Impact of Climate Change on the Soil Water Balance Components in the Area of Sanski Most (Bosnia and Herzegovina)

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Abstract. Given that global climate change affects the agricultural sector, often negatively affecting yields and food quality, it is essential to understand these impacts at the local level. The area of Sanski Most belongs to the Peripannon macroregion and it is located in the northwestern part of Bosnia and Herzegovina, where agriculture represents one of the most important economic sectors. Therefore, it is essential to conduct a detailed analysis of the agroclimatic conditions and soil water balance to determine the current situation and adapt agriculture and society to the coming changes. The impact of climate change was analyzed by observing two climate periods, namely the reference climate period (1961–1990) and the current climate period (1991–2020). Comparing these two clime periods an increase in the annual amount of precipitation by 38 mm was found. Although there is a positive trend at the year's level, it is negative during the summer months (−14.73 mm per decade), when the plant needs water the most. Also, the mean air temperature shows a positive trend in all seasons, with the most significant increase in the summer months (0.49 °C per decade). In summer, the water deficit in the soil becomes more and more present; that is, the need for irrigation increases. The difference in the average amount of soil water deficit between the two climatic periods is 48 mm, with a positive trend of 14.49 mm per decade. Also, one of the more visible differences is the increase in reference evapotranspiration (ET_0), which increased by 50 mm between these two climatic periods.

Keywords: Climate change · agriculture · soil water balance · BiH

1 Introduction

Bosnia and Herzegovina (BiH) can be considered as a country rich in water, but also among the countries with a wide range of water-related problems, especially in the field of agriculture [1]. In such conditions, sustainable development cannot be achieved without the application of sustainable water management in agriculture, strengthening the capacities of all actors in the sector, implementing and improving the existing legislative framework and applying innovative solutions and tools that belong to the domain of smart

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technologies [1–6]. Regarding climate change vulnerability, most vulnerable municipalities in BiH are located across the north, with a gradual decrease in vulnerability towards the central, north, and east of the country.

The area of Sanski Most is located in the northwestern part of BiH, from a macro-regional point of view it belongs to the Peripannon macro-region, while from a meso-regional point it belongs to the Bosnian Krajina meso-region [7].

The city of Sanski Most has an area of 12.90 km^2, while the municipality size is 781.17 km^2 [8]. The relief of Sanski Most is complex, abounding in predominantly hilly areas, with a plain along the Sana River, as well as high mountains: Grmeč (highest, 1500 m.a.s.l.), Mrežnica, Čelić kosa, Mulež and Behramaginica. The altitude of the urban part of the municipality is 160 m, and the average altitude for populated places is 500 m [7, 9]. Sanski Most is located in the area of continental climate, according to the Köppen-Geiger climate classification [10] in type Cfb x"s, which represents temperate warm and humid climates [11].

The municipality has 1,238 agricultural holdings in its register, and 75 registered tradesmen are engaged in agricultural production and contribute to the development of the Sana municipality [9, 12].

This area has very favorable conditions for the development of intensive agriculture, both in the plains in the Sana river valley from 150 to 250 m.a.s.l. with the construction of hydro-melioration systems (drainage and irrigation), as well as at hills of up to 500 m, which are suitable for the development of fruit growing [13]. There is a tradition of cattle breeding in this municipality [14], and some of the largest areas of arable land in BiH are also located here [7].

Although there are great potentials, especially for the development of agricultural production, according to the methodology and criteria for determining the level of development of municipalities in Federation of BiH (FBiH), Sanski Most belongs to the underdeveloped municipalities and is in 63rd place out of 79 municipalities in the FBiH [9]. Also, vulnerability index of this municipality is high [15]. Among other problems, the sensitivity to climate change, the effects of which are becoming more pronounced in the entire area of BiH, is highlighted [16–19].

Many studies carried out for the area of BiH agree on the present changes in the climate on an annual basis [17, 18, 20–22]. In such studies, the need to apply a local approach as well as a more detailed analyses at the changes within each season is often highlighted. Therefore, the goal of this research is to determine the impact of climate changes in different time periods (1961 – 1990 and 1991 – 2020) and seasons (winter, spring, summer, autumn, vegetation and annually) on the parameters of the agro-hydrological balance of the municipality area Sanski Most, to better understand the state of water resources in this area and conclude their more rational use with particular reference to agriculture as a water user.

2 Material and Methods

The research was carried out for the area of Sanski Most, town and municipality located in the Una-Sana Canton of the Federation of Bosnia and Herzegovina, BiH. Climate of this region is represented with one weather station (WS) located at the 158 m above sea level (44°45′N; 16°40′E). It is the only WS in this area that has long-term climate data and continuity as well as all the necessary data for the water balance calculation. Also, the station is located in an urban area, but in the immediate vicinity of agricultural areas, so the data from it can be considered representative.

Daily weather data, including mean (T_{mean}), maximum (T_{max}) and minimum (T_{min}) air temperature, sum of precipitation (P), mean relative humidity (RH_{mean}) and sunshine hours (n) for the period 1961 – 2020 were collected for this WS. Daily climate data were provided by the Federal Hydrometeorological Institute Sarajevo.

The 60-year period is divided into two climatic periods, (I) the climatic period of the reference normal: 1961–1990 and (II) the last climatological standard normal 1991–2020 [23].

Monthly water balance was calculated using the modified Thornthwaite-Mather method [24–26]. Thornthwaite-Mather method (TM) required data on monthly precipitation (P), average monthly air temperature (T), reference evapotranspiration (ET_0) and soil available water content ($SOIL_{max}$). The value $SOIL_{max}$ = 100 mm was used [27] since this is the most commonly used value for the types of soil that are found in the area of Sanski Most [28, 29].

Reference evapotranspiration (ET_0) was calculated using the standard FAO Penman-Monteith 56 equation [30]. All necessary parameters required for the calculation of ET_0 were computed following the procedure developed in FAO-56 [30] via REF-ET: reference Evapotranspiration Calculator [31] model.

All parameters are divided into climate parameters including precipitation (P), temperature (T), insolation (n), relative air humidity (RH_{mean}), amount of snow and water balance components (WB) including calculated values of soil moisture deficit (SMD), Total runoff (TRO), reference evapotranspiration (ET_0) and actual evapotranspiration (AET).

All data are presented by seasons, i.e. winter (XII–II), spring (III–V), summer (VI–VIII), autumn (IX–XI), vegetation (VI–IX) and the entire year. After the calculation of annual means (μ) and the standard deviation (σ) for all analysed water balance components, a statistical measure of the dispersion of data points and the coefficient of variation (CV) were calculated. To detect the trends (b) within time series of climate parameters and water balance components parametric method of linear regression was used.

3 Results and Discussion

3.1 Climate Parameters

Before the calculations of the components of the soil water balance were carried out, an analysis of all collected climate data was carried out. (P, T, n, RH_{mean}). The wind speed parameter was not analyzed because data for a large number of years were missing.

Precipitation (P). Precipitation is a very important climate parameter characterized by high spatial and temporal variability. The following table (Table 1) shows the obtained statistical data for the sum of precipitation by seasons, in vegetation and on an annual basis, for the entire analyzed period (1961–2020), as well as especially for I (1961–1990) and II (1991–2020) climatic period. Also, differences between these two analyzed periods were determined.

Table 1. Statistical data for precipitation sums (P in mm) in the area of Sanski Most period: 1961 – 2020.

Precipitation (mm)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	227	265	269	282	556	1042
	σ	70.3	75.2	96.3	85.5	136.4	154.9
	CV	31.0	28.4	35.8	30.4	24.5	14.9
	b	0.609	0.500	−1.473	1.076	0.031	0.712
I 1961–1990	x̄	214	262	293	254	557	1024
	σ	75.2	68.7	101.7	65.2	122.0	125.1
	CV	35.2	26.2	34.7	25.6	21.9	12.2
	b	−1.698	1.000	−1.388	−0.616	−0.759	−2.702
II 1991–2020	x̄	239	268	245	309	555	1061
	σ	63.7	82.3	86.6	95.2	151.5	180.2
	CV	26.6	30.7	34.9	30.8	27.3	17.0
	b	1.461	1.953	−0.789	−1.785	1.421	0.840
Difference	x̄	26	5	−48	55	−2	38
	σ	11.5	−13.5	16.2	−30.0	−29.4	−55.1
	CV	8.5	−4.5	−0.2	−5.1	−5.4	−4.8

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

In the area of Sanski Most, the annual average amount of precipitation was determined to be 1042 mm. Based on the analysis of two climatic periods, an increase in precipitation of 38 mm was determined, with a trend of 7.12 mm per decade. Of the total precipitation, 53% falls during the vegetation period (growing season), which indicates a uniform seasonal distribution of precipitation in this area (from 227 mm in winter to 282 mm in autumn). However, there is a negative trend of precipitation during the summer period for all three analyzed time periods, i.e. the sum of summer precipitation is 48 mm less in the second period. In contrast to the summer period, during winter and autumn there is an increase in the sum of average precipitation, which amounts to 26 mm (winter) and 55 mm (autumn). It is also important to emphasize that in the second climatic period we have a greater variation in precipitation during the vegetation period and annually.

Although the annual amount of precipitation in the area of Sanski Most is increasing, which is also visible in the positive trend in the II analyzed period, where during the vegetation season and annually we have a trend of increasing (14.21 and 8.40 mm per decade), during the summer months, when water is most needed for plant production, negative trend was determined (−7.89 mm per decade).

Previously, for the territory of Bosnia and Herzegovina, it was determined that the trends of annual, seasonal and monthly precipitation are weak and do not have statistical significance. [18]. The results obtained for the area of Sanski Most agree with the results of other researchers in BiH. So, in the period 1961–2017, the annual amount of precipitation showed a tendency to increase in most areas in the north of the territory (the Peripannon region) from 5.3 mm per decade in Sanski Most to 20.5 mm per decade in Doboj (except in Banja Luka, where the annual amount of precipitation decreased by – 4.4 mm per decade) [18, 32]. Also, in the research of Popov (2020), except for the summer period, positive trends were determined throughout the territory of BiH in the autumn season – from 2.0 mm per decade in Mostar to 12.5 mm per decade in Sanski Most [32, 33].

Air Temperature (T). Air temperature is a climatic parameter that provides energy for evaporation (E) and movement of water vapor from the evaporating surface and significantly affects the value of evapotranspiration (ET). Almost all ET calculation methods base their calculations on this climate parameter, and some methods only require the air temperature for the ET calculation [34].

The following table (Table 2) shows the obtained statistical data and differences between the average air temperature in the entire analyzed period (1961–2020), as well as for I (1961–1990) and II (1991–2020) climatic period. The data are presented by season (winter, spring, summer, autumn), vegetation (April – September) and annually.

In the area of Sanski Most, the determined annual average temperature is 10.64 °C. Based on the analysis of two climatic periods, an increase in temperature by 1.0 °C was determined, with a trend of 0.34 °C per decade.

Analyzing period II (1991–2020), we can conclude that the increase in air temperature is present in all seasons with the most pronounced increase in the winter (0.71 °C per decade) and summer (0.52 °C per decade) periods. It is interesting to note that in the second period the average air temperature during vegetation period increased by as much as 1.2 °C.

These results are in agreement with earlier research related to the territory of BiH. The increase in annual air temperature of BiH ranges from 0.4 to 1.0 °C, while the increase in temperature during the growing season (April–September) even reaches 1,2 °C [22]. These changes are more pronounced in the continental part [22], where the increase in temperatures is generally greatest during the summer, while in the autumn season the temperatures in most areas increased slightly. Analyzes of trends in average, maximum and minimum air temperatures show that the warming of the climate system is present throughout the territory of BiH [18, 21, 35, 36].

Table 2. Statistical data for the average air temperature (T in °C) in the area of Sanski Most period: 1961–2020.

Temperature (°C)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	1.14	10.78	19.75	10.91	16.82	10.64
	σ	1.66	1.08	1.15	1.09	0.89	0.80
	CV	145.62	10.05	5.84	10.04	5.32	7.56
	b	0.043	0.029	0.049	0.016	0.036	0.034
I 1961–1990	x̄	0.64	10.33	18.91	10.61	16.23	10.12
	σ	1.72	1.04	0.62	1.12	0.60	0.52
	CV	269.47	10.08	3.26	10.56	3.70	5.15
	b	0.072	0.008	0.007	−0.032	0.003	0.014
II 1991–2020	x̄	1.63	11.22	20.59	11.21	17.42	11.16
	σ	1.45	0.94	0.93	1.00	0.73	0.69
	CV	88.61	8.42	4.53	8.90	4.19	6.22
	b	0.071	0.044	0.052	0.038	0.047	0.051
Difference	x̄	1.0	0.9	1.7	0.6	1.2	1.0
	σ	0.3	0.1	−0.3	0.1	−0.1	−0.2
	CV	180.9	1.7	−1.3	1.7	−0.5	−1.1

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

Insolation (n). The most important factor in the formation of the climate of an area is solar radiation. Insolation represents the amount of energy that the earth receives with the sun's rays and is expressed in units of time, that is, in hours of sunshine during one day (h/day). Like other climatic parameters, insolation changes in space and time. The following table (Table 3) shows the obtained statistical data for the entire analyzed period (1961–2020), as well as separately for the I (1961–1990) and II (1991–2020) climatic periods. Also, differences between these two analyzed periods were determined.

In the area of Sanski Most, the average annual insolation was determined to be 5.12 h per day. Analyzing the first climatic period (1961–1990), the average value of insolation is 4.82 h per day, which is below the 60-year average, while the second period has an average of 5.42 h per day, that is, between the two climatic periods there was increase in the amount of sunshine, i.e. 0.6 h or there is 11% more sunshine in the area of Sanski Most.

Table 3. Statistical data for insolation (h per day) in the area of Sanski Most period: 1961–2020.

Insolation (h/day)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	2.37	5.65	8.31	4.13	7.21	5.12
	σ	0.67	0.76	0.91	0.56	0.69	0.53
	CV	28.27	13.37	11.00	13.57	9.62	10.31
	b	0.017	0.021	0.027	0.009	0.021	0.019
I 1961–1990	x̄	2.09	5.29	7.84	4.05	6.86	4.82
	σ	0.65	0.65	0.67	0.50	0.49	0.38
	CV	31.25	12.35	8.50	12.39	7.14	7.89
	b	0.026	0.005	−0.005	0.004	−0.002	0.008
II 1991–2020	x̄	2.64	6.01	8.79	4.21	7.57	5.42
	σ	0.57	0.69	0.89	0.61	0.69	0.49
	CV	21.61	11.40	10.07	14.51	9.17	8.98
	b	0.001	0.024	0.028	0.035	0.027	0.022
Difference	x̄	0.6	0.7	1.0	0.2	0.7	0.6
	σ	0.1	0.0	−0.2	−0.1	−0.2	−0.1
	CV	9.6	0.9	−1.6	−2.1	−2.0	−1.1

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

Similar to the temperature, in all seasons there is a noticeable trend of increasing the amount of sunshine and it ranges from 0.9 h to 0.27 h per day per decade. The most pronounced changes are in the summer period, when the differences between the two climatic periods amount to as much as 1 additional hour of sunlight.

Air humidity (RH_{mean}). Air humidity is generally one of the most important parameters in agricultural production due to the relation to occurrence of diseases and their prevention, as well as defining the need for irrigation. The climate in the area of Sanski Most is such that the air circulation is significantly influenced by the inflow of maritime air from the Adriatic Sea and nearby mountain ranges [37] therefore, the area is characterized by moderate air humidity. Data on relative air humidity for different seasons are shown in the following table (Table 4).

The average air humidity for the entire analyzed period is 78.83%, where in the first climatic period we have an annual average of 79.48%, and in the second a decrease of 1.3% or the average relative humidity of 78.18%. This decrease is present in all analyzed seasons, i.e. there is a trend of decreasing air humidity in the area of Sanski Most. The most pronounced change is in autumn, when air humidity dropped from an average of 82.39% to 79.63%. The decrease in air humidity leads to a whole series of other phenomena, of which perhaps the most significant for agriculture and the environment is the increase in evapotranspiration.

Table 4. Statistical data for average air humidity (%) in the area of Sanski Most period: 1961–2020.

Air humidity (%)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	82.39	74.25	76.01	81.01	76.19	78.83
	σ	4.50	2.45	3.61	10.82	2.48	1.84
	CV	5.46	3.30	4.75	13.35	3.26	2.34
	b	−0.040	−0.033	−0.073	0.007	−0.040	−0.033
I 1961–1990	x̄	83.48	74.86	77.18	82.39	76.89	79.48
	σ	2.13	2.39	2.67	1.88	1.89	1.33
	CV	2.55	3.19	3.45	2.28	2.46	1.67
	b	−0.142	−0.051	0.013	0.053	0.013	−0.032
II 1991–2020	x̄	81.30	73.65	74.85	79.63	75.48	78.18
	σ	5.85	2.40	4.07	15.18	2.82	2.07
	CV	7.19	3.25	5.44	19.07	3.73	2.65
	b	0.260	0.025	−0.130	0.555	−0.051	0.029
Difference	x̄	−2.2	−1.2	−2.3	−2.8	−1.4	−1.3
	σ	−3.7	0.0	−1.4	−13.3	−0.9	−0.7
	CV	−4.6	−0.1	−2.0	−16.8	−1.3	−1.0

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

Snow. The role of snow in hydrological processes can be of great importance, above all in the cold period of the year, in higher mountain areas and higher latitudes. Snow represents a critical storage component in the hydrologic cycle. Large waters, and the floods caused by them, occur as a consequence of rapid snow melting. In climatological and meteorological research, especially in the last few decades, snow gained a very significant place, this fact can be explained by the great interest in studying global climate change, especially the consequences of the global warming on snow-related processes.

The annual average amount of snow for the entire analyzed period was determined to be 183 mm. By far, the largest amount of snow is during the three winter months (December, January, and February), whose sum is 159 mm. It is very important to note the negative trend that snow has for all three analyzed periods, i.e. the amount of snow in winter in period II is 9 mm less, while in spring in period II it is less by 10 mm.

The trend of this reduction in the amount of snow for the entire analyzed period is 11.23 mm per decade, while this reduction is even more pronounced in period II, when it amounts to 22.67 mm per decade. A negative trend in the amount of snow was also determined for other parts of BiH, in northern BiH from 11.58 to 16.64 per decade [17], and up to 35.45 mm in the Čemerno mountain range [38] (Table 5).

Table 5. Statistical data for snow in the area of Sanski Most period: 1961–2020

Snow (mm)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	159	12	-	12	-	183
	σ	74.7	19.2	-	23.5	-	82.8
	CV	47.1	162.0	-	194.0	-	45.3
	b	−0.712	−0.339	-	−0.071	-	−1.123
I 1961–1990	x̄	163	17	-	12	-	192
	σ	79.4	23.4	-	18.2	-	84.1
	CV	48.6	139.9	-	152.7	-	43.8
	b	−3.070	−0.350	-	0.456	-	−2.965
II 1991–2020	x̄	154	7	-	12	-	173
	σ	70.7	12.2	-	28.1	-	81.8
	CV	45.9	176.4	-	228.6	-	47.2
	b	−0.762	−0.398	-	−1.107	-	−2.267
Difference	x̄	−9	−10	-	0	-	−19
	σ	8.7	11.2	-	−9.9	-	2.3
	CV	2.7	−36.6	-	−75.9	-	−3.4

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

3.2 Water Balance Components

The components of the water balance are the result of climate, so their values change following the change of climate. In the following text, the four most important components of the soil water balance will be presented: Soil moisture deficit (SMD), total runoff (TRO), reference evapotranspiration (ET_0) and actual evapotranspiration (AET).

Soil Moisture Deficit (SMD). Soil moisture deficit is a very important parameter in agricultural production, because its value shows to what extent irrigation is necessary and to what extent the lack of water affects the yield of agricultural crops. The following table (Table 6) shows the obtained statistical data for the entire analyzed period (1961–2020), as well as separately for the I (1961–1990) and II (1991–2020) climate periods.

In the area of Sanski Most, the annual average amount of soil moisture deficit for the entire analyzed period was determined to be 111 mm, with a positive trend of 13.34 mm per decade. Observed by seasons, during the summer period we have an average of 86 mm, while there is a positive trend during the summer period for all three analyzed time periods, that is, the soil moisture deficit in the II period is greater by 48 mm.

The SMD obtained through the water balance procedure is the result of the determined increase in air temperature and decrease in air humidity and the amount of precipitation, that is, it can indicate the increased dryness in the area of Sanski Most. Based on the obtained statistical data, the SMD in the II period (1991–2020) is more pronounced than in the I period (1961–1990), precisely in that period when there were major droughts in BiH [39–41].

Table 6. Statistical data for soil moisture deficit (SMD in mm) in the area of Sanski Most period: 1961 – 2020.

SMD (mm)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	2	9	86	14	105	111
	σ	2.6	11.2	69.4	19.8	76.3	77.0
	CV	103.3	125.4	80.7	145.5	72.4	69.3
	b	−0.044	0.058	1.479	−0.160	1.420	1.334
I 1961–1990	x̄	3	8	62	15	82	88
	σ	2.9	10.3	53.0	20.5	59.6	62.3
	CV	91.2	134.0	85.4	132.7	73.1	70.4
	b	0.020	0.192	1.201	−0.297	1.306	1.116
II 1991–2020	x̄	2	10	110	12	129	134
	σ	2.0	12.1	76.1	19.2	84.4	84.3
	CV	113.0	118.7	69.4	163.5	65.3	63.1
	b	−0.107	−0.226	1.090	−0.231	0.546	0.525
Difference	x̄	−1	3	48	−4	48	45
	σ	0.8	−1.8	−23.1	1.3	−24.7	−22.1
	CV	−21.8	15.3	16.1	−30.8	7.7	7.3

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

Total Runoff (TRO). Excess water defined here as total runoff, is very important for the agriculture. In contrast to water deficit problems, excess water can also have some negative impacts on agricultural production, causing floods, erosion, landslides or increasing soil drainage requirements. The following table (Table 7) shows the obtained statistical data for the entire analyzed period (1961–2020), as well as for the I (1961–1990) and II (1991–2020) climate periods separately.

The annual average TRO for the entire analyzed period was determined to be 375 mm, with a positive trend of 7.19 mm per decade. Observed by season, the largest TRO is in spring when it amounts to 139 mm. In the first climatic period (1961–1990) there is a negative trend in all seasons and annually. However, in the second climatic period (1991–2020) a positive trend, the exception is autumn with a slight negative (−0.92 mm per decade), was determined. The values of these changes are much smaller in the II period. The obtained values indicate the incoherence of this data.

The period after 1991 is characterized by an increase in the amount of TRO and a higher coefficient of variation, this is precisely the period in which large floods occur in BiH, more precisely in 2004, 2006, 2009, 2010, 2014 [1, 36, 42] as well as the last one in 2021.

Table 7. Statistical data for the average value of total runoff (TRO in mm) in the area of Sanski Most period: 1961 – 2020.

TRO (mm)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	74	139	87	75	202	375
	σ	31.3	47.2	31.9	39.6	68.2	105.3
	CV	42.5	34.0	36.5	53.0	33.7	28.1
	b	0.650	0.080	−0.219	0.207	−0.150	0.719
I 1961–1990	x̄	61	136	91	69	204	357
	σ	30.5	47.9	31.2	34.3	62.3	92.3
	CV	49.9	35.4	34.2	49.8	30.6	25.9
	b	−0.113	−0.959	−0.507	−0.650	−1.187	−2.229
II 1991–2020	x̄	86	142	84	81	201	393
	σ	27.2	47.0	32.7	44.1	74.7	115.7
	CV	31.4	33.2	39.1	54.6	37.2	29.5
	b	0.244	0.341	0.241	−0.092	0.562	0.734
Difference	x̄	25	6	−7	12	−3	36
	σ	3.3	0.9	−1.6	−9.8	−12.4	−23.4
	CV	18.5	2.2	−4.9	−4.7	−6.6	−3.6

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

Reference Evapotranspiration (ET_0). Reference evapotranspiration (ET_0) is a very important element of the water balance. In hydro-reclamation practice, the calculation of evapotranspiration is one of the basic steps in the design of irrigation and drainage systems. ET_0 is necessary for calculation of crop and irrigation water requirements, determination of the correct irrigation regime and sizing the irrigation system [28, 43, 44]. Reference evapotranspiration for the area of Sanski Most was calculated using FAO Penman-Monteith 56 equation [30]. The following table (Table 8) shows the obtained statistical data of reference evapotranspiration in the area of Sanski Most.

The sum of ET_0 for the analyzed period (1961–2020) is 777 mm. Comparing the I (1961–1990) and II (1991–2020) climate periods, an increase of 50 mm was found, with a positive trend of 14.49 mm per decade.

The biggest changes (8.9 mm per decade) are during the summer when the ET_0 value is also the highest (361 mm). In all seasons and all climatic periods, a certain degree of increase in ET_0 was determined, the exception being autumn, with a particularly pronounced negative trend during the II climatic period. In that period, ET_0 in the area of Sanski Most decreases slightly by 2.15 mm per decade.

For agriculture, the vegetation period is the most important, and in that period the sum of ET_0 for the entire analyzed period (1961–2020) is 607 mm, i.e. 78.1% of the total annual ET_0.

Table 8. Statistical data for reference evapotranspiration (ET_0 in mm) in the area of Sanski Most period: 1961 – 2020.

ET_0 (mm)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	52	216	361	147	607	777
	σ	7.7	18.3	28.9	11.9	41.2	50.0
	CV	14.8	8.5	8.0	8.1	6.8	6.4
	b	0.132	0.418	0.897	0.001	1.213	1.449
I 1961–1990	x̄	50	209	346	147	586	752
	σ	8.7	19.1	21.4	13.1	32.0	43.4
	CV	17.4	9.1	6.2	9.0	5.5	5.8
	b	0.489	0.268	0.496	−0.028	0.589	1.226
II 1991–2020	x̄	54	223	377	148	628	802
	σ	6.1	14.4	27.4	10.7	38.9	43.7
	CV	11.3	6.4	7.3	7.2	6.2	5.5
	b	−0.166	0.203	0.526	−0.215	0.693	0.348
Difference	x̄	4	14	31	1	42	50
	σ	2.6	4.7	−6.0	2.4	−6.9	−0.3
	CV	6.1	2.7	−1.1	1.7	−0.7	0.3

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

Actual Evapotranspiration (AET). Actual evapotranspiration (AET) indicates the actual amount of water that evaporates from the surface through the processes of evaporation and transpiration, it is the main component of the hydrological cycle and one of the most important physical processes in natural ecosystems. Estimation of AET can represent an important alternative for agricultural or hydrological studies, for example when measurement techniques are not available due to their high cost, complex installation or intensive maintenance [43, 45].

The following table (Table 9) shows statistical data for AET in the area of Sanski Most observed in certain climatic periods, among which we can see differences.

In the area of Sanski Most, the sum of AET for the entire analyzed period (1961–2020) was determined to be 666 mm, with a slight increasing trend of 1.15 mm per decade. Based on the analysis of the I (1961–1990) and II (1991–2020) climate periods, the determined difference in the average annual amount of AET is only 5 mm.

In research by Čadro and Marković [17] as well as Čadro and Uzunovic [38] carried out in the area of northern BiH where Sanski Most is located, the determined value of the annual AET ranges from 578 mm (Bijeljina) to 667 mm (Banja Luka), and the values obtained for Sanski Most coincide with the upper limit of previously determined values.

Variations of this component of the water balance are not high, however, there are significant differences between the trend of changes by seasons. So, during winter, spring and autumn, we have a slightly positive trend of AET, which ranges from 0.7 to

4.7 mm per decade. On the other hand, during the summer we have a more pronounced negative trend, the value of which varies from 5.6 to 7.0 mm per decade, depending on the observed period. These results confirm the previously explained problem of more pronounced climate changes during the summer period. The differences between the two climatic periods indicate a decrease in the mean annual AET of 17.1 mm, with all that in the summer period, the AET variations are the most pronounced.

Table 9. Statistical data for Actual evapotranspiration (AET in mm) in the area of Sanski Most period: 1961 – 2020.

AET (mm)		Wi	Sp	Sum	Au	Veg	Annual
1961–2020	x̄	50	207	275	134	502	666
	σ	8.4	15.0	45.8	16.2	48.0	50.2
	CV	16.9	7.3	16.6	12.1	9.6	7.5
	b	0.176	0.360	−0.582	0.160	−0.207	0.115
I 1961–1990	x̄	47	201	284	131	505	663
	σ	9.3	15.6	36.1	17.9	40.6	46.6
	CV	19.7	7.8	12.7	13.7	8.0	7.0
	b	0.470	0.076	−0.705	0.269	−0.717	0.110
II 1991–2020	x̄	52	213	267	136	499	668
	σ	6.6	11.9	53.1	14.0	55.0	54.2
	CV	12.7	5.6	19.9	10.3	11.0	8.1
	b	−0.059	0.429	−0.564	0.016	0.147	−0.178
Difference	x̄	5	12	−17	5	−5	5
	σ	2.7	3.7	−17.1	3.9	−14.4	−7.7
	CV	7.0	2.2	−7.2	3.4	−3.0	−1.1

Note: x̄ – Arithmetic mean; σ – Standard deviation; CV – Coefficient of Variation; b – decline of the trend curve; Wi – Winter; Sp – Spring, Su – Summer, Au – Autumn, V – Vegetation

4 Conclusion

Based on a detailed and long-term analysis of climate data and soil water balance in the Sanski Most area, we can conclude that the changes are in line with those of the national or regional level. It is especially important to point out the increase in air temperature (0.34 °C per decade) the duration of sunshine (0.19 h per day per decade), and soil moisture deficit (13.34 mm per decade) i.e. the decrease in the amount of snow (−11.23 mm per decade) and relative humidity (−0.33% per decade). Observed by seasons, the period of summer shows the most intense changes, which are hardly noticeable if only the annual level is observed.

Such data should be a kind of alarm, that is, a warning that adaptation to new challenges is necessary. The responsible institutions, that is, the authorities of this area should provide certain funds and create functional systems for the fight and adaptation to climate change. Institutions should be able to establish early warning systems and decision support systems taking into account the state of all actors in the area.

BiH, as a signatory to various initiatives and international agreements related to the climate, including the latest Green Agenda for the Western Balkans, has accepted certain concepts, among which sustainable agriculture takes a special place. Observing the upcoming trends, certain steps must already be taken.

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