RECIBIDO EL 23 DE OCTUBRE DE 2020 - ACEPTADO EL 23 DE ENERO DE 2021

# V DETERMINATION OF AVERAGE ANNUAL RAINFALL IN THE AGUABLANCA STREAM WATERSHED USING GIS AND IDW METHOD

# V DETERMINACIÓN DE LA PRECIPITACIÓN MEDIA ANUAL EN LA CUENCA DEL ARROYO AGUABLANCA MEDIANTE SIG Y EL MÉTODO IDW

**Javier Alfonso Cárdenas Gutiérrez**[1]

**Jose Leonardo Jacome Carrascal**[2]

**Mawency Vergel Ortega**[3]

*Universidad Francisco de Paula Santander,*

*Cúcuta, Norte de Santander, Colombia*

## ABSTRACT

In this investigation is analized the average annual rainfall of the hydrographic basin of the Aguablanca stream through the data provided by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) ranging from 1976 to 2016, because there aren´t pluviometric stations relatively close, the methodology is used IDW with the intention of interporlation results and have a calculation close to reality. it´s concluyed lhe average annual precipitation of this river is 1327.9 mm/year, a normal value for a river basin in a tropical zone, also calculating the amount of water volume, is possible to calculate the amount of evapotranspired water, parameters that vary according to temperature and type of vegetation.

*1 Engineering Faculty*
*Universidad Francisco de Paula Santander, Cúcuta, Norte de Santander, Colombia*
*Email- javieralfonsocg@ufps.edu.co Orcid: https://orcid.org/0000-0002-9894-0177*
*2 Engineering Faculty*
*Universidad Francisco de Paula Santander, Cúcuta, Norte de Santander, Colombia*
*Email- jose.jacome@ufps.edu.co orcid: https://orcid.org/0000-0002-6022-6891*
*3 Universidad Francisco de Paula Santander, Cúcuta, Norte de Santander, Colombia*
*Email: mawencyvergel@ufps.edu.co orcid: https://orcid.org/0000-0001-8285-2968*

**KEY WORDS**

mean precipitation, watershed, stream, IDW.

**RESUMEN**

En esta investigación se analiza la precipitación media anual de la cuenca hidrográfica de la quebrada Aguablanca a través de los datos suministrados por el Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM) que van desde 1976 hasta 2016, debido a que no existen estaciones pluviométricas relativamente cercanas, se utiliza la metodología IDW con la intención de interporlar los resultados y tener un cálculo cercano a la realidad. Se concluye que la precipitación media anual de este río es de 1327,9 mm/año, un valor normal para una cuenca hidrográfica en una zona tropical, además calculando la cantidad de volumen de agua, es posible calcular la cantidad de agua evapotranspirada, parámetros que varían según la temperatura y el tipo de vegetación.

**PALABRAS CLAVE**

precipitación media, cuenca, arroyo, IDW.

## INTRODUCTION

Precipitation is one of the most important parameters of the hydrological cycle, which, in turn, is one of the main sources of crop supplies, human consumption and necessary for the conservation of wildlife [3] Due to this importance, it is essential to collect all the necessary information to be able to establish hydrological models that allow a more precise understanding of the behavior of the water cycle in any study area.

A hydrological model is a set of historical data that serves to predict long-term changes in hydrological flows, where some of its uses are for: Watershed management, operation of reservoirs, water supplies, planning and design of hydraulic structures, among others [13]. Water resources are scarce and essential in all types of ecosystems [11] in such a way that the spatial distribution and temporal variability of precipitation, control the growth of vegetation and the massive transport of hydrological resources on the land surface [4]. It is for this reason that the influence of precipitation is significant in hydrology, in the environment, since it has a direct effect on types of vegetation and in turn on wildlife. Thus, obtaining accurate and reliable rainfall data becomes a crucial need to be able to make applications for the purpose of this study topic [5].

The way to measure rainfall is mainly through the use of pluviometric stations, which are well known for their installation and easy operation, in addition to the low costs that they require. When there is a considerable amount of stations, the measurements are characterized by consistent and precise measurements, where the results are used to describe the characteristics and regimes of these precipitations [7].

Climate change is one of the aspects that most concern the scientific community, since human activities, such as the burning of fossil fuels and changes in land use, generate an environmental impact that increases atmospheric concentrations of greenhouse gases. This change translates into large-scale climate patterns and these are the ones that end up affecting meteorological variations [2].

Part of this problem has manifested itself over time with the economic development of society [9], since it is directly related to the exploitation of water resources, which leads to significant changes in aquatic ecosystems. Thus, the over-exploitation of this resource leads directly to consequences such as the disappearance of the causes, excessive erosion that affects the workability of soils [6], pollution of rivers and finally the deterioration of ecosystems [10]. Therefore, foreseeing this type of consequences can be achieved with an adequate management of water resources, which will also serve for disaster prevention, which must have an environmental policy with a water quality model that allows a correct handling and delivery of these resources to nature [8] [12] [14] [15].

This type of prevention has already been taken by different European countries, one of them, Switzerland, where approximately more than 3 decades ago, extensive and costly measures have been invested in mitigating the environmental impact to this natural resource [1]. Therefore, in this work we will calculate the average annual precipitation for the Aguablanca stream located in the municipality of Bochalema, Norte de Santander, Colombia, in order to subsequently carry out more detailed studies that will allow the management of these resources in an efficient, administrative manner and with the least environmental impact, contributing to the development and economy of the region in a sustainable manner.

## 1. MATERIALS AND METHODS

To calculate the average precipitation, first, the watershed of the stream of study was delimited, which is the Aguablanca stream, located in the municipality of Bochalema, in the department of Norte de Santander, in the city of Cúcuta.

Figure 1. Hydrographic basin of the Aguablanca stream.

Subsequently, data from 4 nearby rain gauges that had a large historical record of rainfall were used. These data were provided by IDEAM and geographically referenced in the ArcGIS software. The 4 rain gauges are, to the north LA DONJUANA 2, to the east LOS MANZANARES, west CUCUTILLA, and to the south ALSA DE PAMPLONITA.

**Figure 2.** IDEAM stations

**Figure 3.** Basin and pluviometers.

The pluviometers used had records from 1973 to 2016, in which information was only obtained from the pluviometers located to the North, West and South, another analysis was carried out from 1990, which is the year when the pluviometer located to the east started working. For the calculation of the precipitation, the IDW methodology was used, with the average values of each pluviometer, making the corresponding interpolation, then, this value is multiplied by a percentage corresponding to the affected area and finally the average value of the basin is established.

**Table 1.** Coordinates, heights and names of the rain gauges used

| ID | X | Y | Z | Name | Prec_1973 | Prec_1990 |
|---|---|---|---|---|---|---|
| 1 | -72,60547 | 7,6879 | 770 | Don juana | 1176 | 1816 |
| 2 | -72,645 | 7,3731 | 2340 | Pamplona | 755,4 | 1133,4 |
| 3 | -72,772 | 7,5341 | 1280 | Cucutilla | 1755 | 2227 |
| 4 | -72,59 | 7,612 | 1320 | Manzanares | | 831,1 |

## 3. ANALYSIS AND DISCUSSION OF RESULTS

For the development the different tables are inserted in the ArcGIS software to calculate the precipitation by IDW method, with their corresponding x,y coordinates and their height Z, the only variable is the data of the precipitation in mms with their respective year. This procedure is performed a little more than 70 times

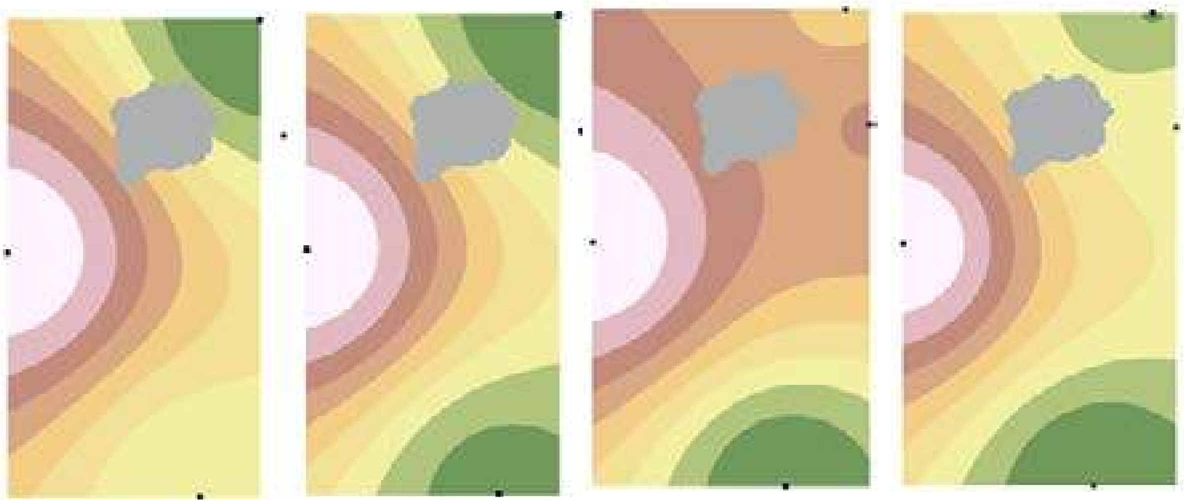

**Figure 4.** Rainfall for the years 1973, 1991, 2010 and 2016, respectively.

Later, for the calculation of the average precipitation, a CAD drawing is used as a reference, where each segment occupies 20% of the total area.

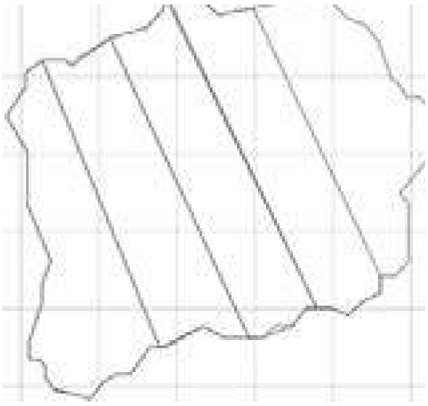

**Figure 5.** CAD of the basin

**Figure 6.** Basin with precipitation.

For example in the above figures an approximate of 10%, 20%, 25%, 25% and 20% can be determined for the stripes that overlap the figure. In this way it is calculated with the values of each precipitation and its percentage, obtaining an average precipitation of the basin with the following table.

**Table 2.** Average precipitation for the years 1973-1979 only with data from rain gauges 1,2 and 3.

| PREC. PROM | YEAR | P1 | % | P2 | % | P3 | % | P4 | % | P5 | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1256.25 | 1973 | 1421 | 15% | 1284 | 55% | 1123 | 30% | | | | |
| 1260.4 | 1974 | 1455 | 30% | 1239 | 50% | 1022 | 20% | | | | |
| 1893.5 | 1975 | 1963 | 50% | 1824 | 50% | | | | | | |
| 1393 | 1976 | 1576 | 10% | 1454 | 30% | 1332 | 60% | | | | |
| 973.2 | 1977 | 1118 | 20% | 1115 | 20% | 912 | 40% | 809 | 20% | | |
| 1375.8 | 1978 | 1595 | 10% | 1458 | 20% | 1321 | 70% | | | | |
| 916.6 | 1979 | 1362 | 20% | 1139 | 20% | 917 | 20% | 694 | 20% | 471 | 20% |

**Table 3.** Average precipitation for the years 1980-1990 only with data from rain gauges 1,2 and 3.

| PREC. PROM | YEAR | P1 | % | P2 | % | P3 | % | P4 | % | P5 | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 994.6 | 1980 | 1174 | 20% | 1084 | 20% | 995 | 20% | 905 | 20% | 815 | 20% |
| 1847.9 | 1981 | 1943 | 30% | 1824 | 60% | 1706 | 10% | | | | |
| 1185.8 | 1982 | 1467 | 20% | 1327 | 20% | 1186 | 20% | 1045 | 20% | 904 | 20% |
| 949.8 | 1983 | 1115 | 20% | 1032 | 20% | 950 | 20% | 867 | 20% | 785 | 20% |
| 1483.8 | 1984 | 1572 | 10% | 1474 | 90% | | | | | | |
| 1425.1 | 1985 | 1540 | 10% | 1463 | 30% | 1387 | 60% | | | | |
| 1539.7 | 1986 | 1747 | 10% | 1678 | 20% | 1489 | 60% | 1360 | 10% | | |
| 1120 | 1987 | 1280 | 20% | 1200 | 20% | 1120 | 20% | 1040 | 20% | 960 | 20% |
| 2195.2 | 1988 | 2179 | 90% | 2341 | 10% | | | | | | |
| 1306.5 | 1989 | 1422 | 10% | 1317 | 70% | 1212 | 20% | | | | |
| 1837.55 | 1990 | 1983 | 5% | 1862 | 70% | 1740 | 25% | | | | |

**Table 4.** Average precipitation for the years 1990-2016 only with data from rain gauges 1,2, 3 and 4.

| **PREC. PROM** | **YEAR** | **P1** | **%** | **P2** | **%** | **P3** | **%** | **P4** | **%** | **P5** | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1358 | 1990 | 1606 | 5% | 1451 | 45% | 1296 | 35% | 1141 | 15% | | |
| 890.7 | 1991 | 1098 | 3% | 998 | 17% | 898 | 50% | 797 | 30% | | |
| 916.85 | 1992 | 1001 | 15% | 917 | 70% | 832 | 15% | | | | |
| 1065 | 1993 | 1287 | 5% | 1176 | 20% | 1065 | 45% | 954 | 30% | | |
| 1351 | 1994 | 1472 | 10% | 1351 | 80% | 1230 | 10% | | | | |
| 1402.4 | 1995 | 1543 | 15% | 1421 | 55% | 1298 | 30% | | | | |
| 1445.05 | 1996 | 1630 | 15% | 1493 | 35% | 1356 | 50% | | | | |
| 740.95 | 1997 | 803 | 5% | 744 | 85% | 684 | 10% | | | | |
| 1630.9 | 1998 | 1767 | 10% | 1631 | 80% | 1494 | 10% | | | | |
| 1699.8 | 1999 | 1806 | 15% | 1688 | 80% | 1570 | 5% | | | | |
| 1431 | 2000 | 1459 | 65% | 1379 | 35% | | | | | | |
| 864.5 | 2001 | 965 | 5% | 898 | 40% | 831 | 55% | | | | |
| 941.55 | 2002 | 1046 | 15% | 969 | 35% | 891 | 50% | | | | |
| 1490.95 | 2003 | 1692 | 5% | 1553 | 45% | 1415 | 50% | | | | |
| 1675.75 | 2004 | 1777 | 50% | 1621 | 35% | 1466 | 15% | | | | |
| 1490.95 | 2005 | 1692 | 5% | 1553 | 45% | 1415 | 50% | | | | |
| 1281.45 | 2006 | 1556 | 5% | 1373 | 45% | 1190 | 45% | 1006 | 5% | | |
| 887.25 | 2007 | 1235 | 5% | 1065 | 20% | 896 | 40% | 726 | 35% | | |
| 1329.4 | 2008 | 1672 | 10% | 1482 | 30% | 1291 | 30% | 1101 | 30% | | |
| 1218.85 | 2009 | 1370 | 5% | 1254 | 60% | 1137 | 35% | | | | |
| 2112.2 | 2010 | 2192 | 40% | 2059 | 60% | 60 | | | | | |
| 2188.6 | 2011 | 2362 | 35% | 2158 | 45% | 1954 | 20% | | | | |
| 1437.3 | 2012 | 1540 | 10% | 1461 | 50% | 1382 | 40% | | | | |
| 1211.9 | 2013 | 1229 | 10% | 1138 | 10% | 1219 | 80% | | | | |
| 905.2 | 2014 | 970 | 5% | 916 | 70% | 862 | 25% | | | | |
| 702.3 | 2015 | 838 | 10% | 779 | 20% | 720 | 20% | 661 | 30% | 602 | 20% |
| 1161.8 | 2016 | 1271 | 20% | 1180 | 40% | 1089 | 40% | | | | |

Therefore, with the calculated data, precipitation can be plotted over the years studied.

**Figure 7.** Annual precipitations of the Aguablanca Stream Basin.

In this way, the following table is obtained with the relevant data for each year and its precipitation value.

**Table 5.** Average multiannual precipitation of the Aguablanca stream basin.

| PREC. PROM | YEAR | PREC. PROM | YEAR |
|---|---|---|---|
| 1256.25 | 1973 | 1402.4 | 1995 |
| 1260.4 | 1974 | 1445.05 | 1996 |
| 1893.5 | 1975 | 740.95 | 1997 |
| 1393 | 1976 | 1630.9 | 1998 |
| 973.2 | 1977 | 1699.8 | 1999 |
| 1375.8 | 1978 | 1431 | 2000 |
| 916.6 | 1979 | 864.5 | 2001 |
| 994.6 | 1980 | 941.55 | 2002 |
| 1847.9 | 1981 | 1490.95 | 2003 |
| 1185.8 | 1982 | 1675.75 | 2004 |
| 949.8 | 1983 | 1490.95 | 2005 |
| 1483.8 | 1984 | 1281.45 | 2006 |
| 1425.1 | 1985 | 887.25 | 2007 |
| 1539.7 | 1986 | 1329.4 | 2008 |
| 1120 | 1987 | 1218.85 | 2009 |
| 2195.2 | 1988 | 2112.2 | 2010 |
| 1306.5 | 1989 | 2188.6 | 2011 |
| 1837.55 | 1990 | 1437.3 | 2012 |
| 890.7 | 1991 | 1211.9 | 2013 |
| 916.85 | 1992 | 905.2 | 2014 |
| 1065 | 1993 | 702.3 | 2015 |
| 1351 | 1994 | 1161.8 | 2016 |

An arithmetic average is then taken, which is simply the sum of all rainfall divided by the total number of years.

$$\sum_{1973}^{2016} P_{anual} = 58428.3\ mm \qquad (1)$$

$$P_{prom} = \frac{58428.3mm}{44\ años} = 1327.9\frac{mm}{año} \qquad (2)$$

## 4. CONCLUSIONS

The average annual precipitation of this river basin was successfully calculated using the IDW model executed by the ArcGIS software, which gives a result of 1327.9 mm/year, a normal value for a river basin in a tropical zone.

Calculating the amount of water volume, it is also possible to calculate the amount of evapotranspired water, which are parameters that vary according to temperature and type of vegetation.

## BIBLIOGRAPHIC REFERENCES

[1] Abbaspour, K. C., Yang, J., Maximov, I., Siber, R., Bogner, K., Mieleitner, J., … Srinivasan, R. (2007). *Modelling*

*hydrology and water quality in the pre-alpine/alpine Thur watershed using SWAT. Journal of Hydrology, 333(2-4), 413–430.* doi:10.1016/j.jhydrol.2006.09.014

[2] Ahmadi, M., Salimi, S., Hosseini, S. A., Poorantiyosh, H., & Bayat, A. (2019). *Iran's precipitation analysis using synoptic modeling of major teleconnection forces (MTF). Dynamics of Atmospheres and Oceans, 85, 41–56.* doi:10.1016/j.dynatmoce.2018.12.001

[3] Ali, A., Xiao, C., Anjum, M., Adnan, M., Nawaz, Z., Ijaz, M., … Farid, H. (2017). *Evaluation and Comparison of TRMM Multi-Satellite Precipitation Products With Reference to Rain Gauge Observations in Hunza River Basin, Karakoram Range, Northern Pakistan. Sustainability, 9(11), 1954.* doi:10.3390/su9111954

[4] Andermann, C., Bonnet, S., & Gloaguen, R. (2011). *Evaluation of precipitation data sets along the Himalayan front. Geochemistry, Geophysics, Geosystems, 12(7), n/a–n/a.* doi:10.1029/2011gc003513

[5] Anjum, M. N., Ding, Y., Shangguan, D., Ahmad, I., Ijaz, M. W., Farid, H. U., … Adnan, M. (2018). *Performance evaluation of latest integrated multi-satellite retrievals for Global Precipitation Measurement (IMERG) over the northern highlands of Pakistan. Atmospheric Research, 205, 134–146.* doi:10.1016/j.atmosres.2018.02.010

[6] Bai, L., Wang, N., Jiao, J., Chen, Y., Tang, B., Wang, H., … Wang, Z. (2020). *Soil erosion and sediment interception by check dams in a watershed for an extreme rainstorm on the Loess Plateau, China. International Journal of Sediment Research.* doi:10.1016/j.ijsrc.2020.03.005

[7] Huang, J., Zhang, J., Zhang, Z., Xu, C., Wang, B., & Yao, J. (2010). *Estimation of future precipitation change in the Yangtze River basin by using statistical downscaling method. Stochastic Environmental Research and Risk Assessment, 25(6), 781–792.* doi:10.1007/s00477-010-0441-9

[8] Huang, Zhang, & Tong. (2019). *Water Environmental Capacity Calculation and Allocation of the Taihu Lake Basin in Jiangsu Province Based on Control Unit. International Journal of Environmental Research and Public Health, 16(19), 3774.* doi:10.3390/ijerph16193774

[9] Ifediegwu, S. I., Nnebedum, D. O., & Nwatarali, A. N. (2019). *Identification of groundwater potential zones in the hard and soft rock terrains of Kogi State, North Central Nigeria: an integrated GIS and remote sensing techniques. SN Applied Sciences, 1(10).* doi:10.1007/s42452-019-1181-1

[10] Li, W., Chen, Q., Cai, D., & Li, R. (2015). Determination of an appropriate ecological hydrograph for a rare fish species using an improved fish habitat suitability model introducing landscape ecology index. *Ecological Modelling*, *311*, 31-38. doi: 10.1016/j.ecolmodel.2015.05.009

[11] Mo, K., Chen, Q., Chen, C., Zhang, J., Wang, L., & Bao, Z. (2019). *Spatiotemporal variation of correlation between vegetation cover and precipitation in an arid mountain-oasis river basin in northwest China. Journal of Hydrology, 574, 138–147.* doi:10.1016/j.jhydrol.2019.04.044

[12] Saddique, Naeem & Khaliq, Abdul & Bernhofer, Christian. (2020). Trends in temperature and precipitation extremes in historical (1961-1990) and projected. Stochastic Environmental Research and Risk Assessment. 10.1007/s00477-020-01829-6.

[13] Seo, S. B., Bhowmik, R. D., Sankarasubramanian, A., Mahinthakumar, G., & Kumar, M. (2019). *The role of cross-correlation between precipitation and temperature in basin-scale simulations of hydrologic variables. Journal of Hydrology.* doi:10.1016/j.jhydrol.2018.12.076

[14] Soares, A. L. C., Pinto, C. C., & Oliveira, S. C. (2020). *Impacts of anthropogenic activities and calculation of the relative risk of violating surface water quality standards established by environmental legislation: a case study from the Piracicaba and Paraopeba river basins, Brazil. Environmental Science and Pollution Research.* doi:10.1007/s11356-020-07647-1

[15] Zhang, Y., He, B., Guo, L., Liu, J., & Xie, X. (2019). *The relative contributions of precipitation, evapotranspiration, and runoff to terrestrial water storage changes across 168 river basins. Journal of Hydrology, 579, 124194.* doi:10.1016/j.jhydrol.2019.124194