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SPATIAL DISTRIBUTION OF ANNUAL RAINFALL IN BOSNIA AND HERZEGOVINA USING SPATIAL KRIGING INTERPOLATOR

AUTHOR

Drešković Nusret
University of Sarajevo, Faculty of Science, Department of Geography, 71000 Sarajevo, Zmaja od Bosne 35, Bosnia and Herzegovina
e-mail: nusret2109@gmail.com

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ABSTRACT
Spatial distribution of annual rainfall in Bosnia and Herzegovina using spatial kriging interpolator

Precipitation and air temperature are the basic meteorological elements in the climate research, indicating and influencing the general characteristics of the atmospheric circulation by their spatiotemporal dynamics, determinating the general climate character of the location. In this paper, the interpretation of the pluviometric regime in Bosnia and Herzegovina will be based on quantitative parameters of the horizontal spatial distribution of the mean annual precipitation sums resulting by applying GIS based kriging spatial interpolator. The results of research have shown the annual pluviometric GRID for Bosnia and Herzegovina of high spatial resolution enabling, beside the horizontal spatial distribution, the production of the detailed transverse and longitudinal pluviometric profiles.

KEY WORDS
precipitation, Bosnia and Herzegovina, annual sum, kriging spatial interpolator, pluviometric profiles

1.Introduction

The precipitation data obtained by the measurements on the basic network with 724 precipitation stations were used to prepare the pluviometric spatial model. The data supplement of the pluviometric regime were made by establishing the supplement network of the hypothetical precipitation stations used for the quality correction of the basic pluviometric model. According to the morphological-morphometrical influence of the relief on the spatiotemporal dynamics of the pluviometric regime, the 720 more hypothetical precipitation stations were established. The morphological-morphometrical relief, horizontal and vertical relief articulation and their mutual distance were the basic criterion for the selection of the hypothetical precipitation station locations. Specifically, hypothetical meteorological stations have been located on the foremost antipode elements of the relief morphostructures, on mountain tops and at the bottoms of the contact valley areas, on the approximately equal mutual distances. Using this criterion, the representative pluviometric net consisting 1, 404 precipitation stations in total were established (Figure 1).

The spatial pluviometric model for the mean annual precipitation height were established and analyzed for the purpose of studying the spatiotemporal dynamics of precipitation in this paper. The spatial pluviometric model were made using the kriging spatial interpolation model based on the precipitation data of the basic and supplement precipitation network. Digital elevation model (DEM) for Bosnia and Herzegovina of 20-meter resolution were used for the spatial validation of the precipitation data. Data spatial interpolation is based on the using of the basic and validation subprocessing model used for the surface interpolation between maximum 200 neighboring precipitation stations and for the determination of the precipitation vertical gradient.

The output annual pluviometric models for Bosnia and Herzegovina were made in the same resolution as the validation subprocessing model based on DEM 20-meter resoultion. The map od the mean annual precipitation height, in a ratio 1 : 200, 000 for territory of Bosnia and Herzegovina, is result of the applying methodological concept. The linear isohyetswith the values 20 mm per each were added to the color charts in the aim of the better illustration of the spatial precipitation distribution. In these models, the third spatial dimension, the relief of Bosnia and Herzegovina, as the one of the basic factors for the spatial isohyets validation, was achieved by adding the hill.

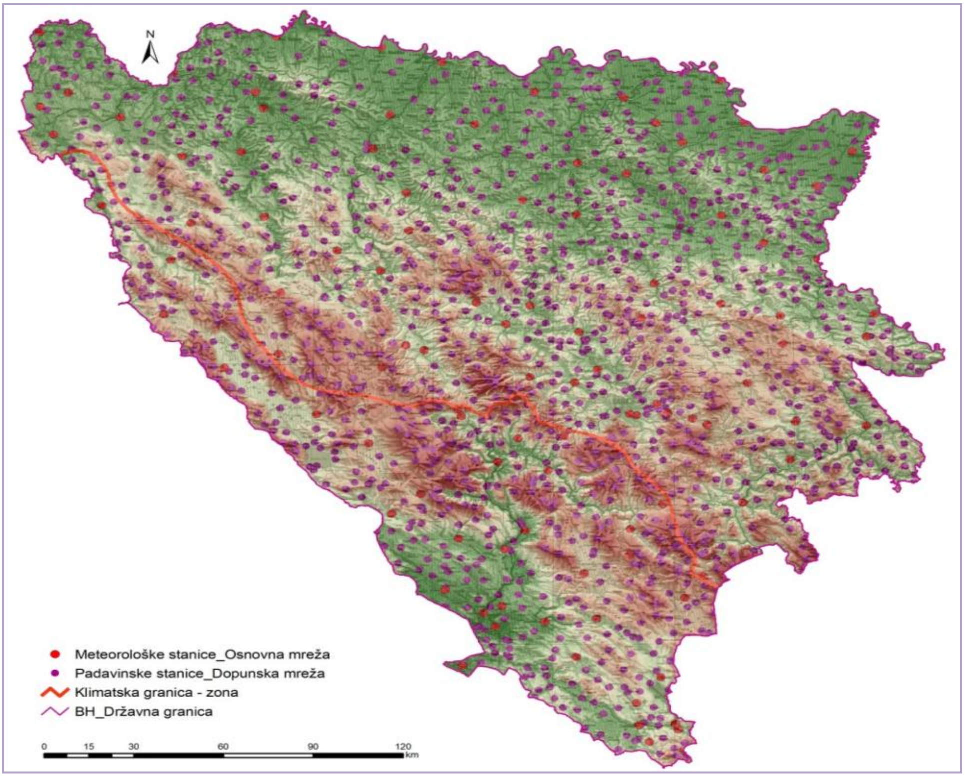

Figure1. Spatial distribution of the basic and supplement network and network of the hypothetical precipitation stations in Bosnia and Herzegovina

2.Space distribution of precipitation height

The mean annual precipitation height for the territory of Bosnia and Herzegovina is cca 1,255 mm, obtained by the analysis of the annual precipitation GRID spatial model and its accompanying geodata, but the spatial distribution variations are very distinctive with the values between 706,0 mm (direct Savariver confluence – wider area around the settlement Domaljevac) and 3.259,0 mm (mt. Orjen –wider area of the peak Velika Jastrebica – 1, 856 m altitude). Based on these data, it can be concluded almost five times lesser precipitation falls down in the driest areas of Bosnia nad Herzegovina. The differences in the spatial precipitation distribution are noticable between two main climatic region. Specifically, in the continental climatic region of Bosnia and Herzegovina, the mean annual precipitation height is cca 1, 080 mm and varies between 706,0 mm and cca. 2.335,0 mm (in the wider area of the highest mountain peaks of mt. Zelengora).

The value of the analog in Mediterranean area of Bosnia and Herzegovina is higher and it is cca. 1, 645 mm, with the limits between 920 mm (wider area near Rama hydro reservoir) and 3, 259 mm. Horizontal change of the mean annual precipitation height in two mentioned climatic zone is also different, generally decreasing from the coastal southern zone toward peripanonic northern area of Bosnia and Herzegovina.

In the aim of the detailed representation of the horizontal distribution of the mean annual precipitation height, one transverse and one longitudinal precipitation profile are designed (Figure 4):

- Župski bay- Sava river (zone of the settlement Batković) – transverse profile (Figure 5),
- Mt. Volujak –Glina river (settlement Ponikva) – longitudinal profile (Figure 6).Both of the profile lines are constructed in the high resolution pluviometric model (20-meter GRID) getting very detailed profiles accurately presenting all the horizontal distribution of the mean annual precipitation height on the profiles.

Transverse precipitation profile begins from the settlement Zavrelje in Bosnia and Herzegovina (in the direction from the central part of Župskibay) descending from the part of the Dubrava karst plateau to the basin of the Popovo field (near the settlement Gomiljani) and further, over Ljubomirsko field to the mt. Viduša, eastern slopes of the mt. Baba and mt. Gatačka Bjelašnica, part of the plateau Vučevo, mt. Zelengora, eastern piedmont of the mt. Lelija and mt.

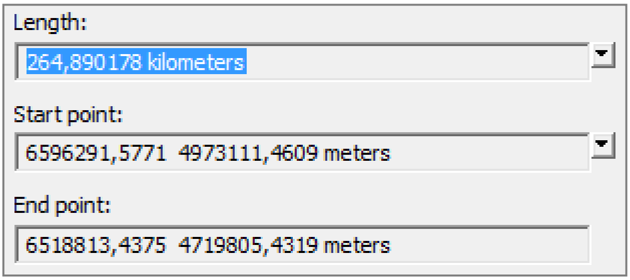

Figure 2. Mathematical-cartographic indicators for the precipitation profile 1

Treskavica, valley of the river Bistrica, eastern slopes of the mt. Jahorina, valley of the river Prača, the plateau of Glasinac, mt. Šljemenska, western slopes of the mt. Javor, valley of the river Drinjača, end of the eastern part of the Sprečko field, southestern slopes of the mt. Majevica, wider area of Semberija, to Sava river (wider area of the settlement Batković).

Total length of the profile air line is cca.264.8 km and the length of the topographic profile is several times bigger (Figure 2). From the graph for the transverse precipitation profile, it can be concluded the mean variation of the annual precipitation height along the profile zone varies between 790 mm and 2, 230 mm, indicating its position just west of the zone with the maximum precipitation in the area of the mt. Orjen. It can also be concluded the shape of the precipitation profile line significantly differs from the the shape of the topographic profile, indicating the dominant significance of the geographical position and the degree of continentality of an area for its annual precipitation height. In other words, the area with the maximum precipitation is located directly in the hinterland of Adriatic Sea, while with increasing distance of the precipitation stations (deeper into the ground interior) precipitation generally be reduced.In this case, annual precipitation height from adriatic coast to Sava river in Bosnia and Herzegovina average decreases for about 5.5 mm/km air line.

Certainly, spatial variations of mentioned average decline exist, where the precipitation after declining to a certain value increase and then decrease again.This is the case with the analyzed profile in the wider mountain morphostructre area of the southeastern Bosnian highlands where the precipitation increases from cca. 1, 600 mm in the mountain piedmont to 2, 000 mm in the zone of the highest mountain peaks. This is the result of the increased intensity of the condesation-sublimation processes following the altitude increase on the wind-hand slopes in the conditions of the permanent delivering the humid and hot air from the south.

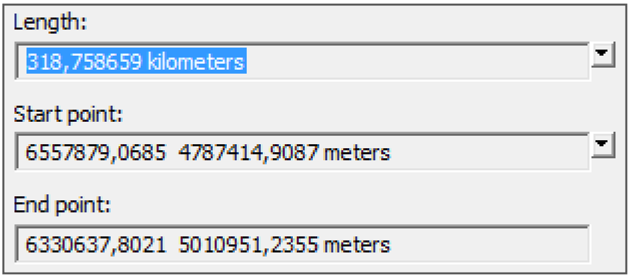

Figure 3. Mathematical-cartographic indicators for the precipitation profile 2

On the northern piedmont of these mountain morphostructures, the intensity of these processes weakens considering that the higer humidity quantity hasalready excreted and the precipitation suddenly falls to the below 1,300 mm. The annual precipitation decreasing trend continues, with the smaller quantity-spatial „disorders“, along the territory, to the Savariver. Longitudinal precipitation profile covers the surface starting from the southwestern slopes of the highest mountain peaks of the mt. Volujak, across the wider zone of the mountain peaks of the mt. Zelengora coveringthe southwestern piedmont of the mt. Lelija, mountain peaks of the mt. Visočica, southwestern slopes of the mt. Bjelašnica, mt. Ivan, southwestern slopes of the mt. Bitovnja, the highest mountain peaks of the mt. Vranica, mt. Radovan, Vinačka canyon, northeastern slopes of the mt. Lisina, Podrašnjičko field, valley of the Sana river (near the settlement Ljubine),

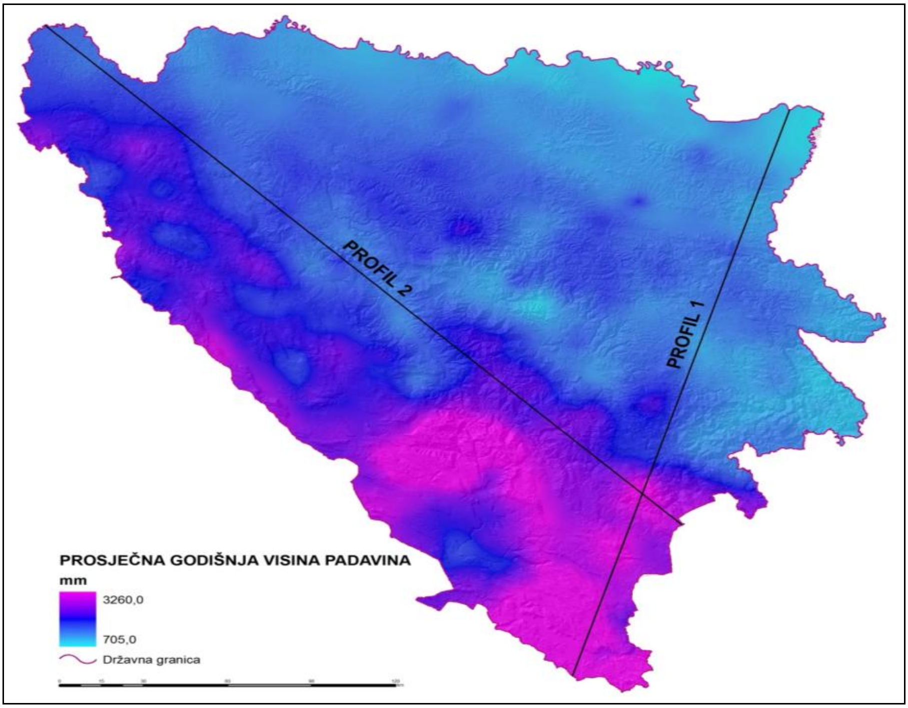

Figure 4. Horizontal distribution of mean annual precipitation height in Bosnia and Herzegovina on the transverse (profile 1) and longitudinal (profile 2) precipitation profile.

mt. Mrežnica, mt. Majdan, valley of the Una river, valley of the Bužimica river to the Glina river (near the settlement Poljana) (Figure 6). Total length of the profile line is cca. 318 km (Figure 3). The degree of the precipitation variation is, as in the previous precipitation profile, very expressed and varies from 960 mm (in the wider area of the Uskopaljska valley) to 2, 300 mm (wider area of the highest mountain peaks of the mt. Zelengora). According to the position of both profile lines, it can be generally concluded that the mean annual precipitation height is significantly above the mean in Bosnia and Herzegovina in the southern and southeastern partsof Bosnia nad Herzegovina, while it decreases below the values of the mentioned mean in central and northwestern parts. These facts indicate the southwestern, southern and southeastern parts of Bosnia and Herzegovina, „richer“ in precipitations, are impacted by stronger climatic influence of Adriatic Sea than the „poorer“ part, placed northward of the orographic watershed, consisting of the highest mountains of the central Dinaric zone (from mt. Plješevica on the northwest to mt. Volujak and mt. Maglić on the southeast).

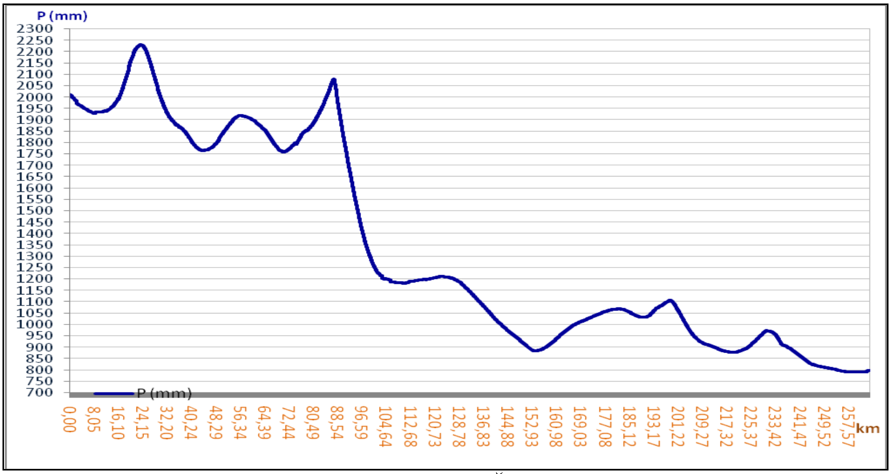

Figure 5. Transverse pluviometric profile: Župski bay - Sava river (settlement Batković)

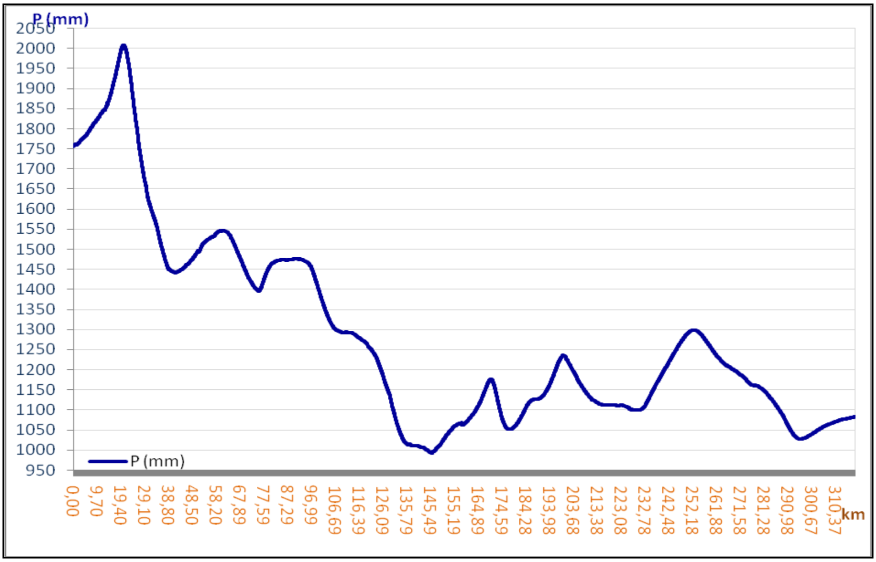

Figure 6. Longitudinal pluviometric profile: peaks of the mt. Volujak - Glina river (settlement Poljana)

The mentioned facts are the practical confirmation of the previous theoretical conclusion that the altitude rise increases the annual precipitation height for cca. 23 mm/100 m on the whole territory of Bosnia and Herzegovina. However, at a regional geographical climate analysis, should certainly be kept in mind that the degree of the continentality dominantly influence the mentioned precipitation relations and it should be analyzed in order to eliminate the errors in precipitation hight assessment.

3.Pluviometric regime types

The main characteristic noticable in precipitation height annual flow on the whole territory of Bosnia and Herzegovina is the existing of two significant precipitation periods. The first one is characterized by significantly increased periodic mean and time- positioned in the latter half of automn and the beginning of the winter climatological season, including period October – December (Figure 7). In this period, the monthly mean iscca. 125 mm or cca. 120 % of the mean annual precipitation height which is why this period has the characteristics of the capital precipitation maxima in Bosnia and Herzegovina.

The second one is characterized by significantly decreased periodic mean in relation to annual value, and during this period of precipitation minimum it is excreted meanly cca.85 mm or 82 % of the mean monthly value. The period of the capital precipitation minimum in Bosnia and Herzegovina performs during the middle and latter half of the summer, in period July – August. The pluviometric regime has the transitional characteristics between mentioned characteristic precipitation periods, and secundary precipitation periods with less expressive increased and decreased precipitation heights can be identified in its annual flow. The secundary precipitation maximum is time-positioned in period of the latter half of spring and beginning of the summer climatological season, in the period April – June, when the mean monthly precipitation height is cca. 108. 5 mm or cca. 101 % of the mean monthly precipitation hight.

The secondary precipitation minimum coincides with the period of the end of the winter and the beginning of the spring climatological season, in the period February – March, during witch it can be on average excreted cca. 90 mm or 87 % per periodically month. However, it is necessary to point out the very significant regional differences in Bosnia and Herzegovina in relation to presented general pluviometric sheme, especially from the aspect of the main climate regions.In this connection, two main pluviometric types can be identified in Bosnia and Herzegovina:

- continental
- maritime (Mediterranean).

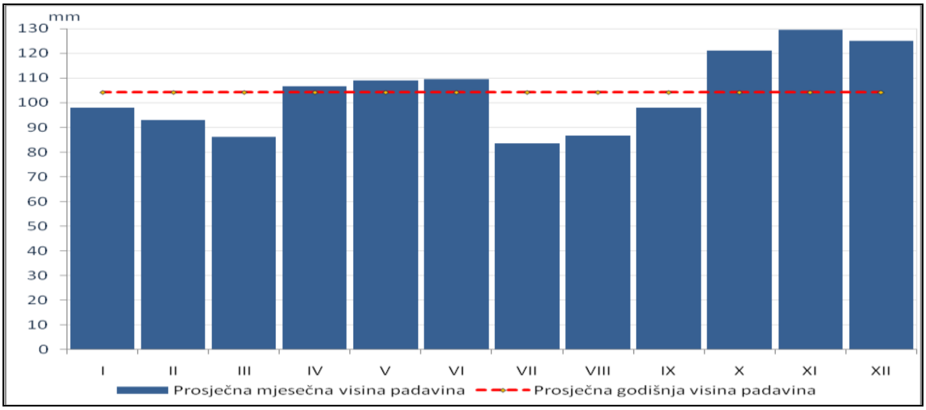

Figure 7.Mean annual flow of the pluviometric regime in Bosnia and Herzegovina

Their main characteristic is that in continental pluviometric type most of the precipitation is excreted in the warmer periods of the year (April - September), while in maritime pluviometric type period with maximum precipitation is positioned in the colder part of the year (October - March). The continental pluviometric type is under the dominant influence of the climatic characteristics of European continent and it is not clearly differentiated on the above characteristic precipitation periods (Figure 8). The reason for this pluviometric scheme lies in the fact that the concrete analysis includes the data from all precipitation stations of continental climatic region, ignoring thealtitude effect.The mean monthly precipitation height in this climatic zone is cca. 90 mm, but, in spite of the above facts, in the flow of the annual pluviometric regime at a general level can be extracted precipitation periods with increased or decreasedprecipitation.

The main precipitation period is time-positioned at the end of spring and the first half of the summer season climate, ie in the period May - July.The value of period average is about 101.5 mm, or approximately 113.0% of the average of all months.The main precipitation minimum is time-positioned at the end of winter and the beginning of spring climatological season, ie. in February - March, during which an average of only 69.0 mm excreted or 77.0%.Secondary precipitation periods are less pronounced than the average for the whole of Bosnia and Herzegovina.

The secondary precipitation maximum falls on the period October - November, with an average of about 99.0 mm which is identical to the monthly average annually.Also not so prominent secondary precipitation minimum is time-positioned in the second half of summer and beginning of autumn climatological season, i. e. the period July - September, during which the average excreted approximately 95.0 mm or approximately 96.0%.

The presented data suggest that the annual flow of pluviometric regime in this climatic region has expressed inconsistent relationship with thermal annual regime, so that regional pluviometric specifics in relation to a given average are very strong and they need to be separately analyzed.

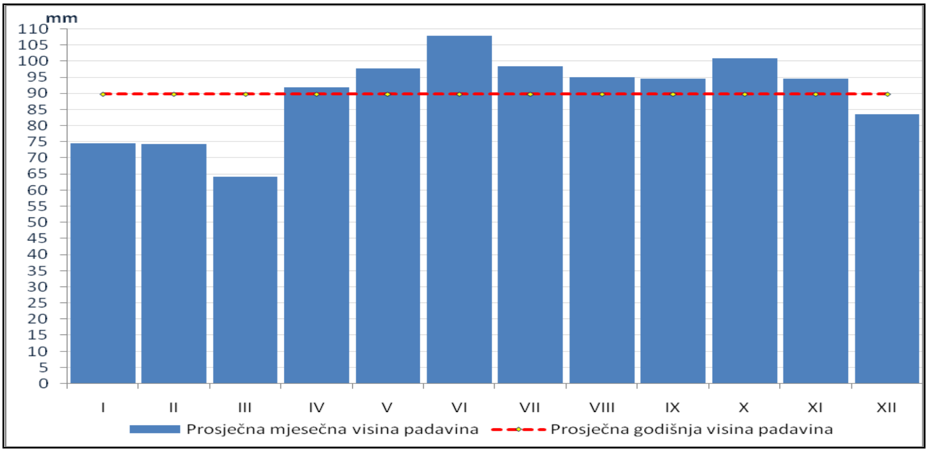

Figure 8.Mean annual flow of the pluviometric regime of the continental climatic zone in Bosnia and Herzegovina

The basic characteristic of the maritime pluviometric type is that the main rain season is time- positioned on the cold period, when excreted average per month season is around 167.0 mm or approximately 122.0% over the annual monthly average, which is about 137.0 mm (Figure 9). The above pluviometric dynamics is the result of regional-geographical distribution and intensity of relative humidity and cloudiness.More specifically, most of the region (as already pointed out) has karst features. Unlike the previous, in the annual flow of pluviometric regime it is possible to clearly allocate the characteristic precipitation periods. The main precipitation maximum is time-positioned on the second half of the autumn and the first half of the winter climatological season, in the period October - December.

The average monthly value of the period average is about 186.0 mm which is about 135.0% over the annual monthly average. The main precipitation minimum occurs during the summer climatological season, or in the period June - August, when the average per month excreted only 83.5 mm or approximately 30.0% of the annual monthly average.The secondary precipitation maximum in average performance in February with average monthly precipitation of about 163.0 mm. Secondary precipitation minimum is not so easily identified although it can be concluded that the average performance during the end of winter and the first half of spring climatological seasons, ie. in the period March - April, with periodic monthly average of about 133.0 mm.

Based on disclosed facts can be stated that in the Mediterranean climate region of Bosnia and Herzegovina annual flow pluviometric regime has extremely noncorrelative (almost reverse) flow in relation to the thermal.

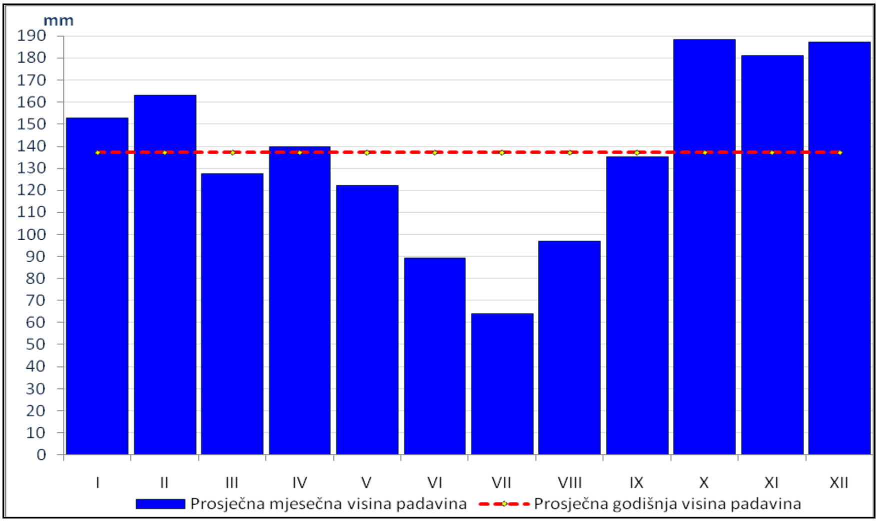

Figure 9.Mean annual flow of the pluviometric regime of the maritime (Mediterranean) climatic zone in Bosnia and Herzegovina

4.Conclusion

On the spatiotemporal dynamics of these two basic types of pluviometric regime, as the main climatological factor that achieves the primary effect can be given the intensity of action and pop-frequency of barometric fields of high and low air pressure of large and medium scale, which in the wider region of the European continent have mostly seasonal character.In connection with their activities are the characteristics of the thermal regime, relative humidity, cloud cover, windiness, which directly determine the precipitation gauge dynamics in space. Therefore, with respect to said pluviometric scheme in Bosnia and Herzegovina, certainly have to set aside the intermediate types, or areas in which are intertwined the influences of the continental and maritime pluviometric variants. For this reason it has determined the limes - zone that separates maritime from continental type in Bosnia and Herzegovina, and defines the areas degree of continentality.

The largest number of pluviometric criteria for assessing the degree of continentality is based on the precipitation distribution in the warmer and colder part of the year.

More specifically, if in the period from October to February (the colder half of the year) is excreted more than 50% of annual precipitation, pluviometric regime has maritime features, i.e., if during the period March - September (warmer half of the year) is excreted less than 50% of total annual precipitation levels, we talk about continental pluviometric regime.Border isocontinentalhas value: q = 50%, so that all areas in Bosnia and Herzegovina to the north of the listed isocontinentalhave continental pluviometric regime and conversely, areas located south of it have a maritime pluviometric regime.

General characteristics of the isocontinental spatial positionin Bosnia and Herzegovina is that its shape quite well follow the broadest relief forms, which is a practical confirmation of attitudes about the direct impact of the relief on the penetration of maritime and continental influences. The isocontinental q = 50% in Bosnia and Herzegovina has a wider zone of mt. Dinara (between Orlovac and Veliki Bat) and in northeast direction reaches mt. Šator, where bends in the southeast and across the northeastern slopes of the mt. Staretina descends in the central part of Glamočko field.Over the parts of the mountain morphostructures Slovinj and Hrbine border isotalantosecomes to the southwest and the west rim of the Kupres field, where in a westerly direction bends in the mt. Ljubuša and south of the Rama hydro reservoir extends further to the south-west slopes of the mt. Pogorelica and mt. Bitovnja.

The isotalantoseq = 50% continues, north of Jablanica hydro reservoir, in canyon valley of the river Neretva (between mountain morphostructures of Bjelašnica, Treskavica, Prenj and Visočica), and following the canyon valley continues to be extended to northwestern slopes of the mt. Lelija, northwestern slopes of the mt. Zelengora, wider area of Perućica,and from there, across the plateau Vučevo, down in the Tara river canyon (in the wider area of the mt.Obzir).Looking at the plan, analyzed border isocontinentalhas a Dinaric general direction, i.e. northwest - southeast. The areas south of the said boundary line - zone have an overwhelming maritime pluviometric regime, or north of it have a dominant continental pluviometric regime.

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