04-006

CONCEPTUAL DESIGN OF A RAINWATER HARVESTING SYSTEM AT THE UNIVERSIDAD CATÓLICA BOLIVIANA SAN PABLO

Pantoja Rico, Rodrigo Antonio (1); Alvizuri Tintaya , Paola Andrea (1)(2); Soria Céspedes, Freddy Angel (1); Lo-Iacono-Ferreira, Vanesa Gladys (2)

(1) Centro de Investigación en Agua, Energía y Sostenibilidad, Universidad Católica Boliviana San Pablo, (2) Universitat Politècnica de València

Rainwater harvesting systems have been a practice used for more than 2,000 years. Its application provides economic and environmental benefits, which makes rainwater harvesting a viable option to save this resource, applicable throughout the world. The Ceiling Rainwater Harvesting System (SCAPT, acronym in Spanish) was designed for the Bolivian Catholic University in La Paz, seeking to turn this institution into a benchmark sustainability pilot for Bolivia. This article presents the analysis of the historical pluviometric data of the area, the determination of the components for the SCAPT, the calculation of the catchment area, the economic analysis of the proposal, and an action plan for the implementation of the system. Finally, the perception of the university community about the proposed system is exposed through a survey carried out.

Keywords: Sustainability; water harvesting; water reuse

DISEÑO CONCEPTUAL DE UN SISTEMA DE CAPTACIÓN DE AGUA DE LLUVIA EN LA UNIVERSIDAD CATÓLICA BOLIVIANA SAN PABLO

Los sistemas de captación de agua de lluvia son una práctica utilizada desde hace más de 2000 años. Su aplicación proporciona beneficios económicos y ambientales, lo cual hace que la cosecha de agua de lluvia sea una opción viable para ahorrar este recurso, aplicable en todo el mundo. El Sistema de Captación de Agua de lluvia Por Techos (SCAPT) fue diseñado para la Universidad Católica Boliviana sede La Paz, buscando convertir a esta institución en un piloto de sostenibilidad referente para Bolivia. Este articulo presenta el análisis de los datos pluviométricos históricos de la zona, la determinación de los componentes para el SCAPT, el cálculo del área de captación, el análisis económico de la propuesta y un plan de acción para la implementación del sistema. Finalmente, se expone la percepción de la comunidad universitaria sobre el sistema propuesto a través de una encuesta realizada.

Palabras clave: Sostenibilidad; cosecha de agua; reúso de agua

Correspondencia: Paola Alvizuri. Correo: palvizuri@ucb.edu.bo

Agradecimientos: Los autores agradecen a la Universidad Católica Boliviana "San Pablo" - Sede La Paz, por la financiación de la formación doctoral de su docente investigadora del Centro de Investigación en Agua, Energía y Sostenibilidad (CINAES) perteneciente a la Carrera de Ingeniería Ambiental.

1. Introduction

Water is a vital resource for life on earth, but its distribution is uneven in time and space. Currently, a large amount of water is wasted and polluted, presenting an unsustainable use of the resource. In this way, water lack is a worldwide problem UNESCO (2015).

In Bolivia, the Supervision and Social Control of Drinking Water and Basic Sanitation Authority (2014), indicates that three out of every ten liters of drinking water are not used correctly. In La Paz city, the seat of government in Bolivia, daily needs take precedence over adequate water resource consumption. In the context of climate change and population growth, the excessive use of drinking water in activities that do not require it makes this city unsustainable in terms of water use (Perales, 2018).

In Bolivia, public and private Universities in the last decade have added, around 135,000 students enrolled (Martínez et al., 2016). The preceding shows greater demand for infrastructure and a greater demand for drinking water in the different study centers.

Faced with the reality of limited access to water, humanity has sought ways to ensure its supply, such as rain harvesting. This technique was applied by ancient cultures worldwide, even as early as 1,700 BC. The rainwater collection for later use generates a better use of the available resource. More than 100 million people in the world depend partially or totally on these systems (Hugues, 2019).

Rainwater harvesting for domestic or institutional purposes can be done by Roof Rainwater Harvesting Systems (SCAPT). The *Organización Panamericana de la Salu*d (2004) considers advantages and disadvantages for SCAPT. The main advantages are that the rainwater collected has a high quality, no energy is required to operate the system, and there is a reduction in rainfall, which reduces the load on the sewage system. As for disadvantages, it's observed that this type of system depends directly on the rain in the area, the implementation costs are not within reach of all contexts, and the collected water is vulnerable to contamination since the roofs are a surface exposed to the environment.

This article takes as its area of study the Bolivian Catholic University (UCB) – La Paz and presents a proposal to implement a rainwater harvesting system. The objective is to cover non-drinking water needs with collected water, such as irrigation of green areas, bathroom and floor cleaning, car washing, and saving drinking water. The project is contributing to the achievement of SDG 6 – Clean Water and Sanitation and SDG 11 – Sustainable Cities and Communities of the Sustainable Development Goals (SDG) (Naciones Unidas en Bolivia, 2018).

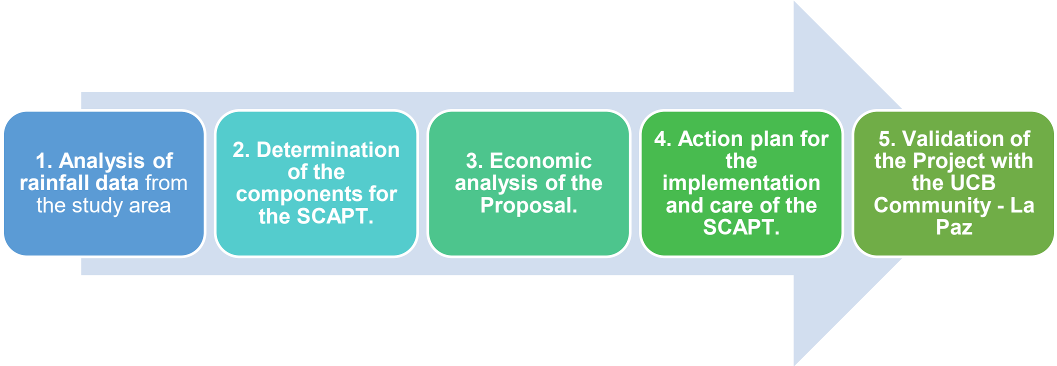
2. Objectives

This article aims to carry out a conceptual design of a rainwater harvesting system for the UCB - La Paz, make better use of the water resource, and promote the implementation of pilot experiences aligned to the SDGs in the La Paz city of Bolivia.

3. Methodology

The study carried out was exploratory-descriptive. Figure 1 presents the steps followed within the methodology.

Figure 1: Methodology



Source: Own elaboration, 2022.
SCAPT: Rainwater Harvesting System Through Roofs.

3.1. Pluviometric Analysis

As a first step, the meteorological information of the SENHAMI San Calixto station for the last 19 years was collected. Subsequently, the monthly average precipitation data were analyzed to obtain the monthly average value. For this, equation 1 was used.

$$P_{P_i} = \frac{\sum_{i=1}^{i=n} P_i}{n} \quad (1)$$

Where:

- P_{pi}= Monthly average precipitation of the month "i" of all the years evaluated. (mm/month)
- P_i= Monthly precipitation value of month "i," (mm)
- n= Number of years evaluated

In this way, the seasons of greater and lesser use for the SCAPT were identified.

3.2. Components of the Roof Rainwater Harvesting System (SCAPT)

The main component within the SCAPT is the catchment area related to the amount of water collected through the system. Determining the approximate amount that can be collected helps to calculate the volume of the storage tank. Finally, the system's total water supply can be exposed. The details of the above are presented in the following sections. The other components of the system, such as gutters, pipes, and pumping equipment, are considered in the economic analysis section of the proposal.

3.1.1. Determination of catchment area

To determine the catchment area, the following steps were followed:

- First, the 1:100 scale plans of the UCB - La Paz were studied with the AutoCAD program. These plans were provided by the architecture department in charge of the university's infrastructure. This is to identify the most convenient area for the system arming.
- Then, a diagnosis of the buildings was made to corroborate the information on the plans and identify the usable slopes.
- After processing the information, the usable buildings of the UCB campus - La Paz were determined for the design of the SCAPT.

3.1.2. Calculation of the amount of water collected

According to the authors Belelli and Vásquez (2018), the amount of precipitation is directly proportional to the water collected on a roof. Equation 2 states that there would be 1 liter of water per m 2 of surface for each millimeter of rain.

$$1\text{mm} = 1\text{L/m}^2 \quad (2)$$

Equation 2 was used in equation 3 to arrive at the necessary units (L/ m^2). This is the approximate volume of catchment in the roof area where the system is located.

$$\text{V= PP*Ac} \quad (3)$$

Where:

- V= Approximate collection volume (L)
- PP= Precipitation (L/m^2)
- Ac= Catchment area (m^2)

3.1.3. Determination of the Volume of the Storage Tank

With the precipitation values in (L/ m^2) thanks to equation 2, knowing the roof material and the runoff coefficient, the amount of water captured for different roof areas for each month was determined, using equation 4.

$$A_i = \frac{PP * C_e * A_c}{1000} \quad (4)$$

Where:

- PP= Precipitation (L/m^2)
- C_e= Runoff coefficient (this data is taken according to the roof material that varies between 0.8 – 0.9)
- Ac= Catchment area (m^2)
- A_i= Volume of water storage in a month “i” (m^3)

3.2.4. Total annual supply

According to Abdulla and AlShareef (2006), the total annual supply was obtained using equation 5, where it is considered that there is a percentage of 20% per year in losses due to evaporation, the processes of capture and collection of water.

$$A_T = A_i - \left(A_i * \frac{0,2}{12}\right) \quad (5)$$

Where:

- A_T= Total supply considering losses
- A_i= Volume of water storage in a month “i” (m^3)
- 0.2= Represents 20% water loss
- 12= Represents the months of the year

3.2. Economic analysis

The viability analysis of the project was carried out in two parts. First, a cost estimate was made of what would be involved in assembling the system. Second, a Cost-Benefit Analysis (CBA) was carried out to identify the viability of the proposals.

3.2.1. Cost Estimates

The cost estimate includes an analysis of all the expenses needed from the implementation of the system to its operation. This estimate was made based on quotes for the necessary materials from different companies in the department of La Paz - Bolivia.

3.2.2. Cost-benefit analysis

A CBA serves to determine the relationship between the costs and benefits of a proposal and identify if it is viable; each analysis is different and requires careful and innovative thinking (Aguilera, 2017). To carry out an ABC, what must be obtained in a quantifiable way is a projection of the economic benefits to be accepted (B) and the costs of implementing the system (C). The benefits and costs are related in equation 6.

$$\frac{B}{C} \tag{6}$$

The quantitative ABC will allow identifying if the project is viable or not.

- If the result of B/C is greater than 1, then the benefits are greater than the costs.
- If the result of B/C is precisely 1, then the benefits are equal to the costs. The intervention is indifferent.
- If the result of B/C is less than 1, it means that the costs outweigh the benefits.

3.3. Action plan

The action plan is a strategy to make a proposal operational and give it a greater probability of success in its implementation UNESCO (2017). The proposed action plan was based on studies on the effective development of an action plan, such as the Community Tool Box (2012). Subsequently, the strategy was contrasted with the work of García and Hernández (2017), "Proposals about Rainwater Harvesting Systems," to better address the context related to this type of system.

3.4. Validation of the Project with the UCB Community – La Paz

For the project's feasibility, an opinion survey was carried out aimed at the administrative staff, teachers, and students of the UCB - La Paz. A sectional survey was used (Quispe, 2010). The survey was structured with five closed questions that are detailed below.

1. Do you think that the lack of water resources is a global problem?
2. Have you ever used rainwater to wash floors or patios, irrigate gardens, or use bathrooms?
3. Do you think it would be good to install a rainwater harvesting system at the UCB – La Paz?
4. Do you think that these systems would help the UCB - La Paz to achieve environmental sustainability?
5. Do you think that these water collection systems would help bring awareness to the use and care of water?

3.4.1. Calculation of the sample in descriptive studies

To know the sample size of a finite population, which is the set of elements that can be counted and know its size, equation 7 (Reyes, Espinosa, & Olvera, 2013).

$$n = \frac{\sigma^2 N \times p \times q}{e^2(N\text{-}1)+\sigma^2 \times p \times q} \tag{7}$$

Where:

- n = Sample size we want to calculate

- N = Population size
- σ = Confidence coefficient for a given confidence level
- p = Probability of success
- q = Probability of failure.
- e = Estimated error margin.

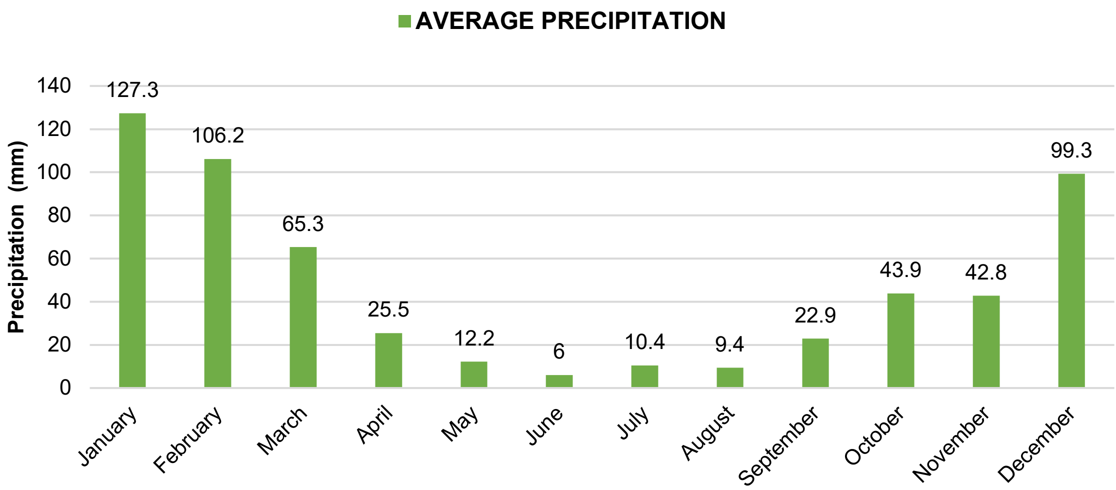
4. Results

In this section the results of the study are presented.

4.1. Pluviometry analysis

The average rainfall for each month was calculated based on the 19-year record obtained from the San Calixto station data. This station was chosen because it has more complete information and it is a SENAMHI 2nd order meteorological station. The resulting averages for each month are presented in Figure 2.

Figure 2: Precipitation Data - San Calixto Meteorological Station - La Paz



Note: Data is in millimeters (mm) which are the units for precipitation.
Source: Own elaboration, 2022.

From the above figure, it can be seen that the months with the highest rainfall are December, January, February, and March. These months would be the most useful for the SCAPT.

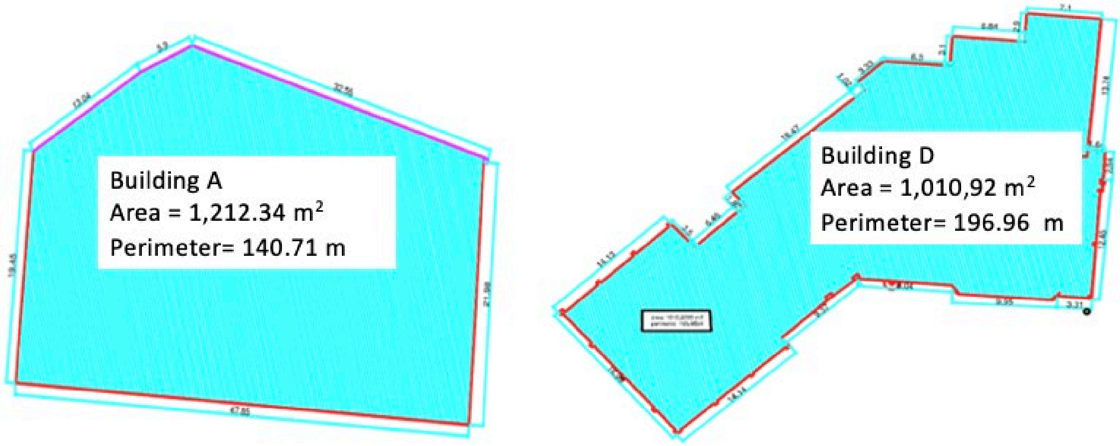
4.2. SCAPT components.

The following sections detail the catchment area available at the university, the volume that can be obtained in that area, the volume necessary for storage, and the total water supply.

4.2.1. Catchment Area

Rainwater harvesting can be carried out in buildings A and D of the UCB campus – La Paz, due to these buildings' good conditions and slope. The top view of both structures is presented in Figure 3.

Figure 1: Catchment area of buildings A and D



Source: Bolivian Catholic University "San Pablo" - La Paz, 2021.

4.2.2. Volume of water collected

To calculate the PP (L/m^2), equation (2) was used, which indicates that 1mm = 1L/m^2, therefore the values obtained now have the units of (L/m^2). The available roof area values from Figure 3 were used. The approximate catchment volume in (L) was calculated for each building in each month of the year. Table 1 presents the calculated values.

Table 1: Volume of rainwater harvesting in building A and D

Month	PP (L/m^2)	Ac building A (m^2)	V building A (L)	Ac building D (m^2)	V building D (L)
January	127.3	1,212.34	154,330.88	1,010.92	128,690.12
February	106.2		128,750.51		107,359.70
March	65.3		79,165.80		66,013.08
April	25.5		30,914.67		25,778.46
May	12.2		14,790.55		12,333.22
June	6.0		7,274.04		6,065.52
July	10.4		12,608.34		10,513.57
August	9.4		11,396.00		9,502.65
September	22.9		27,762.59		23,150.07
October	43.9		53,221.73		44,379.39
November	42.8		51,888.15		43,267.38
December	99.3		120,385.36		100,384.36

Source: Own elaboration, 2022.

From Table 1 it can be seen that the months with the most significant amount of water collected are December, January, February, and March; this is consistent with the months with the highest precipitation identified above.

4.2.3. Volume per month

The storage volumes per month for the two studied buildings are presented in Tables 2 and 3. The storage per month (A_i) was obtained through equation 4.

Table 2: Monthly storage for Building "A"

Month	PP (L/m²)	Ce	Ac building A (m²)	A_i (m³)
January	127.3	0.90	1,212.34	138.90
February	106.2			115.88
March	65.3			71.25
April	25.5			27.82
May	12.2			13.31
June	6.0			6.55
July	10.4			11.35
August	9.4			10.26
September	22.9			24.99
October	43.9			47.90
November	42.8			46.70
December	99.3			108.35
			Building A total storage	**623.26**

Note: Value 0.9 is for the roof material, in this case metallic corrugated iron.
Source: Own elaboration, 2022.

Table 3: Monthly storage for building D

Month	PP (L/m²)	Ce	Ac building D (m²)	A_i (m³)
January	127.3	0.90	1,010.92	115.82
February	106.2			96.62
March	65.3			59.41
April	25.5			23.20
May	12.2			11.10
June	6.0			5.46
July	10.4			9.46
August	9.4			8.55
September	22.9			20.84
October	43.9			39.94
November	42.8			38.94
December	99.3			90.35
			Building D total storage	**519.69**

Note: Value 0.9 is for the roof material, in this case, metallic corrugated iron.
Source: Own elaboration, 2022.

The total net storage for both buildings is 1,142.95 m3, this value does not include the losses that will be considered in the following section.

4.2.4. Total annual offer

The total annual supply was calculated with equation 5 where the losses of 20% were taken into account as mentioned in section 3.3.4. Table 4 shows the values of the total annual offer for each building and the global offer that considers both buildings.

Table 4: Sum of storage of total offer of building D and A

Building	A (m^3)	D (m^3)	Total of both buildings (m^3)
Total	612.73	510.93	**1,123.67**

Source: Own elaboration, 2022.

The total supply of both buildings obtained is the calculated projection, considering losses, that the SCAPT would be able to capture in 1 year.

4.3. Economic analysis of the proposal

This section comprises two parts. The first presents a cost estimate of what the construction of the SCAPT would imply. The second displays the CBA made for the proposal.

4.3.1. Cost Estimates

The cost estimate was made according to the quotes made and SCAPT design sources (Palacio, 2010). The results are shown in Table 5

Table 5: Cost estimate for the SCAPT design

Item	Description	Unit cost (Bs)	Quantity	Total cost (Bs)
1	First water interceptor for building D of 450L	350.0	1	350.0
2	First water interceptor for building A of 650L	475.0	1	475.0
3	25,000 L storage tank	15,600.0	2	31,200.0
4	Simple concrete foundation H15	456.2	2	912.3
5	Submersible water pump 1/3 HP 120 Volts	1,690.5	2	3,381.0
6	Stainless steel mesh filters	105.0	1	105.0
7	Labor of 2 workers for 3 days	450.0	2	900.0
			summation	37,323.3
8	Contingencies	5%		1,866.2
			Total Bs	**39,189.5**
			Total Euro	**5,186.8**

Note: 1 Euro= 1.55557 Bolivianos according to the exchange rate of the National Bank of Bolivia.
Source: Own elaboration, 2022.

From the previous table, it can be seen that the cost to implement the SCAPT is 39,189.5 Bolivianos; this data will be used as the costs within the CBA that will be carried out in the following section.

4.3.2. Cost-benefit analysis

To carry out the CBA, it is necessary to identify the costs and benefits of the SCAPT. The price for the implementation of the system was exposed in the previous section. The use of the SCAPT would be the economic savings that the system would generate for the university. To calculate this saving, Table 6 shows the monthly payments made by the UCB - La Paz for water consumption, contrasted by the water storage that can be had through the SCAPT.

Table 6: Approximate supply of the SCAPT according to billed consumption of the UCB

Month	Cost of water consumption of the UCB (Bs)	Water consumption in the UCB (m^3)	Storage in buildings D and A (m^3)
January	7,513.30	615.34	250.38
February	12,740.30	1,043.43	208.99
March	17,962.70	1,471.15	128.50
April	17,709.00	1,450.37	50.19
May	14,404.30	1,179.71	23.99
June	17,083.10	1,399.11	11.74
July	11,108.50	909.79	20.41
August	13,064.00	1,069.94	18.47
September	21,222.40	1,738.12	45.01
October	21,222.40	1,738.12	86.29
November	21,222.40	1,738.12	84.29
December	14,130.80	1,157.31	195.39
Annual	**189,383.20**	**15,510.50**	**1,123.67**

Source: Own elaboration, 2022.

Considering the annual consumption of water at the UCB - La Paz and the annual storage by the SCAPT, it is noted that the system presents a saving percentage of 7.24%. The previous percentage means 13,711.34 Bolivianos (1,814.73 Euros) of savings, this being the benefit that the system would bring. It should be noted that 1 Euro = 1.55557 Bolivianos according to the exchange rate of the National Bank of Bolivia. In Table 7, the CBA is presented for 5 years from the implementation of the system, this was done in bolivianos (local currency).

Table 7: Data for the Cost-Benefit Analysis for 5 years

Detail	Year 0	Year 1	year 2	Year 3	Year 4
INCOME					
Saving SCAPT buildings D and A	13,711.34	13,711.34	13,711.34	13,711.34	13,711.34
EXPENSES					
SCAPT Implementation Costs	39,189.50	25,878.16	12,566.82	0.00	0.00
System maintenance	400.00	400.00	400.00	400.00	400.00
NET PROFIT	**-25,878.16**	**-12566.82**	**744.52**	**13,311.34**	**13,311.34**

Source: Own elaboration, 2022.

Table 7 shows that the initial investment for setting up the SCAPT would be recovered in year 2 of the system's implementation, stating that there would be a benefit for the university from that same year. As an example, the ABC is presented by applying equation 6 for the years 0 and 2.

- ABC year 0

$$\frac{B}{C} = \frac{13,711.34}{39,189.5} = \mathbf{0.35}$$

- ABC year 2

$$\frac{B}{C} = \frac{13,711.34}{12,566.82} = \mathbf{1.1}$$

As indicated above with a value of 0.35, in year 0 the costs outweigh the benefits. The situation changes for year 2, where it has a value greater than 1, which implies that the benefits are greater than the costs, meaning that the initial investment for implementing the SCAPT has already been recovered.

4.4. Action Plan

An action plan was proposed for adequate implementation, operation, and sustainability of the SCAPT. Figure 4 presents the details of the action plan.

Figure 2: SACPT Action Plan

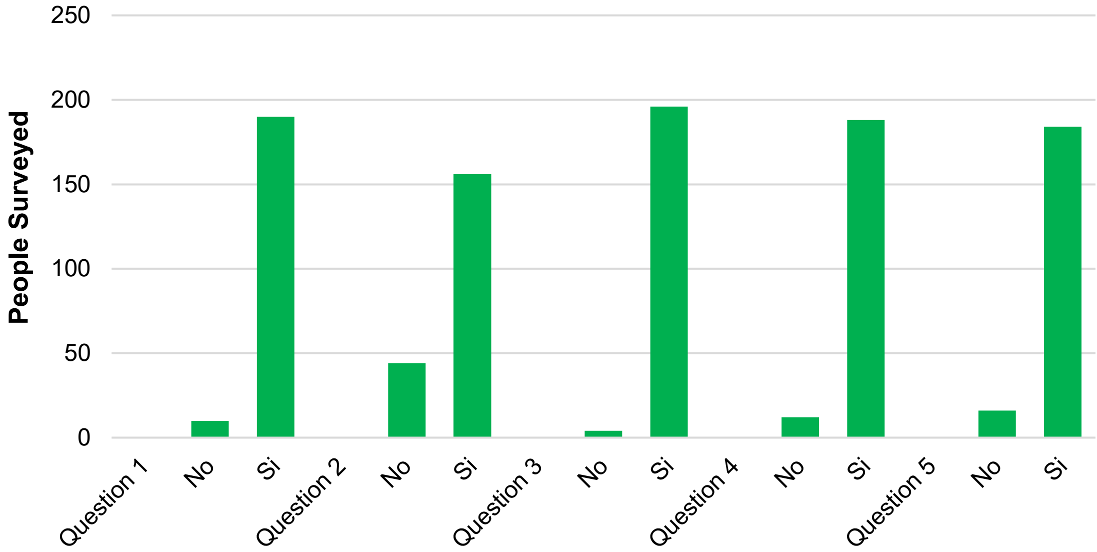
Activities	Months						Goal	Personnel in charge
	1	2	3	4	5	6		
Diagnosis of the components for the SCAPT design	X						Identification of the conditions of the roofs and gutters to be used for SCAPT	UCB Maintenance Department - La Paz
Implementation of the SCAPT in buildings A and D of the UCB - La Paz		X	X				Rooftop water collection system ready to operate	UCB Maintenance Department - La Paz
Promotion of good management of collected and stored water			X	X	X	X	Ensure that the water in the tanks is used appropriately throughout the campus	Control and monitoring by the cleaning and maintenance staff of the UCB - La Paz
Completion of an environmental education course based on the implementation of the SCAPT					X	X	Generating awareness about a way to use rainwater	Environmental Engineering Career

Source: Own elaboration, 2022.

4.5. Surveys

The survey was conducted virtually with the Google Forms program to a sample of 280 obtained by equation 7. Of the total number of respondents, 80 correspond to the teacher/administrative group and 200 to the student group. The implemented survey allowed us to have information about the opinion of the UCB community - La Paz. The responses are shown in Figure 5.

Figure 5. Survey of the UBC community - La Paz Regarding Water Resources



Source: Own elaboration, 2022.

The information collected from the surveys shows that the UCB community is aware of the current water problem (question 1). Most of them express that they take advantage of rainwater (question 2). It is also observed that the majority of the people surveyed would agree with implementing the SCAPT on university premises (question 3). The respondents consider this type of system as a mechanism to make better use of rainwater on campus ((question 4). Finally, the general opinion expressed that through the SCAPT, awareness could be generated of how there are alternatives to face the water lack (question 5).

5. Discussions

Considering that water lack is a more frequent reality in various contexts worldwide, there is a need to find ways to promote better use of the available resource. In this sense, the SCAPT becomes promising as a mechanism for capturing rainwater to put it to use and thus relieve the pressure on the water resource. For these rain harvesting systems to be better known and accepted, they must be set up in strategic places where people usually gather to observe them and see their benefits. In addition, generating small environmental education workshops, where SCAPTs are exposed, and good practices for the use of rainwater are shared, helps to promote awareness about water in the population.

6. Conclusions

According to the projections made, the SCAPT in buildings A and D of the UCB - La Paz could collect a volume of 1,123.67 m^3 of rainwater per year. This amount would mean a saving of 7.24% of the cost of annual water consumption for the university. Specifically, the cost of water would decrease annually by 13,711.34 Bolivianos (1,814.73 Euros) with only the implementation of the system in buildings A and D; the application in other structures would increase the savings.

Through the ACB, it was determined that until year two, the initial investment for the assembly of the SCAPT would be recovered and that from the same year, there would be economic benefits in favor of the UCB.

In this work, he exposed economic savings as the essential benefit of implementing the SCAPT. But it is not the only one; if the system were implemented at UCB - La Paz, it would use rainwater betting on sustainable development. In addition, this project would serve as a reference pilot for other universities, institutions, companies, and even for the population in general, sowing environmental awareness to generate better use of rainwater. Finally, future research should analyze the application of SCAPTs in small buildings to identify if the benefits are the same or if there is any difference in their implementation on a small scale.

7. References

Abdulla, F.A. & AlShareef, A., 2006. Assessment of rainwater roof harvesting systems for household water supply in Jordan. Springer. pp. 291 300.

Aguilera Díaz, Anailys. (2017). El costo – beneficio como herramienta de decisión en la inversión en actividades científicas. *Cofín Habana*, *11*(2), 322-343. Recuperado de http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2073-60612017000200022&lng=es&tlng=es.

Belelli, E., & Vázquez, L. (2018). Captación de agua de lluvia. *Pro Huerta*.

Community Tool Box. (2012). Desarrollar un plan estratégico, capítulo 8. Recuperado de https://ctb.ku.edu/es/tabla-de-contenidos/estructura/estrategia-planificacion/desarrollar-un-plan-de-accion/powerpoint.

Ecolec. (2020). ¿Por qué es importante la educación ambiental? Green blog. Recuperado de https://ecolec.es/greenblog/actualidad/importancia-de-la-educacion-ambiental/.

García, J. & Hernández, M. (2017). Operación y mantenimiento a sistemas de captación de agua de lluvia (SCALL). Morelos (México): Instituto Mexicano de Tecnología del Agua (INTA). Recuperado de https://sswm.info/es/node/11237.

Hugues, Ronnie Torres. (2019). La captación del agua de lluvia como solución en el pasado y el presente. *Ingeniería Hidráulica y Ambiental*, *40*(2), 125-139. Recuperado de http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1680-03382019000200125&lng=es&tlng=es.

Martínez, A., Santillán, S., & Loayza, M. (2016). Informe Nacional: Bolivia. Recuperado de https://cinda.cl/wp-content/uploads/2019/01/educacion-superior-en-iberoamerica-informe-2016-informe-nacional-bolivia.pdf.

Naciones Unidas en Bolivia. (2018). Objetivos del desarrollo sostenible #6. Recuperado de: http://www.nu.org.bo/agenda-2030/13912-2/ods-6/.

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura (UNESCO). (2015). Abordar la escasez y la calidad del agua. Recuperado de https://es.unesco.org/themes/garantizar-suministro-agua/hidrologia/escasez-calidad.

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura (UNESCO). (2017). Adaptación del plan de Acción. Recuperado de http://mspes.ioc-unesco.org/buenas-practicas/paso-10-adaptacion-del-plan-de-accion/.

Organización Panamericana de la Salud. (2004). Guía de Diseño para Captación del Agua de Lluvia. CEPIS/OPS.

Perales Miranda, Víctor Hugo. (2018). La crisis del agua en La Paz: Cambios y racionamiento del agua. Recuperado de http://www.scielo.org.bo/scielo.php?script=sci_arttext&pid=S0040-29152018000200005&lng=es&tlng=es.

Quispe, L. (2010). “Captación, almacenamiento y uso del agua de lluvia a nivel familiar” en Abasto, uso y escasez de agua: un reto actual para asegurar el futuro. Comité de Acción para el Saneamiento del Ambiente A. C. México-Texcoco, Montecillo, Estado de México.

Reyes, O., Espinosa, R., & Olvera, R. (2013). Criterios para Determinar el Tamaño de Muestra en Estudios Descriptivos. Congreso Internacional de Investigación. Recuperado de https://www.researchgate.net/profile/Octavio-Lopez/publication/331687597_Criterios_para_determinar_el_Tamano_de_Muestra _en_Estudios_Descriptivos/links/5c880965299bf14e7e7820d9/Criterios-para-determinar-el-Tamano-de-Muestra-en-Estudios-Descriptivos.pdf.

SENAMHI. Base de datos meteorológico del servicio nacional de meteorología e hidrología-SISMET. Bolivia. 2021. Available online: http://senamhi.gob.bo/index.php/inicio (accessed on 15/03/22).

Communication aligned with the Sustainable Development Goals