Environmentally sustainable universities: the Nueva Granada Campus of the Nueva Granada Military University and its relationship with water

Universidades ambientalmente sustentables: la sede Campus Nueva Granada de la Universidad Militar Nueva Granada y su relación con el agua

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Resumen

Introducción— La sede campus Nueva Granada de la Universidad Militar Nueva Granada (Colombia) se construyó respondiendo a las tendencias globales de la arquitectura moderna para estar en armonía con el ambiente a través de sus construcciones bioclimáticas, iluminación con base en energía fotovoltaica y manejo del recurso hídrico. No obstante, el constante crecimiento de la oferta académica, de la infraestructura y de la comunidad universitaria demanda un mayor uso de los recursos naturales, indispensables para un buen funcionamiento de la sede. Uno de estos recursos es el agua.

Objetivo— En el trabajo se evaluó la sustentabilidad del manejo del agua en la sede Campus de la universidad.

Metodología— Esta evaluación se realizó empleando el Índice de Sustentabilidad del Recurso Hídrico con la integración del concepto de la huella hídrica.

Resultados— Se obtuvo que la universidad ha hecho unos esfuerzos para el manejo eficiente del recurso hídrico. No obstante, estos no son suficientes para evaluar el manejo del agua como sustentable.

Conclusiones— Teniendo en cuenta este resultado se concluye que la universidad debe formular acciones de mejora en los aspectos tecnológico y gestión institucional que permitirán mantener los consumos del agua estables bajo el escenario del crecimiento de la universidad, disminuirán la contaminación de los vertimientos e impactarán de manera positiva la evapotranspiración, como parte fundamental del retorno del agua al ambiente.

Palabras clave— Universidad; gestión sustentable del agua; huella hídrica; recurso hídrico; Colombia

Abstract

Introduction— The Nueva Granada campus headquarters of the Nueva Granada Military University (Colombia) was built responding to global trends in modern architecture to be in harmony with the environment through its bioclimatic constructions, lighting based on photovoltaic energy and management of water resources. However, the constant growth of the academic offer, the infrastructure and the university community demand a greater use of natural resources, essential for the proper functioning of the headquarters. One of these resources is water.

Objective— The work evaluated the sustainability of water management in the campus of the university.

Methodology— This evaluation was carried out using the Water Resource Sustainability Index with the integration of the water footprint concept.

Results: It was obtained that the university has made efforts for the efficient management of water resources. However, these are not enough to evaluate water management as sustainable.

Conclusions— Considering this result, it is concluded that the university must formulate improvement actions in the technological and institutional management aspects that will allow to maintain stable water consumption under the scenario of the university's growth, reduce the pollution of the discharges and impact in a positive way on the evapotranspiration, as a fundamental part of the return of water to the environment.

Keywords— University; water management; water footprint; water resources; Colombia

I. Introduction

The people's lives and all their activities depend on the resources that the earth provides. Population growth and per capita increase in consumption of natural resources in the last 50 years have made possible greater human well-being [1], but they have produced a significant deterioration in the ecosystem services, where 60% of these are degraded or are being used in an unsustainable way [2]. According to some forecasts, in the next 50 years, an increase between 30% and 85% in the demand for water resources is expected and this growth is forecast to be more significant in developing countries than industrialized countries [3]. This perspective leads us to the risk of not fulfilling the sustainable development objectives related to water which are: Health and well-being, clean water and sanitation, sustainable cities and communities, responsible production and consumption, the life of terrestrial ecosystems, among others [4].

Reversing the degradation of ecosystems and natural resources becomes a challenge because it requires comprehensively addressing the issue, involving institutional, technological, and environmental variables [5]. The last decades have been characterized by the creation of environmental policies and the initiative of different state and private institutions that manage their natural resource consumption indicators to rationalized them and guarantee fewer negative impacts on the environment [6]. For this purpose, different methodologies are used, among which the environmental footprint on water and energy resources [7], the carbon footprint [8], and the water footprint [9], among others, stand out. Different universities have joined the initiative to evaluate their environmental impacts to propose actions that lead to sustainable consumption of natural resources [10], [11], [12].

The water footprint methodology was made in 2002 by Arjen Hoekstra who is a professor at Twente University (Netherland) and since then has been widely used to assess the direct and indirect impact of different socio-economic activities on water resources [13]. The results of the methodology are expressed in m^3, which makes possible easier quantitative interpretation. However, the methodology does not guide toward whether the value obtained from direct or indirect water consumption it can be considered sustainable [14]. Therefore, the result obtained by the water footprint methodology must be complemented with an indicator that allows concluding about the sustainability of water resource management [15]. Considering that the use of water includes different dimensions such as environmental, technological, and institutional [16], the indicator must encompass these dimensions and apply to the case study.

In this opportunity, being in tune with national and international trends about sustainability, the Nueva Granada Military University (Colombia) built the Campus Nueva Granada headquarters (SCNG, for its acronym in Spanish), thinking in the harmonious relationship with the environment through bioclimatic buildings [14], using photovoltaic energy for outdoor lighting [15], taking advantage from rainwater to sustain artificial lakes. Considering the water resource as the backbone of sustainability and development of the university, in the present study, the sustainability of water management was evaluated through the Global Water Sustainability Index (GWSI) [16], adapted to the case study. The innovation of the work lies in the integration of the concept of the water footprint [17] to the GWSI which contributed to the understanding of the effect of water pollution and the need for its urgent management to guarantee a more harmonious relationship between the campus and the environmental conditions of the Bogota River. Among the contributions of the study, is the concrete actions proposed to achieve sustainable management of water resources in the SCNG of the Nueva Granada Military University.

II. Materials And Methods

In this numeral, the description of the SCNG and its water cycle is initially made, which enables the development of the methodological part aimed to evaluate sustainability in the management of the water resources in the SCNG of the Nueva Granada Military University, using the GWSI in conjunction with the water footprint methodology [18].

The Nueva Granada Military University - SCNG is located between the towns Cajicá and Zipaquirá, has an area of 0.7609 km^2 and a population of 6 894 people, which includes teachers, students, and administrative personnel, as well as visitors who did not participate in these statistics. Its infrastructure has 10 buildings, identified by the following names: Francisco José de Caldas, Mutis, Camacho Leiva, Sepúlveda, Postgraduate and research, Faculty of Strategic Studies, Eloy Valenzuela, José María Cabal, FAEDIS (Faculty of Distance Studies, for its acronym in Spanish) and an alternate building. To sustain the university, water is used for cleaning and building maintenance, several tasks in laboratories, 4 cafeterias, irrigation of greenhouses and green areas, meeting sanitary demands, and maintenance of 2 artificial lakes. Today the SCNG has the Program for Saving and Efficient Use of Water (PUEAA, for its acronym in Spanish) in conformity with Law 373/1997 [19]. This program started operating in 2017 and is valid for 5 years. Fig. 1 shows the contextualization of the water balance of the SCNG.

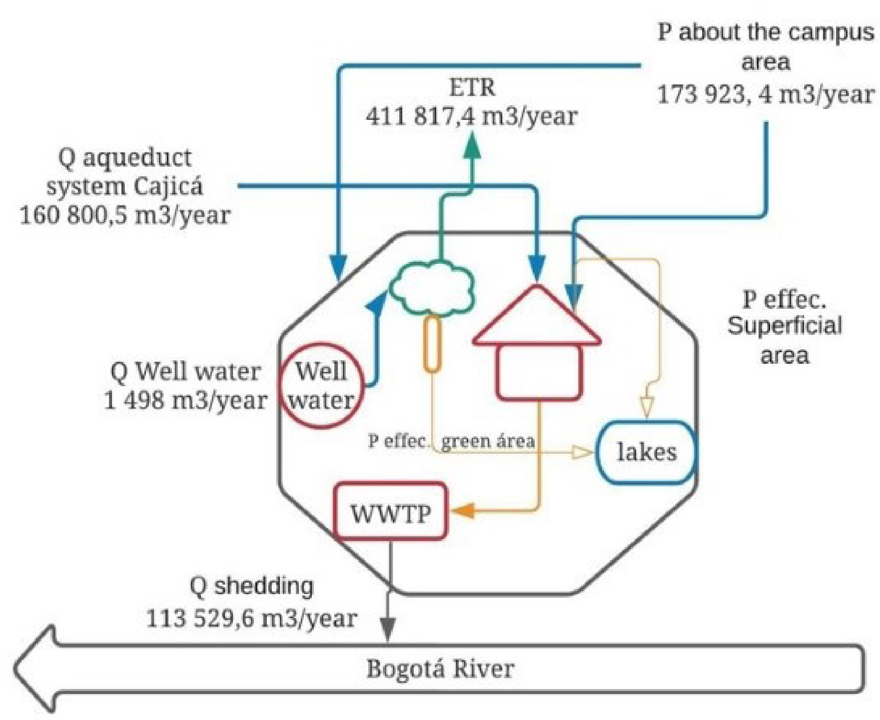

Fig. 1. Water balance scheme of the SCNG.
Source:Authors.

In the SCNG there are three incoming components of water: First, the water supply from de Cajicá aqueduct. The water granted by the aqueduct is used for maintenance and cleaning of the constructions that add up to a total area of 140 147 m^2, their own laboratory needs related to the use of water in different tests, maintenance of equipment, among others. In the SCNG 4 cafeterias use water for cooking, dishwashing, and cleaning. The second incoming component of water to the headquarters is the use of groundwater. In the territory there are two granted underground wells, well 1 is used for irrigation of green areas and greenhouses, and well 2 is currently not in use because there is no treatment system to meet the criteria of respective water quality [20]. The third component is surface water runoff due to precipitation (effective precipitation). One part of precipitations that falls over the natural covers evaporates, and the other part participates in the process of surface runoff. Considering the annual analysis cutoff, it is considered that the accumulation and waste processes of water in the soil are compensated. The water precipitated on the artificial surfaces runs off in its entirety and, therefore, the value of effective precipitation from artificial surfaces is equal to the value of precipitation on said surface. The effective precipitations both from the surface with the natural cover and from the artificial surfaces are sent to the two lakes present in the territory that mainly fulfill a landscape function. In periods with excess water in the lakes, the surpluses are used for the irrigation activities of the crops in the greenhouses of the Campus. Finally, sewage reaches the WWTP (Wastewater Treatment Plant), where primary treatment of the effluent is carried out. After the treatment, the discharge of the discharges to the Bogotá River is carried out.

As previously mentioned, the study aims to evaluate sustainability in water management [21]. Understood by this, the uses of water that allow sustaining a society so that it lasts and develops in an indefinite future without altering the integrity of the hydrological cycle and the ecosystems that depend on it [22].

The concept of sustainability encompasses different dimensions that have to do with the conservation of environmental conditions, the existence of technological tools for the management of water resources, and institutional strength that guides the rational use of water [23]. Therefore, the indicator of the sustainability of water use must include these dimensions that must be measurable and whose interpretation leads to conclude on the evaluation of current water use and allow to generate proposals for improvement in the management of water resources [16]. It is important that the indicators meet the following criteria:

- They cover environmental, institutional, and technological dimensions.
- Inter-independent.
- The clarity in its application and interpretation.
- Based on available supplies.
- The result of the indicator allows generating strategies to improve the use of water resources at the SCNG.
- They depend directly on the actions carried out by the university on the issue of water.

There are different methodologies to evaluate sustainability in the management of water resources [24], [25], [26], among others. However, some are not applied to case study and the others require supplies that are not available in the case study. To evaluate the sustainability of water management in the SCNG, methodology [16], was chosen, with some adjustments to the case. Next, the conceptual framework of the dimensions of sustainability of water consumption is presented together with the sub-indicators associated with each of these.

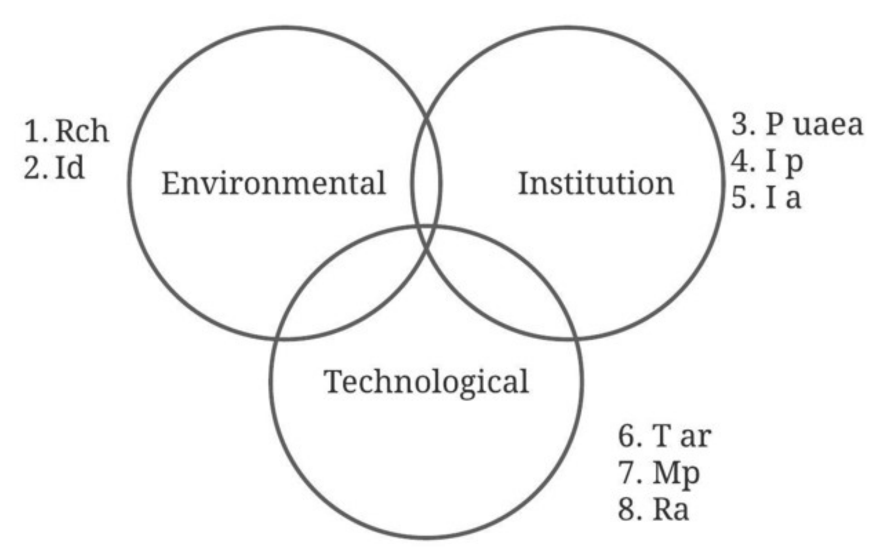

Fig. 2. Conceptual framework of the evaluation of the sustainability of water consumption in the Nueva Granada Campus.
Source: Authors.

As can be seen from Fig. 2, the indicator consists of several sub-indicators that have a numerical value from 0 to 1 [16]. Each of them has an equivalent weight in the final value of the Global Water Sustainability Index (GWSI). The general equation for the Global Water Sustainability Index is presented below (1):

$$GWSI = \frac{\sum_{i=1}^{n} z_i P_i}{P_t} \tag{1}$$

Where:

z_i – Sub-indicator value from 0 to 1. The value of 1 is associated with full compliance and the value of 0 – to the opposite stage.

P_i – Variable weight. The weight from each of the sub-indicators is equivalent and is equal to 0.125.

P_t – Total weighted weight of value 1.

The index interpretation is made through the following ranges:

GWSI ≥ 0.65 – High water sustainability.

0.43 < GWSI < 0.65 – Medium water sustainability.

GWSI < 0.43 – Low water sustainability.

A. *Sub-indicators of the environmental dimension*

To formulate the sub-indicators in the environmental dimension, both the effect of water demands on the supply of the Bogotá River (Id) and Respect for the Hydrological Cycle (Rch) were evaluated.

- *Sub-indicator of respect for the hydrological cycle Rch*: Understood by this that both the supply process and the discharges are carried out to the same river, being in accordance with the natural flow of water [23]. The sub-indicator categorization regarding the hydrological cycle has a score of 0 or 1. The value of 0 is associated when the discharges are made to the receiving source other than the river —supplier and the value of 1 are assigned when the source— supplier as source-receiver of discharges is the same.

- *Sub-indicator of demand for water resources Id*: The water demand sub-indicator was associated with the surface water scarcity index [27]. With a modification, including the value of the gray water footprint for water demands (Blue Water Footprint), as the SCNG's contribution to the contamination of Bogotá river, being aligned with one of the environmental principles of "cradle-to-grave responsibility" [28]. Next, the equation (2) for the definition of the water scarcity index is presented:

$$I_e = \frac{V_{demand}}{V_{offer}} = \frac{HH_{blue} + HH_{gray}}{V_{offer}} \tag{2}$$

Where:

I_e – Water scarcity index.

I_d – Sub-indicator of pressure due to water demands.

V_{demand} – Annual demand for water resources, (mm^3).

V_{offer} – Annual supply of water resources, (mm^3) – is defined as the average value of the flow of the hydrological station closest to the Campus Nueva Granada headquarters.

By the Blue Water Footprint [29], we understand the uses of water derived from the Cajicá aqueduct system, well water, and the effective precipitation of rainfall from both the anthropic and natural surface. The equations that support the blue water footprint are presented below (3)(4):

$$HH_{blue} = HH_{aqueduct} + HH_{well\ water} + HH_{P\ effective} \tag{3}$$

Where:

HH_{blue} – Blue water footprint, m^3.

$HH_{aqueduct}$ – Annual consumption of water from the Cajicá aqueduct, m^3.

$HH_{well\ water}$ – Annual consumption of well water, m^3.

$HH_{P\ effective}$ – Annual effective precipitation, m^3.

Effective precipitation is divided into effective precipitation from the impermeable surface and the natural surface. From the artificial area, the precipitated water runs off directly and, consequently, $P_{effective\ ar}t = P_{about\ the\ area}$. The effective precipitation from the green surface presents the remaining part of precipitation as a product of the difference of $P\text{-}E\text{-}I = P_{green\ effective\ area}$.

The evaporation and infiltration components are defined through Thornthwaite's climatic water balance [30]. Evaporation in the water footprint methodology is defined with green, the green water footprint that reflects the evaporation process that occurs from the green areas of the Campus [31]. Depending on the area of artificial and natural roofs, the precipitation values in mm are transferred to annual flows.

$$P_{effective\ art.} \rightarrow HH_{blue\ P_{effective\ art.}}$$
$$P_{green\ effective\ area} \rightarrow HH_{blue\ P_{effective\ green\ area}} \quad (4)$$

Finally, the sum of the two components mentioned above represents the blue water footprint of effective precipitation (5):

$$HH_{P_{effective}} = HH_{blue\ P_{effective\ art}} + HH_{blue\ P_{effective\ green\ area}} \quad (5)$$

The gray water footprint is related to the volume of water that must be discharged to the receiving source of the discharge to bring its concentration to the natural concentration, mitigating the impact of discharges [32]. Finally, the wastewater reaches the WWPT, where primary effluent treatment is carried out. The receiving source of dischargers is the Bogotá River. The flow rate and the concentration of total suspended solids serve as input to define the gray water footprint. The equation for its calculation is expressed as follows (6):

$$HH_{gray} = \frac{L}{c_{max} - c_{nat}} \quad (6)$$

Where:

HH_{gray} – Gray water footprint, (m³/año).

L – Pollutant load, (kg/year). It is obtained as the average discharge flow multiplied by the average value of the concentration of Total Suspended Solids (TSS).

$c_{máx}$ – Maximum concentration accepted, (kg/m³). Due to the maximum acceptable concentration, the maximum discharge limit stipulated in Resolution 631/2015 [33] of 90 mg/L was considered.

c_{nat} – Natural concentration in the receiving waterbody, (kg/m³). The natural concentration of TSS was consulted from the water quality station monitoring point N° 32 Puente Vargas, monitored by CAR (Regional Autonomous Corporation of Cundinamarca) and located upstream of the SCNG.

To associate a numerical value with the sub-indicator of water demand Id, this was associated with the Ie scarcity index, the categorization of which is presented in Table 1. The value of 0 in the Id sub-indicator was associated with the scarcity index with the large impact (> 0.40), while when the water demands are not significant in relation to the supply (Ie < 0.1) the value of the Id sub-indicator is 1, indicating very low anthropic pressure on the availability of water resources.

TABLE 1. CHARACTERIZATION OF THE ID AND TAR SUB-INDICATORS.

Index Characterization	Parameter Range Ie(SST_{ef} SST_{limit})/SST_{limit}	Value of the subindicators Id/Tar
High	> 0.4	0.00
Medium	0.2 – 0.4	0.66
Moderate	0.1 – 0.20	0.33
Low	< 0.1	1.00

Source: Authors [27] with own settings.

B. *Sub-indicators of the institutional dimension*

Sustainable management of a resource is always achieved when there is an institutional presence in the management of it. The assessment of this dimension was designed through three sub-indicators presented below.

- The first sub-*indicator* is related to the existence of the Water Resource Savings and Efficient Use Plan with measurable indicators of the rational use of water - (PUEAA). The existence of the plan with the compliance indicators is associated with a rating of 1, and the non-existence —a value of zero.
- The second sub-*indicator* is in the existence and application of the protocols for different activities of efficient use and saving of water - Ip. The existence and compliance of these protocols guarantee the adequate use of the water resource, without waste and optimizing its consumption.
- The third sub-*indicator* is related to the evaluation of the actions that have been carried out for the saving and efficient use of water resources - Ia. This sub-indicator refers to all those actions carried out by the institution to achieve rational management of water resources, such as the installation of water-saving systems, rainwater harvesting systems, among others.

C. *Sub-indicators of the technological dimension*

Water management is necessarily linked to the technological dimension, in which the following sub-indicators were chosen.

- The first assesses the efficiency of *Wastewater Treatment* - Tar. If the effluents have an TSS concentration lower than the permitted upper limit recommended by Resolution 631/2015, the value of 1 is associated with the sub-indicator, indicating full compliance with the standard. If the SST value is higher than the allowed limit, the relationship is calculated, presented in equation 7. The value of the Tar sub-indicator is defined based on equation 7 and is presented in Table 1. When the concentration of discharges exceeds the limit allowed by Resolution 631 by 40% [33], the impact due to contamination is considered high and the sub-indicator is assigned a value of 0 and so on according to the categories presented.

$$\frac{SST_{ef}-SST_{limit}}{SST_{limit}} \tag{7}$$

Where:

SST_{ef} – Concentration of total solids in effluent suspension, (mg/L).

SST_{limit} – Limit concentration of total suspended solids according to Resolution 631/2015 (mg/L).

- The second indicator refers to the existence of the Mp - *Micro Measurement System*. An institution can reduce its water consumption through the installation of the micro metering system because through it, partial demands of certain infrastructures of the headquarters and possible water leaks are identified for later control. The latter leads to a reduction in water consumption associated with leaks. Therefore, the second sub-indicator Mp is related to the existence of the water micro measurement system.
- The third sub-indicator Ra measures the existence of water recirculation processes on Campus.

The last two sub-indicators are assigned a value of zero in the case of non-compliance, 1 in the case of full compliance, and the intermediate score is associated in the stage with partial compliance.

As previously mentioned, the water footprint is made up of three elements that are: Blue water footprint that comes from direct water consumption [37]; the green water footprint that reflects the evaporation process that occurs from the green areas of the Campus [31] and the gray water footprint that is related to the volume of water that must be poured into the source receiving the discharge to bring its concentration to the natural concentration, mitigating the impact of discharges [32]. Finally, the total water footprint represents the sum of its three components (8). The inputs for calculating the water footprint of the SCNG are presented in Table 2.

$$HH_{total} = HH_{blue} + HH_{green} + HH_{gray} \tag{8}$$

Table 2. Inputs to define the water footprint of the Campus.

Inputs for the water footprint component	Parameter	Value	Unit	Source
Blue water footpriint	Q Cajicá aqueduct	5.10	L/s	[17]
	Q well	0.19	L/s	
	Hours of use per day of well	6	h/day	
	Green area	620 753	m²	
	Artificial area	140 147	m²	
Green water footprint: Average values of temperatures and total monthly precipitation can be consulted in the records of the climatic stations 21205160 y 21205910.				[41]
Gray water footprint	Q_{WWTP}	0,0036	m³/s	[17]
	TSS_{WWPT}	180.0	mg/L	
	$C_{maximum}$	90.0	mg/L	[33]
	$C_{natural}$	10.0	mg/L	[44]

Source: Authors [17], [33], [41], [42], [43], [44].

III. Results

The results of the evaluation of the sustainability of water management in the SCNG are presented below.

Initially, the results of the annual water balance of the seat are shown, expressed under the water footprint approach [34], that allows evaluating both direct water consumption and the effect of effluent contamination [35] and, consequently, it serves as a comprehensive indicator of water consumption [36]. Subsequently, the results of the evaluation of the sustainability of water management at the Nueva Granada Campus headquarters are presented through the Water Resource Sustainability Indicator. Finally, recommendations are made on some improvements to be made in the management of the resource water so that our relationship with this resource is more harmonious.

The results obtained from the water footprint are presented in Table 3.

Table 3. Values of the total water footprint of the Nueva Granada Campus.

Category	Parameter	Value (m³/year)
HH blue	$HH_{aqueduct}$	160 800.5
	HH_{well}	1 498
	$HH_{P\ effective\ art}$	107 885.2
	$HH_{P\ effective\ area\ green}$	66 038.2
	$HH_{p\ effective}$	173 923.4
	HH_{blue}	336 221.9
HH green	$ETR_{anual} = HH_{green}$	411 817.4
HH gray	HH_{gray}	255 441.6
HH_{total}		1 003 480.9

Source: Authors.

The results obtained indicate the following:

- 41% of the water returns to the environment through the evapotranspiration process. This percentage is due to the predominant extension of the green areas of the campus on the artificial surfaces and to the monthly rates of precipitation that guarantee the availability of water for the evapotranspiration process. The evapotranspiration rate was defined based on the indirect method [38] and could be subject to verification through the calibration of the water balance model, considering the soil conditions and the evaporative characteristics of different surfaces. However, this topic presents an independent research objective and could not be considered in the present study. The result obtained, although it can be considered approximate, indicates that the green areas of the SCNG contribute to the regulation of the hydrological cycle to a significant extent.
- 69.9% of the water supplied from the Cajicá aqueduct and the first well returns to the Bogotá River in the form of discharges from the WWTP, respecting the natural course of the hydrological cycle. This indicates that only 30.1% of the water supplied is related to the consumption of non-returnable water to the environment.
- The gray water footprint represents a quarter of the total water footprint and 75% of the value of the blue water footprint. Applying the environmental principle from the cradle to the grave [28], which in the case of the study would consist of returning the water served to the Bogotá River in the same quality in which it was captured by the supply system, this value should be equal to zero. The existence of this value and its contribution to the total water footprint indicates the need for improvements in the issue of wastewater treatment in the SCNG.

By understanding the hydrological flow of the SCNG and the corresponding water footprints, the sustainability of water resource management was evaluated. The qualification of the sub-indicators and the final value of the adjusted Global Water Sustainability Index (GWSI) are presented in Table 4.

Table 4. Assessment of the GWSI indicator.

Dimension	Environmental		Institutional			Technological		
Sub-indicator	R_h	I_d	P_{auea}	I_p	I_a	T_{ar}	M_p	R_a
Value	1.0	1.0	0.5	0.0	1.0	0.0	0.0	0.5
GWSI	0.50							

Source: Authors.

Next, the explanation of the assignment of the value of each sub-indicator is presented.

A. *Environmental dimension*

R_h– Both the source of supply and the recipient of the discharges is the Bogotá River. Consequently, the hydrological cycle of the SCNG respects the natural flow of the basin and the value of 1 was associated with the indicator.

I_d– The scarcity index has a value of 0.0027 with the total demand flow (aqueduct and the first well) of 0.019 m^3/s and of the water supply of the hydrological station near the El Espino SCNG of 7.012 m^3/s. Consequently, demand relative to supply is characterized as low and the demand sub-index is assigned the value of one. This indicates that the water demands of the university do not generate a significant impact on the water supply of the Bogotá River.

B. *Institutional dimension*

P_{auea}– There is a water-saving and efficient use plan, but there are no water resource management indicators. There is partial compliance with the sub-indicator to which the assessment of 0.5 is assigned.

I_p– There are no protocols for the rational use of water for different activities such as maintenance of infrastructure, outdoor areas, laboratories, among others. For this reason, the sub-indicator was associated with the value of zero.

I_a– The SCNG has water-saving sanitary facilities. The value of one was assigned.

C. Technological dimension

T_{ar}– The TSS value of the effluent is greater than the value allowed according to Resolution 633/2015. For this reason, the value of the relationship was calculated according to (7), and applying Table 1, the value of the sub-indicator Tar is equal to zero, which indicates that the discharges of the wastewater significantly affect the quality of the receiving source.

M_p– The Nueva Granada Campus does not have a loss measurement system, which does not allow us to identify water leaks and control leaks. Therefore, the value of zero of the sub-indicator is assumed.

R_a– On the Campus, there is the use of rainwater to nourish the waters of artificial lakes. However, there is no reuse and recirculation of wastewater from the WWTP due to limiting the quality of the discharges. There is partial compliance with sub-indicator.

As a general result of the GWSI, further improvements must be made in the technological and institutional aspects, showing that an environmental project must be approached from different dimensions to achieve a harmonious relationship between the social and academic-administrative activities at the Campus Nueva Granada headquarters and the water resource [5]. The SCNG and the consequences of its water metabolism produce greater negative impacts through the discharge of discharges that should become the priority issue in the Plan for the Savings and Efficient Use of Water Resources.

According to the ranges of the numerical values of the GWSI, the sustainability in the use of the water resource can be considered as average, since it is in the range of 0.43 and 0.65. The GWSI adopted for the case study demonstrated its applicability for the case study. One of its advantages consists in the adaptability to different study contexts and allows the inclusion of new variables, relevant for the evaluation of our relationship with the management of water resources.

IV. Conclusions And recomendations

The SCNG was designed and built considering different actions oriented towards sustainable water management. Among these, the use of rainwater to sustain landscape lakes, water-saving sanitary facilities, primary treatment of discharges to the Bogotá River, design of a saving plan, and efficient use of water resources can be highlighted. However, in the process of operation and growth of the university, some actions began to be lacking to guarantee the sustainable use of water resources in the short and medium-term.

These faults made the W index value 0.50, indicating that in the institutional and technological dimensions some improvements should be made to bring the value of the SCNG GWSI to higher than 0.65.

Greater improvements should be used in the technological dimension, where it is proposed that micro-measurement systems be installed that will allow not only to evaluate water consumption in different SCNG facilities, but also to manage leaks in the hydraulic network and, in this way, design actions for its eradication. Another technological aspect to take into account is the increase in the efficiency of the wastewater treatment plant, which will not only reduce the pollutant load to the Bogotá River but will also make it possible to design the recirculation of water at the headquarters, using it for different activities that they demand the use of water resources.

Considering sustainability as a whole, the technological, environmental, and institutional dimensions are interrelated and the positive impacts in the management of one dimension will produce improvements in the other. Thus, the implementation of the micro-measurement system (technological dimension) will allow the design of the water resource management indicators in the rational use and saving of water plan (institutional dimension).

Likewise, the design of water use protocols for activities that demand a greater proportion of water resources and the carrying out of awareness campaigns where the advantages of reducing water consumption are highlighted (environmental dimension) will help rational use of water, which will allow the consumption of the water resource to be stable under the scenario of the growth of the academic population in the SCNG.

Following the sustainability objectives of the SCNG, it is also proposed to increase the native forest areas in the SCNG facilities, which would perform functions such as rain interception, infiltration, and water retention [39], improving the capacity for water regulation and serving as a support for other environmental services (biological corridors, maintenance of biodiversity, retention of atmospheric pollution, among others) [40].

According to proposed improvements in the SCNG's water resource management in the institutional and technological dimensions, in the medium term, the GWSI value of 0.81 could be achieved, reducing the value of the blue and gray water footprints.

By associating these recommendations with the efficient water use and saving plan, the following positive impacts could be achieved:

- The consumption of water associated with the blue water footprint could rationalize through the awareness of the rational use of water that takes relevance in the current context of the growth of the academic offer of the headquarters, its population, and infrastructure. Likewise, the implementation of the loss measurement system would contribute to the control of the water leaks, also reducing and/or controlling the cost of water resources at the headquarters.
- The proposed improvements in the wastewater treatment system and the definition of the maximum permissible limit for discharges to the Bogotá River would positively impact the gray water footprint, reducing its value. Improvements in the water quality indicators of the discharges would allow the recirculation of the water resource in the headquarters and its use to satisfy some specific demands. For example, its use could be proposed in maintaining infrastructure and irrigation of crops in greenhouses. In this way, the waters not discharged into the Bogotá River can satisfy some water demands, reducing the use of water from the well and/or the aqueduct. Although this fact would not decrease the value of the blue water footprint, it would decrease the value of the gray water footprint.
- The proposal for the conservation of green areas is given for its intrinsic value to serve as a support for different ecosystem services and, especially, for the conservation of the natural flow of water through the evapotranspiration process. The sowing of native spices in the headquarters could contribute to the improvement of the regulation of the water regime in comparison with the herbaceous covers, currently predominant in the headquarters, and should be the object of independent study.

Finally, the integration of the concept of the gray water footprint with the environmental dimension of the GWSI made it possible to evaluate the impact of direct and indirect water consumption concerning the water supply of the Bogotá River basin. Currently, this relationship does not exceed 2.7%, but, in the scenario of the growth of the university and having the same wastewater treatment system, this relationship could increase in the future. Added to the water demands and pollution of the SCNG is the pressure from other water users in the middle basin of the Bogotá River, violating its environmental conditions and ecosystem functionality.

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