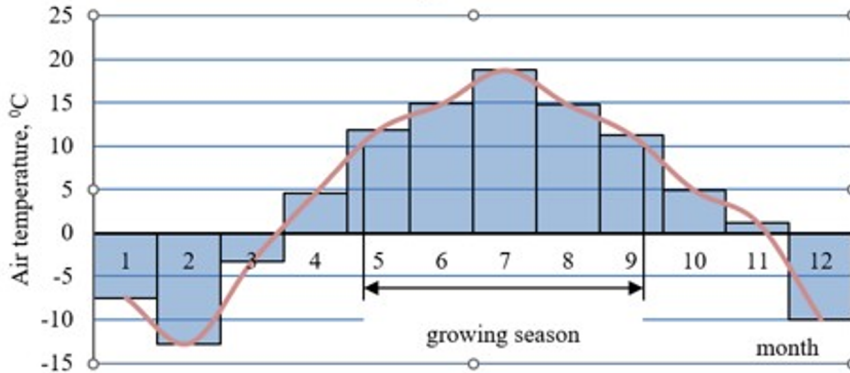


Figure 2. An example of the annual course of air temperature, m.st. Tikhvin (2012).

The dynamics of the sum of active temperatures for the districts of St. Petersburg, Belogorka and Tikhvin is shown in Figure 3.

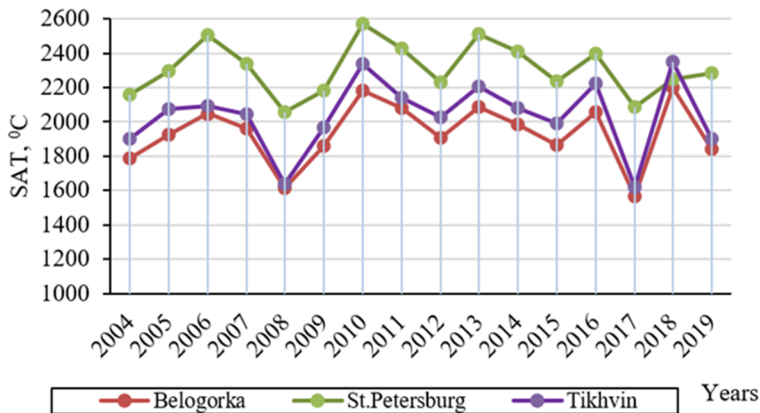


Figure 3. Regional dynamics of SAT in the Leningrad region (2004-2019).

The optimal sum of active temperatures for growing potatoes is 1800 - 2000°C [7-8]. According to the 15-year graph (figure 3), the sum of active temperatures in the region fluctuated between 1340 - 2244°C. St. Petersburg has the best characteristics with an interval from 1773 to 2244°C. At the weather stations Belogorka and Tikhvin, SAT is characterized by lower values. In general, according to the nature of the annual SAT variability in the Leningrad Region, this agrometeorological indicator is formed under the influence of homogeneous synoptic processes. This is evidenced by the coefficient of multiple correlation (R) between the stations of St. Petersburg, Belogorka and Tikhvin, equal to 0.94.

During the analysis of the temperature regime, it was found that the potato yield depends more on the date of transition through +10°C than on SAT (table 2). The pair correlation

coefficient (r) between the yield and the date of transition through +10°C is characterized by an average tightness of the relationship with an inverse relationship and ranges from -0.40 (Tikhvin) to -0.42 (St. Petersburg). Therefore, the later the growing season of potatoes begins, the lower its yield.

The relationship between precipitation and air temperature during the growing season is described using the Selyaninov hydrothermal coefficient (SHC) [7] (1).

$$SHC = \frac{\sum r}{0.1 \sum t > 10^{\circ}C} \quad (1)$$

Where, $\sum r$ is the sum of precipitation during the growing season (mm), $\sum t > 10^{\circ}C$ is the sum of active air temperatures.

The results of calculating the Selyaninov SHC values for the meteorological stations of the region are shown in Table 1.

Table 1. SHC “Selyaninov” in the Leningrad region.

Year	Potato yield (t/ha)	Stations		
		Tikhvin	St. Petersburg	Belogorka
		SHC “Selyaninov”		
2004	9.6	2.7	1.9	2.3
2005	13.1	1.6	1.4	1.7
2006	12.7	1.1	0.9	1.2
2007	14.9	1.9	1.4	1.1
2008	15.3	2.0	1.4	2.2
2009	14.5	1.9	1.8	2.1
2010	14.9	1.5	1.5	1.6
2011	16.6	2.2	1.5	1.6
2012	16.6	1.9	1.7	1.6
2013	17.4	1.3	1.3	1.4
2014	17.7	2.1	1.4	1.6
2015	19.0	1.5	1.0	1.3
2016	13.2	2.2	2.1	1.9
2017	15.4	2.2	2.0	2.2
2018	18.2	1.4	0.9	1.5
2019	18.8	1.7	1.2	1.3

If the Selyaninov SHC is greater than 1.0, then this corresponds to the conditions of increased moisture for the growing season in the European part of Russia [7-8]. According to the calculation results, the Selyaninov SHC values for Belogorka and Tikhvin exceed the SHC values for St. Petersburg, where in 2006 and 2018 the SHC value was 0.9, indicating a slight drought [7]. In general, Selyaninov's SHC in the Leningrad region has remained at a satisfactory level over the past 15 years. But, the increased level of SHC, which in the Leningrad region reflects the excess of precipitation over evaporation, does not contribute to

an increase in yield, as well as SAT during the growing season. This is evidenced by the coefficients of pair correlation between the yield of potatoes and the studied indicators. The results are shown in table 2.

Table 2. Correlation between SAT and SHC with potato yield.

	Tikhvin	St. Petersburg	Belogorka
SAT	0.18	0.31	0.27
SHC Selyaninov	-0.39	-0.48	-0.47

Due to the fact that the potato yield is formed during the flowering period, which occurs in the Leningrad region in June, the correlation coefficients of yield with the June air temperature at the studied meteorological stations were calculated. As a result, the following results were obtained:

- For m.st. Tikhvin, $r = 0.26$.
- For m.st. St. Petersburg, $r = 0.37$.
- For m.st. Belogorka, $r = 0.35$.

In the process of establishing correlations between potato yield and agrometeorological indicators, regression equations were determined that characterize the type of relationship between the studied values. An example of regression analysis is shown in Figure 4.

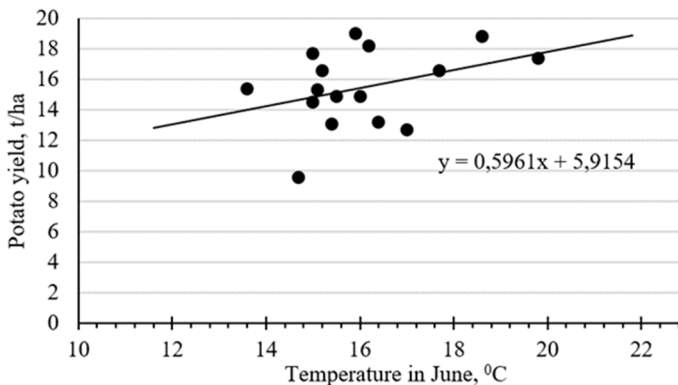


Figure 4. Regression analysis of air temperature and potato yield in the region of St. Petersburg.

4 Conclusion

At the end of the article, based on the results of the analysis of the degree of influence of regional agrometeorological conditions on potato yields, the following conclusions can be drawn:

- Potato yield in the Leningrad region is steadily increasing except for 2016. This decrease in yield is due to increased values of monthly precipitation during the growing season, which is also evidenced by the excess of Selyaninov's SHC value above 2.0. In general, with increased SHC values, a decrease in yield occurs (negative correlation with a correlation coefficient from -0.39 to -0.48).

- The thermal regime of the air is characterized by a relatively favorable condition for growing potatoes, although in some years in the territory of the Leningrad region there are lower values of the sum of active temperatures below 1800°C, with the exception of areas around St. Petersburg. It is in this area that the correlation coefficient between yield and SAT is 0.37. In Belogorka and Tikhvin, the correlation coefficient is much lower and the degree of connection is weakly expressed (0.27 and 0.18, respectively). Somewhat better correlations are observed between the potato yield and the average monthly air temperature in June: in St. Petersburg - $r = 0.37$, in Belogorka - $r = 0.35$, in Tikhvin - $r = 0.26$. The remaining months of the growing season do not have a significant impact on the yield of potatoes.

In conclusion, it should be noted that in the Leningrad region, the yield of potatoes depends to a lesser extent on precipitation, in contrast to the studies of other authors [9]. This is due to sufficient moisture during the growing season in almost all years. To a greater extent, the yield of potatoes depends on the thermal regime. The developed regression equations between potato yield and June air temperature can be used to make a preliminary forecast for the future potato crop in the Leningrad region. But it is somewhat more expedient to predict the future yield of potatoes by the date of a stable transition of the average daily air temperature through + 10°C, because the pair correlation coefficient between these values has the maximum degree of closeness of connection (from -0.40 to -0.42) among all the analyzed agrometeorological indicators, although with an inverse relationship.

References

- [1] *Results of the work of the crop industry in 2017 and tasks for 2018. Ministry of Agriculture of the Russian Federation* Retrieved from: <https://mcx.gov.ru>
- [2] E. Shokurova *Ministry of Agriculture: Russia will fulfill food safety indicators for a number of products* Retrieved from: <https://www.agroinvestor.ru>
- [3] *The database of the "Federal State Statistics Service in the Russian Federation* Retrieved from: www.rosstat.gov.ru
- [4] *All-Russian Research Institute of Hydrometeorological Information - World Data Center (VNIIGMI-WDC)* Retrieved from: www.meteo.ru
- [5] *Report on the implementation of the program of the Leningrad Region "Development of Agriculture in the Leningrad Region" - 2021 Committee for the Agro-Industrial and Fisheries Complex of the Leningrad Region* Retrieved from: www.agroprom.lenobl.ru
- [6] V.Abannikov , A. Budagov and A.Samoylov ,Investment Policy Features In The Agricultural Sector Of Russian Regions. *ICEST 2021 II International Conference on Economic and Social Trends for Sustainability of Modern Society. European Proceedings of Social and Behavioral Sciences EpSBS* 648-655 (2021)
- [7] A.P Losev, *Collection of tasks and questions on agrometeorology: textbook* (Moscow: INFRA-M) 170 (2020)
- [8] I.G Gringof and A.D Kleshenko, *Fundamentals of agricultural meteorology. The need of agricultural crops in agro-theoretical conditions and weather conditions dangerous for agricultural production* (Obninsk: FGBU "VNIIGMI-MTsD") 1 808 (2011)
- [9] K.Rymuza, E.Radzka and T.Lenartowicz, The effect of weather conditions on early potato yields in east-central Poland. *Communications in Biometry and Crop Science* **10** 65–72. (2015)