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PRECIPITATION FORECAST USING STATISTICAL APPROACHES

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Abstract. *A statistical approach is often used in the analysis of time series in climatology and hydrology. One of its advantages is the possibility to predict future time series. This can be applied in many circumstances, such as temperature, precipitation, solar radiation and other studies of climate elements. Several models to determine the time series analysis of rainfall were used in this paper. The goal is to find an appropriate model for predicting the trend forecasting of rainfall series. Trend forecasting is one of the important methods of time series analysis (TSA). The simulation shows that the list of 50 data of elapsed values will produce optimal results. The procedures of model selection and evaluation were applied to a series of annual precipitation in the period 1961–2011 in the weather forecast station in Negotin.*
The obtained results show a decrease in the trend of the total annual precipitation in the period 1961-2011. The results of the analysis and rainfall forecast in the years to follow, in comparison to 2011, show an annual increase of rainfall.

Key words: *meteorological time series, the ARIMA model, trend method, the Mann-Kendall test, precipitation*

INTRODUCTION

Due to the growing concern of scientists about climate change, there is an increasing number of papers and studies with the aim of determining to what extent these changes will affect the plant cover. The condition of plant cover largely depends on air temperature and precipitation. The trend of daily, monthly and annual deficit and surplus of atmospheric precipitation affects the condition of the plant cover.

Using the available climate data, it is possible to obtain adequate information about the capacities of plant cover in any area in the world. The condition of plant cover is directly dependent on precipitation. Frequency and amounts of precipitation increase their

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moisture. Formation, development and abundance of forests, both in a narrow and wide region, is conditioned among other things by precipitation.

Various statistical procedures can be used to model the precipitation amounts. These include various models based on the application of statistical time series analyses. Time series modeling assumes that the time series is a combination of a form and some random error. There are several models used to forecast the time series: autoregressive models, moving-average models, linear regression models, and combined models, i.e. autoregressive integrated moving average models (ARIMA). The authors of this study use the ARIMA model and the Mann-Kendall test as a precipitation forecasting technique.

MATERIALS AND METHODS

During the processing of precipitation data, different methods have been used - mathematical-statistical methods, and computer programs for their spatial interpolation, study of mean values of precipitation, and graphical display of data. After determining the model appropriateness, it is possible to use it in forecasting time series of precipitation in the future, until 2015. In the process of analyzing the trends of precipitation time series, the ARIMA model has been used. Processing of the results has been performed using the STATISTICA software, Release 6 (StatSoft: Tulsa, USA).

For the analysis of the trends of annual precipitation in the Negotin district, we used a series of data for the period 1961-2011 for the main weather station in Negotin (φ44°13'N. λ22°31'E. H = 42m). Determination of the coefficients and indices have been performed according to the methodologies adopted in the World Meteorological Organization. Deficit and surplus of precipitation, or duration of dry and wet periods, have been determined by the Deficit and Surplus of Precipitation (DSP) method (The Palmer Drought Severity Index (Palmer, 1965; Alley, 1984; Guttman, 1998)). Forecasting the amount of precipitation has been analyzed on the basis of the trend method and Mann-Kendall test.

The results for Negotin can be used for the entire Negotin district and a large area of northeast Serbia.

Basic characteristics of precipitation in Negotin

Precipitation is an extremely changeable climatic element in time and space. A number of global and local factors affect the distribution of precipitation, even in a small space. Daily, seasonal and yearly courses of precipitation are typical for large areas. The result of spatial and temporal variations of precipitation is drought and rainy periods. The intensity of rainfall can be viewed on the basis of actual and expected amounts (Radinović D. & Ćurić M). The calculation of the threshold of daily, monthly and annual quantity is important for understanding the deficit and surplus in the soil. During the period 1961-2011, the least measured amounts of rainfall were noted in 2000, only 350.6 mm, while the wettest year was 1982, 1023.1 mm of rainfall, Figure 1. In Negotin, as shown in Figure 2, there is a downward trend of annual precipitation.

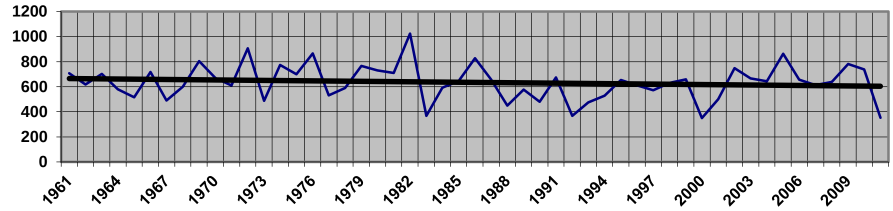

Fig. 1 The annual flow and trend in precipitation for the measuring point Weather Station in Negotin (mm), 1961 – 2011

During normal climatic periods (1961-1990), according to Kepenn, Negotin has a moderately warm and humid climate with extremely hot summers.

Using the methods of Deficit and Surplus Precipitation (DSP) - The Palmer Drought Severity Index (Palmer, 1965; Alley, 1984; Guttmann, 1998), we can determine the deficit or surplus of precipitation by comparing the observed rainfall and expected quantities of rainfall (Radinović D. & Ćurić M). Figure 2 presents the annual deficit or surplus precipitation, for the period 1961-2011, obtained using this method. For this period, the precipitation surplus can be defined over an extended period of time, except in 1965, 1967 and 1968, and during 2000-2004. The trends of the annual values of precipitation surplus or deficit, according to this method, indicate that there has been a precipitation surplus in many different periods, while the precipitation deficit expressed a lack of rainfall recorded during the period 2000-2004.

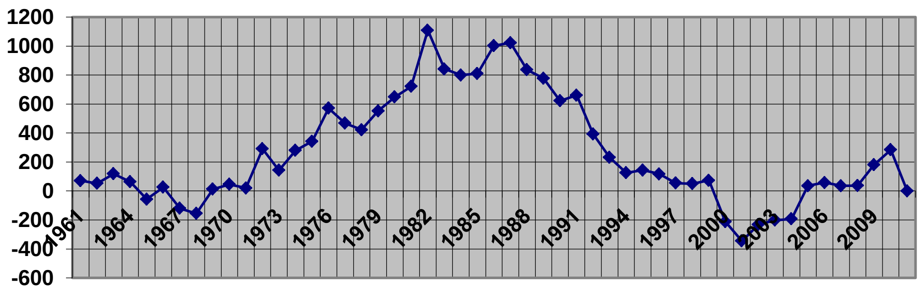

Fig. 2 Graphical presentation of the annual deficit and surplus precipitation in Negotin (mm) (expected average annual rainfall for the period 1961-2011)

The figure shows that for the period 1961-2011, according to this method, the precipitation deficit was significantly emphasized, while in 1982, the precipitation surplus was emphasized. The precipitation deficit ranges from 4 to 284mm per year. The precipitation surplus is represented in the range from 2 to 387mm per year.

Considering the minimum and maximum values of precipitation during certain months in the reporting period (Table 1), we can see obvious deviations.

Table 1 Monthly and annual precipitation in the meteorological station Negotin, mm

	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average 1961÷2011	42.8	46.2	49,4	56.8	59.1	65.9	51.4	44.8	44.0	50.6	59.9	60.9	635.2
Max	83,6	104,2	86,4	86,6	142	139,8	114,7	187,5	123,4	150,6	123,8	163,4	1023,1
Min	9,7	1.8	3,2	0,0	9,2	2,6	2,1	0,3	2,1	2,9	1,0	6,3	350,6

Precipitation frequency and intensity

Inadequate distribution and quantities of precipitation lead to dry periods. A drought is a permanently and significantly high deficit of water needed for plants in an agricultural or forest area, which limits the life processes of plants (V.Aleksić, S. Milutinovic, M.Marić, N. Djordjevic, 2004). The condition of vegetation, as well as crop yield, depends on drought intensity, period of appearance and drought frequency. It is known that drought periods are much longer than the rainy period (except for certain tropical regions). Vujević P. (1956) recommends that the lower limit for the dry period should be five consecutive days without rain.

Pronounced variations in precipitation intensity and frequency can have adverse effects and can represent a danger of drought. The frequency is often more important in the analysis of other characteristics, sometimes more important than strength.

According to the level of their destruction, unfavorable phenomena include:

- precipitation far below normal precipitation (extreme minimum), and
- the frequency of precipitation far below normal.

Great deviation in the intensity and frequency may present adverse effects. The frequency of precipitation can be seen based on the number of days with precipitation ($n_d \geq 0{,}1$mm) and number of days with precipitation over 10mm ($n_d \geq 10$mm), Table 2. The table shows that the minimum number of days with precipitation ($n_d \geq 0{,}1$mm) is in August and the highest number of days is in December.

Table 2 Number of days with precipitation

	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
$n_d \geq 0.1$mm 1961÷2011	11,4	10,8	10,5	11,1	12,2	10,4	8,2	7,1	7,7	8,8	11,7	12,3	122,2
$n_d \geq 10$mm 1961÷2011	1,1	1,1	1,6	1,5	1,9	2,1	1,6	1,4	1,4	1,7	1,9	1,7	19,2

Considering the number of days with precipitation over 10mm, it can be seen that the highest average number of days with precipitation ($n_d \geq 10$mm) is during June.

The use of ARIMA models

Statistical models are used for modelling precipitation series. They include the choice of various models by using statistical analyses of time series. In the case of stationary series, we can often find a moving-average (MA) model, autoregressive models (AR) and the mixed autoregressive-moving-average (ARMA) model. The selection of models can be based on various criteria. One of them is a choice based on the behavior of a sample of serial correlation coefficients and partial serial correlation coefficients.

Chronologically ordered, numerical data about precipitation in the area of Negotin represent the time series. The Box-Jenkins iterative approach [2, 3, 4] and ARIMA method can be applied to these time series. The analysis and precipitation forecast are shown in Figure 3, while numerical values of the forecast are given in Table 3.

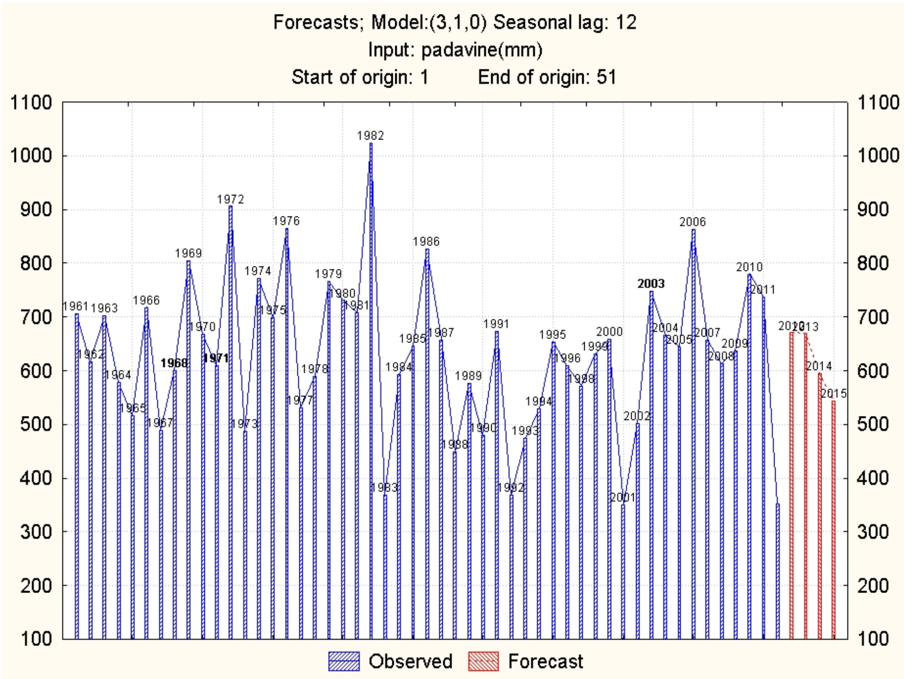

Fig. 3 Precipitation forecast (period 2012-2015).

Table 3 Precipitation forecast for the period 2012-2015 according to the ARIMA model

Forecasts; Model: (3,1,0) Seasonal lag: 12 Input: padavine (mm) Start of origin: 1 End of origin: 51				
Case No	Forecast	Lower 90,0000%	Uper 90,0000%	Std.Err.
2012	670,3754	408,9503	931,8004	155,8024
2013	668,5050	405,4412	931,5688	156,7791
2014	593,8951	325,0275	862,7626	160,2379
2015	543,6710	258,4754	828,88667	169,9691

The results of the analysis and forecasting time series show an increase of 191.3 mm per annum, from the initial 352.4 mm in 2011 to 543.7 mm in the last year of the forecast, Figure 3.

The diagram shows that the precipitation forecast in the period 2012-2015, according to the ARIMA model, is slightly declining. The highest values on an annual basis are predicted for 2013. The lowest precipitation is forecasted for 2014, Table 3.

The trend method

Many researchers [18] indicate that out of all the statistical methods of dynamic analysis of mass phenomena, the trend method is the most complex, so it can be said that this is most important in the time series analysis. This method is used to estimate and forecast future trends and the development of the phenomenon. Mirjana Šekarić [18] states that the trend method proved to be the most appropriate method for the dynamic analysis of the time series in one-year periods. The movement and development of annual precipitation is in a linear direction, so the explicit expression of the general trend value ($\hat{y}$) can be expressed as follows:

$$\hat{y} = a + bx \quad (1)$$

a and *b* are the parameters that determine the position and slope of the trend line. X represents an independent variable used to observe time. The trend must satisfy the following conditions:

- the sum of the distances of the original data from the trend line should be zero

$$\sum = (yi - \hat{y}) = 0 \quad (2)$$

- the sum of the squared deviations from the original data from the trend line should be less than the sum of the square deviations from the original data.

$$\sum = (yi - \hat{y})^2 = \min \quad (3)$$

Using expression 3, we come to the system of equations that we can use to calculate the parameters *a* and *b*, which satisfy the least squares condition:

$$\text{I} \ \sum yi = na + b\sum xi \quad (4)$$

$$\text{II} \sum xiyi = a\sum xi + b\sum xi^2 \quad (5)$$

By solving this system with the conditional method, we can obtain a value for the parameters *a* and *b*, which can be used to calculate the trend value for each period. The parameters *a* and *b* can be calculated using the equation:

$$a = \frac{\sum yi}{n} \quad (6)$$

$$b = \frac{\sum xiyi}{\sum x_i^2} \ 7 \quad (7)$$

The analytical determination of the function of the precipitation trend and the numerical calculation of the values of precipitation elements in the meteorological station in Negotin are shown in Table 4.

Table 4

Year	Precipitation *Yi*	*Xi*	Xi^2	$Xi \bullet Yi$	*Y*
1961	706.0	-25	625	-17650	702,73
1962	616.5	-24	576	-14796	700,03
1963	701.8	-23	529	-16141,4	697,33
1964	578.9	-22	484	-12736,8	694,63
1965	515.5	-21	441	-11341	691,93
1966	717.7	-20	400	-14354	689,23
1967	488.9	-19	361	-9289,1	686,53
1968	600.0	-18	324	-10800	683,83
1969	803.7	-17	289	-13662,9	681,13
1970	668.4	-16	256	-10694,4	678,43
1971	609.8	-15	225	-9147	675,73
1972	905.8	-14	196	-12681,2	673,03
1973	486.8	-13	169	-6328,4	670,33
1974	772.3	-12	144	-9267,6	667,63
1975	698.2	-11	121	-7680,2	664,93
1976	864.0	-10	100	-8640	662,23
1977	531.3	-9	81	-4781,7	659,53
1978	590.1	-8	64	-4720,8	656, 83
1979	765.5	-7	49	-5358,5	654,13
1980	730.7	-6	36	-4384,2	651,43
1981	708.3	-5	25	-3541,5	648,73
1982	1023.1	-4	16	-4092,4	646,03
1983	368.0	-3	9	-1104	643,33
1984	592.9	-2	4	-1185,8	640,63
1985	645.2	-1	1	-645,2	637,93
1986	826.7	0	0	0	635,23
1987	657.6	1	1	657,6	632,53
1988	448.4	2	4	896,8	629,83
1989	576.8	3	9	1730,4	627,13
1990	479.2	4	16	1916,8	624,43
1991	673.9	5	25	3369,6	621,73
1992	367.7	6	36	2206,2	619,03
1993	473.6	7	49	3315,2	616,33
1994	528.8	8	64	4230,4	613,63
1995	654.0	9	81	5886	610,93
1996	609.0	10	100	6090	608,23
1997	571.8	11	121	6289,8	605,53
1998	630.5	12	144	7566	602,83
1999	658.9	13	169	8565,7	600,13
2000	350.6	14	196	4908,4	597,43
2001	501.4	15	225	7521	594,73
2002	748.6	16	256	11977,6	592,03
2003	665.8	17	289	11318,6	589,33
2004	644.0	18	324	11592	586,63
2005	863.4	19	361	16404,6	583,93
2006	657.0	20	400	13140	581,23
2007	613.5	21	441	12883,5	578,53
2008	636.8	22	484	14009,6	575,83
2009	779.8	23	529	17935,4	573,13
2010	737.1	24	576	17690,4	570,43
2011	352.4	25	625	8810	567,73
n=51	$\sum Yi$=32396,7	$\sum Xi$=0	11050	-30033,5	

a) $\hat{y}=a+bx$

$$a=\frac{\sum yi}{n}=\frac{32396,7}{51}=635,23$$

$$b=\frac{\sum xiyi}{\sum xi^{2}}=\frac{-30033,5}{11050}=-2,7$$

$\hat{y}=635,23-2,7x$

b)
$\hat{y}_{1961}$ = 635,23 – 2,7 (–25) = 702,73
$\hat{y}_{1962}$ = 635,23 – 2,7 (–24) = 700,03
$\hat{y}_{1963}$ = 635,23 – 2,7 (–23) = 697,33
$\hat{y}_{1964}$ = 635,23 – 2,7 (–22) = 694,63
$\hat{y}_{1965}$ = 635,23 – 2,7 (–21) = 691,93
$\hat{y}_{1966}$ = 635,23 – 2,7 (–20) = 689,23
$\hat{y}_{1967}$ = 635,23 – 2,7 (–19) = 686,53
$\hat{y}_{1968}$ = 635,23 – 2,7 (–18) = 683,83
$\hat{y}_{1969}$ = 635,23 – 2,7 (–17) = 681,13
$\hat{y}_{1970}$ = 635,23 – 2,7 (–16) = 678,43
$\hat{y}_{1971}$ = 635,23 – 2,7 (–15) = 675,73
$\hat{y}_{1972}$ = 635,23 – 2,7 (–14) = 673,03
$\hat{y}_{1973}$ = 635,23 – 2,7 (–13) = 670,33
$\hat{y}_{1974}$ = 635,23 – 2,7 (–12) = 667,63
$\hat{y}_{1975}$ = 635,23 – 2,7 (–11) = 664,93
$\hat{y}_{1976}$ = 635,23 – 2,7 (–10) = 662,23
$\hat{y}_{1977}$ = 635,23 – 2,7 (–9) = 659,53
$\hat{y}_{1978}$ = 635,23 – 2,7 (–8) = 656,83
$\hat{y}_{1979}$ = 635,23 – 2,7 (–7) = 654,13
$\hat{y}_{1980}$ = 635,23 – 2,7 (–6) = 651,43
$\hat{y}_{1981}$ = 635,23 – 2,7 (–5) = 648,73
$\hat{y}_{1982}$ = 635,23 – 2,7 (–4) = 646,03
$\hat{y}_{1983}$ = 635,23 – 2,7 (–3) = 643,33
$\hat{y}_{1984}$ = 635,23 – 2,7 (–2) = 640,63
$\hat{y}_{1985}$ = 635,23 – 2,7 (–1) = 637,93
$\hat{y}_{1986}$ = 635,23 – 2,7 (–0) = 635,23
$\hat{y}_{1987}$ = 635,23 – 2,7 (1) = 632,53
$\hat{y}_{1988}$ = 635,23 – 2,7 (2) = 629,83
$\hat{y}_{1989}$ = 635,23 – 2,7 (3) = 627,13
$\hat{y}_{1990}$ = 635,23 – 2,7 (4) = 624,43
$\hat{y}_{1991}$ = 635,23 – 2,7 (5) = 621,73
$\hat{y}_{1992}$ = 635,23 – 2,7 (6) = 619,03
$\hat{y}_{1993}$ = 635,23 – 2,7 (7) = 616,33
$\hat{y}_{1994}$ = 635,23 – 2,7 (8) = 613,63
$\hat{y}_{1995}$ = 635,23 – 2,7 (9) = 610,93
$\hat{y}_{1996}$ = 635,23 – 2,7 (10) = 608,23
$\hat{y}_{1997}$ = 635,23 – 2,7 (11) = 605,53

$\hat{y}_{1998}$ = 635,23 – 2,7 (12) = 602,83
$\hat{y}_{1999}$ = 635,23 – 2,7 (13) = 600,13
$\hat{y}_{2000}$ = 635,23 – 2,7 (14) = 597,43
$\hat{y}_{2001}$ = 635,23 – 2,7 (15) = 594,73
$\hat{y}_{2002}$ = 635,23 – 2,7 (16) = 592,03
$\hat{y}_{2003}$ = 635,23 – 2,7 (17) = 589,33
$\hat{y}_{2004}$ = 635,23 – 2,7 (18) = 586,63
$\hat{y}_{2005}$ = 635,23 – 2,7 (19) = 583,93
$\hat{y}_{2006}$ = 635,23 – 2,7 (20) = 581,23
$\hat{y}_{2007}$ = 635,23 – 2,7 (21) = 578,53
$\hat{y}_{2008}$ = 635,23 – 2,7 (22) = 575,83
$\hat{y}_{2009}$ = 635,23 – 2,7 (23) = 573,13
$\hat{y}_{2010}$ = 635,23 – 2,7 (24) = 570,43
$\hat{y}_{2011}$ = 635,23 – 2,7 (25) = 567,73

c) $\hat{y}_{2015}$ = 635,23 – 2,7 (29) = 556,93

The expected amount of precipitation in 2015 will be 556.93 mm.

The MANN-KENDALL trend test of precipitation

The non-parametric Mann-Kendall test, Sen's Nonparametric Estimator of Slope have been widely used to study the time series of climate parameters. This method calculates the slope of all pairs of data in time points, and the average slope is used to calculate the total slope.

If there are n time points and if Yi represents the data value for the i-t time point, the slope of the possible pairs of time points (i, j), where $i < j$, is expressed by the formula:

$$Q = (Yj - Yi) / (j - \mathrm{i}) \qquad (8)$$

where: Q = slope between the data Yi and Yj,
Yi = data in time,
Yj = data in time,
j = each time after time i.

After that, the statistical value S, which represents the difference between the number of positive and negative values of Q, can be calculated using the formula:

Predominantly positive slopes (If $S >> 0$) refer to an increasing trend; on the other hand, predominantly negative slopes (If $S << 0$) are connected to a downward trend. The calculations of positive and negative slopes and their relationship on the example of the weather forecast station in Negotin are presented in Table 5. The table shows the prevailing number of positive slopes (Mann-Kendall S = 1069 – 609 = 460) which means that one can expect a growing trend.

Table 5 The Mann-Kendall test

1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
706	616.5	701.8	578.9	515.5	717.7	488.9	600	803.7	668.4	609.8
	89.5	4.2	127.1	190.5	-11.7	217.1	106	-97.7	37.6	96.2
		-85.3	37.6	101	-101.2	127.6	16.5	-187.2	-51.9	6.7
			122.9	186.3	-15.9	212.9	101.8	-101.9	33.4	92
				63.4	-138.8	90	-21.1	-224.8	-89.5	-30.9
					-202.2	26.6	-84.5	-288.2	-152.9	-94.3
						228.8	117.7	-86	49.3	107.9
							-111.1	-314.8	-179.5	-120.9
								-203.7	-68.4	-9.8
									135.3	193.9
										58.6
1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
905.8	486.8	772.3	698.2	864	531.3	590.1	765.5	730.7	708.3	1023.1
-199.8	219.2	-66.3	7.8	-158	174.7	115.9	-59.5	-24.7	-2.3	-317.1
-289.3	129.7	-155.8	-81.7	-247.5	85.2	26.4	-149	-114.2	-91.8	-406.6
-204	215	-70.5	3.6	-162.2	170.5	111.7	-63.7	-28.9	-6.5	-321.3
-326.9	92.1	-193.4	-119.3	-285.1	47.6	-11.2	-186.6	-151.8	-129.4	-444.2
-390.3	28.7	-256.8	-182.7	-348.5	-15.8	-74.6	-250	-215.2	-192.8	-507.6
-188.1	230.9	-54.6	19.5	-146.3	186.4	127.6	-47.8	-13	9.4	-305.4
-416.9	2.1	-283.4	-209.3	-375.1	-42.4	-101.2	-276.6	-241.8	-219.4	-534.2
-305.8	113.2	-172.3	-98.2	-264	68.7	9.9	-165.5	-130.7	-108.3	-423.1
-102.1	316.9	31.4	105.5	-60.3	272.4	213.6	38.2	73	95.4	-219.4
-237.4	181.6	-103.9	-29.8	-195.6	137.1	78.3	-97.1	-62.3	-39.9	-354.7
-296	123	-162.5	-88.4	-254.2	78.5	19.7	-155.7	-120.9	-98.5	-413.3
	419	133.5	207.6	41.8	374.5	315.7	140.3	175.1	197.5	-117.3
		-285.5	-211.4	-377.2	-44.5	-103.3	-278.7	-243.9	-221.5	-536.3
			74.1	-91.7	241	182.2	6.8	41.6	64	-250.8
				-165.8	166.9	108.1	-67.3	-32.5	-10.1	-324.9
					332.7	273.9	98.5	133.3	155.7	-159.1
						-58.8	-234.2	-199.4	-177	-491.8
							-175.4	-140.6	-118.2	-433
								34.8	57.2	-257.6
									22.4	-292.4
										-314.8
1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
368	592.9	645.2	826.7	657.6	448.4	576.8	479.2	673.9	367.7	473.6
338	113.1	60.8	-120.7	48.4	257.6	129.2	226.8	32.1	338.3	232.4
248.5	23.6	-28.7	-210.2	-41.1	168.1	39.7	137.3	-57.4	248.8	142.9
333.8	108.9	56.6	-124.9	44.2	253.4	125	222.6	27.9	334.1	228.2
210.9	-14	-66.3	-247.8	-78.7	130.5	2.1	99.7	-95	211.2	105.3
147.5	-77.4	-129.7	-311.2	-142.1	67.1	-61.3	36.3	-158.4	147.8	41.9
349.7	124.8	72.5	-109	60.1	269.3	140.9	238.5	43.8	350	244.1
120.9	-104	-156.3	-337.8	-168.7	40.5	-87.9	9.7	-185	121.2	15.3
232	7.1	-45.2	-226.7	-57.6	151.6	23.2	120.8	-73.9	232.3	126.4
435.7	210.8	158.5	-23	146.1	355.3	226.9	324.5	129.8	436	330.1
300.4	75.5	23.2	-158.3	10.8	220	91.6	189.2	-5.5	300.7	194.8
241.8	16.9	-35.4	-216.9	-47.8	161.4	33	130.6	-64.1	242.1	136.2
537.8	312.9	260.6	79.1	248.2	457.4	329	426.6	231.9	538.1	432.2
118.8	-106.1	-158.4	-339.9	-170.8	38.4	-90	7.6	-187.1	119.1	13.2
404.3	179.4	127.1	-54.4	114.7	323.9	195.5	293.1	98.4	404.6	298.7
330.2	105.3	53	-128.5	40.6	249.8	121.4	219	24.3	330.5	224.6
496	271.1	218.8	37.3	206.4	415.6	287.2	384.8	190.1	496.3	390.4
163.3	-61.6	-113.9	-295.4	-126.3	82.9	-45.5	52.1	-142.6	163.6	57.7
222.1	-2.8	-55.1	-236.6	-67.5	141.7	13.3	110.9	-83.8	222.4	116.5
397.5	172.6	120.3	-61.2	107.9	317.1	188.7	286.3	91.6	397.8	291.9
362.7	137.8	85.5	-96	73.1	282.3	153.9	251.5	56.8	363	257.1
340.3	115.4	63.1	-118.4	50.7	259.9	131.5	229.1	34.4	340.6	234.7
655.1	430.2	377.9	196.4	365.5	574.7	446.3	543.9	349.2	655.4	549.5
	-224.9	-277.2	-458.7	-289.6	-80.4	-208.8	-111.2	-305.9	0.3	-105.6
		-52.3	-233.8	-64.7	144.5	16.1	113.7	-81	225.2	119.3
			-181.5	-12.4	196.8	68.4	166	-28.7	277.5	171.6
				169.1	378.3	249.9	347.5	152.8	459	353.1
					209.2	80.8	178.4	-16.3	289.9	184
						-128.4	-30.8	-225.5	80.7	-25.2
							97.6	-97.1	209.1	103.2
								-194.7	111.5	5.6
									306.2	200.3
										-105.9

Table 5 contd.

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
528.8	654	609	571.8	630.5	658.9	350.6	501.4	748.6	665.8	644
177.2	52	97	134.2	75.5	47.1	355.4	204.6	-42.6	40.2	62
87.7	-37.5	7.5	44.7	-14	-42.4	265.9	115.1	-132.1	-49.3	-27.5
173	47.8	92.8	130	71.3	42.9	351.2	200.4	-46.8	36	57.8
50.1	-75.1	-30.1	7.1	-51.6	-80	228.3	77.5	-169.7	-86.9	-65.1
-13.3	-138.5	-93.5	-56.3	-115	-143.4	164.9	14.1	-233.1	-150.3	-128.5
188.9	63.7	108.7	145.9	87.2	58.8	367.1	216.3	-30.9	51.9	73.7
-39.9	-165.1	-120.1	-82.9	-141.6	-170	138.3	-12.5	-259.7	-176.9	-155.1
71.2	-54	-9	28.2	-30.5	-58.9	249.4	98.6	-148.6	-65.8	-44
274.9	149.7	194.7	231.9	173.2	144.8	453.1	302.3	55.1	137.9	159.7
139.6	14.4	59.4	96.6	37.9	9.5	317.8	167	-80.2	2.6	24.4
81	-44.2	0.8	38	-20.7	-49.1	259.2	108.4	-138.8	-56	-34.2
377	251.8	296.8	334	275.3	246.9	555.2	404.4	157.2	240	261.8
-42	-167.2	-122.2	-85	-143.7	-172.1	136.2	-14.6	-261.8	-179	-157.2
243.5	118.3	163.3	200.5	141.8	113.4	421.7	270.9	23.7	106.5	128.3
169.4	44.2	89.2	126.4	67.7	39.3	347.6	196.8	-50.4	32.4	54.2
335.2	210	255	292.2	233.5	205.1	513.4	362.6	115.4	198.2	220
2.5	-122.7	-77.7	-40.5	-99.2	-127.6	180.7	29.9	-217.3	-134.5	-112.7
61.3	-63.9	-18.9	18.3	-40.4	-68.8	239.5	88.7	-158.5	-75.7	-53.9
236.7	111.5	156.5	193.7	135	106.6	414.9	264.1	16.9	99.7	121.5
201.9	76.7	121.7	158.9	100.2	71.8	380.1	229.3	-17.9	64.9	86.7
179.5	54.3	99.3	136.5	77.8	49.4	357.7	206.9	-40.3	42.5	64.3
494.3	369.1	414.1	451.3	392.6	364.2	672.5	521.7	274.5	357.3	379.1
-160.8	-286	-241	-203.8	-262.5	-290.9	17.4	-133.4	-380.6	-297.8	-276
64.1	-61.1	-16.1	21.1	-37.6	-66	242.3	91.5	-155.7	-72.9	-51.1
116.4	-8.8	36.2	73.4	14.7	-13.7	294.6	143.8	-103.4	-20.6	1.2
297.9	172.7	217.7	254.9	196.2	167.8	476.1	325.3	78.1	160.9	182.7
128.8	3.6	48.6	85.8	27.1	-1.3	307	156.2	-91	-8.2	13.6
-80.4	-205.6	-160.6	-123.4	-182.1	-210.5	97.8	-53	-300.2	-217.4	-195.6
48	-77.2	-32.2	5	-53.7	-82.1	226.2	75.4	-171.8	-89	-67.2
-49.6	-174.8	-129.8	-92.6	-151.3	-179.7	128.6	-22.2	-269.4	-186.6	-164.8
145.1	19.9	64.9	102.1	43.4	15	323.3	172.5	-74.7	8.1	29.9
-161.1	-286.3	-241.3	-204.1	-262.8	-291.2	17.1	-133.7	-380.9	-298.1	-276.3
-55.2	-180.4	-135.4	-98.2	-156.9	-185.3	123	-27.8	-275	-192.2	-170.4
	-125.2	-80.2	-43	-101.7	-130.1	178.2	27.4	-219.8	-137	-115.2
		45	82.2	23.5	-4.9	303.4	152.6	-94.6	-11.8	10
			37.2	-21.5	-49.9	258.4	107.6	-139.6	-56.8	-35
				-58.7	-87.1	221.2	70.4	-176.8	-94	-72.2
					-28.4	279.9	129.1	-118.1	-35.3	-13.5
						308.3	157.5	-89.7	-6.9	14.9
							-150.8	-398	-315.2	-293.4
								-247.2	-164.4	-142.6
									82.8	104.6
										21.8

Table 5 contd.

2005	2006	2007	2008	2009	2010	2011	Σ (+)	Σ (-)
863.4	657	613.5	636.8	779.8	737.1	352.4		
-157.4	49	92.5	69.2	-73.8	-31.1	353.6	36	14
-246.9	-40.5	3	-20.3	-163.3	-120.6	264.1	22	27
-161.6	44.8	88.3	65	-78	-35.3	349.1	34	13
-284.5	-78.1	-34.6	-57.9	-200.9	-158.2	226.5	15	32
-347.9	-141.5	-98	-121.3	-264.3	-221.6	163.1	10	36
-145.7	60.7	104.2	80.9	-62.1	-19.4	365.3	33	12
-374.5	-168.1	-124.6	-147.9	-290.9	-248.2	136.5	8	36
-263.4	-57	-13.5	-36.8	-179.8	-137.1	247.6	15	28
-59.7	146.7	190.2	166.9	23.9	66.6	451.3	37	5
-195	11.4	54.9	31.6	-111.4	-68.7	316	27	14
-253.6	-47.2	-3.7	-27	-170	-127.3	257.4	16	24
42.4	248.8	292.3	269	126	168.7	553.4	38	1
-376.6	-170.2	-126.7	-150	-293	-250.3	134.4	7	31
-91.1	115.3	158.8	135.5	-7.5	35.2	419.9	32	5
-165.2	41.2	84.7	61.4	-81.6	-38.9	345.8	26	10
0.6	207	250.5	227.2	84.2	126.9	511.6	34	1
-332.1	-125.7	-82.2	-105.5	-248.5	-205.8	178.9	9	25
-273.3	-66.9	-23.4	-46.7	-189.7	-147	237.7	11	22
-97.9	108.5	152	128.7	-14.3	28.4	413.1	28	4
-132.7	73.7	117.2	93.9	-49.1	-6.4	378.3	25	6
-155.1	51.3	94.8	71.5	-71.5	-28.8	355.9	24	6
159.7	366.1	409.6	386.3	243.3	286	670.7	29	0
-495.4	-289	-245.5	-268.8	-411.8	-369.1	15.6	3	25
-270.5	-64.1	-20.6	-43.9	-186.9	-144.2	240.5	9	18
-218.2	-11.8	31.7	8.4	-134.6	-91.9	292.8	15	11
-36.7	169.7	213.2	189.9	46.9	89.6	474.3	24	1
-205.8	0.6	44.1	20.8	-122.2	-79.5	305.2	17	7
-415	-208.6	-165.1	-188.4	-331.4	-288.7	96	3	20
-286.6	-80.2	-36.7	-60	-203	-160.3	224.4	8	14
-384.2	-177.8	-134.3	-157.6	-300.6	-257.9	126.8	4	17
-189.5	16.9	60.4	37.1	-105.9	-63.2	321.5	16	4
-495.7	-289.3	-245.8	-269.1	-412.1	-369.4	15.3	2	17
-389.8	-183.4	-139.9	-163.2	-306.2	-263.5	121.2	2	16
-334.6	-128.2	-84.7	-108	-251	-208.3	176.4	3	14
-209.4	-3	40.5	17.2	-125.8	-83.1	301.6	9	7
-254.4	-48	-4.5	-27.8	-170.8	-128.1	256.6	4	11
-291.6	-85.2	-41.7	-65	-208	-165.3	219.4	3	11
-232.9	-26.5	17	-6.3	-149.3	-106.6	278.1	4	9
-204.5	1.9	45.4	22.1	-120.9	-78.2	306.5	7	5
-512.8	-306.4	-262.9	-286.2	-429.2	-386.5	-1.8	0	11
-362	-155.6	-112.1	-135.4	-278.4	-235.7	149	1	9
-114.8	91.6	135.1	111.8	-31.2	11.5	396.2	7	2
-197.6	8.8	52.3	29	-114	-71.3	313.4	5	3
-219.4	-13	30.5	7.2	-135.8	-93.1	291.6	3	4
	206.4	249.9	226.6	83.6	126.3	511	6	0
		43.5	20.2	-122.8	-80.1	304.6	3	2
			-23.3	-166.3	-123.6	261.1	1	3
				-143	-100.3	284.4	1	2
					42.7	427.4	2	0
						384.7	1	0
							1069	609

CONCLUSION

Using different methods of precipitation trend forecast, it has been shown that there are minor variations in terms of the quantity of expected precipitation. All the forecasting methods predict an increasing trend in precipitation amounts. The Mann-Kendall test used for the analysis of the precipitation trends in the weather station in Negotin, for the period 1961-2011 shows a growth trend.

The results and the analyses of the anticipated precipitation course in 2015 in the area of the weather station in Negotin, indicate an increased amount of precipitation. The increasing trend of precipitation is also obtained by applying the ARIMA method. According to the trend method, the expected precipitation is 556.93 mm, while according ARIMA method it is 543.7 mm. The main weakness of this approach is the determination in terms of the reference year. The measured precipitation amounts at the weather station in Negotin in 2011 were the smallest in the analyzed period. This is a practical indicator of the sensitivity of different models, and evidence that their users should be careful while applying them.

REFERENCES

1. Box. G.E.P.. Jenkins. G.M. (1976) Time series analysis: Forecasting and control. San Francisco. CA: Holden Day, 575
2. De Gooijer, J., Hyndman, R. (2006) . 25 years of time series forecasting. Elsevier.
3. Davis. J.M.. Rappoport. P.N. (1974) The use of time series analysis techniques in forecasting meteorological drought. *Mon. Wea. Rev*. vol. 102. str. 176-180
4. Delleur. J.. Kavvas. M.L. (1978) Stochastic models for monthly rainfall forecasting and synthetic generation. *Journal of Applied Meteorology*. vol. 17. str. 1528-1536
5. Katz. R.W.. Skaggs. R.H. (1981) On the use of autoregressive-moving average processes to model meteorological time series. *Mon. Wea. Rev*. vol. 109. str. 479-484
6. Ledolter. J. (1977) The analysis of multivariate time series applied to problems in hydrology. *Journal of Hydrology*. vol. 36. str. 327-352
7. Lungu. E.M.. Sefe. F.T.K. (1991) Stochastic analysis of monthly stream flows. *Journal of Hydrology*. vol. 126. str. 171-182
8. Ljung. G.M.. Box. G.E.P. (1979) The likelihood function of stationary autoregressive-moving average models. *Biometrika*. 66. 2. 265-270
9. Mališić. J.. Jevremović. V.. Dmitrović. I. (1998) ARMA modeliranje hidroloških serija. *Vodoprivreda*. vol. 30. str. 203-212

PREDVIĐANJE PADAVINA POMOĆU STATISTIČKIH PRISTUPA

Statistički pristup se često koristi u analizi vremenskih serija u klimatologiji i hidrologiji. Jedna od njegovih koristi je da predvidi trend budućih vremenskih serija. Ovo može da se primeni u mnogim aplikacijama kao što su temperatura, padavine, sunčevo zračenje i druga istraživanja u vezi sa vremenskim serijama klimatskih elemenata. U ovom radu koristimo nekoliko modela za određivanje analize vremenskih serija padavina. Cilj je da se pronađe odgovarajući model u predviđanju trenda serije padavina. Metod trenda je jedan od značajnijih metoda analize vremenskih serija. Simulacija pokazuje da za listu od 50 podataka proteklih vrednosti daje optimalne rezultate. Postupak izbora i ocene modela primenjen je na seriju godišnjih suma padavina osmotrenih u periodu 1961-2011. god. na meteorološkoj stanici u Negotinu. Dobijeni rezultati pokazuju smanjenje trenda ukupnih godišnjih količina padavina u toku perioda 1961-2011. godina. Rezultati analize i predviđanja toka padavina u narednim godinama u odnosu na 2011. godinu, pokazuju povećanje količina padavina na godišnjem nivou.

Ključne reči: *meteorološka vremenska serija, ARIMA model, metod trenda, Mann-Kendall test, padavine*