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Sustainable Water Consumption of Dwellings In The Cuenca City

Consumo sustentable de agua en viviendas de la ciudad de Cuenca

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Abstract

This study proposes and supports the application of 4 criteria for the sustainable management of drinking water inside the dwelling in the city of Cuenca, Ecuador. The criteria determined are: the control of water consumption, the control of leaks, the use of saving devices and water reuse systems. Three levels of assessment are defined for each criterion: standard, best practices and superior practices. For the development of the research, surveys are applied to the population that allow probing the existence and predisposition to incorporate drinking water saving practices in the homes, in addition measurements of water consumption by uses are made in 10 homes for a week, together the official information on the water consumption of the canton Cuenca facilitated by the municipal company of the city is processed, and several standards are analyzed: ISO, INEC and the Ecuadorian Technical Construction Standard, among others. Finally, it concludes with the determination of a percentage of water savings of up to 30%, which can be obtained the application of sustainable practices.

Keywords: Water consumption, water saving strategies, water recycling, water sustainability.

Resumen

El presente estudio propone y sustenta la aplicación de cuatro criterios para la gestión sustentable de agua potable al interior de la vivienda en la ciudad de Cuenca, Ecuador. Los criterios determinados son el control del consumo de agua, el control de fugas, el uso de dispositivos ahorradores y los sistemas de reutilización de agua. Se definen tres niveles de valoración para cada criterio: estándar, mejores prácticas y superiores prácticas. Para el desarrollo de la investigación se aplican encuestas a la población que permiten sondear la existencia y la predisposición de incorporar prácticas de ahorro de agua potable en las viviendas; además, se realizan mediciones del consumo de agua por usos en diez viviendas durante una semana; conjuntamente se procesa la información oficial del consumo de agua del cantón Cuenca facilitado por la empresa municipal de la ciudad y se analizan varias normas: ISO, INEC y la Norma Técnica Ecuatoriana de la Construcción, entre otras. Finalmente, se concluye con la determinación de un porcentaje de ahorro de agua de hasta el 30 %, que se puede obtener con la aplicación de prácticas sustentables.

Palabras clave: Consumo de agua, estrategias de ahorro de agua, reutilización de agua, sustentabilidad del agua.

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1. Introducción

Planet Earth is 70% covered by water, of which 98% is salt water and the current technology to make it drinkable is still very restricted due to its high costs. About 2% of fresh water is located in the polar ice caps or aquifers, so only 0.014% is available in the lakes and rivers of the Earth's surface [1].

In the world, drinking water coverage is still a problem both in cities and in rural areas. By the middle of this century, 7,000 million people in 60 countries will suffer water shortages, in the worst case, and at best it will be 2,000 million people in 48 countries. Recent estimates suggest that climate change will be responsible for around 20% of the increase in the global water shortage [2]. One of the alternatives promoted in recent years is a focus on the human right to water. As such, resolution a/res/64/292 of the UN General Assembly explicitly declares «the right to drinking water and sanitation as an essential human right for the full enjoyment of life and all human rights» [3, 4].

Therefore, populations will be favored to the extent that the use of water is minimized and there is a commitment on the part of the citizens to maintain the liquid they now have to satisfy their basic needs and guarantee the supply for future populations. [1]. In this way, the sustainable consumption of water is defined as «the use of water that allows 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» [5, 6].

At the international level, there are several methods of certification for sustainable housing that incorporate indicators for the saving of drinking water, among the most recognized methods are: VERDE NE Residential Offices [7], LEED® Rating System for Homes [8] and the BREEAM ES VIVIENDA Manual [9].

These methods contemplate several strategies such as the detection of leaks by means of historical records, which allows for a comparison between water supplied and water consumed. [10–12]; the installation of saving devices, which can reduce up to 30% of consumption [1], [13]; the use of rainwater, which can be stored for certain household uses [14, 15]; the use of water recycling techniques, which consists of the reutilization of domestic wastewater, allowing, for example, to reload the toilets with gray water [16, 17]; and the implementation of single jet multiple jet meters, in order to control consumption, achieving savings of up to 20% [18, 19].

1.1. Drinking water in the city of Cuenca

According to the World Health Organization, optimal access to water in order to meet all basic consumption and hygiene needs, in order not to cause negative effects on health, should be greater than 100 l/inhabitant/day [20], while the Ecuadorian Construction Standard 2011 establishes that the provision for a house should be between 200 and 350 l/inhabitant/day, reflecting a very wide range, which prevents the existence of consumption control [21].

This lack of control results in increased levels of consumption over time. Such is the case of Cuenca, which, to guarantee the water service for the community, has a catchment of 120 000 m^3 [22] for a population of 524 563 inhabitants [23]. Taking into account that the population projection for the year 2050 will reach 901 499 inhabitants [24], it will be necessary to capture 4610 l/s of water, if current consumption and demand for drinking water is maintained, which is equivalent to a 71.85% increase in catchment.

Obtaining this percentage of new demand puts water resources at risk considering, in addition, that three of the four rivers in the city are currently exploited. In monetary terms the requirement for infrastructure works for 2050 implies an investment of 6865 million dollars [24].

This would cause the provision of drinking water in the city of Cuenca to increase and compare to other Latin American locations, such as Buenos Aires-Argentina where there is a provision of 356 l/inhabitant/day, Sao Paulo-Brazil with 227 l/inhabitant/day, and Santiago de Chile with 203 l/inhabitant/day [25].

Therefore, a sustainable management of water in the homes of Cuenca is necessary in order to reduce these percentages.

With this background, this study raises the possibility of reducing the consumption of drinking water in homes in this city, without affecting the quality or lifestyle of its inhabitants, through the application of sustainable criteria such as incorporating rainwater for certain domestic uses, using sanitary appliances and water recycling techniques.

2. Materials and methods

The methodology of the present investigation is non-experimental and quantitative, and includes two stages:

2.1. Determination of evaluation criteria to reduce the consumption of drinking water

For the determination of criteria, a comparison of four international assessment methods is carried out, where the subject of the sustainable management of drinking water within the home is studied, in order to find convergences between them and establish the criteria that will be considered. The methods analyzed are GEA VERDE NE [7], LEED® for Homes Rating System [8], CASBEE FOR NEW CONSTRUCTION [26] and BREEAM IS HOUSING MANUAL [9].

To determine if the evaluation criteria are feasible and applicable in the local reality of Cuenca, the following selection judgments are established [27]:

1. The evaluation criteria are compatible with the characteristics of the households and/or the city.
2. The evaluation criterion contributes to overcoming the existing problems in the households and/or the city.
3. The application of the evaluation method was feasible.
4. The levels of demand are in line with local conditions.
5. The type of evaluation implemented is based on performance.
6. The evaluation criterion contributes to improving the comfort of the households and/or the conditions of the city.

2.2. Determination of valuation levels

One of the main challenges of the research is to determine the minimum values or standards to be met in each criterion evaluated, which respond to the local reality. The process used in this stage includes the following three sections:

2.2.1. Surveys of 280 homes in the city of Cuenca

A survey is applied that allows the identification of drinking water saving practices and the predisposition of the population to incorporate sustainable strategies. For the survey, a sample of 280 homes distributed in the urban area of Cuenca is taken.

The specific design of statistical sampling is probabilistic, polymetallic and random. The number of selected sectors was based on the number of households in each parish and the distribution by socioeconomic level (A; B; C +; C-; D). The survey of the National Institute of Statistics and Census (INEC) was used to determine the socioeconomic stratum. The sample has a confidence level of 95% and an absolute error of 0.06.

To estimate the size of the sample, the following formula was used:

$$np' = \frac{K^2 \times N \times PQ}{K^2 \times PQ + NE^2}$$

Where:
np' = size of sample to be assessed
K = confidence coefficient
N = size of the universe
PQ = proportion variance
E = maximum permissible error

The survey considers the following:

- Do you use any equipment, device or system to save water?
- For you, what is the importance of a home that saves energy and water; that less resources are consumed during the construction process, or that it causes a minimum impact on the environment?
- Would you be willing to invest in a home with the characteristics of the previous question?

2.2.2. Measurement of water consumption in 10 homes

In order to determine the water consumption through different uses, a specific analysis is carried out in ten homes. The selection criteria of these houses were the geographical dispersion and the variety in the typology of the building. In addition, the limitation of the number of measuring equipment is considered, but mainly the predisposition of the owners to collaborate with the investigation.

For the measurement, water meters, model S120, of the velocimetric type, which consist of a single jet inferential meter, magnetic transmission, direct reading and super dry watchmaking, meet the metrological requirements of classes A and B of the Resolution 246; 2000 of the INMETRO, of the MERCOSUR NM 212 and ISO 4064 standards [28–30].

These meters were installed in the various water outlets (uses): faucets in toilets, kitchens and laundries, showers, water heaters and toilets. Daily consumption is recorded during a whole week to obtain data on the behavior of a family on working days and non-working days.

Finally, a survey is applied, which is based on the one developed by the Ecuadorian Institute of Sanitary Works [31] and is part of the Ecuadorian construction code [32]. In addition, it has been applied in similar investigations [17, 33]. The questions are:

- How many times does a member of the family that lives in the home use the toilet?
- Would you be willing to use rainwater in your home for sanitary, irrigation and cleaning purposes?
- How much money would you be willing to invest monthly in equipment that allows saving and sustainable use of water?

2.2.3. Drinking water consumption data in Cuenca

The city's municipal public company (ETAPA EP) is asked for monthly drinking water consumption forms for all the residential connections to which it provides the service, in order to calculate the arithmetic average of water consumption per existing residential installation.

With these results and with the INEC population and housing census data [34], the arithmetic mean of drinking water consumption per inhabitant in l/inhabitant/day is obtained.

In addition, the monthly water consumption of the residential connections of the ten case studies was requested during a year, in order to assess the measurements obtained in the readings and determine maximum and minimum variations.

Based on the data obtained from the previous points, standards and strategies for sustainable consumption of water in the homes of the city of Cuenca are defined, which help determine the percentages of savings in consumption and costs that can be achieved.

3. Results and discussion

3.1. Determination of evaluation criteria to reduce the consumption of drinking water

Table 1 shows the results of the evaluation of the 6 judgments on the 17 evaluation criteria determined in the international methods. It is observed that not all the evaluation criteria were compatible with the local reality, since in some cases less than 4 selection judgments are met.

Figure 1 shows the four selected criteria: maximum consumption, control of water consumption and leakage, use of saving devices and rainwater reuse systems, which comply with all selection judgments. These are grouped by requirements according to consumption, savings and recycling.

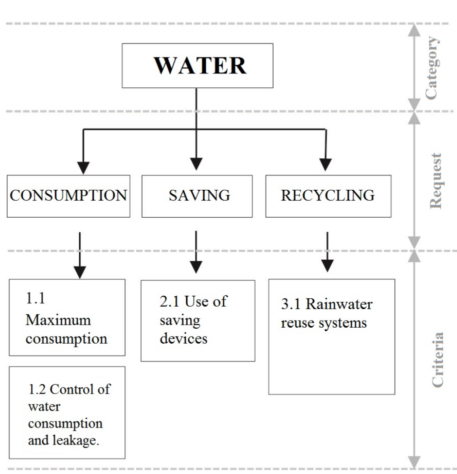

Figure 1. Criterios seleccionados

Table 1. Judgments for the selection of evaluation criteria

Evaluation criteria	Selection judgments 1	2	3	4	5	6
1. Consumption						
BREEAM						
Water meters	x	x	x	x		x
LEED						
Water consumption inside the house	x	x	x			x
GREEN						
Water consumption in sanitary devices	x	x	x	x	x	x
2. Saving						
BREEAM						
Water consumption	x	x	x	x	x	x
Irrigation system	x	x	x	x		x
CASBEE						
Water saved	x	x	x	x	x	x
LEED						
Landscaping	x	x	x	x	x	x
Water savings inside the building	x	x	x	x	x	x
Irrigation system	x	x	x	x	x	x
GREEN						
Water consumption for watering gardens	x	x	x	x	x	x
3. Recycling						
BREAM						
Water recycling	x	x	x	x	x	x
Sustainable water treatment at the site					x	x
Collection of rainwater in artificialized soil	x	x	x	x	x	x
LEED						
Recycle water	x	x	x	x	x	x
VERDE						
Retention of rainwater for reuse	x	x	x	x	x	x
Recovery and reuse of gray water	x	x				x
CASBEE						
Recycling rain water	x	x	x	x	x	x

3.2. Determination of valuation levels

3.2.1. Surveys of 280 homes in the city of Cuenca

The results show that only 24% of households apply a drinking water saving strategy (Table 2).

Table 2. Equipment, devices or systems to save water used at home

Equipment or device	Percentage
Water-saving toilets	6%
Saving devices in the taps	2%
Water-saving washing machine	14%
Water-saving dishwashers	0%
Reuse gray water or rainwater for watering the garden	1%
None	76%
Total	**100%**

Additionally, Table 3 shows that 61% of respondents consider that saving water is important or very important.

Table 3. The importance of a home that saves energy and water; that consumes less resources or causes a minimum impact on the environment for the inhabitants in the city of Cuenca during its construction process

Importance Level	Percentage
Not important	13%
Less important	3%
Indifferent	23%
Important	29%
Very important	32%
Total	**100%**

34% of respondents would be willing to invest in a house with water and energy saving characteristics (Table 4).

Table 4. Would you be willing to invest in a home with the above characteristics?

Provision	Percentage
Yes	34%
No	66%
Total	**100%**

3.2.2. Measurement of water consumption in 10 homes

Results of measurements

The arithmetic mean of the results of the measurements in different uses of the 10 homes is presented in Table 5. It is observed that 54.45% of drinking water consumption is due to sanitary uses, laundry and other uses such as watering gardens, washing yards and cars.

Table 5. Uses of water in homes in the city of Cuenca

Description	Arithmetic media (l)	Percentage %
Total per inhabitant (l/inhabitante/day)	179,508	100
Kitchen	33,531	18,68
Personal hygiene shower	37,386	20,83
Personal hygiene toilets	10,856	6,05
Toilets	50,218	27,98
Laundry and other uses such as watering gardens washing yards and cars	47,518	26,47

Survey results

According to the results of the arithmetic mean applied to the respondents of the ten homes, it is determined that they use the toilet 3.3 times a day (Table 6). This value of perception of use of the toilet is below the actual use, which is 5 times per day on average [35]. As such, this research takes measured data of real use in the households into account.

Table 6. How many times does a member of the family who lives in the household use the toilet?

Household	Daily toilet use
1	3
2	4
3	4
4	4
5	3
6	2
7	5
8	3
9	4
10	1
Arithmetic average	**3,3**

None of the homes surveyed has any system to collect rainwater and 90% would be willing to use rainwater for sanitation, irrigation and cleaning (Table 7. The monthly amount that they would be willing to invest in equipment that allows a sustainable use of water is shown in Table 8.

Table 7. Would you be willing to use rainwater in your home for toilets, irrigation and cleaning purposes?

Availability	Percentage
Sí	90
No	10
Total	**100**

Table 8. Monthly amount that they would be willing to invest in equipment that allows a sustainable use of water

Rank	Percentage
From \$0,00 to \$10,00	50
From \$10,00 to \$20,00	30
From \$20,00 to \$50,00	10
From \$50,00 to \$100,00	0
More than \$100,00	10
Total	**100%**

3.2.3. Drinking water consumption data in Cuenca

Table 9 shows the water consumption of all household connections in Cuenca over a year.

Table 9. Water consumption during 2015 of the households served by ETAPA EP in the city of Cuenca

Month	Total consumption) (m^3	Industrial and commercial consumption (m^3)	Residential consumption (m^3)	Number of residential facilities
dic-15	2 613 187,00	357 176,00	2 256 011,00	104 392,00
nov-15	2 473 961,00	343 162,40	2 130 798,60	104 171,00
oct-15	2 551 035,00	368 922,00	2 182 113,00	104 041,00
sep-15	2 558 923,00	357 506,80	2 201 416,20	103 956,00
ago-15	2 453 018,00	342 898,40	2 110 119,60	103 493,00
jul-15	2 512 488,00	311 477,40	2 201 010,60	105 028,00
jun-15	2 466 598,00	310 049,10	2 156 548,90	104 482,00
may-15	2 556 930,00	308 137,60	2 248 792,40	104 076,00
abr-15	2 774 639,00	274 218,85	2 500 420,15	103 645,00
mar-15	2 657 568,00	257 141,45	2 400 426,55	103 415,00
feb-15	2 752 265,00	260 831,70	2 491 433,30	98 420,00
ene-15	2 760 075,00	261 616,50	2 498 458,50	103 038,00
Total	31 130 687,00	3 753 138,20	27 377 548,80	1 242 157,00
Arithmetic average	2 594 223,92	312 761,52	2 281 462,4	103 513,08

The data shows that the city has an arithmetic mean of 103 513 residential installations. On the other hand, total water consumption is 31 130 687.00 m^3, where residential water consumption represents 27 377 548.80 m3. If the arithmetic mean of the existing facilities is multiplied by 3.73, which corresponds to the average number of inhabitants per household according to the data established by INEC [34], a total of 386 103 people is obtained. Then, if the total residential consumption is divided for the number of people served and transformed into days, an average water consumption of 194.27 l/inhabitant/day is obtained.

In addition, Table 10 shows the variations in water consumption during one year in the ten households. The table shows an arithmetic mean variation of 15.12%, which allows to deduce that, if the variation is greater than this, there may be leaks.

Table 10. Variations of drinking water consumption in housing case studies provided by ETAPA EP

Household	Consumption arithmetic mean (m^3)	Variance	Standard deviation	Variation coefficient in %
1	30,44	23,24	4,82	15,83
2	21,53	62,48	7,9	36,69
3	75,29	96,56	9,83	13,06
4 y 5*	30	10,12	3,18	10,6
6	17,8	1,76	1,33	7,47
7	30,71	21,14	4,6	14,98
8	39,41	23,66	4,86	12,33
9	9,65	2,11	1,45	15,03
10	12,94	1,68	1,3	10,05
Arithmetic average				15,12%

* Houses 4 and 5 share a general meter.

3.2.4. Definition of assessment levels for each evaluation criterion

With the results obtained, three levels of assessment, one basic, one intermediate and one superior, are determined for each of the four evaluation criteria defined in the comparative analysis of international methods, based on Quesada's research (2014) [27].

- **Maximum consumption criterion**

Basic level

The arithmetic mean of drinking water consumption per inhabitant obtained from the measurement of 10 houses is 179.51 l/inhabitant/day (Table 5) and the consumption in the city according to the data of the municipal company during a year is 194.27 l/inhabitant/day. Both numbers are inferior to the Ecuadorian Construction Standard NEC-11 [21], which establishes that household consumption can range between 200 to 350 l/inhabitant/day.

Therefore, given that the values obtained in the case studies and actual consumption are close to 200 l/inhabitant/day, this value is established as a standard for the basic level.

Intermediate level

The surveys carried out in the 280 households show that only 6% use saving toilets (Table 2); the data obtained from the ten households (Table 5) shows that the use of potable water in toilets represents 27.98% of the total consumption.

Therefore, the use of saver toilets with a discharge of 4.8 liters is established as the intermediate level, and considering that a person uses the toilet 5 times a day, it would reflect a consumption of 24 l/inhabitant/day in toilets.

Thus, if the 27.98% consumption by toilets is taken from the total value of 200 l/inhabitant/day, the result is a consumption of 55.96 l compared to the 24 l with the use of a saver toilet, which translates to savings of 31.96 l/inhabitant/day.

The reuse of rainwater adds 40 l in savings (the justification for this data is detailed in the criterion of water reuse), finally obtaining feasible savings of 71.96 l/inhabitant/day. For this reason, a consumption between 160 and 120 l/inhabitant/day is established for the intermediate level.

Superior level

To reach the superior level, it is necessary to demonstrate drinking water consumption of less than 120 l/inhabitant/day per household.

- **Control of water consumption and leakage**

Basic level

It is necessary to establish a leakage control plan, which consists of recording the water consumed, using a meter at the entrance of the household, which enables the generation of a consumption history.

The meter must have the following characteristics: be of multiple jet and comply with the metrological requirements of classes A and B of Resolution 246; 2000 of INMETRO, of MERCOSUR standards NM 212 and ISO 4064. NTE INEN-OIML R 49-1:2009 [29], [36].

Table 10 shows that the arithmetic mean of consumption variation is 15.12%, so it can be said that a variation of more than 15% with respect to the arithmetic average of monthly consumption is an indicator of possible water leaks in the household.

In addition, adequate maintenance must be given to the water facilities, through a plan that indicates the exact place where the pipes are installed. The INEN 1373 standards required for PVC pipe, INEN 2955 and 2956 for thermofusion pipe and other standards for water pipes and fittings must be complied with. Each toilet device must have an angular key or a stopcock, in order to facilitate the maintenance and replacement of the equipment [37].

Therefore, the basic level establishes the use of pipes and sanitary equipment that comply with the aforementioned standards, installed in accordance with technical specifications of each equipment and accessory; in addition, each piece of equipment must have an angular key or a stopcock to facilitate its replacement and maintenance.

The existence of a management plan is also evaluated, which includes:

- a consumption meter that meets the aforementioned characteristics, and
- a monthly record to detect possible leaks.

- **Criteria on the use of saving devices**

Basic level

The basic level is defined in accordance with the stipulations of the local standard NTE INEN 1571: 2011 second revision 2011-07, section 3.1.6.7, for toilets.

The average maximum water consumption per discharge at a pressure of 0.3 MPA should be:

- 6.2 liters per flush for low consumption toilets
- 3.8 liters per flush for low consumption urinals

For saving devices such as faucets and showers with aerators, there is no local standard that establishes an average consumption, so the following evaluation methods are considered:

- Faucets with a maximum flow rate of less than or equal to 5/6 liters at a hydraulic pressure of 0.3 MPa.
- Showers with a maximum flow of less than or equal to 6/9 liters at a hydraulic pressure of 0.3 MPa.

The pressure implemented in the city by ETAPA is continuous service of around 0.5 and 0.7 MPa at the exit of the control meter. From the meter to the supply points, due to the loss of pressure along the path, it can reach the 0.3 MPa that is established for the saving devices.

In the same way, for lack of local regulations on the consumption of water for household appliances, evaluation methods are considered, and a consumption not greater than 40/45 liters per use and for the dishwasher not more than 7/10 liters per use is established for washing machines.

Intermediate level

To reach the intermediate level, in addition to fulfilling the conditions of the basic level, the consumption of water in toilets and urinals must be reduced. The values that are required are taken from the local standard NTE INEN 1571: 2011:

- 4.8 liters per flush for high efficiency toilets
- 1.9 liters per flush for high efficiency urinals

In the case of double-flush toilets, the maximum water consumption should be 4.8 liters per flush on average.

Superior level

For the upper level, it is necessary to comply with the requirements of the intermediate level and demonstrate an improvement in water saving, that is, use devices that have a lower consumption than the ones previously discussed.

- **Criteria for rainwater reuse systems**

Basic level

It is considered that 61% of the people from the 280 households believe in the importance of saving drinking water. In addition, in the ten cases studied, 90% of the owners would be willing to use rainwater in house cleaning, for washing vehicles, and other uses.

Therefore, the basic level contemplates the existence of a rainwater collection system in the household, where the collected water can be used for irrigation, cleaning the house, washing vehicles, and in toilets.

Intermediate level

To determine a maximum consumption range within the intermediate level, the calculation of rainwater supply that could be achieved with the cover of a minimum lot is considered. The formula that is applied is the following:

Supply = 0,8 x effective catchment area x amount of rain [38]

The arithmetic average of constructible area in minimum lots attached to the canton of Cuenca is 71.17 m^2 (Table 11) according to data taken from the ordenance plan [39]. Therefore, a land area land of 120 m^2 is established as a minimum lot, where a continuous building can be located with a frontal and posterior setback of 3 m, since it is the type of implementation with minimum setbacks in the city. Considering this lot, a roof with a length of eaves of 0.6 m is proposed, respecting the setbacks, with which a total cover area of 85.4 m^2 would be available.

Table 11. Characteristics of minimum lots in sectors of continuous typology, taken from the Ordenance Plan of the Cuenca canton

Minimum front	**Minimum area (m^2)**	**Front setback (m)**	**Back setback (m)**	**Buildable area (m^2)**
6	75	0	3	57
7	90	3	3	48
7	100	3	3	58
7	120	3	3	78
9	150	5	3	78
9	180	5	3	108
Arithmetic average				**71,17**

Regarding the amount of rainwater, Table 12 shows the month by month arithmetic mean of rainfall in Cuenca. These data correspond to the records from the Directorate of Aviation from the last 30 years [40]. The arithmetic mean of rainfall per year is 869.9 mm, which means that an amount of 869.9 liters of rainwater per year can be captured per square meter of surface area.

Table 12. Arithmetic average of the monthly results of rainfall in mm/m2 in the city of Cuenca from 1977 to 2015. Taken from the General Directorate of Civil Aviation.

Month	**Arithmetic average**
January	62,4 mm
February	85,9 mm
March	113,7 mm
April	120 mm
May	85,5 mm
June	44,9 mm
July	29,8 mm
August	22,3 mm
September	48,5 mm
October	92,5 mm
November	84,2 mm
December	80,5 mm
Total	**869,9 mm**
Arithmetic average	**72,49 mm**

Applying the formula, a supply of 4.26 m^3 is obtained for the month of January:

$$\begin{aligned} Supply &= 0,8 \times 85,4m^2 \times 62,4mm \\ &= 4,26m^2 \end{aligned}$$

Table 13 shows the amounts of rainwater that could be collected monthly in the partial supply column. The following column shows the accumulated amount per month, and in the last column, the difference in the collection with respect to the previous month is determined. As seen, it is possible to capture a total of 59.45 m3 of rain water per year. If this data is divided for 3.73 inhabitants per household, and it is converted to l/inhabitant/day, it is determined that 43.66 l/inhabitant/day of rainwater can be used. Therefore, a daily rainwater supply of 40 l/inhabitant/day can be established. This number corresponds to 20% of the total water demand of 200 l/inhabitant/day, and represents 4.5 m^3 of water that could be used in toilets, for laundry and for house cleaning.

If the same example of minimum cover is incorporated as a collection area in the laundry yard and garage zones, an area of 21 m^2 of catchment would be increased, so that a total of 55 l/inhabitant/day of rainwater could be incorporated.

Therefore, the intermediate level is defined as the use of between 40 l/inhabitant/day and 55 l/inhabitant/day of rainwater for laundry, irrigation of gardens, household cleaning and toilets.

Superior level

At the superior level, the household should have a rainwater catchment system, which can incorporate an amount greater than 55 l/inhabitant/day for use in laundry, garden irrigation, household cleaning and toilets.

Table 13. Calculation of the catchment volume

Month	Arithmetic mean (mm)	Supply (m³) Partial	Supply (m³) Acumulated	Demand (m³) Partial	Demand (m³) Acumulated	Difference (m³)
January	62,4	4,26	4,26	4,5	4,5	-0,24
February	85,9	5,87	10,13	4,5	9	1,13
March	113,7	7,77	17,9	4,5	13,5	4,4
April	120	8,2	26,1	4,5	18	8,1
May	85,5	5,84	31,94	4,5	22,5	9,44
June	44,9	3,07	35,01	4,5	27	8,01
July	29,8	2,04	37,05	4,5	31,5	5,55
August	22,3	1,52	38,57	4,5	36	2,57
September	48,5	3,31	41,88	4,5	40,5	1,38
October	92,5	6,32	48,2	4,5	45	3,2
November	84,2	5,75	53,95	4,5	49,5	4,45
December	80,5	5,5	59,45	4,5	54	5,45

4. Conclusions

This research demonstrates the possibility of reducing the consumption of drinking water up to 30% in homes in the city of Cuenca, without affecting the quality of life of its inhabitants, through the application of sustainable strategies.

Projecting the percentage of savings in consumption (30%) to the entire city of Cuenca, the current consumption of 27 377 549 m^3 (Table **??**) would be reduced to 19,164,284 m^3, a situation that would ensure that the existing infrastructure provides potable water service for more years than expected, avoiding short-term costs due to new infrastructures and consequent damage to the ecosystem.

Making an economic valuation, a consumption of 200 l/inhabitant/day (basic level) for a house of four inhabitants, equals an average of 24 m^3 at a rate of $0.60 per m^3 plus $3.00 charge, resulting in a cost of $17.40. However, if the requirements of intermediate level of the analyzed criteria are met, consumption would be reduced in the worst case to 140 l/inhabitant/day, with which a family of four members would consume an average of 16.8 m^3, generating a cost of $9.72, which represents savings of $7.68 per month, equivalent to 44%.

Finally, the present study could be taken as a reference to establish a reduction of water consumption standards in the local norm, since it was observed that in Cuenca consumption is 194.27 l/inhabitant/day, a value relatively below that established by the national norm. If the savings resulting from the use of efficient toilets is added, taking into account that the use of this type of toilets is more and more common, this would result in an approximate consumption of 162 l/inhabitant/day, a value which is 20% below the national standard.

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