Climatic characteristics changes analysis of the agroclimatic Novgorod regions

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Abstract. The article focuses on the problem of changes in meteorological parameters – average air temperatures and annual precipitation amount within the agroclimatic areas of the Novgorod region. Despite the small size of the region, its location in the North-West of the European part of Russia and fairly small differences in hypsometric parameters, there are significant differences in climate parameters within the region. The factors, mentioned in the article, are the cause for the climate heterogeneity of the region. The authors attribute these climate changes within the boundaries of agroclimatic regions with specific meteorological changes in local climates. The article presents the factors that determine the differences in climatic conditions and, as a result, the agroclimatic zoning of the region.

1. Introduction
Agriculture is one of the most strategically important branches of the national economic activity. Its comprehensive support is among the priorities of national and regional development. In turn, for conducting agricultural production, a good knowledge of the agroclimatic conditions of the area is a fundamental thing. The high dependence of the industry productivity components on natural conditions, even in the presence of modern approaches and the latest agricultural technologies makes it necessary to constantly monitor the landscape and climatic parameters of the area for making important decisions in the development of agricultural production and the food industry.

Novgorod region is located in the north-west of the Russian plain, which determines its climatic conditions. In general, the region belongs to the region of moderate continental climate, which has features of the sea climate, and is subject to the main influence of the Western transfer of air masses from the Atlantic region. At the same time, the underlying surface correlates climatic conditions in different parts of the region, which may be fundamental for determining the specialization of crop production and agricultural machinery.

Located in the nonblack soil (Nonchernozyom) zone, the Novgorod region traditionally belongs to the territories of “risky agriculture”. Prolonged off-seasons, late frosts, periods with increased precipitation, spring and autumn flooding of territories, soil erosion as a result of water saturation – this is just an incomplete list of weather and climate phenomena that adversely affect the agricultural sectors, especially crop production. At the same time, weather shifts observed in recent years, anomalous phenomena and deviations from the norm against the General background of changes in climate parameters contribute to changes in the agro-climatic conditions of the region. As a result of fluctuations in the ratio of heat and moisture, there are changes in the soil cover of localities, which is the focus of interaction of all components of the landscape. To understand trends in changes in landscape and climate
conditions, constant monitoring of the dynamics of certain parameters in ecosystems is necessary. In this article, we will focus specifically on the meteorological parameters of agroclimatic regions.

2. Objects and methods of research
The object of the study was the agro-climatic Novgorod regions. The key method of research was a comparative analysis of climatic characteristics within agroclimatic regions and local climates of the region. Preliminary analysis of meteorological parameters for the period from 2009 to 2020 was carried out.

3. Results and discussion
The territory of the Novgorod region has a large extent from West to East and from North to South, a diverse terrain (Prilemanskaya Lowland, Valdayskaya Upland, Mstinskaya Depression, etc.), the presence of lakes such as Ilmen, large swamps such as Rdeiskoe, Dolzhinskoe, Bor, Spassky Mkhi. Changes in climate processes are caused by: air circulation (breezes, winds along valleys, etc.), heat exchange and moisture exchange. The influence of large lakes is that a large volume of water affects the meteorological elements of the climate. Air masses passing over the lake have time to warm up or cool down a little. During the warm period, the difference in the thermal regime of water and the earth's surface causes the appearance of local winds-breezes – and an increase in the speed of the prevailing winds of the western and northern points. The dissected elevated terrain of the Valday Hills affects the direction and speed of the wind. Wind speed increases on windward slopes, on the tops of hills separated by basins and valleys. There are winds that contribute to the cold flow of cold air in the lowlands, where there is an inversion of temperatures. The presence of through valley-depression impact on wind regime increases in winter the frequency of south-east winds along the valley.

The heterogeneity of the underlying surface, the presence of large reservoirs and the peculiarities of air mass circulation determine the heterogeneity of landscape and climatic conditions in the region, which create specific conditions for farming in various parts of it and allow us to justify agroclimatic zoning. At the same time, both the boundaries of agroclimatic regions and the parameters that characterize them may change as a result of evolutionary and dynamic climate fluctuations. Any changes, both short-term and long-term, should be taken into account when forecasting and planning the agricultural development of the region.

The study of agroclimatic resources in Russia has been going on for decades. For the first time, the map of the general agroclimatic zoning of the territory of the USSR was compiled in 1933 by G. T. Selyaninov, who justified a number of parameters for agricultural climate assessment and developed a system of agroclimatic zoning. Further research was continued by many scientists, having developed a variety of different zoning types – P. I. Koloskov, 1947, 1958; S. A. Sapochnikova, 1958; F. F. Davitaya, 1938, and others. The allocation of taxons and territorial units depends on the methodology used and the set of parameters, and may change depending on changes in soil and climate parameters. This is due to the variety of author's approaches to this issue. From modern works, a large-scale study of the group of scientists of Dokuchaev Soil Science Institute deserves attention [1]. The authors proposed the allocation of agroclimatic areas for optimal cultivation of major agricultural crops within the boundaries of natural and agricultural zoning of the territory of Russia, conducted under the leadership of I. I. Karmanova. There are 64 areas on the territory of the country that characterize the soil and agro-climatic conditions of cultivation of the main and accompanying crops in the crop rotation. In each area, a set of crops is allocated, the biological potential of which is linked to the soil potential of the corresponding territory. A combined scheme of natural-agricultural zoning and soil-agroclimatic areas is presented. According to the results of the study, the territory of the Novgorod region is located within two areas: northern southern-taiga, sod-podzolic with the participation of sod-carbonate and swampy soils, rye-barley-oat-potato-flax and feed, and southern-taiga central, sod-podzolic, rye-barley-oat-flax-potato and feed (with corn for silage).
A range of contemporary publications devoted to assessing the climate and agroclimatic resources, to the studying of the climate oscillations influence on soil, special methods of agroclimatic zoning, the study of the differentiation of agro-climatic conditions of individual regions [1, 2, 3, 4, 5, 6, 7].

Agro-climatic resources of the Novgorod region were characterized in the period of 50–80-ies of the last century by scientists of the Leningrad State University, Novgorod State Pedagogical Institute on the basis of data from agroclimatic reference books and general analysis of meteorological parameters and their determining factors. During this period, considerable attention was paid to the identification and characterization of local climates. Research on these issues is presented in the works of A. I. Ovchinnikov, A. A. Barysheva, Z. E. Antonova [8, 9] and other scientists. As a result, agroclimatic regions and local climates were identified within the region.

The analysis of two zoning areas of the region (agroclimatic area and local climates area) suggests that the boundaries of the selected taxonomic units are quite close in their configuration. Let's look at this question in more detail. An agroclimatic region of the Ilmen lowland was identified around the lake Ilmen. The area of local climate is called here – lakeside. The most significant difference in the location of the two districts is the greater coverage of the agroclimatic area to the south and southwest of the lake. It occupies the center of the region (Priilmenskaya Lowland). The district follows the contours of the lake, expanding within the adjacent river valleys up to 100 km.

Priilmensky agroclimatic district is the warmest, and, therefore, have better conditions for growing crops in the Novgorod region. There are mild short winters, the longest growing season and the period of sunshine. Active vegetation of plants lasts for 130 days with the sum of temperatures up to 2000 °C. Lakeside position with characteristic processes of climate formation leads to a decrease in the annual amount of precipitation to 550 mm per year and 350 mm during the growing season. The region is located in an area with excessive moisture; the region's soils need to be drained, so the decrease in precipitation is a positive factor for the development of agriculture. The height of the snow cover is not great – from 10 to 30 cm. A stable snow cover lasts about 100 days. The winter period is characterized by frequent and prolonged thaws. The region has the longest frost-free period, which lasts from the beginning of May to the end of September and can reach 150 days.

Analysis of climate changes over the past 10 years (2009–2020) has shown that in the Priilmensky agroclimatic region, the average temperature of January has increased from –8.5 °C to –7.1 °C, which is an average of 1.4 °C, and the temperature of July has also increased by 1.2 °C, from +18° to +19.2 °C. The annual precipitation in the period from 1960–2008, on average, was 550–600 mm, over the period of observations in the last 10 years, this value has increased on an average annual basis by 77 mm, and amounted to 677 mm. The average thickness of the snow cover was 20–30 cm; recently this parameter was 17 cm. The number of low-snow winters has also increased, from three to four. Generally, the region retains the best agroclimatic conditions of the growing season in the region. Here it is sufficient to successfully grow warm-weather crops – cucumbers, tomatoes, peppers. Cherry orchards were actively cultivated on the south-western coast of the lake Ilmen in the nineteenth century.

The second agroclimatic region is at the south of the region. It stretches along the western and southern borders of the region from Soletsky to Krestetsky District, covering the Priilmensky District from West to East. The contours of the area of its shape superimposed on the South-Priilmensky and South-Predvaldaysky local climates.

It is also a warm agroclimatic region with a long growing season, mild winters and moderate precipitation. Stable snow cover lasts here for 105–110 days. The height of the snow cover is from 15 to 30 cm. in some years, it does not fall due to thaws. Winter thaws are frequent here, which, in alternation with periods of soil freezing, leads to the death of some winter crops and the active growth of weeds. The period of active vegetation is 130–145 days, and the sum of temperatures for this period is 1900–1950 °C. The frost-free period is also 130–140 days from mid-may to mid-September. The annual precipitation is 650–800 mm, during the growing season 350–375 mm, and in the very East of the district about 400 mm.

The climate of the region has been warming over the past 10 years; the average temperature in January increased by 1 °C from –8 °C to –7 °C, in July by 0.9 °C, from +18 °C is +18.9 °C.
precipitation has also increased, from 600–650 mm on average, to 725–780 mm. The average thickness of the snow cover from 25–30 cm has decreased by 10 cm, and the average value is now 15–18 cm. With the overall reduction in average power, the number of low-snow winters has not changed. It should be noted that with a slight warming, the area began to receive more precipitation, which is not a positive factor for an area with excessive moisture. Temperature characteristics, as well as in the first district, allow you to grow enough warm-season crops in the field — tomatoes, cucumbers, peppers, pumpkins, zucchini. In the area there are suitable conditions for gardening — not only for apple trees and plums, but also more thermophilic pears and cherries.

The third agroclimatic region stretches along the western and northern borders of the region from Soletsky District to Lyubykinsky District. It also includes the territory of the Msta Basin (Msta river valley). In the South, its borders meet those of the two districts described above. Located in the North-West, the moderately warm region corresponds to the North-Priilmen, Middle-pre-Valday and Mstinsky climates.

It has moderately warm summers and moderately cold winters, with moderate precipitation of 700–800 mm per year. In the area of a shorter frost-free period — 100–120 days, frequent frosts are observed in may, in some years there are also the first decade of June. In winter, there are frosts up to −30 °C and below. The climate of the Mstinkaya Depression is particularly harsh, where frosts of up to −40 °C are observed on average once every five years. Along with a small snow cover, unfavorable conditions for freezing crops are created. The average snow cover height is 30–35 cm, and in some winters it does not exceed 10 cm. The period of active vegetation lasts from mid-may to mid-September and is 120–125 days with a total temperature of 1750–1800 °C. The annual precipitation is 700–800 mm. In the Mstinkaya Depression, summer temperatures are higher, and the frost-free period is somewhat longer, so it is more successful to cultivate warm-season crops and orchards, but the latter suffer from severe frosts in winter. There has been a slight warming in the agroclimatic region over the past decade. Average January temperatures were previously −9.2 °C, July +17 °C, now they are −8.3 °C in January, and +17.8 °C in July. Annual precipitation increased to 760–840 mm, and snow cover averaged 33–38 cm. The average temperature in January in the Mstinkaya Depression increased by 1.4 °C, and was −7.1 °C, July by 1.2 °C, from +17.5 °C to +18.7 °C, respectively. The annual precipitation from 550–600 mm has increased by an average of 165 mm, and is 765 mm.

The fourth agro-climatic region occupies the south-eastern part of the region. Geographically, it corresponds to the territory of Okulovsky, Valdaysky and Demyansky Districts. Significant elevation of the terrain causes a slight decrease in heat resources, increased precipitation and increased cloud cover. The district borders roughly coincide with the southern Valday and Middle Valday local climates. The rugged terrain contributes to a wide variety of microclimatic conditions. Warm-season crops are grown on the slopes of the southern exposure.

This is a colder area, where the period of active vegetation and frost-free period lasts 120–125 days with air temperatures totaling about 1750–1800 °C. Spring frosts negatively affect the cultivation of gardens, since their arrival coincides with the flowering period. In winter, the temperature drops to −30 °C, which happens almost every year. The region has a significant amount of precipitation — 850–900 mm, half of which falls during the growing season. In winter, there is a stable snow cover of 40–45 cm in height for up to 140 days. When comparing climate data there is an increase in average January temperatures by 1.5 °C, from 9–10 °C to −7.5 °C, July temperatures − to 1.6 °C, from +16.5–17 °C to +18.6 °C. Annual precipitation also increased to 860–940 mm. The average thickness of the snow cover decreased to 34 cm.

The fifth agroclimatic region occupies the Eastern part of the region. The district includes sections of Borovichsky, Lyubyinsky Districts, as well as Moshovsky, Khvoininsky and Pestovsky Districts. The borders of the district roughly correspond to the North-pre-Valday and eastern local climates.

This is a cold region of the Novgorod region, where climate parameters change from the characteristics of a moderate sea to continental. There is a long winter—the average daily temperature below −5 °C is typical for 105–110 days a year. Winter frosts up to −30 °C are indicated annually. The height of the snow cover is at least 40–50 mm due to low winter temperatures and the absence of frequent
thaws. At the same time, the amount of precipitation is less than in the previous area – 700–800 mm. The distribution of precipitation over the year is quite favorable. The vegetation period accounts for 350–400 mm. Active vegetation of plants lasts 115–120 days, the sum of temperatures during this period is 1650–1700 °C. The frost-free period is 100 to 115 days. Typical May and June frosts, as well as August, when cold dews fall and conditions are created for the development of phytophthora. Frosts in the first decade of June are observed annually, which negatively affects the cultivation of plants with a long growing season. Among the positive factors, we can point to fairly high summer temperatures and stable periods without precipitation, which allows for haymaking. This agro-climatic region also has a warming effect, with the average temperature in January rising by 0.7 °C from −10–10.5 °C to −9.3 °C, in July by 1.2 °C, from +17 °C to +18.2 °C. The annual precipitation has slightly decreased to 650–720 mm. The average snow cover has decreased, and this value is 30–40 cm in different years. When the average power is reduced, the number of snow-free winters has not changed.

The sixth agroclimatic region is the coldest and occupies the north-eastern part of the region. A small area, closed within the limits of Sherekhovichi heights district. In terms of climate, it corresponds to the North-Valdai local climate. It is located to the North of the Mstinskaya Depression, in the high part of the Tikhvin Ridge, called the Sherekhovichi Heights. Absolute surface marks range from 150 to 280 m.

The agroclimatic region is characterized by a long severe winter and a significant amount of precipitation. The average annual precipitation ranges from 850–900 mm, and the growing season is 400–450 mm. Even in the low-snow, warm winters typical of the region, snow cover is established here. Usually it has a capacity of 40–50 cm. Frosts up to −30 °C is observed almost every year, in some years, the temperature drops to −40 °C. The period of active vegetation of plants is not long – no more than 110–115 days, and the sum of temperatures in the region of 1550–1600 °C. The frost-free period lasts about the same number of days. Frosts are typical for May and June. It is impractical to grow heat-loving crops in the open ground, as well as plants with a long growing season. In the last decade, the average temperature in January has increased slightly from −10–10.5 °C to −9.5 °C, in July from +16 °C to +16.7 °C. Annual precipitation exceeds 800 mm and reaches 940 mm. The thickness of the snow cover remains at the level of 40–50 cm, but due to the large terrain, its value varies between 5–50 cm.

4. Conclusion
In conclusion, it can be noted that the agroclimatic and climatic zoning of the Novgorod region is similar in configuration, and changes in the conditions for growing crops can be traced by the average long-term data for a fairly short period. The general slight climate warming and increase in precipitation over the past decade can be observed in all agroclimatic regions of the region. Generally, changes in the average long-term parameters over a ten-year period did not significantly affect the characteristics of agroclimatic areas, and, consequently, the conditions for growing crops.

References
[1] Bulgakov D S, Rukhovich D I, Shishkonakova E A et al. 2016 Separation of agroclimatic areas for optimal crop growing within the framework of the natural-agricultural zoning of Russia Eurasian Soil 49 1049–60
[2] Zoidze E K 2002 On the agroclimatic resource assesment system of the Russian Federation Meteorologiya i gidrologiya 3 90–100 [In Russ]
[3] Kislov A V 2019 [Regional climate modeling for geographical analysis Vestnik Moskovskogo universiteta Ser. 5: Geografiya 5 3–12 [In Russ]
[4] Polyakov D V 2012 Cluster analysis appliance to assessing of temperature and humidity conditions during active vegetation in the South of Western Siberia and its association with the hydrothermal coefficient of T G Selyaninov Vestnik Tomskogo gosudarstvennogo universiteta 360 188–92 [In Russ]
[5] Alyabina I O and Nedanchuk I M 2014 Assessment of the relationships between the distribution of soil horizons and the climatic parameters Eurasian Soil 47 968–79
[6] Levykin S V, Chibilev A A, Kazachkov G V et al. 2017 Application of the soil-ecological
multiplicative index to assess suitability of Cis-Ural chernozems for cultivation with due account for economic parameters *Eurasian Soil* 50 246–52

[7] Rozhkov V A 2009 Soils and the soil cover as witnesses and indicators of global climate change *Eurasian Soil* 42 118–28

[8] Barysheva A A 2008 Local climates and landscapes of the Novgorod region (Veliky Novgorod) p 166 [In Russ]

[9] Razumihin N V 1978 *Natural zoning of the Novgorod region* (Leningradskij universitet) p 244 [In Russ]