Rainwater volume at the Alberto Santos Buitrago school in El Socorro, Colombia

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Abstract. This study calculated the volume of capturable rainwater over a three-month period at the Alberto Santos Buitrago school in the municipality of El Socorro, Colombia. Rainwater is frequently an under-developed natural resource, due to the minimal investment by public entities, and to the lack of awareness and education of the local inhabitants in this regard. Due to the significant climatic changes occurring across Colombia, however, new interest has arisen in utilizing this resource. The Universidad de Santander, Bucaramanga, Colombia, and the Universidad Libre in El Socorro, Colombia, have joined forces to promote projects focused upon the use of these resources to ameliorate the condition of vulnerable green areas, which tend to deteriorate during dry summer months, as occurred during this study, due to local geographic conditions and the impacted population; in these cases young, low-income students of this rural municipality. Such a water storage and distribution system could also serve a valuable role in the school’s sanitary facilities, and for cleaning public areas, with a total of 35.01 m³ of rainwater collected on school roofs. Nevertheless, upon the delivery of the results of the current study, a significant lack of interest was evident on the part of the directors of public institutions in implementing this type of sanitary system. It is thus necessary for the community itself to commit to incentivizing and promoting the implementation and improvement of these new mechanisms.

1. Introduction
In recent years, climate change has lead to the existence of unusually severe summer and winter periods [1-2], thus directly and indirectly impacting the normal functioning of various economic sectors, and of society in general. One of the resources affected is the water supply, which is of great importance due to its central role in human health and survival. The local population accesses water supplies either through public utility companies, or directly from natural sources for locations outside the utilities’ coverage area [3].

In the municipality of El Socorro, Santander, Colombia, both sources are of special interest, as climate change has led to summer temperatures of approximately 35 °C, and a considerable decrease in water resources. Although public utilities generally cover the needs of the municipality’s entire population, the service is subject to frequent interruptions, and is sometimes limited to certain hours and days throughout the week; in essence, a forced rationing system [4].

Among water users within the municipality, schools are of special interest due to the large number of children gathered within them, and because of the importance of creating a suitable educational environment. Within the region, there are 12 primary and secondary educational institutions (which can
be treated as homogeneous for the purposes of the problem [5], as well as two universities, which are also vulnerable to the lack of water.

The current investigation aims to raise awareness of the importance of water resources and their limitations, as such awareness can lead to a society which actively participates in usage reduction and in appropriate use. Such initiatives must be led and structured by government entities in support of academic organizations, in order to design meaningful strategies able to achieve the minimum practical consumption of water [6].

The design, implementation, and maintenance of a rainwater usage system benefits users both within and without public service coverage [7], reduces the consumption of treated water by schools, directly and indirectly reduces drinking water costs, improves green areas, and creates a culture of care for the environment in the youth who represent the future of the municipality and, indeed, of the nation.

Equally, the current research can be useful to create a positive impact for many educational institutions with similar conditions to those described herein (which includes the majority of rural schools in Colombia) to implement water reutilization systems for basic services and avoid the wastage of potable water in activities such as cleaning washrooms and watering plants, among others; and to take advantage of a currently neglected but fundamental resource in the form of rainwater.

2. Methodology
In support of the goals described above, it is necessary to identify areas where rainwater can be collected using rain gauges [8], and to calculate the volume of rainwater capturable based on the precipitation results obtained over a three-month period. This work is intended to serve as the basis for future studies with a view towards capturing and storing rainwater for long-term use. These studies will need to plan for appropriate filtration of captured water to remove suspended solids, and for the system of valves and plumbing required to deliver the water to users [9].

The purpose of the current study is thus the observation of drinking water consumption in a Santander educational institution, the Colegio Alberto Santos Buitrago, El Socorro, Santander; analysis of existing structures towards the subsequent design of possible rainwater collection and storage systems; and the measurement of rainwater characteristics to determine a future scope for consumption and the reduction of current drinking water usage [10-11].

The target population for the study will be the educational institutions of El Socorro, Santander, Colombia from which sample information will be collected.

2.1. Collection of information
Direct observation and documentary evidence will be used to obtain information for the study’s input variables. Forms and measuring equipment such as a rain gauge will be used to collect and store specific figures. The data of interest include:

- Architectural and topographical information provided by the institution which serves as the study’s sample.
- Collection of rainwater from school rooftops identified as possible collection points.
- Procedures for calculating rainwater volumes [12-13].

3. Analysis and discussion of results
Firstly, a topographic survey was carried out as an instrument to undertake the necessary rainwater volume calculations, given that this is the primary source of the current project. The survey yielded the area of the school’s roofs. These surfaces were then analyzed to establish their slopes, and the runoff direction of rainwater into channels and downspouts. The results of this analyses are depicted in Figure 1. These calculations are necessary to determine the volume of water which can be captured, and thus establish the characteristics of the water collection system to be designed. Total roof area = 171.22 m².

The information depicted in Figure 1 represents the slopes of each of the roofs of the Colegio Alberto Santos Buitrago, El Socorro, Colombia. It can be noted that the roofs have the form of two surfaces
descending from a central peak (a system known in engineering terms as “two waters”) which slope down at approximately 0.5%. The roof area was thus calculated to be 171.22 m$^2$.

Figure 1. Topographical survey of the Alberto Santos Buitrago School, El Socorro, Colombia.

3.1. Installation of a rain gauge
A rain gauge was installed in the school for three months. Meteorologists use this instrument to measure the amount of precipitation in a given place during a specified period of time, however it can be easily installed by any person with the training required to situate it correctly. It is frequently used in farms, homes, and business or academic institutions, among others. The instrument is notable for its simplicity of fabrication or a acquisition in the market.

The rain gauges used in the present study were constructed and installed in the educational institution, and data was collected from August 12th to October 11th, 2017. Measurements were made daily by teachers on weekdays, as well as by parents during weekends and holidays. A total precipitation of 255.6 mm (equivalent to 255.6 liters/m$^2$) was recorded over the 90-day period.

Figure 2 illustrates the daily rainfall behavior for August, September, and October (depicted in blue, brown, and yellow, respectively) as well as the accumulation of the three months in orange. As indicated in Figure 2, during the month of August, information was collected for 19 days, with a peak rain fall of 57.1 mm. Less than 15 mm (as indicated in the graph) fell daily for the remainder of the month. Data was collected for each day of September, in which an upward trend was noted as the month progressed – increasing from approximately 10 mm to 26.3 mm per day. Only 11 days of data were collected during October, however, a peak close to 22 mm occurred during the month.

Based on the information collected, September was found to be the rainiest month of the period, confirming the area’s tendency towards a rainy season beginning in August and culminating at the end of October. It is important to verify the rainfall figures over a significant period of time, as shown in Figure 2, in order to observe the true behavior of the local climate, towards a correct determination of
the utility of a rainwater collection system for the school, and of how to use the volume of water acquired. With the data obtained from the rain gauge and the topographic survey of the school roofs, the volume of rainwater that could be collected across the three months was calculated as follows (see Equation (1)):

\[ V_{\text{cap}} = C \times P \times \left( \frac{A_o}{10000} \right) \]  

(1)

Where, \( V_{\text{cap}} \) = Collection volume (m\(^3\)), \( C \) = Runoff coefficient, \( P \) = Daily precipitation (mm), \( A_o \) = Area (m\(^2\)) of the roofs. Runoff coefficient = 0.8.

**Precipitation months of study**

![Figure 2. Daily precipitation for August, September, and October, 2017.](image)

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Figure 3 sets out the volume of water that could be collected from school roofs during the three-month period and stored for uses where no purification is required. Here, the volume of water captured can be seen in cubic meters for the months of August, September, and October, as well as the total accumulated volume during this period.

**Collection volume**

![Figure 3. Volume of rainwater (by month and total accumulated).](image)
With the volumes obtained during the three months as depicted in Figure 3, both individually as well as cumulatively, the required storage space can be estimated within which the water collected can be maintained over a long period without danger of wastage. Given that this water is not intended for human consumption, it would be possible to store it for a considerable period of time when it is not immediately required.

4. Conclusions
Having completed the data collection phase and analysis of the topography required to establish the catchment area, a peak value of 57.1 mm of rain was obtained on August 19, and a three-month accumulated rainfall of 255.6 mm. Catchment was thus found to be variable across each of the months of analysis, with August demonstrating the highest individual value of 14.34 m³. The total volume that could be captured from the roofs is 35.01 m³; an environmentally-friendly resource which would be useful in garden irrigation, floor washing, or other purposes that do not require purification of stored water.

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