ANALYSIS OF PRECIPITATION QUANTITIES AND TRENDS FROM PANNONIAN AND PERIPANNONIAN PARTS OF SERBIA

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Abstract
Annual and seasonal quantities and trends of precipitation were analyzed for twelve stations located in Pannonian and Peripannonian parts of Serbia. Investigated period was from 1949 to 2010. The results showed that the precipitation trends during winter and spring had decreased, while in summer and autumn had increased. Tendencies of annual precipitation time series show rise on most analyzed stations as a consequence of rainy years and extreme rainfall events in the last 15 years. In the investigated period, 10 years with severe and extremely severe drought occurred and they tend to occur in subsequent years. Cluster analysis gave very good picture of precipitation distribution.

Key words: precipitation, climate change, Pannonian Basin, Serbia

ANALIZA PADAVIN V PANONSKEM IN OBPANONSKEM DELU SRBIJE

Izvleček
Analizirali smo letne in sezonske količine ter trende za 12 meteoroloških postaj v panonskem in obpanonskem delu Srbije za obdobje 1949–2010. Rezultati kažejo trend zmanjševanja padavin pozimi in spomladi ter trend porasta poleti in jeseni. Časovne serije letnih količin padavin kažejo porast padavin na večini preučevanih postaj in so posledica bolj namočenih let ter ekstremnih padavinskih dogodkov v zadnjih 15 letih. V preučevanem obdobju je bilo tudi 10 let z močno in ekstremno sušo s tendenco pojavljanja v več zaporednih letih. Dobro sliko o razporeditvi padavin je dala tudi metoda razvrščanja v skupine (cluster analiza).

Ključne besede: padavine, klimatske spremembe, Panonska nižina, Srbija

1. INTRODUCTION

Southeastern part of Pannonian plain is located in North Serbia (Autonomous Province of Vojvodina) while its Peripannonian part is represented by a narrow belt south from Autonomous Province of Vojvodina. Pannonian part of Serbia has an area of 21,506 km^2 and consists of three regions: Srem, Banat and Bačka (Marković, Pavlović, 1995). Peripannonian part of Serbia has an area of 22,199 km^2 and consists of two regions: Northwest and Central Serbia (Marković, 1968).

Relief of Pannonian part of Serbia is plain with seven investigated stations located between 80 and 102 m a.s.l. It consists of plain, river valleys and hills with five stations located on the elevations between 82 and 185 m a.s.l.

Climate of Serbia can be described as moderate-continental with more or less pronounced local characteristics. Spatial distribution of climate parameters is caused by geographic location, relief and local influence as a result of combination of relief, distribution of air pressure of major scale, terrain exposition, presence of river systems, vegetation, urbanization, etc. (Republic Hydrometeorological Service …, 2012).

Judging by the atmospheric processes and relief characteristics, precipitation over the territory of Serbia is temporary and spatially unevenly distributed. Major part of Serbia has continental precipitation regime with higher quantities in warmer part of the year. Normal annual precipitation sum for the whole country is 896 mm. Most of the Pannonian part of Serbia has precipitation amount below 600 mm (Ducić, Radovanović, 2005). Influence of Arctic and North Atlantic Oscillations on precipitation anomaly can be seen in the period January–March and September–November for the period 1958–2007 (Pavlović Berdon, 2012).

Precipitation extremes since the beginning of measuring in Serbia are:

- The driest year was 2000 when 223.1 mm was measured in Kikinda;
- The rainiest year was 1937 when 1324.5 mm was measured in Loznica;
- The highest monthly precipitation quantity was registered in June 1954 in Sremska Mitrovica with 308.9 mm and
- The highest daily precipitation quantity of 211.1 mm was registered on 10 October 1955 in Negotin (Precipitation regime in Serbia …, 2012).

2. DATABASE AND METHODS

Amount of precipitation has been analyzed for 12 stations distributed over the territory of Pannonian and Peripannonian Serbia (Figure 1). The period covered by this survey is from 1949 to 2010. The data has been provided by the Meteorological Yearbooks of the Republic Hydrometeorological Service of Serbia (Table 1).

For obtaining important results, several methods were employed, such as simple linear regression, Mann-Kendall test, cluster analysis and aridity index by Emmanuel de Martonne.

The trends of seasonal and annual precipitation values were detected with simple linear regression using the least squared method. Mann-Kendall nonparametric statistical test (Sneyers, 1991) was used for detecting statistical significance of trends. For calculation

MAKESENS software package was used, developed by Finnish Meteorological Institute (Salmi et al., 2002). Statistical significance was defined on the level of freedom of 90%, 95% and 99%.

Cluster analysis was used for joining together a set of objects (in this case, meteorological stations) into groups (called clusters), so that the objects (meteorological stations) in the same cluster are more similar (in some sense or another) to each other than to those in other clusters. Cluster analysis was performed by software program Statistica 9.0. Joining tree cluster was used for analysis of variables, while Ward's method and Squared Euclidean Distance were used for evaluation of similarities. Special diagram called dendrogram was used for graphical presentation of the results.

To calculate the degree of dryness of the climate, the aridity index of Emmanuel de Martonne (I_s) was used. It is calculated by dividing the annual average amount of precipitation (x) to annual average temperature (t) and adding 10: Is = x/(t+10).

Figure 1: Geographical locations of investigated meteorological stations (red rectangles) in Pannonian and Peripanonnian parts of Serbia
Slika 1: Geografski položaj preučevanih meteoroloških postaj (v rdečih okvirih) v panonskem in obpanonskem delu Srbije

Source of the map/Kartografska podlaga: Ezilon Maps (http://www.ezilon.com/maps/europe/serbia-physical-maps.html); scale: 1 cm=17.5 km

Table 1: Main characteristics of the investigated meteorological stations
Preglednica 1: Glavne značilnosti preučevanih meteoroloških postaj

Meteorological station	Coordinates		Elevation (m)
	N	E	
Palić	46°06′	19°46′	102
Sombor	45°46′	19°09′	88
Novi Sad	45°20′	19°51′	84
Kikinda	45°51′	20°28′	81
Zrenjanin	45°24′	20°21′	80
Vršac	45°09′	21°19′	85
Sremska Mitrovica	45°06′	19°33′	82
Beograd	44°48′	20°28′	132
Veliko Gradište	44°45′	21°33′	82
Valjevo	44°19′	19°55′	176
Smederevska Palanka	44°22′	20°57′	121
Kragujevac	44°02′	20°56′	185

Source/Vir: Republic Hydrometeorological Service of Serbia, 2012

3. RESULTS AND DISCUSSION

In this work, trends of annual and seasonal quantities of precipitation were analyzed and graphically displayed. Amount of precipitation varies from one year to another, so the trend line is the best and most obvious evidence of precipitation increase or decrease during the investigated period.

3.1. Precipitation values of annual and seasonal time series

Average annual precipitation at research area in the period 1949–2010 was 637.6 mm. Only 3 stations received less than 600 mm of precipitation and they are located in North Serbia where continental influences are the strongest (Palić 556.0 mm; Kikinda 563.3 mm; Zrenjanin 583.0 mm). Stations with highest precipitation quantities are Valjevo (793.2 mm), Beograd (696.5 mm) and Veliko Gradište (673.8 mm; Table 2). The reason is the location of Valjevo in the southwest of the investigated area in Kolubara river basin surrounded with mountains; Beograd is situated on two rivers (Danube and Sava) and with a lot of aerosols providing condensation nuclei. Veliko Gradište is situated at the right bank of Danube river near the Carpathian Mountains. The biggest difference in precipitation amounts (238 mm) is between stations Valjevo and Palić.

On seasonal level similar results are obtained. Stations located in the Peripannonian part of Serbia have more precipitation than those in Pannonian part during all four seasons. The biggest difference is in summer (68 mm) while the smallest is in winter (44 mm).

Table 2: Average precipitation amounts (mm) on seasonal and annual level in Pannonian and Peripannonian parts of Serbia in the period 1949–2010
Preglednica 2: Povprečne letne in sezonske količine padavin v panonskem in obpanonskem delu Srbije v obdobju 1949–2010

Meteorological station	Winter	Spring	Summer	Autumn	Year
Palić	112.0	130.4	185.1	128.9	556.0
Sombor	118.1	140.3	197.5	144.2	600.4
Novi Sad	125.5	147.1	208.9	143.5	624.8
Kikinda	114.6	132.5	187.3	129.1	563.3
Zrenjanin	121.2	139.5	190.8	132.2	583.0
Vršac	134.2	157.1	223.7	144.1	658.7
Sremska Mitrovica	129.7	146.9	202.1	149.6	627.7
Beograd	151.3	169.9	219.9	156.0	696.5
Veliko Gradište	147.9	168.7	205.8	152.0	673.8
Valjevo	156.5	196.7	253.5	187.3	793.2
Smederevska Palanka	134.3	156.1	199.4	152.3	642.2
Kragujevac	124.0	162.1	202.7	143.0	632.0
Pannonian and Peripannonian Serbia	**130.8**	**153.9**	**206.4**	**146.8**	**637.6**

3.2. Trends of annual and seasonal precipitation time series

Trends of annual precipitation quantities show rise on all analyzed stations, except Sremska Mitrovica and Veliko Gradište (Table 3). Based on Mann-Kendall test, only trend of annual amount of precipitation in Palić is statistically significant with 105.8 mm (1949–2010). The 'biggest' decrease of the precipitation amount on annual level was in Sremska Mitrovica with –10.9 mm (1949–2010). Trend of annual precipitation amount for whole investigated area is 45.3 mm (1949–2010) and is not statistically significant. Only precipitation trend in autumn is statistically significant for whole investigated area with 37.9 mm (1949–2010). Positive trends on most stations are a consequence of rainy years and extreme rainfall events during last 15 years.

Table 3: Trends (in mm) of seasonal and annual amount of precipitation in Pannonian and Peripannonian parts of Serbia in the period 1949–2010: **bold+** *– significance 90%;* **bold*** *– significance 95%;* **bold**** *– significance 99%*
Preglednica 3: Trendi sezonskih in letnih količin padavin v panonskem in obpanonskem delu Srbije v obdobju 1949–2010: **polkrepko+** *– statistično značilno 90 %;* **polkrepko*** *– statistično značilno 95 %;* **polkrepko**** *– statistično značilno 99 %*

Meteorological station	Winter	Spring	Summer	Autumn	Year
Palić	–2.9	22.6	**45.8+**	**32.1+**	**105.8***
Sombor	–14.5	6.6	45.6	**46.0***	86.4
Novi Sad	–23.6	16.1	55.9	**63.9****	116.0
Kikinda	–25.3	11.7	23.5	**28.6+**	45.7
Zrenjanin	–30.3	–13.7	26.0	42.4	30.7
Vršac	–19.1	–4.2	6.0	28.5	14.5
Sremska Mitrovica	**–51.2***	–15.4	7.8	**41.3***	–10.9
Beograd	–0.7	–22.3	25.1	31.2	36.8
Veliko Gradište	–25.8	–23.6	0.1	37.0	–7.4
Valjevo	–9.2	–18.5	36.0	26.5	37.2
Smederevska Palanka	11.6	–10.9	25.7	34.1	60.2
Kragujevac	–0.5	–18.1	4.2	**43.3***	28.0
Pannonian and Peripannonian Serbia	**–16.0**	**–5.8**	**25.1**	**37.9+**	**45.3**

During the winter, 11 from 12 stations show negative trend of precipitation with values from –0.7 mm in Beograd to –51.2 mm in Sremska Mitrovica which is statistically significant. Only Smederevska Palanka shows positive trend of precipitation with 11.6 mm in the period 1949–2010.

Only four stations show positive trend of precipitation amount during spring and they are all located in Pannonian part of Serbia (Palić, Sombor, Novi Sad and Kikinda). Other stations show negative trend of precipitation ranging from –4.2 mm in Vršac to –23.6 mm in Veliko Gradište. Eastern part of research area, from Kikinda to Veliko Gradište, Smederevska Palanka and Kragujevac had a negative trend of precipitation quantities. None of these trends show statistical significance.

Contrary to the winter and spring trends, summer precipitation quantities show positive trend on all 12 stations. The biggest rise was detected in Palić (45.8 mm in the period 1949–2010) and it is statistically significant while the smallest rise was in Veliko Gradište with 0.1 mm (1949–2010).

Precipitation increase is continued in autumn when all stations have positive trends. On six stations positive trends are statistically significant for the period 1949–2010: Kikinda (28.6 mm), Palić (32.1 mm), Sremska Mitrovica (41.3 mm), Kragujevac (43.3

mm), Sombor (46.0 mm) and Novi Sad (63.9 mm). Trend of precipitation quantities for whole research area is statistically significant with 37.9 mm during the period 1949–2010.

In the southern Europe, IPCC scenario showed that amount of precipitation will decrease in summer from 5% to 15% and increase during the winter until 2020 (Popović, Jovanović, 1994). Based on the obtained results from research area, it is obvious that they are opposite to the given scenario because precipitation has tendencies to increase in summer and decrease in winter.

The results of precipitation analysis indicate that climate events with extremely high precipitation quantity were more frequent on the stations Sombor, Novi Sad, Kikinda, Beograd, Smederevska Palanka and Kragujevac during the period 1961–2006. Results for Beograd showed positive trend of annual precipitation quantity for the period 1888–2006 with 8.9 mm/100 years (Đorđević, 2008) and this increase has continued during the researched period.

It can be concluded that in Pannonian and Peripannonian Serbia three trends of precipitation amount exist:

- negative trend during winter and spring;
- positive trend during summer and autumn and
- positive trend on annual level.

3.2. Analysis of precipitation regime

Besides the amount of precipitation, very important characteristic of precipitation is its regime. Precipitation regime or its distribution during the year could be calculated using this formula:

$$r = [(R_{x-Rn})/Rg]*100\%$$

where Rx is amount of precipitation in the wettest month, Rn is amount of precipitation in the driest month and Rg is annual amount of precipitation (Lazić, Pavić, 2003).

On meteorological stations Novi Sad, Sremska Mitrovica, Sombor, Beograd, Valjevo and Kragujevac (northwestern Serbia), there is declining trend of precipitation regime for the investigated period. This means that the precipitation amount is getting more evenly distributed over the year. Contrary to that, on stations Kikinda, Zrenjanin, Vršac, Veliko Gradište and Smederevska Palanka (northeastern Serbia) the trend of precipitation regime is rising which means that distribution of precipitation amount during the year is getting more unevenly distributed.

3.3. Detection of dry and wet periods

Drought with its characteristics is a phenomenon with very complex properties. It can be determined by either one or more components such as: periods of no rainfall, insufficient rainfalls, high air temperature (Hobai, 2009), low relative air humidity, high evapotranspiration, some dryness indexes (Dragotă, Kucsicsa, 2011; Rajić, Bezdan, 2012).

In the investigated period, four shorter periods with different precipitation characteristics can be distinguished (Figure 2):

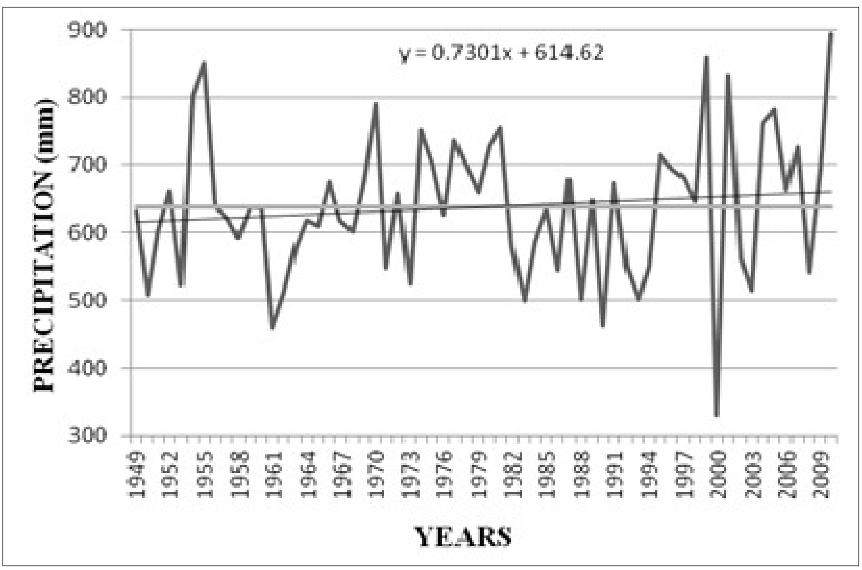
- First period from 1949 to 1973 with deficit of precipitation;
- Second period from 1974 to 1981 with excess of precipitation;
- Third period from 1982 to 1994 with deficit of precipitation and
- Forth period from 1995 to 2010 with excess of precipitation.

For the first period, two thirds of investigated years had less precipitation than average. Moderately dry years were 1950 (–129.6 mm), 1953 (–114.7 mm), 1962 (–129.1 mm) and 1963 (–112.7 mm) with one fifth less precipitation than average. The driest year in this period was 1961 (–178.9 mm) with almost one third less precipitation than average. Years with highest amount of rainfall were 1954 (165.1 mm), 1955 (212.2 mm) and 1970 (152.8 mm) with more than one third more precipitation than average. Other years had about average amount of precipitation.

During the second period, seven of eight years had more precipitation than average. Years with the most excess of precipitation were 1974 (114.3 mm) and 1981 (117.7 mm) with one sixth more precipitation than average.

In the third period, 10 of 13 years had less precipitation than average. The driest years were 1988 (–136.9 mm), 1990 (–174.8 mm) and 1993 (–135.9 mm) with one quarter less precipitation than average. All other years had about average amount of precipitation.

Figure 2: Curves and trends of annual precipitation time series from Pannonian and Peripannonian parts of Serbia (gray line = mean annual precipitation quantity; black line = trend line of mean annual precipitation quantity)
Slika 2: Krivulja in trendi časovnih vrst letnih količin padavin v panonskem in obpanonskem delu Srbije (siva črta = povprečna letna količina padavin; črna črta = trend povprečne letne količine padavin)



Between 1995 and 2010, three quarters of years had excess of precipitation. Years with the highest excess of precipitation were 1999 (221.1 mm), 2001 (194.0 mm) and 2010 (255.8 mm) with one third more precipitation than average, and 2004 (124.4 mm) and 2005 (142.8 mm) with one quarter more precipitation than average. Driest years were 2000 with extremely severe drought (–307.3 mm) with almost half of average precipitation. Severe drought hit Serbia in 2003 again with –122.7 mm precipitation less than average.

3.4. Aridity index

There are several aridity indexes that show how much the amount of precipitation and its distribution varies from average value during at least 30 years for investigated time unit.

Aridity index was introduced in science by Emmanuel de Martonne. It can be used to determine dry, wet and moderate regions. For calculation of drought index (I_s), values of precipitation amount (x) and air temperature (t) are used in formula:

$$Is = x/(t+10)$$

Values of Is between 20 and 30 match wooded steppe with exorheic drainage. As aridity index value is closer to 30, there is less need for irrigation. Values of Is and its characteristics by E. de Martonne are the following:

- Is <5: arheic arid areas (Sahara, Arabia, Central Australia);
- Is 5–10: endorheic areas: border areas of deserts, desert steppe;
- Is 10–20: relief is crucial for endorheic or exorheic areas, grass formations with shrubs or thorny trees; irrigation is useful or necessary. These are zones of irrigated crops;
- Is 20–30: exorheic areas; as aridity index value is closer to 30, there is less need for irrigation, only for huge water consumers;
- Is 30–40: permanent runoff of water but not abundantly; intensive agriculture;
- Is >40: abundant runoff of water, excess of water for cereals (Republic Hydrometeorological Service of Serbia, 2012).

Data in Table 4 show that values of Is over 30 are characteristic for stations in or near mountain areas, while values of Is below 30 are characteristic for stations in flat areas (Figure 1).

Values of aridity index for Pannonian and Peripannonian parts of Serbia show small rising trend, especially during several last years when it was higher than 30.

Values of aridity index by Emmanuel de Martonne show similar results as trends of annual amount of precipitation. The smallest value of aridity index was from 1950s to middle 1970s and from middle 1980s to middle 1990s. Years with smallest values of aridity index were 2000 (Is = 14.3), 1990 (Is = 21.1) and 1961 (Is = 21.1) because of small precipitation amount and high average annual temperature.

Mann-Kendall test was applied for detection of statistical significance of annual aridity index values for all stations during investigated period and it showed no statistical significance.

Table 4: Values of aridity index by Emmanuel de Martonne for the period 1949–2010 from Pannonian and Peripannonian parts of Serbia
Preglednica 4: Vrednosti indeksa aridnosti E. de Martonna za obdobje 1949–2010 za panonsko in obpanonsko Srbijo

Meteorological station	Aridity index
Palić	27.7
Sombor	28.8
Novi Sad	29.6
Kikinda	26.8
Zrenjanin	27.6
Vršac	30.5
Sremska Mitrovica	29.9
Beograd	31.6
Veliko Gradište	31.9
Valjevo	37.6
Smederevska Palanka	30.2
Kragujevac	29.7

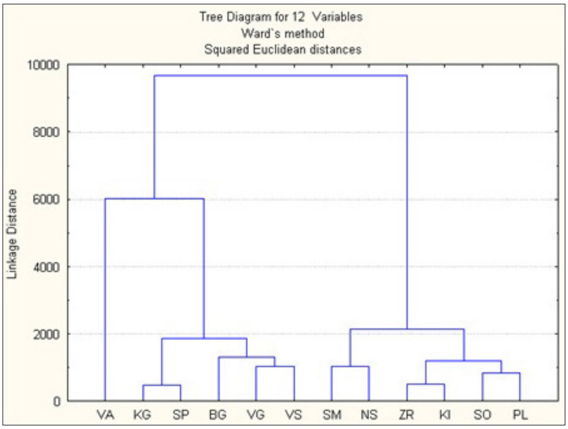
3.5. Cluster analysis

Cluster analysis was used for joining together meteorological stations into groups based on similarities of aridity index values. Special diagram called dendrogram (Figure 3) was created using values of aridity index for 12 investigated stations. At first, they are divided into two clusters. First cluster consists of stations located in Peripannonian Serbia (Valjevo, Kragujevac, Beograd, Veliko Gradište and Vršac) while second consists of stations located in Pannonian Serbia (Sremska Mitrovica, Novi Sad, Zrenjanin, Kikinda, Sombor and Palić).

First cluster consists of four smaller clusters. Valjevo represents distinct cluster because it is located far from other stations and surrounded by mountains. Second smaller cluster consists of stations Kragujevac and Smederevska Palanka which are close to one another. Third smaller cluster consists of Beograd located on two rivers and where 'urban heat island' effect is present. Forth smaller cluster consists of stations Veliko Gradište and Vršac. These stations are relatively close to one another, both in hilly area of Eastern Serbia.

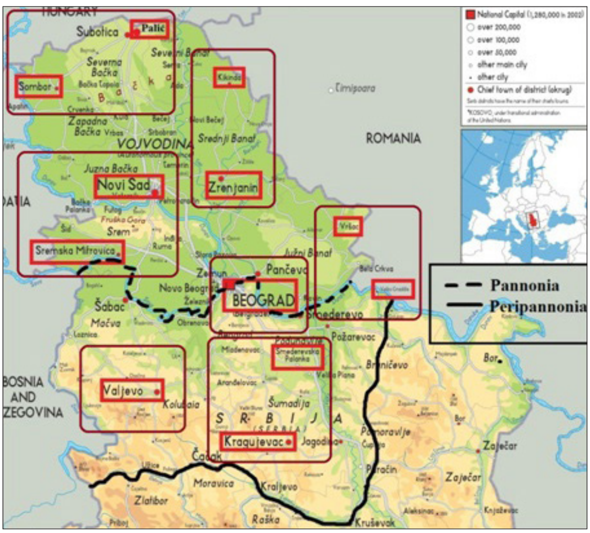
Second cluster with stations in Pannonian part of Serbia consists of three smaller clusters. First smaller cluster consists of stations Novi Sad and Sremska Mitrovica. These cities are relatively close to one another on opposite slopes of Fruška gora mountain (539 m) and both are located on rivers. Second smaller cluster consists of stations of Zrenjanin and Kikinda and third of Sombor and Palić. These stations are located near one another and on similar elevation.

Figure 3: Tree diagram (dendrogram) for 12 investigated stations based on aridity index values (Is) from Pannonian and Peripannonian parts of Serbia
Slika 3: Dendrogram za 12 meteoroloških postaj na osnovi vrednosti indeksa sušnosti (Is) za panonsko in obpanonsko Srbijo



Abbreviations for meteorological stations/ kratice za meteorološke postaje: VA = Valjevo, KG = Kragujevac, SP = Smederevska Palanka, BG = Beograd, VG = Veliko Gradište, VS = Vršac, SM = Sremska Mitrovica, NS = Novi Sad, ZR = Zrenjanin, KI = Kikinda, SO = Sombor, PL = Palić

Figure 4: Clusters of aridity index values represented on the map of investigated area
Slika 4: Skupine vrednosti indeksa aridnosti, prikazane na karti preučevanega območja



Source of the map/Kartografska podlaga: Ezilon Maps (http://www.ezilon.com/maps/europe/serbia-physical-maps.html); scale: 1 cm = 17,5 km

It could be concluded that cluster analysis gave good picture about precipitation characteristics of investigated area. Aridity index values showed existence of seven clusters or seven areas with different precipitation amount what coincides with geographical location and relief characteristics.

4. CONCLUSIONS

In Pannonian and Peripannonian parts of Serbia, the average annual precipitation amount for the investigated period is 637.7 mm. Higher precipitation quantities are in Peripannonian part of Serbia both on annual and seasonal level. Highest amount of precipitation in research area is during summer (206.4 mm) while the smallest amount of precipitation is in winter (130.8 mm).

Trends of precipitation amount on annual level on most of the meteorological stations are positive with statistical significance only in Palić (105.2 mm for the period 1949–2010). During winter, eleven of twelve stations show negative trends of precipitation amount. Negative trend of precipitation is present during spring on most stations. During summer, all stations show positive trend of precipitation amount with statistical significance only in Palić (45.8 mm for the period 1949–2010). Positive trend of precipitation continues during autumn on all stations and is statistically the most significant. Negative trends of precipitation quantities are present during winter and spring and they have smaller negative trend values in winter and spring compared to larger positive trend values in summer and autumn. Positive and higher trends are present during summer and especially in autumn on most of the stations. Declining trend of precipitation regime is present in northwestern Serbia, while in northeastern Serbia it is the opposite.

During the investigated period, two shorter periods with deficit of precipitation can be distinguished: periods from 1949 to 1973 and from 1982 to 1994. Two shorter periods with excess of precipitation can be also distinguished: from 1974 to 1981 and from 1995 to 2010.

Values of aridity index for Pannonian and Peripannonian parts of Serbia show small rising trend, especially during several last years when the index was higher than 30. Cluster analysis, based on aridity index values, showed existence of seven areas with different precipitation amounts in Pannonian and Peripanonian Serbia. This coincides with geographical location and relief characteristics of the research area. Three areas with different precipitation characteristics exist in Pannonian part of Serbia – in the north, east and southwest (Figure 4). In Peripannonian part of Serbia, three areas with different precipitation characteristics also exist. One cluster with two stations exist in the central part, while Beograd and Valjevo represent single clusters because of its location on two big rivers and ‘urban heat island’ effect in first, and location in the western part of investigated area in Kolubara river basin surrounded with mountains, in second case. In the eastern part of research area, one cluster consists of stations from Pannonian and Peripannonian parts of Serbia as a consequence of a small distance between the stations. Difference in precipitation quantities between Pannonian and Peripannonian parts of Serbia goes up to 237.2 mm (between Valjevo and Palić). This shows that local factors have a major role in precipitation distribution in investigated part of Serbia.

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ANALIZA PADAVIN V PANONSKEM IN OBPANONSKEM DELU SRBIJE

Povzetek

Avtorja v članku prikazujeta rezultate preučevanja količine padavin na 12 meteoroloških postajah v panonskem in obpanonskem delu Srbije v obdobju 1949–2010. Poleg količine sta preučevala tudi trende spreminjanja količin na letnem in sezonskem nivoju.

Povprečna mesečna količina padavin za celotno preučevano območje znaša 637,6 mm. Meteorološke postaje z manj kot 600 mm padavin letno se nahajajo v panonskem delu Srbije (Palić 556,0 mm, Kikinda 563,3 mm, Zrenjanin 583,0 mm), medtem ko so meteorološke postaje z največjo povprečno letno količino padavin v obpanonskem delu Srbije (Valjevo 793,2 mm, Beograd 696,5 mm, Veliko Gradište 673,8 mm). Razlogi za te razlike so močnejši kontinentalni vplivi v panonskem delu Srbije v primerjavi z južnejšim, obpanonskim delom, nadalje reliefne značilnosti, lega meteorološke postaje, itd. Količina padavin v obpanonskem delu Srbije je večja od količine padavin v panonskem delu tudi v vseh letnih časih.

Trend povprečne letne količine padavin znaša za preučevano območje +45,3 mm za obdobje 1949–2010 in ni statistično pomemben. Za isto obdobje so ugotovljeni negativni trendi povprečne količine padavin pozimi (–16.0 mm) in spomladi (–5,8 mm), medtem ko sta poletni (+25,1 mm) in jesenski trend pozitivna (+37,9 mm). Na osnovi Mann-Kendallovega neparametričnega statističnega testa je bilo ugotovljeno, da je bil na celotnem preučevanem območju trend spreminjanja količine padavin statistično značilen samo v jesenskem letnem času.

Trendi povprečnih količin padavin na posameznih meteoroloških postajah so pozitivni na vseh analiziranih postajah, razen v Sremski Mitrovici in Velikem Gradištu. Mann-Kendallov neparametrični statistični test kaže, da je statistično pomemben samo trend srednje letne količine padavin na meteorološki postaji Palić (+105,8 mm v obdobju 1949–2010).

Analiza padavinskih režimov je pokazala, da je povprečna letna količina padavin enakomerneje porazdeljena preko leta na postajah v zahodnem delu preučevanega območja v primerjavi s postajami v vzhodnih delih.

V preučevanem obdobju (1949–2010) lahko izdvojimo štiri krajša vremenska obdobja z različnimi padavinskimi značilnostmi. Za prvo obdobje (1949–1973) je značilna podpovprečna količina padavin v enajstih od dvanajstih let. V drugem obdobju (1974–1981) je bilo v sedmih od osmih let več padavin kot v dolgoletnem povprečju. V tretjem obdobju (1982–1994) je imelo deset let od trinajstih manj padavin kot znaša dolgoletno povprečje. Za četrto obdobje (1995–2010) je značilno, da je bilo v treh četrtinah let padavin več kot znaša dolgoletno povprečje. Nihanja v količini padavin med leti so velika; leto 2000 je bilo ekstremno sušno s skoraj polovico manj padavin kot v povprečju, v naslednjem letu (2001) pa je bilo kar za tretjino več padavin kot znaša dolgoletno povprečje.

Analiza de Martonnovega indeksa sušnosti (I_s) je pokazala, da je njegova vrednost višja v obpanonskem delu Srbije (Is > 30) kot v panonskem delu (Is < 30). Indeks sušnosti kaže trend naraščanja, a Mann-Kendallov test ni pokazal njegove statistične značilnosti.

Vrednosti indeksa sušnosti smo uporabili za razvrščanje v skupine (cluster analizo), s čimer smo želeli razvrstiti meteorološke postaje v skupine na podlagi podobnosti vrednosti indeksa sušnosti. Ta analiza nam je dala dobro sliko razporeditve padavin na preučevanem območju. Določili smo sedem skupin, kar se dobro sklada z lego meteoroloških postaj in reliefnimi značilnostmi (slika 4). Tri skupine so v panonskem delu, prav tako tri v obpanonskem delu, sedma skupina je prehodna. V panonskem delu Srbije imamo severno skupino (Palić in Sombor), južno (Novi Sad in Sremska Mitrovica) in vzhodno skupino (Kikinda in Zrenjanin). V obpanonskem delu Srbije smo izločili zahodno (Valjevo), centralno (Kragujevac in Smederevska Palanka) in severno skupino (Beograd). V vzhodnem delu preučevanega območja smo določili prehodno skupino z eno meteorološko postajo v panonskem (Vršac) in eno postajo v obpanonskem delu Srbije (Veliko Gradište), ki pa sta tudi prostorsko relativno blizu.

(Iz srbskega jezika prevedel Karel Natek)