THE SPATIAL VARIABILITY OF PRECIPITATION DURING THE GROWING SEASON OF 2018-2019.

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Abstract. *When it comes to climate change, the very first thing comes to most of our mind is the rising temperature, even though climate change is having a significant impact on the water cycle. Agriculture, including crop cultivation, is the most weather- and climate-dependent economic activity. With the help of various weather-plant models and statistical correlation studies, it can be established that the average yield-increasing and yield-reducing effect of weather reaches or exceeds 20% for most economic plants. Precipitation is a climatic element which is showing extreme variability in space and time and the spatial distribution of precipitation is becoming more and more extreme year after year. Our research focused on the spatial distribution of precipitation on horizontal scale up to 1-2 km. We established a low-cost rain gauge network in Csabacsűd located on the Great Hungarian Plain where we did daily measurements (N46.49°, E20.39°, 85 m above sea level) with 18 plastic rain gauges which is widely used in the Hungarian private sphere. We examined the qualitative and quantitative correlations of the data with the help of the ESRI ArcGIS software. Spatial variance, deviation, an CV values of precipitation were calculated using Microsoft Office Excel. The results show significant areal differences in daily amount of precipitation within the small (1.5 km x 0.8 km) study area. The largest absolute difference in the small settlement reached 17 mm on 12.07.2018. The smallest value was 25 mm, the largest value was 42 mm and the distance between these stations is 1.4 km. Precipitation shows a large spatial inhomogeneity especially in daily or shorter timescales. It was clearly visible in 2019 that the standard deviation and the CV value showed a decrease compared to the 2018 research year. However, larger differences were also detected this year with a difference of 8.8 mm in the case of a distance of 1400 meters. On 22.06.2019, a difference in the amount of precipitation of 3.7 mm was detected between two gauges located 220 meters apart. This value represents a difference of 1.68 mm/100 m. These data show that on-site measurements are needed in the growing season for practical agrometeorological purposes such as irrigation scheduling.*

Keywords: *precipitation, spatial distribution, rain gauge network*

INTRODUCTION

Precipitation is a major source of revenue for the surface water balance. Precipitation information is extremely important in agriculture and water management both of a practical and a research point of view as it helps farmers schedule the planting and harvesting of crops.

It also helps in irrigation planning and management. Furthermore precise measurement of rainfall is crucial for the proper management of water resources. It is the primary source of water for many regions, and accurate data helps in regulating dams and reservoirs, predicting floods or droughts, and managing water supply for households, industries, and agriculture.

Due to its ecologically significant role, precipitation is one of the oldest observed and measured climatic elements and the most varied climate element in Hungary. Due to the geographical location and varied topography of the Carpathian Basin, there may be significant differences in the amount of precipitation and its temporal and spatial distribution, especially in case of rain showers.

The spatial variability of the precipitation can be very varied during the growing season, even within a small area there are significant differences. Pedersen et al., (2010) showed that there can be a difference between 2,5-12,4 mm of precipitation just in 0,25 km2 area.

The regional distribution of precipitation can be easily quantified with the spatial variation coefficient. Jensen and Pedersen (2005) surprisingly showed that the results of the experiment showed large fluctuations within independent events during the precipitation event observed by the nine gauges. Expressed as a coefficient of variation (CV), the variability ranged from 10% to 100%, and even when the most extreme measurement device was omitted from the analysis, the standard deviation exceeded 50% in several cases.

The structural function gives the characteristic deviations of the precipitation values as a function of the horizontal distance. Determined in the average of a longer period, the structural function provides a basis for optimizing the station network to calculate the area average and the interpolation with sufficient accuracy. (Czelnai R., 1981)

One of the most frequently used functions for describing and analyzing the spatial structure of precipitation events is the semivariogram. (Ly et al., 2011)

$$y(h) = \frac{1}{2 \cdot N(h)} \cdot \sum_{i}^{N(h)} \left(Z_{s_i} - Z_{s_i+h}\right)^2$$

Further information on spatial variability is provided by the Pearson „r"-value of the correlation large number of events. The Pearson „r" values generally show a decreasing trend in a function of the distance of station pairs. (Habib E., and Krajewski W.F, 2001)The value of Pearson's correlation is significantly affected (reduced) by extreme values and is not sensitive to additive and proportional differences in data sets, so its use requires caution.

If we observe research covering a longer period, then for example, in the Amazon rainforest, areas along the eastern edge receive an average of 1700-2500 mm of rainfall per year while areas just a few hundred miles west can receive as little as 250-500 mm of rainfall per year. (Phillips et al., 2009) This dramatic difference in precipitation is caused by the region's complex atmospheric and geological processes.

Mean areal precipitation (MAP) is commonly used as input to hydrologic and hydraulic models. If MAP is measured with a low-density network of gauges, we can experience very significant errors. (Chen et al., 2020; Michaud and Sorooshian, 1994)

The World Meteorological Organization has defined the requirements for various instruments and measuring stations at several points in order to obtain the most accurate data possible on the state of the atmosphere and its changes. This requires instruments that can be used to make reliable and accurate measurements over the long term.

Rain gauges are considered by most to be able to provide accurate measurements in all conditions. However it has been long known that precipitation measurement is loaded with errors, most of them are systematic errors. None of these rain gauges are an exception, the difference can only be found in the degree of error. Nowadays the most commonly used tool to preform precipitation measurement is the tipping bucket rain gauge, but this type of rain gauge is also loaded with errors. For medium-intensity 10 mm / h precipitation, HABIB and KRAJEWSKI (2001) showed a measurement error of 6.4% on a 5 minute time scale and 2.3% on a 15 minute time scale. (Grzegorz J. C., (2002) performed similar measurements using 15 tipping bucket rain gauges. During a medium-intensity precipitation he was able to detect an error of a 4.9% for the 5 minute time scale and 2.9% for the 15 minute time scale.

A particularly good supplementary form of point precipitation measurement is precipitation measurement by radar. (Gombos, 2011)

Sempere-Torres et al., (1999) showed that even raw radar data provide better data than data from a dense rain gauge network. Nowadays, however, the reviews of the literature show that in order to make the rainfall estimated by the radar more precise, we also have to carry out measurements on the ground surface.

Huff F. A, (1970) reported an error of less than 5%, measuring in an area of 1,000 km2 and placing a rain gauge on every 65 km2 . Based on similar data, Woodley L. W. and Simpson J. (1975) reported a much larger measurement error of 10–40% compared to a traditional rain gauge. Different techniques have been proposed in order to be able to accurately measure precipitation by radar.(Goudenhoofdt and Delobbe, 2009; Krajewski, 1987; Sinclair and Pegram, 2005)

MATERIAL AND METHODS

The aim of our research was to investigate the spatial variability of precipitation during the growing season. In Hungary, the Hellman rain gauge used for official measurements, but unfortunately that was only available in limited quantities, so during our research we used a commercially available plastic rain gauge. It cannot be used for official measurements, but when we try to examine the spatial variability of precipitation, due to its low purchase price, it can even be used at a higher density. However, it is worth noting that its use is only advisable during the growing season, as it can easily freeze in the winter and is inaccurate for measuring snow.

The measurements were carried out in the interior of a lowland village Csabacsűd located on the Great Hungarian Plain (N46.49°, E20.39°, 85 m above sea level). The size of the sample area is about 1.2 km^2. A high-density rain gauge network with 18 measurement points was established within the settlement. The distance between the two measuring points closest to each other is 150 m, while the distance between the two furthest rain gauge is 1.5 km

Figure 1. Precipitation measurement locations in the settlement

We examined the qualitative and quantitative correlations of the data with the help of the ESRI ArcGIS software, which has the following main elements:

- display data on point map
- determining station pair distances
- calculation of precipitation gradients
- use of different interpolation methods

There are several interpolation methods to choose from in ArcGIS, but we used the Kriging method, which is also most often used in the literature.

Spatial variance, deviation, and CV values of precipitation were calculated using Microsoft Office Excel.

The main systematic error of precipitation measurements is caused by wind (Chvíla et al., 2005; Førland, E. J. et al., 1996; Sevruk et al., 2009; WMO World Meteorological Organization, 2008), which has been kept low and unified by the targeted placement of the rain gauges (unified, wind-protected microenvironment in gardens), which is one of the most important aspects when measurements are made to explore the spatial variability of precipitation.

RESULTS AND DISCUSSIONS

Precipitation activities took place over 11 days during the 2018 research period (Fig. 2.) and 13 days during the 2019 research period (Fig. 6.) were measured at all 18 stations. With one exception (on 05/05/2019, the daily average of precipitation was 4.2 mm), the amount of measured precipitation events reached an average of 5 mm/day.

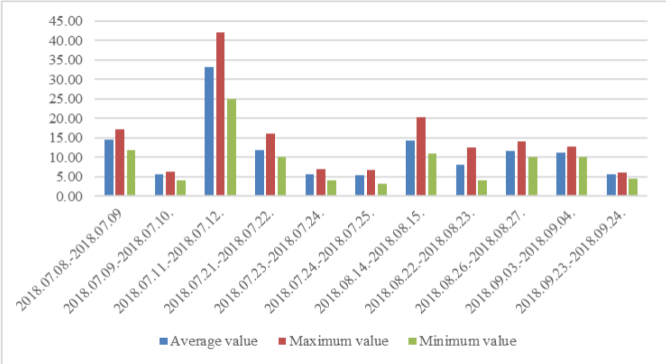

Figure 2. Average, maximum and minimum values of precipitation events in 2018 expressed in mm.

The deviation which could be used to examine the spatial variability increased with the amount of precipitation. (Fig. 3.) This is also natural, as larger amounts of precipitation can lead to larger square differences. However the coefficient of spatial variation is, a better expression of spatial variability.

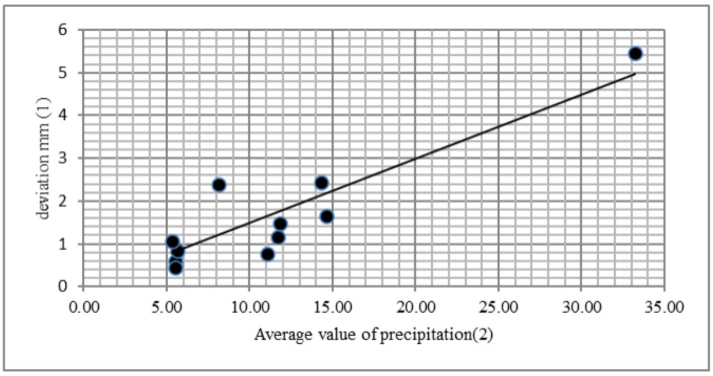

Figure 3. The value of the deviation (1) as a function of the precipitation average (2).

The highest CV value was 29%, the precipitation event was measured on 2018.08.23. The average value of precipitation was 8 mm on this day in the settlement. The minimum and maximum value of precipitation measured between two stations was 4 mm and 12,5 mm. Figure 4. illustrates that the minimum of precipitation was in the south-central part of the settlement, and an increase in precipitation was observed in the east-west direction.

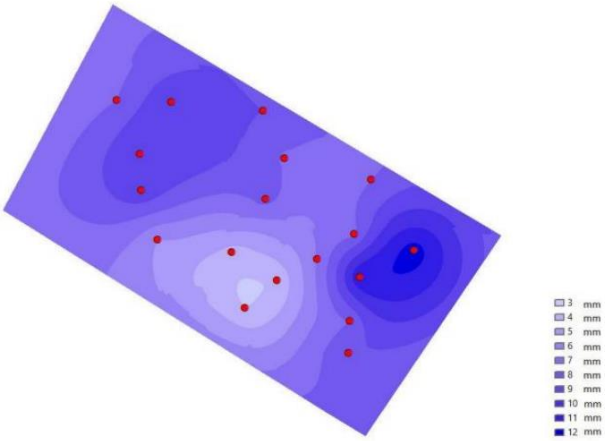

Figure 4. Spatial variability of precipitation in Csabacsűd 2018.08.23.

Of the CV values, only the fourth largest data is measured on 2018.07.12 with 16%, but with a daily average of 33 mm it stands out from other precipitation events. The measured minimum value was 25 mm and the maximum is 42 mm. On this day the difference between two measure station reached 17 mm, the distance between the two station was 1,4 km, this data is equivalent to 12,2 mm/km horizontal gradient. Shown well in the 5. figure that the precipitation maximum was in the western part of the settlement, then a steady decline to the east can be observed. That is worth noting that on this day the automatic rain gauge of the Szent István University only measured 7 mm rainfall on the neighboring settlement Szarvas.

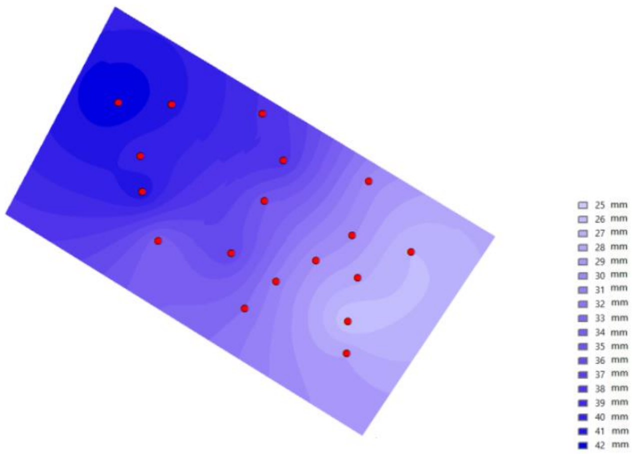

Figure 5. Spatial variability of precipitation in Csabacsűd 2018.07.12.

The difference between the highest and lowest precipitation measured in the settlement on each day is a good illustration of the spatial variability: there were 5 days during the research period when the difference reached 5 mm. The average CV value was 14% for the 11 measurement days. During the research period, there were much more spectacular, nearly double gradients between the measuring points closer to each other so 3,6 mm per 100m. Using the ArcGIS program, I determined Using the ArcGIS program, I determined the distance between the station pairs, followed by the calculation of the difference in precipitation between the two stations, and the last step was to determine the precipitation gradient in mm / 100 m.

The CV values and the spatial variability of precipitation showed extremely varied differences in 2018 after one rain shower precipitation event on the other hand for a longer period of time, precipitation amounts show an equalization.

In 2019, no significant difference could be observed during major precipitation events, as was the case more often in 2018. During the 13 days, the value of the standard deviation exceeded the value of 2 mm only once with its value of 2.77 mm on 22.06.2019, with an average of 13 mm/day. (Fig. 7.)

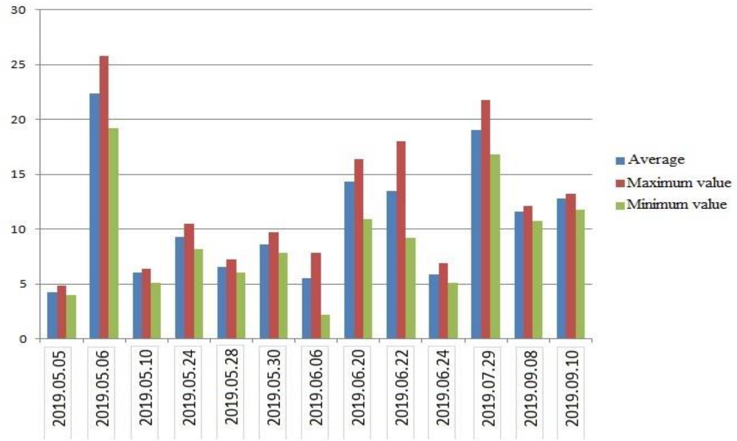

Figure 6. Average, maximum and minimum values of precipitation events in 2019 expressed in mm.

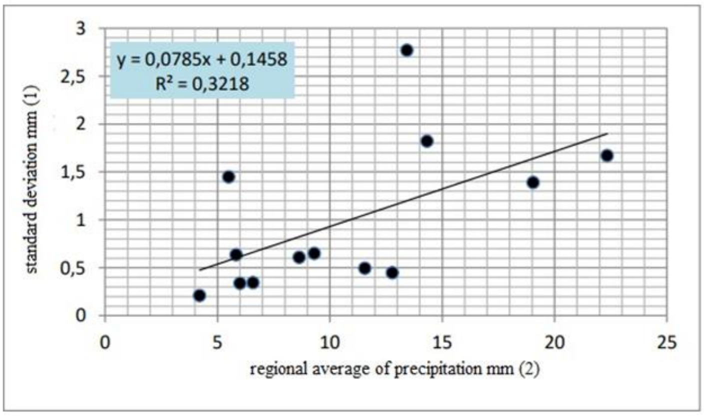

Figure 7. The value of the standard deviation (1) as a function of the precipitation average (2)

The minimum value of the CV value was 6%, and the maximum value was 26% based on the data of the 13 days, in the area of approx. The CV value of 26% belongs to the precipitation event measured on 06.06.2019. On this day, the regional average of precipitation was 5 mm, with a maximum of 7.8 mm and a minimum of 2.2 mm. The minimum amount of precipitation was in the north-western part of the settlement, then it reached the maximum in the central part, and a minimal decrease was observed in the north-east direction. (Fig. 8.)

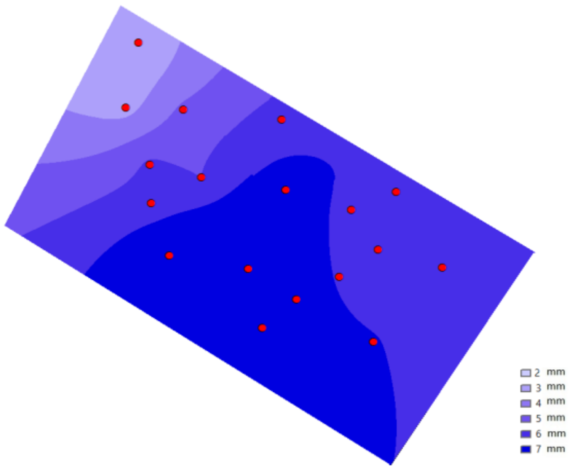

Figure 8. Spatial distribution of precipitation on 06.06.2019

In the 2019 research period, the second highest CV value with 21% was on 22.06.2019. On this day, the average of precipitation was 13 mm, while the maximum and minimum values were between 18 mm and 9 mm. The maximum amount of precipitation was on the west side of the settlement, and then showed a decrease towards the east. (Fig. 9.)

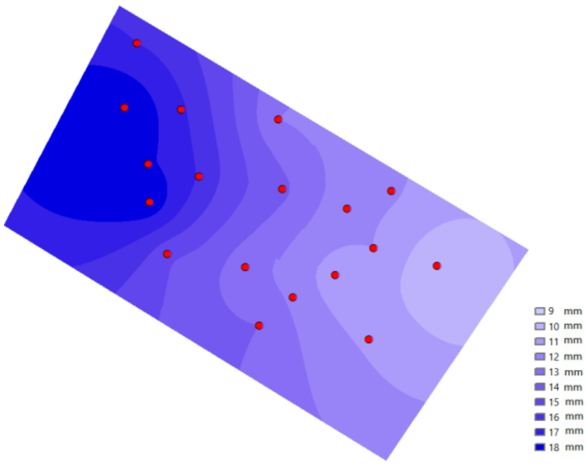

Figure 9. The precipitation distribution on 22.06.2019

In the 2019 period, only 4 days of CV value reached or exceeded 10%, and 4 days did not even exceed 5%. During the research period, although there were precipitation events where spectacular differences were created in the entire area of the settlement, however, in the case of pairs of stations close to each other, the differences were no longer so spectacular.

It is also worth examining Figure 10., which clearly shows that the north-west side of the village had the smallest amount of precipitation, while the north-east side showed an increase in precipitation. On this day, the CV value was only 7%, and the difference between the highest and lowest precipitation amount was 6.6 mm, and the average was 22 mm.

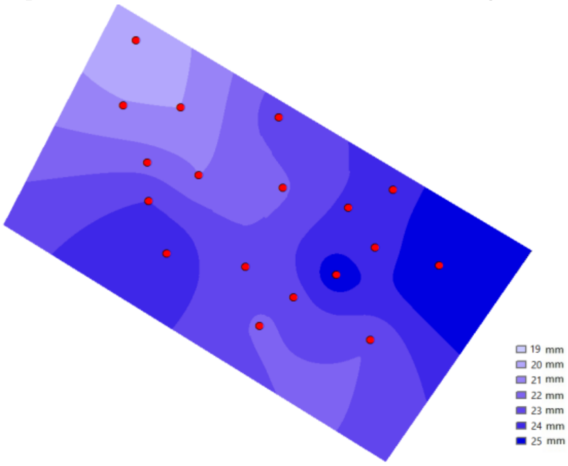

Figure 10. The Spatial distribution of precipitation on 06.05.2019

On 22.06.2019, a difference in the amount of precipitation of 3.7 mm was detected between two gauges located 220 meters apart. This value represents a difference of 1.68 mm/100 m. In the 2019 research year, this precipitation event gradient was the most prominent.

CONCLUSIONS

During the research aimed at examining the spatial variability of precipitation, it was clearly visible that the value of the standard deviation and the CV value showed a decrease in 2019 compared to 2018.

The areal standard deviation and the absolute deviations also increase with higher daily precipitation, while the coefficient of variation shows the opposite trend.

The variation in the amount of precipitation shown in the research can already affect the optimization of the decision in the operative practice of irrigation, therefore it may be advisable to measure the local precipitation during the growing season. It is important to pay attention to the following steps, because these are essential in order not to lose the advantages of the on-site measurements.

- should be placed vertically so that its upper edge is 1 meter above the ground
- place them at least as far away from the landmarks as their height, thus ensuring that the precipitation can already fall from a direction of 45°
- reading within short time after the precipitation event in order to minimalize evaporative loss

Outside the growing season, the amount of precipitation taken over a longer period counts, for which the standard deviation is usually much lower. It may be sufficient to use data of a correctly installed precipitation gauge within a distance of 5-10 km.

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