Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume XI, Issue 1 (June 2012), pp. 81-89
http://dx.doi.org/10.5775/fg.2067-4635.2012.044.i

# Changes in Air Temperature and Precipitation and Impact on Agriculture

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Received on <30-10-2011>, reviewed on <01-09-2011>, accepted on <02-09-2011>

**Abstract**

Air temperature and precipitation are among the main factors for agricultural production. The aim of the present research work is to analyse changes in air temperature and precipitation in non-mountainous part of Southern Bulgaria in terms of the opportunities for the development of agriculture in the region. The trend in variability of seasonal and annual air temperature and precipitation is determined by the linear regression method. An analysis of the combination between air temperature and precipitation gives a tool to classify the climate according to dry and wet conditions of the territory. For this purpose the Gaussen-Bagnouls classification method is used in the present paper. In terms of air temperature, the investigated area is favourable for growing thermophilic plants. In order to investigate thoroughly the impact of climate change, the quantitative research has been complemented by a qualitative study – case study of farmers from the region of Stara Zagora. Case studies show that farmers are vulnerable to various degrees to the expected annual variability and average changes in yields depending on farm size, crop varieties and availability of irrigation.

**Keywords:** *air temperature, precipitation, Gaussen-Bagnouls classification, case study of farmers, climate change, agriculture*

**Rezumat. Schimbările în regimul temperaturii aerului și al precipitațiilor și impactul acestora asupra agriculturii**

Temperature aerului și precipitațiile se numără printre principalii factori ce influențează producția agricolă. Scopul acestei cercetări este să analizeze schimbările din regimul temperaturii aerului și precipitațiilor din parea sudică a Bulgariei, cu relief mai jos, prin prisma oportunităților pentru dezvoltarea agriculturii în regiune. Tendința variabilității anotimpuale și anuale a temperaturii aerului și a precipitațiilor este determinată cu ajutorul metodei regresiei liniare. O analiză a interacțiunii dintre temperatura aerului și precipitații reprezintă un instrument util în clasificarea climatului în funcție de condițiile de uscăciune și de umezeală ale teritoriului. În acest scop a fost utilizată clasificarea Gaussen-Bagnouls. În ceea ce privește temperatura aerului, arealul analizat este favorabil culturii plantelor termofile. Pentru o analiză amănunțită a impactului schimbărilor climatice, cercetarea cantitativă a fost completată de un studiu calitativ – studiul de caz al fermierilor din regiunea Stara Zagora. Studiile de caz arată că fermierii sunt vulnerabili într-o măsură diferită la variabilitatea anuală și schimbările medii în producție în funcție de dimensiunea exploatației agricole, varietatea culturilor și posibilitățile de practicare a irigațiilor.

**Cuvinte-cheie:** *temperatura aerului, precipitații, clasificarea Gaussen-Bagnouls, studiu de caz al fermierilor, schimbări climatice, agricultură*

## Introduction

Many research works (Majstorović et al, 2008; Eitzinger et al., 2008; Alexandrov and Hoogenboom, 2001) point out that climate is one of the main factors for agriculture. Air temperature and precipitation are very important climate elements which determine the thermal resources and humidity necessary for crops. The knowledge on spatial and temporal variability of the main climate elements and its impact on agriculture may help developing long-term agricultural policies and various strategies for mitigation and adaptation to climate change.

Most of the publications for Bulgaria consider climate change in regard to past or future tendencies in air temperature and precipitation variability (Alexandrov, 2004; Topliisky, 2005; Nikolova and Boroneant, 2011 etc.). Scenarios developed by research works in recent years show an increase of air temperature and decrease of rainfall in Bulgaria during the warm half of the year. The results of CLAVIER project (http://clavier-eu.org/) indicate that for the 2011-

2050 period, the annual air temperature in Bulgaria will increase by 1.78°C and the 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). Climate change impact on agriculture has been investigated mainly by analyses of changes in air temperature, precipitation, humidity. Various specific indices as De Martonne index (Vladut, 2010; Majstorovic et al., 2008), SD (spatial-dryness) index (Tran et al., 2002) are also applied. The impact of climate change on agriculture has been investigated by Alexandrov, 2008, Kazandjiev, 2008; Slavov and Alexandrov, 1994, CLAVIER project.

During the recent years the necessity of climate impact studies, especially on a local level increased (Mochurova, 2010). In spite of growing knowledge about climate change and its impact on agriculture, many questions still look for their answers.

The object of this study is air temperature and precipitation in Southern Bulgaria. The scope of the research work includes also a case study of farmers from one of the most important agricultural regions in Bulgaria, the region of Stara Zagora. The aim of present research work is to analyse changes in air temperature and precipitation in non-mountainous part of Southern Bulgaria in terms of opportunities for the development of agriculture in the region. In order to achieve this aim, two main tasks are defined: 1) determination of the trend and main features of the annual cycle of air temperature and precipitation and 2) conducting surveys and interviews with farmers in the region to determine which of their interests and areas of activity are affected most by climate.

## Data and methods

Monthly and annual data for air temperature and precipitation from five meteorological stations are used for the research. The stations are situated in agricultural areas of Southern Bulgaria - lowlands and valleys (Fig. 1). The climate is transitional between moderate continental and Mediterranean.

The main period under investigation is 1931-2010. On the base of monthly data seasonal and annual values are calculated. The seasons are determined as follows: winter – December, January, February; spring – March, April, May; summer – July, June, August; autumn – September, October, November.

The climate impacts are driven not only by changes in mean annual temperature and/or precipitation regime, but also by site-specific monthly relationships between the two (Priceputu and Greppin, 2004).

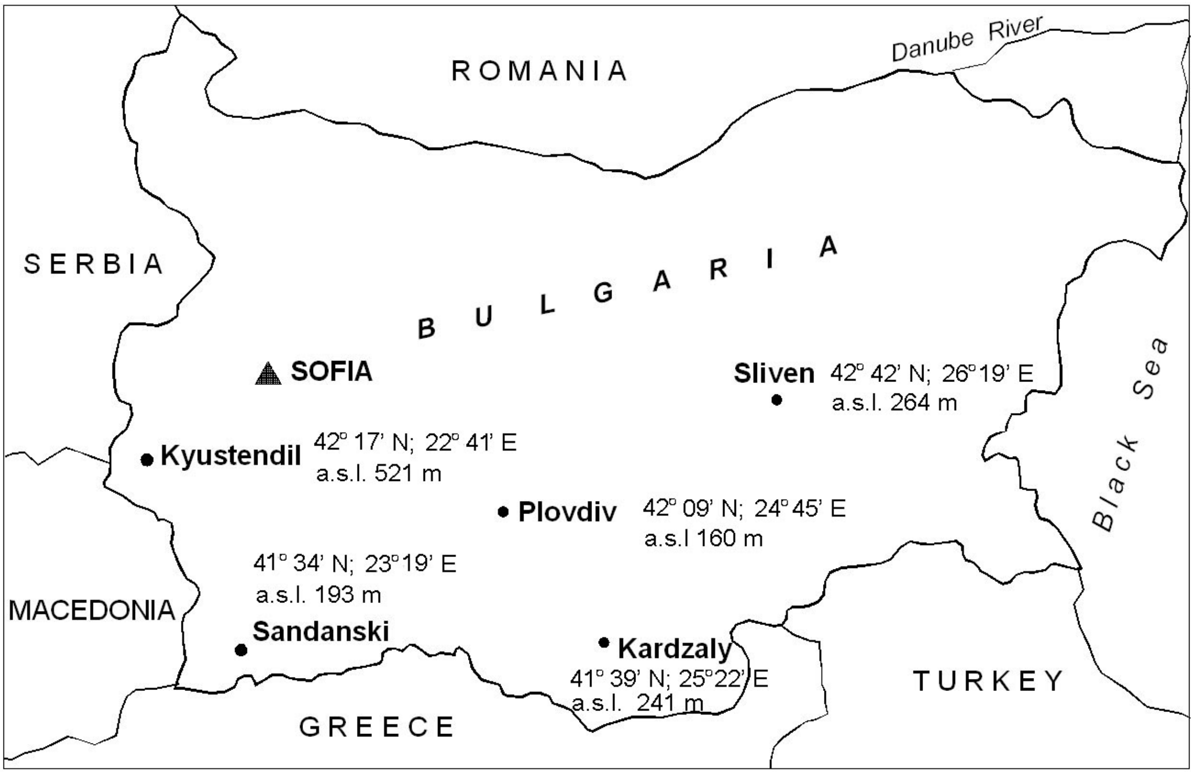


**Fig. 1: Meteorological stations used in the study**

*Forum geografic. Studii și cercetări de geografie și protecția mediului*
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Analysis of the combination between air temperature and precipitation gives a tool to classify the climate according dry and wet conditions of the territory. For this purpose the Gaussen-Bagnouls classification method is used in the present paper. The advantage of this method is that it is based only on monthly air temperature and precipitation data and it gives more precise climatic information by determining separately the numbers of dry and wet months. Gaussen-Bagnouls index is used by many authors (Priceputu and Greppin. 2004; Simota and Dumitru, 2010; Parvari et al., 2011 etc.) in order to determine precipitation deficit from a meteorological point of view. The Gaussen-Bagnouls classification method allows determining the aridity of the climate as a long-term climatic phenomenon (permanent pluviometric deficit) unlike drought, which is a short-term phenomenon (temporary pluviometric deficit). On the base of monthly data for air temperature and precipitation, the Gaussen-Bagnouls classification method was applied and the three types of climate are determined: humid if $P > 3T$; semi-humid - $3T>P>2T$ and arid - $P<2T$, where P is monthly precipitation total and T – average monthly temperature (Ernani and Gabriels, 2012).

The trend in variability of seasonal and annual air temperature and precipitation is determined by a linear regression method.

In order to investigate thoroughly the impacts of climate change, the quantitative research has been complemented by a qualitative study – case study of farmers from the region of Stara Zagora. A case study is "an intensive study of a single unit for the purpose of understanding a larger class of (similar) units" (Gerring, 2004; Yin, 2003). The following definition of a case study is applied in present research work – the case study is an intensive study with qualitative methods of a single economic unit (a farm) for a given period of time in order to understand the economic impacts and vulnerability of climate changes. Taking into account that climate change economic impacts are a complex social and economic phenomenon, case study is a very beneficial method also due to its capacity of a triangulated research strategy. Triangulation is the use of two or more methods of data collection to test hypothesis and measure variables in order to minimise the degree of specificity or dependence on particular methods that might limit the validity or scope of findings (Frankfort-Nachmais et al., 2000). In the case study the following sources of information are used: documentation, interviews, and direct observations. The method of the in-depth structured interview has been applied and a scenario with topics formulated in advance and open-ended questions have been used. The interviews were conducted by the authors in July 2011. The aim is to study how farmers perceive the dependence of their farms on the climatic conditions.

## Results and discussions

**1. Air temperature**

The analysis of winter air temperature shows a relatively high temperature level in the study area in comparison with the rest of the country. The mean winter temperature for the period 1931-2010 is between 0.8 °C in the north part of the area (station Kyustendil) and 3.7 °C in the south part (station Sandanski), tabl. 1. For the last 30 years (1981-2010) of the investigated period the mean winter temperatures are quite similar to these for the period 1931-2010. The maximum values are above 6°C and are observed in 1966 and 1951. The maximum of winter temperature for the period 1931-2010 is observed in various years for different stations, while the minimum is in 1954 for all of investigated stations. The year 2007 makes impression with the hottest winter for the period 1981-2010.

The positive trend is characteristic for winter temperature for both periods – 1931-2010 and 1981-2010, but the values are close to 0 and the trend is not statistically significant (Table 1).

In spring, seasonal temperatures are between 11 and 14°C (Sndanski 13.9°C in 1981-2010). The maximum temperature is around 14-16°C and the hottest spring for whole period has been registered in 1947. The minimum values for spring temperature (8.6 – 8.9°C) has been observed mainly in 1987 (Table 2.). The positive trend of seasonal temperature during spring is better established for the period 1981-2010, but it is not statistically significant.

Mean summer temperatures range from 20.7°C (Kyustendil station) to 24.0 (24.4)°C, Sandanski station. There is no difference between seasonal temperatures for summer for the 1931-2010 and 1981-2010 periods. Maximum summer temperatures (22.8 – 26.6°C) are observed mainly in 2007. For the stations Kyustendil and Kyrdzali the hottest summer is in 1946. Minimums of summer temperatures in various stations are between 17 and 20°C and were observed in 1976 or after 1980. In most cases the trend of summer temperature is positive. The negative trend is established in the Kyustendil and Plovdiv stations for the 1931-2010 period, but the values are close to 0 and the trend is not statistically significant. A statistically significant positive trend of summer temperature is established for the period 1981-2010 (Table 3).

**Table 1. Statistical characteristics and trend of winter air temperatures**

| Meteorological stations | mean | std.dev | max | year | min | year | trend/10 years |
|---|---|---|---|---|---|---|---|
| | | | | 1931-2010 | | | |
| Kyustendil | 0.8 | 1.6 | 4.4 | 1951 | -3.7 | 1954 | 0.0 |
| Plovdiv | 1.7 | 1.6 | 5.7 | 2009 | -3.8 | 1954 | 0.190* |
| Sliven | 2.5 | 1.4 | 5.5 | 1936 | -1.8 | 1954 | 0.0 |
| Kyrdzali | 2.7 | 1.7 | 6.3 | 1966 | -3.4 | 1954 | 0.1 |
| Sandanski | 3.7 | 1.3 | 6.7 | 1951 | -0.2 | 1954 | 0.1 |
| | | | | 1981-2010 | | | |
| Kyustendil | 0.7 | 1.4 | 2.9 | 2007 | -1.9 | 1985 | 0.3 |
| Plovdiv | 2.1 | 1.3 | 5.7 | 2009 | 0.3 | 1985,1993 | 0.2 |
| Sliven | 2.4 | 1.3 | 4.9 | 2007 | 0.0 | 1994 | 0.2 |
| Kyrdzali | 2.7 | 1.2 | 4.9 | 2007 | 0.7 | 1985 | 0.2 |
| Sandanski | 3.8 | 1.1 | 5.9 | 2007 | 2.0 | 1985,1990 | 0.4 |

**Table 2. Statistical characteristics and trend of spring air temperatures**

| Meteorological stations | mean | std.dev | max | year | min | year | trend/10 years |
|---|---|---|---|---|---|---|---|
| | | | | 1931-2010 | | | |
| Kyustendil | 10.9 | 1.1 | 13.8 | 1934 | 8.6 | 1987 | 0.0 |
| Plovdiv | 11.8 | 1.2 | 14.6 | 1947 | 8.5 | 1997 | 0.0 |
| Sliven | 11.4 | 1.2 | 14.4 | 1947 | 8.9 | 1987 | 0.0 |
| Kyrdzali | 11.7 | 1.1 | 14.6 | 1947 | 8.8 | 1987 | 0.0 |
| Sandanski | 13.5 | 1.0 | 16.0 | 1947 | 11.3 | 1940 | 0.104* |
| | | | | 1981-2010 | | | |
| Kyustendil | 10.9 | 1.0 | 12.4 | 1994 | 8.6 | 1987 | 0.3 |
| Plovdiv | 11.6 | 1.5 | 13.8 | 1983 | 8.5 | 1997 | 0.1 |
| Sliven | 11.4 | 1.2 | 13.3 | 2008 | 8.9 | 1987 | 0.4 |
| Kyrdzali | 11.6 | 1.1 | 13.2 | 1994 | 8.8 | 1987 | 0.3 |
| Sandanski | 13.9 | 0.9 | 15.3 | 1983,1988 | 12.0 | 1997 | 0.2 |

**Table 3. Statistical characteristics and trend of summer air temperatures**

| Meteorological stations | mean | std.dev | max | year | min | year | trend/10 years |
|---|---|---|---|---|---|---|---|
| | | | | 1931-2010 | | | |
| Kyustendil | 20.7 | 1.1 | 23.4 | 1946 | 17.2 | 1976 | -0.1 |
| Plovdiv | 22.0 | 1.3 | 24.6 | 2007 | 17.8 | 1997 | -0.1 |
| Sliven | 22.2 | 1.0 | 25.1 | 2007 | 20.0 | 1976 | 0.0 |
| Kyrdzali | 22.3 | 1.0 | 24.3 | 1946 | 19.9 | 1976 | 0.0 |
| Sandanski | 24.0 | 1.0 | 26.6 | 2007 | 21.1 | 1976 | 0.116* |
| | | | | 1981-2010 | | | |
| Kyustendil | 20.7 | 1.0 | 22.8 | 2007 | 18.7 | 1983 | 0.609* |
| Plovdiv | 21.8 | 1.9 | 24.6 | 2007 | 17.8 | 1997 | 0.4 |
| Sliven | 22.3 | 1.2 | 25.1 | 2007 | 20.2 | 1998 | 0.735* |
| Kyrdzali | 22.4 | 1.2 | 24.3 | 2000 | 20.0 | 1983 | 0.628* |
| Sandanski | 24.4 | 1.1 | 26.6 | 2007 | 22.0 | 1983,1988 | 0.789* |

*Forum geografic. Studii și cercetări de geografie și protecția mediului*
*Volume XI, Issue 1 (June 2012), pp. 81-89*
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The average temperature for spring and summer characterizes the thermal optimum for plants during the period of their high biological activity and helps to identify the most typical plants under thermal conditions of a given territory. In terms of air temperature for the warm half of the year, the investigated area is favourable for growing thermophilic plants. The values of mean autumn temperature are between 11.5°C in the north and 14.6°C in the southern part of the study area. The maximum values reach 15.8–17.0°C in 1932 (Table 4). The minimum autumn temperatures range between 8.6 and 11.4°C and are observed in various years during the 1941-1978 period. For the last 30 years (1981-2010) of the investigated period the minimum autumn temperatures are in 1988, 1995 or 1996. The trend of autumn temperature is negative for the 1931-2010 period and positive for the 1981-2010 period, but it is not statistically significant in most of the cases.

The annual air temperatures in the study area range from 11°C (Kyustendil) to 14°C (Sandanski), table 5. The maximum mean annual temperature is about 14°C and reaches more than 15°C in the south-western part of the region (Sandanski station). The synchronization is not established in the occurrence of years with the highest temperature for the periods 1931-2010 and 1981-2010. For most of the investigated stations, the maximum mean annual temperature occurs in 1994 or 2007 (2008). The minimum mean annual temperatures (9.4–13.4°C) are observed in 1940 and the '90s. The positive trend of annual temperature is statistically significant for the period 1981-2010 and the values of the coefficients are 0.3 – 0.4 °C/10 years (Table 5).

**Table 4. Statistical characteristics and trend of autumn air temperatures**

| Meteorological stations | mean | std.dev | max | year | min | year | trend/10 years |
|---|---|---|---|---|---|---|---|
| | | | | 1931-2010 | | | |
| Kyustendil | 11.5 | 1.1 | 14.1 | 1932 | 8.6 | 1978 | -0.172* |
| Plovdiv | 12.5 | 1.1 | 14.3 | 1932 | 9.0 | 1995 | -0.115* |
| Sliven | 13.1 | 1.2 | 15.8 | 1932 | 9.7 | 1996 | -0.125* |
| Kyrdzali | 13.2 | 1.0 | 15.7 | 1932 | 10.3 | 1941 | -0.1 |
| Sandanski | 14.6 | 1.1 | 17.0 | 1932 | 11.4 | 1978 | -0.1 |
| | | | | 1981-2010 | | | |
| Kyustendil | 11.1 | 1.0 | 12.9 | 1994 | 8.7 | 1988 | 0.2 |
| Plovdiv | 12.2 | 1.4 | 14.2 | 1984 | 9.0 | 1995 | 0.2 |
| Sliven | 12.7 | 1.4 | 14.6 | 2010 | 9.7 | 1996 | 0.3 |
| Kyrdzali | 13.0 | 0.9 | 14.5 | 1994 | 10.9 | 1988 | 0.3 |
| Sandanski | 14.5 | 1.0 | 16.2 | 1994 | 12.6 | 1995 | 0.2 |

**Table 5. Statistical characteristics and trend of annual air temperatures**

| Meteorologica l stations | mean | std.dev | max | year | min | year | trend/10 years |
|---|---|---|---|---|---|---|---|
| | | | | 1931-2010 | | | |
| Kyustendil | 11.0 | 0.7 | 12.7 | 1952 | 9.6 | 1940 | -0.1 |
| Plovdiv | 12.0 | 0.8 | 13.9 | 2008 | 9.4 | 1997 | 0.0 |
| Sliven | 12.3 | 0.8 | 13.8 | 2007 | 10.3 | 1998 | 0.0 |
| Kyrdzali | 12.4 | 0.6 | 13.7 | 1966 | 11.0 | 1940 | 0.0 |
| Sandanski | 14.0 | 0.6 | 15.4 | 1994 | 12.4 | 1940 | 0.058* |
| | | | | 1981-2010 | | | |
| Kyustendil | 10.8 | 0.6 | 12.0 | 1994 | 9.9 | 1991 | 0.379* |
| Plovdiv | 11.9 | 1.1 | 13.9 | 2008 | 9.4 | 1997 | 0.2 |
| Sliven | 12.2 | 1.0 | 13.8 | 2007 | 10.3 | 1998 | 0.410* |
| Kyrdzali | 12.4 | 0.6 | 13.7 | 1994 | 11.5 | 1991 | 0.386* |
| Sandanski | 14.2 | 0.6 | 15.4 | 1994 | 13.4 | 1983,1988,1997 | 0.414* |

## 2. Precipitation

The comparisons between seasonal and annual precipitation amount show that there is not a big difference between precipitation total for various seasons (Fig. 2). In the northern part of the study area (stations Kyustendil, Sliven) spring and summer precipitation has the main contribution to the annual precipitation total, with 25-27% of annual precipitation for each season. In the southern part of the investigated territory (Sandanski and Kardazali stations), autumn-winter maximum in rainfall regime is typical. The amount of winter precipitation represents the total amount of water derived from solid and liquid precipitation. In terms of rainfall and water resources, the cold half of the year is not less important than the warm one. During cold periods, water accumulates in the soil and can be used during the first phenological phases of plants.

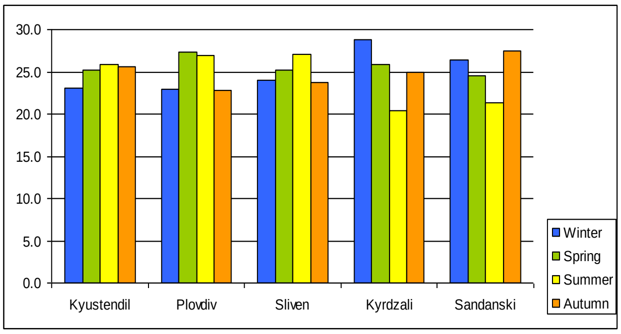


**Fig. 2: Seasonal distribution of precipitation totals (% of annual values)**

The linear regression equations for the 1931-2010, 1981-2010 periods point out to some important changes in the precipitation patterns. Decreasing trend of precipitation for each of the seasons and annual precipitation has been identified for the 1931-2010 period (Table 6).

**Table 6. Linear regression of winter precipitation (trend/10 years)**

| Meteorological stations | Winter | Spring | Summer | Autumn | Annual |
|---|---|---|---|---|---|
| | | **1931-2010** | | | |
| Kyustendil | -5.9 | -4.5 | -0.8 | -3.3 | -14.56* |
| Plovdiv | -1.7 | 1.3 | 0.8 | -2.3 | -2.3 |
| Sliven | -7.05* | -4.91* | -4.4 | -3.7 | -20.13* |
| Kyrdzali | 2.0 | 6.0 | 3.9 | 5.8 | 17.2 |
| Sandanski | -3.4 | -3.2 | 1.2 | -4.1 | -9.6 |
| | | **1981-2010** | | | |
| Kyustendil | -1.1 | 9.1 | 13.1 | 12.3 | 36.1 |
| Plovdiv | 16.6 | 12.3 | 8.9 | 19.8 | 49.9 |
| Sliven | 6.3 | -5.8 | 4.5 | 5.0 | 6.4 |
| Kyrdzali | 34.7 | 39.06* | 4.5 | 67.89* | 138.79* |
| Sandanski | 4.4 | 7.3 | 6.7 | 19.2 | 37.5 |

The exception is the station Kyrdzali with a positive trend. During the 1981-2010 period, the trend of seasonal and annual precipitation total is positive with a few exceptions (Kyustendil station, winter and Sliven station, spring). In most cases, the trend is not statistically significant.

### 3. Aridity index. Gaussen-Bagnouls classification method

The analysis of combination between air temperature and precipitation and application of Gaussen-Bagnouls classification method shows that climate in the investigated area during most months (from October to May, with a few exceptions) is humid (Table 7).

Aridity is established during August and September in most of the investigated stations. At some of the stations, arid climate is also registered in July and even June (Sandanski). In Sliven and Sandanski stations, the number of arid months increases during the period 1981-2010 in comparison with 1931-2010.

In spite of the positive trend of precipitation for the 1981-2010 period established by linear regression, Gaussen-Bagnouls method shows that due to high temperature in July, August and September, there is a precipitation deficit during summer and at the beginning of autumn. The tendency of aridity is not observed in Kyustendil and Kyrdzali stations.

*Forum geografic. Studii şi cercetări de geografie şi protecţia mediului*
*Volume XI, Issue 1 (June 2012), pp. 81-89*
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**Table 7. Types of climate according to Gaussen-Bagnouls classification method**

| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kyustendil | 1931-2010 | Humid | | | | | | Semi-humid | | | Humid | | |
| | 1981-2010 | Humid | | | | | | Semi-humid | | | Humid | | |
| Plovdiv | 1931-2010 | Humid | | | | | Semi-humid | | Arid | | Humid | | |
| | 1981-2010 | Humid | | | | | Semi-humid | | Arid | | Humid | | |
| Sliven | 1931-2010 | Humid | | | | | | Semi-humid | Arid | | Humid | | |
| | 1981-2010 | Humid | | | | Semi-humid | | Arid | | | Semi-humid | Humid | |
| Kyrdzali | 1931-2010 | Humid | | | | | | Arid | | Semi-humid | Humid | | |
| | 1981-2010 | Humid | | | | | Semi-humid | | | | Humid | | |
| Sandanski | 1931-2010 | Humid | | | | Semi-humid | | Arid | | | Humid | | |
| | 1981-2010 | Humid | | | Semi-humid | | Arid | | | | Humid | | |

**4. Qualitative study - case study of farmers**

In order to investigate thoroughly the impacts of climate change, the quantitative research has been complemented by a qualitative study. The method of the in-depth structured interview has been applied. The first interview has been with a manager of a limited liability company – situated in Stara Zagora. The company was established in the mid-1990s, cultivates about 6000 dka land – mainly grapes and fruit gardens, but also crops and vegetables. Only about 25-30% of the land is irrigated. The irrigation network that existed in the past has been destroyed. About fourteen people work on permanent labour contracts, temporary workers are hired during watering sessions.

According to the interviewee the meteorological conditions are very important for the farm. The farm has equipment for measuring precipitation and measurements are recorded in a diary. Moreover, weather forecast on mass media is watched every day. The most important problem for the farm is the drought. In his opinion winters have become predominantly dry; crops are not able to develop normally, fertilizers cannot dissolve in the soil. That is why the farm has begun to apply leaf fertilization in recent years. On the one hand, climate changes in spring give rise to a number of problems. E.g. in dry years the fruits of cherry trees cannot reach the necessary size; if springtime cultures are "deceived" to germ by the unusual warmth, they may be damaged by frost after that. On the other hand, grapes are impacted positively by warming.

The manager explained also about another change observed by farmers – the shift of spring precipitation to summer months June and July. Farmers try to adapt to the change by looking for plants (and seeds respectively) with a longer vegetation period, which could endure drought. It is a problem that the seeds supplied on the market by French and American companies do not thrive well in Bulgarian conditions. Also the seeds offered by the Institute of Plant Genetic Resources, Sadovo do not correspond to the local climatic conditions.

The farm incurs losses because of the unfavourable climatic conditions. Although they perform all the necessary agronomic activities and use contemporary agricultural equipment, yields do not reach the maximum levels. Concerning the compensation of losses – on principle the company does not insure the production, except in cases when it is required by a bank when it extends credit for a certain production. Farm's experience with insurances in recent years shows that compensations are quite small, but the procedure for getting them is very slow. The costs of the insurance were bigger than the benefits.

The second interview was conducted with a representative of the agricultural cooperative in the village of Hrishtene cultivating 9000 dka land. The main crops in the farm are corn, sunflower, tobacco and small areas with grapes. No areas are under irrigation. There are about fifteen workers permanently employed by the cooperative, as well as a number of seasonal workers. The structural changes in the farm are caused mainly by the changes in prices and markets.

Like in the first case study, here farmers also observe some climate changes – increase in the number of extreme events (hail storms), irregularity of precipitation, lack of snow cover in winter, the four seasons are not well differentiated, spring and summer have become shorter. The high amplitudes in temperature are stressful for the crops. According to the interviewee warming is visible (tangible) in the region – snowless winters with dry frost are dominating, there is irregularity in precipitation regime – e.g. it is raining continuously one week and after that it does not rain at all for a long time. People in the village have started growing subtropical plants in their gardens. All these changes lead to reduction in the yields and financial losses, respectively. Drought has a negative impact especially on cereal plants. However, the losses do not influence directly the number of employees in the farm – on the contrary, in some cases if the crops are destroyed by unfavourable climatic conditions, sowing begins again and more workers are hired.

In addition, the interviewee drew our attention especially to the problems related with air pollution and acid rains.

The cooperative does not insure the production for reasons similar to that described above. Like the farmers in the first case study, farmers in Hrishtene keep track of the current meteorological conditions, forecasts and measure precipitation in the farm. The farm takes actions for adaptation such as change in the sowing dates, growing of drought- resistant varieties. However, this is not always a solution to climate change problems, because it is not possible to foresee the succession of dry and wet years. There were cases when they cropped fields of drought-resistant sunflower, but the year turned to be wet.

## Conclusions

The analysis of air temperature shows high temperature levels in the study area. During winter, mean seasonal temperatures are positive. In summer mean temperature reaches 22-24°C. The trend of seasonal temperature is positive for all seasons and annual values also. The positive tendency is established for two investigated periods, 1931-2010 and 1981-2010, and it is better expressed during the second period. Exceptions are autumn temperature with negative trend in 1931-2010 and changes to positive trend in 1981-2010. The temperature conditions in the investigated area are favourable for growing thermophilic plants.

The distribution of seasonal rainfall is relatively evenly throughout the year. In the northern part of the study area, spring and summer precipitation register higher values, while in the southern parts maximum values have winter or autumn precipitation. Linear regression shows different tendencies in seasonal and annual precipitation for both investigated periods: negative tendency during 1931-2010 and positive during 1981-2010. In spite of the positive tendencies during the second period, due to high temperature, the arid climate is characteristic for July, August and September.

As a result of the interviews, the following conclusions could be made and hypotheses formulated concerning climate change and agriculture. Farms are vulnerable to various degrees to the climate changes and average changes in yields depending on farm size, crop varieties and availability of irrigation. It could be assumed that larger farms are less vulnerable, when and if they have opportunities for diversification of production. It is expected that they could even make profits from global warming because most climate models predict increase in average crop yields in the mid-term. On the other hand, small farms will be impacted negatively by the cyclic variations and they are vulnerable to possible losses in a given financial year. The support by the government will be very important during unfavourable years. Climate changes do no influence directly employment in farms.

According to the farmers during the recent years climate has been changed. This leads to various problems, e.g. the crops are not able to develop normally because of dry winters or shifting of spring precipitation to summer months. The farm incurs losses because of the unfavourable climatic conditions. Case studies show that farmers are quite active, take initiative and look for ways to adapt to changes on a micro-level through suitable crop varieties, shifting of the sowing dates, irrigation techniques, etc.

However, most of the possible adaptation measures are out of their control – reconstruction of irrigation facilities, research and selection of new varieties, development of the insurance market for agriculture products, etc.

## Acknowledgements

This study was supported by the Sofia University Science Fund contract No N 30 / 03.04.2011 under the Grant for the scientific project "The Impact of Agrometeorological Drought on Agriculture in Southern Bulgaria".

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