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Assessment of air temperature trend in South and Southeast Bosnia and Herzegovina from 1961 to 2017

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Abstract— Recent climate change has been caused by interaction of natural processes and the anthropogenic factor. In turn, it incites the pronounced natural and socio-economic changes. It is the air temperature that plays a pertinent role in understanding the climate change problem. Southeast Europe, including Bosnia and Herzegovina (B&H), is highly relevant for the observations of regional differences in changes of air temperature regime. From the regional-geographical point of view, South and Southeast B&H cover 26.5% (13.568 km²) of B&H territory (51.209 km²). It is from south and southeast that the Mediterranean impacts from the Adriatic Sea penetrate into the defined region, which further affects the variability of climate conditions in B&H. The paper presents trends in three parameter categories: mean annual, mean maximum, and mean minimum air temperatures in the territory of South and Southeast B&H. The aim of the paper is to demonstrate the likely climate change based on air temperature trends. Methodologically, temperature trends were processed by using the Mann-Kendall trend test. For the purpose of the analysis, available data from four meteorological stations in South and Southeast B&H for a 56-year period were used. Based on the obtained results, a statistically relevant positive trend was observed in all twelve time series. According to the analyzed trends, the increase of air temperature was dominant in the target area. The application of Geographical Information System (GIS) tools indicated the presence of regional differences in air temperature distribution. An evident phenomenon is the combined impact of the orography of the region and the maritime influence. The occurring climate change affects specific social sectors, so the problem must be addressed properly. Another pertinent fact is that the climate change problem has not been adequately analyzed in the strategic documents in B&H.

Key-words: climate change, air temperature trends, Mann-Kendall trend test, GIS tools, South and Southeast Bosnia and Herzegovina

1. Introduction

According to highly reliable data from IPCC, the period from 1983 to 2012 was the warmest thirty-year period in Northern Hemisphere over the last 800 years (*IPCC*, 2014). The mean global surface temperature on Earth determined by the linear trend indicated the 0.85 °C increase during the period from 1880 to 2012. Regional differences referring to the increase of mean global temperature range from 0.65 °C to 1.06 °C (*Blunden, et al.,* 2018). Interactions between natural processes and human activities have caused the global air temperature values for the 2005–2015 decade to increase (0.87 °C) in comparison with the preindustrial values. If the current trend remains unchanged, projections of the global air temperature indicate a 1.5 °C increase for the period from 2030 to 2052 (*Papalexiou,* 2018; *IPCC,* 2018). There have been multiple attempts to reduce the anthropogenic impact on global climate. It was in 1989 that the Montreal Protocol was ratified by 197 countries in order to preserve the ozone layer (*Downie,* 2012). The 1997 Kyoto Protocol projected the reduction of gas emissions affecting the global warming (*Breidenich,* 1998). The current Paris Agreement on Climate Change ratified in 2015 has resulted in many controversies, as the signatory countries lack the uniformity in its implementation (*Teske,* 2019). The mean annual air temperature in Europe was 1.6–1.7 °C higher over the last decade (2008–2017), which made this decade the warmest ever documented (*EEA,* 2018). Apart from reports, many authors have analyzed temperature trends. *Klein Tank* and *Können* (2003) used data from 168 European meteorological stations for the period 1946-1999 and specified the tendency of growth of mean European air temperature. From 1977 to 2000, the trends grew in Central and Northeast Europe. Mediterranean air temperature trends were lower and the temperature increase was more evident in winter than in summer (*Alcamo et al.,* 2007). Therefore, the 20th century witnessed the air temperature increase in most Europe, and the changes were most evident in the 1990s (*Kovats, et al.,* 2014). A similar trend continued in the years to follow as it was in the 21th century, that the four warmest years were registered ever since the first measurements started - 2015, 2016, 2017, and 2018 (*WMO*, 2019). Time-space interruptions and different methods of interpolation have been the main shortcomings of all measurement results so they should be used carefully (*Blunden* and *Arndt,* 2015). Generally, there have been both annual and seasonal increases of mean air temperature in Europe (*Brázdil et al.,* 1996*; Brunetti et al.,* 2004*; Feidas, et al.,* 2004*; Brunet et al.,* 2007; *Chen et al.,* 2015*; Werz* and *Hoffman,* 2016).

Earlier studies in Southeast Europe addressed the air temperature trends on regional levels (*Jovanović et al.*, 2002; *Đorđević,* 2008; *Unkašević* and *Tošić*, 2013; *Burić et al.*, 2014; *Bajat et al.,* 2015; *Tošić et al.*, 2016; *Gavrilov et al.*, 2015, 2016, 2018; *Trbić, et al.*, 2017; *Bačević et al.*, 2018; *Popov et al.*, 2018b, *Vukoičić et al.*, 2018) and dealt with aridity as an indicator of climate change in higher regions (*Bačević et al.*, 2017; *Radaković et al.*, 2017; *Milentijević et al.,* 2018).

This paper analyzes recent air temperature trends. Earlier studies in Bosnia and Herzegovina (*Trbić et al.*, 2017; *Popov et al.*, 2017, 2018a, 2018b) also established an increasing trend of mean annual air temperature.

Speaking of the impact of climate change onto specific economic areas in Bosnia and Herzegovina, there is a high risk of extreme climate events such as drought (*Sheffield* and *Wood*, 2007; *Orlowsky* and *Senewiratne*, 2013; *Stagge et al.*, 2015; *Spinoni et al.*, 2015, 2017). Future projections anticipate a growing frequency of this natural disaster in Europe, so it is crucial to undertake adequate measures. These measures are actually adaptation to the drought phenomenon, which is the cause of many socio-economic changes connected with nature, agriculture, and available water resources (*Bressers et al.*, 2016).

This scientific paper comprises the following sections: 1) introduction; 2) description of research area; 3) used data and methodology; 4) obtained results; 5) discussion; 6) concluding remarks.

2. Study area

South and Southeast B&H share the borderline with Republic of Croatia in southwest and south and Republic of Montenegro in southeast, whereas the northern line of delineation follows the municipalities of Livno, Tomislavgrad, Prozor, Konjic, Kalinovik, Foch, and Čajniče (Republic of B&H) (*Fig. 1*). The research area is located between the 44°23' (the municipality of Livno) and 42°55' (the municipality of Trebinje) northern latitudes and 16°52' (the municipality of Livno) and 19°25' (the municipality of Čajniče) eastern longitudes. The following meteorological stations were used for the purpose of the research: Livno (43°49′22″ N, 17°00′04″ E, and 739 m altitude), Mostar (43°20′53″ N, 17°47′ 38″ E, and 48 m altitude), Ivan Sedlo (43° 45′04″ N, 18°02′10″ E, and 955 m altitude), and Bileća (42°52′04″ N, 18°25′29″ E, and 480 m altitude) (*Fig. 1, Table 1*).

Fig. 1. Geographical position of South and Southeast B&H with landmarks of analyzed meteorological stations.

Table 1. Meteorological stations in South and Southeast Bosnia and Herzegovina

Station No.	Station location	Altitude	Latitude	Longitude
1	Livno	739 m	43° 49′ 22″ N	17° 00′ 04″ E
2	Bileća	480 m	42° 52′ 04″ N	18° 25′ 29″ E
3	Mostar	48 m	43° 20′ 53″ N	17° 47′ 38″ E
4	Ivan Sedlo	955 m	43° 45′ 04″ N	18° 02′ 10″ E

From physical-geographical aspects, the area is characterized by extreme holokarst located in the Outer Dinarides. The region covers watersheds of the Neretva and Trebišnjica rivers and their tributaries, as well as the upper Drina River. Holokarst largely affects the air temperature, particularly in summer, due to bare rocky ground which heats quickly (e.g., Mostar area). The climate is diverse ranging from the pronounced Mediterranean climate on the Adriatic coast (Neum), the altered Mediterranean climate in the lower Neretva River (Mostar at 48 m altitude) suitable for early vegetable and Mediterranean fruit (this type of climate also occurs in Trebinje and Popovo Polje at around 280 m altitude), the continental climate in most of the region, and, finally, typical mountain climate at high mountain ranges (*Marković*, 1972; *Rodić*, 1975).

3. Data and methods

3.1. Data

The paper analyzed air temperature trends in the target area for the period from 1961 to 2017. Data from four meteorological stations published at Meteorological almanacs of the Hidrometeorological Institute of the Republic of Srpska (https://rhmzrs.com/?script=lat) and the Hidrometeorological Institute of the B&H Federation (https://www.fhmzbih.gov.ba) were used. There were interruptions in measurement at most meteorological stations, especially during the 1991–1995 war. The percentage of the missing data is 8.9% for Livno and Ivan Sedlo and 7.1% for Bileća. An exception is the Mostar meteorological station, at which there were intermittent measurements during the target time frame. Due to reasonable grounds, the missing data were compiled by using an interpolation method (*Kilibarda et al.,* 2015). The paper uses linear interpolation which represents the simplest method for interpolation of a data set. It is defined as the arithmetic mean of linear interpolants between two neighboring data pairs (*Hazewinkel,* 1990). MICROSOFT OFFICE EXCEL was the program used for the interpolation of the missing data.

Geographical coordinates and altitudes of meteorological stations are given in *Table 1*. The hypsometry of selected stations differs. For instance, relative altitude difference between Mostar meteorological station (48 m) and the highest meteorological station at Ivan Sedlo (955 m) reaches 907 m, which indicates the diversity of climate conditions. The pronounced hypsometric differences among the stations generate a vertical thermal gradient – the average decline in air temperature is 0.65 °C/100 m altitude (*Oliver,* 2005). The terrain orography and the vicinity of the Adriatic Sea contribute to the climate diversity, so the analyzed data are presented for each meteorological station independently.

The paper displays results obtained through analysis of air temperature as a climate variable. The air temperatures are categorized in three classes: mean (YT), mean maximum (YTx), and mean minimum air temperatures (YTn). The mean air temperature values are available from meteorological yearbooks. The extreme temperature values are presented by using mean maximum and mean minimum air temperature values. These were calculated as a ratio of the sum of mean monthly air temperatures and interval duration, i.e., the number of months in a year (*Milosavljević,* 1990).

The total of twelve time series was determined through the analysis of the aforementioned parameters. Each of the series was assigned an adequate acronym combining the abbreviation of the meteorological station, the year, and the temperature type (*Table 2*).

Table 2. List of 12 time series to calculate surface air temperature trends in South and Southeast Bosnia and Herzegovina

Station	**Year (*Y*)**
Livno (L)	$L - YT$
	$L - YTx$
	$L - YTn$
Bileća (B)	$B - YT$
	$B - YTx$
	$B - YTn$
Mostar (M)	$M - YT$
	$M - YTx$
	$M - YTn$
Ivan Sedlo (I)	$I - YT$
	$I - YTx$
	$I - YTn$

3.2. Methods

Three statistical approaches were used in the air temperature trend analysis. The first approach refers to the linear trend equation (*Draper* and *Smith,* 1966), which was designed for each time series separately. Independent of the initial step, all trends were tested by using the non-parametric MK trend test (*Mann,* 1945*; Kendall,* 1938). The third step referred to the definition of trend magnitude determined through the trend equation (*Gavrilov et al.,* 2016). The MICROSOFT OFFICE EXCEL program was used to determine air temperature trends. XLSTAT software (https://www.xlstat.com/en) was used to calculate the *p* reliability level and test our hypotheses. GIS is used as a potent tool for the analysis and numerical modeling of a whole range of climate data (*Collins* and *Bolstad,* 1996).

3.2.1. Trend equation

The linear trend method is an extremely relevant technique used in order to analyze, evaluate, and distribute both long-term and short-term changes in air temperature (*Herrmann et al.,* 2005; *Heim,* 2015; *Ghebrezgabher et al.,* 2016). Its general form is:

$$y = ax + b\,, \tag{1}$$

in which y is the air temperature expressed in °C, a is the gradient, x is the time series, and b is the initial temperature. The air temperature trend value correlates with the gradient. There are three possible scenarios: a) the gradient is higher than zero – the trend is positive (growing); b) the gradient is smaller than zero – the trend is negative (declining), or c) the gradient is equal to zero – there is no trend (without alterations).

3.2.2. Trend magnitude

The trend magnitude is determined by using the linear trend equation (*Gavrilov et al*., 2016) as follows:

$$\Delta y = y(1961) - y(2017), \tag{2}$$

in which Δy is the trend magnitude expressed in °C, y (1961) is the air temperature at the beginning of the period, and y (2017) is the air temperature at the end of the period. There are three possible scenarios with the trend magnitude: a) Δy is higher than zero – the trend is negative (declining); b) Δy is smaller than zero – the trend is positive (growing), and c) Δy is equal to zero – there is no trend (without alterations).

3.2.3. Mann-Kendall (MK) test

Apart from the regression analysis, the non-parametric Mann-Kendall test was used to additionally assess the presence or absence of the trend (*Mann,* 1945; *Kendall,* 1938). The following two hypotheses were tested by using the MK test: the zero hypothesis (H_0), which indicates the absence of the trend in the time series and the alternative hypothesis Ha, in which there is a statistically relevant trend in the time series for the given relevance level (α). The p value has a central role in the MK test (*Karmeshu,* 2012; *Razavi et al.,* 2016). The p value determines the hypothesis reliability level. If the p value is smaller than the selected α relevance level (commonly α=0.05 or 5%), the hypothesis H_0 should be rejected and the hypothesis H_a should be adopted. As opposed, if p is larger than the α relevance level, then the hypothesis H_0 is adopted (*Mudelsee,* 2010; *Hennemuth et al.,* 2013).

3.2.4. Geographical Information Sistem (GIS) numerical analysis

Geographical Information System (GIS) is a powerful tool for modeling climate data. The greatest advantage of the GIS numerical analysis is the analysis of the region itself with all its integrated climate data. Geostatistical methods of interpolation and semi-variogram are of primary pertinence in the numerical GIS analysis. These classical statistical methods combined with kriging methods provided outstanding results (*Valjarević et al.,* 2018a; *Petterson* and *Hoalst-Pullen,* 2011). Other geostatistical methods used for the purpose of this research enabled a better distribution of climate data within a specific territory. The advantage of the Open Source software is the possibility of coding and decoding within the software itself, and the best-known instances of the software were used such as QGIS, SAGA, and GRASS GIS. The greatest benefit of the climate data processing in this software is a specific numerical methodology which adjusts to the target geospace. In this manner, each geospace is processed through a specific numerical analysis, and the errors are minimal as characteristics of both the geospace and the data are taken into account (*Valjarević et al.,* 2018b; *Pew* and *Larsen,* 2001).

4. Results

4.1. Trend parameters

The paper provides results of mean annual air temperature values (Y). The data are categorized in line with temperature types. The analysis covers the total of four meteorological stations in Livno, Bileća, Mostar, and Ivan Sedlo, i.e., twelve time series. *Figs. 2–5* display mean annual air temperatures ($\mathrm{Y}T$), mean annual maximum air temperatures ($\mathrm{Y}Tx$), and mean annual minimum air temperatures ($\mathrm{Y}Tn$), as well as trend test equations and linear equations for each meteorological station in South and Southeast B&H for the observed period from 1961 to 2017. Trend magnitudes Δy(°C) and trend probability p for each time series and each meteorological station within the observed territory are provided in *Tables 1* and *2.* The results are displayed in *Table 3* presenting both parameters and trend equations for all twelve time series.

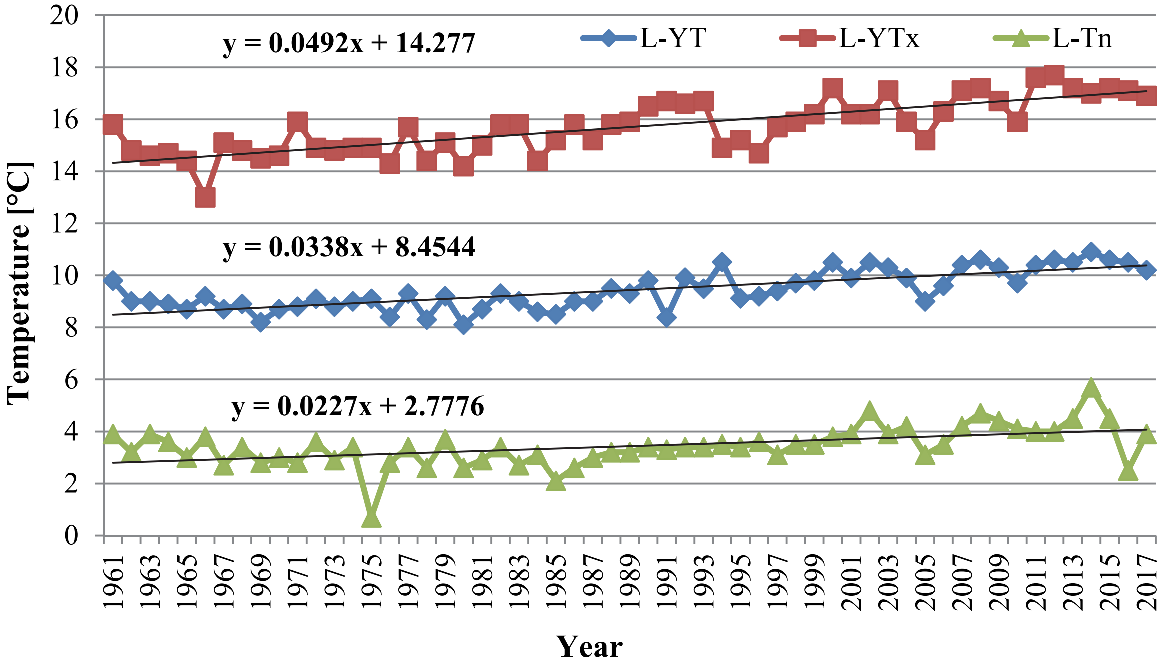

Fig. 2. Average annual mean, maximum, and minimum air temperatures, trend equations, and linear trend in Livno for the observed period 1961–2017.

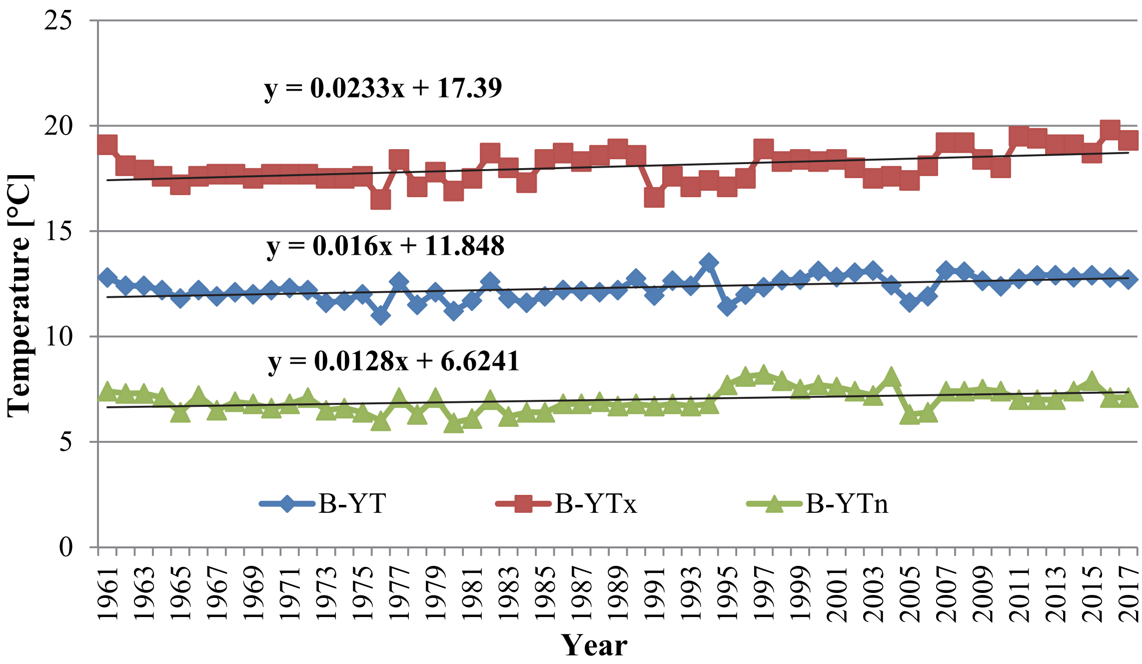

Fig. 3. Average annual mean, maximum, and minimum air temperatures, trend equations, and linear trend in Bileća for the observed period 1961–2017.

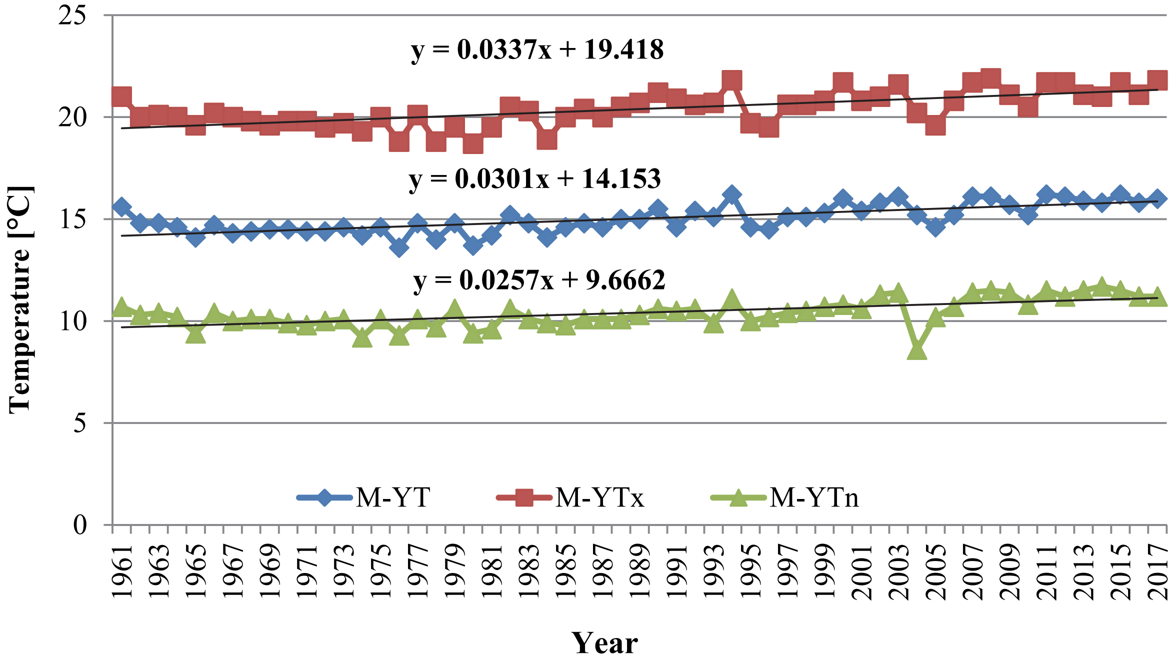

Fig. 4. Average annual mean, maximum, and minimum air temperatures, trend equations, and linear trend in Mostar for the observed period 1961–2017.

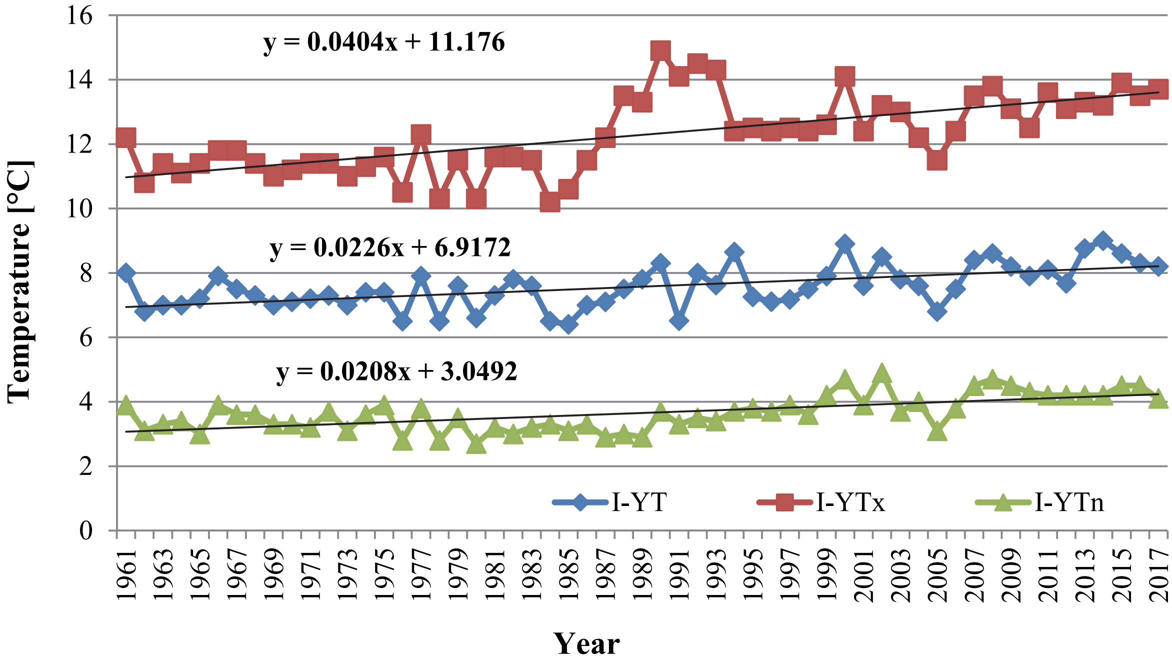

Fig. 5. Average annual mean, maximum, and minimum air temperatures, trend equations, and linear trend in Ivan Sedlo for the observed period 1961–2017.

Table 3.Trend equation y, trend magnitude Δy, and probability p of the reliability for 12 time series

Time series	**Trend equation**	**Δy (°C)**	***p* (%)**
$L-YT$	*y=0.492x+14.277*	1.9	< 0.0001
$L-YTx$	*y=0.0338x+8.4544*	2.8	< 0.0001
$L-YTn$	*y=0.0227x+2.7776*	1.3	< 0.0001
$B-YT$	*y=0.0233x+17.39*	0.9	< 0.0001
$B-YTx$	*y=0.016x+11.848*	1.3	0.0001
$B-YTn$	*y=0.0128x+6.6241*	0.7	0.0059
$M-YT$	*y=0.0337x+19.418*	1.7	< 0.0001
$M-YTx$	*y=0.0301x+14.153*	1.9	< 0.0001
$M-YTn$	*y=0.0257x+9.6662*	1.4	< 0.0001
$I-YT$	*y=0.0404x+11.176*	1.3	< 0.0001
$I-YTx$	*y=0.0226x+6.9172*	2.6	< 0.0001
$I-YTn$	*y=0.0208x+3.0492*	1.2	< 0.0001

4.2. Trend estimation

Main results of the MK air temperature trend test displayed in T*able 3* are supported by *Figs. 2–5*. Hence, the character and intensity of the analyzed air temperature trends in our target region are corroborated. *Figs. 2–5* and *Table 3* show that the trends for all twelve time series were positive. It is the MK test that helps us infer whether these claims were true.

If probability p for the time series YT, YTx, and YTn in the target territory is smaller than α*,* the hypothesis H_0 (the trend does not exist) will be abandoned and the hypothesis H_a (the trend exists) will be adopted for all these time series. The p value is < 0.0001 in time series YT, YTx, and YTn for the meteorological stations in Livno, Mostar, and Ivan Sedlo and in time series YTn for the meteorological station in Bileća. The prevailing hypothesis is H_0. The risk of abandoning the hypothesis H_0 is smaller than 0.01%. The p value is 0.0001 for the time series YTx for the meteorological station in Bileća. The risk of abandoning the hypothesis H_0 is 0.02%. For the time series YTn for the meteorological station in Bileća, the p value is 0.0059. The risk of abandoning the hypothesis H_0 is 0.02%.

4.3. GIS numerical analysis

The mean annual air temperatures (YT) within the target territory from 1961 to 2017 are displayed in *Fig. 6*. The spatial distribution of isotherms indicates the intraregional temperature differences resulting from the terrain orography. For instance, in Ivan Sedlo located within the mountain notch and Livno located in a typical karst field, YT varies from 8 °C to 10 °C. Mostar meteorological station is located at low altitude (48 m) and is under a direct maritime impact from the Adriatic Sea along the Neretva River valley; its YT varies from 11 °C to 14 °C and summer temperature is often higher than in the coastline. The temperature regime in Bileća is determined by different climate modifiers, especially in regards to altitude, continental, and maritime impacts, location within the basin and the Bilećko Lake. These are all factors which resulted in YT value of 12 °C. The construction of the artificial accumulation of water in Bileća in 1968 caused the change of microclimate elements as the mean air temperature decreased, and the air humidity and mean precipitation sum increased (*Marković*, 1990).

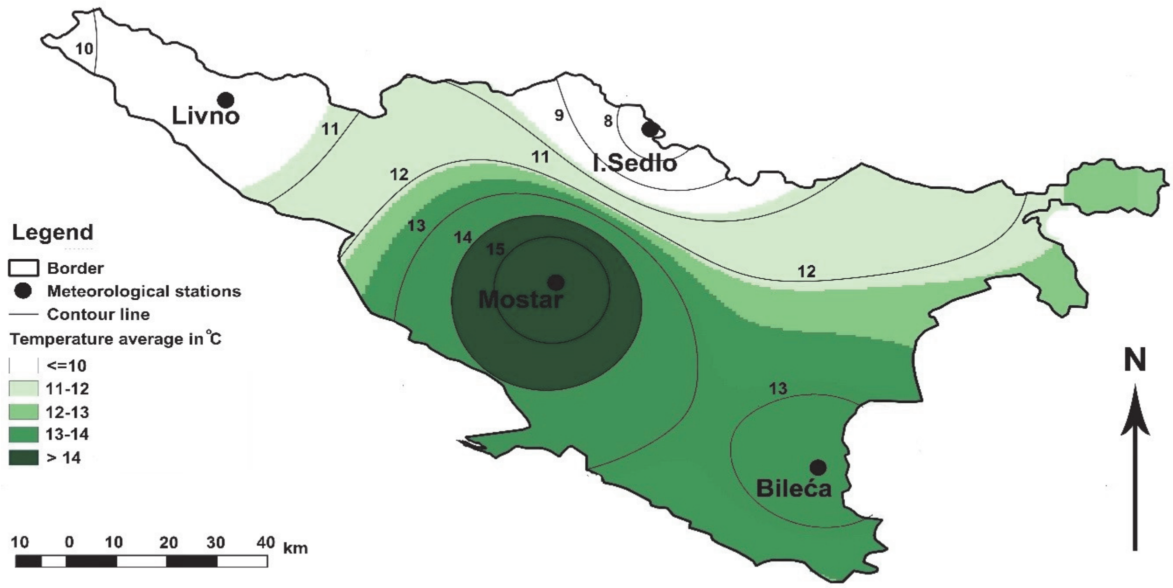

Fig. 6. Distribution of YT in South and Southeast Bosnia and Herzegovina territory in the period 1961–2017.

Mean maximum annual air temperatures (YTx) in the target territory from 1961 to 2017 are displayed in *Fig. 7*. For instance, in Ivan Sedlo YTx is 13 °C and in Livno it is 16 °C. The lowland positioned station in Mostar has the YTx of 20 °C, and in Bileća it is 19 °C.

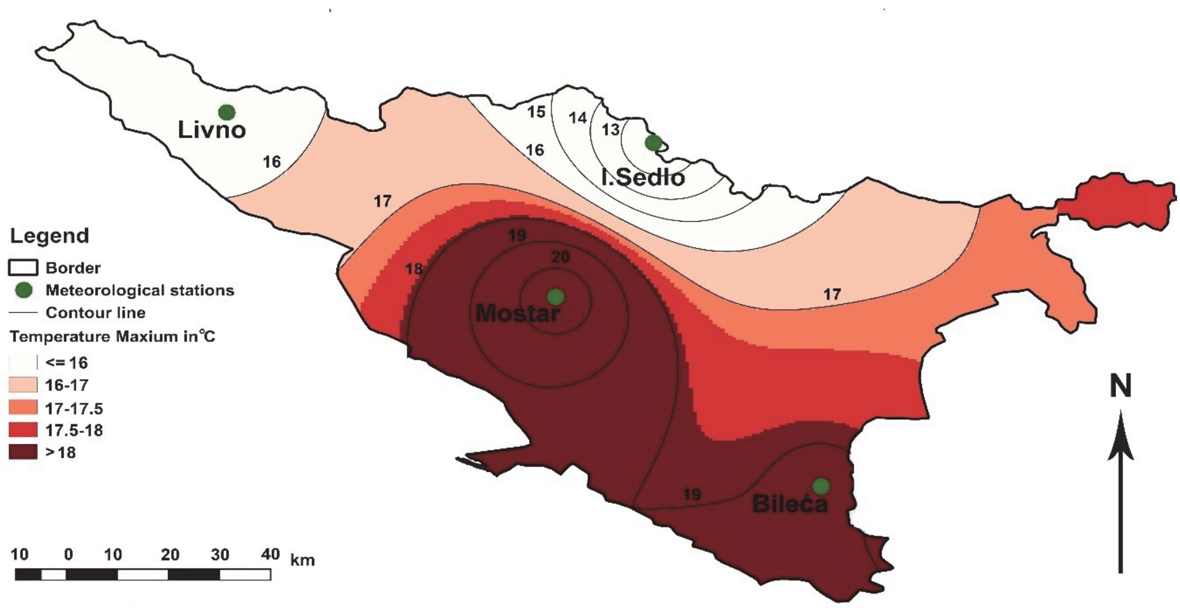

Fig. 7. Distribution of YTx in South and Southeast Bosnia and Herzegovina territory in the period 1961–2017.

Mean minimum annual air temperatures (YTn) in the target territory in the period 1961–2017 are displayed in *Fig. 8.* In line with the map, YTn is 4 °C for Ivan Sedlo and Livno, whereas it is 10 °C in Mostar and 6 °C in Bileća.

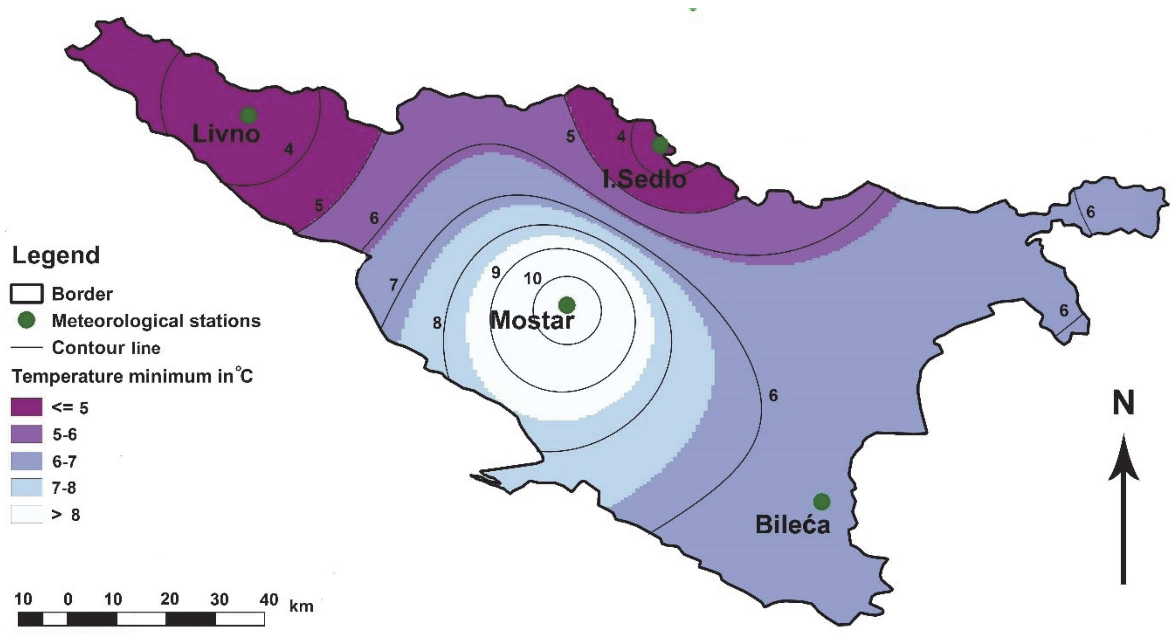

Fig. 8. Distribution of YTn in South and Southeast Bosnia and Herzegovina territory in the period 1961–2017.

5. Discussion

According to the obtained results, the air temperature increase prevails in South and Southeast Bosnia and Herzegovina. The trend magnitude (*Table 3*) identifies an evident increase of values of mean, mean maximum, and means minimum air temperatures. When it comes to individual instances, most pronounced changes occur with mean maximum air temperatures. The mean increase is 2.8 °C in Livno, 2.3 °C in Ivan Sedlo, 1.9 °C in Mostar, and 1.3 °C in Bileća. In cases of mean annual air temperatures, the results are as follows: Livno 1.9 °C, Mostar 1.7 °C, Ivan Sedlo 1.3 °C, and Bileća 0.9 °C. The least pronounced changes occur with mean minimum air temperatures and these are registered in Ivan Sedlo (1.2 °C) and Bileća (0.7 °C). Identical results are difficult to find in the large body of works. The trend of increase of mean air temperature in Europe has been growing since 1979 both seasonally and annually (*Klein-Tank and Können*, 2003). Speaking of regional level, there have been similar trends. For instance, *Brázdil et al*., (1996) found that in ten states of Central and South Europe there was an increase in cases of mean maximum and mean minimum air temperatures (from 1951 to 1990). A study performed by *Brunetti et al.,* (2004) identified a trend in mean annual air temperatures. The mean annual air temperature trend varies from 0.4 °C/100 years in North Italy to 0.7 °C/100 years in the south of the state. A statistically relevant increase of trends of mean, mean maximum, and mean minimum air temperatures was identified in all of Slovenian territory and it varied from 0.3 °C to 0.5 °C per decade (*Milošević et al.,* 2013*,* 2017). In addition, *Mamara et al.,* (2016) processed data from 52 meteorological stations in Greece and found a statistically negative trend between 1960 and 1976. On the other hand, a statistically positive trend was identified between 1977 and 2004. It was in northern parts of Greece that the warming was particularly intensive. Similarly, an air temperature increase was determined in Vojvodina (*Gavrilov et al.,* 2015), Kosovo (*Gavrilov et al.,* 2018), and Montenegro (*Burić et al.,* 2014). A general conclusion is that there is a correspondence between air temperature changes in B&H and in the wider region.

6. Conclusions

The annual and seasonal trends of mean, mean maximum, and mean minimum air temperatures in South and Southeast B&H from 1961 to 2017 were analyzed. The air temperature trends were analyzed for twelve time series by using: a) trend equation, b) trend magnitude, and c) MK trend test. There was a positive trend for all twelve time series for mean, mean maximum, and mean minimum air temperatures. The regional positive trends of air temperatures represent a climate change pattern in Northern Hemisphere, which is in line with conclusions of the Intergovernmental Panel on Climate Change (IPCC, 2014).

Climate change does not only affect the nature but the society as well. Agriculture is a particularly sensitive sector as its ratio in total economy is 7% of the B&H Gross Domestic Product (GDP). The population engaged in the sector suffers directly, too. In addition, pronounced climate change threats food safety, which raises the need for adaptation of agricultural production in affected regions. Nevertheless, the whole process is an interaction among geographical, socio-economic, political, cultural, ecological, and institutional factors. Unfortunately, the problem of climate change has not been paid adequate attention in B&H strategic documents (*Trbić et al.,* 2018). Opportunities to adapt the economy sector to climate change in B&H are defined in the document titled *„Climate change adaptation and low emission development strategy for Bosnia and Herzegovina“.* Its application should reduce negative impacts of climate change and increase adaptation options and usage of development opportunities caused by climate change (*Radusin et al.,* 2013). In line with the set tasks, this document should be implemented into the B&H development strategy. Future studies should focus on climate change projections and analysis of climate change impact on the economy sector.

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