The Impact of Climate Change on the Modification of Bioclimatic Conditions in Bosnia and Herzegovina

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Abstract: This paper presents the results of research into possible climate change in Bosnia and Herzegovina and its potential impact on bioclimatic conditions. Results of possible changes in surface air temperature and precipitation, obtained using the regional climate model EBU-POM, were used to assess changes on the Hydrothermal coefficient of Seljaninov (HTC) for the 2001–2030 and 2071–2100 periods, according to the A1B and A2 scenarios of IPCC. For this study, initial and lateral boundary conditions for the regional model were taken from the ECHAM5 global climate model. More serious changes can be expected during the period of 2071–2100.

Key-Words: Climate change, climate models, bioclimat conditions, Bosnia and Herzegovina

1 Introduction

Global climate change is one of the most important scientific, environmental, economic, and political problems of the present time. The most significant consequences of climate change in Bosnia and Herzegovina are: increase in temperature, pluviometric regime change, reduced rainfall during the vegetation period, increased intensity and frequency of drought periods, floods, and the emergence of a large number of days with tropical temperatures (over 30°C) [1, 2]. According to the Intergovernmental Panel's 4th Report on Climate Change, major impacts of climate change on ecosystems and people have been manifested through changes in the earth's water cycle [3]. Climate change has resulted in an intensive strain on the environment of Bosnia and Herzegovina, with especially large impacts on agriculture and water resources [4]. Because of its exposure and sensitivity to natural changes, agriculture is the sector that is most susceptible to climate change. The agricultural soil of Bosnia and Herzegovina constitutes forty-six percent of the total area of land. Air temperature and precipitation are the primary determinants of the agricultural productivity of the country. It is anticipated that the impact of future climate change on the agricultural sector will increase, but its effects may not be entirely negative [5].

In accordance with the climate model's projections, it is expected that the mean seasonal temperature changes in the 2001–2030 period will range from +0.8°C to +1.0°C above the average temperature. It is anticipated that the winter will be warmer (+0.5°C to +0.8°C), while the largest changes will occur during the summer months, with expected forecast changes of +1.4°C in the northern areas and +1.1°C in the southern areas [5]. It is anticipated that the amount of rainfall will be reduced by 10 % in the western parts of the country and increased by 5 % in the east. It is expected that the seasons of autumn and winter will have the greatest decrease in precipitation.

There are very few scientific research papers that focus on the effects of climate change on individual sectors in Bosnia and Herzegovina. In the First and Second National Report of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change (UNFCCC), it was found that agriculture and water management sectors are most at risk to the threat of climate change [5]. Future climate scenarios demonstrate an increase in temperature and decrease in precipitation during the growing season. This paper considered the possible changes in the Hydrothermal coefficient of Seljaninov (HTC) in accordance with expected climate change by the end of the 21st century. The HTC provides a more detailed definition of humidity and drought climate conditions.

2 Materials and methods

2.1. Climate data

For the calculation of HTC the following basic input variables are used: average daily air temperature in ° C and daily precipitation in mm. The calculation of the bioclimatic index was performed for three climatic periods: the baseline climate period 1961–1990, the future periods 2001–2030 and 2071–2100, with scenarios A1B and A2. For the basic climatic period (1961–1990), observed data from seven meteorological stations in Bosnia and Herzegovina were used (Fig.1).

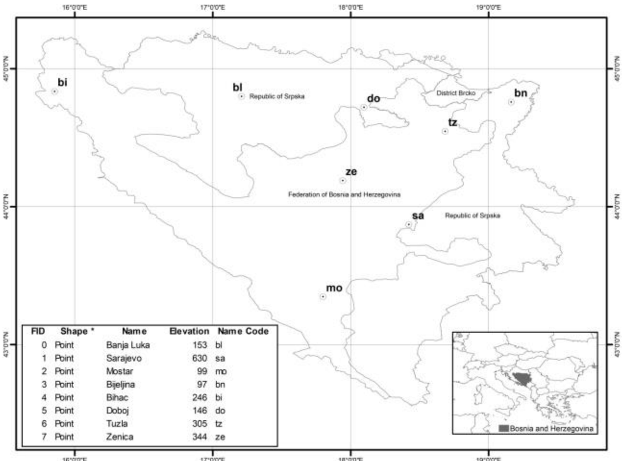

Fig.1. Study area and locations of meteorological stations

The input variables to calculate the bioclimatic index for model-based periods used are the results of a regional climate model EBU-POM [6, 7]. EBU-POM is a coupled regional climate model, and has been used for similar impact studies in agronomy and forestry for the region of Southeast Europe [8–10]. For these downscaling integrations, domain for the atmospheric part of the model was set up over the Euro-Mediterranean region, with 0.25 degrees horizontal resolution, and domain for the ocean part of the model was set up over the Mediterranean Sea with a horizontal resolution of 0.2 degrees. Three time slices were selected for downscaling: 1961–1990 following the 20c3m experiment, then 2001–2030 following the A1B scenario, and finally 2071–2100 following the A1B and A2 scenarios [11]. Time slices were selected to assess potential climate change in both near and distant future time horizons. For the near future time slice only one scenario was selected since, according to green house gasses concentrations defined by scenarios, especially for CO_2 and CH_4, there is no significant difference between A1B and A2. For this study, the initial and lateral boundary conditions for the regional model were taken from the ECHAM5 global climate model, coupled with the Max Planck Institute Ocean Model (MPI-OM) [12–14].

To reduce model bias in key climate variables, temperature and precipitation from which index is calculated, statistical bias correction [8, 15, 16] was applied on model results. The method is based on a construction of correction functions derived from differences between the cumulative density functions of modeled and observed variables for the selected location over a common time period, which was in our case 1961–1990. Cumulative density functions are calculated from daily data for each month separately, assuming that temperature follows normal precipitation gamma distribution. Once correction functions are calculated they can be applied on model results, either for the time period 1961–1990, over which functions are derived, or for time periods in the future.

2.2. HTC: general description

Based on the defined input variables, HTC calculations were produced for seven selected sites (Figure 1). HTC expresses the relationship between rainfall and potential evaporation during the period when the mean monthly temperature is higher than 10°C, and as such, can be used as an indirect measure of available moisture in the soil. In a review of available publications it can be concluded that HTC is used as a drought index to identify arid areas [17], and as a bioclimatic index to identify climatic conditions [18–22]. The mathematical expression of HTC is [23]:

$$HTC = \frac{10\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} t_i},\ T > 10^{o}C. \quad (1)$$

Where is: P: daily accumulation of precipitation; t: meandaily temperature; T: mean monthly air temperature; i = 1, 2, 3...; n: number of days during the selected period.

The significant value for HTC is 1. The areas with HTC < 1 are defined as “arid” and the areas with HTC > 1 as “humid” [18]. Despite the precision of the HTC, results lower and higher than 1 are interpreted differently by various authors [18-22]. Based on the interpretation of quoted papers we suggest the classification results of HTC (Table 1) should be regarded as a statistical measure for comparison and identification of changes in HTC.

Table 1. Limiting values and corresponding HTC index category

HTC	Characteristic
< 0.5	Extremly dry
0.5– 0.7	Very dray
0.7–1.0	Dry
1.0–1.3	Insufficiently wet
1.3–1.5	Moderately wet
1.5–2.0	Wet
2.0–3.0	Very wet
> 3	Extremely wet

3 Results and discussions

3.1. The differences among modelled and observed data

We selected the city of Zenica to demonstrate the method for model bias correction. Model bias can be rated by comparing model results from simulations of the 1961–1990 period to observed values from same period. Fig.2 presents the observed and simulated distributions of the monthly mean temperature and precipitation in the 1961–1990 period for Zenica.

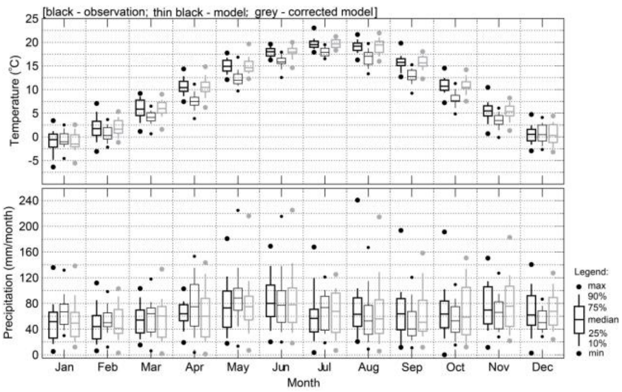

Fig. 2. Box-and-whisker plot for the distributions of mean monthly temperature (upper graph) and mean monthly accumulated precipitations (lower graph) for Zenica for the period 1961–1990 obtained from observed values (black), model values without bias correction (thin black) and after bias correction of model results (grey)

In regards to temperature, it is evident that negative model bias is present in all months, with the exceptions of January and December, for distribution median and for other plotted percentiles. Concerning precipitation, positive bias of the distribution median is present in the first half of the year and is negative in the second, with the exception of June and July. For these two months the bias is relatively small. Other percentiles of precipitation do not strictly follow this rule, but generally the model overestimates precipitations from January to May, and underestimates from August to December. It can be expected that these biases in key climate variables will introduce bias in the calculated index, with the potential to be amplified, since biases from temperature and precipitation can be eventually superimposed.

Calculated HTC index using the uncorrected model temperature, precipitation, and observations for the Zenica station is presented in Fig.3. For the April-September season, all percentiles of index calculated using uncorrected model data are shifted one or two categories to wetter categories in comparison to values calculated using observation. For the June to August season, the situation is the same for percentiles ranging from the 25th to 75th. This 'wet' bias in calculated HTC index using uncorrected model data is probably primarily driven by negative temperature bias, since that index is inversely proportional to temperature. Alternatively, precipitation bias in these periods of the year has a changeable sign.

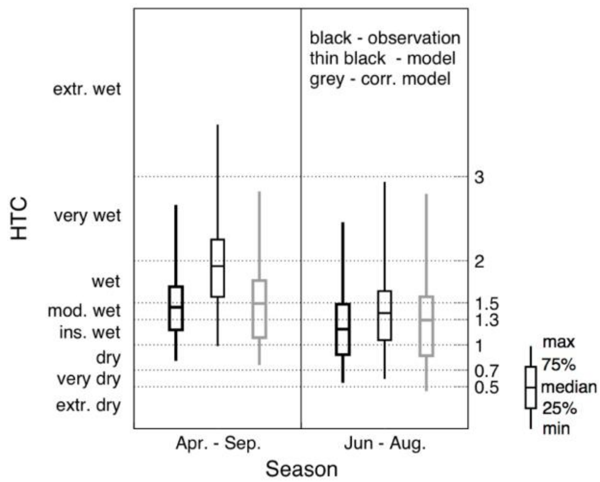

Fig.3. Box-and-whisker plot for the distributions of HTC index for two seasons for Zenica and for the period 1961–1990 obtained from observed values (black), model values without bias correction (thin

black) and after bias correction of model results (gray)

Following the application of bias correction on model results for temperature and precipitation, difference between distributions of monthly mean values between observed and model results are noticeably reduced (Fig.2). This is evident in the April and May temperatures when the difference between observations and the uncorrected model is largest. For precipitation, reduction in bias can also be seen, especially for the distribution median. Finally it is evident from Fig.3 that HTC, calculated using corrected model results, is much closer to values calculated using observed temperature and precipitation. This is particularly apparent during the April to September period, for which all percentiles fall under the same category following correction.

3.2. Changes in HTC due to climate change

Fig.4a shows the distribution of the annual HTC index values for the specified thirty-year period, scenarios, and selected locations (y-axis). Distribution of observed data for the 1961–1990 period and the distribution of obtained model results are also shown. The left column provides data for the season of April–September and the right column provides the data for the June–August season. The mean values (median distribution) of the index obtained from the model simulation for the 1961–1990 period (left and right graph in the first row) only slightly deviate from the index values obtained from observed data for the same time period.

Analysis shows that the mean index values calculated from the model, for all locations and both seasons, are in the same category as values obtained using observed data. Furthermore, for most locations, especially in the June–August season, the distribution range between the 25th and 75th percentile corresponds to the range of observed data. Comparing the maximum model deviation with observed conditions, (taking into account the results between minimum and maximum index values), during the period between 1961–1990, indicated a larger range of threshold within the model in both seasons and in almost all conditions. However, this difference is no larger than one category, and in approximately half of all possible cases, it is in the same category as the observed values.

In the 2001–2030 period (Fig.4b) there are no significant changes in mean index values, so that for most stations and both seasons the index value remains in the same category as in the 1961–1990 period. The most interesting change is in moving the maximum index distribution to smaller values, especially for the June–August season, indicating a decrease in the number of years marked as very wet and extremely wet. In the case of Mostar, there is a clear and significant change in minimum distribution for the season June–August, with the minimum displacement values well below 0.5, indicating the existence of extremely dry conditions during the 2001–2030 period.

Serious changes can be expected in the 2071–2100 period (Fig.4c). According to the scenario A1B for the April–September season, the average index value and minimal distribution value are shifted by one to two categories, to more arid categories, depending on the location, while the highest values shift one category, also to more arid categories. More drastic changes take place in the index values for the June–August season, when the mean index value is less than 1 in the case of all locations, which corresponds to very dry conditions. For locations such as Banja Luka, the index value moved three categories, from the category wet to the category dry. The minimum value of all the locations are even lower than 0.5 (extremely dry), which indicates the existence of at least one year during this period with extremely arid conditions. In the case of Mostar, the mean value is lower than 0.5.

According to the A2 scenario for the 2071–2100 period (Fig.4d) and the April–September season, the shift to more arid index categories is even more noticeable than in the case of the A1B scenario. For all locations, the mean index value is approximately 1 or below, which is the border between the dry and wet categories. For the June–August season, in all locations except Tuzla, the mean value of the distribution is close to or below the value of 0.7, a value that falls between the categories of dry and very dry. The minimum value of the distribution has been shifted far away from the threshold of 0.5 to very low values in the case of all locations. It is interesting that in the case of Mostar, the range from the minimum to 75th percentiles is below 0.5, indicating that ¾ of the years in the 2071–2100 period will be in the category of extremely dry. Additionally, all distributions were below 0.7, indicating an extreme reduction in climate variability between years, most likely the result of permanent precipitation deficit.

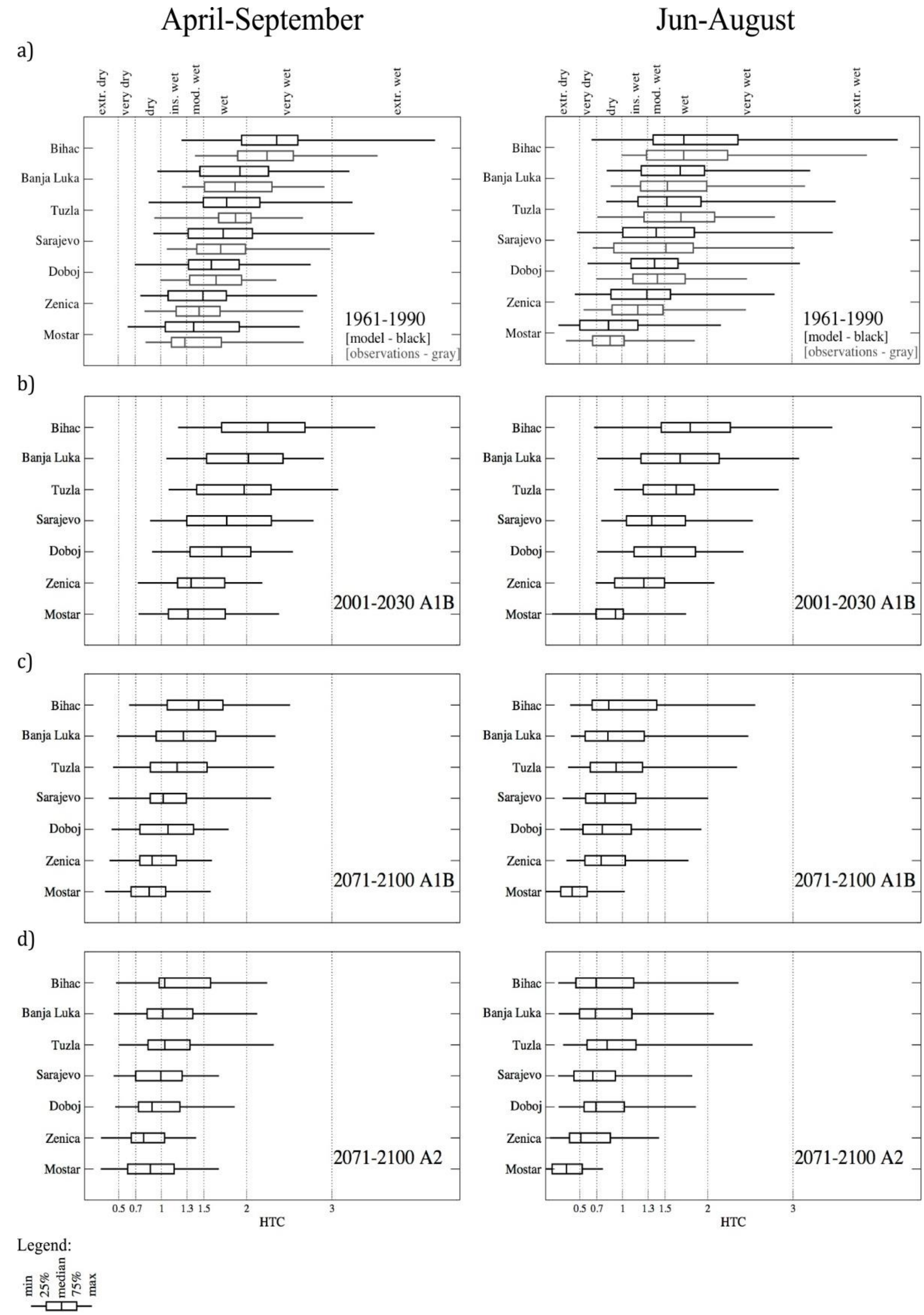

Fig.4. HTC index values for the selected locations (y-axis) and indicated thirty-year period and scenario. On left panels (a-d) are values for season April to September, and right panels (e-h) for season Jun to August

4. Conclusions

According to the future climate change scenarios, an increase in temperature and decrease in precipitation is expected in Bosnia and Herzegovina. Based on changes in the HTC index values, we discovered that in the 2001–2030 period aridity will increase during the growing season, especially in the northern and southern part of Bosnia and Herzegovina. Drastic changes can also be expected in the 2071–2100 period. According to the A1B scenario, during the April–September season the average index value and the minimum distribution value are shifted by one to two categories, to more arid categories, depending on the location, while the peak values shifted one category, also to more arid categories. More drastic changes in the index values are anticipated for the June–August season. The average index value is expected to be less than one in the entire territory of Bosnia and Herzegovina, which corresponds to very dry conditions. For certain locations, such as Banja Luka shifts of three categories are expected, from category wet to category dry. The minimum values of all locations are even less than 0.5 (extremely dry), which indicates that at least one year during this period will have extremely arid conditions. If accurate, these predicted changes in the HTC index indicator will have an impact on agriculture. In such altered climatic conditions, agriculture in Bosnia and Herzegovina will have to undergo major structural reforms. Intensive development of agricultural crops will have to adapt to the changing climate and bioclimatic conditions. This will primarily involve the development and improvement of irrigation systems, and the choice and selection of new varieties and crops.

The fact that these extreme conditions have already been registered during 2012 almost throughout the entire territory of Bosnia and Herzegovina is immensely concerning. This indicates the need for practical planning and adaptation measures based on the most extreme scenario, A2. It is important to emphasize that the impact of future climate change on the agricultural sector will be significantly, but not entirely, negative.

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