DOI: 10.17707/AgricultForest.65.3.02

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CHANGES IN THE WATER BALANCE OF BOSNIA AND HERZEGOVINA AS A RESULT OF CLIMATE CHANGE

SUMMARY

The analysis of meteorological data from the period 1961–2014 show the rise in the mean annual temperature in the entire territory of Bosnia and Herzegovina. The changes are more pronounced in the central – hilly part of the country. The increase in annual air temperature ranges from 0.4 to 1.0°C per decade, whereas temperature increases during vegetation period were up to 1.2°C per decade. Additionally, increases in air temperature over the last fourteen years are even more pronounced. Changed distribution of precipitation, significant variations and the increasing soil moisture deficit during vegetation period (April – September) are also evident in Bosnia and Herzegovina. The increase in air temperature combined with changes in the distribution of precipitation has resulted in a change of evapotranspiration and annual water balance. The main objective of this study was to determine and compare the severity of changes in mean annual water balance components between different regions in Bosnia and Herzegovina. Monthly weather data from 26 weather stations in Bosnia and Herzegovina, for the time period of 50 years (1967 – 2016) were used to determine and analyze impact of climate change on the following water balance components: temperature, precipitation, reference evapotranspiration, actual evapotranspiration, total runoff, soil moisture deficit and amount of snow. The results indicate that climate change has a substantial effect on the all water balance components. Air temperature (0.21 - 0.7 ^{o}C per decade), reference evapotranspiration (0.61 - 42.81 mm per decade) and soil moisture deficit (1.35 - 27.71 mm per decade) show an increasing trend over the entire territory of Bosnia and Herzegovina with the strongest increase in the north-west part of the country.

Keywords: climate change, soil water balance, soil moisture deficit, evapotranspiration

INTRODUCTION

Based on the analysis of meteorological data from the period 1961–2016, the mean annual temperature is showing a continuous rise on the entire territory of Bosnia and Herzegovina (BiH). The increase in annual air temperature ranges

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Paper was presented at the 10th CASEE Conference, Sarajevo 2019
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

from 0.4 to 1.0°C, with more pronounced changes in the continental part (Radusin et al., 2016). There is a positive trend in the mean (0.2-0.5 ^{o}C per decade), the maximum (0.3-0.6 ^{o}C per decade) and the minimum temperatures (0.3-0.5 ^{o}C per decade) throughout the year (Popov et al., 2018b; Trbic et al., 2017), with a significant increase in the frequency of warm extremes (Popov et al., 2018a).

The average annual precipitation is 1,255 mm and it is characterized with the high variation in spatial distribution, which ranges between 706 mm to 3,259 mm (Drešković & Mirić, 2013). In the period 1961–2016 most of the territory of BiH is characterized by a slight increase in the amount of annual sum of precipitation (Popov et al., 2019; Radusin et al., 2016; Vucijak et al., 2014). However, due to the increased intensity and variability of precipitation as well as the increased share of heavy rains in the total amount of rainfall, there is the increased risk of flooding, landslides, hail and soil erosion especially in the north-eastern part of BiH (Radusin et al., 2016). Thus, the most vulnerable municipalities to climate change in BiH can be found in this area (Zurovec et al., 2017).

The changes in the air temperature and the amount of precipitation results in changes in evapotranspiration (Cadro et al., 2019; Cadro et al., 2017) and the values of different soil water balance elements (Giugliano et al., 2013). Understanding the spatial and temporal variability of soil water balance elements such as evapotranspiration, water surplus, runoff, soil moisture deficit is essential for many hydrological, agricultural and environmental models (Guler, 2014; Huntington, 2006), especially in assessing regional climate change scenarios and natural hazards (landslides, floods, droughts, wildfires, disease epidemics, insect/animal plagues).

Changes in the soil water balance in the territory of BiH are until now analyzed only for a specific area using a smaller number of weather stations. Increase of potential evapotranspiration (PET) and soil moisture deficit (SMD) was found for Banja Luka, Tuzla, Zenica and Mostar (Čadro et al., 2016). Increasing trends in reference evapotranspiration, runoff and soil moisture deficit and decreasing trend in the amount of the snow were found for the Sarajevo located in central part of BiH (Čadro et al., 2018; Miseckaite et al., 2018).

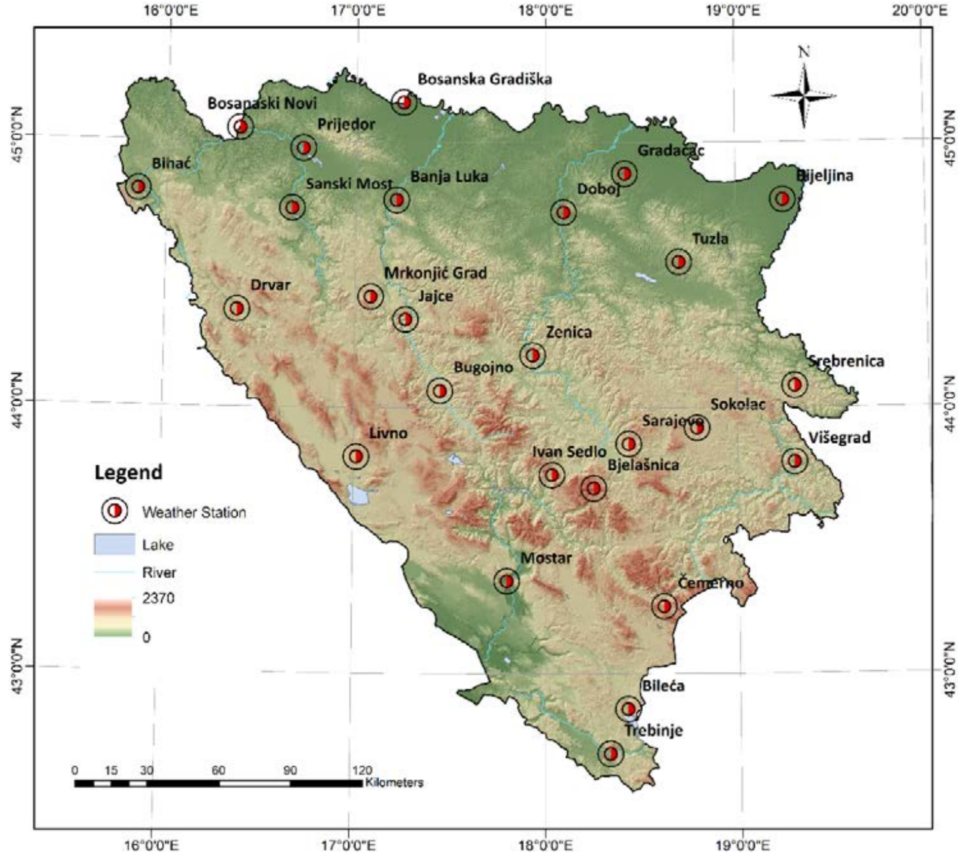
The main challenges when performing this kind of research in BiH is limited data availability, discontinuity of data records and low station density (Cadro et al., 2019) that combined with complex interactions between the nature of the climate parameters and topographical features (Mardikis et al., 2005) especially in areas with the complex terrain such as BiH, additionally makes it difficult to obtain precise results. For all these reasons, when analyzing soil water balance, it is necessary to include as many weather stations (WS) as possible.

Based on the above, the main objective of this study was a precise calculation of all the soil water balance elements in BiH and analysis of their changes in time as a result of climate change taken into consideration long period of time and as many weather stations as possible.

MATERIAL AND METHODS

Study area and data availability

BiH is a country located in south-eastern Europe. It covers an area of around 51,209 km², that is equivalent to 0.5 % of the Europe. Based on the climate regionalization, temperate warm and humid climate has a dominant surface share (64.62 %), followed by *Df* - humid boreal (24.53 %), and Mediterranean climates (10.71 %) (Drešković & Mirić, 2013). The land is mainly hilly to mountainous, with 5% is lowlands, 24% hills, 42% mountains, and 29% of karst area (Čadro et al., 2012; Radusin et al., 2016; Žurovec et al., 2017).



Map 1. Location of 26 selected weather stations in BiH.

Twenty-six weather stations (WS), relatively regularly distributed thought BiH, were selected for this study (Table 1, Map 1). These WS are collecting all daily climate data required for evapotranspiration and soil water balance calculation and almost all have historical data records for a period of at least 30 years (360 months). Exception are Bosanska Gradiška (240), Trebinje (192), Srebrenica (216), Višegrad (228) and Mrkonjić Grad (264) that are included for a better spatial coverage.

Daily climatic data, including mean (T_{mean}), maximum (T_{max}) and minimum (T_{min}) air temperature, sum of precipitation (P), mean relative humidity (RH), wind speed (u) and sunshine hours (n) for the period 1967 - 2016 (50 years) were collected and averaged over each month. Data were provided by the *Federal Hydrometeorological Institute Sarajevo* and the *Republic Hydrometeorological Service of the Republic of Srpska*. Basic location characteristics and number of months used for each location are shown in Table 1.

Table 1. Location, observation periods and climate characteristics of 26 selected weather stations (WS) in BiH.

WS	z (m)	^oE	^oN	Time period	P (mm)	T_{mean} (°C)	T_{max} (°C)	T_{min} (°C)	RH (%)	u (m s^{-1})	n (h)
Bijeljina	90	19.250	44.783	1967-2016	756	11.56	17.50	6.41	79	1.23	4.69
Banja Luka	160	17.216	44.783	1967-2016	1043	11.29	17.34	5.89	76	1.51	5.01
Doboj	147	18.095	44.739	1967-2016	931	11.12	17.05	6.16	79	1.41	4.55
Gradačac	225	18.417	44.883	1981-2016	851	11.90	16.79	7.63	74	2.35	5.59
Bosanska G.	94	17.250	45.150	1986-2016	800	12.30	17.72	7.44	74	2.15	-
Bosanaski N.	134	16.384	45.051	1967-2016	1027	10.72	16.66	5.64	78	1.66	-
Prijedor	141	16.721	44.976	1967-2016	960	11.28	16.82	6.19	77	1.1	5.02
Tuzla	305	18.700	44.550	1967-2016	911	10.46	16.80	5.47	76	1.19	4.9
Bileća	443	18.425	42.868	1967-2016	1642	12.24	18.10	6.82	72	1.77	6.52
Mostar	99	17.800	43.350	1967-2016	1474	15.03	20.39	10.48	62	2.51	6.42
Trebinje	280	18.333	42.700	1986-2016	1728	14.48	19.84	10.48	62	-	-
Bihać	246	15.850	44.816	1967-2016	1341	11.10	16.49	6.03	74	1.65	5.04
Drvar	485	16.383	44.367	1967-2016	1134	9.56	16.28	3.71	77	2.98	5.01
Livno	724	17.016	43.816	1967-2016	1147	9.46	15.77	3.54	71	1.71	6.32
Sanski Most	158	16.666	44.750	1967-2016	1044	10.62	17.07	5.16	79	1.85	5.07
Sokolac	913	18.789	43.926	1967-2016	867	7.10	13.21	1.13	79	1.63	4.9
Srebrenica	377	19.300	44.083	1967-2016	985	10.41	15.72	5.77	80	1.2	3.9
Višegrad	416	19.295	43.796	1986-2016	751	11.14	18.26	5.65	76	1.44	-
Čemerno	1304	18.612	43.254	1967-2016	1790	6.21	10.41	2.79	79	2.52	5.35
Ivan Sedlo	968	18.033	43.750	1967-2016	1471	7.58	12.22	3.7	78	2.16	4.5
Jajce	440	17.267	44.333	1967-2016	907	10.27	16.06	4.9	77	1.56	4.05
Bugojno	562	17.450	44.066	1967-2016	839	9.37	15.7	3.79	75	1.99	4.61
Bjelašnica	2067	18.250	43.700	1967-2016	1233	1.49	3.68	-0.66	84	7.87	4.77
Mrkonjić G.	575	17.084	44.419	1986-2016	1053	9.71	15.5	5.06	77	2.27	4.54
Sarajevo	630	18.433	43.866	1967-2016	938	10.01	15.62	5.31	71	1.63	4.96
Zenica	344	17.933	44.200	1967-2016	812	10.68	17.13	5.38	74	1.54	4.48

Reference evapotranspiration (ET_o)

Reference evapotranspiration (ET_0) required for the soil water balance calculation, was calculated using standard FAO-PM equation, given by (Allen et al., 1998):

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

where ET_o 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, Δ the slope of the vapor pressure curve (kPa ^{o}C^{-1}) and γ is the psychrometric constant (kPa ^{o}C^{-1}).

All necessary parameters required for calculation of ET_o where computed following the procedure developed in FAO-56 (Allen et al., 1998) via *REF-ET: reference Evapotranspiration Calculator* (Allen & Zhenguli, 2016) software.

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

$$R_s = (a_s + b_s \cdot \mathrm{n/N}) \cdot R_a \tag{2}$$

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 (δ) 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 four WS (Bosanska Gradiška, Bosanski Novi, Trebinje and Višegrad) where measured solar radiation data (R_s) or sunshine hours data were missing for a certain month, solar radiation was estimated using Hargreaves' formula (Hargreaves & Samani, 1985) (Eq. 3), as suggested in Allen et al. (1998):

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

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 (°C$^{-0.5}$). Value of k_{Rs} = 0.16 was used for Trebinje, k_{Rs} = 0.14 for Višegrad and Bosanski Novi and k_{Rs} = 0.13 for Bosanska Gradiška as suggested by Cadro et al. (2019) and Čadro et al. (2017a).

Actual vapor pressure (e_a) was derived from relative humidity data (Allen et al., 1998) as:

$$e_a = \frac{e^0(T_{min})\frac{RH\,max}{100} + e^0(T_{max})\frac{RH\,min}{100}}{2} \tag{4}$$

where e_a is actual vapor pressure (kPa), $e°(T_{min})$ saturation vapor pressure at daily minimum temperature (kPa), $e°(T_{max})$ saturation vapor pressure at daily maximum temperature (kPa), RH_{max} maximum relative humidity (%), RH_{min} minimum relative humidity (%). In the absence of relative humidity data, e_a was estimated by assuming that the dew pint temperature (T_{dew}) is close to daily minimum temperature (T_{min}) (Allen et al., 1998). When wind speed was not available, the average regional wind speed value was used.

Soil water balance

Monthly water balance was calculated by using Thornthwaite-Mather method (Thornthwaite & Mather, 1955; Thornthwaite & Mather, 1957) that was modified and later described in Dingman (2002). Except data on monthly precipitation (*P*) and evapotranspiration (ET_o) 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 it is regionaly (BiH, Serbia and Croatia) the most commonly used value (Šimunić, 2013; Vlahinić, 2004).

To detect the trends within time series of water balance components (annual precipitation - *P*, reference evapotranspiration - ET_0, actual evapotranspiration - *AET*, soil moisture deficit - *SMD*, total runoff – *TRO* and *SNOW*) parametric method of linear regression was used, as shown in following equation:

$$y = a + b \times x \tag{5}$$

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

The descriptive statistics (mean and CV) and the slope (*b*) for all analyzed climate and soil water balance elements (T_{mean}, *P*, ET_0, *AET*, *SMD*, *TRO* and

SNOW) at 26 selected WS for the period 1967 – 2016, are summarized in table 2, 3 and 4.

Table 2: Results for the statistical tests for the annual air temperature (T_{mean}) and sum of precipitation (*P*) - 26 weather stations (WS) in BiH, period 1967 – 2016.

Element	T_{mean}			*P*		
Weather station	Mean	*b*	CV	Mean	*b*	CV
Bijeljina	11.56	0.047	0.255	756	0.535	36.85
Banja Luka	11.29	0.049	0.249	1,042	-0.228	52.50
Doboj	11.12	0.038	0.211	931	2.555	53.77
Gradačac	12.05	0.070	0.272	840	1.465	48.78
Bosanska G.	12.24	0.063	0.224	799	2.111	52.92
Bosanaski Novi	10.72	0.043	0.248	1,027	0.690	49.42
Prijedor	11.28	0.039	0.255	947	-0.994	44.74
Tuzla	10.45	0.036	0.221	919	0.422	48.02
Bileća	12.18	0.021	0.167	1,658	0.733	99.06
Mostar	15.03	0.037	0.191	1,474	-1.021	95.06
Trebinje	14.95	0.037	0.150	1,747	-0.792	107.59
Bihać	11.10	0.036	0.215	1,341	2.804	59.67
Drvar	9.48	0.034	0.189	1,125	2.461	55.28
Livno	9.46	0.043	0.206	1,147	0.826	55.08
Sanski Most	10.62	0.036	0.204	1,045	0.507	45.71
Sokolac	6.89	0.046	0.241	854	3.406	42.08
Srebrenica	10.41	0.033	0.215	985	4.155	51.30
Višegrad	11.15	0.052	0.217	757	4.318	40.54
Čemerno	6.21	0.031	0.183	1,790	-1.914	92.46
Ivan Sedlo	7.57	0.028	0.184	1478	0.648	76.58
Jajce	10.16	0.028	0.177	909	-0.799	39.69
Bugojno	9.37	0.046	0.233	841	-0.382	35.75
Bjelašnica	1.49	0.023	0.154	1,228	10.093	81.96
Mrkonjić Grad	9.71	0.039	0.216	1,053	7.647	58.66
Sarajevo	10.01	0.037	0.202	937	0.824	41.05
Zenica	10.68	0.044	0.218	812	0.842	37.39
BiH	**10.28**	**0.040**	**0.211**	**1,094**	**1.574**	**57.77**

Note: *b* – slope (^{o}C year^{-1} and mm year^{-1}), CV – Coefficient of variation (%).

The mean annual air temperature in BiH is 10.20 ^{o}C, ranging from 1.49 ^{0}C (WS Bjelašnica) to 15.03 ^{o}C (WS Mostar). The T_{mean} shows increasing trends at all WS, ranging from 0.021 ^{o}C year^{-1} (WS Bileća) to 0.070 ^{o}C year^{-1} (WS Gradačac). In general, the entire territory of BiH shows worming trend of 0.4 ^{o}C per decade (Table 2). In addition, increases in air temperature over the last ten years are even more pronounced (Radusin et al., 2016). Trend intensity differ between country regions. It is highest in the north (0.036-0.070 °C year^{-1}) and lowest in the south - Mediterranean part of the country (0.021-0.037 °C year^{-1}). The highest variations in annual temperature are determined for the 3 WS (Bijeljina, Gradačac and Prijedor), all located at the north of BiH.

Mean annual precipitation in BiH is 1,094 mm, ranging from 756 mm (WS Bijeljina) to 1,747 mm (WS Trebinje). Trends of the annual amount of precipitation (*P*) for majority of analyzed WS are increasing (0.507-10.093 mm year^{-1}). However, there is few locations (Mostar, Trebinje, Bugojno, Mrkonjić Grad), especially in Hercegovina (south BiH), that are showing decreasing trend of precipitation, ranging up to -1.914 mm per year. Similarly, in other studies decrease in total precipitation and the number of days with precipitation occurrence was found, whereas the duration of dry periods is prolonged over the entire East Herzegovina region (Popov et al., 2019).

On the other hand, the highest increasing trend is found for mountain WS Bjelašnica, ranging 10.093 mm of precipitation per year, or a 100 mm over a period of 10 years. The highest variations in annual precipitation was found for WS in south (Trebinje) and WS at higher altitudes (Bjelašnica and Čemerono). Also, as confirmed with other studies, trends are not spatially and temporally coherent (Popov et al., 2017). For the most of WS changes in annual precipitation are not significant, they are more pronounced by seasons (Radusin et al., 2016), especially during the last decade (2007-2016), resulting in increased frequency of months with extreme precipitation (Popov et al., 2017), catastrophic floods landslides and soil erosion.

The air temperature and precipitation change patterns in BiH are consistent with the predominant trends in other areas of East Europe (Branković et al., 2013; Bukantis & Rimkus, 2005a; Bukantis & Rimkus, 2005b; Burić et al., 2013; Jaagus et al., 2009; Rutgersson et al., 2014; Tripolskaja & Pirogovskaja, 2013; Unkasevic & Tosic, 2013) and with trends observed globally (Jacob et al., 2018; Kharin et al., 2013; Popov et al., 2018b; Trenberth et al., 2013).

Based on 26 analyzed WS, the mean ET_0 for BiH is 780 mm, while *AET* that beside climate conditions depend on the soil moisture, is 140 mm lower, or 640 mm in average, the difference represents *SMD* (Table 3). In study that included 108 WS in BiH and similar methodology, mean annual *SMD* of 143 mm was found (Cadro et al., 2019), the small difference in *SMD* confirms the accuracy of the data obtained in this study. Similarly, to the T_{mean} reference evapotranspiration (ET_0) shows increasing trends at all WS, ranging from 0.061 mm year^{-1} (WS Trebinje) to 4.281 mm year^{-1} (WS Višegrad).

In general, for the entire territory of BiH increasing trend of ET_0 is 20.59 mm per decade (Table 3). The highest trend is found for the area from Drvar in the west to Banja Luka at the north of the country, as well as the area around Višegrad in the east.

Table 3. Results for the statistical tests for the annual reference evapotranspiration (ET_0), actual evapotranspiration (*AET*) and soil moisture deficit (*SMD*) - 26 weather stations (WS) in BiH, period 1967 – 2016.

Element	ET_0			*AET*			*SMD*		
Weather station	Mean	*b*	CV	Mean	*b*	CV	Mean	*b*	CV
Bijeljina	714	0.549	11.91	578	-0.102	19.50	136	0.651	22.56
Banja Luka	785	3.242	17.86	667	0.502	16.03	118	2.739	25.93
Doboj	725	1.308	13.53	624	-0.025	15.22	101	1.333	21.60
Gradačac	860	2.897	17.32	645	1.367	20.99	215	1.529	32.61
Bosanska G.	798	2.278	17.27	600	1.182	21.52	198	1.096	32.00
Bosanaski N.	763	1.610	15.46	650	-0.195	17.11	113	1.804	23.61
Prijedor	668	3.034	20.01	582	0.597	13.01	87	2.438	21.82
Tuzla	730	1.443	12.54	637	0.195	15.62	92	1.249	22.25
Bileća	896	3.509	20.16	694	0.738	21.52	202	2.771	29.70
Mostar	1,086	1.640	19.61	770	-0.597	24.96	316	2.237	36.94
Trebinje	1,190	0.061	15.52	854	-1.900	26.59	336	1.961	37.05
Bihać	782	1.734	12.99	699	0.044	14.13	83	1.690	19.49
Drvar	827	3.947	23.26	694	2.084	19.49	133	1.863	28.35
Livno	809	0.826	12.13	640	-0.161	16.44	168	1.369	21.91
Sanski Most	777	1.652	14.04	668	-0.278	13.07	109	1.931	21.75
Sokolac	680	1.946	17.23	574	1.946	15.18	106	1.361	20.10
Srebrenica	675	1.780	18.32	617	0.531	15.38	58	1.248	19.83
Višegrad	843	4.281	15.20	614	4.056	25.39	229	0.225	28.81
Čemerno	695	0.664	12.61	607	0.028	12.05	88	0.636	14.20
Ivan Sedlo	694	2.029	14.65	626	1.450	13.03	69	0.579	16.45
Jajce	717	1.805	13.25	623	0.977	15.56	94	0.828	19.96
Bugojno	766	1.597	13.51	620	0.672	14.12	146	0.925	22.13
Bjelašnica	516	1.570	16.94	441	1.435	11.87	75	0.135	11.70
Mrkonjić Grad	749	3.516	17.88	653	3.530	16.16	96	-0.014	19.74
Sarajevo	780	2.009	13.18	641	0.953	16.05	139	1.056	22.45
Zenica	777	2.617	19.91	614	0.743	17.86	163	1.874	29.59
BiH	**780**	**2.059**	**16.01**	**640**	**0.760**	**17.22**	**141**	**1.366**	**23.94**

Note: *b* – slope (mm $year^{-1}$), CV – Coefficient of variation (%).

AET trend has a similar spatial distribution but higher variation than ET_0 trend. For the south, north-west and north-east part decreasing (from -0.025 to -1.900 mm $year^{-1}$) or low increasing trend (0.028-0.597 mm $year^{-1}$) was found. While for the central part, from Drvar to Višegrad, or the mountainous region of the country (Dinarides), high increasing trend were recorded (0.597-4.054 mm $year^{-1}$). *AET* can be a measure of agricultural water productivity, these results indicate an improvement of general conditions for agricultural production in the central - mountainous region of BiH. Thus, Climate change may have a positive effect on the yield in this area (Čadro et al., 2018; Radusin et al., 2016), and in same time negative effect on the rest of the country (north and south). Such positive effect also found in similar studies, especially for the northern Europe (Jacob et al., 2018), while the rest of Europe, especially the Mediterranean region, will mostly be negatively affected (Behrens et al., 2010).

Table 4. Results for the statistical tests for the annual total runoff (*TRO*) and amount of snow soil moisture deficit (*SNOW*) - 26 weather stations (WS) in BiH, period 1967 – 2016.

Element	*TRO*			*SNOW*		
Weather station	Mean	*b*	CV	Mean	*b*	CV
Bijeljina	178	0.922	18.20	118	-0.920	15.62
Banja Luka	377	-0.497	33.80	170	-1.696	23.25
Doboj	308	2.871	34.97	150	-0.932	19.53
Gradačac	195	1.142	22.79	115	-2.471	17.32
Bosanska Gradiška	207	0.230	32.47	115	-2.469	16.15
Bosanaski Novi	380	0.784	33.85	176	-1.590	22.74
Prijedor	368	-1.545	30.02	163	-1.922	20.27
Tuzla	280	0.374	30.06	157	-1.171	20.66
Bileća	963	-0.079	79.66	201	-0.607	32.44
Mostar	711	-0.522	74.67	40	-1.050	13.83
Trebinje	885	5.361	78.62	46	-1.363	17.36
Bihać	640	2.559	45.85	216	-1.035	31.19
Drvar	432	-0.395	42.87	240	-2.295	27.54
Livno	511	0.926	42.94	298	-2.366	36.73
Sanski Most	379	0.950	30.17	180	-0.979	22.67
Sokolac	285	1.560	24.22	266	-0.409	19.42
Srebrenica	361	3.621	36.50	157	-0.965	22.78
Višegrad	149	-0.349	18.04	133	-1.042	17.24
Čemerno	1,190	-1.906	86.51	820	-3.545	62.67
Ivan Sedlo	855	-0.770	61.39	520	-2.284	49.87
Jajce	286	-2.153	26.77	163	-2.363	20.54
Bugojno	223	-1.115	22.85	184	-1.848	22.29
Bjelašnica	783	8.770	75.13	697	6.611	55.53
Mrkonjić Grad	405	4.441	42.30	216	-0.418	30.87
Sarajevo	299	-0.165	26.14	204	-0.917	25.42
Zenica	200	0.196	19.96	148	-1.010	18.23
BiH	**456**	**0.970**	**41.18**	**227**	**-1.194**	**26.24**

Note: *b* – slope (mm year^{-1}), CV – Coefficient of variation (%).

SMD is result of difference between evapotranspiration and available soil moisture (Kos et al., 1993; Žurovec, 2012). The *SMD* shows increasing trends at all WS (0.135-2.771 mm $year^{-1}$) except Mrkonjić Grad (-0,014 mm $year^{-1}$). In average the entire BiH territory shows the increasing trend in *SMD*, ranging 13.66 mm per decade (Table 3) that will in the future cause more severe long-lasting and extreme droughts and higher yield reduction. The increasing trends and year to year variations are high at the north-west (1.096-2.739 mm $year^{-1}$) and south regions (1.961-2.771 mm $year^{-1}$), while the central and east parts (-0.014-1.361 mm $year^{-1}$) of BiH are less affected by the changes in *SMD*. These results are in line with previous studies of water scarcity and vulnerability to climate change all over BiH and region (Cindrić et al., 2010; Čadro et al., 2017b; Čadro et al., 2016; Čustović et al., 2015; Hodžić et al., 2013; Miseckaite & Čadro, 2018; Miseckaite et al., 2018; Perčec Tadić et al., 2014; Vlahinić et al., 2006; Whan et al., 2015; Žurovec & Čadro, 2015; Žurovec et al., 2017).

The mean *TRO* for BiH is 465 mm, the highest was found for the WS Čemerno (1190 mm) and the lowest, almost ten time smaller, for the WS Višegrad (149 mm). It is interesting to note that these locations are relatively close to each other (Map 1), and this confirms the statement of the complexity of natural conditions in BiH and the need for as many WS as possible. *TRO* trends are not spatially coherent. The high variations in trend, from decreasing (-2.153 mm $year^{-1}$) to increasing (8.770 mm $year^{-1}$) trends were found. In average for BiH there a low positive trend of *TRO*, which amounts 9.70 mm per decade.

The average amount of snow for BiH is 227 mm, and this climate element, comparing to all others, shows decreasing trend for all WS. Exception is mountain WS Bjelašnica (6.611 mm $year^{-1}$). The average decreasing trend of snow for BiH is -11.94 mm per ten years and the highest decreasing trend was found for WS Čemerno (-35.45 mm per decade). Also, the highest variations were found for mountain WS, Čemerno, Bjelašnica and Ivan Sedlo.

CONCLUSIONS

Linear regression was applied to determine soil water balance response to climate change in BiH. The air temperature, precipitation, FAO-56 PM reference evapotranspiration and water balance components: actual evapotranspiration, total runoff, soil moisture deficit and amount of snow trends were analyzed. Monthly weather data from 26 weather stations, for the time period of 50 years (1967 – 2016) were used.

If observed on the level of BiH, the results obtained show increasing trends in *T, P*, ET_0, *AET, SMD* and *TRO* series and decreasing trend in the amount of the *SNOW*. However, at the regional level, there are a lot of differences between climate elements trends. This is especially evident for the *P*, *AET* and *TRO*.

At the regional level, as the result of climate change, the highest increase in dry conditions was found for the north-west BiH (Bosanski Novi, Prijedor, Sanski Most, Banja Luka, Gradačac), where high increase in temperature (0.36 – 0.70 ^{o}C per decade) and *SMD* (18.04 – 27.39 mm per decade) trends were identified, while the trend of *AET* is showing decline for the most of weather stations. Similarly, high increase of *SMD* and decline of *AET* was found in the south, for the weather stations Mostar, Bileća and Trebinje (19.61 – 27.71 mm per decade), however, there the intensity of the temperature increase is lower (0.21 – 0.37 ^{o}C per decade).

When it comes to surplus, the biggest changes or the highest increasing trends are in the area of Bjelašnica, Trebinje and Drina and Bosna river basins. Area already affected by heavy rains cosign soil erosion, landslides and floods (2010, 2014, 2019). In same time, increasing trends of *AET* are indicating an improvement of general conditions for agricultural production in the central - hilly region of BiH, from Drvar in the west to Višegrad in the east.

Based on these results, priority areas for the regionally specific climate change adaptation measures, protection from natural hazards (drought, floods, landslides) as well as actions for the disaster risk reduction could be identified.

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