CLIMATE CHANGE AND ADAPTATION OPTIONS IN BOSNIA AND HERZEGOVINA – CASE STUDY IN AGRICULTURE

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Apstract: This paper presents the results of a research of possible climate fluctuations in Bosnia and Herzegovina and their potential impact on agriculture. Analyses of climate change have been determined based on fluctuations in air temperature and precipitation. Results of a regional climate model EBU-POM calculated for possible changes in air temperature and precipitation and Seljaninov hydrothermal coefficient (HTC) for the periods 2001–2030 and 2071–2100, according to the scenarios A1B and A2 have also been used for these analyses. The results indicate the climate changeability and its severe impact on the agricultural sector in Bosnia and Herzegovina. These findings show that fundamental changes in agriculture and approach to land treatment and management are required. Anticipated reduction in annual rainfall by 30% and decrease of summer rainfall in the north region of Posavina and in the south of Bosnia and Herzegovina of up to 50% will certainly have negative implications on agricultural sector.

Key words: Climate change, climate models, Bosnia and Herzegovina, agriculture, adaptation.

Introduction

Global climate change is one of the most important scientific, environmental, economic and political problems of the present time. The most important elements but also the consequences of climate change in Bosnia and Herzegovina are: increase in temperature fluctuation, change of pluviometric regime, reduced rainfall during the growing season, increased intensity and frequency of periods of drought, floods and the emergence of a large number of days with tropical temperatures (over 30°C) [1, 2]. According to the fourth IPCC (Intergovernmental Panel on Climate Change) report, the most of the major impacts of climate change on ecosystems and the people have been manifested through changes in the water cycle of the Earth [3]. Climate change has made a huge 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, which is the most vulnerable to climate change. Forty-six percentage of the total area of Bosnia and Herzegovina is agricultural land. Air temperature is the primary determinant of agricultural productivity of the country. It is anticipated that the impact of future climate change on the agricultural sector is to be much more, but not entirely, negative.

Despite the abundant water resources in the country, irrigation infrastructure is very limited. For example, only 0.65% of arable land is irrigated (before the war from 1992 to 1995, the percentage was only 1.0%, but it was significantly reduced due to war damage, mined land and lack of maintenance). A larger number of hot days, reduced precipitation and dryness / aridity will increase the likelihood of droughts. Due to the current limitations of existing infrastructure, these problems cannot be solved only by introducing reliable irrigation system. The risks faced by the agriculture sector are caused primarily, but not exclusively by a combination of increased probability for droughts and shortage of options for irrigation. Mostar, Bijeljina and Tuzla are areas which are most affected by the shortage of water in the soil. There is a real risk that reduced crop yields lead to an increase in food prices, which would result in negative implications for the safety of food [5].

In short, the projected rise in temperature in combination with changes in precipitation and evaporation rates is likely to affect negatively the agricultural systems in Bosnia and Herzegovina, particularly in Mediterranean areas and in the north of the country. Approaches to adapting to climate change will need to focus on improved management of water resources and irrigation systems, new farming systems suitable for warmer and drier climate, as well as various improvements of local crops varieties in order to maximize agricultural production in arid conditions.

In accordance with the climatological forecasting models, it is expected that the mean seasonal temperature changes in the period 2001–2030 are in the range of +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 – June, July and August, with the forecasted changes of +1.4°C in the northern areas and +1.1°C in the southern areas. 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.

In paper Trbic et al. [6] show that there is a high correlation, with correlation coefficients of 0.67, between the annual production of corn and HTC index values for the season April–September and June–August in the territory of Bosnia and Herzegovina during the three dry years: 2003, 2007 and 2011. However, when the value of the HTC index for the season June–August was below 1,value of annual yields were up to 50% lower compared to the years for which the index value was higher than 1 in the same season.

Methods

Based on the results of a regional climate model EBU-POM, potential changes of Seljaninovhydrothermal coefficient (HTC) have been calculated for the periods 2001–2030 and 2071–2100, according to the scenarios A1B and A2.

Seljaninov hydrothermal coefficient can be calculated based on a value series of the mean daily temperatures and daily rainfall accumulations for the selected location and during the selected time period [7]. For the purposes of this study, selected locations are Banja Luka, Sarajevo, Mostar, Doboj, Bihac, Tuzla and Zenica. The values of this coefficient can be correlated with annual yields of grains, while its future changes may indicate the degree of vulnerability of the agricultural sector in the future changed climate conditions. Seljaninov hydrothermal coefficient (HTC) is very frequently used index for assessing aridity of a region during the warmer part of the year i.e. from April to September. Also, as shown in several studies, there is a high correlation between the level of this coefficient and annual grainyields [5, 8]. The index value is calculated based on analysis of the two main climatic elements, the daily accumulation of precipitation and mean daily temperature, which are routinely monitored at all meteorological and climatological stations. HTC is defined as the ratio of the amount of precipitation and temperature sums higher than 10ºC during selected periods of the year. The definition of the index is given by the equation 1, where P is the daily accumulation of precipitation, T is mean daily temperature, n is a number of days during the selected period.

$$\mathrm{HTC} = \frac{10\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} T_i \left(T > 10°\mathrm{C}\right)} \tag{1}$$

Generally, index values below one, small amounts of precipitation and high temperatures correspond to drought conditions throughout the season, and values over one to wet conditions during the season. Table 1 provides more detailed breakdown into appropriate categories, as well as threshold index values that separate individual categories.

Table 1: Limiting values and corresponding category of HTC index

HTC	Characteristic
<0.5	Extremely dry
0.5 - 0.7	Very dry
0.7 - 0.9	Dry
1.0 - 1.3	Insufficiently wet
1.3 - 1.5	Moderately wet
1.5 - 2.0	Wet
2.0 - 3.0	Very wet
> 3.0	Extremely wet

In addition, HTC can be calculated by using the model values, which at the same time presents an indirect method for verifying climate models that have been done for Bosnia and Herzegovina [9]. The projections were made in relation to the standard climatological period 1961–1990, having in mind that this period was covered by model and observed values.

Results

In order to obtain an answer to the question about the possible impact of climate change on grain yields for the specified region, the value of the HTC index can be calculated using the results of the chosen scenario for the future time horizons.

As a model results contain a certain level of error/deviation from model verified through simulation of the existing climatic conditions (simulation for the period 1961–1990), one should expect that this will be a noticeable deviation in the value of the index as well, especially in the case of nonlinear dependence of the index from basic meteorological parameters, or when the index is a combination of several parameters so that it can reach the superimposition of individual errors. To avoid this kind of 'infecting' the results by model deviation (bias), the proposed statistical method for correction of model results is a method of quantiles [10, 11]. It assumes that the results of the model for integration of the period 1961–1990 are statistically corrected by using observed data for the same period. Correction factors are derived from the difference between the cumulative density function of two sets of data, observed and model, so that after the application of correction factors to a model series, corrected and observed flood series have approximately the same density distribution. The same correction would be applied for the simulation of future climate, which would exclude the discrepancy model in this series.

Figure 1 shows the values of mean monthly temperature (upper graph) and monthly accumulated rainfall (lower graph) for Zenica during the period 1961 to 1990 obtained via observation, model values without statistically corrected results and model values with statistical correction. The model has a maximum deviation of the mean temperatures for the months of December, January and February. For all the months, the model has a positive deviation compared to observation, i.e. positive bias. The maximum deviation is during spring and autumn months and is approximately about 3°C. On the other hand, concerning the rainfall during the first half of the year, the model has a positive bias comparing to the observed values while in the second half of year, it has negative bias. It is also interesting to note that based on the climate model, a month with maximum rainfall is May, while observation data show that it is June. After statistical correction of the raw model results, we can see that the deviation of the model results is significantly reduced in the case of temperature and precipitation event.

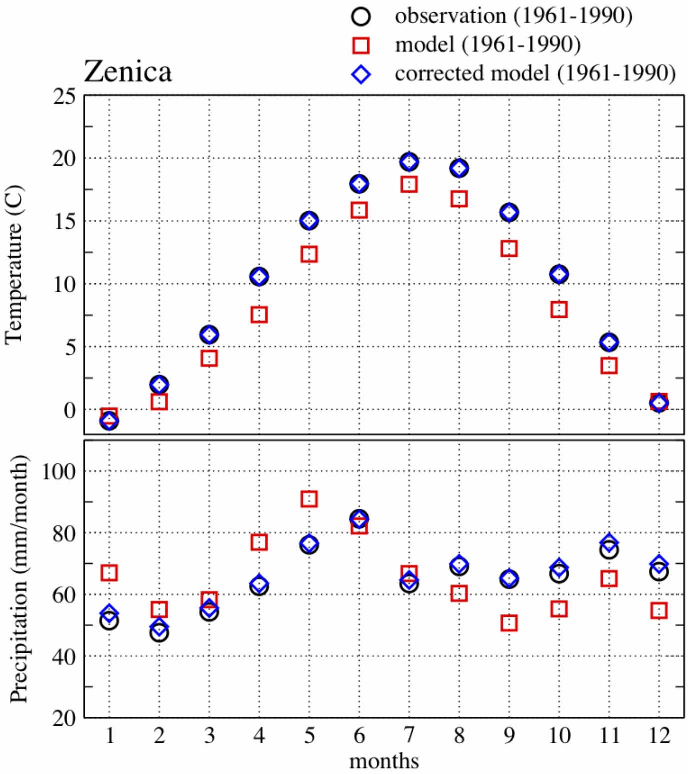

Figure 1: Values of mean monthly temperature (upper graph) and monthly accumulated precipitations (lower graph) for Zenica for the period 1961–1990 obtained from observed values (black circles), model values without statistical correction (red squares) and after statistical correction of model results (blue rhombs)

Figure 2 shows the distribution of the annual values of the HTC index during the specified thirty-year period, scenarios and selected locations (y-axis). Distribution of observed data for the period 1961–1990 is in red, while the distribution obtained from the model results is in black. Left column provides data for the season April–September and the right column provides the data for the season June–August. The mean values (median distribution) of the index obtained from the model simulation for the period 1961–1990 (Left and right graphin the first row) only slightly deviates from the index values obtained from observed data for the same time period.

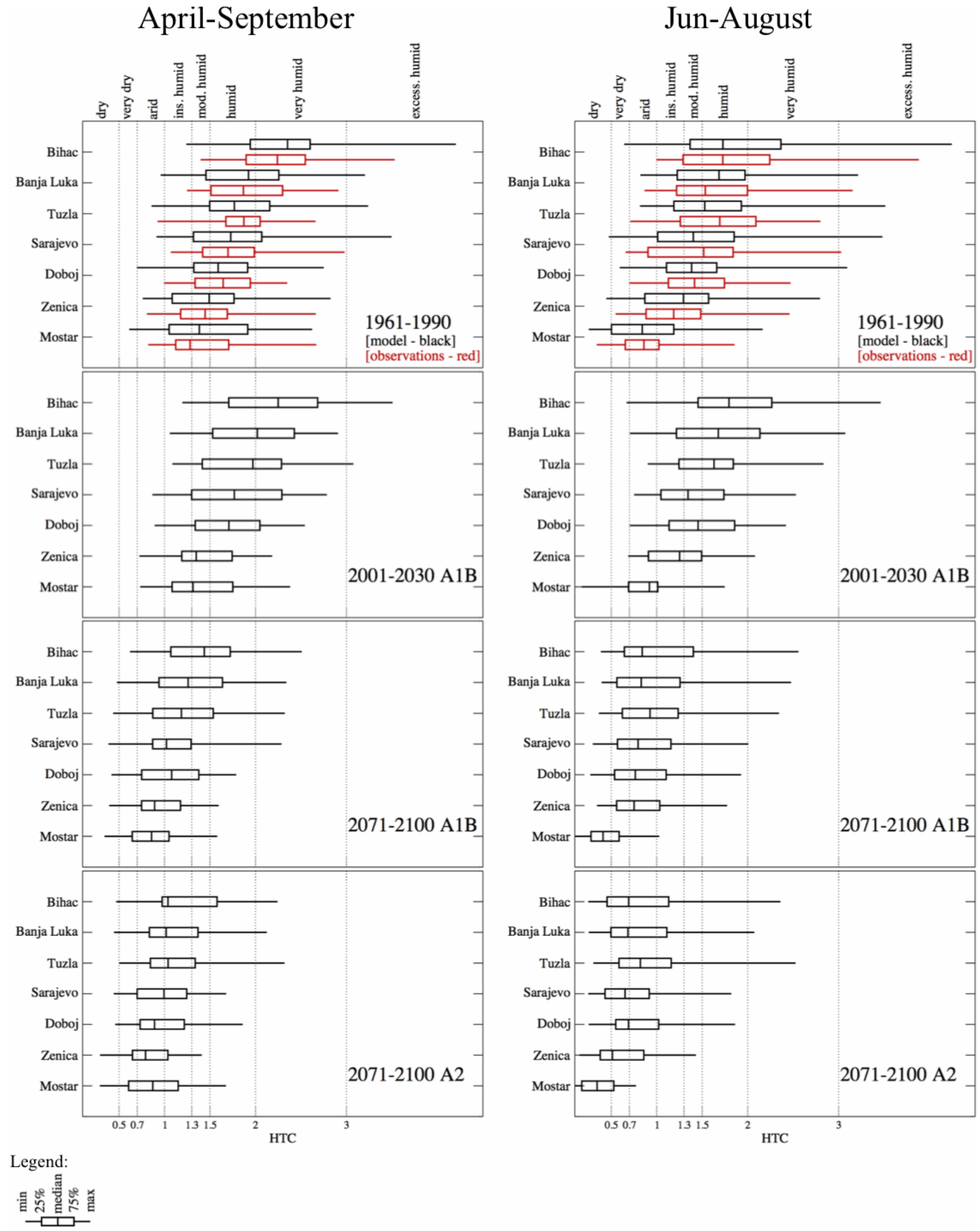

Figure 2: HTC allocation index for the indicated thirty-year periods, scenarios and selected locations (y-axis). - Red is the distribution of observed data for the1961–1990. period, model results are in black.The left column provides distribution data for the season April–September and the right column provides data of distribution for the season May–August.

When analyzing categories, we can see that the mean index values calculated from the model, for all locations and both seasons is in the same category as and values obtained by using observed data. Also, for most locations, especially in the case of the season June–August, the distribution range is between 25. and 75. percentile which corresponds to the range of observed data. The maximum models deviation comparing to the observed conditions is in the case of the overall range of distribution i.e. a value between minimum and maximum value of the index during the period 1961–1990, where we can see that in almost all locations and for both seasons, the model has a larger range of thresholds, but this difference is not exceeding the difference of one category. In approximately half of the possible cases, it is in the same category as the observed values.

During the period 2001–2030 (Figure 2, second row) we can see that there is no significant change in mean values of the index for this thirty-year period, so that for most stations and both seasons index value remains in the same category as in the period 1961–1990. Even in some cells, we notice shifting towards higher values. The most interesting change is actually moving the maximum index distribution to smaller values, especially for the season June–August, 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 a minimum displacement values well below 0.5, indicating the existence of the years during the 2001 to 2030 simulation with extremely dry conditions.

Serious changes can be expected during the period 2071–2100 (Figure 2, third row). According to the scenario A1B for the season April–September average value of the index and minimal distributions value are shifted by one to two categories, to more arid categories, depending on the location, while the highest values have shifted for one category, also to the more arid categories. More drastic changes take place in the index values for the season June–August, when the mean value of the index is less than 1 in the case of all locations, which corresponds to very dry conditions. For some location such as Banja Luka, index value has been moved for even 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, even a mean value is lower than 0.5.

According to the A2 scenario for the period 2071–2100 (Figure 2, last row) and season April–September, we can see that the shift to more arid index categories is even more noticeable than in the case of A1B scenario. For all locations, a mean value of the index is very close to 1 or below this value that separates the dry and wet categories. For the season June–August, we see that in the case of all locations except Tuzla, the mean value of the distribution is close to or below the value of 0.7, which is the value between 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 minimum to 75 percentiles is below 0.5, indicating that the ¾ of the years in the period 2071–2100 will be in the category of extremely dry. Also, the entire distribution is below 0.7, which indicates an extreme reduction in climate variability between years, probably caused by permanent precipitation deficit.

Discussion and conclusions

Previous studies indicate that climate change is putting considerable pressure on agriculture in Bosnia and Herzegovina [4, 5]. Key changes are reflected in the increasing temperature and decreasing rainfall in the warmer half of the year. Such changes already require fundamental changes in agriculture and approaches in the treatment and management of land. In recent years, there has been a growing phenomenon of drought causing great damage to agricultural crops. In particular, the damage occurring in the northern part of Bosnia and Herzegovina where the decline in the yield of agricultural crops has been recorded. The main cause of drought is the lack of and uneven distribution of rainfall accompanied high temperatures. Although during the vegetation period there are plenty of rainfall, in the summertime drought is a regular phenomenon that occurs every year with ups and downs. It is this lack of rainfall, which is accompanied by relatively high temperatures, that leads to a deficit of water in the active zone of the root system where it hinders the soil water balance, as well as physiological processes in plants. Water deficit reduction leads to an increase in crop and biomass production, and reduced increase in cells, and photosynthesis. It is estimated that drought leads to reduced yields by 20% compared to the genetic potential of plants. These are some key measures that could be applied in the fight against drought irrigation [6].

In accordance with the climatological forecasting models, it is expected that the mean seasonal temperature changes in the period 2001–2030. are in the range of +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 occur during the summer months – June, July and August, with the forecasted changes of +1.4°C in the northern areas and +1.1°C in the southern areas. Predictive that precipitation will decrease by 10% in the western parts of the country, and it will increase by 5% in the east. It is expected that the seasons of autumn and winter have the greatest decrease in precipitation [9].

Based on changes in the index HTC by Seljaninov we found that in the period 2001–2030 aridity increase during the growing season and especially in the northern and southern part of Bosnia and Herzegovina. Serious changes can be expected during the period 2071–2100, where according to the scenario A1B for the season April–September average value index and value minimum distribution are shifted by one to two categories, to more arid categories, depending on the location, while the peak value in the shifted and for one category, also to more arid categories. More drastic changes in the index values for the season June–August, when the entire territory of Bosnia and Herzegovina is expected average value of the index is less than one, which corresponds to very dry conditions. For certain locations, such as Banja Luka expected shifts for three categories from category wet to category dry. The minimum value of all the locations are even less than 0.5 (extremely dry), which indicates the existence of at least one year during this period with extremely arid conditions. The fact that this extreme conditions are already registered during 2012 to almost the entire territory of Bosnia and Herzegovina is concerning. This indicates the need for practical planning 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. Despite the countries abundant water resources, irrigation infrastructure is very limited. A larger number of hot days, reduced precipitation and dryness/aridity will increase the likelihood of droughts

(Republic Hydrometeorological Institute Banja Luka, Federal Hydrometeorological Institute). Due to the current limitations of existing infrastructure, existing problems cannot be solved only with the help of a reliable irrigation system. The risks faced by the agriculture sector – primarily due to a combination of increasing the probability droughts and shortage of options for irrigation – are not uniform. Approaches to adapting to climate change will need to focus on improved management of water resources and irrigation systems, new farming systems that are suitable for warmer and drier climate, as well as various improvements varieties of local crops with a view maximizing agricultural production in arid conditions.

At present, adaptive capacity to climate threats in the agriculture sector is low. In terms of available information and knowledge, there is a lack of detailed analysis on regional changes within Bosnia and Herzegovina and a lack of crop modeling. Climate data is not fed into early warming systems for farmers, and farmers lack information about adaptive farming techniques, seed varieties, and crops that may be more appropriate with changes in season temperature and preicipitation patterns. In terms of skills and management, there is a general need for training farmers in less labor-intesive methods of agriculture, cultivation techniques for better-adapted crops, and hail protection techniques. In the economic sector, there is an overall lack of investments and a lack of crop insurance, which will become increasingly important with future increases in extreme weather.

In terms of physical capacity, there is a lack of modern technology (many farmers use obsolete farm equipment, and there is a low uptake of new technologies due lack of funding and the small-scale structure od farming). There is also lack of infrastructure that could address climate threts, such as irrigation systems and reservoirs and rainwater collection. In addition, farmers lack access to broader varieties of climate-suitable seeds and plant varieties. In the institutional sector, there is a lack of integration of climate change issues into policies on agriculture and rural development, a lack of coordination and clear jurisdiction for agricultural policies, and a lack of support for agricultural extension programs [9].

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