Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XII, Issue 1 (June 2013), pp. 16-24
http://dx.doi.org/10.5775/fg.2067-4635.2013.016.i

The impact of the drought on the main crops cultivated in Northeastern Bulgaria

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Received on <02-05-2013>, reviewed on <30-05-2013>, accepted on <15-06-2013>

Abstract

Drought is one of the consequences of a reduction of rainfall over a long period of time. Often a number of meteorological elements as high temperatures, strong winds and low relative humidity occurs in conjunction with the drought. These facts make drought very strongly expressed. The present paper aims to analyze the intensity and the seasonal differences of meteorological drought in Northeastern Bulgaria and to characterize the drought impact on the main crops cultivated in the study area.
The tendencies of the seasonal and the annual air temperatures and precipitation are investigated. Drought periods are revealed on the base of precipitation anomalies and the drought indices as Standartized Precipitation Index (SPI) and De Martonne Index. The driest years for the period 1961 – 2011 have been established. The production of the main crops in the study area is analyzed on the background of climate change. The information from climate models is used in order to describe future climate and to make the recommendations for crop cultivation in relation to climate impact.

Keywords: *drought, precipitation anomaly, SPI, crops production, adaptation*

Rezumat. Impactul secetei asupra principalelor plante cultivate în nord-estul Bulgariei

Seceta este o consecință a reducerii cantității de precipitații într-o perioadă lungă de timp. Deseori, anumite elemente meteorologice, cum ar fi temperaturi ridicate, vânturi puternice și umiditate relativă redusă se înregistrează o dată cu seceta, ceea ce duc la accentuarea acesteia. Lucrarea de față analizează intensitatea și diferențele sezoniere ale secetei meteorologice în nord-estul Bulgariei, prezentânt totodată și impactul secetei asupra principalelor culturi din aria de studiu.
Sunt analizate tendințele temperaturilor și cantităților de precipitații anuale și anotimpuale. Perioadele de secetă sunt identificate pe baza anomaliilor de precipitații și a indicilor de secetă precum Indicele Standardizat al Precipitațiilor (SPI) și Indicele DeMartonne, stabilindu-se cei mai secetoși ani pentru perioada 1961-2011. Pe fondul schimbărilor climatice, au fost analizate și producțiile obținute la principalele culturi. Informațiile din modelele climatice sunt folosite pentru a caracteriza climatul viitor și pentru a face recomandări cu privire la culturi în funcție de impactul climatic.

Cuvinte-cheie: *secetă, anomalia precipitațiilor, SPI, producții agricole, adaptare*

Introduction

Drought is a normal feature of climate, but it can occurs as an extreme phenomenon and become a natural hazard. The difference between drought and other disasters is that drought occurs slowly. Its effects accumulate and occur over a long period of time and may be observed years after the dry period ends affecting a wider geographical area than the area which is directly affected by the disaster (European Communities, 2007).

There are many definitions of drought and authors distinguish various types of drought – meteorological, agricultural, hydrological, social or economic (Motha, 2000). Common to all types of drought is a lack of precipitation (WMO, 1993). One of the basic definition of drought is that, "…drought originates from a deficiency of precipitation over an extended period of time--usually a season or more--resulting in a water shortage for some activity, group, or environmental sector.", National Drought Mitigation Center. http://drought.unl.edu/DroughtBasics/WhatisDrought.aspx

Drought can damage the harvest if it coincides with the growth season of crops. Often a number of meteorological elements as high temperatures, strong winds and low relative humidity occur in conjunction with drought. The plants are in the most unfavorable conditions when precipitation reduction produces a decrease on soil moisture. When the atmosphere and soil moisture is not enough to satisfy the water demand of the plants various physiological processes are affected.

During the recent years severe droughts occurred and persisted in the southern Europe including Bulgaria and more frequent heat waves during ~~the~~ summers illustrate how the climate extremes become more frequent and more intense. Several studies on drought provide details about its characteristics and occurrence in Bulgaria during the last decades or century (Alexandrov, 2011, Alexandrov, 2006, Knight et al, 2004, Nikolova et al. 2012). Despite numerous publications on the topic of climate change, the previous studies of the

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impacts of drought on agriculture in Bulgaria are relatively small (Alexandrov, 2008, Kazandjiev, 2008; Nikolova and Mochurova, 2012, Mochurova, 2010, CLAVIER project). Because of this in-depth statistical and geographical analysis need to be done in order to throw light in some yet unanswered questions about recent climate change and its impact on regional and local levels.

The aim of this study is to determine the severity of drought and its impact on the main crops cultivated in Northeastern part of Bulgaria. The study area is part of one of the main agricultural regions in Bulgaria. That is way the investigation of climate change and extreme events, such as drought, is very important for this area. In order to achieve the aim of the present research work the analysis is done in two main directions: 1) statistical analysis of precipitation and air temperature in the study area, calculation of drought indices and determination of dry periods and 2) analysis of productivity of the main crops in the study area on the background of drought occurrence and intensity. The paper shows also application of different indices (percent of normal, SPI and De Martonne aridity index) for drought.

Data and Methods

Monthly data for air temperature and precipitation from four meteorological stations situated in Northeastern Bulgaria are used in the present research work (Table 1). The analysis of drought occurrence and intensity is made on the base of seasonal and annual values. The seasons are determined as follows: winter – December, January, February; spring – March, April, May; summer – July, June, August; autumn – September, October, November.

Table 1 Meteorological stations used in the present research

Meteorological stations	Latitude (N)	Longitude (E)	Altitude (m)
Russe	43°51�###	25°58‛	44
Razgrad	43°31‛	26°31′	206
Shumen	43°16‛	26°55‛	216
Varna	43°13‛	27°55‛	4

The main investigated period is 1961-2011 and the reference period is 1981-2010. The current World Meteorological Organization (WMO) standard reference period is 1961-1990. However several Member States use more recent periods (e.g., 1971-2000, 1981-2010).

The data about production of the main crops (wheat, maize, barley and sunflower) in the study area for the period 2000-2011 is analyzed on the background of climate condition and drought occurrence.

The information from climate models is used in order to describe future climate and to make the recommendations for crop cultivation in relation to climate impact.

In the scientific literature various specific indices as De Martonne’s aridity index (Vladut, 2010, Majstorovic et al., 2008, Paltineanu et al. 2007), SD (spatial-dryness) index (Tran, et al. 2002) are applied for the investigation of drought events. In the present study we investigate the drought on the base of calculation of Standardized Precipitation Index (SPI), precipitation anomaly (Percent of Normal) and De Martonne’s aridity index. In order to characterize drought and its impact seasonal and annual air temperatures are taken into consideration also.

Standardized Precipitation Index (SPI) is an index based on the probability distribution of the long-term precipitation record for a desired period of time. In 2010 WMO selected the SPI as a key meteorological drought indicator to be produced operationally by meteorological services (JRC, EC, 2011). SPI is calculated on a monthly basis for a moving window of n months, where n indicates the rainfall accumulation period. In the present paper SPI is calculated for 3-months and 12-months scales. The SPI-3 is the best related with soil moisture, which respond to precipitation anomalies on a relatively short scale

SPI-12 indicates a long term rain deficit and is included to have into account the relation between the long term rain shortages with the water reservoirs and the water table. The software provided by the National Drought Mitigation Center, University of Nebraska (http://drought.unl.edu/MonitoringTools/ClimateDivisionSPI.aspx, accessed by 7 September, 2012), is used for calculation of SPI.

The value of the SPI gives a measure of the severity of dry event as follow: moderate drought with SPI between -1 and -1.49; severe drought – SPI vary from -1.5 to -1.99 and extreme drought with SPI -2 and bellow (McKee et al., 1993, Ceglar et al., 2008).

The exact relationship between accumulation period and impact depends on the natural environment (e.g., geology, soils) and the human interference (e.g., existence of irrigation schemes). Therefore a comparison with other drought indicators is needed to evaluate actual impacts on the vegetation cover and different economic sectors (JRC, EC, 2011). In order to explain more effectively the drought events we use also precipitation anomaly and De Martonne’s aridity index.

Precipitation anomaly (percent of normal) is a simple calculation effective for comparing between single regions or seasons. The deviations of the seasonal and annual precipitation from normal (precipitation for the period 1981-2010) are used to determine dry periods in the investigated stations. We have calculated this indicator by dividing actual seasonal or annual precipitation by normal seasonal or annual precipitation which is considered to be 100%. In the present research we determine dry years according to Slavov et al., 2000 as following: weak drought – the years with precipitation anomaly between 76 and 99% of climate norm, average drought - the years with precipitation anomaly between 50 and 75% of climate norm and strong drought – the years with precipitation anomaly less than 50% of climate norm.

In the scientific literature **De Martonne aridity index** is used as a numerical indicator of drought. This index is frequently used for assessment of hydrothermal conditions for plant growing. De Martonne aridity index *Im* is defined as the ratio of the annual precipitation sum *P* in mm and the annual mean temperature T in °C +10. The following formula is used in order to calculate the annual values of the De Martonne aridity index:

$$I_m = \frac{P}{T+10}$$

In the present paper we accept as thresholds the annual values 10 and 20 of De Martonne index. The regions with annual De Marton index less than 10 are characterized by an arid climate. If De Martonne index is between 10 and 20 the climate is semi-arid.

The analysis of production of the main crops (wheat, maize, barley and sunflower) in the study area for the period 2000-2011 is made on the background of local climate change and drought occurrence.

Study area

The investigated meteorological stations are situated in the Northeastern part of Bulgaria which is one of the main agricultural regions in the country. This is the eastern part of the Danube Valley. The relief is represented by valleys of hilly areas north and south. Station Varna is on the Black Sea coast and station Russe is on the Danube River. The climate is moderate continental with the influence of the Black Sea on the east. The average monthly temperature in January is about -2 to -3 ºC, while in July average monthly temperature is 23 - 24ºC. Annual temperature amplitudes reach 25-26ºC. The average annual temperature in the area is around 11ºC. Due to the effect of the Black Sea in the eastern part of the Danube valley winter is relatively mild and summer temperatures are lower than in other parts of the study area. The annual precipitation amount is less than the annual average for the country. Rainfall amounts in Dobrudja plateau reached not more than 450-500 mm per year.

Results and Disscusions

In the first part of this section the occurrence and intensity of drought is analyzed and in the second the agricultural aspects are considered. The drought events are characterized at the seasonal and annual scale by the means of precipitation anomaly and SPI. The annual De Martonne's aridity index is also taken into consideration.

Drought – intensity and seasonal differences

The analysis of average winter temperature for the period 1961-2011 shows that the values vary from 0.4 °C (Razgrad) to 3 °C (Varna). The maximum winter temperatures are registered in 2007 and the values are between 4.2°C (Razgrad) и 6.2°C (Varna). The winter in 2007 is the warmest during the investigated period. The minimum winter temperatures are observed in 1985 with negative values (-2.5 to -3.6 °C) for all of investigated stations. The only exception is Varna station on the Black Sea coast with positive average winter temperature but close to 0 (0.1 °C).

Despite of the lack of plant growing outside in the winter, the analysis of winter precipitation and drought is important because ~~the~~ water accumulates in the soil during ~~the~~ winter and it can be used during the first phenological phases of plants. In addition, moisture and rainfall in winter also influence the feeding of plants with fertilizers - in dry weather during winter fertilizers cannot penetrate into the soil and this has a negative effect on plant growth during the warm half-year.

According to the precipitation anomaly the driest winters has been observed in 1974, 1976, 1989 (Table 2.a) and in the beginnings of 90's when the seasonal precipitation has been less than 50% of the climate norm (average for the period 1981-2010). These results are confirmed by calculation of SPI (Table 2b). In 2001 and 2007 winter precipitation were between 50 and 75% of climate norm but occurrence of drought events is not established by SPI. Precipitation anomalies show that during the period 1961-2011 strong winter drought is observed in most of cases in stations Russe (7) and Razgrad (6). According to SPI severe drought is most often established in stations Razgrad and Shumen (Table 2b).

The average temperatures for spring 1961-2011 are around 10.5°C only in station Russe (on the Danube river) the value reach 12.7°C. The maximum seasonal temperature in spring for various stations is observed in 1968 or 2008. The values are between 12.3°C (Razgrad) and 15.1°C (Russe). The minimal seasonal temperature is established for 1987 in all of the investigated stations with average values from 7.3 to 9.7°C.

Table 2. Drought occurrence in winter according various indices

a) percent of normal

Stations	**average drought** (precipitation anomaly between 50 and 75% of climate norm)	**strong drought** (precipitation anomaly less than 50% of climate norm)
	Winter	
Russe	1964, 1972, 1985, 1988, 1992, 2001, 2006, 2007	**1974, 1976**, 1983, **1989, 1993**, 1999, 2000
Razgrad	1972, 1975, 1983, **1989**, **1992**, 2001, 2007	**1974, 1976**, 1977, **1993**, 1994, 1999
Shumen	1964, 1972, 1973, **1982**, **1983**, 1990, **1999**, 2001, 2007	**1974, 1976, 1989**, 1992, 1994
Varna	1972, 1974, 1980, 1982, 1983, 1985, 1987, 1999, 2001, 2007, 2008, 2011	**1976, 1989**, 1992, **1993**

b) SPI

Stations	**moderate drought** (SPI from -1 to -1.49)	**severe drought** (SPI from -1.5 to -1.99)	**extreme drought** (SPI -2 and bellow)
		Winter	
Russe	1974, 1993, 1989	**1976**	2000
Razgrad	**1989**, **1992**, 1973, **1972**	**1974**, **1976**, 1994, 1977, 1999, **1993**	
Shumen	**1982**, **1999**, **1983**	1992, **1976**, 1994, 1989, **1993**, **1974**	
Varna		1992, **1989**, **1976**	1983

*- in bold are the years with drought events according to 2 methods

Strong drought occurred in the winters of 1974 and 1976 is not characteristic for spring. In spring strong drought is observed in 1968, Table 3a. The year 1983 also makes impression with strong spring drought observed in all of the investigated stations as in winter the drought in 1983 is average. The occurrence of drought in spring during 1968, 1983, 1996, 1999, 2000 and 2007 is confirmed by the calculation of precipitation anomaly and SPI (Table 3b). Average summer temperatures for the period 1961-2001 reach values between 20.5 and 23.1 °C. The highest values are established in Russe. Maximum summer temperatures are between 23.8 and 26.0 °C. As in winter the hottest summer are observed in 2007. The minimum summer temperatures are in 1976 (exception station Varna 1984) with values between 17.8 and 20.5 °C. The average summer temperatures as those for spring are an important feature for the development of crops because those periods of the year are with the highest biological activity of plants.

Table 3. Drought occurrence in spring according various indices

a) percent of normal

Stations	**average drought** (precipitation anomaly between 50 and 75% of climate norm)	**strong drought** (precipitation anomaly less than 50% of climate norm)
	Spring	
Russe	1963, 1972, 1985, 1996, 2003, 2004, 2007, 2009	**1968, 1983, 1986**, 1999, 2000
Razgrad	1963, 1967, 1972, 1976, 1986, 1990, 2003, 2007, 2009	**1968, 1983**, 1996, 1998
Shumen	1967, 1972, 1974, 1990, 1996, 2003, 2008, 2009	**1968, 1983**, 1985, **1986**, 2007
Varna	1976, 1994, 2000, 2003, 2008, 2009	**1968, 1983**, 1985, **1986**, 2007

b) SPI

Stations	**moderate drought** (SPI from -1 to -1.49)	**severe drought** (SPI from -1.5 to -1.99)	**extreme drought** (SPI -2 and bellow)
		Spring	
Russe	1983, 2007	1999, **1968**, **1986**	2000
Razgrad	1986, 2007, 1972	1996, **1983**	**1968**, 1998
Shumen	1996	**1983**, 2007, 1985	**1968**, **1986**
Varna	2011, 2003, 1976, 1994	2007	**1968**, **1983**, 1985, **1986**

*- in bold are the years with drought events according 2 methods

The calculation of precipitation anomaly shows that summer precipitation has been less than 50% of the climate normal most often in the end of the 90's and in the beginning of the 21st century, (Table 4a). Strong summer drought was also observed in1965 in all of the investigated stations. Summer drought in the 80's is classified as average. According to SPI strong summer drought, revealed by precipitation anomalies, is manifested as severe or extreme drought (Table 4b).

Table 4. Drought occurrence in summer according various indices

a) percent of normal

Stations	**average drought** (precipitation anomaly between 50 and 75% of climate norm)	**strong drought** (precipitation anomaly less than 50% of climate norm)
	Summer	
Russe	1963, 1978, 1981, 1987, 1988, 1990, 1992, 1999, 2007	**1965**, 1984, **1996, 1998, 2000**, **2003**, **2008**
Razgrad	1962, 1978, 1987, 1988, 2007, 2008	**1965, 1996, 1998, 2000, 2003**
Shumen	1962, 1969, 1981, 1986, 2008	**1965**, 1988, 1990, **1996, 1998, 2000, 2003**, 2007
Varna	1962, 1964, 1966, 1981, 1983, 1984, 1986, 1989, 2000, 2003	**1965**, 1974, **1996**, 2007

b) SPI

Stations	**moderate drought** (SPI from -1 to -1.49)	**severe drought** (SPI from -1.5 to -1.99)	**extreme drought** (SPI -2 and bellow)
		Summer	
Russe	**1998**	1996, **1965**, **2008**	**2000**
Razgrad	1988	**2003**, **1965**, **2000**	**1998**, **1996**
Shumen	1990, 1998, 1986, 2008	**2007**, **1988**, **1996**, **2003**	**1965**, **2000**
Varna	2007, 1974, **1965**		2011, **1996**

*- in bold are the years with drought events according 2 methods

Seasonal autumn temperatures for the period 1961-2001 are between 11.2 and 13.6 °C. The highest autumn temperatures for the investigated period are established in 1963 for stations Russe (14.8 °C) and Razgrad (14.0 °C), in 2010 for station Shumen and in 1966 for station Varna (15.4 °C). The coldest autumn for the period 1961-2011 is in 1988 when the seasonal temperatures were between 8.5 and 11.1 °C.

Precipitation anomalies show low autumn precipitation in some years in the beginning of the 21st century but the occurrence of drought is not confirmed by the calculation of SPI. The occurrence of drought in autumn 1969, 1983 and 1992 is confirmed by two methods used in the present research. The difference is that according to precipitation anomalies the intensity of drought is strong as according to SPI in most of cases the drought is moderate (Table 5). As in summer, in autumn seasonal precipitation is between 50 and 75% of the climate norm in several years during the 70's and the 80's, but the values of SPI do not confirm manifestation of drought during these periods.

The average annual temperatures for the period 1961-2011 are between 10.7 and 12.5°C. The year with the highest average annual temperature is 2007 and with the lowest is 1997.

Drought in annual aspect is studied by the application of three indices: percent of normal, SPI and De Martonne aridity index. The driest years in the Northwestern part of Bulgaria are during the 80's and the 90's. This fact is pointed out in many publications about different part of the country. The drought is observed also during 2000, 2008 and 2011 (Table 6). The difference between seasonal and annual drought is that in annual aspect the drought is manifested as average as in seasonal it is most often strong.

In average values De Martonne's aridity index does not show arid or semi-arid climate in the stations from the Northeastern part of Bulgaria. The annual De Martonne's aridity index is calculated for three periods (Table 7) and the values are between 27 and 29. The exception is station Varna, situated at the eastern part of the study area on the Black Sea coast with De Martonne's aridity index 21-22. In fact there are not differences in the values of De Martonne's index for various investigated periods.

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
*Volume **XII**, Issue **1** (**June 2013**), pp. **16-24***
*http://dx.doi.org/**10.5775/fg.2067-4635.2013.016.i***

Table 5. Drought occurrence in autumn according various indices

a) percent of normal

Stations	**average drought** (precipitation anomaly between 50 and 75% of climate norm)	**strong drought** (precipitation anomaly less than 50% of climate norm)
Autumn		
Russe	1965, 1970, 1973, 1974, 1977, 1984, 1991, 1994, 2001, 2006, 2010	1963, **1969**, 1982, **1983**, **1986**, 1990, **1992**, **2000**, **2004**, 2011
Razgrad	1963, **1965**, 1970, 1980, 1984, 1986, 1987, 1990, 1996, 2006, 2010, 2011	1961, **1969**, 1982, **1983**, **1986**, 1990, **1992**, **2000**, **2004**, 2011
Shumen	1963, 1965, 1967, 1973, 1974, 1977, **1980**, 1990, 1991, 2001, 2011	1961, **1969**, **1983**, 1984, **1986**, **1992**
Varna	1965, 1967, 1970, 1976, 1986, 1987, 1989, 1990, 1997, 2001	1961, 1963, **1969**, 1973, 1978, 1980, **1983**, **2000**, **2004**, **2010**

b) SPI

Stations	**moderate drought** (SPI from -1 to -1.49)	**severe drought** (SPI from -1.5 to -1.99)	**extreme drought** (SPI -2 and bellow)
Autumn			
Russe	**1969**, **1992**, **2011**		1999
Razgrad	1983, 1992, 1977, 1973	1972, **1965**	**1969**
Shumen	1983, 1989, 1984, **1992**, **1980**	1961, **1969**, **1986**	
Varna	**2010**, **1969**, 1983		2011, 1984

*- in bold are the years with drought events according 2 methods

Table 6. Annual drought occurrence according various indices

a) percent of normal

Stations	**average drought** (precipitation anomaly between 50 and 75% of climate norm)	**strong drought** (precipitation anomaly less than 50% of climate norm)
Annual		
Russe	1965, 1985, 1986, **1992**, 1996	1999, 2000
Razgrad	**1976**, **1990**, **1992**, **1996**, **2000**, **2008**	**1998**
Shumen	**1974**, **1983**, **1986**, **1990**, **2008**	-
Varna	1974, 1976, **1983**, **1984**, 1990, **2000**, 2008	**2011**

b) SPI

Stations	**moderate drought** (SPI from -1 to -1.49)	**severe drought** (SPI from -1.5 to -1.99)	**extreme drought** (SPI -2 and bellow)
Annual			
Russe	**1992**		**2000**, **1999**
Razgrad	**2000**, **1992**, **1990**, **2008**	**1976**	**1998**, **1996**
Shumen	**2008**, 1985, **1974**, 1992	**1986**, **1983**	**1990**
Varna	**1984**	**1983**, **2000**	**2011**

c) De Martonne aridity index

	Russe	Razgrad	Shumen	Varna
Semi-arid De Martonne aridity index is between 20 and 10	**1992**	**1976**	**1983**	**1972**
		1990	**1986**	**1974**
		1992	**1990**	**1976**
		1996	**2008**	**1983-1986**
		1998		**1989**
		2000		**1990**
		2008		**2000**
				2008
Arid De Martonne aridity index is less than 10	**1999**			**2011**
	2000			

*- in bold are the years with drought events according 3 methods

Table 7. Average annual De Martonne's aridity index

	Russe	Razgrad	Shumen	Varna
1961-2011	28	29	29	22
1971-2000	27	28	27	21
1981-2010	27	28	28	22

The similar results are published by Moteva et al., 2010, who investigated hydro-thermal and evapotranspiration conditions of the planning districts of Bulgaria. The authors point out that for Northeast region average value of De Martonne's aridity index during potential vegetation period is 23, but climate during July – August is classified as sub-arid with De Martonne's index 16.5.

Analysis of production of main crops in the study area on the background of climate change

The meteorological conditions are one of the most important reasons for the changes in the yields of agricultural crops in different years, even in high yield and technological level. According to Nikolova, 1999, weather and soil conditions are a major risk factor agricultural production. On the Bulgarian territory, droughts cause significant losses of agriculture. The impact of drought is related to fluctuations of some weather conditions that lead to growth impairment of the crops and their yields fall below 50% of average annual (Knight et al, 2004). The influence also has long periods without rainfall in late summer and early autumn, and consecutive months with precipitation under the climate normal (Koleva, 1991).

In order to investigate the impact of drought on crop growing the data for the production of wheat, maize, barley and sunflower in the Northeastern region for the period 2001-2011 are used. Analysis of the data shows a decrease in the yield of corn and sunflower in 2001 and of wheat and barley in 2005 and 2009 (Fig. 1). Decreasing of the yield of the four considered crops (wheat, maize, barley and sunflower) is observed in 2003 and 2007. On the other hand, the analysis of rainfall anomalies and SPI indicates that the summer of 2003 is one of the driest periods with the seasonal anomalies of precipitation below 50% of climate normal in all investigated stations. Low yields were obtained in 2007, when in a significant number of investigated stations spring precipitation is below climate normal. Drought at moderate intensity is observed in the summer of 2007 also. Calculated SPI and comparison with data about yields allow us to conclude that the decrease in crop yields coincide with the periods of severe drought in the spring of 2007 (station Shumen) and summer drought in 2003, 2007 and 2008, established in the four studied stations (Razgrad, Shumen, Rousse and Varna).

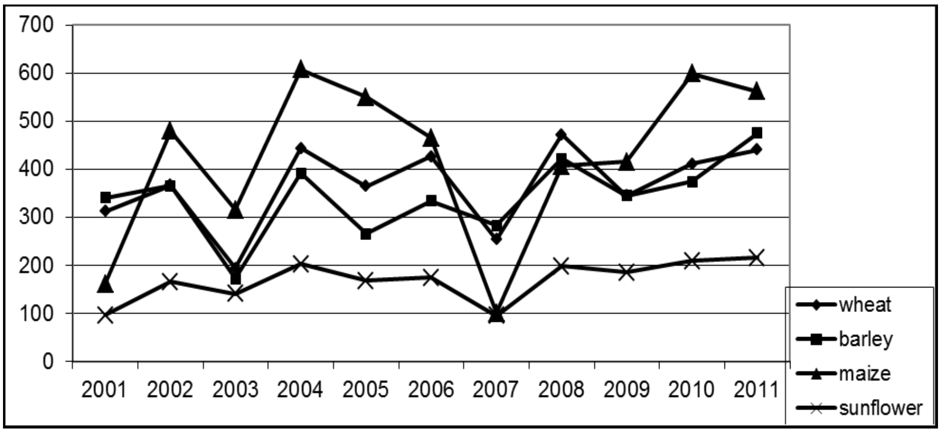

Fig. 1: Production of wheat, maize, barley and sunflower in Northeast region for the period 2001-2011 (kg/dka)

Identified by De Martonne's aridity index drought years (2000, 2007, 2008) coincided with the years of reduced yields from the crops.

Future climate change and agriculture

Scenarios developed by research works in recent years show the increasing of air temperature and decreasing of rainfall in Bulgaria during the warm half of the year. The results of CLAVIER project (http://clavier-eu.org/) indicate that for the period 2011-2050 annual air temperature in Bulgaria will increase by 1.78 □C and annual precipitation total will decrease by 32 mm. According to a number of climate models the number of consecutive dry days in the country will increase (Jacob D. 2009).

The publication from the COST Action 734 (Alexandrov et al, 2011) points out that the ECHAM4 climate change scenarios for the 2050-s shows a lower warming in the east Bulgaria as well as in southeast Romania and northeast Turkey. The annual precipitation in 2050-s and 2100s will decrease as follow: 6-9% (HadCM2) and 4-5 % (ECHAM4) for the middle of the current century and 12-18% (HadCM2) and 8-10 % (ECHAM4) for the end of 21-st century. According to HadCM2 precipitation total for June – August will decreases in 2100 with more than 30%.

Alexandrov (2008) assessed the risk of drought in Bulgarian municipalities. The results from survey show that most of the municipalities located in the Danube valley have average or substantial risk of drought. The greatest risk of drought is established in the eastern parts of the study area.

Due to the expected increase in summer and autumn temperatures maturation of a number of agricultural crops will occur earlier, indicating shorter growing season. Based on climate models, Alexandrov et al. (2011) found shorter growing season in the 21st century for maize and winter wheat. The temperature and rainfall conditions show that agriculture in the Northeastern part of Bulgaria should focus on growing thermophilic crops. In order to reduce the yield loss caused by the increase in temperature the earlier sowing date for various crops has to be chosen. Another option to adapt to the climate change and drought is to look for plants (and seeds respectively) which could endure the drought and to correspond to the local climate condition also.

Conclusion

The analysis of climate data allows us to conclude that the drought in the northeastern part of Bulgaria is normal and a relatively common phenomenon observed, especially from the 80's of the 20th century. Because of this it is important to know about spatial and temporal variability of drought occurrence and its impact on agriculture. This may help for developing long-term agricultural policies and various strategies for mitigation and adaptation to climate change. Often the periods of droughts have been observed with periods of high seasonal and annual temperatures, which increase the negative effect of drought on crops.

Despite the well-established dependence, drought is not the only factor that affects crop yields. Air pollution, acid rain, a number of economic and social conditions also play important role and have significant pressure on production. Based on this, some adaptation measures (changes in the dates of sowing, growing a xerophilous crop varieties, etc.) have to be implemented.

Acknowledgements

This study is supported by Sofia University Science Fund under the Grant for the Project ” Monitoring and Assessment of Agrometeorological Drought in Danube Plain”, 2009.

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