LOCAL-SCALE DISTRIBUTION OF PRECIPITATION IN THE GROWING SEASON OF 2019

R. HUDÁK, B. GOMBOS
Hungarian University of Agriculture and Life Sciences Institute of Environmental Sciences Department of Irrigation and Land Improvement
Corresponding author: Roland HUDÁK, hudak.roland@uni-mate.hu

Abstract. *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 with 18 plastic rain gauges which are widely used in the Hungarian private sphere in the settlement Csabacsűd located on the Great Hungarian Plain (N46.49°, E20.39°, 85 m above sea level) where we did daily measurements between May and September 2019. It was clearly visible in the results of the 4-month measurement program 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

There are several reasons why accurate rainfall measurement is important, for example in agriculture accurate rainfall data is critical for agricultural production 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.

During the measurement of precipitation, several parameters are determined:

- The amount of precipitation: this is expressed as the height of the layer of water that would stand on the completely smooth, horizontal surface after precipitation, if nothing from it would flow, leak or evaporate. In some places, the amount of precipitation is measured with an accuracy of 0.2 mm, but the most accepted measurement accuracy is 0.1 mm. 1 mm of precipitation on 1 square meter of surface corresponds to 1 litre of water.

- Rainfall duration
- Rainfall intensity, its unit of measurement is mm/hour. In this measurement, we examine the amount of precipitation that falls during the unit of time.

Understanding the temporal and spatial distribution of precipitation is also a prerequisite for climate change impact assessment. (BUSUIOC ET AL. 2001)

The spatial variability of precipitation can vary greatly across different regions and even within the same region. In some cases, certain regions may experience heavy rainfall while nearby areas remain dry for extended periods of time. The spatial variability of precipitation can be quite spectacular even in a small sample area. PEDERSEN (2010) was able to show a difference of 2.5-12.4 mm in an area of 0.25 square kilometers.

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.

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

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

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, SOROOSHIAN 1994)

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. Different techniques have been proposed in order to be able to accurately measure precipitation by radar. (GOUDENHOOFDT, DELOBBE 2009; KRAJEWSKI 1987; SINCLAIR, 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 (Fig.1).

It is worth mentioning that this is the second year of the research period, the data of 18 stations was still available. During the research period, 13 precipitation events were assessed.

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 most common systematic errors in precipitation measurement may include errors due to wind, evaporative loss, under-collector and instrument problems, however, the most significant of those listed is the measurement error caused by the wind (CHVÍLA ET AL. 2005; FØRLAND, E. J.ET AL. 1996; SEVRUK ET AL. 2009; WMO 2008), which was kept at a low level and unified by purposefully placing the gauges (unified, wind-protected microenvironment in the gardens), which is one of the most important aspects when we try to explore the spatial variability of precipitation.

RESULTS AND DISCUSSIONS

Precipitation activity occurred on 13 days and was reliably 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. (Fig. 2.)

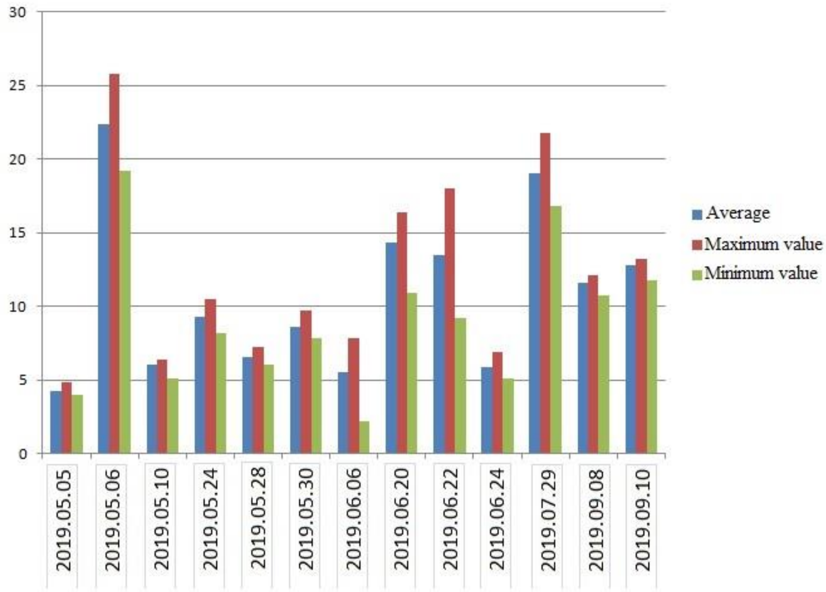

Figure 2. Average, maximum and minimum values of precipitation events in 2019 expressed in mm.

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. 3.)

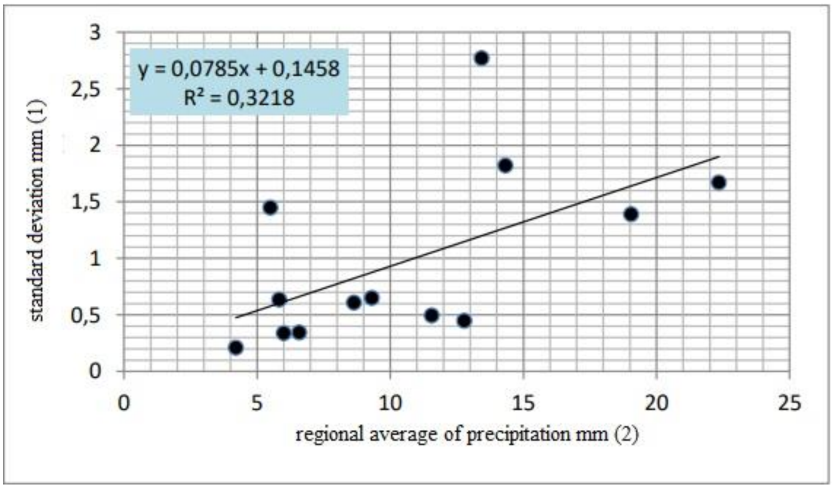

FIGURE 3. THE VALUE OF THE STANDARD DEVIATION (1) AS A FUNCTION OF THE PRECIPITATION AVERAGE (2)

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. 4.)

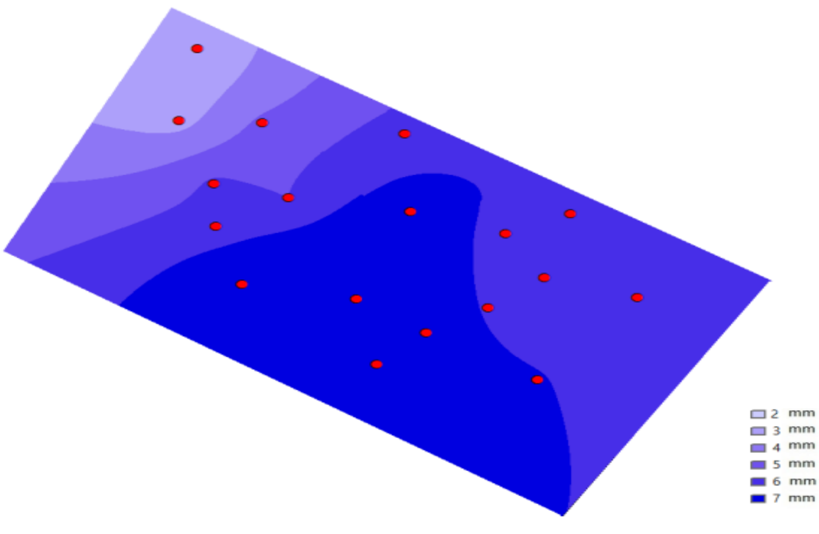

Figure 4. Spatial distribution of precipitation on 06.06.2019.

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. 5.)

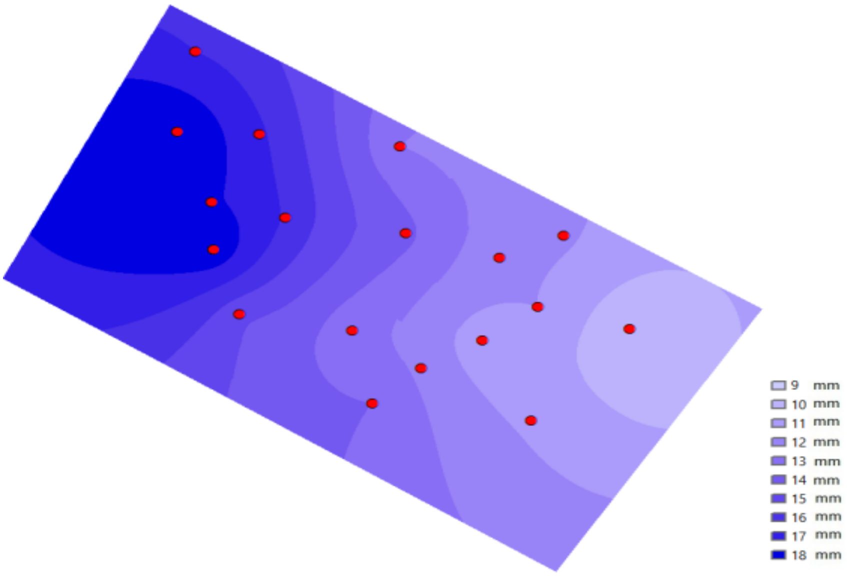

Figure 5. The precipitation distribution on 22.06.2019.

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 6., 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.

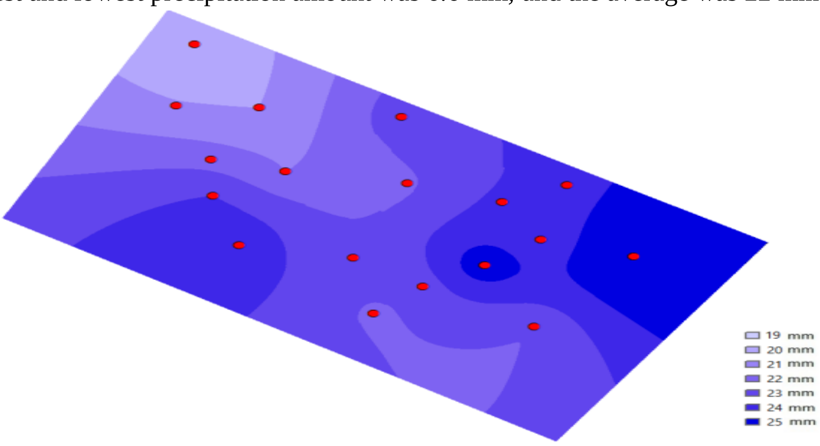

Figure 6. The Spatial distribution of precipitation on 06.05.2019

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 from the results of the 4-month measurement program that the value of the standard deviation and the CV value showed a decrease compared to 2018. However, larger differences were also detected this year with a difference of 8.8 mm in the case of a distance of 1400 meters.

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.

BIBLIOGRAPHY

BUSUIOC A, CHEN D., HELLSTR ̈OM C. 2001. „Performance of statisticaldownscaling models in GCM validation and regional climate changeestimates: application for Swedish precipitation. Int. J. Climatol.21:557 – 578".

CHEN LU, KANGDI HUANG, JIANZHONG ZHOU, HUAN-FENG DUAN, JUNHONG ZHANG, DANGWEI WANG, ÉS HONGYA QIU. 2020. „Multiple-Risk Assessment of Water Supply, Hydropower and Environment Nexus in the Water Resources System". *Journal of Cleaner Production* 268:122057. doi: 10.1016/j.jclepro.2020.122057.

CHVÍLA B., B. SEVRUK, M. ONDRÁS. 2005. „The Wind-Induced Loss of Thunderstorm Precipitation Measurements". *Atmospheric Research* 77(1–4):29–38. doi: 10.1016/j.atmosres.2004.11.032.

FØRLAND E. J., ALLERUP P., DAHLSTROM B., ELOMAA E., JONSSON T., MADSEN H., PERALA J., RISSANEN P., VEDIN H., VEJEN F. 1996. „Manual for operational correction of Nordic precipitation data Report Nr. 24/96, DNMI, P.O. Box 43, Blindern, Oslo, Norway, pp. 66."

GOMBOS BÉLA. 2011. „Hidrológia-hidraulika, Szent István Egyetem 2019.08.27. https://www.tankonyvtar.hu/hu/tartalom/tamop412A/2010-0019hidrologiahidraulika/ch01.html#id465081".

GOUDENHOOFDT E., L. DELOBBE. 2009. „Evaluation of Radar-Gauge Merging Methods for Quantitative Precipitation Estimates". *Hydrology and Earth System Sciences* 13(2):195–203. doi: 10.5194/hess-13-195-2009.

JENSEN N. E., L. PEDERSEN. 2005. „Spatial Variability of Rainfall: Variations within a Single Radar Pixel". *Atmospheric Research* 77(1–4):269–77. doi: 10.1016/j.atmosres.2004.10.029.

KRAJEWSKI WITOLD F. 1987. „Cokriging Radar-Rainfall and Rain Gage Data". *Journal of Geophysical Research* 92(D8):9571. doi: 10.1029/JD092iD08p09571.

LY, S., C. CHARLES, A. DEGRÉ. 2011. „Geostatistical Interpolation of Daily Rainfall at Catchment Scale: The Use of Several Variogram Models in the Ourthe and Ambleve Catchments, Belgium". *Hydrology and Earth System Sciences* 15(7):2259–74. doi: 10.5194/hess-15-2259-2011.

MICHAUD JENE DIANE, SOROOSH SOROOSHIAN. 1994. „Effect of Rainfall-Sampling Errors on Simulations of Desert Flash Floods". *Water Resources Research* 30(10):2765–75. doi: 10.1029/94WR01273.

PEDERSEN LISBETH, NIELS EINAR JENSEN, LASSE ENGBO CHRISTENSEN, HENRIK MADSEN. 2010. „Quantification of the Spatial Variability of Rainfall Based on a Dense Network of Rain Gauges". *Atmospheric Research* 95(4):441–54. doi: 10.1016/j.atmosres.2009.11.007.

PHILLIPS OLIVER L., ET AL. 2009. „Drought Sensitivity of the Amazon Rainforest". *Science* 323(5919):1344–47. doi: 10.1126/science.1164033.

SEMPERE-TORRES DANIEL, CARLES CORRAL, JORDI RASO, PERE MALGRAT. 1999. „Use of Weather Radar for Combined Sewer Overflows Monitoring and Control". *Journal of Environmental Engineering* 125(4):372–80. doi: 10.1061/(ASCE)0733-9372(1999)125:4(372).

SEVRUK B., M. ONDRÁS, B. CHVÍLA. 2009. „The WMO Precipitation Measurement Intercomparisons". *Atmospheric Research* 92(3):376–80. doi: 10.1016/j.atmosres.2009.01.016.

SINCLAIR SCOTT, GEOFF PEGRAM. 2005. „Combining Radar and Rain Gauge Rainfall Estimates Using Conditional Merging". *Atmospheric Science Letters* 6(1):19–22. doi: 10.1002/asl.85.

WMO World Meteorological Organization (WMO). 2008. „Guide to meteorological instruments and methods of observation. WMO-8 8 1-681".