# Justification of irrigation reclamation using data on the probability of heat and moisture in the Central Non-Chernozem Zone of Russia

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**Abstract.** Ongoing climate change creates risks for many sectors of the economy. They can have a particularly strong impact on agriculture, since the amount of incoming heat and moisture is one of the most important factors in agricultural production. The main goal of this study was to analyzed of the provision of heat and humidity by indicators, temperature more than 10 °C, the sum of factors during the growing season, differences in temperatures and evaporation, humidification coefficients to justify the need for irrigation measures. The calculations were carried out for the growing season, that is, when positive values of average daily air temperatures were recorded. In all calculations, observational data from the V.A. Mikhelson Meteorological Observatory (in Moscow) was used for 30 years (period from 1993 to 2022). The study analyzed the provision of the central part of the Non-Chernozem Zone of Russia according to such indicators as the sum of temperatures of the growing season greater than 10 °C, the sum of precipitation for the growing season, the difference between the sum of precipitation and evaporation for the growing season, G.T. Selyaninov hydrothermal coefficient, D.I. Shashko coefficient of natural moisture. The analysis of the assessment of the heat supply and moisture supply of the territory and the attitude of agricultural and fruit crops to drought demonstrate the need to moisten the root layer of the soil even in zones of excessive moisture, when during the growing season there are separate periods with insufficient and uneven atmospheric moisture.
**Keywords:** irrigation, agrometeorological indicators, probability curve, European part of Russia.

## 1 Introduction

Ongoing climate change creates risks for many sectors of the economy [1, 2]. Many studies have shown that in the European part of Russia a positive trend in changes in average annual temperatures has emerged since the 1980s [3]. They can have a particularly strong impact on agriculture, since the amount of incoming heat and moisture is one of the most important factors in agricultural production [4, 5, 6].

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In conditions of rising air temperatures, there are risks of lack of moisture when growing agricultural products. Irrigation is one of the most important factors in regulating the water balance in agricultural landscapes [7, 8, 9]. Currently, many irrigation methods are known, among which preference is given to low-volume methods. Low-volume irrigation is a term combining the above irrigation methods, most accurately reflecting their common features [10, 11]: strictly metered irrigation rates, within 20-100 $m^3$ per ha, consistent in volume with plant water consumption and ensuring that soil moisture in the root layer is maintained within optimal limits due to compensation for evapotranspiration for the previous period.

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## 2 Materials and methods

In order to determine the need for irrigation reclamation, it is necessary to study the likelihood of drought and stressful conditions, as well as the degree of their influence on the individual development of the agricultural or fruit crop being grown. As part of the study, the frequency of dry periods was assessed using a probabilistic method, which consists of calculating the probability. The calculations were carried out for the growing season, that is, when positive values of average daily air temperatures were recorded. In all calculations, observational data from the V.A. Mikhelson Meteorological Observatory was used for 30 years (period from 1993 to 2022).

To assess the provision of heat and moisture to individual periods of the growing season, the G.T. Selyaninov hydrothermal coefficient was calculated [12]:

$$HTC = \frac{\sum P}{\sum t_{10}} \times 10,$$

where *HTC* – G.T. Selyaninov hydrothermal coefficient; $\sum P$ – the amount of precipitation for the period with temperatures above 10 °C; $\sum t_{10}$ – the sum of temperatures above 10 °C for the same period.

To assess the degree of heat and moisture supply using the HTC, a scale is used: HTC < 0.7 – drought, 0.7 < HTC < 1.0 – insufficient moisture, 1.0 < HTC < 2.0 – sufficient moisture and HTC > 2 ,0 – excessive moisture.

In addition to the HTC, the D.I. Shashko natural moisture coefficient was additionally analyzed [13]:

$$NMC = \frac{\sum P}{\sum d},$$

where *NMC* – D.I. Shashko natural moisture coefficient, $\sum P$ – sum of precipitation, $\sum d$ – sum of air humidity deficits for the same period.

Using the classification of NMC values, moisture supply conditions are identified. When the NMC value is more than 0.6, excess moisture is observed, from 0.6 to 0.45 – sufficient moisture, from 0.45 to 0.35 – insufficient moisture, when agrotechnical measures can be used, from 0.35 to 0.25 – not enough moisture when periodic irrigation is required, less than 0.25 – dry conditions.

To construct empirical probability curves, before plotting them on a coordinate grid, the observation values are ranked in descending order and for each observation the probability value is calculated using the formula:

$$P = \frac{100(m - 0,3)}{(n + 0,4)},$$

where $P$ – probability, %; $m$ – serial number of observations; $n$ – the number of observations in the series.

Data analysis was performed in the Microsoft Office Excel 2016. The coefficients of empirical polynomial probability curves were calculated using regression analysis methods.

## 3 Results and discussion

The sum of active temperatures is an indicator characterizing the amount of incoming heat. For the period from May to September 2023, the probability of territories with active temperatures is showed in Figure 1. In 50% of cases for the experimental plot, the years are characterized by the sum of active temperatures exceeding 2650 °C, which is sufficient for growing most vegetable and fruit crops in the conditions of the central region of the Non-Black Earth Zone of Russia.

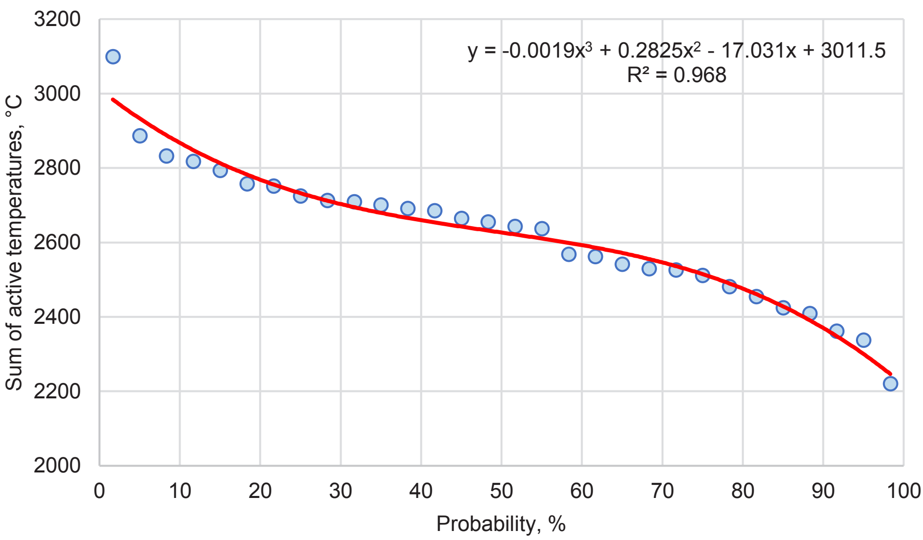


**Fig. 1.** Probability of active temperatures from 1993 to 2022.

The probability of precipitation to the territory during the growing season (from May to September) is shown in Figure 2. Precipitation during the growing season is an important component of the water balance when growing crops [14]. The amount of precipitation in individual years determines such characteristics of the irrigation regime as irrigation norms and irrigation frequency. Over the 30-year period of meteorological observations, the highest amount of precipitation was 593 mm, and the least was 198 mm. In general, years characterized by precipitation of more than 400 mm during the growing season occur with a probability of 35%.

The moisture probability curve for the territory based on the difference in the amount of precipitation and evaporation during the growing season from 1993 to 2022 is shown in Figure 3. According to the empirical supply curve, in 63% of cases there is a moisture deficit and only in 37% of cases the difference between the amount of precipitation and evaporation is positive. It is believed that the need for moisture for the growth and development of seedlings of fruit and berry crops is very high, since they have a shallow root system and require stable, good moisture in the top layer of soil up to 0.3-0.5 m deep.

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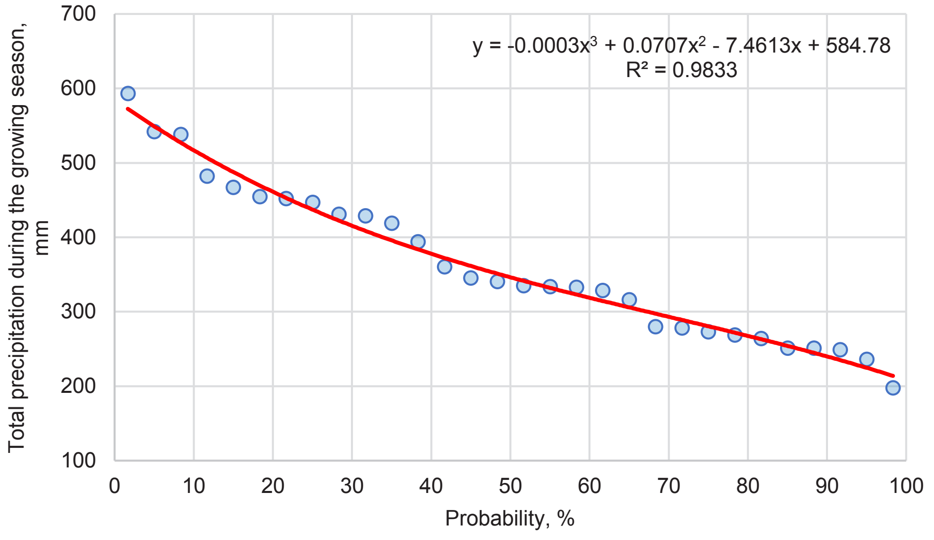


**Fig. 2.** Probability of precipitation during the growing season (from May to September) from 1993 to 2022.

Probabilistic characteristics of the provision of the territory of the Michurinsky Garden with heat and moisture according to the G.T. Selyaninov hydrothermal coefficient are shown in Figure 4. During the growing season, excessive moisture (HTC > 1.3) is observed in 48% of cases, adequate moisture (1.0 < HTC < 1.3) – in 30% of cases, and drought conditions – in 22% of cases. The G.T. Selyaninov hydrothermal coefficient is not the only indicator that allows one to assess the provision of heat and moisture in a territory; in agriculture and horticulture, it is necessary to focus on other criteria to make a decision.

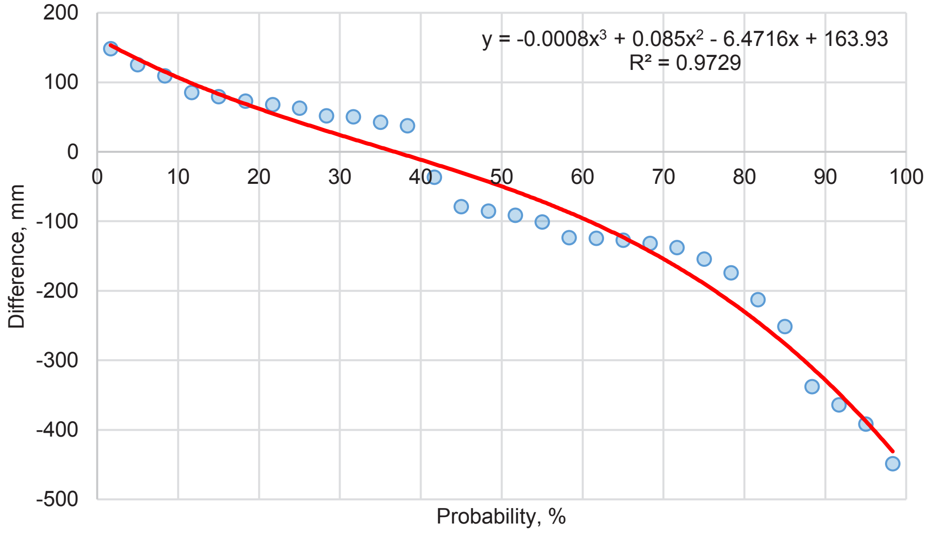


**Fig. 3.** Moisture probability based on the difference between the amount of precipitation and evaporation (from May to September) from 1993 to 2022.

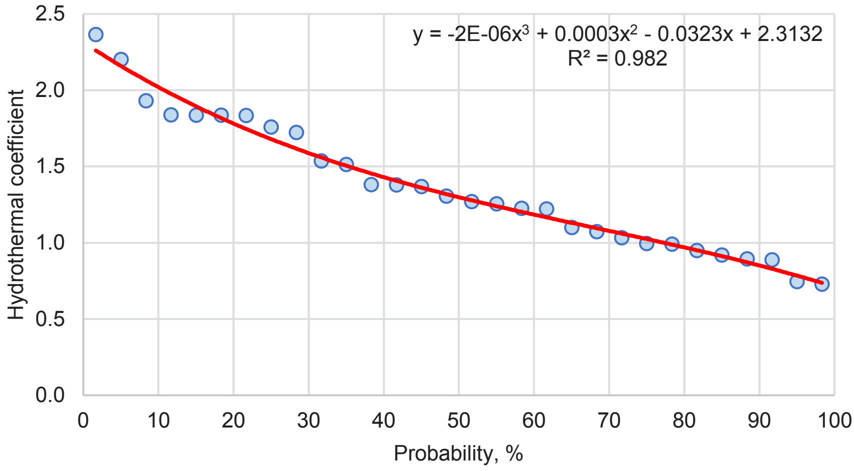


**Fig. 4.** Probability of heat and moisture according to the G.T. Selyaninov hydrothermal coefficient (from May to September) from 1993 to 2022.

The analysis of the moisture supply assessment of the territory of the Michurinsky Garden of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy and the attitude of agricultural and fruit crops to drought demonstrate the need to moisten the root layer of the soil even in zones of excessive moisture, when during the growing season there are separate periods with insufficient and uneven atmospheric moisture.

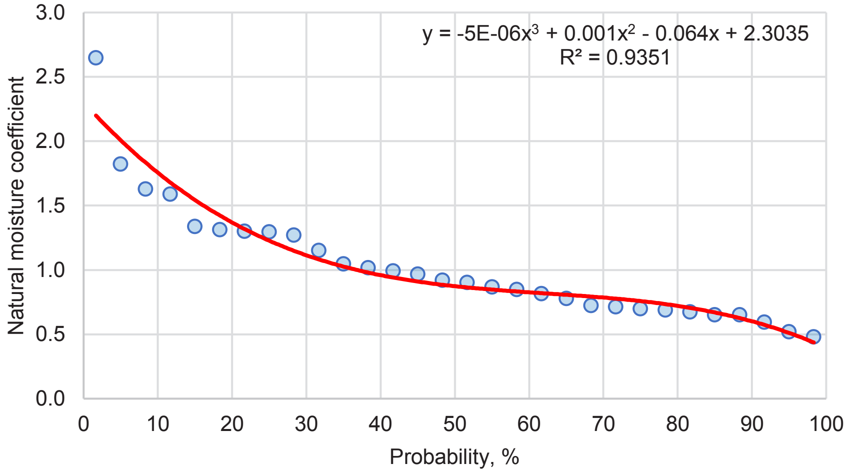


**Fig. 5.** Moisture probability according to the D.I. Shashko natural moisture coefficient (May to September) from 1993 to 2022.

The provision of moisture to the territory according to the D.I. Shashko natural moisture coefficient for the growing season is shown in Figure 5. For the considered growing seasons, in 92% of cases they are characterized by excessive moisture (NMC > 0.6), and in 8% of cases by sufficient moisture (0.6 < NMC < 0.45). Data averaged over a 30-year period on the ten-day dynamics of the D.I. Shashko natural moisture coefficient by show that the average values are in the range from 0.5 to 1.5. At the same time, the minimum ten-day coefficient values throughout the entire growing season can reach zero values, i.e. Maximum drought conditions arise when irrigation is necessary. Such periods can often be accompanied by high ambient temperatures, when berry crops are characterized by the highest water consumption. Average ten-day values of the D.I. Shashko natural moisture coefficient over a 30-year series of observations have high variability. The coefficient of variation varies from 80 to 134%.

## 4 Conclusions

The study analyzed the provision of the central part of the Non-Chernozem Zone of Russia according to such indicators as the sum of temperatures of the growing season greater than 10 °C, the sum of precipitation for the growing season, the difference between the sum of precipitation and evaporation for the growing season, G.T. Selyaninov hydrothermal coefficient, D.I. Shashko coefficient of natural moisture. The analysis of the assessment of the heat supply and moisture supply of the territory and the attitude of agricultural and fruit crops to drought demonstrate the need to moisten the root layer of the soil even in zones of excessive moisture, when during the growing season there are separate periods with insufficient and uneven atmospheric moisture.

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