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# IMPACT OF CLIMATE CHANGE ON THE ANNUAL WATER BALANCE IN A HUMID CLIMATE

## SUMMARY

Lithuania and Bosnia and Herzegovina are considered as countries with high vulnerability and low adaptive capacity to cope with climate change. The entire territory of these countries is characterized by the warming trend, with positive trends in both the maximum and the minimum temperatures throughout the year. The increase in air temperature has resulted in change of evapotranspiration and mean annual water balance values. These countries are also frequently faced with an occurrence of severe droughts and heavy floods. The main purpose of this study was to determine and compare the severity of changes in mean annual water balance for two humid climatic zones, in order to understand how different areas of similar climate characteristics react to climate change and to analyze the significance of their influence. Monthly weather data from two weather stations, Kaunas (Lithuania) and Sarajevo (Bosnia and Herzegovina), for the time period of 30 years (1988 – 2017) were used to determine and analyze the mean annual water balance. The results indicate that climate change has a different effect on the water balance of these two humid areas. Both locations showed a positive trend of reference evapotranspiration, with an increase of 1.450 mm year$^{-1}$ to 1.503 mm year$^{-1}$. However, the total runoff and soil moisture deficit are decreasing in Kaunas (-0.480 mm and -2.114 mm year$^{-1}$, respectively), while they are increasing in Sarajevo (0.492 mm and 0.485 mm year$^{-1}$, respectively).

**Keywords:** climate change, water balance, humid climate, Bosnia and Herzegovina, Lithuania

## INTRODUCTION

Human pressure on the natural environment resulted in the decrease in availability of freshwater supplies for consumption and agricultural production. Global climate change and associated impacts on water resources are the most urgent challenges facing mankind today and will have enduring societal implications for generations to come. Potential impacts may include the changes

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in watershed hydrologic processes including timing and magnitude of surface runoff, stream discharge, evapotranspiration, drought occurrence and flood events (Simonovic & Li, 2004). There is an essential need for effective management of limited water resources while increasing agricultural productivity (Sharma & Irmak, 2012).

Lithuania and Bosnia and Herzegovina (B&H) are considered as countries with high vulnerability and low adaptive capacity to cope with climate change (Easterling *et al.*, 2000; Žurovec *et al.*, 2017). The entire territory of these countries is characterized by the warming trend with positive trends in both the maximum and the minimum temperatures throughout the year (Radusin *et al.*, 2013; Radusin *et al.*, 2016; Merl, 2017; Popov *et al.*, 2018; Povilaitis *et al.*, 2018).

The average annual precipitation from 1977 to 2016 was 642 mm, or 1.4% higher than the climate normal (CN, defined as the three-decade 1981-2010 average) in Kaunas, Lithuania. The annual air temperatures in Kaunas for the 1977-2016 period (with an average of 7.0°C) showed increasingly variable patterns (Povilaitis *et al.*, 2018). According to Trbic *et al.* (2017) the entire territory of B&H is characterized by prominent and significant annual warming. The annual temperature increase was in the range of 0.2–0.5°C per decade (Radusin *et al.*, 2016; Trbic *et al.*, 2017). In addition, increase in the extreme precipitation is present over the entire territory of Bosnia and Herzegovina (Popov *et al.*, 2017).

The increase in air temperature and changes in precipitation amount has resulted in change of evapotranspiration ($ET_0$) and mean annual water balance values (Giugliano *et al.*, 2013). Water balance is important for determination of water availability, crop irrigation requirement, flood risk assessment, regional water management decision-making, drought analyses, environmental studies, understanding the possibilities of organizing agricultural production in a given area and it is used to model climate change impacts and design effective adaptation and mitigation measures (Žurovec, 2012; Pereira *et al.*, 2015; Pandey *et al.*, 2016; Čadro S. *et al.*, 2017; Žurovec *et al.*, 2017).

Thornthwaite and Mather (1955) developed a simple heuristic model of water balance that estimates monthly actual evapotranspiration (*AET*), runoff (*RO*) and soil moisture deficit (*SMD*) as a function of soil-moisture storage and potential evapotranspiration (*PET*) via a “bookkeeping” procedure. Since then, many authors developed a large number of different versions of this water balance method (Thornthwaite & Mather, 1957; Alley, 1984; Dingman, 2002; Legates & Mccabe, 2005; Mccabe & Markstrom, 2007; Westenbroek *et al.*, 2010). Trends of main water balance components have been extensively analyzed globally. Gocic and Trajkovic (2014) analyzed data from 12 weather stations in a humid area of Serbia, for the period 1980 – 2010. They found significant increasing trends in $ET_0$ for the majority of the stations. Tabari *et al.* (2011) analyzed the annual, seasonal and monthly trends of the $ET_0$ series for 20 stations in the western half of Iran during 1966 – 2005. They concluded that the increasing trends in all seasons. This condition is followed by increasing trends in soil moisture deficit and drought occurrence. The similar results are found in Spain (Espadafor *et al.*, 2011), Iran (Amirataee *et al.*, 2016), Montenegro (Knežević *et al.*, 2018), Slovenia (Zupanc & Pintar, 2004) Brazil (Silva *et al.*, 2016) and Togo (Djaman & Komla, 2015). Likewise, many authors reported the increased trend in the annual value of potential evapotranspiration (Čadro *et al.*, 2016), soil water deficit (Bukantis A. & Rimkus E., 2005; Žurovec & Čadro, 2010, 2015; Cammalleri *et al.*, 2016) and drought severity (Vlahinić *et al.*, 2001; Stankūnavičius, 2009; Žurovec *et al.*, 2011; Hodžić *et al.*, 2013; Taparauskienė & Lukševičiūtė, 2015; Čadro Sabrija *et al.*, 2017; Merl, 2017) in humid areas of Bosnia and Herzegovina and Lithuania.

The main objective of this study is to determine and compare the severity of changes in mean annual water balance for two humid climatic zones (Lithuania and B&H) using the linear regression methods, in order to understand how different areas of similar climate characteristics react to climate change and to analyze the severity of their influence.

## MATERIAL AND METHODS

Two countries have been the subject of this research, Lithuania and Bosnia and Herzegovina (B&H) (Figure 1). Lithuania is located in the Baltic region of northern-eastern Europe. The capital city is Vilnius, situated at latitude $54^{0}41'$ N and longitude $25^{0}19'$ E. Bosnia and Herzegovina is located in south-eastern Europe, with capital city Sarajevo situated at latitude $43^{0}52'$ N and longitude $18^{0}25'$ E. The basic characteristics of both countries are given in the Table 1.

**Table 1**. Lithuania and B&H country profiles

| **Characteristic** | **Lithuania** | **Bosnia and Herzegovina** |
|---|---:|---:|
| Area ($km^2$) | 65,300 | 51,129 |
| Water (%) | 1.35 | 1.4 |
| Coastline (km) | 90 | 20 |
| Mean elevation (m) | 110 | 500 |
| Highest point (m) | 297 | 2,386 |
| GDP per capita[1] | 18,857 | 5,806 |
| Population | 2,823,859[2] | 3,531,159[3] |
| Population density (per $km^2$) | 43.24 | 69.06 |
| HDI[4] for 2017 | 0.858 | 0.768 |
| BTI[5] for 2017 | 9.24 | 6.28 |
| Köppen climate classification[6] | *Dfb* | *ET, Dfb, Cfa, Cfb, Csa* |
| CRI[7] for 1997–2016 | 121.83 | 72.00 |
| CRI rank | 136 | 69 |

[1]Gross domestic product, International Monetary Fund (2017).
[2]Estimation for 2017, Oficialiosios statistikos portalas.
[3]Agency for Statistics of Bosnia and Herzegovina, Census 2013 (Jukić, 2016).
[4]Human development index, source: United Nations Development Programme.
[5]Bertelsmann Stiftung's Transformation Index (Stiftung, 2018a, 2018b).
[6]*Dfb* - humid continental climate, *Cfa, Cfb* - temperate warm and humid climates, *Csa* - mediterranean climate and *ET* - tundra climate.
[7]Global Climate Risk Index (Eckstein *et al.*, 2018).

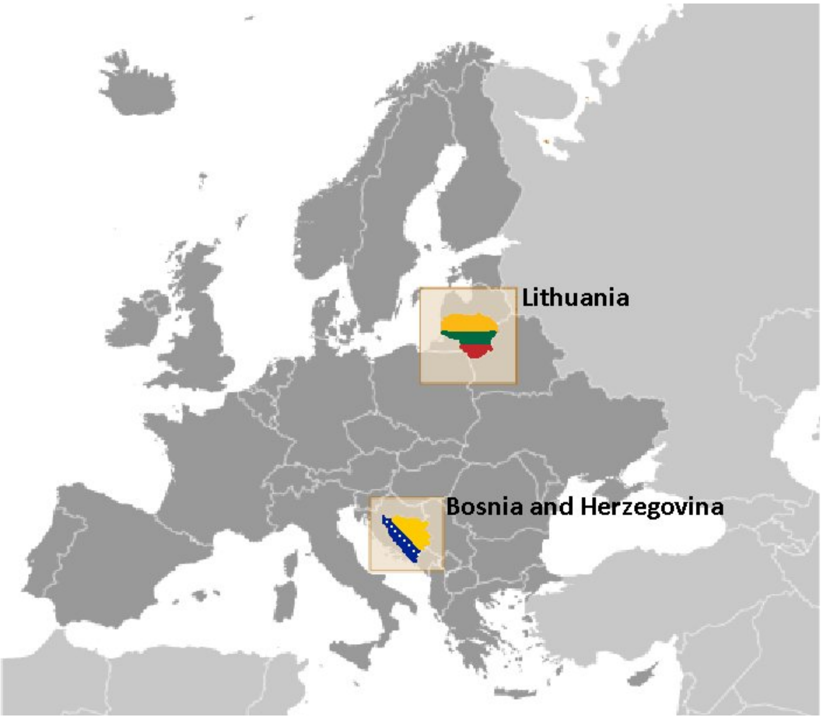


**Figure 1:** Locations of the Bosnia and Herzegovina and Lithuania with in the Europe

Humid climate prevails in both countries. In Lithuania, it is mostly humid continental climate (*Dfb*), while in B&H in addition to *Dfb*, temperate warm and humid climates (*Cfa*, *Cfb*) and mediterranean climate (Giugliano *et al.*) are also present.

The Global Climate Risk Index 2018 (CRI) analyses to what extent countries have been affected by the impacts of weather-related loss events (storms, floods, heat waves etc.). Less developed countries are generally more affected than industrialized countries (Eckstein *et al.*, 2018). The most recent data available from 1997 to 2016, places B&H at 69$^{th}$ place, and Lithuania at 136$^{th}$.

Monthly climatic data, including mean maximum and minimum air temperature ($^{0}$C), minimum and maximum relative humidity (%), wind speed (m s$^{-1}$) and sunshine hours (h) from 2 humid weather stations (WS), Kaunas in Lithuania and Sarajevo in B&H, for the period 1988 - 2017 (30 years) were obtained from state weather services. Before use, the data quality was checked with quality-control procedures recommended by Allen *et al.* (1998).

Reference evapotranspiration ($ET_0$) was calculated using standard FAO-PM equation (Eq. 1) that is closely resembling the evapotranspiration of an extension surface of green grass of uniform height (0.12 m), actively growing with enough water, with a fixed surface resistance (70 s m$^{-1}$) and an albedo of 0.23, given by (Allen *et al.*, 1998):

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T_{mean} + 273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

where $ETo$ is the reference evapotranspiration (mm day$^{-1}$), $R_n$ the net radiation at the crop surface (MJ m$^{-2}$ day$^{-1}$), $G$ the soil heat flux density (MJ m$^{-2}$ day$^{-1}$), $T_{mean}$ the mean daily air temperature at 2 m height ($^{o}$C), $u_2$ the wind speed at 2 m height (m s$^{-1}$), $e_s$ the saturation vapor pressure, $e_a$ the actual vapor pressure, $e_s$ - $e_a$ the saturation vapor pressure deficit, $\Delta$ the slope of the vapor pressure curve (kPa $^{o}$C$^{-1}$) and $\gamma$ is the psychrometric constant (kPa $^{o}$C$^{-1}$).

All necessary parameters required for calculation of $ET_0$ where computed following the procedure developed in FAO-56 (Allen *et al.*, 1998).

Since reflected solar radiation ($R_s$) is required for $R_n$ calculation and this parameter is not measured on WS in B&H, it was estimated from the measured sunshine hours data (The Campbell–Stokes sunshine recorder) with the Ångström (1924) equation:

$$R_s = \left(a_s + b_s \frac{n}{N}\right) R_a \quad (2)$$

where $R_a$ is the extraterrestrial radiation (MJ m$^{-2}$ day$^{-1}$) calculated for each day of the year and for different latitudes, from the solar constant ($G_{sc}$ = 0.0820 MJ m$^{-2}$ min$^{-1}$), the solar declination ($\delta$) and the time of the year ($J$) and then by selecting the $R_a$ for 15th day of each month converted to monthly values, $n$ is the actual duration of sunshine (h), $N$ is the maximum possible duration of sunshine or daylight hours (h), as is the regression constant, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0) and $a_s + b_s$ is the fraction of extraterrestrial radiation reaching the earth on clear days ($n = N$).

In the absence of actual solar radiation ($R_s$) measurements, the values $a_s$ = 0.25 and $b_s$ = 0.5 were used as suggested by Allen *et al.* (1998).

For the Kaunas WS measured solar radiation data ($R_s$) or sunshine hours data were missing, so solar radiation was estimated using Hargreaves' formula (Hargreaves & Samani, 1985) (Eq. 3), as suggested in Allen *et al.* (1998):

$$R_s = k_{R_s}\sqrt{(T_{max} - T_{min}) \times R_a} \quad (3)$$

where $R_a$ is extra-terrestrial radiation (MJ m-2 d-1), $T_{max}$ maximum air temperature (°C), $T_{min}$ minimum air temperature (°C), $k_{Rs}$ adjustment coefficient (0.16 .. 0.19) (°C$^{-0.5}$).

In the case of Kaunas, since it is located inland ("interior" location) where land mass dominates and air masses are not strongly influenced by a large water body, value of $k_{Rs}$ = 0.16 was used (Čadro S. *et al.*, 2017).

Monthly water balance was calculated as described in Dingman (2002). Except data on monthly precipitation (*P*) and evapotranspiration ($ET_0$) applied water balance requires data on soil available water content ($SOIL_{max}$). The value $SOIL_{max}$ = 100 mm was used (Mcbean *et al.*, 1995) since this is the most commonly used value for the types of soil that are found on the study locations.

To detect the trends within time series of water balance components (annual precipitation, reference evapotranspiration, actual evapotranspiration, soil moisture deficit, total runoff and snow) parametric method of linear regression was used, as shown in equation (4):

$$y = a + b \times x \tag{4}$$

where *x* is the explanatory variable, *y* the dependent variable, *b* the slope of the line and *a* the intercept.

The slope indicates the mean temporal change of the studied variable. Positive values of the slope show increasing trends, while negative values of the slope indicate decreasing trends (Gocic & Trajkovic, 2013, 2014).

## RESULTS AND DISCUSSION

Descriptive statistics (mean, standard deviation – SD, coefficient of variation – CV) for the air temperature (*T*), precipitation (*P*), $ET_0$ and via water balance calculated actual evapotranspiration (*AET*), soil moisture deficit (*SMD*), total runoff (*TRO*) and snow for the 2 WS for the period 1988 – 2017 are summarized in Table 2.

**Table 2:** Annual statistic for the climate and water balance components in Kaunas and Sarajevo WS during the period 1988-2017.

| Climate and water balance components | Kaunas, Lithuania | | | Sarajevo, B&H | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **CV** | **Mean** | **SD** | **CV** |
| Air temperature *(T)* | 7.27 | 0.81 | 11.19 | 10.41 | 0.69 | 6.61 |
| Precipitation *(P)* | 645 | 85.50 | 13.25 | 947 | 156.51 | 16.52 |
| Reference *ET* ($ET_0$) | 636 | 25.40 | 3.99 | 805 | 45.17 | 5.61 |
| Actual *ET (AET)* | 503 | 56.63 | 11.25 | 653 | 54.32 | 8.31 |
| Total runoff *(TRO)* | 141 | 44.50 | 31.49 | 295 | 86.78 | 29.47 |
| Soil m. deficit *(SMD)* | 133 | 62.06 | 46.63 | 151 | 85.69 | 56.70 |
| *SNOW* | 179 | 39.55 | 22.10 | 193 | 99.11 | 51.33 |

The averages of all analyzed and calculated climate and water balance characteristics are higher in Sarajevo than in Kaunas. The mean annual air temperature is 7.27 $^0$C and 10.41 $^0$C for Kaunas and Sarajevo, respectively. Annual sum of precipitation is for 302 mm higher in Sarajevo. These climatic differences have also caused the differences between water balance components. Mean $ET_o$ for Kaunas is slightly lower than the annual sum of precipitation, while in Sarajevo this difference is much higher (142 mm). In Sarajevo, a big part of precipitation cannot be lost to the atmosphere by evapotranspiration and it is retained by the soil or it appears in form of surface or subsurface runoff. Thus, total runoff (*TRO*) is much higher in Sarajevo than in Kaunas, 295 mm compared to 141 mm. *SMD* and amount of snow have similar values between analyzed locations. The highest coefficient of variation (CV) is for *SMD* ranging from 46.63 % in Kaunas to 56.70 % in Sarajevo. These high *SMD* variations are in line with many previous studies of water scarcity and high sensitivity of this locations to climatic extremes (Čustović & Vlahinić, 2004; Žurovec *et al.*, 2011; Hodžić *et al.*, 2013; Taparauskiene & Lukševičiute, 2015; Taparauskienė *et al.*, 2015; Radusin *et al.*, 2016; Čadro Sabrija *et al.*, 2017). Especially, this applies to agriculture production that depends on the soil moisture (Žurovec & Čadro, 2015; Miseckaite *et al.*, 2018). High variations were also obtained for total runoff (*TRO*) and snow ranging from 29.47 to 31.49 % and 22.10 to 51.33 % for Kaunas and Sarajevo, respectively.

Results of the regression analysis for annual air temperature (*T*), precipitation (*P*), $ET_0$ and via water balance calculated actual evapotranspiration (*AET*), soil moisture deficit (*SMD*), total runoff (*TRO*) and snow for the Kaunas and Sarajevo WS for the period 1988 – 2017 are presented in Table 3 and Fig. 2.

**Table 3.** Results for the statistical tests for the annual climate and water balance components in Kaunas and Sarajevo WS during the period 1988-2017.

| Climate and water balance components | Kaunas, Lithuania | | | | Sarajevo, B&H | | | |
|---|---|---|---|---|---|---|---|---|
| | **p-value** | **R** | **$R^2$** | **b** | **p-value** | **R** | **$R^2$** | **b** |
| *T* | 0.001 | 0.562 | 0.316 | 0.052 | 0.000 | 0.607 | 0.368 | 0.047 |
| *P* | 0.044 | 0.369 | 0.136 | 3.582 | 0.610 | 0.097 | 0.009 | 1.724 |
| $ET_0$ | 0.003 | 0.521 | 0.271 | 1.503 | 0.130 | 0.282 | 0.079 | 1.450 |
| *AET* | 0.003 | 0.521 | 0.272 | 3.355 | 0.409 | 0.156 | 0.024 | 0.965 |
| *TRO* | 0.617 | 0.094 | 0.009 | -0.480 | 0.793 | 0.049 | 0.002 | 0.492 |
| *SMD* | 0.161 | 0.262 | 0.069 | -1.851 | 0.794 | 0.050 | 0.002 | 0.485 |
| *SNOW* | 0.008 | 0.471 | 0.222 | -2.114 | 0.759 | 0.058 | 0.003 | -0.656 |

The results clearly show increasing trends in *T*, *P*, $ET_0$ and *AET* series and decreasing trend in the amount of the snow. The increasing trends of the air temperature (*T*) are similar for Kaunas and Sarajevo WS, ranging from 0.052 $^0$C to 0.047 $^0$C. Increasing trends ware also detected for the annual amount of precipitation, ranging from 3.582 mm year$^{-1}$ in Kaunas to 1.724 mm year$^{-1}$ in Sarajevo, Annual sum of precipitation has increased by more than 100 mm in Kaunas for a period of 30 years (1988-2017). The observed air temperature and precipitation change patterns in Lithuania and B&H are consistent with the predominant trends in other areas of East Europe (Bukantis A. & Rimkus E., 2005; Bukantis ArūNas & Rimkus Egidijus, 2005; Jaagus *et al.*, 2009; Branković *et al.*, 2013; Burić *et al.*, 2013; Tripolskaja & Pirogovskaja, 2013; Unkasevic &

Tosic, 2013; Rutgersson *et al.*, 2014) and with trends observed globally (Kharin *et al.*, 2013; Trenberth *et al.*, 2013; Jacob *et al.*, 2018; Popov *et al.*, 2018).

The annual increasing $ET_0$ trends between Kaunas and Sarajevo are similar, they ranged from 1.503 mm year$^{-1}$ to 1.450 mm year$^{-1}$. However, the annual increasing trend of *AET* has a lot higher rate in Kaunas than Sarajevo. The magnitude of increasing trends of annual *AET* varied from 3.355 mm year$^{-1}$ in Kaunas to 0.965 mm year$^{-1}$ in Sarajevo. Since *AET* can be considered as the measure of agricultural water productivity, obtained results indicate an improvement of general conditions for agricultural production. This is especially true for the study location in Lithuania (Kaunas). This indicates that the consequences of climate change are predominantly, but not exclusively negative and dependent on geographical location. Climate change may have a positive effect on the yield and quality of winter crops due to the extended growing period in northern Europe (Radusin *et al.*, 2016; Jacob *et al.*, 2018). However, the rest of Europe, especially the Mediterranean region, will mostly be negatively affected (Behrens *et al.*, 2010).

A negative trend in *TRO* was found for Kaunas, which decreased by 0.480 mm each year, and positive in Sarajevo, with an increase of 0.492 mm each year. Furthermore, there is a decreasing trend in the amount of snow in both locations, from -2.114 mm year$^{-1}$ to 0.656 mm year$^{-1}$. Such runoff and snow amount trends have already been recorded in Lithuania (Stonevičius *et al.*, 2014) and they are results of changes in influencing climatic elements - temperature and precipitation (Bukantis ArūNas & Rimkus Egidijus, 2005).

Soil moisture deficit occurs when the demand for water ($ET_0$) exceeds that which is actually available from the precipitation (*P*) or reserved in the soil (Žurovec & Čadro, 2015). In terms of *SMD*, two analyzed locations differ. The increasing trend in the *SMD* was found for Sarajevo (0.485 mm year$^{-1}$) and decreasing for Kaunas (-2.114 mm year$^{-1}$). Presence of positive trend in *SMD* causing more severe long-lasting droughts and yield reduction was found all over B&H (Vlahinić, 2000; Alagić, 2003; Žurovec & Čadro, 2010; Čadro Sabrija *et al.*, 2017).

Linear trends, correlation coefficient (*R*) and coefficient of determination ($R^2$) of annual air temperature (*T*), precipitation (*P*), reference evapotranspiration ($ET_0$), actual evapotranspiration (*AET*), soil moisture deficit (*SMD*) and total runoff (*TRO*) for the both analyzed locations are presented in Table 3. and Figure 2. The values of R and $R^2$ for all analyzed parameters are generally lower for Sarajevo than Kaunas. This is the result of much higher variations in the annual values of all the obtained parameters in Sarajevo. Variations can be clearly seen in Figure 2, or by comparing the standard deviation (SD) and coefficient of variation (CV) between these two locations (Table 2). The annual amount of precipitation, *TRO*, *SMD* and snow showed the highest variations. Such variations indicate extreme weather conditions, shifting between years with extremely high levels of precipitation, causing soil erosion, landslides and floods, and years with low precipitation causing prolonged droughts and serious yield declines. Agriculture is one of the most important socioeconomic sectors in B&H, but at same time a sector mostly affected by climate change (Žurovec *et al.*, 2015).

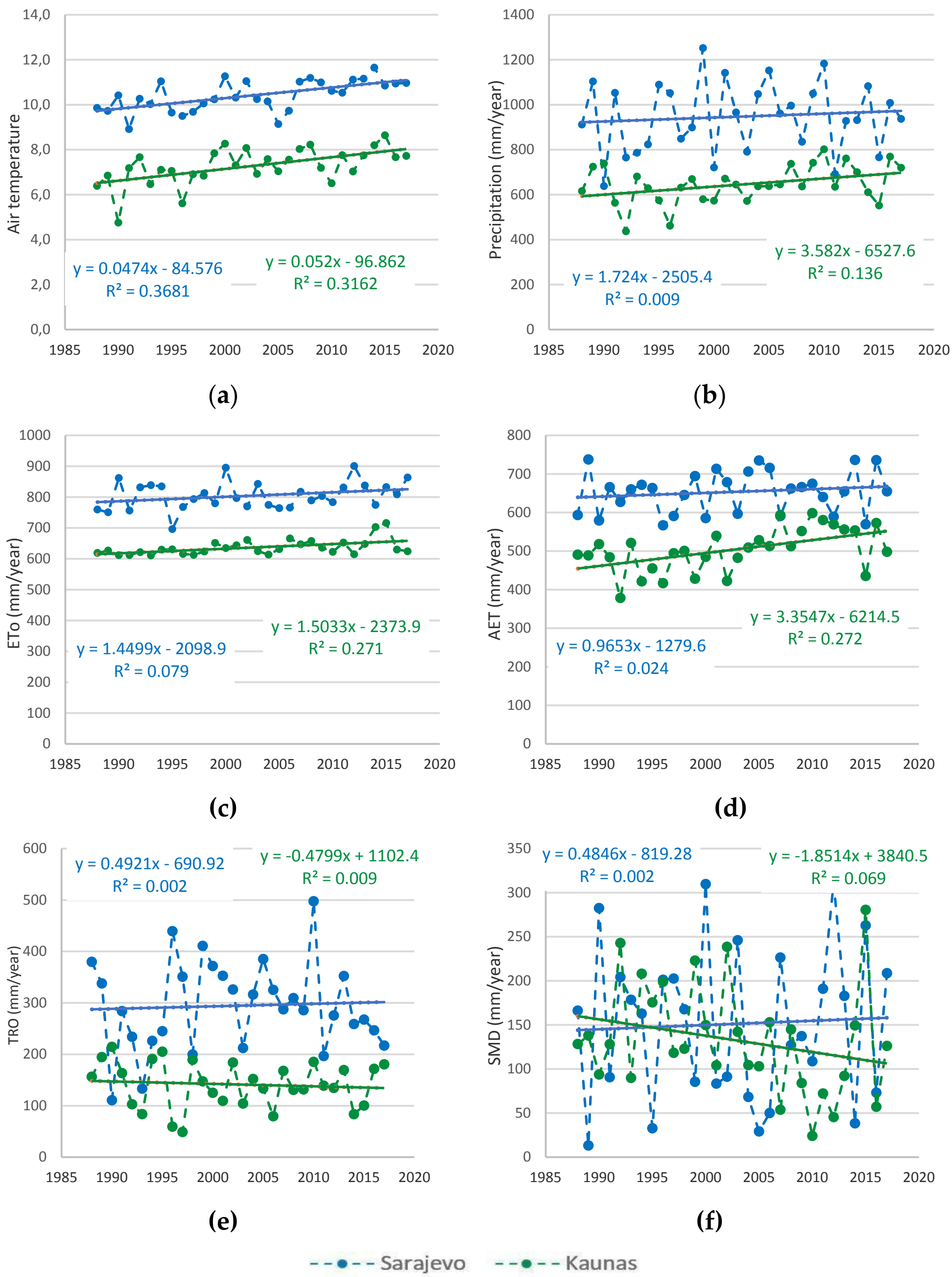


**Figure 2:** Linear trends, correlation coefficient ($R$) and coefficient of determination ($R^2$) of annual air temperature (a), precipitation (b), reference evapotranspiration (c), actual evapotranspiration (d), soil moisture deficit (e), and total runoff (f) are presented for the Kaunas and Sarajevo weather stations for the period 1988 – 2017.

There is an obvious need for planning and implementation of appropriate measures of adaptation to climate change (Zurovec *et al.*, 2017; Assan *et al.*, 2018). In the first place developing of the appropriate irrigation systems should be a preferred option, as well as the development and introduction of varieties resistant to dry climate conditions. Irrigation will certainly be one of the key mechanisms for adaptation. However, flood protection and drainage of excess waters from the plot, and in general regulation of water and air regime is a matter of priority for further development of the agricultural sector (Radusin *et al.*, 2016).

## CONCLUSIONS

Linear regression was applied to analyze annual trends in the air temperature, precipitation, FAO-56 PM reference evapotranspiration and water balance components (actual evapotranspiration, total runoff, soil moisture deficit and amount of snow). Monthly weather data from two humid weather stations, Kaunas (Lithuania) and Sarajevo (Bosnia and Herzegovina), for the time period of 30 years (1988 – 2017) were used. The main purpose was to determine and compare the severity of changes in mean annual water balance components for two humid climatic zones.

Results indicated that climate change differently affects the water balance of these two humid areas. Increasing trends in $T$, $P$, $ET_0$ and $AET$ series and decreasing trend in the amount of the snow were found. Both locations are showing a positive trend of reference evapotranspiration, with an increase of 1.450 mm year$^{-1}$ to 1.503 mm year$^{-1}$. Increasing trends of annual $AET$ varied from 3.355 mm year$^{-1}$ in Kaunas to 0.965 mm year$^{-1}$ in Sarajevo. However, total runoff and soil moisture deficit are decreasing in Kaunas (-0.480 mm and -2.114 mm year$^{-1}$, respectively) and increasing in Sarajevo (0.492 mm and 0.485 mm year$^{-1}$, respectively). In general, results showed an increase in irrigation water demand for agricultural crops in Sarajevo (Bosnia and Herzegovina) and decrease in Kaunas (Lithuania).

Compared to Lithuania, location in B&H is highly vulnerable to climate change. High sensitivity is the result of large variations and positive trends of almost all analyzed parameters. The annual amount of precipitation, total runoff, soil moisture deficit and snow showed the highest variations (16.54 – 56.70 %). In comparison, same parameters for the area of Lithuania (Kaunas), indicate that climate change may have some positive effects on general conditions for agricultural production, such as increase of precipitation and actual evapotranspiration, and the decline in soil moisture deficit.

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