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Climate Variability and Change Impact on Water Resources in Bulgaria

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Abstract: Variability of air temperature, precipitation and river runoff during the 20th century in Bulgaria was investigated. Possible scenarios for air temperature, precipitation and annual runoff in Bulgaria assuming the current trends and also the last severe drought period were created. According to the GCMs used in the study air temperature is expected to increase between 3 to 5°C till the end of the 21st century. In general, precipitation is expected to increase during the winter and to decrease during the warm half-year. Total precipitation during the potential crop-growing season will increase due to projected increase of the duration of the potential crop-growing season caused by warming. However, the total precipitation amount during the actual crop-growing season is projected to decrease due to the GCM simulated decrease of precipitation and because of shortening the actual crop-growing season caused also by expected warming. The Decision Support System for Agrotechnology Transfer DSSAT was used to simulate the impact of climate variability and climate change scenarios on the parameters of the soil water balance during the maize growing season. Adaptation strategies and options in respect to water resources including irrigation under climate change are also listed at the end of the study.

Key words: climate variability and change, river runoff, soil water balance, maize, DSSAT

INTRODUCTION

The Earth's climate has exhibited marked "natural" variations and changes, with time scales ranging from millions of years down to one or two years. The global average surface temperature increased over the 20th century by 0.6±0.2°C (e.g. *IPCC WG1 TAR, 2001*). Europe has a very diverse hydrological background, reflecting its varied climate and topography. In the south, including Bulgaria, there is very significant variation in flow through the year, with long, dry summers (e.g. *IPCC WG2 TAR, 2001*). A succession of droughts has illustrated southern Europe's vulnerability to hydrological extremes. There are many other water-related pressures on Europe's environment, however (e.g. *Stanners and Bourdeau, 1995*), such as increasing demand for water, particularly in the south, and subsequent increases in abstractions (e.g. *IPCC WG2 TAR, 2001*).

The objective of this study was to assess some aspects of water resources (precipitation, river runoff, groundwater, components of the soil water balance under maize growth) in Bulgaria under climate variability during the 20th century and projected climate change for the 21st century.

2. MATERIAL AND METHOD

Daily data for mean air temperature and precipitation from 16 weather stations across the country with elevations below 800 m were gathered for the period 1901-2000 (Fig. 1). All observed meteorological data that were used in this study were provided by the weather network of the Bulgarian National Institute of Meteorology and Hydrology.

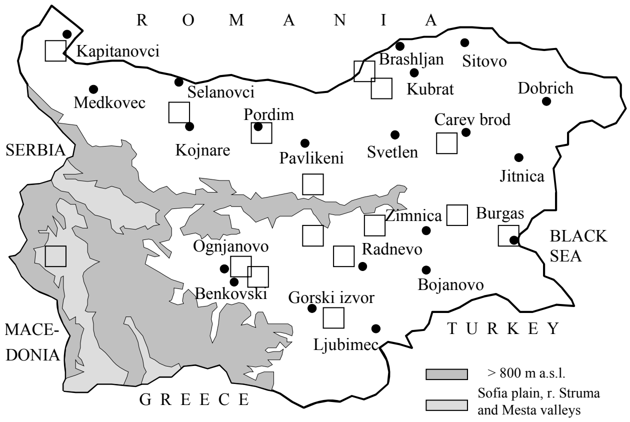

Figure 1. Spatial distribution of weather (the squares) and experimental crop variety (the points) stations, used in the study

Three hydro-climatic regions are detached in Bulgaria: the Danubian catchment basin (North Bulgaria), the Black Sea catchment basin (East Bulgaria) and the Mediterranean catchment basin (South Bulgaria). The river runoff was investigated for the period 1935-1997 on the base of 152 hydrological stations.

The IBSNAT project has developed a computerized Decision Support System for Agrotechnology Transfer (DSSAT) which integrates soil, weather and crop data bases with dynamic crop simulation models (e.g. *Tsuji et al., 1998*). The DSSAT CERES model for maize was previously (e.g. *Alexandrov and Eitzinger, 2001*) calibrated and validated for the agrometeorological conditions of 21 experimental crop variety stations across the country (Fig. 1). A maize hybrid with a medium crop-growing season was used. Standard agrotechnological data such as planting date, depth and density as well as fertilizing amounts were averaged for the last years and applied as model input. The automatic irrigation option of the CERES model was selected for irrigation applications, so that water would not be a limiting factor in the simulation. Respective soil profiles, applicable for the locations used in this study, were also applied as required model input. Daily weather data for the period 1961-1997 were gathered from the nearest weather stations.

Most climate change studies use estimates of regional climate change from global circulation models. The 30-year averaged transient GCM (global circulation model) meteorological outputs were provided for this study by the IPCC DDC (Intergovernmental Panel on Climate Change Data Distribution Center) for the periods: 1961-1990, 2010-2039, 2040-2069 and 2070-2099 (the last 3 periods are referred to as 2020s, 2050s and 2080s). The GCMs, which were used in the study, include the ECHAM4, HadCM2, CGCM1, CSIRO-Mk2b and GFDL-R15 models (e.g. *IPCC DDC, 1999*).

3. RESULTS AND DISCUSSION

3.1 Climate and river runoff long-term variability during the 20th century

A minimum of annual temperature in the country appeared in the 1900s. In the earlier 1940s there was also a cold spell. There were no significant air temperature fluctuations in the 1970s and 1980s. A slight warming has been observed since the middle of 1980s. Generally, there is no significant overall trend of mean annual air temperature in Bulgaria for the 20th century (Fig. 2).

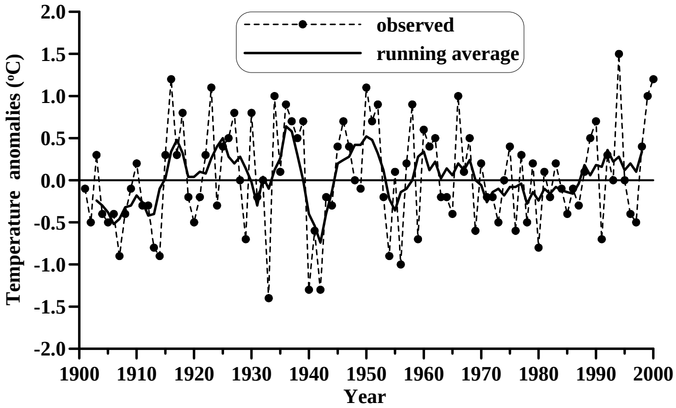

Figure 2. Long-term anomalies of annual air temperature, relative to 1961-1990

Annual precipitation in Bulgaria varied considerably from year to year during the 20th century (Fig. 3). The country has experienced several drought episodes during the 20th century, most notably in the 1940s and 1980s. Drought spells in the 1940s and 1980s were observed everywhere across the country. Drought in Bulgaria was most severe in 1945 and especially year 2000 with precipitation less than 30% of the current climatic (1961-1990) values (Fig. 3). Generally, the variations of mean annul precipitation in Bulgaria showed an overall decrease.

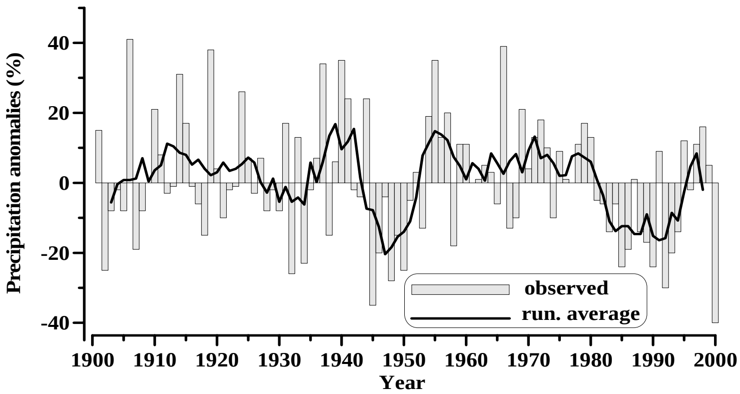

Figure 3. Long-term anomalies of annual precipitation, relative to 1961-1990

Figure 4 represents anomalies and 5-year running average of annual river runoff in North Bulgaria from 1935 to 1997.

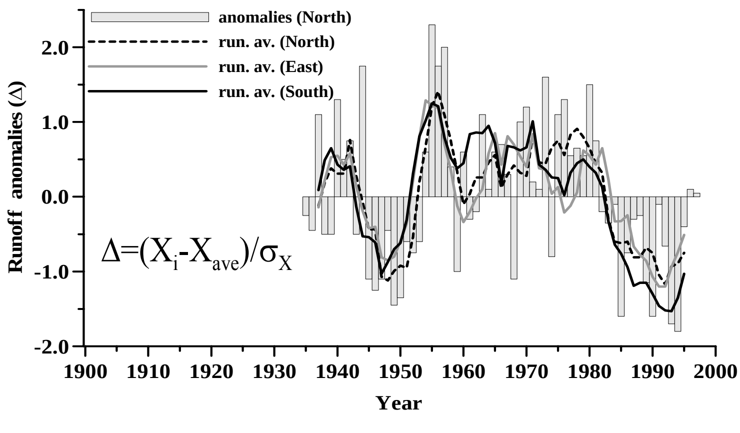

Figure 4. Anomalies of annual river runoff in Bulgaria, relative to 1961-1990

The running averages of runoff in East Bulgaria and South Bulgaria are also shown. The runoff anomalies are following the anomalies of annual precipitation (Fig. 2 and 4). There were significant runoff reductions at the end of the 1940s and especially during the last two decades (1980s and 1990s). According to the obtained results the runoff status was worst in South Bulgaria (Fig. 4).

The period in which runoff and precipitation in Bulgaria were below the norm is 1982-1994. It is characterized with 31% decrease of runoff in Bulgaria towards the norm for the period 1980-1996. The depressions in the dry spell were most strongly expressed in 1990, 1993 and 1994 when an absolute minimum of the period 1980-1995 occurred: from 0.31 till 0.43, relative to the norm, with a very low return probability.

The last drought period (1982-1994) affected considerably groundwater in Bulgaria. Most of springs presented a reduction of discharge and wells showed lower water levels. The reduction of spring discharge was determined to be up to 20-30%. The chronological structure of the drought was similar to this of the river discharge. Generally, the groundwater anomalies were following the river runoff and therefore the precipitation anomalies (Fig. 5). For North Bulgaria and South Bulgaria the groundwater decrease was most severe in 1994 as well as in 1992 and 1993. The highest observed decrease in East Bulgaria occurred in 1989 and 1994, respectively.

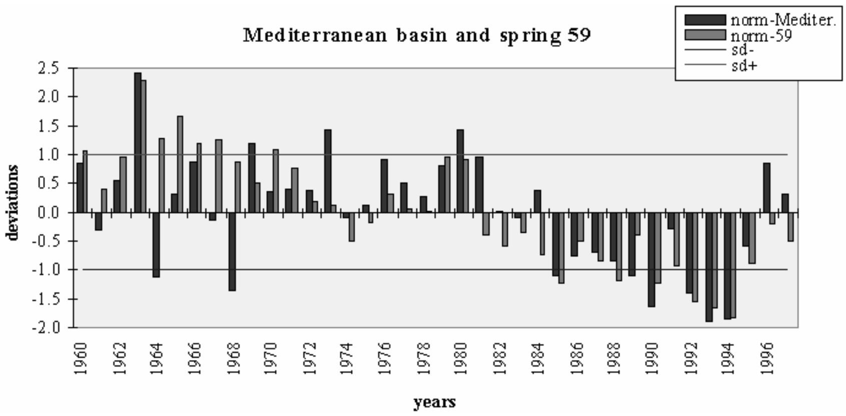

Figure 5. *Variations of Mediterranean basin runoff and spring 59 in South Bulgaria*

3.2 Simulation of soil water balance components for the period 1961-1997: a case study for maize

The DSSAT program was used to simulate different components of the soil water balance during the crop-growing season of maize from 1961 to 1997. The numbers of irrigation applications vary around their averages (between 8 to 11 in North Bulgaria and from 9 to 12 in South Bulgaria). Naturally, there is strong correlation between irrigation and precipitation amounts – seasons with lower precipitation were characterized with higher irrigation totals. Total irrigation amount in 1996 which was necessary for normal maize growth development and yield formation in the country was around 350 mm. The water demands for irrigation applied in South Bulgaria were higher than the irrigation amounts in North Bulgaria due to less precipitation and higher air temperatures. Seasonal precipitation varied considerably during the investigated period – from less than 100 mm to more than 500 mm. The evapotranspiration variations were higher in North Bulgaria than in South Bulgaria. The variations of surface runoff were following precipitation variations. Seasonal water drainage, for example, was above 160 mm in 1991 at experimental crop variety station Kubrat (North Bulgaria) due to higher seasonal precipitation, followed by significant seasonal runoff. However in some years, water drainage was very low, for example in 1968, 1985 and 1985.

3.3 Trend scenarios

The results obtained for the 20th century showed there would be some changes in the water resources in the country. Table 1 represents five future scenarios for annual air temperature, precipitation and runoff in Bulgaria assuming the current trends and also the last severe drought period (1982-1994). Annual river runoff is expected to decrease up to 14% in 50 years and to be 20% less at the end of the century in respect of the current climate. In case that a severe drought period is also assumed within the study, the expected decrease of annual runoff in Bulgaria is between 39 and 45%.

Table 1. (Pessimistic) scenarios for future development of hydrological process in Bulgaria

Element	Model 1 Trend 2050 T1	Model 2 Trend 2100 T2	Model 3 Drought 1982-1994 D	Model 4 T1+D	Model 5 T2+D
Air temperature	+0.5°C	0.7°C	0.2°C	0.5°C	0.7°C
Precipitation	-4%	-6%	-12%	-15%	-17%
Runoff	-14%	-20%	-31%	-39%	-45%

3.4 Impact of GCM climate scenarios on maize water use

The transient GCMs predicted that annual temperatures in Bulgaria are to rise between 0.7° and 1.8°C in the 2020s. A warmer climate is also predicted for the 2050s and 2080s, with an annual temperature increase ranging from 1.6° to 3.1°C in the 2050s, and 2.9° to 4.1°C in the 2080s. In general, precipitation is expected to increase during the winter and to decrease during the warm half-year.

Total precipitation during the potential crop-growing season will increase due to projected increase of the duration of the potential crop-growing season caused by warming. However, the total precipitation amount during the actual crop-growing season is projected to decrease due to the GCM simulated decrease of precipitation and because of shortening the actual crop-growing season caused also by expected warming. As a result of projected warming and precipitation deficit the simulated irrigation demands increased, however the total water amount for irrigation decreased due to considerable shortening of the maize crop-growing duration. As a result of the irrigation decreasing and shortening of the growing season, seasonal evapotranspiration is also expected to decrease at the ECHAM4 2050s up to about 20% (Fig. 6).

4. CONCLUSIONS

The study results show the currently observed decreasing trend of water resources in Bulgaria is expected to continue into the future due to warming and especially precipitation reductions. As a result of the current and expected water shortage conditions in Bulgaria, general and specific strategies can be recommended (*Vodno delo, 2001*): saving water resources; overcoming water-supply crisis; securing water for irrigation and related efficiency; formation of knowledge and sense of water resources saving.

The save of water resources could include, for example, providing water resources management based on reservoir principle, allowing maximum and effective utilization of water resources; additional runoff regulation; providing minimum runoff into rivers; conserving or liquidation of drillings, regarding not utilized groundwater; providing waste water purification; etc.

To overcome the water-supply crisis the following could be implemented: building water reservoirs to catch spring high water; reconstruction of water-supply networks; appropriate water-supply zoning and provision of necessary equipment providing utilization of the whole water input;

completing buildings/equipment/etc. of local importance for solving the problems of water-supply for drinking and daily wants; etc.

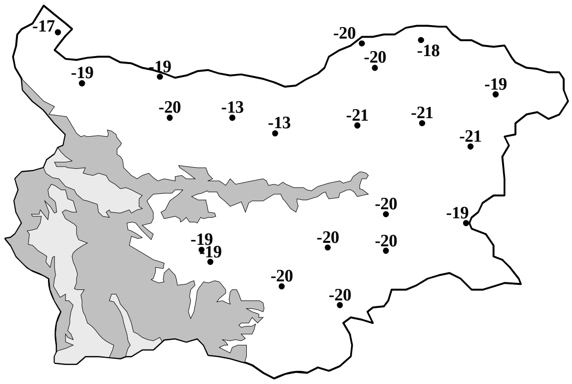

Figure 6. Changes (in %) of the total evapotranspiration during the growing season of maize under the ECHAM4 climate change scenarios for the 2050s

As a result of expected warming and precipitation deficit changes in water use of maize in Bulgaria are projected. The simulated irrigation demands increased, however the total water amount for irrigation decreased due to considerable shortening of the maize crop-growing duration. That result doesn't mean avoiding the expected problem with water scarcity. It should be noted that decreasing the growing season leads to decrease of maize yield, that is why maize hybrids with longer growing duration should be grown under expected warming. Therefore, the problem concerning the water applied for crop irrigation definitely exists. The adaptation options for an increase of the irrigation effectiveness should include: introduction of irrigation technologies with decreased water charges and without losses under water transport and spreading; restoring and reconstruction of the already constructed hydromeliorative fund; reconstruction and building of new test-pits for utilization of groundwater; utilization of river water and precipitation for moisture storing irrigation during the winter season; utilization of waste water and drainage system water.

Finally, the formation of knowledge and sense of water resources saving may include active media policy; development of a new attitude of population to water; development of regular rubrics informing population about current status of water resources; public control on water thefts and waste; involving non governmental organizations in the problems of water saving and waste.

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REFERENCES

Alexandrov V., Eitzinger, J., 2001. Adaptation of crop-weather models in Austria and Bulgaria. Proceedings of the Fifth European Conference on Applications of Meteorology ECAM' 2001, Budapest, Hungary (CD version).

Intergovernmental Panel on Climate Change Data Distribution Centre (IPCC DDC), 1999. Data/Information Supplied by the IPCC Data Distribution Centre for Climate Change and Related Scenarios for Impact Assessments, Version 1.0, April 1999.

Intergovernmental Panel on Climate Change Working Group I Third Assessment Report (IPCC WG1 TAR), 2001. Climate Change 2001: The Scientific Basis. http://www.ipcc.ch/pub/tar/wg1/index.htm

Intergovernmental Panel on Climate Change Working Group II Third Assessment Report (IPCC WG2 TAR), 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability. http://www.ipcc.ch/pub/tar/wg2/index.htm

Stanners D., Bourdeau P., 1995. Europe's Environment: The Dobris Assessment. European Environment Agency, Copenhagen. Denmark, 385 pp.

Tsuji G., Hoogenboom G., Thornton P., 1998. Understanding Options for Agricultural Production. Kluwer Acad. Publ., 399 pp.

Vodno delo, 2001. Programme of the government of Republic of Bulgaria for the necessary measures under drought conditions, Vodno delo; 1/2: 4-7 (in Bulgarian)