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Temporal trends of precipitation in Debrecen (Hungary) in the period 1901-2011

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ABSTRACT

The primary objective of the study is to follow-up the quantitative changes in precipitation between 1901 and 2011 in the city of Debrecen. This dataset of 111-year interval allows us to reveal the quantity and distribution of precipitation changes and modification as part of today's global climate change. The amount of annual precipitation in Debrecen showed a decreasing trend during the examined period but not significantly (~30 mm decrease in 100 years). It can be seen from each seasons that in winter and spring there are approximately no changes in the trend, while in summer an increase and in autumn about a same level decrease can be identified. Thereafter we determined the 80 % design storm, which is widely used in practice, based on the data measured in the last 30 years.

Keywords: precipitation, temporal trend, design storm**,** Hungary,

1. Introduction

Two basic input units of the municipal water management system are the following: waters from natural ways (such as rivers, precipitation), and from artificial ways to satisfy human needs (for example water supply from surface or underground water bases). Two sub-systems can be identified in a settlement's artificial water distribution: water supply and sewerage. As our water supply systems can be characterized by few days residence time, water supply and sewerage systems are made up of continuous, predictable and scalable parts. However there is a different situation in the case of natural waters. The discharge of rivers, the amount and time distribution of annual precipitation are only known retrospectively with high accuracy.

On the basis of about 20 years' international research in the frame of the Intergovernmental Panel on Climate Change (IPCC), there is no doubt that due to anthropogenic activity the Earth is facing a global warming (IPCC 2007). More regional climate models have been successfully adapted and tested in this region for example: PRECIS (Providing Regional Climates for Impact Studies), and RegCM (Regional Climate Model) (Bartholy et al. 2009a). By now after completing several RCM experiments for the Carpathian Basin and its vicinity, it is possible to estimate the future changes in the climatic means and extremes in this region for the 21st century (Torma et al. 2008, Bartholy et al. 2009, Pieczka et al. 2010, Krüzselyi et al. 2011).

Hungary's climate is warming caused by global warming according to our country's climate models, and drier summer periods are expected. As a result of average temperature increase due to drier summers the decrease in summer precipitation can be 50 to 110 mm per degree Celsius (Mika 1998, 2002). Based on recent years several models predict increase in annual precipitation besides warming, for example the PRECIS (Providing Regional Climates for Impact Studies), and RegCM (Regional Climate Model) (Bartholy et al. 2009). These models was developed at the Hadley Centre of the UK Met Office (Wilson et al. 2009), and it can be used over any part of the globe (e.g., Hudson – Jones 2002, Rupa Kumar et al. 2006, Taylor et al. 2007, Akhtar et al. 2008).

There is an increasing amount of precipitation in Hungary, but like world-wide it is not uniform and growing number of extreme events are expected (Magana et al. 2003). Barrov et al. reached a similar conclusion when they determined the change of the quantity of precipitation in winter (0.4 –3.6%) and summer ((–0.5)–3.7%) periods between 1961–1990 (Barrov et al. 2000). The design and operation of settlements cannot work without accurate knowledge of urban hydrology elements.

The knowledge of precipitation is also important for developing sewerage systems, treating internal water problems and fighting against pollution based on precipitation leaching.

Defining the design storm serves the same purpose as well.

2. Materials and methods

2.1 Description of the study area

Debrecen is the second largest city in Hungary after Budapest. This city is the regional centre of the Northern Great Plain region and the seat of Hajdú-Bihar county. Debrecen is located on the Great Hungarian Plain, 220 km east of Budapest.

Debrecen is one of the few cities in Hungary, where meteorological measurements began in the middle of the 19th century (Figure 1). In our investigations data from the Debrecen Airport measuring station (north latitude 47°29'44 ", east longitude 21°37'48") operated by the National Weather Service was analyzed.

Figure 1: Geographical location on the research area

During the 20th century measurements were conducted in a more uniform way, so measured data from 1901 to 2011 was dealt for the reason of comparison with other municipalities. Average monthly mean temperature years of Debrecen can be said that the coldest month is January while the warmest is July. The annual average temperature range 22.3 ° C.

Debrecen average annual precipitation amount of 540 mm more rain in the summer half-year, while the drier winter semester. The least rain falls from January to March period, while the wettest months - nearly two and a half times the amount - in June.

2.2 Database

Meteorological data measured by the weather station was analyzed statistically. The daily values were processed (monthly, seasonal and annual sums were also formed). During processing the dataset statistical analyzes were preformed (e.g. linear trend calculation, standard deviation, range etc.). Comparative analysis of these data will be introduced in the assessment of the results. In addition 80 % design storm was also determined by data of 30 years precipitation measured in the city.

3. Results and conclusion

Debrecen is located in the eastern part of Hungary, in the northern Great Plain, and from this location follows that it is drier then the western part of the country. The precipitation data similarly to other neighbouring settlements in the Great Plain shows a decreasing trend. The decrease of annual averages does not reflect the frequency and intensity of precipitation events. The general perception is also right for Debrecen that the precipitates are less common, but their quantity and intensity is increasing. This comes from its geographical location, as the Carpathian Basin is further away from the seas and oceans, so their impact prevails only in the case of higher intensity weather events (Horváth et al. 2003).

3.1 Precipitation data measured in the city

The calculated annual precipitation of Debrecen from the 111-years line of data is 570 mm with 118 mm standard deviation. The data range is 632 mm, and its mean absolute deviation is 92 mm. The easiest way to approach the precipitation change is to fit a linear trend line, which shows a ca. 0.30 mm annually decreasing in precipitation quantity (Figure 2).

In the next step the data set was divided into 10-year intervals, and the averages of these periods were compared to the arithmetical mean of the whole period. The 1951-1960 and the 1980-2000 periods were drier than the average, while 1911-1920 and 2000-2010 periods were the wettest decades. The driest was the 1991-2000 period, while the wettest was the 2000-2010 decade. It is interesting that these two extreme periods were two consecutive decades in the end of the last century. The lack of precipitation was more than 50 mm to the average in the minimum period, while there was a 90 mm surplus in the wettest period compared to the 111-year average.

Despite their extremes the last three decades from 1981 to 2010 of the divided data series show a growth compared to the average precipitation decreasing trend. Due to this increase of precipitation the overall decrease for the entire interval is only 30 mm/100 years.

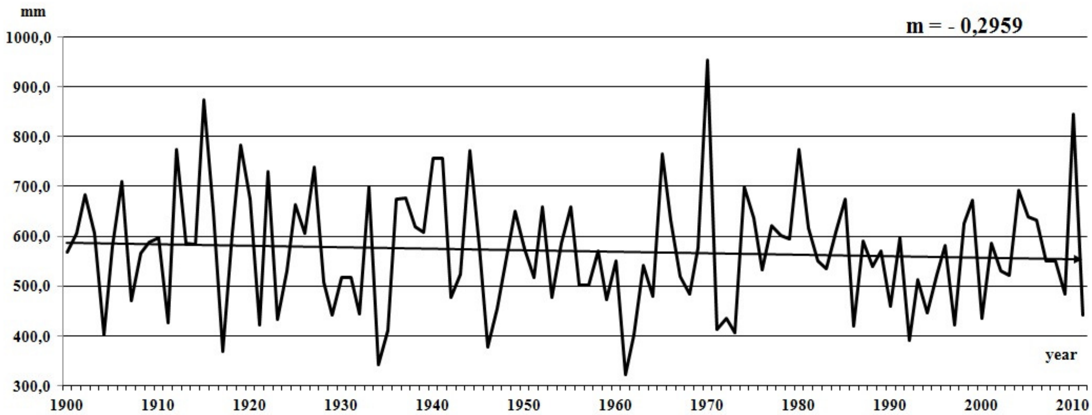

Figure 2: Precipitation data of Debrecen measured between 1901 and 2011

3.2 Seasonal trend in precipitation

The seasonal changes in precipitation are more important for farmers, but high-intensity precipitation may have an effect on houses and buildings status in many settlements. There are urban areas in Debrecen, like many other municipalities in Great Plain, which can be swamped by internal water during wetter periods. In addition, the city's surface water and sewerage systems are also encumbered during these periods. These events are common during spring because of snow melting and also in summer, when heavier rainfalls can be occurred. Therefore, the trend of the seasonal precipitation amounts were also examined in addition to the annual precipitation values. Linear trend was fitted for each season to the seasonally scaled data of the 111-year period in order to determine the direction of possible changes in each season's precipitation characteristics (Table 1). It can be concluded from the slope of the trend lines, that next to the increasing summer precipitation the amount of precipitation in autumn is decreasing. The spring precipitation amounts are considered to be practically unchanged, while the winter precipitation amounts show a slightly increasing trend.

Table 1: The seasonal changes in precipitation amounts in Debrecen between 1901 and 2011

Season	Winter	Spring	Summer	Autumn
Slope	0,00003	-0,00001	0,00020	-0,00020
R^2	0,00020	0,00002	0,00280	0,00640

The results are not significant, so it cannot be clearly declared that the change in seasonal precipitation conditions is observed in the case of Debrecen. By Bartholy and his colleagues' national season estimation increasing precipitation can be expected during the winter months, declining rainfall in the summer, and very little change in the transitional seasons. The statistical characteristics of the seasons are summarized in Table 2.

Table 2: Statistical parameters of seasonal precipitation events

Season	Winter	Spring	Summer	Autumn
Mean [mm]	109,66	136,47	195,78	135,27
Min. [mm]	25,10	43,10	54,60	20,60
Max. [mm]	228,00	262,40	510,70	264,70
Standard deviation (SD)	41,14	47,64	76,47	55,33
Range (R)	202,90	219,30	456,10	244,10

It must be noted, that these results are not significant for either one of the seasons, so it cannot be declared for sure that there is a movement in the data variability. The further analysis of seasonal precipitation (SPSS v.17.0) showed us that the number of bigger precipitation events in spring and autumn was grown considerably (Figure 3).

Next to decreasing monthly average precipitation quantities the increasing maximum values can be an important signal for analyzing weather anomalies. The data was divided into 30-year groups backwards, so the first and oldest period contains 21 years, the others ones 30 years. We chose these time periods for better comparison. It can be seen from the figure that the precipitation amounts of autumn months are getting closer to each other (smaller box sizes) next to the decreasing monthly average precipitation amount.

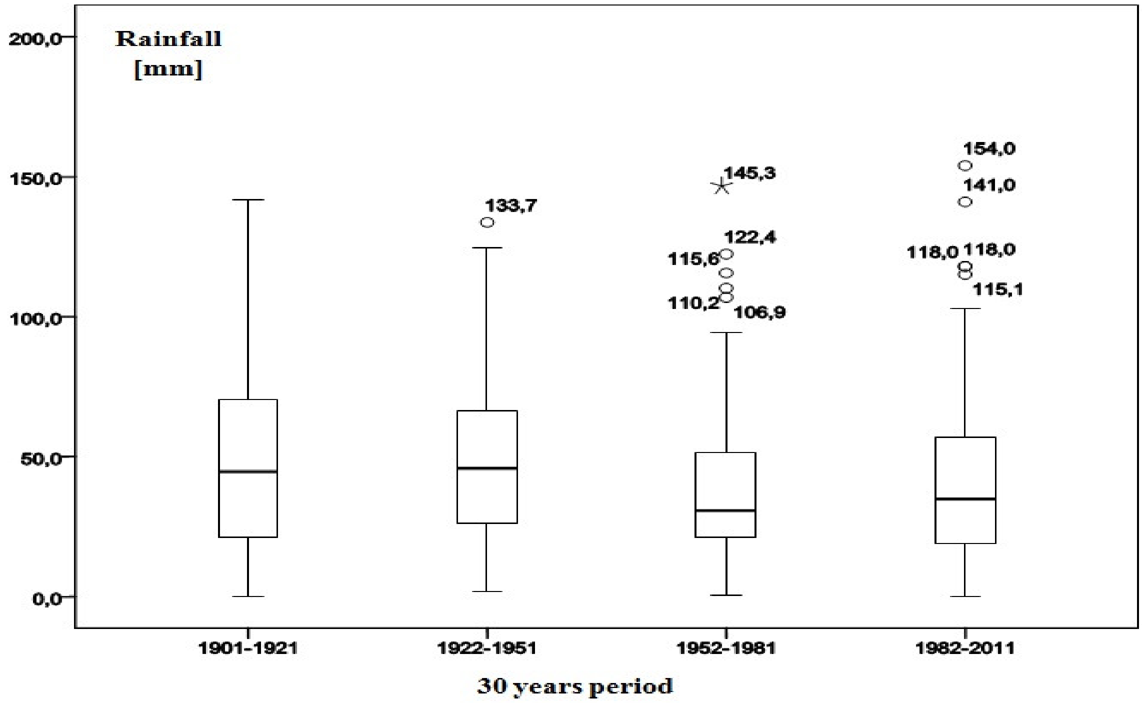

Figure 3: Monthly precipitation statistics of autumn months between 1901 and 2011

Furthermore the number of highly differing from average events is increasing in the last 40-50 years. This also means that the durations of drier periods are longer, since the average decreases. The precipitation maximums that show a greater deviation from the average can be divided into two groups. The outstanding (sign:°), which exceeds 1.5 times the range determined by half of the data, and the extreme (sign:*), which exceeds 3 times the range. 5-5 events are included to these groups from the last two periods, and it is likely that the next 30 years will also bring such big precipitation events. These events are serious challenges for the operators of municipal utilities between longer dry periods as well.

3.3 The trends of monthly precipitation amounts

In Debrecen the monthly amount of precipitation is increased continuously after the early years of stagnation, up to the maximum level in June, as it is typical in the Northern Great plains of Hungary. We know that this trend is very favourable in terms of agricultural production in the region, which is exactly corresponded to the plant needs with the gradually increasing temperature. Beside the principal maximum occurring in early summer in most of the meteorological stations of Hungary the secondary maximum in autumn is also observed to characterize the temporal distribution of precipitation, which hardly emerged in case of Debrecen. According to Figure 4 the precipitation amounts of the autumn months appear quantitatively balanced.

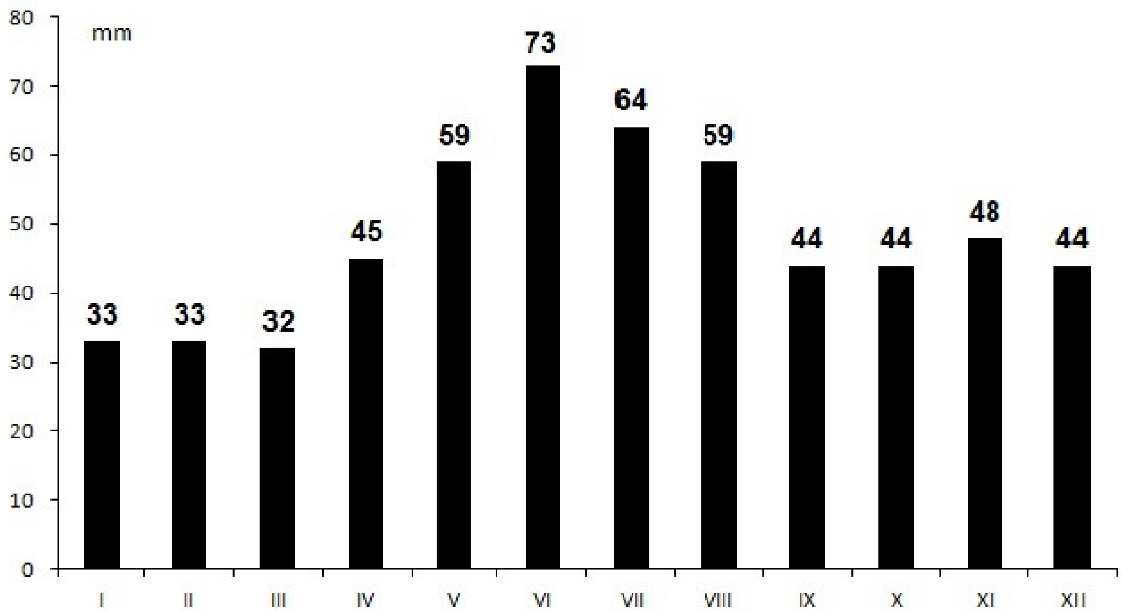

Figure 4: Monthly precipitation averages (1901 – 2011)

The disparities of 111-year data of total amount of the monthly precipitation are illustrated by linear trend (Table 3.). The total amounts of precipitation in the period from August to December in addition with March are decreased.However, the R^2 values indicating fitting of linear trend line draw attention to changes in trends of monthly precipitation amounts do not conceal any significant changes, so in the case of Debrecen the fact of reduced precipitation should be treated with reservations. The spring - summer precipitation increase cannot complement the lack of water caused by reduced autumn precipitation, so the decline in autumn precipitation through the soil water depletion can be occurred as a limiting factor.

Table 3: Changes in trends of monthly precipitation amounts based on 111-year data in Debrecen

Months	Slope	R^2
January	8,E-05	0,0024
February	6,E-05	0,0011
March	-3,E-04	0,0189
April	2,E-05	1,00E-04
May	1,E-04	0,0018
June	8,E-05	0,0007
July	5,E-04	0,0239
August	-8,E-05	0,0006
September	-6,E-06	5,00E-06
October	-5,E-04	0,0293
November	-1,E-04	0,0039
December	2,E-04	0,0046

Analyzed the extreme values and intensity of precipitation the largest variability is observed in July, August and June (Table 4). There moved half of the data in the widest range. The absolute maximum values occurred in August. The variability is the lowest in the winter months.

3.4 Determination of design storm based on 30-year data

This is the precipitation amount which can be certainly expected in a period under certain climatic conditions and specified probability. In Hungary, for example to the planning of irrigation this value is the precipitation amount above frequency of 75-85% of rainfalls, so that amount which surely drop off 75 to 85 years in 100 years.From the available data the precipitation function was determined, from which the 80 % probability occurrence of precipitation was defined.

Table 4: Changes in statistics of monthly precipitation amounts based on 111-year data in Debrecen

Months	Mean [mm]	Min. [mm]	Max. [mm]	SD	Range
I	33,22	3,30	110,00	19,28	106,70
II	32,82	0,30	87,40	20,55	87,10
III	32,43	1,10	108,00	23,00	106,90
IV	44,99	5,00	122,30	24,21	117,30
V	59,05	6,90	161,00	32,66	154,10
VI	72,99	19,40	175,90	36,25	156,50
VII	64,16	4,90	164,00	38,98	159,10
VIII	58,63	6,70	232,30	38,18	225,60
IX	43,85	0,00	154,00	32,74	154,00
X	43,69	1,40	145,30	34,27	143,90
XI	47,73	0,00	141,80	28,16	141,80
XII	44,24	0,80	130,30	26,19	129,50

Precipitation data between 1982 and 2011 were arranged in descending order and classes were formed by steps of 25 mm. The lower limit of the classes was 375 mm, and the upper limit was 850 mm, respectively (Figure 5).

Then, the histogram was created by frequency of occurrence. The precipitation curve was prepared in the histogram for that period in relation to the relevant area by the percentage enhancement of classes (Fórián, 2011).

Extrapolating the intersection point of the line of the 80% probability, which is parallel to the ordinate axis, to the axis of precipitation amount in the precipitation curve, the demanded value can be determined.

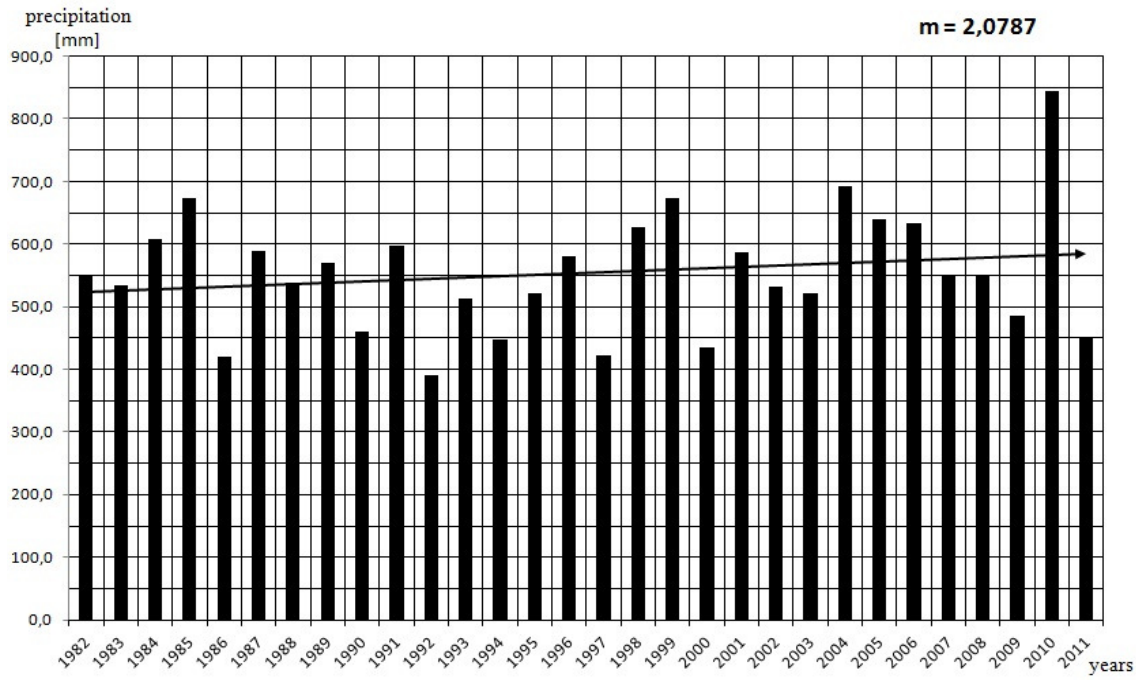

Figure 5: 30-year measured precipitation data in Debrecen (1982 to 2011)

We determined that 80% chance 455 mm of precipitation will certainly occur in the next few years, based on data of the last 30 years in Debrecen (Figure 6). Of course it must be said here that this data shows the minimum limit value during the technical designs, so this value surely occurs in 80 years in 100 years, therefore the applying of the safety factor cannot be dispensed. In a previous study the design storm value was 445 mm by the calculations from data between 1951 and 2000. The calculations were performed by the ten-year periods between 1961 and 2010 and the design storm value was 450 mm.

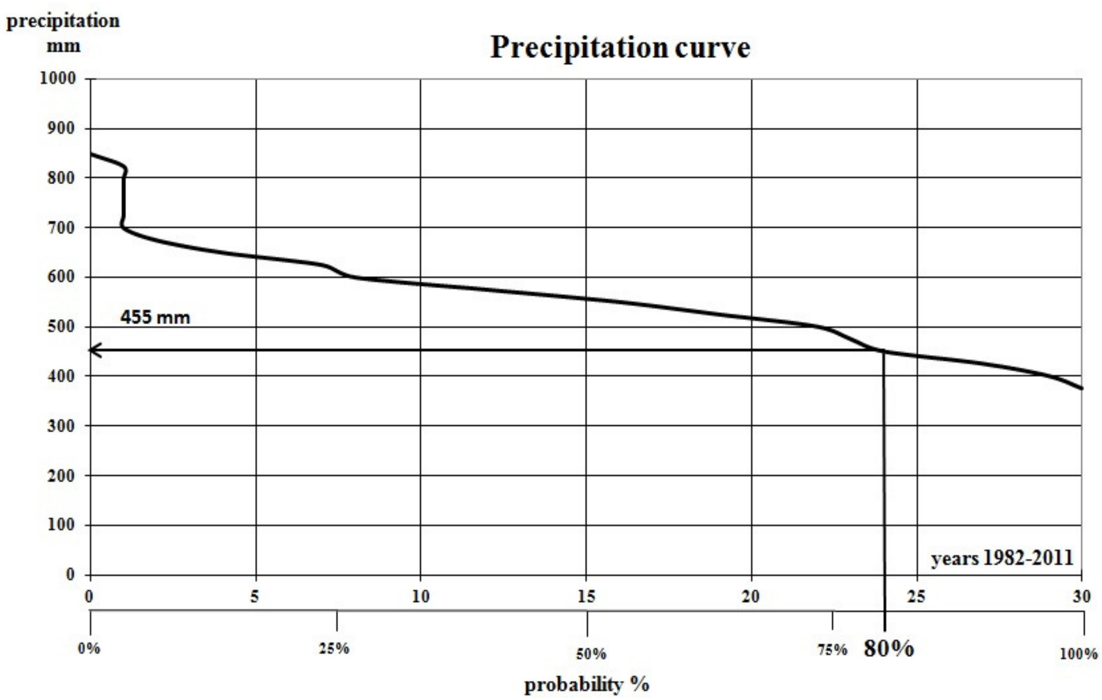

Figure 6: Determination of the design storm amount based on data of 1982 – 2011 period

The 5 mm difference between these two fifty-year periods was caused by the last ten years which was the wettest decade in the analyzed period, so it contributed to the growth of value. The same conclusion can be laid down from the last 30-year data analysis (1982 to 2011). According to our based on different time periods the annual design storm value is around 450 mm at the desired 80% level of probability.

4. Summary

The results showed that the annual precipitation amount during the examination period (1901-2011) in Debrecen was decreasing, but not significantly. The decline of annual precipitation was 30 mm in 100 years.

Based on the quantitative analysis of monthly precipitation a smaller decreasing was identified in the August-November period and in March, while there was a slightly increase in January, February and from April to July. According to the monthly precipitation amounts the second maximum of autumn precipitation seems to disappear in the case of Debrecen.

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