International Scientific Conference *People, Buildings and Environment 2014* (PBE2014)
15-17 October, 2014, Kroměříž, Czech Republic, www.fce.vutbr.cz/ekr/PBE

THE CLIMATE DATA ANALYSIS OF BANJA LUKA AREA AS THE BASIS OF AGRICULTURAL ADAPTATION TO CLIMATE CHANGE PLANNING

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Abstract

Banja Luka area has characteristics of moderate continental climate. Data used for the analysis covers the time period of 52 years (1961-2012) and it refers to precipitation and air temperature data obtained from Banja Luka Meteorological Station. The objective of the data analysis is proving current climate changes. For their better understanding, the climate data are divided into two periods: a) from 1961 to 2009 and b) from 2010 to 2012. Potential evapotranspiration, as well as the soil water balance, were calculated for these two periods. The potential evapotranspiration has been calculated using Thornthwaite's method. The analysis of meteorological data for the first period (1961-2009) showed that the average annual air temperature was 11.0ºC and the average amount of annual rainfall was 1038.8 mm. However, for the second period (2010-2012) the average annual air temperature was 12.2ºC, and the average amount of annual rainfall was 975.2 mm. The calculated results showed that the recent climate change happening on a global scale, with global warming, has also been present in the Banja Luka area. Such climate change could have immense harmful consequences on the overall economic development, public health and the safety of material goods. Changes of the climate, with global warming, reflect negatively, primarily in terms of agriculture, water resources, land and especially natural ecosystems, such as forests. The climate data and soil water balance analysis is a good basis for planning agricultural adaptation to climate change conditions.

Key words

Air; climate; change; temperature; water balance

To cite this paper: *Komljenović, I., Mišić, M., Marković, M., Pešević, D., Marković, M. (2014). The climate data analysis of Banja Luka area as the basis of agricultural adaptation to climate change planning, In conference proceedings of People, Buildings and Environment 2014, an international scientific conference, Kroměříž, Czech Republic, pp. 592-603, ISSN: 1805-6784.*

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1 INTRODUCTION

By large, the Banja Luka area in Bosnia and Herzegovina (BiH) has characteristics of moderate continental climate. The main characteristics of moderate continental climate are sharp and relatively snowy winters and hot summers. These climate conditions are often modified by morphological characteristics of the terrain and other local factors.

In the summer months stable and good weather with north-west air stream prevails. In the winter months, due to faster cooling and higher land, known Siberian anticyclone arises - a vast continental area of high pressure. In the winter, north and northeast air streams prevail.

The climate in Banja Luka affects complexes of green areas, the Vrbas river and its tributaries and the urbanization of the city to a significant degree. The Banja Luka area is completely open to the north, and especially in the winter it is exposed to the influence of cold air masses from the Pannonian Plain, while a high mountain range in the southern Dinarides, prevents any significant influence of the Mediterranean climate on the area.

2 MATERIAL AND METHOD

Collected data referring to precipitation and temperature are separated into two periods, from 1961 to 2009 (previous climate data) and from 2010 to 2012 (recent climate data). This was done in order to distinguish recent climate from previous climate [1], [2]. Soil water balance for these periods has been made based on the following input data:

- mean monthly precipitation (P) in mm,
- mean monthly potential evapotranspiration (PET) in mm,
- reserve of available soil water (RASW) of 100 mm.

Other elements of the water balance, such as:

- actual evapotranspiration (AET) in mm,
- water surplus (WS) in mm and
- water deficit (WD) in mm, were produced by using continuous balancing of the above mentioned monthly values of inputs.

Potential evapotranspiration was calculated using the Thornthwaite's model based on the values of mean monthly air temperature, corrected relative to the latitude of the study area.

The method according to Thorntwaite uses the following formula to calculate PET:

$$PET = 16\left(\frac{10T}{I}\right)^{a} \tag{1}$$

- PET - mean monthly potential evapotranspiration in mm
- T - mean monthly air temperature in ºC
- I - annual heat index, which is the sum of monthly heat index, as follows:

$$I = \sum_{1}^{12} i \tag{2}$$

Monthly heat index = "i" has been calculated according to the next formula:

$$i = \left(\frac{T}{5}\right)^{1.514} \tag{3}$$

a - the exponent which has been calculated from the formula

$$a = 0.00000075 \times I3 - 0.0000771 \times I2 + 0.01792 \times I + 0.49239. \qquad (4)$$

3 RESULTS AND DISCUSSION

The region of Southern Europe, where BiH is situated, has been ranked as one of the world's regions that are highly vulnerable to climate change (Fig.1). In this region there is a further increase in temperature of about 2ºC in the winter, and 2-3ºC in the summer, above the long-term average [3].

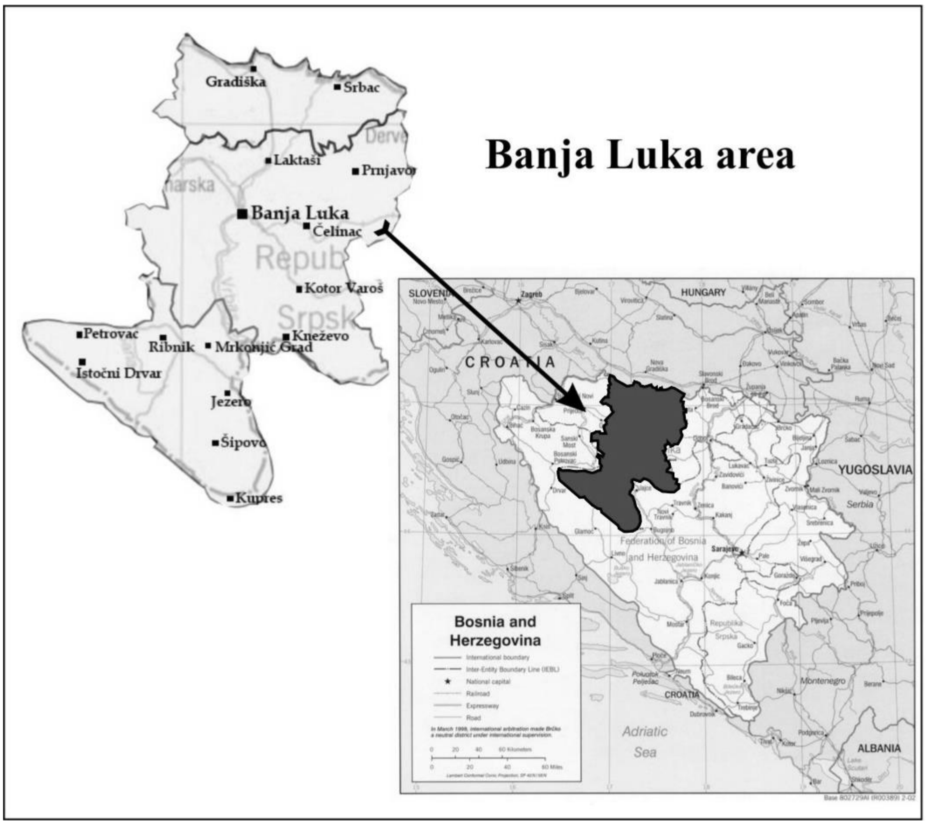

Fig. 1: Map of study area (Banja Luka, RS, Bosnia and Herzegovina)

Minimum temperature in Banja Luka area sometimes goes below -20°C, while the maximum reaches up to 40ºC. Annual precipitation in the area of Banja Luka is between 700 and 1100 mm of rainfall. The area beyond Banja Luka has an average annual number of days with snow cover of about 50 days except in mountainous areas, above 1000 m of altitude, where the number of days with snow cover is sometimes doubled. In the Regional Plan for the city of Banja Luka, it is stated in the draft document that average annual temperature for Banja Luka in the period 1951-2004 was between 10.0 and 11.5°C [4]. Mean minimum temperature was -2.0ºC, and mean maximum temperature was 23.5°C. The absolute minimum temperature was -27.4°C (February, 1956), and the absolute maximum temperature was 41.4°C (August 1957). The mean annual cloudiness was 62% and average annual precipitation was 1017 mm [5].

Tab. 1: Mean monthly and annual air temperature for the area of Banja Luka, in the periods from 1961 to 2009 and from 2010 to 2012 (in °C)

Periods	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1961-2009	-0.1	2.0	6.5	11.1	16.1	19.5	21.1	20.6	16.1	11.2	6.2	1.4	11.0
2010-2012	1.4	0.4	8.0	12.6	16.2	21.5	23.8	28.3	18.3	11.0	7.3	2.2	12.2

Tab. 2: Mean monthly and annual rainfall for the area of Banja Luka, in the periods from 1961 to 2009 and from 2010 to 2012 (in mm)

Periods	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1961-2009	69.1	62.1	79.4	89.0	93.3	110.7	92.4	86.1	92.4	78.3	95.0	91.0	1038.8
2010-2012	84.0	66.4	51.0	70.6	126.2	113.8	77.4	32.6	104.8	77.8	52.4	118.2	975.2

Analysis of meteorological data for the two above-mentioned periods shows that the average annual temperature was 11.0°C and the average amount of annual rainfall was 1038.8 mm for the period 1961-2009. Average annual temperature and annual rainfall for the period 2010-2012 were 12.2°C and 975.2 mm, respectively (Tab. 1 and Tab. 2).

3.1 Indicators of climate change in the area of Banja Luka

The results showed that current climate change on a global scale has immense adverse consequences on the overall economic development, public health and safety of material goods.

During the 20th century mean annual global surface air temperature has increased by 0.6°C. Changes in the climate have been recorded in the northern hemisphere [6]. In addition to changes in the thermal regime, changes were also recorded with respect to the precipitation regime. During the 20th century a rising trend of precipitation in northern Europe was registered, while in Southern Europe, which includes Republic of Srpska, decrease in precipitation by an average of 13% was recorded [4]. In addition to changes in temperature and precipitation regime, significant changes were registered in terms of intensity and frequency of climate extremes, such as extreme high and low temperatures, heat waves, storms accompanied by hail, electrical discharge, destructive effects of wind, floods, reduction of snow cover and masses of snow, conditions conducive to forest fires, landslides, increased erosion and other forms of land degradation.

Changes in the climate reflect primarily in agriculture, water resources, land, and especially in natural ecosystems, such as forests [7].

Agriculture directly contributes to 10–12% of global anthropogenic GHG emissions [8], [9]. Many of the same practices that reduce GHG emissions can also improve efficiency of resource use, and create synergy with rural development and food security goals [10].

It is estimated that, in temperate latitudes of northern hemisphere, which include Republic of Srpska, the warming increase will be greater than the global average, and will range between 0.8°C and 1.0°C for every 10 years [4].

Temperature trends - an indicator of climate change

Although the data on air temperature in Banja Luka has been collected since 1892, the first continuous data series for a 10-year period refers to the period between 1900 and 1909 with an average annual temperature of 10.7°C.

In the first decade of the period, from 1950 till 1959, the average annual temperature was 10.8°C, while in the last decade, from 2001 till 2010, the average annual temperature was 12.0°C, which is an increase of 1,2°C. From 1950 till 2010, the average annual temperature in the period increased by 2.3°C. Thus, an obvious trend (Fig. 2, [11]) is noticeable, there is increase in air temperature in Banja Luka, which confirms the interpretation given in the previous subsection. In addition, it leads us to the conclusion that if these trends (Fig. 2, Fig. 3, [7]) continued in the future, by the mid-21st century, we could expect that the average annual temperature in Banja Luka reaches 13°C. All this speaks towards the realistic necessity for application of irrigation in agricultural production if we want to get high rate and stable yields of cultivated plants [11].

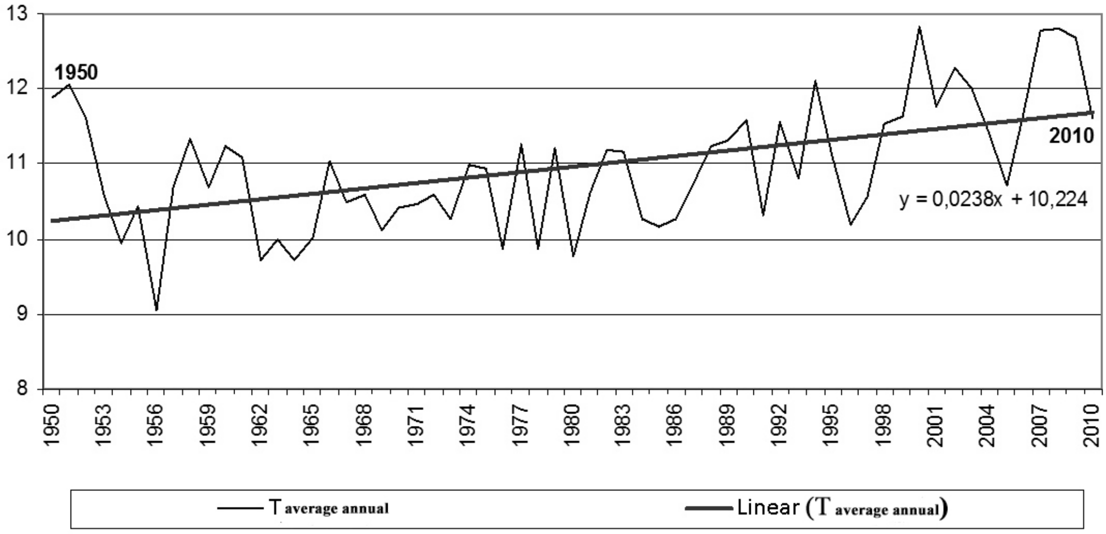

Fig. 2: Mean annual temperature (in °C) in Banja Luka for the period 1950-2010

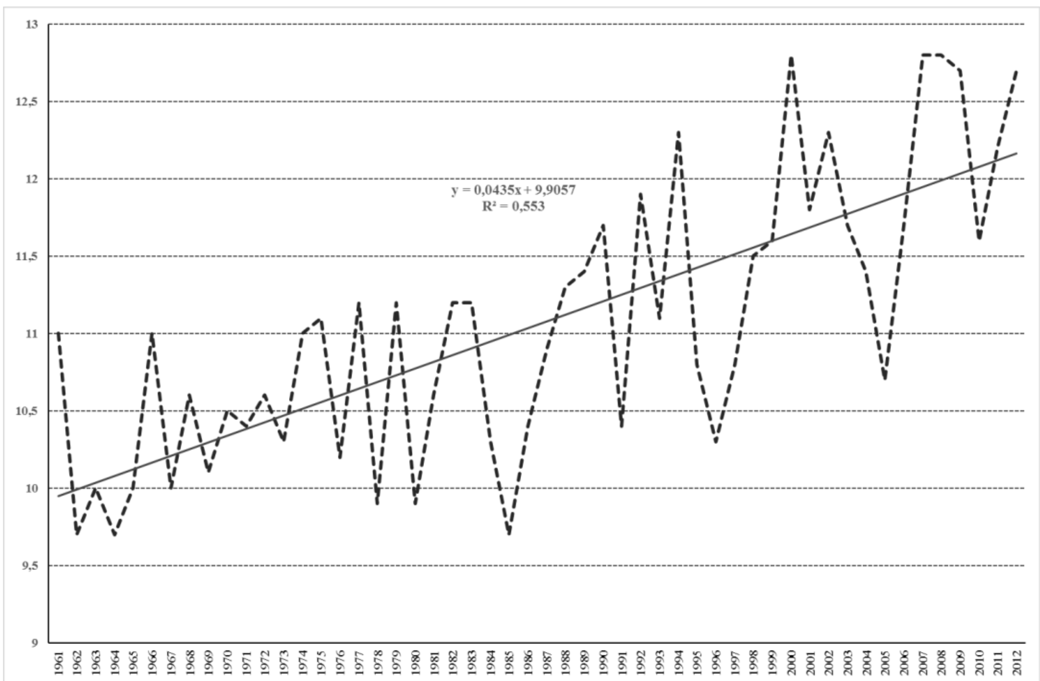

Fig. 3: Trend of average annual temperature for Banja Luka region from 1961 to 2012

Soil water balance by Thorntwaite and Walter's climate diagram for Banja Luka area, for the period from 1961 till 2009

Average data of PET and AET for Banja Luka area in the period from 1961 till 2009 indicate that the excess moisture in soil occurs in March (Tab. 3 and Fig. 4).

Tab. 3: PET, AET, WS and WD in Banja Luka area, for the period from 1961 till 2009

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
PET	0.0	24.3	37.6	57.2	85.3	109.6	118.0	105.9	72.8	46.9	29.8	19.8
AET	0.0	24.3	37.6	57.2	85.3	109.6	115.0	100.0	72.8	46.9	29.8	19.8
WS	0.0	52.0	150.8	31.8	8.0	1.2	0.0	0.0	0.0	14.6	65.3	17.1
WD	0.0	0.0	0.0	0.0	0.0	0.0	3.0	5.9	0.0	0.0	0.0	0.0

Apart from the growing precipitation, a significant proportion of moisture comes from the melted snow, after air temperature increase in late January. This dry period is not so noticeable when viewed on the long-term basis from 1961 till 2009, the average of which is probably the result of harmonizing the elements of water balance, the "cover-up" extreme, as it occurs with other meteorological data. Example of this are oscillations in the absolute maximum temperature in Banja Luka, for the period 1951-2004, which was 37.6°C for June (2000), 40.9°C for July (2000), 41.4°C for August (1957), while the absolute minimum for the same period in temperature was as follows: 0.9°C for June (1962), 5.3°C for July (1984) and 5.0°C for August (1980). Due to the annual air temperature increment in the period since the end of January, melting of snow increased with rainfall, increasing absorption of moisture in the soil, and thus increasing the accumulation of moisture (maximum in March).

At the same time, due to rapid melting of snow, surface water drainage showed on slopes, and frequent saturation and excess moisture in the surface horizons on flat ground of heavier, clay soil as pseudogley and others similar to it. This often leads to choking crops.

With the increasing air temperature, moving into the summer period, the absorption of moisture in the soil is reducing, and the accumulation and swelling, as well. The months with the highest average temperature during a year (from third decade of June till middle of September) are followed by a slower inflow of moisture. On average, the lack of soil moisture (WD) appears regularly in August.

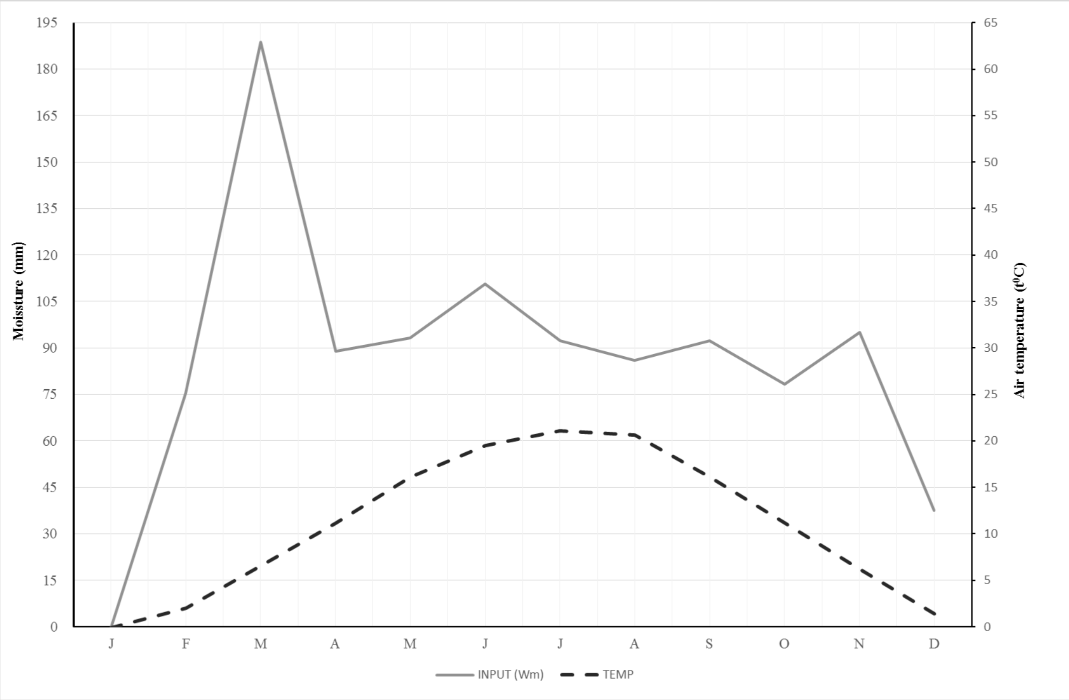

Fig. 4: Climate diagram by Walter in Banja Luka area for the period from1961 till 2009

Soil water balance by Thorntwaite and Walter's climate diagram for Banja Luka area, for the period from 2010 till 2012

Observing a long-term average for Banja Luka area (1961-2009), the state of soil moisture, PET and AET, the most evident water surplus was in March (Tab. 4, Fig. 4 and Fig. 5).

Tab. 4: Meteorological data for Banja Luka area for the period from1961 till 2009

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
P mm	0.0	76.3	188.4	89.0	93.3	110.7	92.4	86.1	92.4	78.3	95.0	36.9	1038.8
T °C	-0.1	2.0	6.5	11.1	16.1	19.5	21.1	20.6	16.1	11.2	6.2	1.4	11.0

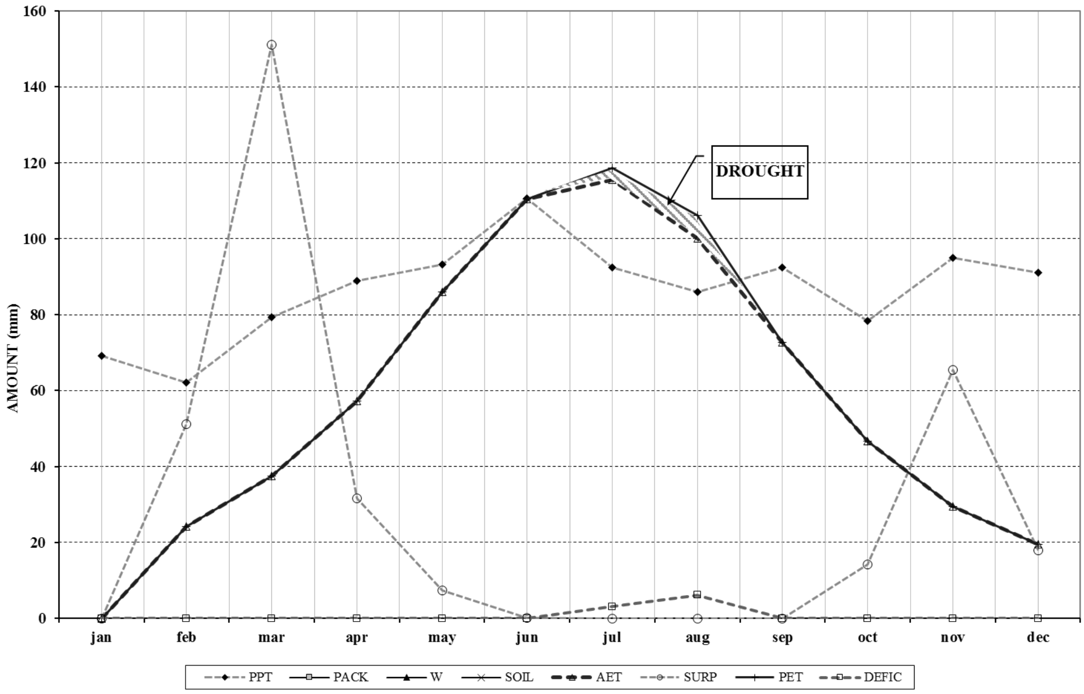

Fig. 5: The average annual water balance in Banja Luka area for the period 1961-2009

On the other hand, in case of deficiency of moisture, as opposed to the previously analysed, long-term average for the same area, in the analysed period, from 2010 till 2012 from mid-June to mid-September, there was a very significant deficit of moisture (WD) and no significant difference between PET and AET. This led to a very dry period and the lack of moisture in the soil. From mid-September, a balance between PET and AET has been established, until occurrence of excess moisture drop in air temperature from mid–November, (Tab. 5, Fig. 6).

Tab. 5: PET, AET, WS and WD in Banja Luka area, for the period from 2010 till 2012

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
PET	20.5	21.8	41.4	62.6	85.9	123	137.5	124	82.6	46.2	31.9	21.0
AET	20.5	21.6	41.4	62.6	85.9	123	118.5	62.3	82.6	46.2	31.9	21.0
WS	24.0	0.0	141	7.9	40.3	0.0	0.0	0.0	0.0	0.0	0.0	44.9
WD	0.0	0.2	0.0	0.0	0.0	0.4	19.1	61.2	0.0	0.0	0.0	0.0

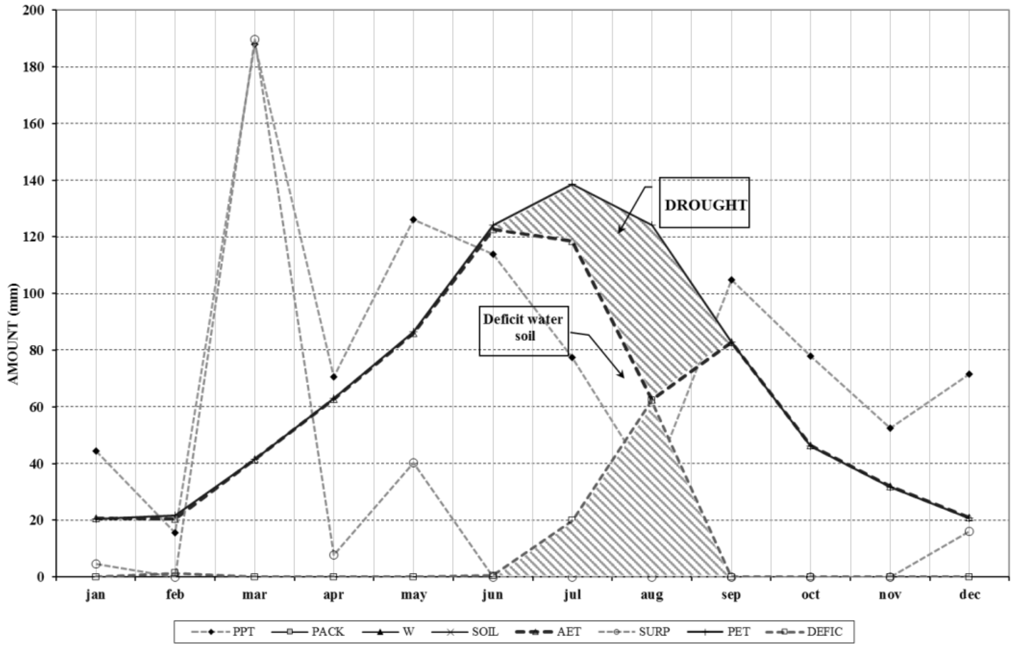

Fig. 6: The average annual water balance in Banja Luka area for the period 2010-2012

Despite the increasing monthly average air temperature from the second week of February, the snow melt and increased inflow of moisture, due to extremely large amount of rainfall (188 mm in March), caused increased infiltration of moisture in the soil, water outflow on slopes or a surplus wetting of surface horizons in pseudogley or similar soils on a flat surface [12].

However, due to extremely high average monthly air temperature from the third decade of June to mid-September, followed by a weak inflow of moisture in the form of precipitation, a very noticeable soil water deficit (WD) was present or extreme drought, during this period, which resulted in large losses in yields of cultivated plants [13].

Tab. 6: Meteorological data for Banja Luka area for the period from 2010 till 2012

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec	Ann.
Pmm	44.5	15.5	188.0	70.6	126.2	113.8	77.4	32.6	104.8	77.8	52.4	71.6	975.2
T°C	1.4	0.4	8.0	12.6	16.2	21.5	23.8	23.3	18.3	11.0	7.3	2.2	12.2

Based on the climate diagram according to Walter’s climate diagram for Banja Luka area for the tested period from 2010 till 2012, it can be clearly noted that during mid-June to late August there was extreme drought, (Tab. 6, Fig. 7). This is the most critical period for flowering, fertilization and grain filling of maize. Lack of moisture during this period caused a significant drop in the yield of corn. This suggests that irrigation of cultivated crops, with their growing period coinciding with the mentioned period of the lack of water, becomes necessary in the agricultural production within the area.

Finally, it should be noted that previous studies of these phenomena [12] have shown that, for the period from 1951 till 2001 and the calculations that were analysed, the average annual excess water was 603 mm if RASW was 100 mm, if RASW was 50 mm excess of water amounted to 653 mm, or 793 mm if RASW was 25 mm [5].

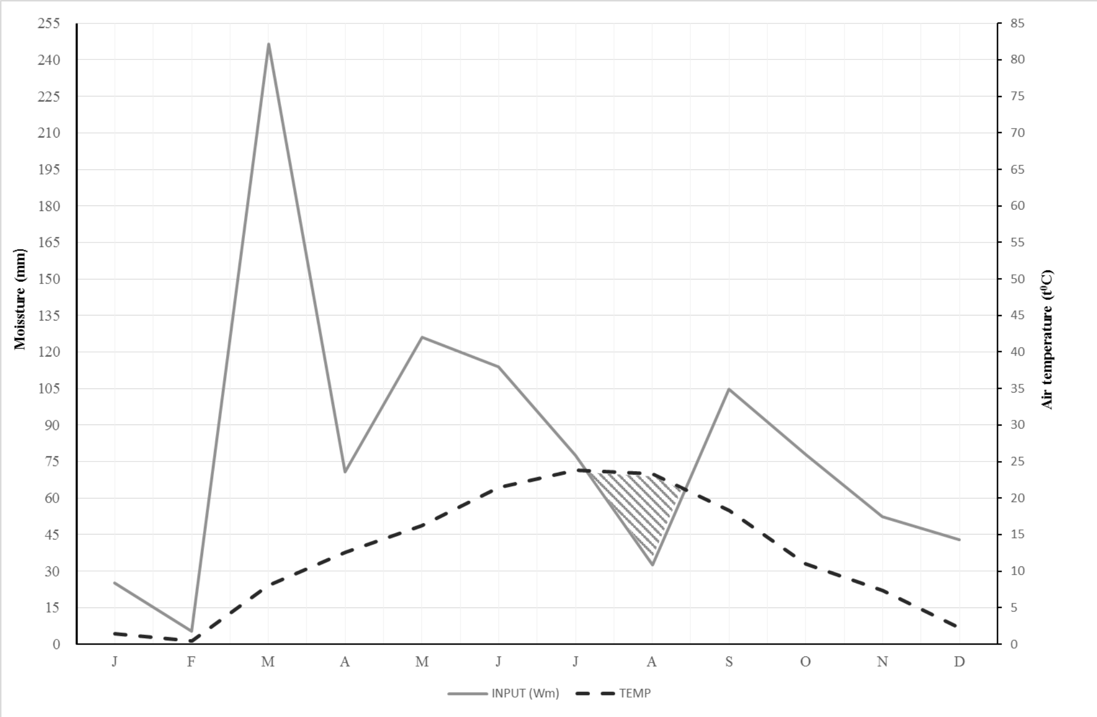

Fig. 7: Climate diagram by Walther in Banja Luka, from 2010 till 2012

Surpluses are distributed throughout all months, with monthly sums of surplus amounting from an average of 44 mm in September to 86 mm in December. On the other hand, the average annual water deficit was 131 mm for RASW of 100 mm, 200 mm for a RASW of 50 mm and 345 mm for RASW of 25 mm. On the basis of the soil water balance calculations the obtained results showed that in Banja Luka area 24% of analyzed years had humid climate and 2% of years had slightly humid climate [5], [14].

4 CONCLUSION

Global climate change has been caused by increase of anthropogenic emissions of greenhouse gases and reflected in terms of changes in extreme values, especially the absolute maximum values of air temperature, with increased frequency and longer duration of warm weather wave in the summer.

There is an evident increase in average monthly temperature on the territory of Banja Luka, for the period 2010-2012 compared to the period 1961-2009, as well as in the mean annual temperature.

At the same time, the amount of monthly precipitation for the period 2010-2012 was lower than from 1961 to 2009, with a clear deficit of soil moisture from June to September.

The analysis of climate data and soil water balance is a good basis for agricultural adaptation planning to climate change.

ACKNOWLEDGMENT

Part of research for this paper was developed within framework of the following project: Agricultural Adaptation to Climate Change – Networking, Education, Research and Extension in the West Balkans, approved by Norwegian funded Program in Higher Education, and Development, Research (HERD) in the Western Balkans: HERD/Agriculture.

Expenses for publication of this paper in the Proceedings of the International Scientific Conference People, Buildings and Environment 2014 (PBE2014), 15-17 October, 2014, Kroměříž, Czech Republic, www.fce.vutbr.cz/ekr/PBE is also paid from this Project, in accordance with Agreement, between Noragric, Norwegian University of Life Science (UMB), Noragric, Department of International Environment and development studies, Ås, Norway and Faculty of Agriculture, University of Banja Luka, Bosnia and Herzegovina, signed in April 2014.

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