DETERMINING THE REGIONS WITH METEOROLOGICAL CONSTRAINS FOR AGRICULTURE IN BULGARIA UNTIL 2030-2050

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Abstract

Agriculture is a branch that develops entirely outdoors and under the immediate influence of weather conditions. At the same time, the climatic anomalies and changes that are observed everywhere throughout the country and above all in the agricultural regions of the country have increased in frequency and intensity.

To be competitive as an industry, agriculture must produce quality and environmentally friendly products in the largest possible quantities to satisfy the local market and for export. Under these conditions, farmers must control all additional costs and especially those related to the need to improve environmental conditions and above all the lack of heat and moisture.

The aim of the present research is to analyze the agrometeorological conditions obtained as a result of a simulation with a numerical climate model for the next 30-year period until 2050. In order to get a more concrete idea of these conditions, some agrometeorological indices will be used - transition dates of the average daily temperature during 5 and 10ºC, duration of the vegetation period, sum of precipitation during the vegetation and non-vegetation period, values of evapotranspiration (ET) and drought index (AI).

Keywords: *agrometeorological conditions, future climate 2020-2050, duration of the growing season, sum of temperatures, evapotranspiration, drought index*

INTRODUCTION

The frequent climatic anomalies in the first 20 years of the XXI century are increasingly the subject of research by specialists in the fields of meteorology, climatology, agrometeorology and ecology, as well as by politicians, political analysts and futurologists. This concern is further heightened by the need to provide sustenance for a growing global population.

Food production is a process that entirely depends on the degree of development of technologies and their applicability in agricultural production; from soil fertility and soil processing technologies; from the varieties / hybrids of agricultural crops - resistant to disease and pests and unfavorable phenomena of meteorological origin. But above all, the productivity of agricultural crops depends on the specific agrometeorological conditions in each individual year, and as is known from many years of practice, they are different in each specific year.

The main elements of the agrometeorological conditions on which the productivity of agricultural crops depends are the temperature and humidity conditions during the growing season (1).

Winter wheat (Triticum aestivum L.) is the main crop throughout the world, and Portugal is a country that is still heavily dependent on wheat imports, for example, used as a fodder crop in many dairy farms. In this context, meeting domestic needs through increased domestic production can play a vital socio-economic role (Páscoa et al. 2017). Wheat production is mainly concentrated in southern Portugal, namely the Alentejo region, which contributes more than 75% of national wheat production (INE 2018). In the Alentejo, the spread of dryland farming systems led to the cultivation of wheat under rain fed conditions (Valverde et al. 2015). Approximately 95% of the wheat-grown area in the Alentejo is dedicated to bread wheat production (Gouveia and Trigo 2008). The typical Mediterranean climate in this region causes a high evaporative demand in late spring (c. April–June) when rainfall is low, greatly increasing the risks of severe water deficits during the most sensitive growth stage of winter wheat, i.e. flowering and post-anthesis period of grain filling (Costa et al. 2013; Páscoa et al.

2017). A previous analysis for this region revealed that climatic water deficits in May and June, largely coinciding with the grain filling and ripening stages, could impose a strong limitation on wheat yields (Páscoa et al. 2017). Furthermore, such a critical growth period is also often exposed to extremely high temperatures, with clear detrimental effects on final grain yield (Dias and Lidon 2009; Scotti-Campos et al. 2014). For example, high post-anthesis temperature (> 30 °C), which is common in the Alentejo (Scotti-Campos et al. 2014), can lead to a significant reduction in grain yield, as a result of a shortened grain filling phase and increased leaf senescence (Asseng et al. 2011; Dias and Lidon 2009). A modeling study in the major wheat growing regions of Australia suggests that variations in average growing season temperature of ± 2 °C could force a significant reduction in wheat grain production by up to 50% (Asseng et al. 2011). Observed climatic conditions in southern Portugal have shown a clear trend towards a drier climate with increased average temperature and reduced annual precipitation, especially spring precipitation (Páscoa et al. 2017; Rolim et al. 2017; Valverde et al. 2015). . The observed warming and drying trends are likely to intensify in a future climate (Páscoa et al. 2017; Rolim et al. 2017), with a concomitant increase in the frequency and intensity of extreme weather events such as drought (Santos et al. 2016, Yang 2019). By making this review, we should pay attention to the results of the researches of H. Boogard, I. Sapit, J. Olesen, K. Keresbaum, J. Eitzinger, M. Trunka, P. Nezhedlik and others.

The European Union is a large consumer and producer of food. Population growth, dietary changes (in particular increased meat consumption) and increasing demand for biofuels (Godfray et al., 2010) are expected to lead to the need for increased production. Overall in Europe, actual yields are high and the gap between potential or water-limited yields and actual yields is relatively narrow. However, it is important to identify regions where and to what extent yields can still be increased.

Many global scale crop simulation studies do not focus on potential or water-limited yields, but on actual crop yield levels (Stehfest et al., 2007; Liu et al., 2007; Parry et al., 1999, 2004; Deryng et al., 2011; Bondeau et al., 2007). As such, the results of these studies cannot be used for determination and comparative analysis yield gap. Global model-based research follows a grid top-down strategy using global datasets of monthly weather (usually interpolated to daily data), crop and soil data fed into common crop models with little to no local model calibration and validation . Although these studies lack the inclusion of locally relevant information and factors that may affect mining potential, they have the advantage of global spatial coverage and the use of a worldwide method, as opposed to very fragmented local studies, each with own method (Lobell et al., 2009; Van Ittersum et al., 2013).

We used the WOFOST crop growth model implemented in the Crop Growth Monitoring System (CGMS) to estimate the yield gap of autumn-sown wheat in the European Union (EU25).1 Autumn-sown wheat is Europe's main crop in terms of area (about 18 million ha in the EU25); stands for winter wheat in most of the EU25, except southern Italy, southern Spain and most of Portugal, where spring wheat varieties are sown. CGMS relies on local weather, soil and crop data as much as is currently available, as recommended by Van Ittersum et al. (2013) but has full spatial coverage so does not require additional scaling procedures. Typically, CGMS is applied to monitor growth conditions for major crops in Europe at a regional scale (Supit et al., 2012, 2010; Baruth et al., 2008). This system is an integral part of the MARS crop yield forecasting system (MCYFS; Micale and Genovese, 2004; Lazar and Genovese, 2004; Genovese and Betio, 2004), which provides the European Commission (EC) with timely and quantitative yield forecasts of the major European cultures. In this paper, we assess the strengths and limitations of CGMS for estimating fall wheat yield gaps for the EU25.

MATERIAL AND METHODS

In the realization of the present study, data were used for 54 meteorological stations, from the agricultural territory of the country, whose spatial distribution is shown in fig. 1. In this paper we select only 12 representative stations in the agricultural zone of Northern and Southern Bulgaria to represent agrometeorological conditions in the future, as follows - Vidin, Knezha, V. Tarnovo, Ruse, G. Toshevo, Varna, Karnobat, Yambol, Haskovo, Plovdiv, Petrich and Sofia.

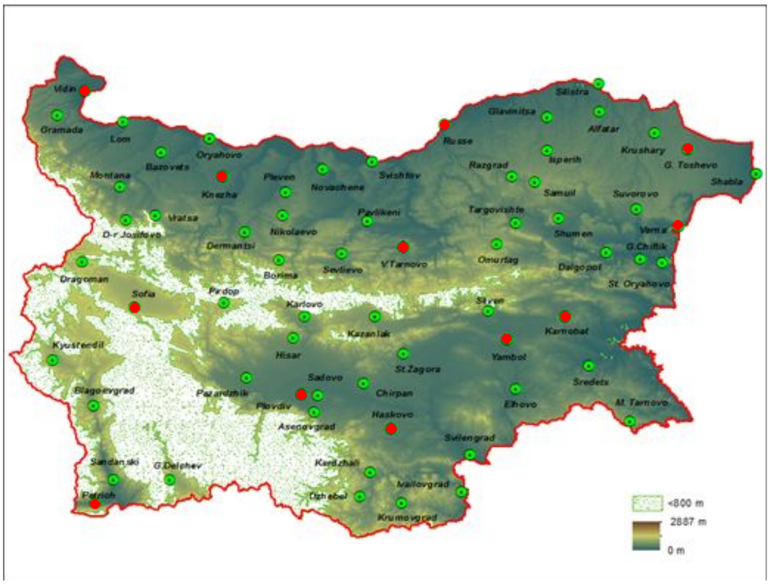

Fig. 1. Spatial distribution of meteorological stations, used for climate prediction for the next 30 years (2021-2050) in the territory of the country

To assess the presence of climate change for each weather element, two climate model simulations are performed. One is for a past 30 year period for which the amounts of greenhouse gases are known and a future period for which greenhouse gases are according to a selected scenario from the mentioned IPCC classification. Both simulations are for 30-year periods. In order to obtain statistically significant changes, the two periods are separated by a 30-year period. The first period is called 'reference' and the second is called 'future'. Generally accepted periods are 1961-1990 for the reference period and 2021-2050 or 2071-2100 years for future periods. Here we will consider the effect of the changes for the near term. In order to make a specific assessment of the change of a given meteorological element, real measurements of it during the reference period are also necessary. In our case, the numerical model ALADIN was used to simulate the meteorological conditions for the period 2021-2050. This model got its name, as an acronym, from Aire Limitée Adaptation Dynamique développement InterNational. It is an international project involving 14 meteorological services http://www.cnrm.meteo.fr/aladin/. ALADIN is built on the basis of compatibility with the IFS/ARPEGE system. The latter is a joint project of Meteo-France and the European Center for Medium-Range Forecasts (ECMWF). The history of ALADIN-Climate is much shorter and started in 2005, Spiridonov et al. (2005). The model uses successively the six hourly results of ARPEGE-Climate, (Déqué and Piedelievre, 1995) as well as its physical part.

Data homogenization is an important element of the data processing process because it affects all climate change assessments, i.e. of the norms for the reference period and, accordingly, of the M1 method, as well as of the various indices. In all methods, the main stages are:

- filling in the blanks;
- control of the data regarding set limits, characteristic of the climatic area;
- control of statistical characteristics.

Initially, base stations without gaps were selected. These are observations by full-time employees, mainly at the synoptic stations of NIMH and some stations in experimental fields of agricultural institutes or other departments. They are sufficient in number to be used to fill gaps at adjacent stations.

In addition to standard statistical methods for evaluating the characteristics of the rows, specialized methods of the EC for Agriculture were also used for evaluating the unfavorable areas for agriculture according to meteorological conditions. By applying the formula (1) recommended by J.-M. Terres, T. Toth, A. Wania, A. Hagyo, R. Koeble, L. Nisini in the methodology for determining areas with natural constraints from JRC Ispra, the values of the "dryness" index were calculated:

$$\mathbf{AI_{UNEP}} = \boldsymbol{P/PET}, \qquad (1)$$

Where: AI - drought index, P - annual amount of precipitation; and PET – sum of annual potential evapotranspiration. All drought index values are calculated to the sixth decimal place.

RESULTS AND DISCUSSION

To characterize the agrometeorological conditions in the following years, a simulation was conducted with the climate model ALADIN for the period 2021-2050, and the homogenized data from the period 1961-1990 were used to train the model. The data obtained from this simulation are used and form the basis of all assessments of the future climate and agro-climatic conditions in the country's agricultural regions. According to the criteria of the already cited methodology of the SIC in Ispra and DG Agriculture of the EC, the limiting factors are heat and the presence of water, respectively moisture in the soil. For this purpose, we investigated the transition dates of average daily temperatures through 0, 5 and 10ºC and, accordingly, the duration of periods with frost, of the potential and actual growing season, and also the accumulated sums of active temperatures. The data on the annual amount of precipitation and its distribution during different periods of the vegetation of agricultural crops were also analyzed. The monthly and annual sum of the potential evapotranspiration and the values of the drought coefficient were calculated.

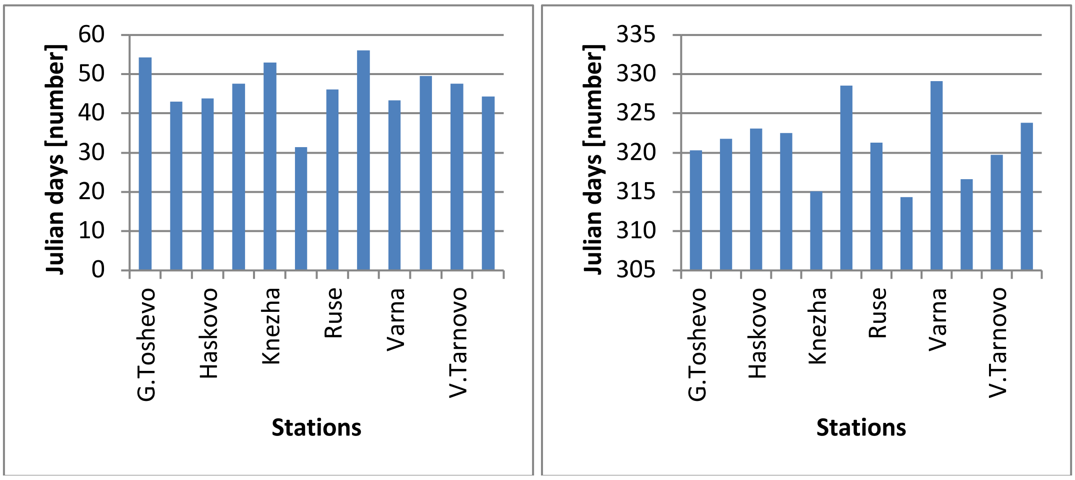

Fig. 2. Average multiannual dates of daily average temperature transition across 5ºC in the spring and in the autumn

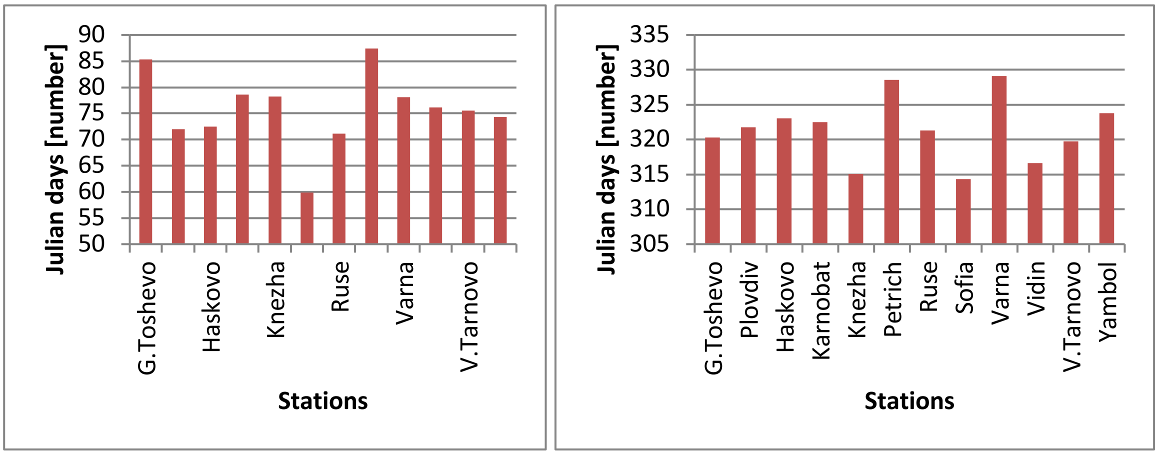

Fig. 3. Average multiannual dates of daily average temperature transition across 10ºC in the spring and in the autumn

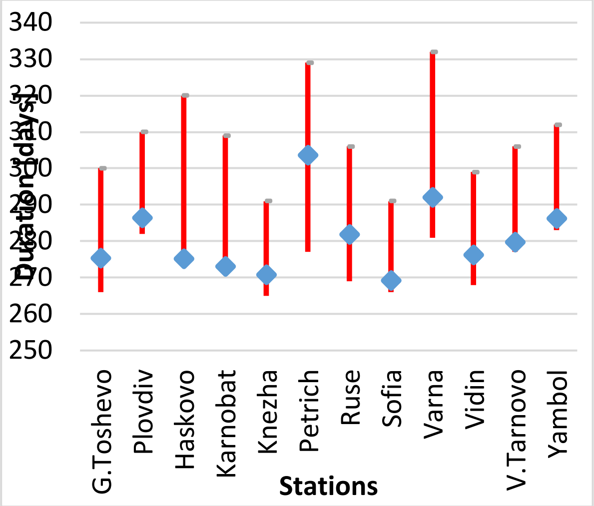

Fig. 4. Duration of the period (days) with average daily temperature ≥ 5ºC

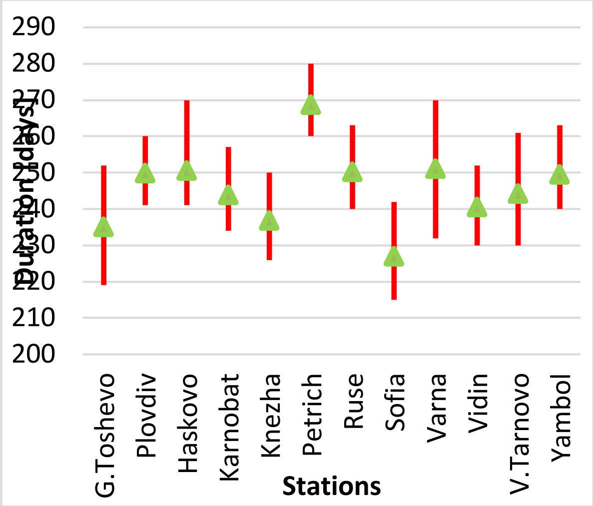

Fig. 5. Duration of the period (days) with average daily temperature ≥ 10ºC

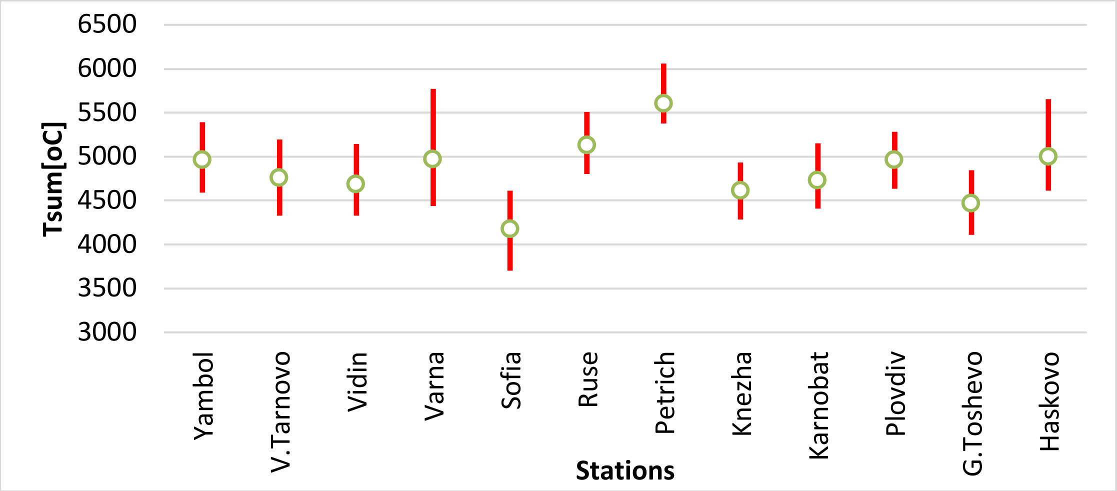

Fig. 6. Degree days sum for the period with average daily temperatures ≥ 5ºC

During the period 2021-2030-2050, the increase in average, maximum and minimum temperatures will continue, which will cause the extension of the potential and real vegetation periods, which corresponds to the permanent transitions of the air temperature by 5 and 10ºC in spring and autumn, fig. 2-3. This will be the basis of an increased length of the potential growing season on average to 270-310 days in different regions of the country, and the actual growing season will be 230-270 days, Fig. 4-5. In this sequence of increasing periods, the sum of the active temperatures will also increase, which determine the growth and growth rates of all plant ecosystems - agricultural and forest. Their values in the next 30 years will reach average values of 4200-5600ºC in different regions of the country, fig. 6.

The increase in temperatures indisputably causes an acceleration of growth by shortening the interphase periods of phenological development of crops, but only under the condition that there is a sufficient amount of water in the soil. Water reserves in soils are determined by their ability to retain moisture, and this is determined by their physico-mechanical properties. Different soils have different hydrological properties and therefore different capacity to hold water, which depends on the hydrological constants full soil moisture capacity (FSMC) and wilting point (WP). The difference between FSMC and WP determines the available water content (AWC), or capacity.

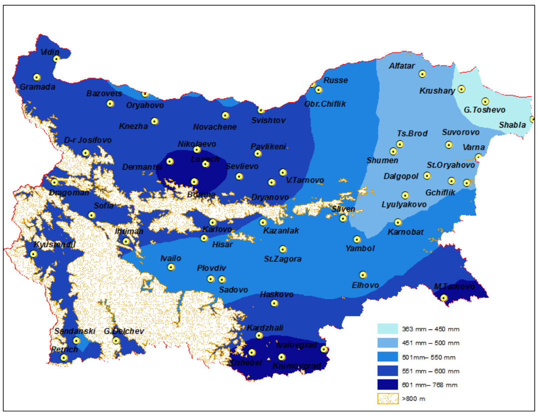

Fig. 7. Average annual amount of precipitation for the period of 2021-2050

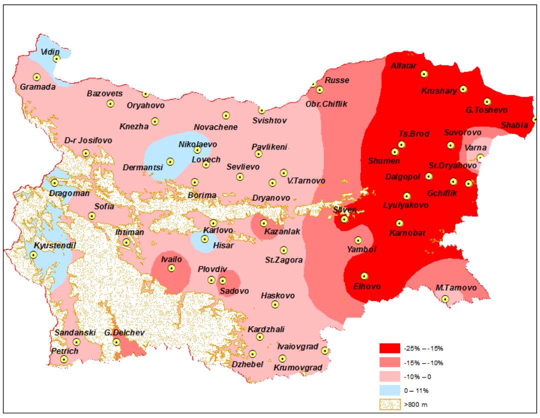

Fig. 8. Deviation of the annual amount of precipitation for 2021-2050 compared with the same values for 1961-1990

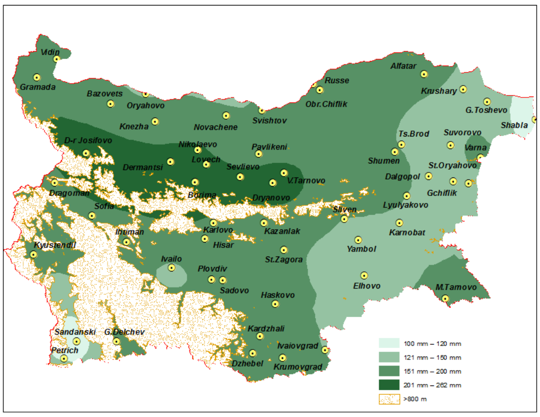

Fig. 9. Average multiannual amount of precipitation for the period of April-June for 2021-2050

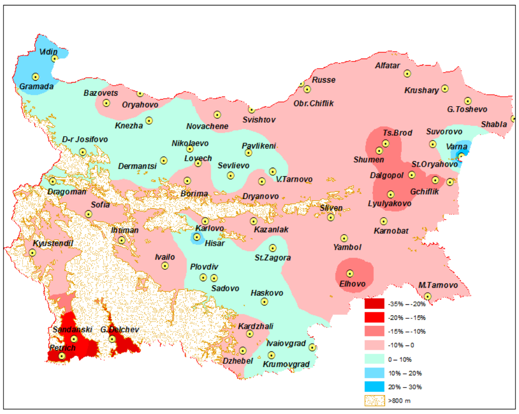

Fig. 10. Deviation of the amount of precipitation during the period of April-June for 2021-2050 compared to the same values for 1961-1990

Precipitations are the main source of water saturation of soils. During the period 2021-2050, an annual amount of precipitation of 550-600 mm will prevail, but in the extreme northeastern regions it will be 350-450 mm, and in the greater part of the Thracian lowland 500-550 mm, Fig. 7. These values of the precipitation amounts correspond to a decrease of 10-25% compared to the period 1961-1990, fig. 8. The presence and amount of water in the soil during certain periods of crop development is very important. Such a period for agriculture in Bulgaria is the period April-June, when autumn crops form yields, and spring crops increase their biomass and form a photosynthetic surface. During this period of the next 30 years, no significant changes will occur and the amounts of precipitations will be 120-200 mm, in the pre-Balkan area in the northwest up to 260 mm, which in most cases corresponds to a reduction of these amounts by up to 10% in comparison with 1961-1990 period.

The values of the AI index were obtained and analyzed in time and space, as a result of which the dry and wet years during the studied period were determined (criterion - the number of stations with AI≤0.5 for a given region should be more than half), and also the regions in which AI≤0.5 by years (criteria – the number of years with AI≤0.5 is greater than or equal to 7, which is in accordance with the already cited JRC methodology.

Dry, wet and normal years are defined according to the drought index values which are shown in Table 1 as follows:

Dry years - 2021, 2022, 2024, 2025, 2027, 2028, 2030, 2031, 2033, 2034, 2035, 2039, 2041-2050

Wet years - none

Normal years - 2023, 2026, 2029, 2032, 2038, 2040.

Table 1. Values of drought (aridity) index for the agrarian regions of Bulgaria (excluding mountain regions)

Year/Station	Vidin	Knezha	V. Tarnovo	Russe	G.Toshevo	Varna	Karnobat	Yambol	Haskovo	Plovdiv	Petrich	Sofia
2021	0.39	0.43	0.47	0.32	0.31	0.27	0.33	0.28	0.49	0.60	0.41	0.37
2022	0.51	0.46	0.51	0.30	0.26	0.36	0.31	0.33	0.49	0.49	0.55	0.39
2023	0.52	0.52	0.64	0.29	0.31	0.33	0.51	0.34	0.59	0.53	0.51	0.55
2024	0.47	0.56	0.65	0.42	0.34	0.32	0.47	0.38	0.64	0.39	0.46	0.49
2025	0.34	0.43	0.60	0.28	0.29	0.37	0.43	0.34	0.39	0.30	0.45	0.32
2026	0.64	0.87	0.94	0.62	0.57	0.50	0.61	0.63	0.64	0.57	0.56	0.48
2027	0.39	0.45	0.56	0.36	0.31	0.37	0.36	0.32	0.56	0.46	0.36	0.48
2028	0.40	0.42	0.51	0.29	0.23	0.27	0.32	0.34	0.38	0.33	0.32	0.38
2029	0.59	0.57	0.84	0.66	0.37	0.34	0.49	0.45	0.48	0.40	0.51	0.47
2030	0.60	0.53	0.62	0.40	0.41	0.35	0.42	0.33	0.31	0.24	0.47	0.45
2031	0.46	0.49	0.66	0.42	0.39	0.32	0.42	0.41	0.50	0.45	0.60	0.49
2032	0.67	0.53	0.70	0.47	0.40	0.31	0.52	0.37	0.58	0.33	0.66	0.48
2033	0.45	0.48	0.89	0.46	0.41	0.37	0.46	0.45	0.47	0.38	0.53	0.52
2034	0.51	0.50	0.58	0.33	0.28	0.26	0.31	0.28	0.36	0.37	0.51	0.47
2035	0.53	0.61	0.83	0.37	0.46	0.45	0.45	0.53	0.66	0.37	0.48	0.49
2036	0.61	0.57	0.52	0.34	0.36	0.28	0.35	0.39	0.36	0.44	0.50	0.92
2037	0.37	0.47	0.49	0.28	0.33	0.33	0.35	0.34	0.42	0.45	0.40	0.53
2038	0.53	0.54	0.56	0.42	0.32	0.34	0.41	0.41	0.62	0.54	0.76	0.51
2039	0.63	0.51	0.64	0.47	0.45	0.41	0.40	0.46	0.45	0.53	0.61	0.44
2040	0.57	0.55	0.59	0.43	0.36	0.36	0.40	0.41	0.50	0.46	0.70	0.65
2041	0.53	0.41	0.58	0.36	0.40	0.40	0.36	0.40	0.34	0.35	0.59	0.50

2042	0.51	0.35	0.51	0.32	0.34	0.46	0.39	0.44	0.41	0.43	0.58	0.49
2043	0.36	0.38	0.68	0.29	0.21	0.21	0.47	0.35	0.37	0.46	0.46	0.49
2044	0.42	0.47	0.58	0.40	0.41	0.39	0.36	0.46	0.51	0.38	0.42	0.41
2045	0.52	0.30	0.42	0.25	0.25	0.26	0.27	0.29	0.23	0.28	0.36	0.35
2046	0.54	0.34	0.51	0.28	0.23	0.24	0.26	0.29	0.27	0.25	0.35	0.48
2047	0.53	0.46	0.65	0.36	0.30	0.34	0.30	0.30	0.46	0.39	0.53	0.59
2048	0.37	0.42	0.55	0.34	0.34	0.44	0.35	0.26	0.36	0.32	0.39	0.46
2049	0.38	0.37	0.46	0.32	0.27	0.35	0.29	0.30	0.40	0.28	0.40	0.46
2050	0.34	0.29	0.33	0.26	0.19	0.28	0.28	0.25	0.37	0.29	0.31	0.43

CONCLUSION

As a result of the conducted research, several more significant findings related to the agro-climatic conditions in the agricultural regions of the country during the next 30 years until 2050 were outlined.

1. Earlier transition of temperatures between 5 and 10ºC in spring and later in autumn. As a result, an extension of the growing season on average to 270-310 in different regions of the country.
2. Increase of the sum of active temperatures in different regions of the country up to 4200-5600ºC;
3. An average decrease in the annual amount of precipitation by 15%, in the greater part of the Thracian lowland by 20%, and in the extreme northeastern regions by 25%;
4. Under the conditions of increasing temperatures and decreasing annual precipitation totals, conditions will exist for severe and widespread drought throughout the country. The number of dry years is predominant and in the first decade of the period they are 8, in the second 5, and in the third 10;
5. The period 2021-2050 will be characterized by a growing need for irrigated agriculture and an increasing impossibility of obtaining high yields in conditions of natural humidification.
6. The drought will be the weakest in the coming years in the regions of V. Tarnovo and Vidin. It will be relatively weak in the fields around Haskovo, Petrich and Sofia.

ACKNOWLEDGEMENT

This work was supported (partially) by the Bulgarian Ministry of Education and Science under the National Research Programme "Healthy Foods for a Strong Bio-Economy and Quality of Life" approved by DCM # 577 / 17.08.2018".

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