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THE MAIN ABIOTIC STRESS FACTORS LIMITING CROP CULTIVATION AND PRODUCTION IN BULGARIA. CLIMATE CHANGES, DROUGHT, WATER DEFICIT AND HEAT STRESS

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Abstract

The plants as all living systems can exist only in particular parameters of the outer environment, thus they are part of the open dynamic systems with automatic regulations. This adjustability of the plants is a result of their long evolutionary pathway and mainly by the joint action of instability, heredity (or the genetic traits) and the natural selection. During the phylogenies, each species has acquired its adaptability to certain environmental conditions of the medium by a different mechanism. At the same time, today plants are frequently exposed to environmental stresses due to climate changes.

Drought is becoming a serious problem for humanity on a global and regional scale, including in Bulgaria. Drought and extremely high temperatures are the most common stressors for agricultural crops in Bulgaria. The negative influence on agricultural crops and crop production is complex and its effect on all plant physiological processes. As a result of this impact, there is a decrease in the quantity and quality of agricultural production.

Keywords: stress factors, drought stress, water deficit, heat stress, climate changes.

INTRODUCTION

Stress is usually defined as an external factor that exerts a disadvantageous influence on the plants. The physiological processes are dependent on the stress effect, and the adaptation and acclimation mechanism of plants to environmental stress are of immense importance for both agriculture and the environment (Jenks and Hasegawa, 2005; Shanker and Venkateswarlu, 2011; Andy, 2016). The high level of structuring the plant organisms presumes the presence of complex and numerous bonds and mechanisms between them and the environment (Ahmad and Prasad, 2011).

The character of the influence of the medium is defined by the force as well as by the duration of the action of the relevant factor. The factors of the medium are not constant. They can change naturally and accidentally. The seasons are changed naturally and this encodes in the plant's genetical adjustability to these conditions. In the frames of the seasons, the main factors of the medium change more or less and this affects the life cycle of organisms, including plant life.

The capability of a plant to adjust to a complex of unfavourable factors of the environment, which is connected with the evolution of the species, is called adaptation (Kerin et al., 2011). If tolerance increases as a result of exposure to prior stress, the plant is acclimated (or hardened). Acclimation can be distinguished from adaptation, which usually refers to a genetically determined level of resistance acquired by a process of selection over many generations. Adaptation and acclimation to environmental stress result from integrated events occurring at all levels of the organization, from the anatomical and morphological levels to the cellular, biochemical, and molecular level.

The possibility of a single organism to adapt is established of the so-called reserve strength of the metabolism, in which the plasticity is included. That means a bigger adjusting capability is developed by the ability of the plant to store its metabolic processes in the norm of a reaction which has more wide variation in this factor.

In-plant physiology, stress is perceived as some limitation on normal physiological functions and other processes that impair the ability of organisms to reach their full potential for growth and development.

The stressful factors can occur and retain for a longer time or their action to affect for a little bit to have a vast impact. This defines the character of the self-protecting reactions: In the first case the specific mechanisms of stability appear and in the second case the nonspecific mechanisms take roles. The factors that can provoke stress in plants are divided into two main groups: abiotic and biotic (Mittler, 2006). Biotic stress factors include infections, chemicals, and concurrence. The list of abiotic stress factors indicates the temperature, water, light, nutrition and gas regimes of the plants.

In addition to all of this, lost of anthropogenic factors have to stress characteristic.

RESEARCH ON DROUGHT, WATER STRESS AND DROUGHT-RESISTANCE

Drought is not only a meteorological phenomenon. Drought is undoubtedly one of the worst natural hazards (Koleva and Alexandrov, 2008). Not only does it affect the social and economic life of millions of people every year, but from time to time the existence of a whole nation is endangered. Its beginning is subtle, its progress is insidious and its effects can be devastating. Drought may start at any time, last indefinitely and may attain many degrees of severity (Koleva and Alexandrov, 2008)

Investigations of drought are carried out all over the world. However, because of the complexity of this natural phenomenon, a uniform methodology for implementing drought studies has not yet been developed, although some indices of drought are widely used. Drought classification is one basic reason for this dearth of methodologies. Typically, there are five types of drought: soil drought, atmospheric drought, soil-atmospheric drought, hydrological drought and socioeconomic drought (Koleva and Alexandrov, 2008). Soil drought occurs during long periods without precipitation. When this type of drought occurs, soil moisture decreases considerably, and crops and natural plant communities suffer. Reduced precipitation and high air temperatures are observed during atmospheric droughts when hot, dry winds are frequent. The high rates of evapotranspiration during these atmospheric conditions disrupt the water balance of plants. However, crop damage is most extensive during soil-atmospheric droughts. Long-term droughts that reduce river runoff, underground sources of water, and moisture are categorized as hydrological droughts. Common to all types of drought is a lack of precipitation.

There are many definitions of drought in the scientific literature but one of them is very characteristic: Drought is a condition of insufficient water to meet needs (Redmond, 2002, by Nikolova et al., 2018). Motha (2000) defines four main types of drought: 1) meteorological drought, which is connected to the period with precipitation averaging below a critical threshold; 2) agricultural drought refers to the lack of sufficient moisture available for crops, forests, rangelands, and livestock; 3) hydrological drought, associated with water supply systems such as river drainage basins and aquifers; 4) social or economic drought which is complex interaction of the natural phenomenon, environmental degradation, and human impact.

At any given time, at least one nation in the world is being adversely affected by drought. Although drought is a natural component of the climate in arid and semi-arid areas, it can occur in areas that normally receive adequate precipitation (e.g. Li and Makarau, 1994; WMO, 1975, by Koleva and Alexandrov, 2008). There are a lot of examples of several droughts and extremely hot and dry weather in Europe. More recently, in the summer of 2003 and 2019 many parts of Europe were affected by heatwaves and severe drought. Record-breaking temperatures blasted France, Belgium, Germany, Netherlands, Britain (AccuWeather, 28 July 2019). Absolute national records were broken across Western Europe during 25 July 2019:Lingen, Germany 42.6°C; Begijnendigk, Belgium 41.8°C; Luxemburg, Luxemburg 39°C; Cambridge, England 38.7°C; Gilze-Rijen, Netherlands 40.7°C – first time above 40°C in the Netherlands.

A lot of analyses show that recently the number and intensity of droughts in the EU have dramatically increased. The number of areas and people affected by droughts went up by almost 20% between 1976 and 2006 (Nikolova et al., 2012). One of the most widespread droughts occurred in 2003 when over 100 million people and a third of the EU territory were affected (COM/2007/0414, by Nikolova et al., 2012). Total economic cost (primarily from agriculture) of the drought in 2003 was approximately US$13 billion, and in general higher than for floods.

Drought has affected 37% of the European Union’s territory over the past three decades, causing ecological, social, and economic damage, and impacting more than 100 million inhabitants (Radeva et al., 2018).

Common to all types of drought is a lack of precipitation (WMO, 1993). The precipitation is one of the main climate elements with an important impact on various aspects of anthropogenic activity. The quantity of precipitation determines the quantity of river runoff and underground water. The analysis of the trend of annual precipitation total for the period 1901–2005 shows increasing precipitation in many regions from the Northern hemisphere with 20 to 40% (IPCC, 2007). On the other hand, the Balkan Peninsula is characterized by a general decreasing trend of precipitation since the beginning of the 1980s (Alexandrov, 2004, by Nikolova, 2012). One of the features of the contemporary climate in many regions in Europe and Bulgaria also is the increasing occurrence of extreme events – heavy precipitation or droughts. In the last years, the interest in scientific investigations related to many-years variability of precipitation increases because of the importance of the problems caused by intensive or insufficient precipitation. Many publications analyze the variability of precipitation in Bulgaria (Vekilska and Rathcev, 2000; Topliiski, 2005, etc.). Petkova et al. (2008) show an overall decrease in winter precipitation in many areas in North Bulgaria during the period 1931–2005. In the scientific literature, there are many publications related to the methods of investigation of drought or to the analysis of draught regarding its occurrence, intensity and factors (Nikolova et al., 2012).

Scientific investigations on the regime and many-years variability of precipitation in Bulgaria show the tendency to decreasing precipitation totals and drought in various regions in the country. Alexandrov's research (2011) shows three drought periods in Bulgaria: 1902–1913, 1942–1953 and 1982–1994. During the first period, the dry years are about 20%, in the second period dry years increase to 40% and during the period 1982–1994, about 50% of the years are dry. During the period 1931–2005 and mainly during the last decades extreme dry months occurred more often than extreme wet months (Nikolova, 2008). Despite many publications on precipitation in Bulgaria deep statistical analyses are needed to answer various questions related to contemporary climate change on a regional scale (Nikolova et al., 2012).

There have been various studies in Bulgaria in the field of drought risk assessment (Radeva et al., 2018). The majority of publications assessing drought variability are concerned with its temporal and spatial distribution (Koleva and Alexandrov, 2008; Alexandrov, 2011; Radeva et al., 2018). Classification of atmospheric drought periods has been conducted based on different indices, e.g. the Palmer drought severity index (PDSI) and the standard precipitation index (SPI) (Gocheva et al., 2010; Alexandrov et al., 2011; Nikolova et al., 2012). Drought is a typical phenomenon for all agricultural regions in Bulgaria and this is a part of climate change (Peev et al., 2000; Peev and Kouzmova, 2001; Kouzmova, 2001; Peev and Kouzmova, 2002; Nikolova, 2008, etc.).

Climate change, food shortage, water scarcity, and population growth are some of the threatening challenges being faced in today's world. Drought stress poses a constant challenge for crops and has been considered a severe constraint for global agricultural productivity; its intensity and severity are predicted to increase soon (Muhammad Nadeem et al., 2019).

Environmental stress factors, namely, heat, salinity, and drought, affect almost all aspects of the plant ranging from germination to the maturity stage (Muhammad Nadeem et al., 2019). Drought is a major threat and the most unpredictable constraint, with adverse effects on crop production worldwide. Drought induces several devastating effects on plants by disturbing various plant activities such as the carbon assimilation rate, decreased turgor, increased oxidative damage, and changes in leaf gas exchange, thereby leading to a reduction in yield. Plant sensitivity to drought is a complex phenomenon and depends on numerous factors including the growth stage of the plant, genetic potential, duration and severity of stress. Drought also affects the leaf development, activity of enzymes, ion balance, and ultimately leads to yield reduction. Effect of drought stress on plants and possible responses is presented in Figure 1.

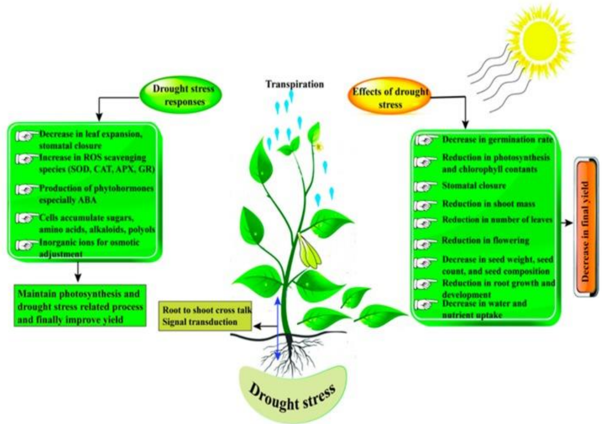


Figure 1. *Effect of drought stress (DS) on plants and possible responses (Source: Muhammad Nadeem et al., 2019)*

Drought affects several aspects of plant growth and development, including germination, shoot and root development, photosynthesis, and the reproductive stage. Due to global climate change, drought has become one of the most uncontrolled and an unpredicted factor which is continuously limiting crop production and has adverse effects on crops (Figure 1). Severe drought conditions disturb plant morphology, physiology, and growing period, whereas moisture contents play an essential role in enzyme activation during germination which could help to elucidate the sensitivity of plants to drought at the germination stage. Germination and reproductive stages are highly sensitive to water deficit. Under drought stress, the germination rate was significantly reduced in soybean (Muhammad Nadeem et al., 2019). Given global climate change, the sustainability of crop production is a serious challenging issue due to the increasing incidences of both biotic and abiotic stresses in the farmer's field. Among the various abiotic stresses, drought stress is garnering serious attention, as it restricts plant growth and development and causes significant yield loss in crops, causing global food insecurity. Drought stress negatively impacts overall plant growth ranging from the seedling stage to the reproductive stage and maturity stage (Muhammad Nadeem et al., 2019).

One of the most important constraints for agriculture is water limitation. More recently, global warming may be worsening this situation in most agricultural regions. Thus, it is quite relevant to understand the mechanisms that enable plants to cope with water deficit. Indeed, plants show a wide range of adaptations, at different levels, to drought stress (Beatriz Xoconostle-Cazares et al., 2010).

Crop yield improvement is necessary to keep pace with increasing demand for food. Due to climatic variability, the incidence of drought stress at crop growth stages is becoming a major hindering factor to yield improvement. New techniques are required to increase drought tolerance along with improved yield. Genetic modification for increasing drought tolerance is highly desirable, and genetic engineering for drought tolerance requires the expression of certain stress-related genes. Genes have been identified which confer drought tolerance and improve plant growth and survival in transgenic wheat. However, less research has been conducted for the development of transgenic wheat as compared to rice, maize, and other staple food. Furthermore, enhanced tolerance to drought without any yield penalty is a major task of genetic engineering. In this review, we have focused on the progress in the development of transgenic wheat cultivars for improving drought tolerance and discussed the physiological mechanisms and testing of their tolerance in response to inserted genes under control or field conditions (Shahbaz Khan et al., 2019).

Drought is the most important abiotic factor limiting growth, adversely affect growth and crop production. Stresses, resulting in the non-normal physiological processes that influence one or a combination of biological and environmental factors (Amin Fathi et al., 2016). Stress can damage which has occurred as a result of abnormal metabolism and may reduce growth, plant death or the death of the plant develops. Production is limited by environmental stresses, according to different scholars estimates, only 10% of the world's arable land is free from Stress, in general, a major factor in the difference between yield and potential performance, environmental stresses. Drought stress is the most common environmental stress that almost 25% of agricultural land for agricultural farm products in the world is limited. Drought risk to successful crop production worldwide and occurs when a combination of physical and environmental factors causing stress in plants and thus reduce plant production.

The crop growth and development are constantly influenced by environmental conditions such as stresses which are the most important yield-reducing factors in the world (Amin Fathi et al., 2016). Drought stress is considered one of the crop performance limiting factors and a threat to successful crop production. Drought tolerance is an important trait related to yield. Drought, one of the most important environmental stresses that in many parts of the world, especially in warm and dry areas of crop yield are limited. International Maize and Wheat Research Center researchers believe that the stiffness on wheat growth stages occurs in three ways (Amin Fathi et al., 2016). In the first case, which is specific to the Mediterranean climate, the rainfall occurs during the winter and transplant only after the flowering stage drought is faced. The stiffness of about 6 million hectares of land occurs in wheat. The second type drought during the winter and the plants before flowering occurs after this period will not be an encounter with drought. More than 3 million hectares of land under wheat cultivation of this type are affected by drought. The third type of wheat growth period occurs continuously in all of the moisture stored in the soil and plant growth follows. Two to three million acres of wheat in the world of this type of drought is affected.

Drought stress in the vegetative stage less important than in the reproductive stage of tension and the impact on yield and yield components (Amin Fathi et al., 2016). However, since the stress at this stage of development of leaf, stem development, photosynthesis, leaf, and the accumulation of great importance is the impact in the plant. Plants in most arid regions of the world, more or less exposed to stress.

Drought and high temperature (heat) stress are considered to be the two major environmental factors limiting crop growth and yield. These two stresses induce many biochemical, molecular and physiological changes and responses that influence various cellular and whole plant processes that affect crop yield and quality (Prasad and Staggenborg, 2008). The impacts of environmental stress, particularly those of drought and heat, have been studied independently. However, under field conditions, both of these stresses often occur in combination. The interactive effects of various stresses on crop plants have received far less attention.

A new report by the conservation organization WWF in 2019 (www.novinite.com) warns that the climate crisis poses an increasing real risk of global droughts. According to the study, these processes put pressure on wetlands and the urban environment and negatively impact the lives of 55 million people each year, putting energy supplies and food production at risk. The WWF report also indicates that 22% of major food crops such as wheat are grown in areas with a high to very high risk of drought. In such areas, 19% of cities with a population of over one million falls, and nearly 370 million are affected. The list also includes six metropolitan areas with more than 10 million inhabitants – Delhi, Cairo, Karachi, Istanbul, Rio de Janeiro and Hyderabad.

From an agronomist point of view, the drought-resistant plant should decrease its productivity (yields) in a dry regime at a minimal level. This means that from one side, the plant should be well adapted to dry conditions but from the other side, it is supposed to recover its disrupted functions of the drought after passing by the dry period, i.e. there should be good adaptive and repairable ability. The drought-resistance is a very complexed quality of the plant organism. The mechanisms to define this quality are various and can be anatomical, morphological, physiological and biochemical by their nature. They provide in the plant a successful defence against water deficiency in the medium.

During the different phases of individual growth and development, cultural plants don`t suffer equally from drought. Some of these periods are recalled critical periods in terms of water content, during which plants are especially sensitive. They hardly regenerate and at this time the highest negative influence on the yield appears. This is because the drought coincides with processes that require much water for their going-off. On the cellular level, the embryonic period is very critical when the division of the meristemic cells gives the beginning of every organ. To pass the division and growing of cells a great amount of water is needed. Another critical period for the water is the formation of reproductive organs, pollination, and fertilization. It has been proved that all those processes happen in a highly watered medium, therefore, the decrease of water can be disastrous for their normal passing.

RESEARCH ON SPATIAL DISTRIBUTION OF PRECIPITATION AND THE REGIONS IN BULGARIA VULNERABLE TO DROUGHT

Bulgaria is a surprisingly dry European country, subject to frequent short term and long term drought (Sharov et al.,1994a, 1994b, by Liem Tran et al., 2002). During the period from 1980 to 2000, Bulgaria experienced three instances of two or more successive years of drought, the latest of which had important environmental and social consequences.

Despite many publications on precipitation variability in Bulgaria, deep statistical and geographical analyses are needed to answer the various questions related to features, dynamics, and consequences of the different types of drought (Radeva et al., 2018).

Bulgaria is not rich in terms of precipitation. Mean annual precipitations are between 410 mm and 650 mm in lowland areas and between 650 mm and 1,200 mm in semi-mountainous and mountainous areas. Hence topography is a key factor in the distribution of precipitation over Bulgaria. About three-fourths of Bulgaria is classified as having a continental climate, with peak precipitation in late spring or early summer (May–June), whereas the southern fringe has a transitional continental-Mediterranean climate with both winter and late spring precipitation peaks (Bulgarian Academy of Sciences, 1987; Velev, 1990, by Liem Tran et al., 2002). Similar to other areas with a continental climate regime, the ratio of precipitation to evaporation in Bulgaria is less than one (moisture deficit) in summer, except at highest elevations, and greater than one (moisture excess) in fall, winter, and spring (Knight et al., 1995, by Liem Tran et al., 2002).

Despite a large number of surveys on droughts abroad and in Bulgaria, a unified methodology for their study has not yet been developed due to the complexity of the phenomenon and the versatility of its manifestation and impact. A basic methodical problem in studying droughts is their typing. Usually, there are four or five types of drought: soil, atmospheric, soil-atmospheric, hydrological and socio-economic.

Soil drought is a long period of disruption of water balance in soil and plant ecosystems, whereby the physiological state of plants is deteriorating and yields are sharply declining. In the atmospheric drought, besides low precipitation, high temperatures and low humidity are observed. Typical phenomena are the dry and hot winds whereby the large evapotranspiration, the water balance of the plants is disturbed. Plants are in the most unfavourable conditions in the presence of soil-weather drought. Hydrological drought typically takes a long enough dry time to cause water deficiency due to a decrease in water levels in the river below normal and a decrease in soil moisture or groundwater level.

During the different seasons, the drought is characterized by some features. Spring drought is characterized by low temperatures, and humidity and strong winds, which aggravates the conditions for sowing, germination, and normal development. Delaying germination aggravates the conditions of agroecosystem development throughout the growing season. Under such conditions, the population of several pests is growing sharply, causing additional damage. Spring droughts are particularly typical for Northwest Bulgaria (40% of cases) and the Black Sea coast (50%).

Summer droughts are characterized by high temperatures, low air humidity and intensive total evaporation (physical and transpiration). These are typical soil-atmospheric droughts, especially when productive soil moisture begins to drop sharply below 70% of the average moisture content. The intensive summer droughts are the longest on the Black Sea coast and in the Upper Thracian Plain. In the autumn, drought affects unfavourably the autumn ploughing, the sowing and the germination of autumns that enter the winter under-developed and often suffer from frost. These droughts are characteristic of the Black Sea coast, Northeastern Bulgaria and the Upper Thracian Plain.

The problem of drought has been the subject of research by many authors (Kouzmova, 2001; Alexandrov, 2006; Koleva and Alexandrov, 2008; Gocheva et al., 2010; Alexandrov, 2011, etc.).

A summary assessment of the spatial distribution of precipitations and drought risk across Bulgaria has been made by Alexandrov (2006). The average annual precipitation in Bulgaria varies widely from 500–550 mm in some parts of the Danube Plain and the Thracian Plain, up to 1.000–1.400 mm in the highest parts of the mountains (Figure 2). The smallest (below 500 mm) is the precipitations in the northeastern and eastern regions of the Danube Plain, east of the Silistra – General Toshevo – Varna. In a small part of the Danube plain, the annual precipitations are 500–550 mm and in the rest of the plane 600–700 mm. In the Thracian lowland, 500–700 mm fall annually. On the Black Sea coast the precipitations are relatively small (450–500 mm) and just south of the Oil Nose they are growing rapidly. In Sozopol, they are about 500 mm, in Michurin – 650 mm, and in Rezovo – about 800 mm. In the mountains, the annual precipitations increase linearly with altitude.

The spatial distribution of the annual rainfall sums determined as drought (due to insufficient annual rainfall in the climate aspect) the following territories in the country (Fig. 3): the Danube municipalities in Montana, Vratsa and Pleven regions; some municipalities in Sofia and its districts, the municipalities along the Struma River (Kyustendil and Blagoevgrad regions); the municipality of Pazardzhik and the municipalities located in the central part of Plovdiv District; most of the Yambol area; as well as several municipalities from Eastern Bulgaria – Shumen, Silistra, Dobrich, Varna and Bourgas. It should be noted that the Dobrich region is entirely at risk of drought. The low annual rainfall is a prerequisite for significant drought vulnerability of the municipalities of General Toshevo, Shabla, Kavarna and Balchik. The districts of Varna and Burgas also include municipalities with a high risk of drought – Aksakovo, Varna, Nesebar, and Pomorie.

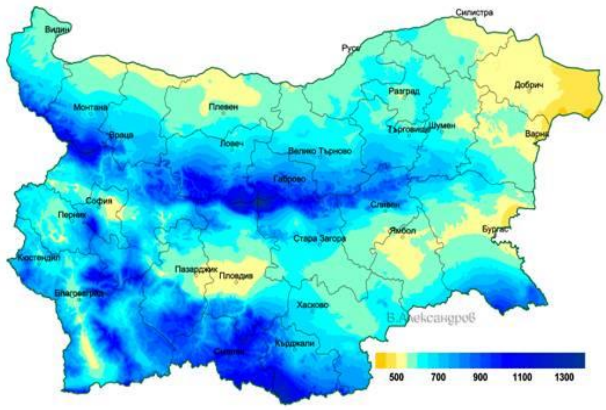


Figure 2. *Spatial distribution of annual rainfall in Bulgaria (Source: Alexandrov, 2006, copy by http://landsinvest.blogspot.com/2015/05/blog-post_26.html)*

The precipitations in Bulgaria is unevenly distributed during the different seasons of the year. During the warm half-year, most municipalities on the Black Sea coast are at high risk of drought, including the municipalities of Petrich, Sandanski, and Strumyani in the Blagoevgrad region.

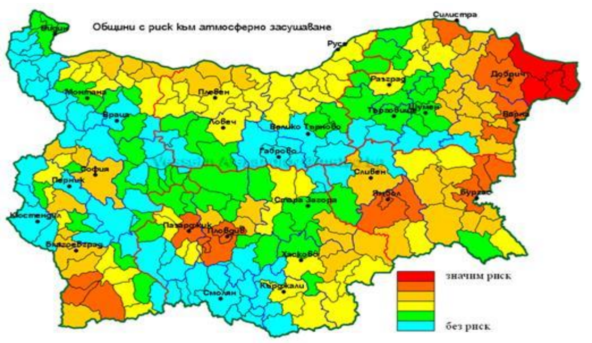
It is important to note that all of Southeastern Bulgaria (except for the municipality of Malko Tarnovo) is potentially vulnerable to atmospheric drought during the period from April to September.

Territories of Sofia-city and Sofia regions have limited precipitations in the winter. The risk of winter drought is higher in Northern Bulgaria than the risk in southern Bulgaria, where rainfall, especially in mountain areas, is significant.

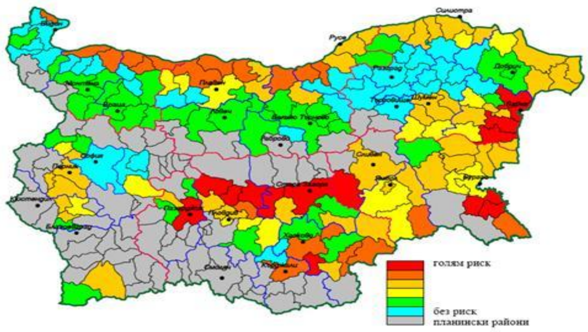
Extremely valuable for agricultural practice are the maps for the spatial distribution of droughts and the municipalities with the highest risk of drought, presented by Alexandrov, 2006 (Fig. 3 A, B, C). Eastern municipalities in Dobrich are the least precipitations during most of the year and therefore are at higher risk to atmospheric drought. The following are other threatened municipalities in eastern Bulgaria, Pazardzhik municipality and municipalities in the districts of Plovdiv, Yambol and Blagoevgrad (Fig. 3A).

There are municipalities with an increased risk of soil drought in all planning regions (Fig. 3B). For example, in northwestern Bulgaria - from Lom municipality to Dolna Mitropolia municipality; in eastern Bulgaria – Shumen region; in southern Bulgaria – municipalities in the districts of Pazardzhik, Plovdiv and Stara Zagora; in western Bulgaria – the municipalities of Dragoman, Tran and others. The municipalities in the country, with an increased risk of soil-atmospheric drought (based on the summarized information on soil moisture during different periods of the year), are located in southern and eastern Bulgaria (Fig. 3C). The northern municipalities and the region of southeastern Bulgaria are also potentially vulnerable to the soil-atmospheric drought in the event of a reduction in soil moisture.

A



B



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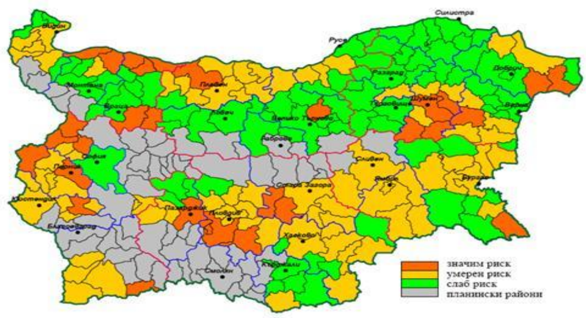

Figure 3. *Municipalities in Bulgaria, with risk of drought (Source: Alexandrov, 2006, copy by http://landsinvest.blogspot.com/2015/05/blog-post_26.html)*
A – atmospheric drought;
B – soil drought;
C – soil-atmospheric drought

CLIMATE AND DRY CHANGES IN BULGARIA

Bulgaria is expecting to warm and reducing rainfall in the coming decades (Figure 4, 5), especially during the warm half-year. Decreasing rainfall will result in a change in water resources.

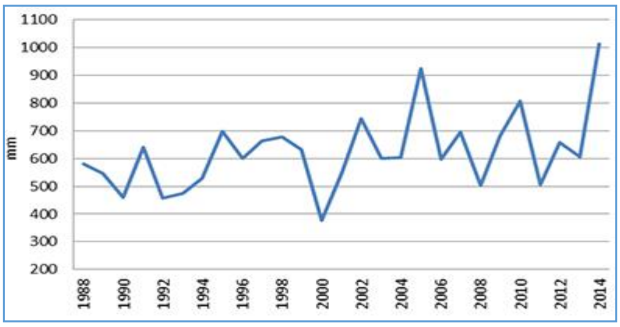

Figure 4. *Fluctuations in average annual precipitations (mm) during the period 1988-2014 (Source: National report on the status and environmental protection in Bulgaria, based on data NIMH, 2016)*

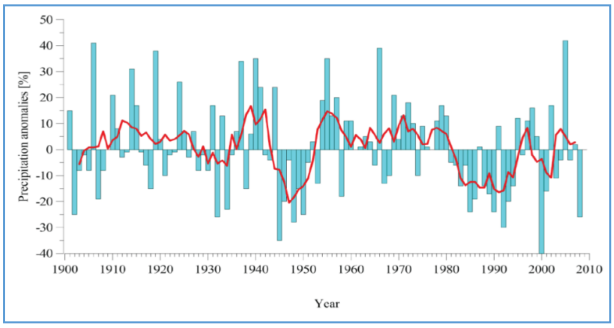

Figure 5. *Anomalies in the historical average annual precipitations in Bulgaria (Source: Advisory Services on National Strategy and Action Plan for Climate Change Adaptation, Sectoral Assessment of the Agriculture, based on data NIMH, 2014)*

Remark: Pillars measured monthly precipitations anomalies compared to the period 1961–1990; the red line shows the movement of average.

Climate uncertainty affects the performance and management of agriculture. Extreme weather events, as drought, lead to a substantial increase in agricultural risk and unstable farm incomes (Popova et al., 2015). The recent study by Olesen et al. (2011) on the impacts of climate change in European agriculture supports the hypothesis that Bulgarian agriculture is becoming more vulnerable to droughts and climate variability. This study shows that most negative effects are expected for the Pannonian zone – that includes Bulgaria, Hungary, Serbia, and Romania where increased heatwaves and drought events are expected.

Analysis of national crop yields and the questionnaire survey shows large differences in vulnerabilities to the current climate and climatic variation across Europe (Olesen et al., 2011). Cool temperatures and short growing seasons are main limitations in northern Europe, whereas high temperatures and persistent dry periods during summer limits crop production in southern Europe. There are clear trends in increasing temperature affecting crop production and crop choice throughout Europe, with increasing frequency of droughts negatively affecting crop yield in southern and central Europe. There are also indications of increasing yield variability linked with higher frequencies of heatwaves and both droughts and persistent wet periods. Farmers are already adapting to changing climate with the area of silage and grain maize expanding northwards. Other currently observed adaptation to climate change includes changes in the timing of cultivation, variety choice, water-saving techniques, irrigation and breeding. There are large regional variations in expected impacts of climate change on crop cultivation and crop productivity in Europe by 2050. The expected impacts, both positive and negative, are just as large in northern Europe as in the Mediterranean countries, and this is largely linked with the possibilities for effective adaptation to maintain current yields.

The most negative effects were found for the continental climate in the Pannonian zone, which includes Hungary, Serbia, Bulgaria and Romania. This region will suffer from increased incidents of heatwaves and droughts without possibilities for effectively shifting crop cultivation to other parts of the years. A wide range of adaptation options exists in most European regions to mitigate many of the negative impacts of climate change on crop production in Europe. However, when all effects of climate change are considered, including crop yields, soil fertility, pesticide use, and nutrient runoff, the effects of climate change are still mostly negative in most regions across Europe.

In Bulgaria, climate change, which has a potential impact on the agricultural sector in Bulgaria is presented in Full Report draft (2017-12-20) – BG, Advisory Services on National Strategy and Action Plan for Climate Change Adaptation presented (Table 1).

CONCLUSIONS

1. Drought is becoming an increasing problem for Bulgaria. Droughts disrupt plant growth and development. As a result of the sharp discrepancy between the need of the plants from moisture and insufficient input from the soil, crop yields are significantly reduced. There is a decrease in the quantity and quality of agricultural production.

2. Drought and high temperatures are the most common stressors for agricultural crops in Bulgaria. Their negative influence on crops and crop production is complex and causes direct or indirect disturbances in almost all physiological processes – water exchange, mineral nutrition, photosynthesis, growth, etc. The negative effects of these stress factors are particularly great during the reproductive period, especially in the formation of the gametes and the initial stages of seed and fruit formation. It is necessary to deepen studies on the drought stress and heat stress and tolerance of different agricultural crops to stress factors under climate change.

Table 1. Climate change, which has a potential impact on the agricultural sector in Bulgaria (Source: Republic of Bulgaria, Agriculture – Full Report – Draft 2017-12-20, with changes)

Affected Agricultural Sector Aspects	High temp.		Low temp.		Prolonged rainfall		Drought		Water table rise		Sea level rise		Specific effects of CC relevant for agriculture: Water supply shortage		Soil degradation		Pests/ diseases	
	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P
Land losses	L	L	-	-	H	M	H	H	L	L	-	-	M	M	H	H	M	M
Crop yield	M	M	M	L	M	M	H	H	L	L	-	-	M	L	M	M	M	M
Crop productivity	M	M	M	L	M	M	H	M	M	M	-	-	M	L	M	M	M	M
Crop diversification	M	L	M	L	M	M	H	M	L	L	-	-	M	M	L	L	L	L
Livestock productivity	M	M	M	L	L	L	M	M	L	L	-	-	M	L	-	-	H	M
Crop output	M	M	M	M	M	M	M	M	L	L	-	-	M	L	M	M	M	M
Animal output	M	M	L	L	L	L	H	M	L	L	-	-	L	L	-	-	H	M
Loss of income	M	L	L	L	L	L	M	L	L	L	-	-	M	L	M	M	-	-
Unemployment	L	L	-	-	-	-	M	L	-	-	-	-	-	-	L	L	M	L
GVA agriculture	M	L	L	L	M	L	H	M	L	L	-	-	L	L	M	L	M	L
Risk of poverty	L	L	L	L	M	L	M	L	-	-	-	-	L	L	M	L	M	M
Crop quality	L	L	L	L	L	L	H	M	-	-	-	-	M	L	M	L	M	L
Agricultural facilities	-	-	-	-	L	L	-	-	-	-	-	-	-	-	-	-	-	-

Legend: D = damage; P = probability of occurrence by 2050 at latest; U = unknown; H = high; M = medium; L = low (red = negative impact; green = positive impact; **blank** = neutral impact)

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