Impact of Climate Change on Water Supply of Winter Wheat in Bulgaria

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Summary

From an agricultural point of view Bulgaria has insufficient and uncertain water resources. For the last decades, the potential vegetation period temperature sums submit to a positive tendency and the rainfall sums – to a negative one almost all over the country. This is evidence for the current drought processes determined by the global climate change. The increasing atmospheric drought impacts negatively water content in soil, especially that one available for plants.

The paper deals with the impact of the contemporary climate changes upon the available soil water under winter wheat - one of the most important of our country crops for the food balance. The data processed have been gathered from 24 sites and refer to six soil types all over the agricultural territory. They cover the period of the "contemporary climate" (1961-2000). Actualized zoning of the soil water resources and maps of the changes in the availability of soil water have been elaborated. The results obtained allow development of adaptation farming strategies for management of the irrigation scheduling and maintaining of the other agricultural practices according to the climate changes. They will also be used for working out new standards for irrigation network design.

Key words

winter wheat, availability of soil water, cotemporary climate, zoning, Bulgaria

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Introduction

From an agricultural point of view Bulgarian moisture conditions are hazardous for insufficiency of the water resources and their uneven occurrence during the potential vegetation period. In most years the spring crops, and often the winter ones are grown under water deficit conditions. The yields obtained are short to provide the population with food. Nowadays agriculture suffers from warming and drought processes typical of the contemporary global climate change. Availability of soil water has turned into a problem in most parts of the country. To solve this problem and to obtain high crop productivity it is necessary: 1) to assess the long-term dynamics of the available water content; 2) to carry out constant monitoring of its current status, and 3) to particularize measures for adaptation of the agricultural practices to the climatic changes. Dilkov (1959, 1960), Vangelov (1963, 1965), and Dilkov & Vandova (1972) have evaluated the water supply probability of chernozems, leached smolnitza, and cinnamonic forest soils but on the basis of short data series. Later on, considering perennial trends, Slavov (1995) and Slavov & Georgieva (2001, 2002, 2003, 2005) have investigated longer series and derived conclusions.

The goal of this investigation is to determine the changes within the period of the contemporary climate in the water supply of winter grain crops over the territory of the country.

Material and methods

The investigation deals with the multi-layer soil water content, registered at the very beginning of the following main phenological stages of winter wheat: sowing; the end of the early vegetation stage notified by the autumn date of air temperature durable transition below 5ºC; the beginning of the late vegetation stage, notified by the spring date of air temperature durable transition above 5ºC; anthesis; and wax maturity. The data processed cover the period of the contemporary climate 1961-2000. Data have been gathered from 24 agro-meteorological stations, spread over six soil types - chernozems, gray forest soils, cinnamonic forest soils, leached smolnitza, alluvial meadow soils, and deluvial meadow soils. The available water content has been integrated per each 0-50 and 0-100-cm soil layer. A regression analysis has been used to establish the 40-year trends of the changes. For each trend the difference between the final and the initial values has been calculated and turned into % of field capacity (FC). Then, by an interpolation over the territory of the country the zones of changes have been determined and mapped.

As soil moisture is influenced by the variation of the climatic elements, the 40-year trends of the coefficient of air humidity, characterizing the atmospheric moisture conditions, are also presented in the paper. The air humidity coefficients of the autumn-winter (October-March) and spring (April-June) vegetation periods have been calculated using the formula:

$$k = \frac{\sum R}{\sum E},$$

where:

ΣR – precipitation sum [mm],

ΣE – evaporativity sum [mm].

Evaporativity has been estimated according to Ivanov's equation: $E=0.0018\ (t+25)^2\ (100-a)$, where: t – monthly air temperature [ºC]; a – monthly relative air humidity [hPa].

Results

The 40-year trends of the air humidity coefficient are plotted on Figs. 1 and 2. The highest cold-period values of this precipitation-evaporation ratio are observed in the northeastern part of the country. In some years this ratio is 3.0 for the particular region, while in the northwestern and southern parts of the country it rarely overcomes 2-2.5. Almost all over the country the trends are negative. They vary within the range of 1.3-1.4 for northeastern, and within 1.4-1.1 for northwestern Bulgaria. The slope of the straight line, denoting the tendency of the winter air humidity coefficient in southern Bulgaria is comparatively more abrupt than that attributed to northern Bulgaria. The latter decreases from about 1.4-1.5 to 1.0-1.2.

The spring tendencies of k all over the country vary between 0.6-0.7, i.e. the rainfall income is about one half of the potential evaporation losses. The trends characteristic of northeastern Bulgaria are almost parallel to the horizontal axis. This indicates no change in moisture conditions during the 40-year period. The trends representative of northwestern and southern Bulgaria follow the downward direction. The ratio changes negatively with 0.2-0.5. The greatest decrease is found in the Thracian Lowlands – from 1.0 to 0.5.

Zoning maps of the perennial changes in the available water content per phenological stages and integrated soil layers over the territory of the country are presented in Figures 3-7. The isohyets notifying today's deficit in comparison with that of 1970s are marked in blue, and the corresponding values are inscribed with minus. The lines of positive changes are green. The territories colored in dark-green are not suitable for cultivation, and those shaded in yellow are not convenient for winter grain crop production. Figs 3(a)-7(a) refer to the 0-50-cm soil layer while Figs. 3(b)-7(b) - to the 0-100-cm one.

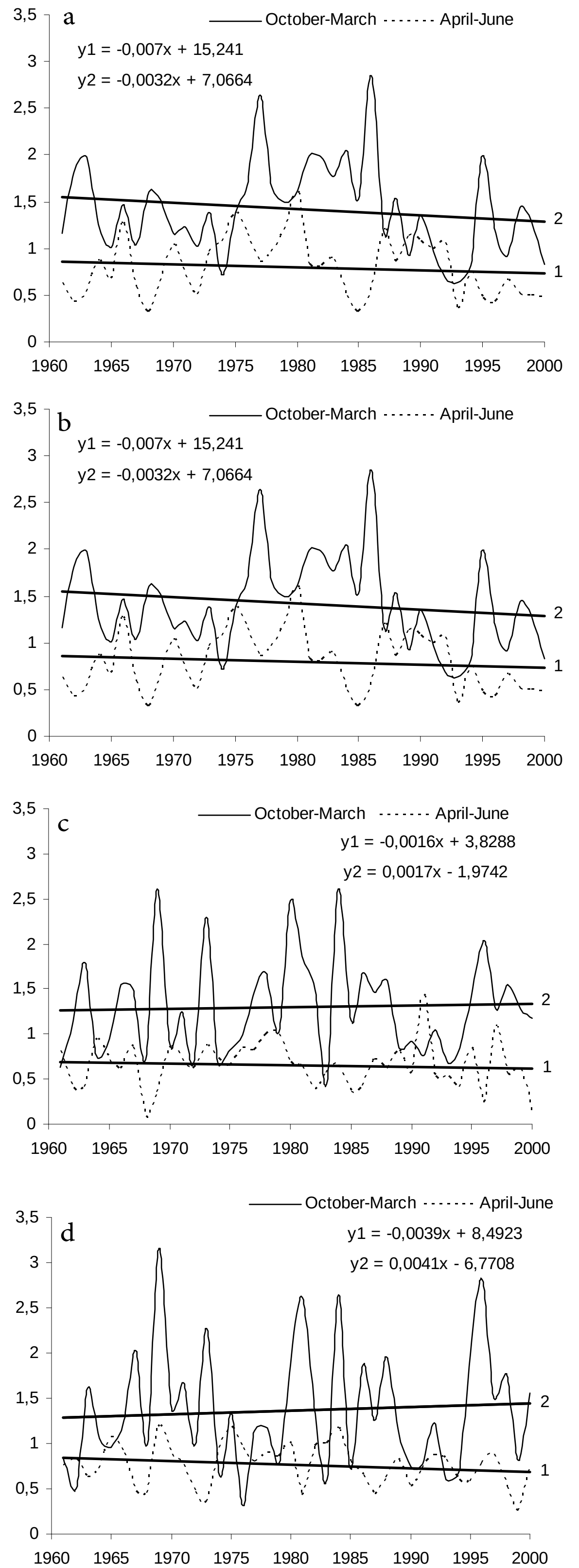

Figure 1. Trends of the air humidity coefficient in Northern Bulgaria for the two sub-periods of the vegetation period of winter wheat: a) D-r Yosifovo; b) Kneja; c) Obraztzov Chiflik; d) Isperih

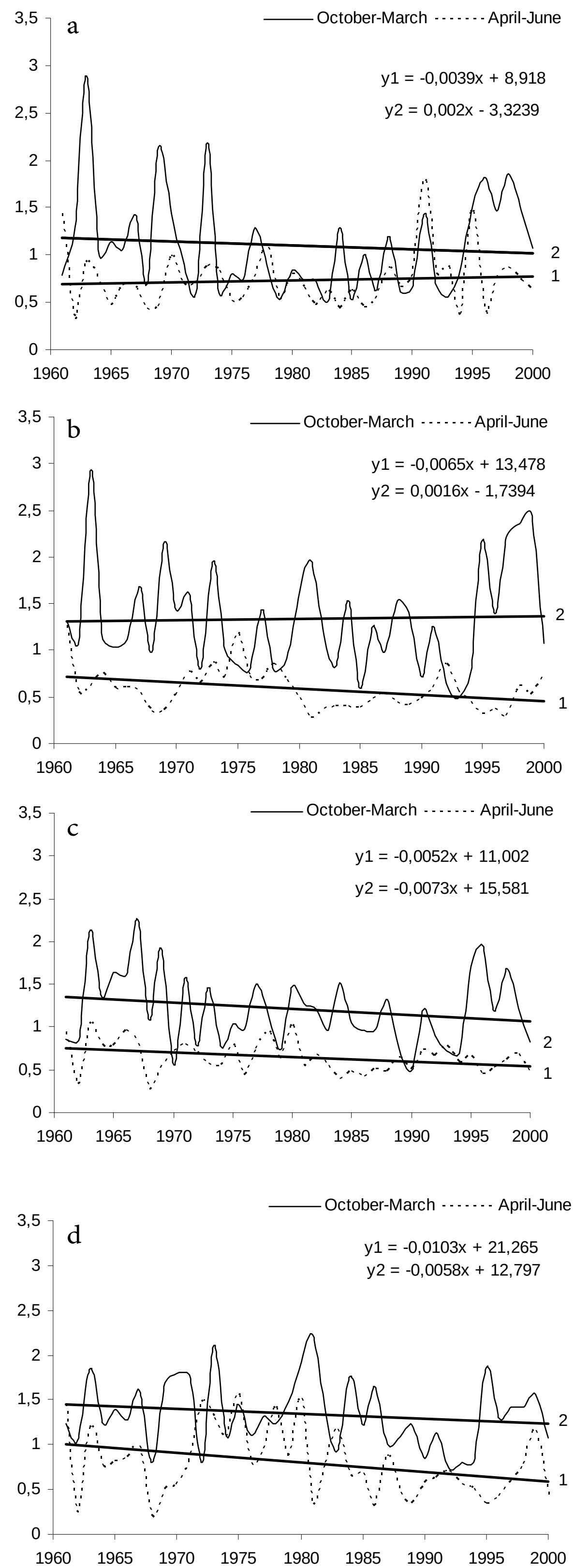

Figure 2. Trends of the air humidity coefficient in Southern Bulgaria for the two sub-periods of the vegetation period of winter wheat: a) Kazanlak; b) Chirpan; c) Karnobat; d) Haskovo

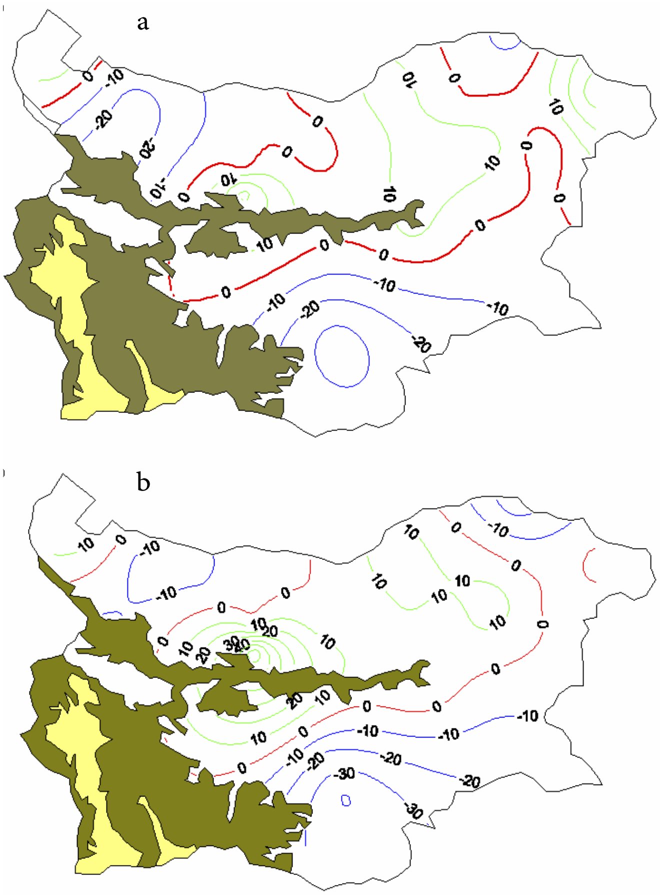

Figure 3. Change in the available water content (1961-2000) over the territory of Bulgaria at sowing in: a) 0-50-cm soil layer; b) 0-100-cm soil layer

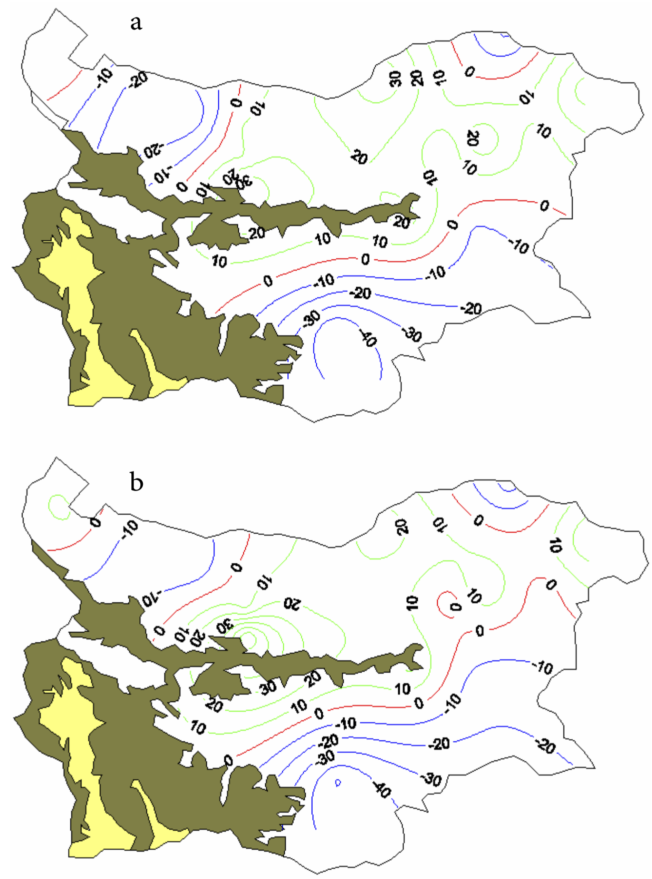

Figure 4. Change in the available water content (1961-2000) over the territory of Bulgaria at end of early vegetative stage at the date of proof air temperature falling below 5^{o}C in the autumn in: a) 0-50-cm soil layer; b) 0-100-cm soil layer

Discussion

The 40-year trends of the autumn-winter coefficient of air humidity in northeastern Bulgaria show no certain changes in winter wheat water supply during the period of the contemporary climate (Fig. 1). Moisture conditions of Dobrudja region (Northeast Bulgaria), wherein winter wheat is basically grown in Bulgaria, are favorable. The water content in the 0-50-cm soil layer on the date of sowing has increased in the course of the 40 years with 5-20% (Fig 3a). No tendency of change has occurred in the 1-m root zone (Fig 3b). Hence, in the future decades, there will be probably no risk for the emergence and autumn development of winter wheat. The available water content at the end of the early vegetation stage also shows no change tendency for both 0-50-cm and 0-100-cm layers (Fig. 4). The moisture conditions on the date of air temperature durable transition above 5^{o}C in spring, i.e. at the start of the late vegetation stage, show a slight worsening tendency (Fig 5). The available water content decreases for 5-10%.

Autumn-winter drought is inevitably settling in the northwestern and southern parts of the country. The air humidity coefficient trends drop (Fig. 1a, b and 2b, c, d). Therefore, a decrease in the autumn–winter accumulation of water is expected in future. The perennial change in the available water contents in the 50-cm layer in northwestern and southern Bulgaria on the sowing date can be seen on Fig. 3a. It has decreased considerably (5-20% and 5-30%, respectively) during the period of the contemporary climate. Analogously, the decrease in the integrated 0-100-cm layer in southern Bulgaria (Fig. 3b) is of the same value and it is smaller (down to 10%) in northern Bulgaria. At the end of the autumn growth period soil moisture is much exhausted – down to 40% in both soil layers (Fig. 4). Despite of the fact that a period of autumn-winter moisture accumulation follows the available water content at the opening date of spring growth period drops even to 50% (Fig.5).

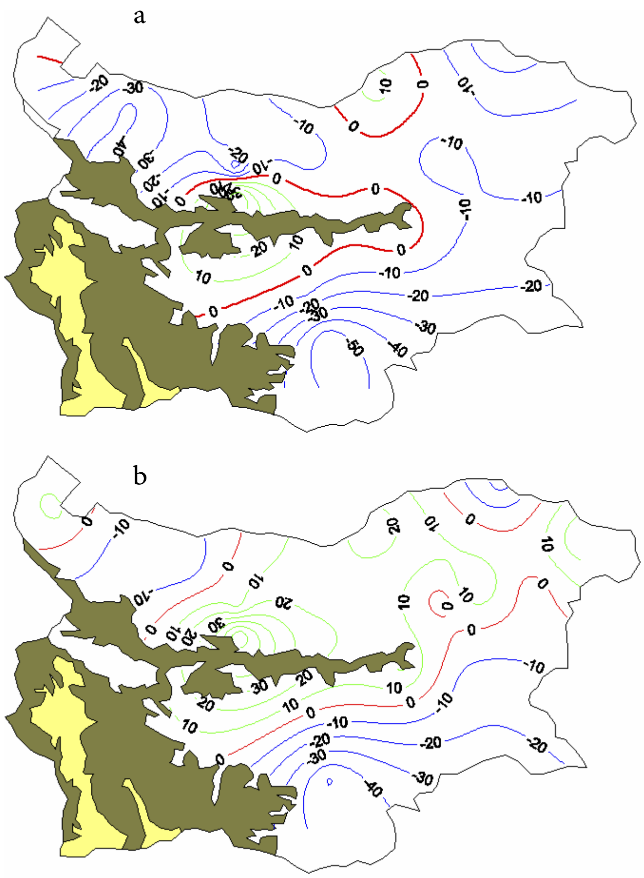

Figure 5. Change in the available water content (1961-2000) over the territory of Bulgaria at the start of the late vegetative stage at the date of proof air temperature rising above 5°C in: a) 0-50-cm soil layer; b) 0-100-cm soil layer

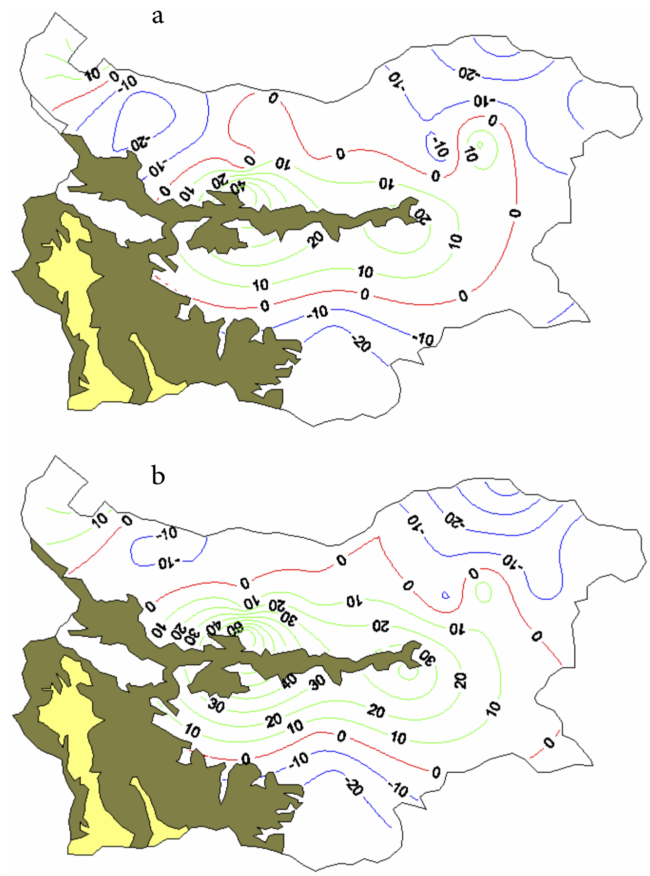

Figure 6. Change in the available water content (1961-2000) over the territory of Bulgaria at head development in: a) 0-50-cm soil layer; b) 0-100-cm soil layer

Most unfavorable in spring are the tendencies in the southern parts of Thracian Lowlands (Fig.5). The precipitations during the winter dormancy of the crop are insufficient to complete field capacity (FC) of soils. What is more, even the lower limit of the readily available water could hardly be reached. The hydrothermal conditions of that region, compared to those of the other parts of the country at that time of the year, have changed mostly to the worse. A possible reason might be climate warming and the autumn delay and spring earlier setting of the air temperature durable transition through 5°C. Thus, the winter dormancy period is shorter than that in the past years and hampers the accumulation of sufficient water amounts. Best conditions are observed in Fore Balkan region and the sub-Balkan areas. In the course of 40 years the available water content there has increased.

The spring values of the air humidity coefficient show that the rainfalls all over the country are far insufficient to meet the evaporation losses. The coefficient trends in northwestern and southern Bulgaria, except in Rose Valley (Kazanlak) are decreasing (Fig 2). Anthesis notifies the opening of the reproductive stage. It lasts during the period of the maximum rainfalls in our country. This period is, at the same time, the period of the maximum daily evapotranspiration rate of winter crops. Fig. 6a shows that the 40-year changes in water availability in the 0-50-cm soil layer are positive only in Fore Balkan region and in the northern part of Thracian Lowlands. Large territories in northwestern Bulgaria, Dobrudja inclusive, and in the southern part of Thracian Lowlands suffer of 10-20% drought.

Drought tendencies both in the 0-50-cm and 0-100-cm layers are registered almost all over the country at wax maturity (Fig. 7). This fact is not disturbing because transpiration at that phenological stage gradually ceases and water availability does not impact the yield of winter wheat any more.

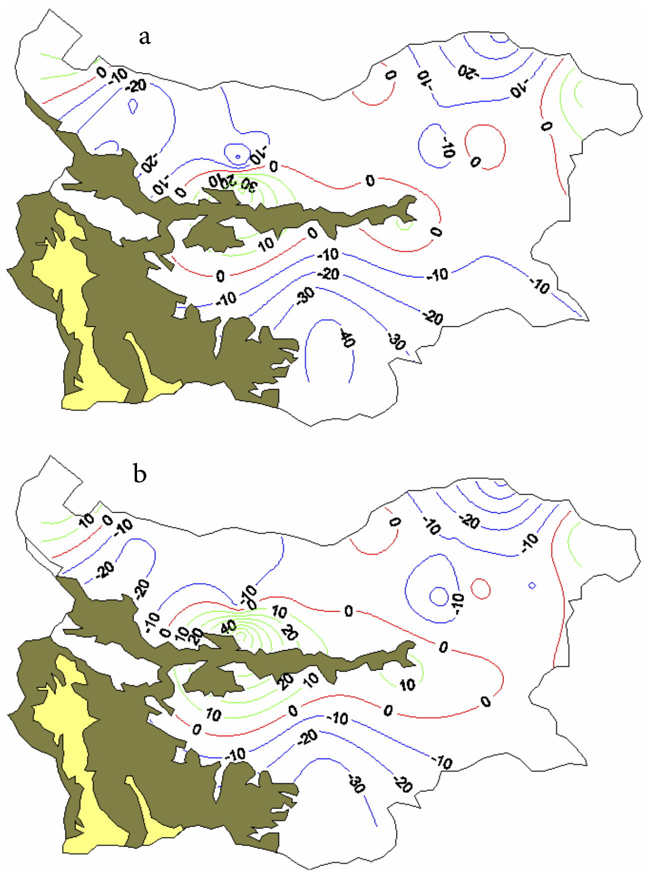

Figure 7. Change in the available water content (1961-2000) over the territory of Bulgaria at wax maturity in: a) 0-50-cm soil layer; b) 0-100-cm soil layer

Conclusion

1. Soil water availability in Bulgaria is affected by climate changes. Negative contemporary climate tendencies in accumulation of soil water during the vegetation period of winter crops are established almost everywhere in the country.
2. The drought tendencies are most apparent in two parts of the country – the northwestern and the southern ones. Growing winter grain crops there is vulnerable to future drought.
3. Slight negative changes are observed in Northeastern Bulgaria. The autumn-spring climate conditions in that region are most favorable for growing winter grain crops.
4. The highest soil moisture deficit occurs at the start of the late vegetation stage in spring, when air temperature overcomes 5 °C .

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