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The Study of Possible Soybean Introduction into New Cultivation Regions Based on the Climate Change Analysis and the Agro-Ecological Testing of the Varieties

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Abstract: Analyzing agro-climatic conditions for the period of 1981–2020 has revealed a tendency for local climate warming under the condition of its aridization in the territory of the Central region of the Russian Non-Chernozem zone, and the new northern borders for soybean growing in the region have been marked. The isotherm of the sum of active temperatures has been established to have shifted towards high latitudes by 150–200 km. The values of the sum of active temperatures have increased from 1700–2200 °C to 1950–2400 °C, while the amount of precipitation during the growing season has decreased by 20–40 mm on average, from 270–280 mm to 190–230 mm. Three agro-climatic subzones—northern (NAS), central (CAS) and southern (SAS)—have been identified, each characterized by similar temperature and humidity conditions during the growing season. Thus, in the northern agro-climatic subzone, the sum of temperatures during the growing season is 2000–2200 °C, the *HTC* (hydrothermal coefficient) is 1.4–1.7, and the sum of precipitation is 285–295 mm; in the central subzone, the sum of temperatures is 2200–2400 °C, the *HTC* is 1.1–1.4, and the sum of precipitation is 265–285 mm; in the southern one, the sum of temperatures is 2400–2600 °C, the *HTC* is 0.7–1.1, and the sum of precipitation is 255–265 mm. Along with the northern ecotype varieties recommended for this zone, the vegetation features of early maturing soybean varieties of other ecological types—southern and Far Eastern—were studied. As a result of the agro-ecological analysis of early maturing soybean varieties, it has been found that the soybeans belonging to the group of very early or early maturing with a determinant type of growth are recommended for cultivation in the northern agro-climatic subzone of the Central region of the Non-Chernozem zone; the soybean varieties belonging to the group of very early or early maturing with a determinant or semi-determinant type of growth—in the central zone; the soybean varieties belonging to the group of very early or early maturing with a determinant, semi-determinant, and indeterminant type of growth—in the southern zone. Considering the variety characteristics and the agro-ecological tests conducted, it has been found that the northern ecotype varieties can sustainably ripen in all agro-climatic subzones in the Central region of the Non-Chernozem zone, the southern and the Far Eastern varieties—in the central and the southern zones.

Keywords: soybean; varieties; ecotypes; introduction; climate change; shift of the northern border of cultivation; agro-climatic subzones

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1. Introduction

The importance of legumes (*Fabaceae*) in the world's agricultural production is very high, since their cultivation contributes to solving the problem of providing the planet's population with relatively cheap vegetable protein, often not inferior in nutritional value to protein of animal origin [1]. Among all the legumes, the soybean (*Glycine max* (L.) Merr.), in the seeds of which the protein content in most cases exceeds 40% [2], takes a special place. Apart from protein, its seeds contain up to 27% of fat and valuable macro- and microelements [3,4].

Climate is the most important factor influencing the formation of biosystems on the planet. Due to significant changes in the climate system caused by both natural processes and anthropogenic impact resulting from all types of industries, the assessment of their impact on the transformation of ecosystems and individual crops becomes particularly relevant [5–7].

The yield potential of soybeans is based on the requirement to meet its biological needs in terms of environmental factors and agro-climatic characteristics of the cultivation region, primarily, they are warmth [8] and water supply both in certain periods of its growth and development, and in general during the growing season [9]. The weather component of the crop yield variability can reach 60–80% of all other factors [10–12] influencing the soybean production process. So, in Russian Non-Chernozem zone, the main limiting factor for soybean cultivation is warmth supply [13].

According to Rosgydromet, over the past half century there has been a tendency towards an increase in the average air temperature. At the same time, the average rate of warming in Russia significantly exceeds the average one for the globe, and for the period from 1976 to 2020, its value was 0.5 °C per decade [14–16]. Comparing one of the most important climate indicators—the sum of active temperatures [17]—revealed their widespread increase throughout the territory of European Russia and a shift in the borders of agro-climatic zones by several degrees to the north [18]. These processes will lead to an increase in the duration of the growing season and the warmth supply for agricultural crops in the northern regions [19,20]. Climate change will further contribute to the use of early maturing soybean varieties, not only determinant, but of rather more productive, semi-determinant and indeterminant growth type varieties, for cultivation in the Central region of the Non-Chernozem zone, ensuring maximum use of the agro-climatic potential of the region, due to the local climate change [21–23].

Two main soybean clusters have been formed in the country: the traditional one—Far Eastern, and the new one—central, located on the European territory of the Russian Federation. Due to the specifics of the domestic soybean market, which could be characterized by significant geographical distance of the main areas of soybean production from the regions of its processing and consumption, the Far Eastern soybean cluster is focused on exports to China, and the central one is focused on supplying the processing industry. Current soybean production does not satisfy the needs of the Russian processing industry, which requires about 4 million tons per year, providing only half of the required amount. Therefore, in these regions, it is necessary to increase the yield of early maturing soybean varieties. In order to achieve this, one should (1) intensify the applied agricultural technologies [24]; (2) conduct a more in-depth analysis of agro-climatic potential of the territory [25], and (3) evaluate the possibility of cultivation varieties belonging to semi-determinant and indeterminant growth types.

The expansion of soybean cultivation areas in the Central region of the Non-Chernozem zone is hampered by stressful conditions during the period of seed filling and maturing, primarily the limited warmth resources [26]. Along with development of new varieties with a reduced response to a day's length and adapted to the agro-climatic conditions of the growing zone, as well as considering the analysis of soybean agro-phytocenosis parameters at different stages of the production process [27], the possibilities of growing the crop and shifting its cultivation borders to the north are getting higher [28]. The introduction of soybeans into the Non-Chernozem zone of Russian European territory, which begun in the 1980s, continues to the present day and in recent decades has received a powerful potential for further development.

Thus, it seems relevant to justify from the agrobiological point of view the production process of early maturing soybean varieties and develop the recommendations for its optimization. These recommendations are to be based on the changed weather and climatic conditions, resulting in extension of the soybean cultivation area borders to the north, and supposing to solve the problem of vegetable protein production and varietal assortment expansion [29].

The main opportunities for widening soybean cultivation area to the regions of the Central region of the Non-Chernozem zone are in growing range of varieties suitable for cultivation in the region, and the further shift of the northern border of sowing, resulting from the changed agro-climatic conditions of the zone [30–32].

The purpose of the research: to analyze the parameters of climate change in the Central region of the Non-Chernozem zone, to confirm the shift in the northern border of the permissible soybean cultivation area and to introduce new varieties of different ecological and geographical origin for this zone.

The scientific hypothesis was to justify the possibility of soybean introduction to new regions of cultivation, due to the adaptive capacity of varieties and the climatic changes that have occurred.

2. Materials and Methods

Evaluation of soybean varieties of different origin was carried out from 2008 to 2020, on the experimental base of the Institute of Seed Production and Agrotechnologies—a branch of the Federal Scientific Agroengineering Center VIM (Ryazan region). The experimental site has the following geographic coordinates: 54° north latitude and 39° east longitude. Plant material for field experiment was selected on the basis of the analysis of changes in the agro-climatic regional conditions and its requirements for growing. The experiments were carried out in a four-field grain crop rotation, with a black fallow as a preceding crop. The agrotechnics in the experiments was generally accepted for the Central region of the Non-Chernozem zone.

The research was conducted using traditional early maturing soybean varieties of northern ecotype, the ones of southern and Far Eastern ecological and geographical origin, under the conditions of the Central region of the Non-Chernozem zone.

All studied soybean varieties were divided into 3 groups relying on the geography of the scientific organization where they were obtained and the regions of zoning:

- the northern ecotype varieties that were taken as a control—Mageva, Okskaya, Svetlaya, Kasatka, Georghiya, developed by the Institute of Seed Production and Agrotechnologies—a branch of the Federal Scientific Agroengineering Center VIM, recommended for the Central Region of the Non-Chernozem zone [33];
- the southern varieties—Lira, Avanta, Bara, selected by the Federal State Budgetary Scientific Institution of the Federal Scientific Center "All-Russian Research Institute of Oilseeds named after V.S. Pustovoit" and "Soybean Complex" Company LLC;
- the Far Eastern varieties—Persona, Umka, Lydia, Gratsiya, selected by the Federal Research Center of the Federal State Budgetary Scientific Institution "All-Russian Research Institute of Soybeans".

All studied varieties belong to the group of early maturing—from very early maturing with a vegetation period of 76–95 days to early maturing with a variation of the interval of the growing season within 83–109 days. According to the type of growth, varieties of the northern ecotype belong to determinant (Mageva, Kasatka, Svetlaya), semi-determinant (Okskaya), and indeterminant (Georghiya) forms. Southern varieties also included both semi-determinant (Bara) and indeterminant (Lira, Avanta) forms. Far Eastern varieties were represented by determinant (Persona), semi-determinant (Umka). and indeterminant (Lydia, Gratsiya) forms. Plant height ranged from 65 cm in varieties of the northern ecotype to 115 cm in southern varieties. Depending on plant height, the first pod height varied from 8–12 cm in soybean varieties of the northern ecotype and to 13–15 cm in southern and Far Eastern varieties [34].

The sowing was carried out at the optimal time limits when the soil was warmed up at the seed embedding depth to the level of 12–15 °C. Sowing was carried out using a mounted seed drill CH-16. The method of sowing was conventional: row one with a row spacing of 15 cm, plot sizes: length—6 m, width—3 m. Each variety was sown in four replications, density of plants after germination—600 thousand plants per 1 ha; plot placement was randomized, the area of the accounting plot was 18 m^2. The yield was recorded by the total harvesting method, i.e., the yield from the entire area of each plot was counted, with corrections for crop losses and thinning, but not from selected rows, portions, samples, etc. Seeds were brought to the standard 14% moisture content and 100% purity.

As the main agro-climatic indicators characterizing the territory's natural and resource potential, warmth and moisture supply have been taken. We have calculated the average monthly air temperatures, the sums of precipitation by months and for the growing season, the sums of active temperatures, and hydrothermal coefficients (*HTC*). The data were obtained by studying the climatic data set compiled by the All-Russian Research Institute of Hydrometeorological Information [35] for the period from 1981 to 2020.

Hydrothermal coefficient is calculated according to the G.T. Selyaninov [36] formula:

$$HTC = \sum p \ / \ 0.1 \sum T_{act}$$

where $\sum p$—the sum of precipitation for the vegetation period; $\sum T_{act}$.—the sum of active temperatures for the vegetation period.

According to the *HTC* scale, *HTC* = 1.0 when moisture supply is equal to moisture expenditure; *HTC* > 1.5 corresponds to excessive humidification; *HTC* < 1.0—corresponds to droughts of varying severity.

The phenological observations were carried out according to the American microphenology [37,38], where the vegetative growth phases are marked with letter V with the corresponding number, and the reproductive growth phases with letter R, where the scale allows comparing the dynamic indicators of yield formation of different varieties obtained under different conditions [39]. The phenological observations were carried out. During the growing season, the density of plants was determined, phenological observations were carried out, the dates and periods of emergence, the beginning bloom, the beginning of pod formation, pod growth, seed filling, and maturity were recorded. Biometric parameters were noted every 15 days during the growing season. Plant samples were used to determine plant height, crude and dry biomass of plants, leaves, pods, seeds, number, and weight of root nodules. Photosynthetic potential, net photosynthetic productivity and other parameters of photosynthetic and symbiotic activity of soybean plants were determined.

The statistical analysis of the results was performed with the licensed mathematical software packages for PC: Microsoft Excel, STATISTICA-6.0, MathCAD 14.0.

3. Results and Discussion

Based on the analysis of changes in the climatic conditions in the Central region of the Non-Chernozem zone for the period of 1981–2020, new borders for the shift of the isotherm of the active temperature sum towards high latitudes were determined in the conditions of the Central region of the Non-Chernozem zone.

The meteorological conditions of the growing season in 2008–2020 had significant differences in temperature and moisture regimes among themselves and compared to the long-term average values. Year 2010 was extremely hot and dry in the Central region of the Non-Chernozem zone, when the average daily temperature exceeded the long-term average values by 5–8 °C during the entire growing season. Due to significant differences in meteorological conditions during the years of agro-ecological testing of soybean varieties in Ryazan Oblast, they were combined into 3 groups according to the moisture supply for the growing season and the value of the hydrothermal coefficient (*HTC*) by Selyaninov. The highlighted years with extremely dry conditions (*HTC* < 0.7) were 2009, 2010, 2011, 2018, 2019; the years with the most frequently recorded moisture supply were quite close to optimal (*HTC* 0.7–1.4) over the years of research which were 2012, 2013, 2014, 2015, 2016, 2017; the years with the excess of moisture supply (*HTC* > 1.4)—2008, 2020. In 2010, Moscow Oblast witnessed severely arid conditions; the conditions close enough to optimal were in 2011, 2012, 2014, 2018, and 2019; excess precipitation was recorded in 2008, 2009, 2013, 2015, 2016, 2017, and 2020.

In the Non-Chernozem zone, warmth (temperature) resources are the main limiting factor, so, agricultural crops of the temperate zone are predominantly distributed here, requiring low temperatures at the level of 18–22 °C for their growth and development. However, in recent decades, there has been a tendency to increase in the sum of active temperatures that plants can potentially accumulate in a particular region of the Non-Chernozem Zone.

Studying the database of average monthly temperatures and precipitation, the sums of active temperatures and the *HTC* from 1981 to 2020, compiled by the All-Russian Research Institute of Hydrometeorological Information [35], the authors have technically divided the Central Economic Region of the Non-Chernozem Zone of the Russian Federation into 3 agro-climatic subzones: northern, central, and southern (Figure 1) to facilitate the analysis and to comply with the tasks listed above.

Figure 1. Agro-climatic subzones in the Central region of the Non-Chernozem zone.

The classification was based on the temperature climatic factors—the average temperature for the growing season and the sum of active temperatures for the vegetation. Along with the temperatures, the total precipitation and the *HTC* value for the growing season were analyzed (Table 1).

Table 1. Characteristics of the agro-climatic subzones of the Central region of Russian Non-Chernozem zone (1981–2020).

Agro-Climatic Subzone	Color	Average Temperature for May–August, °C	$\sum T \geq 10$ °C	$\sum$ Precipitations, mm	*HTC* for the Growing Season
Northern (Tver, Yaroslavl, Kostroma Oblast)		16.0–18.0	2000–2200	285–295	1.4–1.7
Central (Smolensk, Moscow, Kaluga, Vladimir, Ivanovo Oblast)		18.0–19.0	2200–2400	265–285	1.1–1.4
Southern (Bryansk, Oryol, Ryazan, Tula Oblast)		19.0–21.0	2400–2600	255–265	0.7–1.1

Tver, Yaroslavl, and Kostroma Oblast were assigned to the northern agro-climatic subzone (NAS). The average air temperature during the growing season from May to August here is 15.0–16.0 °C, the sum of active temperatures is 2000–2200 °C. *HTC* is within or above the optimum range, which is 1.0–1.5 for soybeans.

The central agro-climatic subzone (CAS) included Smolensk, Moscow, Kaluga, Vladimir, and Ivanovo Oblast. The average temperature for the growing season from May to August is 16.0–17.0 °C here, the sum of active temperatures is 2200–2400 °C. The *HTC* for the growing season is within the optimal range, thus providing conditions for sufficient moisture supply.

The southern agro-climatic subzone (SAS) (Bryansk, Oryol, Ryazan, Tula Oblast) is characterized by higher air temperatures, which average 17.0–18.0 °C during the growing season. The sums of active temperatures are on average at the level of 2400–2600 °C. It should be noted that over the past decades, this indicator in some years significantly exceeded the average values and reached 2900 °C in some regions. Along with higher temperatures, this agro-climatic subzone quite often experiences years with insufficient precipitation and the *HTC* is within the range of 0.7–1.1 °C.

A tendency towards an increase in the sums of active temperatures and a decrease in the value of the hydrothermal coefficient was noted in all agro-climatic subzones in the Central region of the Non-Chernozem zone (Figure 2).

The maximum increase in the amounts of active temperatures that soybean plants can potentially accumulate occurred in the southern agro-climatic subzone, while the central and the northern ones were slightly inferior. Along with the increase in the sums of active temperatures, a decrease in the value of the hydrothermal coefficient during the growing season was recorded over the study period. To a greater extent, the *HTC* during the growing season decreased in the northern and the southern agro-climatic subzones. The studies revealed an increase of 3–4 °C in the average monthly temperatures in all agro-climatic subzones (Figure 3).

The most significant increase in average monthly temperatures occurred in May and August: in the northern agro-climatic subzone—by 0.9 °C and 1.2 °C, in the central—by 1.8 °C and 1.4 °C, and in the southern—by 2.0 °C and 2.3 °C, respectively [40]. Such a trend has a positive effect on the distribution of soybean crops in the Central region of the Non-Chernozem zone. In August, there was a decrease in the amount of precipitation, while there was a relative increase in May. The amount of average monthly precipitation increased at the beginning of the growing season—in May—by an average of 16–18 mm; in the following months, on the contrary, a decrease from 10 to 22 mm was observed in most of the considered subzones.

A decrease in the amount of precipitation in August over a 40-year period was recorded in the central and the southern agro-climatic subzones. The northern agro-climatic subzone is characterized by a large amount of precipitation in August, therefore, this fact must be considered in the future when selecting soybean varieties.

The analysis of the sums of active temperatures, which is one of the most important climate indicators, has revealed their widespread increase throughout the territory of European Russia and a shift in the borders of agro-climatic zones by several degrees to the north (Figure 4). The Moscow region found itself in a belt with the sum of active temperatures from 2200 to 2800 °C during the growing season, while a few decades ago, the maximum sum of active temperatures in the region had reached only 2200 °C [41]. At the same time, the region has remained in the zone of sufficient moisture supply with a probability of dry periods of no more than 25%.

The agro-climatic zone significantly moved northward with the sum of active temperatures during the growing season at the level of 2800–3400 °C. This zone includes the southern regions of the Central Non-Chernozem Region, where the probability of drought is already up to 50%, that is, every second growing season.

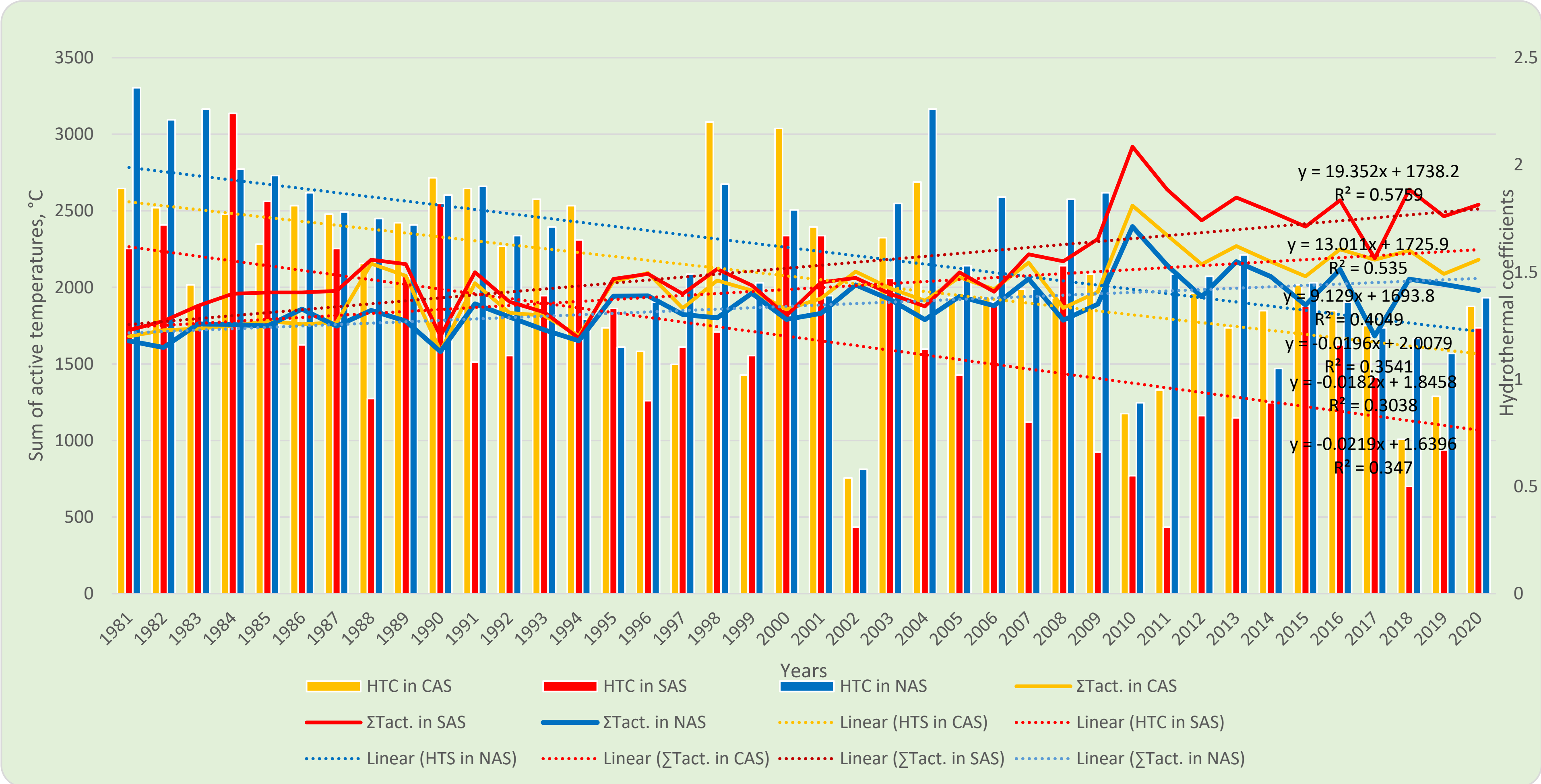


Figure 2. Dynamics of the sum of active temperatures and *HTC* in the agro-climatic subzones of the Central region of Russian Non-Chernozem zone over a 40-year period.

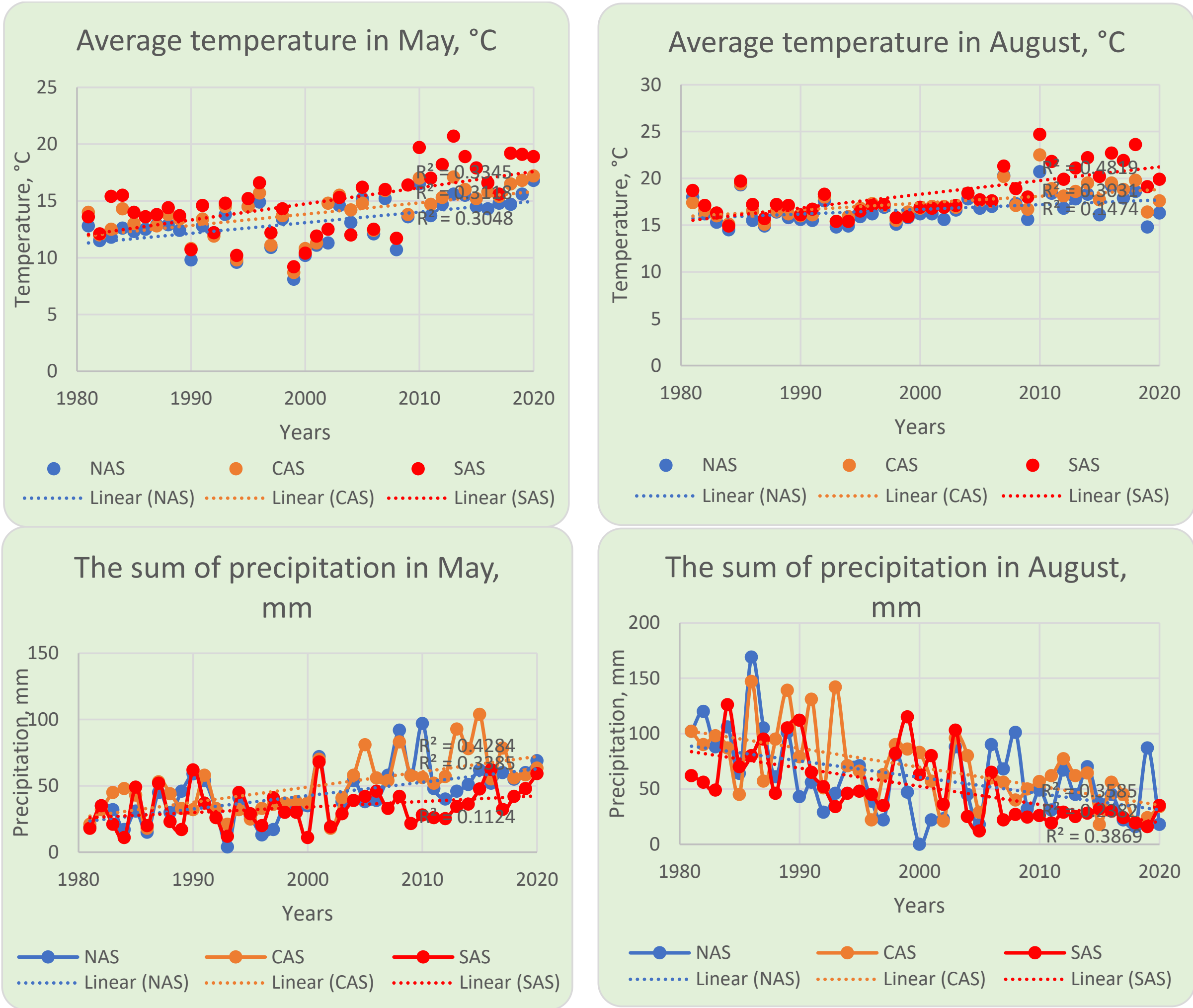
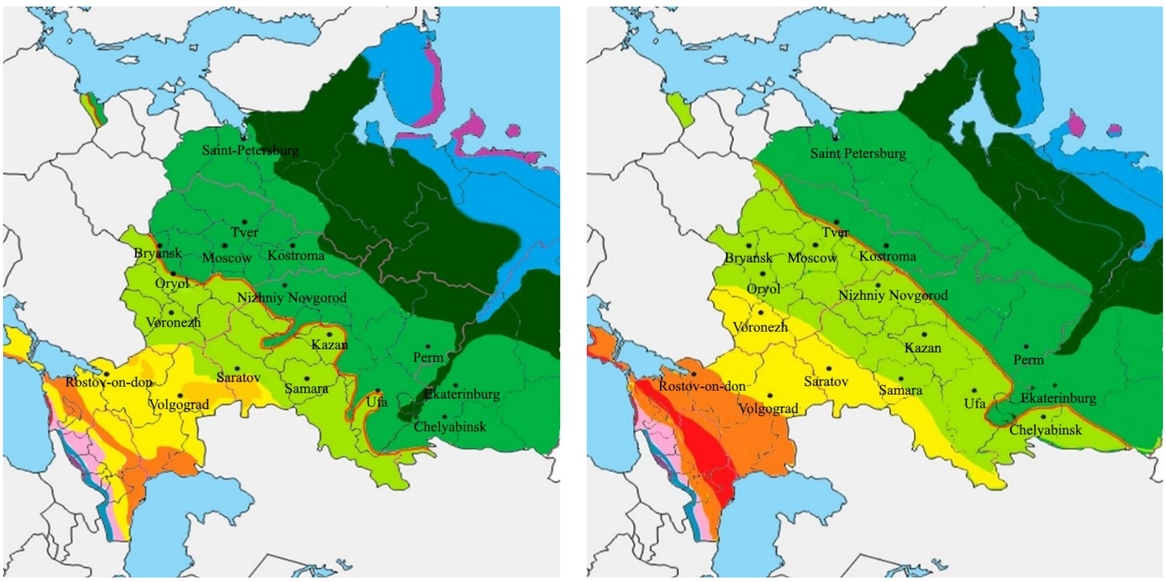


Figure 3. Dynamics of average monthly air temperatures and precipitation in May and August for the period from 1981 to 2020 by agro-climatic subzones in the Central region of the Non-Chernozem zone.



(**a**) (**b**)

Figure 4. *Cont.*

Zone	Color	∑*T Act.*, °C	*HTC*
Cold zone		under 400	Excessive humidification (>1.5)
		400–1000	
Temperate zone		1000–1600	
		1600–2200	Enough humidification (1.0–1.5), the possibility of droughts—25%
		2200–2800	
		2800–3400	Dry growing season (0.5–1.0), the possibility of droughts—25–50%
		3400–4000	Dry growing season (0.3–0.5), the possibility of droughts—over 70%
Subtropical zone		over 4000	

Figure 4. Borders of agro-climatic zones in the European territory of Russia: (**a**) in 1964; (**b**) currently.

Thus, in the Central region of the Non-Chernozem zone, local climate warming led to a shift in the isotherm of the sum of active temperatures by 150–200 km towards higher latitudes: if in 1981, the isotherm went through the northern part of Bryansk and Oryol Oblast, including a small part of Kaluga and Ryazan Oblast, currently it goes through the northern part of Moscow Oblast, partially including the territory of Tver Oblast, including Vladimir Oblast and the southern part of Kostroma Oblast.

The studies revealed small varietal differences in the duration of the growing season within one year, while the number of days of the growing season could vary significantly by year (Figure 5).

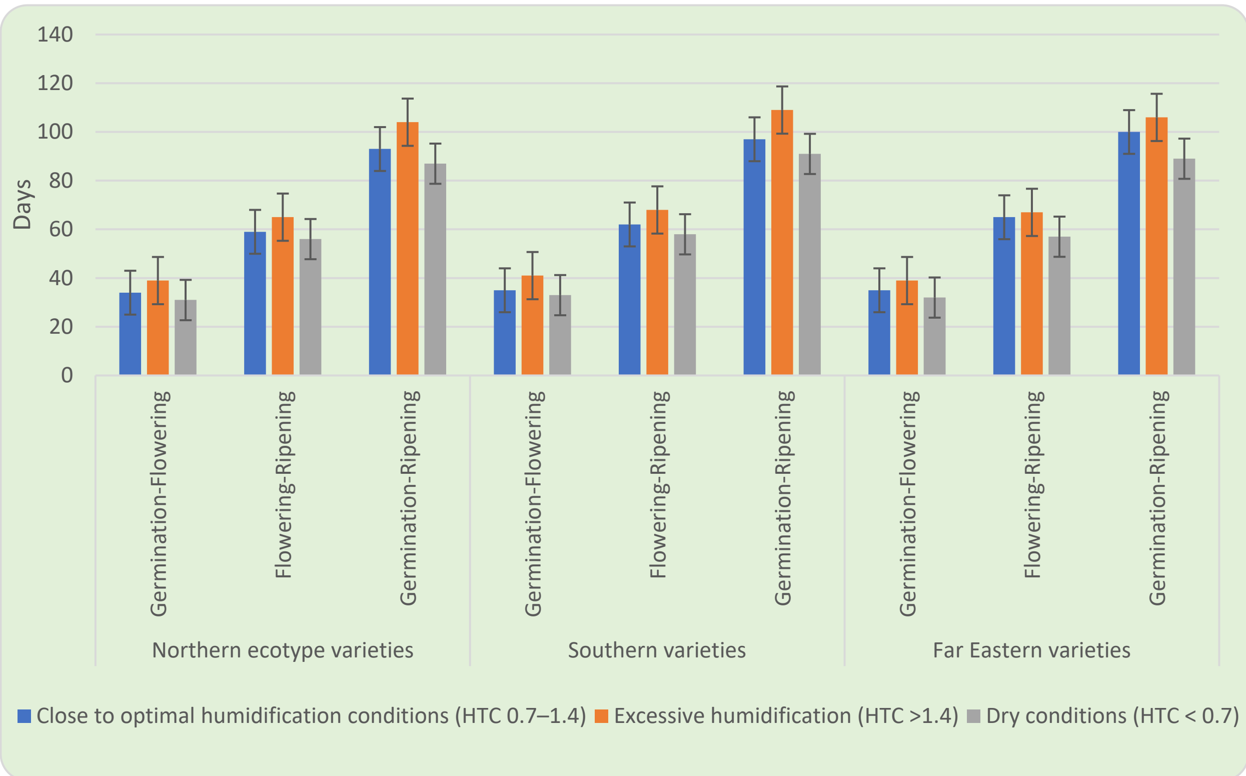


Figure 5. The duration of the growing season for soybean varieties of different ecological and geographical origin, depending on the humidification conditions (Ryazan Oblast, 2008–2020).

The duration of the growing season for early maturing soybean varieties in the conditions of Ryazan Oblast from sowing to maturity did not exceed 120 days and varied more by years of the research than by varieties within one year. The average duration of the period from sowing to germination was the same for all varieties and averaged 10–14 days. At the same time, the duration of the growing season from germination to maturity varied quite significantly among varieties—the differences could range from 20 to 35 days.

The yield of soybean seeds depended both on the agro-ecological conditions of the growing season, and on the biological characteristics of the varieties [42–44]. At the same time, the highest yields of varieties were recorded in the years that were favorable in terms of temperature and humidity (Figure 6).

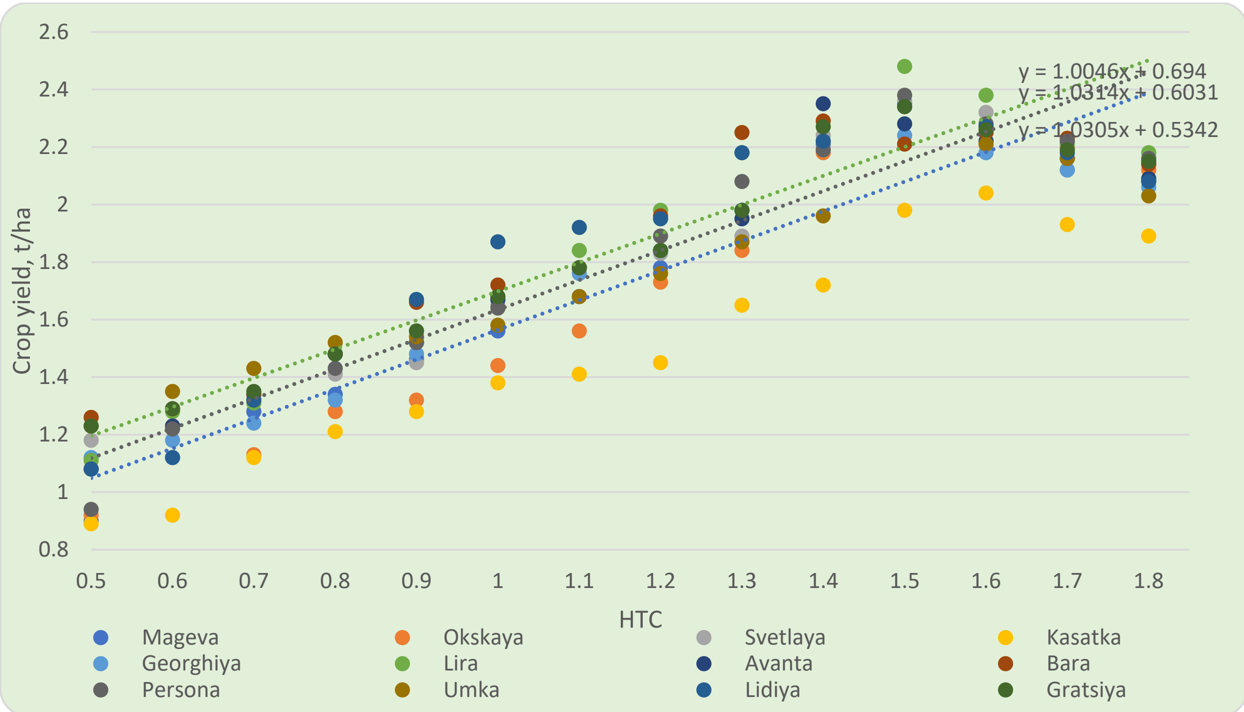


Figure 6. The correlation between soybean yield and the *HTC* of the growing season. Dotted lines are trend lines for Lira, Umka, Mageva varieties according to the colors in the legend.

In general, one could notice a tendency to increasing yield with an increasing *HTC* during the growing season for all the varieties, while the differentiation of varieties within groups in response to changes in the humidity regime remained. The highest yield was formed for the varieties with an *HTC* in the range of 0.7–1.4 and amounted to 2.32–2.56 t/ha, the lowest—in 2010 with the *HTC* = 0.5 and amounted to 0.89–1.28 t/ha.

At the same time, there were years with a low *HTC* during the growing season, but the yield was quite high. This is due to the fact that at the beginning of generative development and the formation of reproductive organs, a sufficient amount of precipitation fell, which resulted in the potential for future high yields. An example of such a year can be 2012, when the variety yield formed at the level of 1.90–2.52 t/ha, while the *HTC* averaged 0.7 during the growing season.

Analyzing the changes in the climatic conditions for the growing season in the agro-climatic subzones of the Central Region in the Non-Chernozem Zone over the past decades, and assessing the correlation dependences for the yield formation of soybean varieties of various ecological and geographical origins in this zone, we have developed the characteristics of soybean variety models which are potentially suitable and recommended for the cultivation in every agro-climatic subzone (Figure 7).

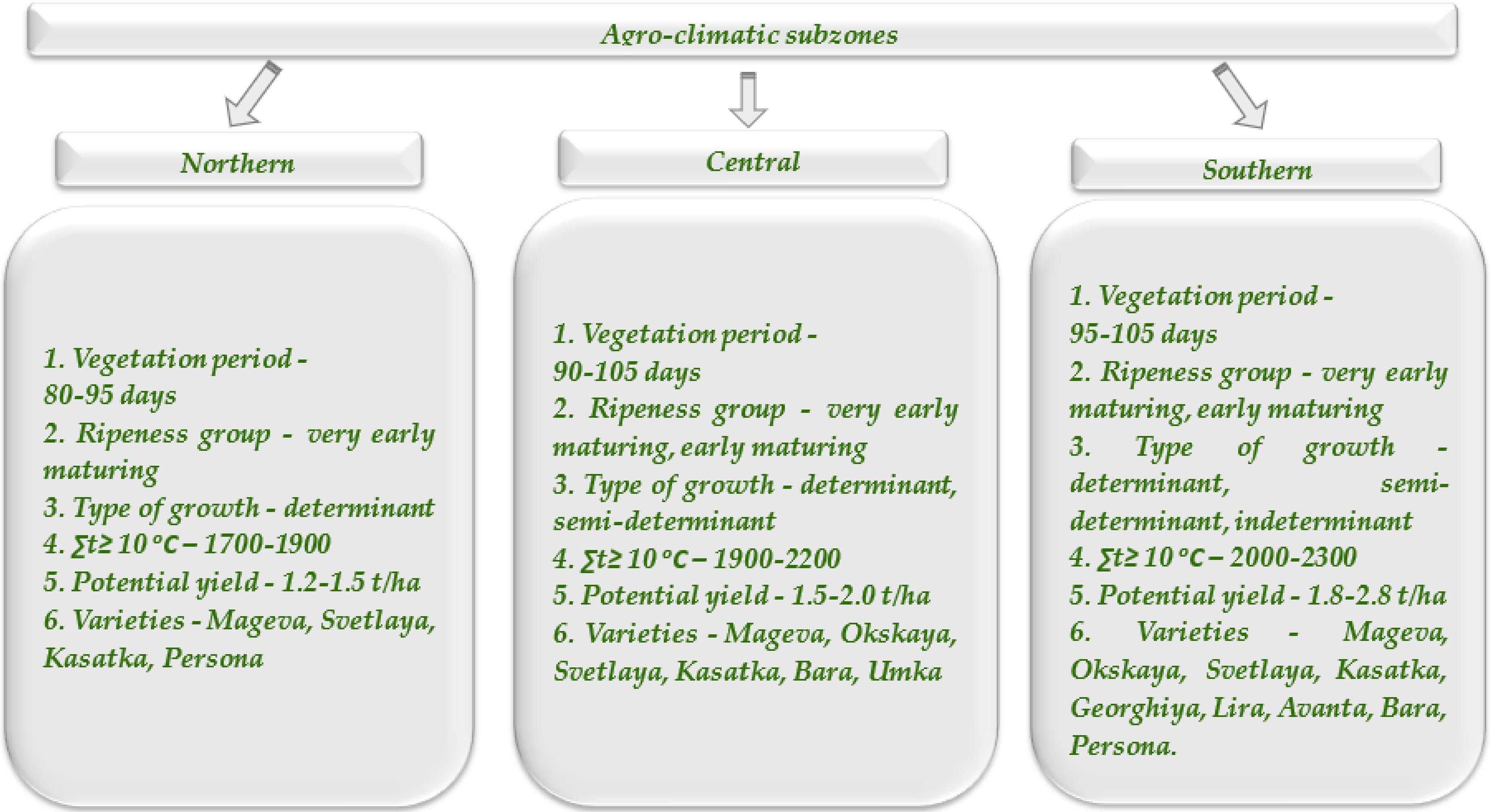


Figure 7. Models of soybean varieties recommended for cultivation depending on the agro-climatic subzone in the Central region of the Non-Chernozem zone.

The instability of temperature and humidity climate parameters, and the increase in average monthly temperatures over the droughts which more frequently occurred, set new requirements for the variety selection—they must have a higher ecological plasticity, with resistance to adverse environmental factors. In the conditions of the Central region of the Non-Chernozem zone, along with the soybean varieties of the northern ecotype, it seems possible to introduce varieties with a longer vegetation period, a semi-determinant type of growth, with a higher potential of productivity.

As a result of studying the response of soybean varieties of different ecological and geographical origins to the hydrothermal conditions during the growing season and considering the results of agro-ecological tests, it was found that the varieties of the northern ecotype can stably ripen in all agro-climatic subzones of the Central region in the Non-Chernozem zone, the southern and the Far Eastern ones—in the central and the southern zones. Complying with the technology, which includes methods to optimize the length of the growing season, the seed yield in favorable years can reach 2.5–2.8 t/ha.

4. Conclusions

The analysis of agro-climatic conditions for the period of 1981–2020 has shown the tendency to local climate warming amidst the general climate aridization in the territory of the Central region of the Non-Chernozem zone. The sum values of active temperatures have increased depending on the agro-climatic subzone from 1700–2200 °C to 1950–2400 °C, while the amount of precipitation during the growing season has decreased by an average of 20–40 mm, from 270–280 mm to 190–230 mm; Selyaninov hydrothermal coefficient (*HTC*) has decreased on average by 0.3–0.4 points, its value is in the range from 1.4–1.6 to 1.1–1.4 in different agro-climatic subzones. Local climate warming in the Central region of the Non-Chernozem zone has led to a shift in the isotherm of the active temperature sums by 150–200 km towards higher latitudes.

Climatic conditions in the agro-climatic subzones in the Central region of the Non-Chernozem zone currently have significant differences: in the northern agro-climatic subzone (Tver, Yaroslavl, Kostroma Oblast) the sum of temperatures is 2000–2200 °C, the *HTC* is 1.4–1.7 and the total precipitation is 285–295. In the central agro-climatic subzone (Smolensk, Moscow, Kaluga, Vladimir, Ivanovo Oblast)—the sum of temperatures is 2200–2400 °C, the *HTC* is 1.1–1.4, the sum of precipitation is 265–285. In the southern agro-climatic subzone (Bryansk, Oryol, Ryazan, Tula Oblast)—the sum of temperatures is 2400–2600 °C, the *HTC* is 0.7–1.1, the sum of precipitation is 255–265. At the same time, all stages of plant growth and development can withstand biological temperature minima, ensuring stable soybean maturing in all areas in August to early September.

The agro-ecological analysis of early maturing soybean varieties allowed concluding that soybean varieties belonging to the group of very early or early maturing ones and with a determinant type of growth are recommended for cultivation in the northern agro-climatic subzone of the Central region in the Non-Chernozem zone; in the central—soybean varieties belonging to the group of very early maturing or early maturing with a determinant or semi-determinant type of growth; in the south—soybean varieties belonging to the group of very early maturing or early maturing with a determinant, semi-determinant, and indeterminant type of growth.

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