Scientific Papers. Series A. Agronomy, Vol. LVI, 2013
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

CLIMATE CHANGE AND AGROMETEOROLOGICAL CONDITIONS FOR GROWING WINTER CROPS IN BULGARIA

Veska GEORGIEVA, Valentin KAZANDJIEV

National Institute of Meteorology and Hydrology, 66 Tzarigradsko Shausse 1784, Sofia, Bulgaria

Corresponding author email: Veska.Georgieva@meteo.bg

Abstract

During the last decade climate variability and anomalies become more evident and their impact is more expressive. Appearances are different - sudden changes in weather conditions transitional seasons are becoming shorter with fuzzy borders, dry spells and droughts in combination with forest and field fires. Simultaneously, there are torrential rains accompanied by devastating floods that caused significant damage to agriculture. These anomalies affect on the conditions for grow of crops because 90% of the yields depend from weather conditions. The winter wheat has a long vegetation period. Development of wheat crops depends of different combinations from state of basic meteorological elements.

Main purpose of this paper is to assess the agro-climatic conditions in major grain producing regions of Bulgaria to the use of agroclimatic potential of each. This investigation covers the period 1981-2010, and refers to occupied territories with winter wheat and barley. Data were analyzed for fundamental values of weather elements - maximum, minimum and average daily air temperature (°C), rainfall sum (mm). An assessment of agro-meteorological conditions during critical phases of crop values on the main weather elements - sowing winter conditions, water saving, tillering, stem elongation, earing and milk ripening. It is traced as the dynamics of the main meteorological elements and their complex effects on growth and development of crops from the calculation of some indices characterizing hydrothermal conditions.

Key words: *climate change, agrometeorological resources, winter crops.*

INTRODUCTION

Winter crops in Bulgaria are growing on three basic regions - Danubian Plain, Northeastern Bulgaria and Thracian Lowland. Productivity depends on the maximum use of agro-climatic resources in these areas. The climatic zoning (The climate of Bulgaria, 1991) of the country shows that they are in two climatic regions and four sub regions, with typical manifestations of basic meteorological elements forming agro-climatic conditions. The temperature conditions in the production areas of winter crops are suitable, but the humidity conditions of the majority of these areas characterized with drought different level (Hershkovich, 1984; Kazandjiev et al., 2011).

Analysis of multi annual data of basic meteorological elements in Bulgaria tends to rise in temperature and decrease or change in the distribution of rainfall seasons (Kazandjiev, 2008, E. Koleva et al., 2008). The average annual temperature in these areas during 1971-2000 compare with the period to the contemporary climate has risen by 1.5°C. The increase is greater in Northern Bulgaria, but in South this trend was not observed. (Kazandjiev C. 2008; Eitzinger et al., 2008; Kazandjiev et al., 2009). As a result, the duration of the period with temperatures above 5°C is extended by 6-10 days for the two periods being compared. Humidity conditions are directly related to the amount of rainfall. E. Koleva at all, 2008, found that the annual amount of precipitation decrease in the Danubian Plain and the Thracian Lowland and the increased frequency of dry years in the last century. For the period 1971-2000, the trend is towards a decrease, compared to 1961-1990, the annual rainfall sum on the territories of agricultural production decreased by 40 mm, with the exception of the district of northeastern Bulgaria (Kazandjiev et al., 2011). It should be noted that the area of eastern Dobrudja is characterized by the lowest annual rainfall (The climate of Bulgaria, 1991).

Increasing the number and frequency of extreme events - sudden changes in weather conditions transitional seasons are becoming shorter, dry spells and droughts in combination with forest fires increasingly large areas in Europe. Gocheva et al. (2010) found that during the period from 1961 to 2000 the most frequently dry winds occur in July and August, with duration 3-4 days in Northern Bulgaria is happening 25% of these phenomena, and in South 40%, the trend is an increase over the last ten years (1991-2000).

The studies on the frequency of dry periods with different duration have special interest in view of driest character of climatic conditions in the agricultural regions. The driest periods occur most frequently in the period from August to October, and the areas with the highest number of droughts are Seaside and Southern parts of the lowland of Tundja, Maritsa and Struma (Drought in Bulgaria, 2003). A similar trend is observed in the last 20 years - increased frequency and the dry period compared to the modern climate, especially in the Thracian Lowland and Northeastern Bulgaria (Alexandrov et al., 2011). For the period 1971-2000, the country has been a total of 4,536 cases where the maximum temperature was ≥ 35°C, 2,185 of them are Tmax≥36°C, 225 case Tmax≥40°C and 18 times was measured maximum temperature ≥ 43°C. The distribution of maximum temperatures during the period was almost evenly with the exception of 1975 and 1976 when no product temperatures ≥ 35°C. The highest number of days with maximum temperature above 35°C is observed during 2000. These days are concentrated in July and August. The most often observed from 3 to 5 consecutive days with maximum temperature ≥ 35°C. In some cases, this number is reached, and up to 7-10 days (Kazandjiev, 2008).

Frequency cases and duration of retention of temperatures below critical plants levels and the presence of snow cover characterized of conditions for winter. The contemporary bulgarian wheat varieties have high resistance to cold (Dochev et al.. 2009). Barley, which is grown mainly in areas of unstable snow with a small depth have lower cold resistance. According to research Petkova at all, 2010, snow cover in the flat part of Bulgaria is unstable and thin. It stays longer in Northern Bulgaria, the Western and Central Danubian Plain 42 to 48 days, and in the Eastern Danubian Plain, 32 to 42 days. In the Thracian lowland snow cover is retention 20 to 30 days, in the central part and 26÷28 days. The maximum height of snow in Northern Bulgaria is changed in the range 30÷40 cm, and in the Thracian Lowland 20÷30 cm.

Agroclimatic indices - Selyaninov hydrothermal coefficient, an index of De Marton, coefficient of atmospheric humidity, evaporability-precipitation balance etc, are used for a comprehensive assessment of temperature and humidity conditions in the area under consideration. The most commonly used is evaporability-precipitation balance because it gives an idea of the real water deficit for a certain period. Dilkov, 1960 found that the period of spring wheat growth evaporability-precipitation balance values are exceeding -200 mm in each 2 to 4 years i of 10 years. More recent studies (Moteva et al., 2009; Kazandjiev et al., 2010) that the evaporability-precipitation balance in the spring growing season for the period 1971-2000, the range between -223 mm and +15 mm, the largest deficit of water resources is observed in some areas of the Thracian lowland and especially in Svilengrad, Ivaylo, Plovdiv (-180 mm). The values of De Marton in agricultural areas ranged from 20-40 mm $^{o}C^{-1}$, (Moteva et al., 2010) which defines the terms as moderately moist, HTK Selyaninov of about 1, and wheat yields are obtained when values of the De Marton than 30 mm $^{o}C^{-1}$. Comprehensive assessment of conditions in the areas of agricultural production shows that in the region of Thracian lowland and Dobrudja to obtain high yields of wheat is necessary to compensate the water deficit, is to conduct additional irrigation at critical growth and yield formation of cultivations.

The results of climatic scenarios for the values of the basic meteorological elements during 2050 and 2070, shows a tendency toward deterioration in agro-meteorological conditions. From insufficient when using HTK to Selyaninov the conditions are characterized as deficient. According to the index in De Marton - moderately moist become dry and will not be able to rely on economical effective values yields without irrigation in some areas

The main goal of this paper is to assess the climatic changes and the agro-climatic conditions in major grain producing regions of

Bulgaria to the use of agroclimatic potential of each.

MATERIALS AND METHODS

Traditional areas for growing winter cereals include lowland areas, plains and low undulating character with altitude up to 1000 m - lowland areas of Northern Bulgaria, Thracian lowland, southeastern Bulgaria and the Sofia field. According to climatic zoning of Bulgaria (The climate of Bulgaria, 1991), they are located in two climatic regions and four subregions, with typical manifestations of basic meteorological elements forming agro-climatic conditions.

Long-term 1971-2010 daily and monthly meteorological data from 40 agrometeorological and 20 agrometeorological stations, evenly spread over the agricultural territory of the country, have been processed (Figure 1). Basic period of investigation is 1981-2010. Comparison is made with period 1971-2000.

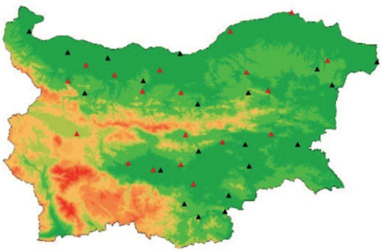

Figure 1. Spatial distribution of meteorological and agrometeorological stations

RESULTS AND DISCUSSIONS

Bulgaria is situated in a zone with insufficient soil water supply. Soil water resources at many regions of the country during the some phases of development stages are insufficient for growing winter wheat. Soil water supply during sowing and beginning of spring vegetation is related with the rest soil water supply. In the end of the summer available soil water supplies in the top 100 cm soil layer varied between 10 and 80 mm. The lowest supply have station Haskovo (10 mm) and the biggest Pavlikeni and Kneja (82 mm). The spatial distribution describes the regions with different AWC deficit on the territory of the country (Figure 2). With bigger deficit are characterized the regions of Central and Eastern part of South Bulgaria, and the Danubian Plain on the Russe region-more than 100 mm. The maximum value is 146 mm in Haskovo.

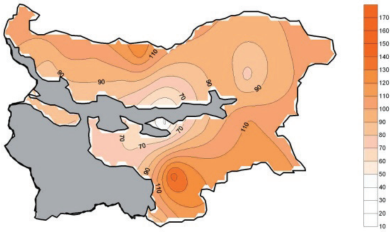

Figure 2. Soil water deficit (in mm) in the top 100 cm in the beginning of autumn growing season

The comparison between two periods 1971-2000 and 1981-2010 shows that in the regions of Thracian Lowland and North Western Danubian Plain soil water deficit increase. To assess the differences between mains for two periods with t-test is established that no statistically significant differences, with except the region of Haskovo. The biggest deviation (Figure 3) are observed in Haskovo (33mm) and lower they are in Plovdiv (-17mm).

Considering the critical values of available water supply in the end of vegetation season the decreasing tendency would lead to their depletion.

The sowing date depends mostly from soil water supply on the top 20 cm depth. Average sowing date varies between 13 and 30 October. Earlier date – second decade of October on North-Western Bulgaria, during the third decade on the Danube plain, and latest on the Thracian lowland (Figure 4).

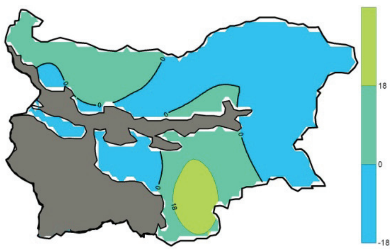

Figure 3. Deviation of deficit soil water supply (in mm) in the top 100 cm in the beginning of autumn growing season

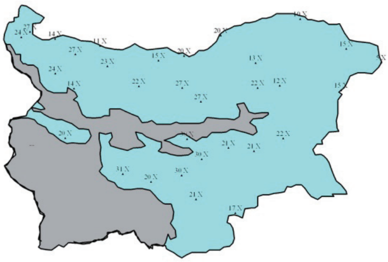

Figure 4. Average sowing date

The soil water availability (SWA) during the sowing period on the top 20 cm depth show that they are sufficiently on the central part of Danubian Plain and Eastern Bulgaria Thracian Lowland and western and eastern part of Danubian Plain they bellow optimal values (> 70% FC) (Figure 5).

Figure 5. SWA (% FC) of winter wheat during the sowing on top 20 cm layer depth

The deviation of SWA on the top 20 cm for the period 1981-2010 in relation to 1971-2000 varies between-10 to 8% FC. They are increase only on Eastern Thracian Lowland and region of Sliven (Figure 6). For the rest territory of the arable land is observed the decreasing. The differences between means of two data series (rainfall sum for two comparing periods) are not statistically significant except the eastern part of Thracian Lowland (Chirpan, Haskovo).
The rainfall sum 20 days before the sowing is related with duration the emergency period. This sum is more than 30 mm (Figure 7) and varies between 33 and 57 mm, which ensure the top 20 cm layer with water resources necessary for emergency in most of the concerned regions. Greater rainfall sum are measured in South Eastern Bulgaria and Thracian Lowland, where the soil water supplies are insufficient.

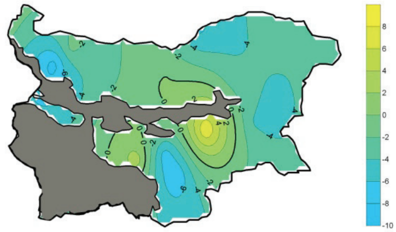

Figure 6. Deviation of SWA (% FC) of winter wheat during the sowing on top 20 cm layer depth

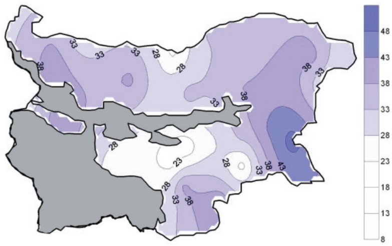

Figure 7. Rainfall sum [mm] in October

In the Eastern Bulgaria, western part of Forebalkan and Thracian Lowland the deviation of rainfall sum in October are increased, but in the regions with the insufficient soil water supply during the sowing they decrease (Figure 8). The differences vary between 19 mm (Burgas) and-14 mm (Svishtov), but they are no statistically significant.

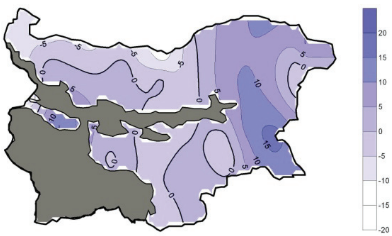

Figure 8. Deviation of the rainfall sum [mm] in October

The duration of the period sowing-emergency is in depending from the quantity of soil water supply (Figure 9). They vary between 17 (Dobrich) and 33 days in the North-Western Bulgaria and central part of Danube plain. The duration of the period of sowing-emergency is longer in the regions with biggest soil moisture deficit and at the latest sowing date.

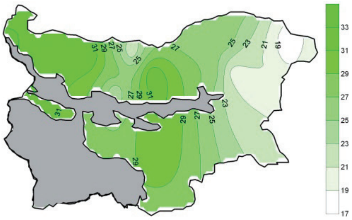

Figure 9. Duration of the period sowing-emergency

The end of the early vegetative stage at the date of air temperature falling below 5^{o}C in the autumn for the largest part of agricultural regions occurred in late November (Figure 10). Exceptions are the southernmost areas where transition is observed in 5^{o}C in early December. No change in the termination date of vegetation compared to the rate for the period 1971-2000. Because of our climatic conditions that limit is relative after the termination the vegetation are observed the cold and warm periods with different duration.

The frequency and duration of retention of extreme minimum air temperature and availability and snow depth are limited during the winter dormancy. Number of years in which the air temperature in January was lower than-15^{o}C, expressed in percentage is shown in Figure 11. It varies between 3% (Shabla), 60% (Chirpan) and 63% (Kneja). There are two regions which more than 50% from the period of investigation the temperature are bellow-15^{o}C – central part of Danubian Plain (Kneja, Pavlikeni) and central part of Thracian Lowland (Chirpan, Sadovo).

Single decrease the air temperature below-15^{o}C is not always occur damages and dead of plants. The shortages of snow cover and duration of influence of low temperature are precondition for partial or seriously damages of winter wheat. Figure 12 shows the number of cases with minimum air temperature below-15^{o}C more than 3 days during January. Most of such cases are occurred in North and Medium climatic region of Danubian Plain and in central part of Thracian Lowland. Greatest duration is occurred in these regions (Kneja – 12 and Chirpan-9 days).

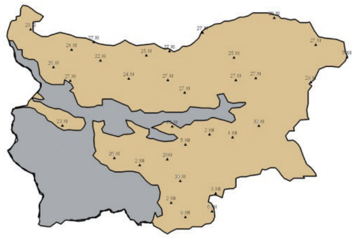

Figure 10. End early vegetative stage at the date if air temperature falling bellow 5^{oC}

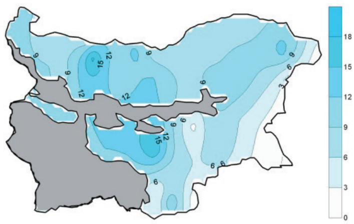

Figure 11. Number of years where the minimum air temperature is lower than-15^{o}C during January

Table 1. Multi annual mean values of snow cover depth, number of days withaut, partial and snow cover bellow 10 cm depth and number days with temperature bellow -15^{o}C

Station	Snow cover depth (cm)		Days without snow cover (%)	Days with partial snow cover (%)	Days with snow cover depth bellow 10 cm (%)	Number of days with air temperature bellow -15^{o}C
	Maximum	Minimum				
Vidin	2	53	6	-	20	87
Bazovetz	2	51		-	14	58
Montana	5	50	2	-	16	51
Kneja	1	58	5	-	20	117
Pavlikeni	2	49		-	29	45
Razgrad	1	41	3	-	48	41
Shunen	1	45	16	3	32	38
Silistra	1	38		-	19	26
Dobrich	1	30	2	19	24	43
Siven	-	-	100	-	-	3
Plovdiv	2	56	-	2	32	62
Chirpan	2	55	2	7	15	109
Sofia	4	50	4		24	49

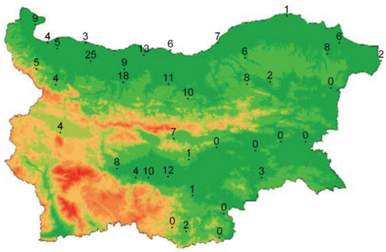

Figure 12. Cases with minimal air temperature below-15oC for more than 3 days during the dormancy

Figure 13. Beginning of the late vegetative stage at the date of air temperature proof rising above 5^{o}C

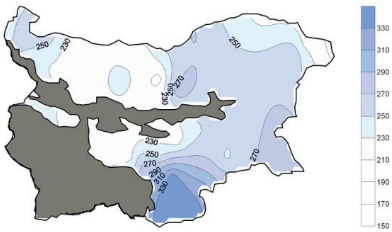

Figure 14. Rainfall sum for the period October-March

Probability of happen of such precipitations in these areas varies between 27% in the region of Silistra and Shabla (in extreme eastern districts) and 72% in the region of Veliko Tarnovo, Targovishte (67%) and Rouse (63%). Approve the tendency of increasing of the winter rainfalls as show the deviations for two periods of investigation. They are not statistical significant (Figure 15).

In early spring growing season in Northwestern Bulgaria, part of the Central Danube Plain and Dobrudja region in Northern Bulgaria SWA are between 90 and 95% of the FC (Figure 16). In Southeast Bulgaria (Haskovo, Sliven and Karnobat) precipitations for the period from October to March are no sufficient to compensate the water deficit in the soil in early spring vegetation. SWA varies between 85-90% of FC.

Figure 15. Deviation of rainfall sum during the period October-March

On the all over the arable land the SWA are decrease, except the western part of Thracian Lowland (Figure 17). The biggest decreasing in the northern part of Danubian Plain and the rest part of Thracian Lowland (stations Haskovo, Chirpan and Sliven), where are observed statistical significance difference between SWA during two periods of investigation.

In the early stages of spring vegetation soil water supply is usually sufficient, but in the process of developing their consumption increases.

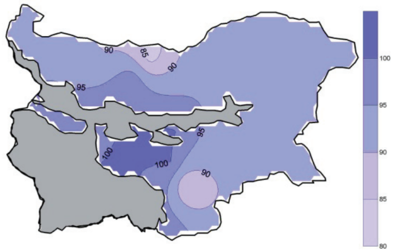

Figure 16. SWA in the beginning of wheat's spring vegetation for the top 100 cm

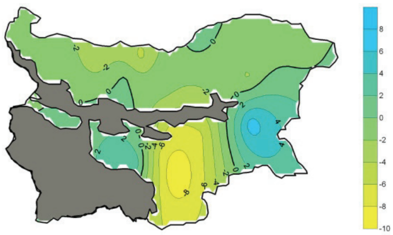

Figure 17. Deviation of SWA in the beginning of wheat's spring vegetation for the top 100 cm

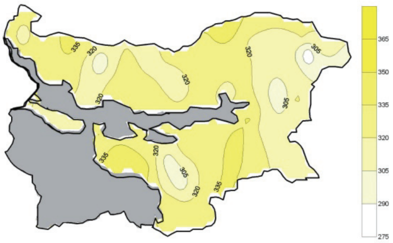

Figure 18. Evapotranspiration of winter wheat for April – June

CONCLUSIONS

During the autumn growing season SWA in layers 0-20 cm is sufficient Eastern Bulgaria and the central part of the Danubian Plain. During the sowing soil water supply in layer 0-20 cm ranges from 61% to 82% FC. The deviation of SWA on the top 20 cm for the period 1981-2010 in relation to 1971-2000 varies between -10 to 8% FC. They are increase only on Eastern Thracian Lowland and region of Sliven. Significant difference is established on the eastern part of Thracian Lowland (Chirpan, Haskovo).

Analysis of winter conditions shows that there are two areas in which more than 50% of the period temperatures remain below -15°C for more than three days - Central part of the Danubian Plain and the Central part of the Thracian Lowland. Analysis of cases with temperatures below -15°C, compared with the availability and snow cover depth shows that the largest percentage of days with snow cover less than 10 cm in Razgrad (48%), lowest in Buzovets (14%) and between 2-16% of cases there is no snow cover. The greatest risk of damage is in Northeastern Bulgaria and the North-Western regions;

In early spring growing season in Northwestern Bulgaria, part of the Central Danubian Plain and Dobrudja region in northern Bulgaria SWA are between 90 and 95% FC. Decreasing is observed in Thracian Lowland. The comparison between means for two periods 1971-2000 and 1981-2010 shows that statistically significant is the difference only in Haskovo.

Precipitation sum for October-March varied between 203 mm and 339 mm. Smaller are rainfall sums in Central part of Danubian Plain and Northern part of Thracian Lowland and greatest they are in Southern Bulgaria. Approve the tendency of increasing of the winter rainfalls as show the deviations for two periods of investigation. They are not statistically significant.

Water consumption of wheat during the period after the restoration of vegetation varies between 348 mm (Brashlyan) and 275 mm (Dobrich), the highest values are in the Thracian Lowland and the northern part of the Danubian Plain and Dobrudja in the Black Sea region wheat evapotranspiration is least.

The rainfall sum for the period April - June is the highest values in the regions of the Danube Plain and the Forebalkan. The Black Sea region, Dobrodja and the Thracian Lowland is characterized by the lowest values of the rainfall sum during this period. The comparison of two periods of investigation shows that the deviation varies between 0-30 mm, but on the bigger part is decrease with 10-20 mm. The t-test shows that no statistically significant differences between two periods of investigation.

Soil water availability during the earing ranges from 58 to 92% FC but in the majority of regions of investigation is 70-80% of FC. They are lower only in extreme eastern and part of northern regions. The difference between SWA during two thirty-year periods varies from - 9 to 5% and they are decrease on almost all arable land, except western part of Thracian Lowland. Bigger decreasing is observed in central part of Thracian Lowland and northern part of Danubian Plain where statistically significant differences (Haskovo, Novachene and Bazovetz) have.

In 50% of the years the rainfall sum during ear formation of watary ripe are sufficient to provide water for most of the agricultural areas, with the exception of some of the Northern areas of the Danube Plain, where the soil is more assured than optimal boundary during ear formation. There has been found correlation between the yield and the rainfall sum for the period of earing-watery ripe.

The values precipitation evaporation balance larger than 160-170 mm for the period April-June leads to depletion of soil water supply below optimal boundary. These include the region of Thracian Lowland, part of Dobrudja and the Northern part of the Central Danubian Plain. In areas with less water deficit can ensure normal growth and development and obtaining higher yields - Black Sea region, part of Ludogorie Balkan and northwestern Bulgaria.

REFERENCES

Dilkov D., 1959. Soil water supplying and regime at chernozems in Bulgaria during the spring. Proceeding of IHM, II, p. 3-43 (in Bulgarian).

Dochev V., Petrova T., Atanasov A.,. 2009. Frost resistance of distributed winter common wheat varieties (*Triticum aestivus* L.). FCS, Vol. V (1), p. 45-49 (in Bulgarian).

Drought in Bulgaria-contemporary analog of climatic changes, 2003. Publ. BAS, p. 283 (in Bulgarian).

Kazandjiev V., 2008. The climate change, agroclimatic resources and determination of unfavorable regions in Bulgaria, in "The future development of agriculture in Bulgaria, Sirius, V. Tarnovo, p. 139-154 (in Bulgarian).

Kazandjiev V., 2008. Unfavourable regions in Bulgaria determination by the climatic indicators and agroclimatic resources during the period 1971-2000, Expert report for MZH, 50 p. (in Bulgarian).

Kazandjiev V., et al., 2011. Climate variability and change and conditions for winter wheat production in notrhest Bulgaria, FCS 7(2), 195-200 (in Bulgarian).

The climate of Bulgaria, 1991. Edited by Sv. Stanev, M. Kuchukova, St. Lingova. Publ. BAS, 498.

Harshkovich E., 1984. Agroclimatic resources of Bulgaria. Publ. BAS, p. 115 (in Bulgarian).

Alexandrov V., Radeva S., Koleva E., 2011. Utilization of SPI, PDSI, and RDI as drought indicators in South Bulgaria. 11th International Multidisciplinary Geoconference Proceedings Volume II, p. 969-976.

Eitzinger J., Thaler S., et al., 2008. Agroclimatic Indices and Simulation Models, in "Survey of Agrometeorological Practices and Applications in Europe, Regarding Climate Change Impacts", ESF, COST 734, 15-114 p.

Gocheva A., Malcheva K., 2010. Droughtly spells on the territory of Bulgaria. BGMH, V-15, p. 54-63.

Kazandjiev V., 2008. Agroclimatic resources and definition of less favored areas at the beginning of XXI century in Bulgaria, Conference "Global Environmental Change – Challenges to Science and Society in Southwestern Europe". CD version.

Kazandjiev V., Moteva M., Georgieva V., 2010k. Climate Change, Agroclimatic Resources and Agroclimatic Zoning of agriculture in Bulgaria, Agricultural engineering, 3, p. 109-116.

Kazandjiev V., Georgieva V., Moteva M., 2009. Climate change, agroclimatic resources and agroclimatic zoning of agriculture in Bulgaria, 2009. 9-th EMS / ECAM Conference, Toulouse, France http://www.emetsoc.org/fileadmin/ems/dokumente/annual_meetings/2009/AW12_EMS2009-543.pdf

Koleva E., Alexandrov V., 2008. Drought in the Bulgarian low regions during the 20th century. TAC, 92, p. 113-120.

Moteva M., Kazandjiev V., Georgieva V., 2009. Assessment of the contemporary hydro-thermal conditions for crop growing in Bulgaria. Proc. Int. Conf. "Soil Tillage and Ecology", 1-5 Sept., Albena, Bulgaria, p. 134-141.

Moteva M., Kazandjiev V., Georgieva V., 2010. Climate change and the hydrothermal and evapotranspiration conditions in the panning regions in Bulgaria in Proceedings of 14-th, IWTC, Cairo - Egypt 12 p.

Petkova N., Alexandrov V., Koleva E., 2010. Snow Cover Variability in Bulgaria, 1931-2005. *In* Proceedings of International conference: „Geography and regional development", 14-16 October, 2010, Sofia.