REGRESSION ANALYSIS OF PRECIPITATION DEPENDENCE ON THE ALTITUDE IN RASINA RIVER-BASIN

Ljiljana Stričević

[1] *Department of Geography, Faculty of Sciences and Mathematics, University in Niš*

Abstract: Precipitation is the most significant climate element in hydrologic study. Basic characteristics of the regime of surface and underground waters are directly conditioned by intensity, as well as space – time distribution. As the basis for hydrologic study in Rasina river-basin, a regression analysis of precipitation dependence on the altitude based on the data on average annual precipitation amount in the period 1961 – 2009 was done. The study comprised 10 rainfall measurement stations in the very basin of Rasina and its immediate surroundings.

On the basis of studies conducted we obtained data on the amount of precipitation in the areas where there are no rainfall measuring stations. Assumed precipitation dependence on the altitude is confirmed by a high correlation quotient of 0.85.

On the basis of defined dependencies for the territory of Rasina river-basin, we obtained mean precipitation amounts in altitude zones, as well as mean precipitation amount for the river-basin of 755.3 mm. An isohyet map of Rasina river-basin was made on the basis of these data and altitude zones map.

Key words: precipitation, altitude, regression analysis, Rasina

1. Introduction

Rasina river-basin is situated in the south part of Central Serbia on the surface of 979.6 km² (Dimitrijević, 2010.). The basin is bounded by the mountains of Goč (1124 m), Ljukten (1219 m), Crni vrh (1543 m) and Željin (1785 m) in south-west and west.

South-west part of the basin is represented by the mountain of Kopaonik with the highest tops in the basin Karaman and Gobelja (1934 m). Farther towards the east the basin is bounded by the mount of Lepenac, easternmost slopes of which extend to the left part of Jankova gorge. Mountain range of Jastrebac with its top Zmajevac (1381 m), which is the

highest mountain top in this part of Rasina river-basin, continues east of Lepenac.

In the outmost north-east, Rasina river-basin reclines to Mojsinjske mountains (501 m), which represent a part of the Stalać horst. This horst is fully surrounded by Pomoravlje tertiary.

There are several basins among these mountains. Broad Kruševac basin extends to north and north-east. Secondary Župski basin continues south-west from Kruševac basin. Dobroljubačka basin, which takes up central position in this area, lies east of Župski basin. In the outmost south-east, there is a part of Toplički basin, which is separated from the middle part of Rasina river-basin by Jankova gorge (Dimitrijević, 2010).

Since watercourses are formed by precipitation, they represent the most important climatic element in hydrologic study. Intensity, as well as space and time distribution of precipitation directly condition basic characteristics of a watercourse regime. To study precipitation in Rasina river-basin, the data of Republic Hydro-meteorological service of Serbia for the period from 1961 to 2009 were used.

The amount of precipitation most often increases with the altitude, although there are cases when the highest terrains do not pick up the highest amount of precipitation.

The highest annual amount of precipitation in the immediate Rasina river-basin was measured on the mountain of Goč (990 m altitude) - 1005.7 mm. The station on Kopaonik (1710 m), where 981.8 mm average annual precipitation amount was recorded is on the highest altitude in the river-basin. Such a state is largely conditioned by the position and orientation of Kopaonik ridge. Namely, humid air masses development from the west is conditioned by numerous mountain notches over which the masses smoothly pass and excrete larger amount of precipitation on lower areas on the east slopes of this mountain (Stričević, 2015).

At the stations of Kupci, Razbojna and Petina, situated at the altitude of 200 – 335 m high mean annual amount of precipitation is measured. These stations are located on the north-west slopes of Jastrebac, where humid air masses get smoothly and excrete larger amount of precipitation. On Jastrebac, as well as on Kopaonik, there is a significant difference in the amount of precipitation on the north and the south expositions. Slopes on the south have considerably lower precipitation, which can be confirmed by the data from the stations in Kupci and Velika Plana. Namely, the village of

Kupci which lies in the north-west mountain region of Jastrebac at the altitude of 200 m gets about 250 mm of sediment more annually when compared to Velika Plana which is situated in the south bottom of the mountain at 505 m altitude (Ducić V., Radovanović M., 2005).

Table 1 - Comparative view of annual precipitation amounts (mm) for the periods 1961-1990, 1991-2009 and 1961-2009

Station	N	E	altitude (m)	Pcp. 1961-1990	Pcp. 1991-2009	Pcp. 1961-2009
Kruševac	43º34´32´´	21º21´08´´	166	647.8	614.4	641.8
Kupci	43º27´09´´	21º14´09´´	200	726.1	748.7	733.2
Razbojna	43º20´37´´	21º10´18´´	320	807.7	717.1	780.1
Petina	43º29´27´´	21º25´25´´	335	725.6	686.2	714.5
Blace	43º23´04´´	21º17´37´´	395	656.3	649.0	655.7
Brus	43º23´04´´	21º02´09´´	440	684.0	611.1	662.4
Milentija	43º26´06´´	20º59´44´´	500	676.9	650.9	669.0
Pleš	43º29´02´´	20º55´16´´	600	815.7	785.3	806.7
Goč	43º34´10´´	20º47´52´´	990	1003.8	1049.6	1005.7
Kopaonik	43º20´56´´	20º47´25´´	1710	920.9	991.4	981.8

To analyze the change in mean annual precipitation amounts, we used 30-year period from 1961 – 1990, according WMO recommendation, as well as the period from 1991 – 2009, so as to track recent developments in pluviometric regime.

When analyzing the data on mean precipitation amounts in given periods given in Table 1, it was determined that precipitation amount has been in the increase in three rainfall measuring stations in the last nineteen years of study, while there has been decrease in precipitation amount in seven stations. Increase in mean annual precipitation amount goes from 22.6 mm in Kupci station to 70.5 mm in Kopaonik station. The biggest decrease in mean annual precipitation amount in the last 19 years was recorded in Razbojna station – 90.6 mm, whereas the lowest decrease was recorded in Blace station – 7.3 mm.

2. Study methodology

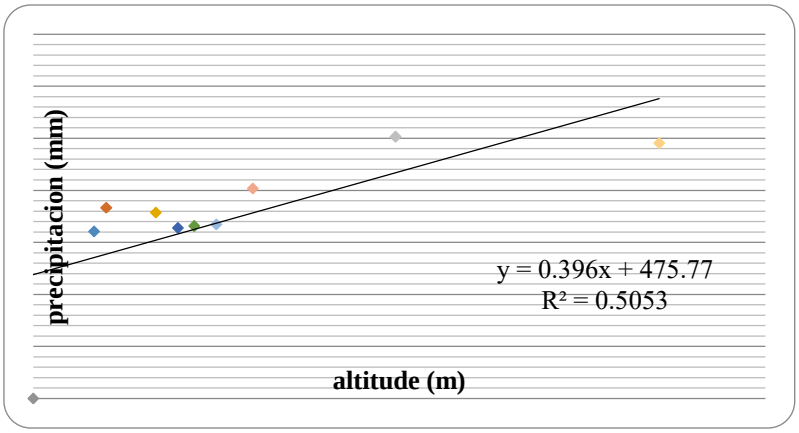
Dependence of precipitation and altitude is not consistent. Precipitation amount increases with the altitude up to a certain altitude, and then it gradually decreases. If we analyze the changes in mean annual

precipitation values in Rasina river-basin with the altitudes of measuring stations where precipitation was measured, we can observe that precipitation amount gradually increases from the lowest Kruševac station up to Razbojna station, and then decreases upstream to Milentija, only to increase again up to the highest stations in the river-basin.

To determine how precipitation amount changes with the increase in altitude as precisely as possible, we performed a correlation between the values of mean annual precipitation in the period 1961 – 2009 and the altitudes on the territory of Rasina river-basin and its immediate surroundings. In the dependence analysis we exempted the data for Razbojna station which is situated at low altitude and has high precipitation amount. The obtained correlation quotient amounts to 0.85, whereas vertical precipitation gradient is 24.6 mm/100 m.

Analytic form of the applied model for determining precipitation amount in Rasina river-basin is:

$$X_0(mm)= 0.246 * H + 617,5; \quad R^2=0.72$$



Picture 1 – Linear regression precipitation dependence on the altitude in Rasina river-basin

3. Study results

Based on the obtained results, shown in Table 2, we can conclude that the highest difference in obtained and measured values was noticed in Petina, Blace and Pleš. Mean multi-annual precipitation amount in these stations, based on the formed dependence, should be from 8.6 to 10% higher than measured values. In Petina station, located on north-west slopes of Jastrebac,

calculated precipitation amount has 10% higher value than the amount obtained by measuring. This station is located in the direction of humid air masses from the west, that is, north-west, which bring higher precipitation amount to this area. Such high measured values of mean annual precipitation amounts on low altitudes can also be the consequence of inadequate position of the station.

Table 2 – Comparative view of measured and obtained values of mean annual precipitation amounts

Station	**altitude (m)**	Measured	Obtained	Difference (%)
Kruševac	166	641.8	641.2	-0.1
Kupci	200	733.2	690.6	-5.8
Razbojna	320	780.1	775.3	0.6
Petina	335	714.5	785.9	10.0
Blace	395	655.7	714.7	9.0
Brus	440	662.4	699	5.5
Milentija	500	669	713.3	6.6
Pleš	600	806.7	737.2	8.6
Goč	990	1005.7	932.1	7.3
Kopaonik	1710	981.8	1002.5	2.1

The territory of Rasina river-basin belongs to Moravički region according to M. Ocokoljić (1987) classification. He determined that precipitation in this area increases up to approximately 1000 m above sea level, and then decreases in a non-linear way. These data are in accordance with the data obtained in measuring stations on the territory of the district and its immediate surroundings, since mean multi-annual precipitation amount of 1005.7 mm was recorded in Goč station (990 m altitude), while in the highest station Kopaonik (1710 m altitude) the same precipitation amount was 981.8 mm.

Table 3 - Vertical precipitation gradient (mm/100 m) in the period 1961- 2009

	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Annually**
Kruševac - Kopaonik	1.17	1.64	1.79	2.01	2.85	1.84	1.91	2.12	2.44	1.35	1.30	1.26	21.68
Brus - Kopaonik	1.59	1.69	1.97	3.02	2.26	1.80	2.68	3.30	3.31	0.57	1.48	1.47	25.15
Blace - Kopaonik	1.44	1.79	2.02	2.65	3.31	2.32	2.30	2.17	2.14	1.72	1.41	1.51	24.80

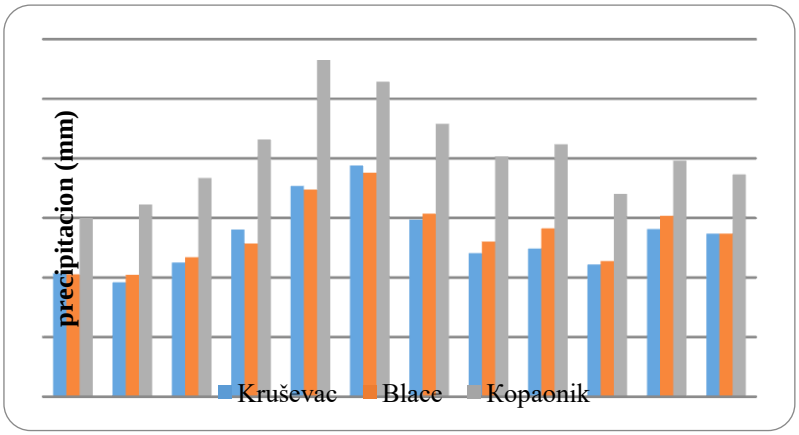
Živković and Anđelković (2004) engaged in analysis of precipitation gradients on the territory of Serbia, south of Sava and Danube. In so doing,

they distinguished 59 homogenous areas for the relation precipitation – altitude. Vertical precipitation gradients were also calculated for Rasina river-basin. They reflect well the increase in precipitation together with the altitude.

Precipitation gradient values, done on the basis of measured monthly and annual precipitation amounts are shown in Table 3. These data show that annual precipitation amount on the profile Brus – Kopaonik increases 25.15 mm each one hundred meters. The highest amounts were recorded in August, 3.30 mm/100 m, while the lowest amounts were recorded in November – 1.41 mm/100 m.

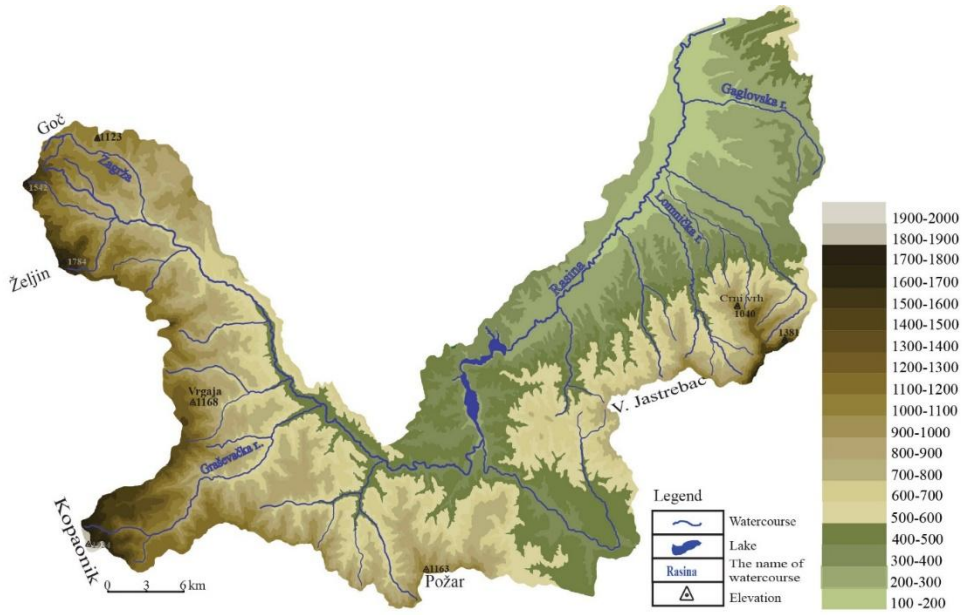
On the profile Kruševac – Kopaonik annual precipitation amount increases 21.68 mm each one hundred meters. The highest amounts were recorded in May - 2.85 mm/100 m, whereas the lowest amounts were recorded in January – 1.17 mm/100 m.

Gradient value obtained in the relation altitude - precipitation amounts to 24.60 mm/100m on annual level.

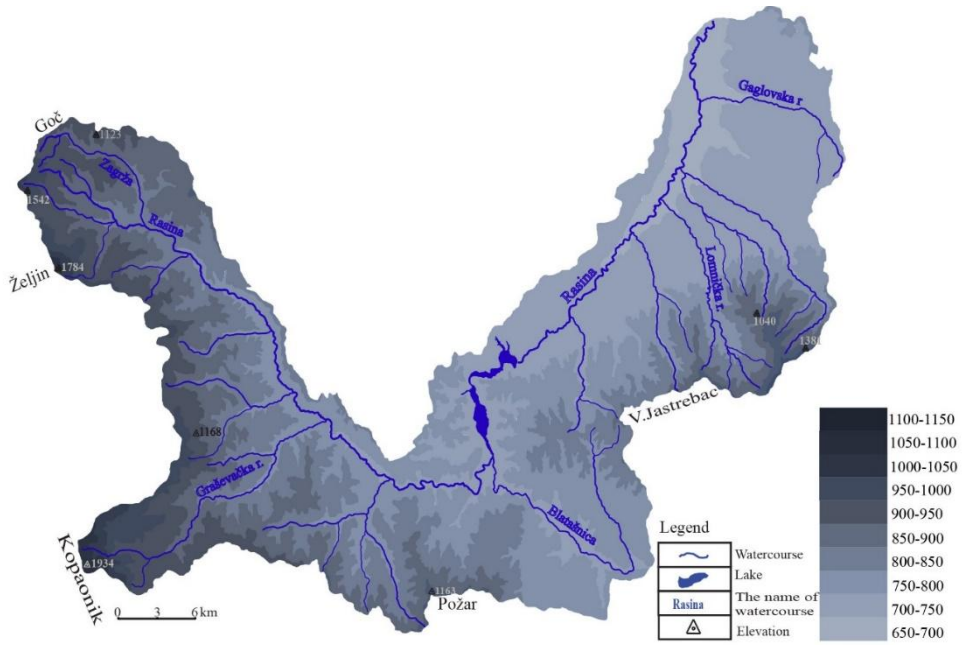


Picture 2 – Comparative view of annual precipitation distribution on the stations Kruševac, Blace and Kopaonik in the period 1961-2009

On the basis of defined dependences for the territory of Rasina river-basin, we obtained mean multi-annual values of precipitation amounts for altitude zones, as well as mean precipitation amount for the river-basin which amounts to 755.3 mm. Based on these data and altitude zones map, an isohyet map of Rasina river-basin was made. To construct these maps we used topographic maps 1: 50 000 which comprise the territory of Rasina river-basin as the basis for computer programs (Inkscape and GIMP).



Picture 3 – Altitude zones in Rasina river-basin



Picture 4 – Isohyet map of Rasina river-basin

4. Discussion

When analyzing the data shown in this study, it can be concluded that dependence of precipitation and altitude is not consistent. Precipitation amount increases with the altitude up to a certain altitude, and then it gradually decreases. Analyzed changes in mean annual precipitation values in the very river-basin and its immediate surroundings, together with the altitudes of the stations where they were measured, point to certain specificities. They are reflected in the fact that high precipitation amounts, which could be expected at significantly higher altitudes, were measured on the stations located at low altitudes, in river valleys. Likewise, a significant difference in precipitation amount on higher grounds is noticeable. It is largely conditioned by the orientation of mountain ridges and their exposure to dominant air flows. So the highest precipitation amount in the analyzed period was measured on Goč, where 1005.7 mm of precipitation was measured at the altitude of 990 m. Except on Goč, higher precipitation amount was measured on the mountain of Jastrebac, where 979.7 mm of annual sediment amount was registered at the altitude of 575 m, which is almost the same amount as on Kopaonik, at 1710 m altitude. Such a high precipitation amount on north-west slopes of Jastrebac is the consequence of penetration of air masses from the north-west which freely move from the valley of Zapadna Morava to the valley of Rasina. These air masses have so called foehn characteristics which condition their rising anew and increased precipitation excretion. North-west slopes of Jastrebac are in a direct way of these fronts (Živković and Anđelković, 2004).

Studies so far on dependence of mean annual precipitation amounts on altitudes where rainfall measuring stations are located, as well as what was done in this study, point to the fact that regression analysis represents a good way to determine the difference in spatial precipitation distribution, as well as to determine vertical precipitation gradients.

By applying this method it is possible to determine the values of mean annual precipitation amounts on certain territories where measures are not done, which also enables more adequate hydrologic studies in these environments.

Taking into consideration that precipitation is a very changeable climatic element conditioned by the influence of numerous factors, such as relief, directions of air masses development, etc., a detailed analysis of the

change in precipitation amount should be included in the future development of the model.

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