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A systemic methodology for the reduction of water consumption in rural areas

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Abstract

Purpose – This study aims to present a systemic methodological proposal for the reduction of water consumption in rural areas, based on participatory tools.

Design/methodology/approach – A theoretical framework was constructed based on the importance of stakeholders' participation in the adequate use of the hydro resources, technologies to save water and modeling the adoption of possible water-saving technologies. After that, it was proposed a methodology for the reduction of water consumption in rural areas. This methodology was tested in a participatory study case, including the system dynamics model.

Findings – This study proposes a participatory systemic methodology – PAWAME – participation-water waste-adoption-model-empowerment, which consists of four steps: identify stakeholders and the activities related with the waste of water in the study site and establish their values, measure the adoption that the technology would have based on the awareness generated, relate in a model the variables of the water-consuming activities and the variables of the technology and its adoption to analyze possible future behaviors and empowerment of the technology to reduce water consumption.

Practical implications – In Colombia, part of the population has the wrong perception about the abundance of the hydro resource, and for this reason, people do not use water in a correct way. The inclusion of a participatory systemic methodology was fundamental to apprehend the dynamic aspects of users' behaviors, as well as of the management of the water resource. The model addresses the complexity of the situation, allowing exploring future scenarios of environmental protection.

Originality/value – This study advances the knowledge in participatory systemic methodology to design and adopt a local technology to save water.

Keywords Stakeholders, Participation, Water consumption

Paper type Research paper

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Introduction

Water is a limited and irreplaceable resource, key for human well-being, essential to sustain life (Singh *et al.*, 2010). One of the biggest problems that affects societies is the potable water supplying (catchment, treatment and delivering), especially in some regions of Colombia. A study from the Department of Protection of Citizens' Rights of Colombia shows that 5.4 from 13.6 million who live in rural areas do not have access to water supply systems, 8.2 million do not have sanitary units or sewage and just 1.5 million have access to potable water. In Colombia, lack of these services generates health problems such as being a representative cause of infant mortality and morbidity. Between 2004 and 2006, 20,000 children died because of diseases caused by poor water quality.

On the other hand, part of the population has the wrong perception about the abundance of the hydro resource, in particular, those in rural areas which have proximity to the paramos, because those provide around 70 per cent of the water of the big cities (Instituto Alexander van Humboldt, 2011).

To tackle the above problem, a group of professors and students from different universities co-designed together with the community a methodology that contemplates the generation of awareness and creation of a technology to contribute to the reduction of water consumption in the rural area and contribute with the quality of life of different communities.

The purpose of this article is to present the methodology that was co-designed and to show the results of its implementation in a study case. Accordingly, the structure of this paper is as follows:

- A theoretical framework is presented in which is highlighted the importance of the participation of stakeholders, the mechanisms and technologies that contribute to saving water and the way in which adopting a certain technology can be modeled.
- An analysis of the theoretical implications of this framework.
- Systemic methodology propose.
- The case study of the Reserva Encenillo is analyzed.
- Finally, the main conclusions about this application are presented, along with suggestions for future works.

Theoretical framework

In this section, a literature review is presented in which is highlighted the importance of the participation of stakeholders to achieve solutions for the water waste reduction. Also, are presented mechanisms and technologies that contribute to saving water and the way in which adopting a certain technology can be modeled to analyze the results of its implementation.

Stakeholder participation in water-consumption experiences

To develop a proposal where adequate use of the hydro resource is generated, it is necessary to dvelop an interest in designing and maintaining an optimal management process. In consequence, a bibliographical review is carried out to understand how different stakeholders can generate a contribution in this kind of processes. As Tweneboah (2016) uphold, deciding which direction to go requires stakeholder participation and consensus.

Linkov *et al.* (2009) present a model where the heart of the hydro management is brainstorming and the development of workshops so that those making decisions make them in the moment of the design itself. Bates and De Roo (2000) argue about the need for a permanent articulation between those called decision-makers, meanwhile Morss *et al.* (2005) emphasize in the articulation between those who model and those who make decisions. Based on the above, methodological proposals that include participation of different stakeholders have been built to generate interactive models.

In that sense, the authors of previous articles emphasize in the relevance, not only of the technical solution, but also of the interactivity from the stakeholders in the design of the whole model. This model was called the interactive water simulation model, designed by researchers of Delft University of Technology. This model includes:

(1) *understanding* the needs of the stakeholders who manage water, and therefore understand the technical requirements of a proposal using semi-structured interviews; and

(2) reaching *technical modeling* based on the needs and variables that include simulations, testing and visualization of results.

Fratini *et al.* (2012) add a fundamental financial analysis that includes the description of current practices in urban water management and the identification of barriers and opportunities for sustainable transactions. This framework implies:

(1) in the first phase, a macroeconomic research based on existing literature should be made (benchmarking)

(2) stakeholder analysis is carried out based on a recollection of qualitative data. The objective is to collect micro-knowledge to give a first description of the situation that the companies are studying. Finally

(3) the identification of patterns that should be considered and used within the meso dimension.

What is relevant of these proposals is that the selected variables for simulation must have an impact over the economic, social and environmental setting of all interested parties, and that the latter strengthens any hydro resource optimization model that may be proposed (Jiménez and Pérez-Foguet, 2011).

Technologies and mechanisms identified to achieve water savings

There are different technologies that could be implemented by communities to contribute with water savings. One kind of technology is the one that allows obtaining water from sources other than rivers or lakes such as rainwater gathering or fog collection systems. These technologies are of major help for the communities that lack access to water from an aqueduct or do not have rivers or brooks nearby from which they can obtain water to satisfy their needs. It should be considered that not all zones have a high precipitation or fog index, so this type of technologies do not apply for all contexts (Pascual and Naranjo, 2011).

Other technology is the cold-water diverting systems which allows to redirect water from the shower until it starts to warm up (Castelazo, 2014). The faucet aerators are devices that can be screwed in the mouths of the faucets to incorporate air to the jet of water, and thus reduce the consumption of water without diminishing the quality, saving more than 40 per cent of water (Agenda 21 Local de Salamanca, 2010). Water meters are devices that count the water that passes through them, helping thus to raise awareness, and in some cases, decrease the regular consumption of water. In a dry toilet, feces are separated from urine, urine can be treated along with graywater or stored for later use in irrigation, and feces can be treated by dehydration, composting or anaerobic fermentation and serve as a fertilizer (Conant and Fadem, 2012).

This system of dry toilets has been implemented in several parts of the world such as Ecovillage El Romero in La Serena, Chile (Ecoaldea EL ROMERO, 2014). Another case in Chile is the Ecocenter Eluwn, which is being developed since 2004 in Loica (Commune of San Pedro, Province of Melipilla), just 110 km from Santiago de Chile (Ecocentro Eluwn, 2018). In Colombia, there are places where this system has been implemented; such is the case of Palomino, Guajira.

There are other technologies which do not require the use of infrastructure but are related with changes in the behavior of the user, adjustments in value, social and individual aspirations, financial incentives, ethical and moral imperatives and changes in government and laws/regulations (Roccaro *et al.*, 2011).

Modeling of the adoption of a technology

Having reviewed the experiences of stakeholders' participation in water management, and once a review of the technologies that allow water saving in rural and semi-rural areas has been made, this section intends to introduce a way for modeling the adoption of a technology to achieve such savings. Modeling is important because, as Zhang *et al.* (2010) says, the water resources system is characterized by non-linearity and multi-way of feedback.

Forrester, creator of the system dynamics, highlights the importance of describing the way in which a system variable influences the others through time. A model of dynamics can provide information at lower cost and enable the achievement of a faster knowledge of the conditions that are not observed in real life. In this case, system dynamics is a tool that leads to identify all the variables that affect other variables and to what extent they do it (Forrester, 1987). As Salhieh and Singh (2003) said, an advantage in adopting system dynamics as an analytical tool is that it displays the many interrelationships that influence the behavior of a complex system. A system is defined as "a set of parts in interaction which satisfy a certain objective" (Tarride, 2006). Besides, system dynamics modeling helps in bridging organizational hindrances to their change, if the change is required (Ambroz and Derencin, 2010).

The relations between the water infrastructure system, its environment and the social system become of foremost importance because, whenever a certain technology is being considered for being used, it should be considered the role that people play in the process, because they are the ones that generate awareness and make action adopting decisions based on it. Hamid *et al.* (2017) support that changes in behavior are brought through raising awareness regarding an issue and by fostering an appropriate attitude. Etzion (2014) proposes that it is not only necessary to decide whether awareness was generated or not, but also if once awareness is generated, action was adopted. In this manner, the adoption decision also depends on the benefits that the person sees in the action when he/she evaluates if these are greater than the costs. Additionally, it is important to highlight that the awareness and adoption decision can change, and one of the factors that influence this is the adoption decision that others take. To the extent that the number of people adopting the action increases, it will generate greater adoption by other people.

A particular model, used by Sterman, is the Bass model, proposed by Frank Bass, which is one of the most relevant models to describe and forecast the diffusion of innovation. The Bass model is about the adoption and dissemination of new products and technologies. This model allows to estimate the number of consumers who will adopt (begin to use) a new product or technology over time. There are two types of adopters, some are considered innovators who dare to adopt a technology independently from what the rest of the society does and others are the so-called imitators who begin adopting a technology once they observe that there are others already using it (Sterman, 2000). Based on the aforementioned, it can be sustained that both types of adopters are two types of stakeholder with different interests, which makes this Bass model fit to model pluralist systems and in particular, systems where analyzing the adoption of a technology is wanted. Figure 1 shows the diagram of the Bass model.

The Bass model is defined as follows (Sterman, 2000):

$$AR = aP + ciPA/N$$

Where:

AR = number of consumers who adopt the product in the moment t;

A = persons who have adopted the technology;

N = total population;

i = imitation coefficient. This is the probability that an imitator adopts the new product by having contact with an adopter. This coefficient reflects the effect that already existing consumers can produce over potential consumers;

c = contact rate between potential adopters and adopters;

a = coefficient of innovation. This is the probability that an innovator buys or adopts the product in a *t* period; and

P = potential persons to adopt.

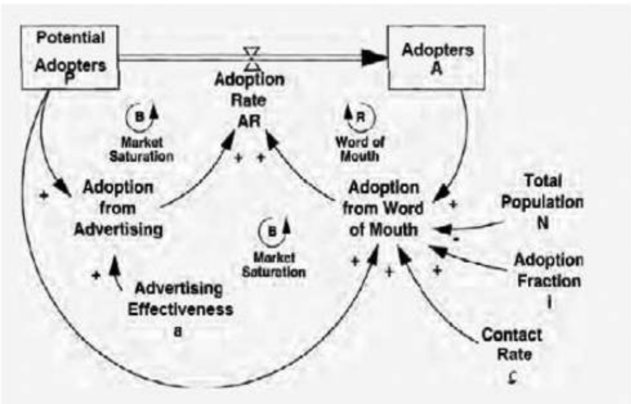
Based on the above, it can be said that a high value in "a" indicates that the new product will be adopted rapidly even though it has a low probability of imitation, whereas a low level of "a" will make adoption slower even though "i" has a high value, because imitators have a small group of innovators to copy. The number of imitators grows first at an increasing rate and later at a decreasing rate until it reaches a peak of adopters (Weissmann, 2008).

Theoretical framework analysis

From the analysis of the previous theoretical framework, two extensive ideas can be concluded:

The intervention methodology should be based on agents of change in the communities

The intervention of different stakeholders is necessary for the proper water use in different contexts. In the theoretical framework, there is evidence about the relevance of



Source: Sterman (2000)

Figure 1. Bass model of diffusion

the intervention of different interested parties in the management of such a valuable resource as it is the hydro one. The question that will remain is, if the situation was not felt as an immediate and of their own problem, would it be included in the main problems to be solved? In the best of cases, it would. However, that would not necessarily guarantee learning and feasible process permanence in the long term. In that sense, why do not think about designing a participatory methodology where learning can be the fundamental scenario for water protection? To include the new generations of the communities as active managers of the maintenance of natural resources supported in the learning process inside the schools, Colombia has to follow South Africa's steps, where water conservation is already being integrated into the teaching curriculum, and further publicized and implemented within surrounding communities (Oliver and Brümmer, 2007).

Technologies should be combined with social competences in the communities.
It is not enough to identify the shortage of water. It is necessary that the different agents in the community understand in a systemic manner the problem associated with such shortage. In that sense, it is necessary to identify the direct and indirect variables to make long-term decisions to generate innovative savings and optimization solutions. Furthermore, the adoption of the innovative technology is relevant if the different agents in the community understand that the decisions made will have an impact over many variables. Therefore, such adoption of technologies must be based in systems where each agent understands how their own decision makes a sense over the optimization of the system as a whole. To facilitate this, it is possible to relate all the variables involved in a diagram or a model to see how changing of a variable affects other variables.

Methodological proposal for the reduction of water consumption

Based on the problem of water shortage presented in the introduction and the conclusions obtained from the analysis of the theoretical framework, in this setion is proposed the methodology – PAWAME – participation-**w**ater **w**aste-**a**doption-**m**odel-**e**mpowerment. PAWAME is a methodology that contributes to the reduction of water consumption in rural areas through the introduction of a technology and awareness generation. PAWAME can be considered as a participatory methodology because it considers the opinion of the different stakeholders of the system. Besides, PAWAME is a systemic tool because as Bunge (as cited in Johannessen, 2012) says, concerns the study of social systems and the relationships within and between them and how it relates to the outside world. In Figure 2, the graphic of the proposal is presented, and in Table I, each step of this proposal is explained.

The following is a detailed description of each of the steps of the PAWAME methodology.

Participation

Based on the need of build solutions for the water waste in a collective way, it is necessary to involve in the proposed methodology permanent activities of participation. It is important that the community participates during the evaluation of their problem and in the implementation of projects focused on natural resources and their sustainability. This method is appropriated to work with rural communities because it helps the emergency of sustainable solutions, generates a progressive change in the society, increases the community participation degree and allows feedback and adjusts to the proposes. Besides, systemic participation allows organizations to contribute to the community as part as their social responsibility programs, opening to real problems and

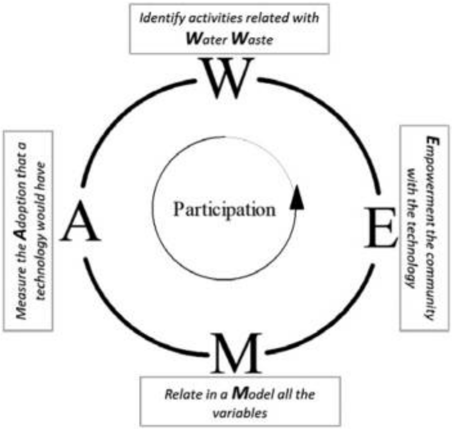


Figure 2.
PAWAME methodology structure

Table I.
PAWAME methodology outline

Stage	Description
PW	Identify stakeholders and the activities related with the waste of water in the study site and establish their values
PA	Measure the adoption that the technology would have based on the awareness generated
PM	Relate in a model the variables of the water-consuming activities, the variables of the technology and its adoption to analyze possible future behaviors
PE	Empowerment with the technology to reduce water consumption

search real solutions and generate educational and investigative process that involves all the stakeholders (Ramírez *et al.*, 2011). Consequently, each letter of the methodology is joined by "P" of participation.

PW – identify stakeholders and the activities related with the waste of water in the study site and establish their values

In this stage, the aim is to identify the main stakeholders, and together with them, list all the activities in which water is consumed in the study site (toilet, shower, bathroom sink, dishwasher sink, agriculture, livestock, etc.). After obtaining a list of activities, the variables that influence each activity are identified, and values to each of these variables are assigned. At this point, all the different water flows, such as the dishwasher, sink and shower, are gauged, if applicable. It is recommended to use the methodology described below in methodology to calculate amount of water spent to calculate the amount of water spent on the different activities.

To gauge sink, dishwasher and shower, perform the following steps:

- Grab a measuring cup and a stopwatch.
- Open the faucet and count the time it takes to fill the container.
- Calculate the container volume.
- Count the time it takes a sample of persons to wash their hands.
- Calculate the average time a person takes in washing their hands.
- Calculate the amount of water being spent with the following formula:

$$\textit{Water spent per person}\,[\textit{volume}] = \textit{container volume} \times \frac{\textit{average time a person washes hands}}{\textit{time in which the container is filled}}$$

To determine the volume of water spent per flush in a toilet, perform the following steps:

- Measure the area of the base of the toilet tank.
- Measure the initial height of the water before flushing.
- Measure the height of the water after flushing.
- Calculate the volume of water spent per flush with the following formula:

$$\textit{Water spent per flush}\,[\textit{volume}] = \textit{tank area} * (\textit{water height before flushing} - \textit{water height after flushing})$$

To calculate water spent in agriculture and livestock, perform the following steps:

- Measure the dimension of the tank used for irrigating the crops or livestock.
- Count the number of tanks used to feed the crop or livestock.
- Calculate the volume of water spent in irrigating crops and livestock with the following formula:

$$\textit{Water spent in irrigation or livestock}\,[\textit{volume}] = \textit{volume of the tank} * \textit{number of tanks used in irrigation or livestock}$$

PA – measure the adoption that the technology would have based on the awareness generated. Through workshops and focus groups with stakeholders, select the technologies that are appropriate for the community considering at least the following criteria:

- *Replicability*: technology must be able to be implemented in different places.
- *Low cost*: the elements that make up the technology should be low cost, as well as its maintenance.
- *Easy to build*: technology should allow the community to get involved in its construction.
- *Easy installation*: the technology must be able to be adapted to the housing conditions of the communities of the region and must be able to be installed by the same community.

It is recommended to make a table with the possible technologies and their criteria which will be used to select the most appropriate ones (Table II). A certain weight should be applied to each criterion based on the opinions of the stakeholders, and therefore it will be possible to determine which technology to implement. Doing this comparison is important to

Technology	Replicate	Low cost	Easy to build	Easy installation	. . .
Technology #1 *(Example)*	Yes	Yes	Yes	No	. . .
Technology #2	. . .	. . .	. . .	. . .	. . .
Technology #3	. . .	. . .	. . .	. . .	. . .
Technology #4	. . .	. . .	. . .	. . .	. . .
Technology #5	. . .	. . .	. . .	. . .	. . .
. . .	. . .	. . .	. . .	. . .	. . .

Table II. Competition of technologies according to criteria make sure that the technology that selected is appropriate in the context, considering the expertise of the community members and the resources that they have.

In this step, the adoption of the selected technology and awareness of savings are determined through surveys. These surveys can be formulated with two questions, one initial and one final, each one with two options of responses established, from which one option must be chosen. The reason for choosing this type of surveys is that they allow eliminating the ambiguity factor and their use requires less time. Tables III and IV show examples of answer options for different technologies, but the survey should be made considering only the technology selected in Step 2.

The initial question is: *Which of the following options do you prefer? Mark with an "x"*.

The final question: *Think about the consequences that may carry the choice you have made in the initial question and answer. Which of the following options do you choose? Mark with an "X"*.

As it is shown in Tables III and IV, for each question, there are two options for answer. For the case of the initial question, marking option A indicates that there is an initial

Technology	Option A	Option B
Dry toilets	Use a dry toilet	Use a conventional toilet
Rainwater gathering system	Collect and use rainwater	Not collecting rainwater and using tap water
Cold-water diverting systems in showers	Install a cold-water diverting system in showers	Let cold water run in showers until it is hot
Faucet aerators	Install faucet aerators	Keep faucets without aerators
Water meters	Have water meters to keep track of consumption	Not having water meters to not worrying about consumption
Fog collection systems	Use water harvested in a fog catcher	Use tap water

Table III. Initial question to measure the adoption of the initial technology

Technology	Option A	Option B
Dry toilets	Use dry toilet + have enough water in 10 years to take a shower daily	Use conventional toilet + not having enough water in 10 years to take a shower daily
Rainwater gathering system	Collect and use rainwater + have enough water in 10 years to take a shower daily	Not collecting rainwater and using tap water + not having enough water in 10 years to take a shower daily
Cold-water diverting systems in showers	Install a cold-water redirection system in showers + have enough water in 10 years to take a shower daily	Let cold water run in showers until it is hot + not having enough water in 10 years to take a shower daily
Faucet aerators	Install faucet aerators + have enough water in 10 years to take a shower daily	Keep faucets without aerators + not having enough water in 10 years to take a shower daily
Water meters	Have water meters to keep track of consumption + have enough water in 10 years to take a shower daily	Not having water meters to not worrying about consumption + not having enough water in 10 years to take a shower daily
Fog collection systems	Use water harvested in a fog catcher + have enough water in 10 years to take a shower daily	Using tap water + not having enough water in 10 years to take a shower daily

Table IV. Final question to measure the adoption of the initial technology adoption of the technology, while marking option B shows no initial adoption of the technology. In the case of the final question, marking option A indicates awareness of saving, while marking option B shows a low saving awareness.

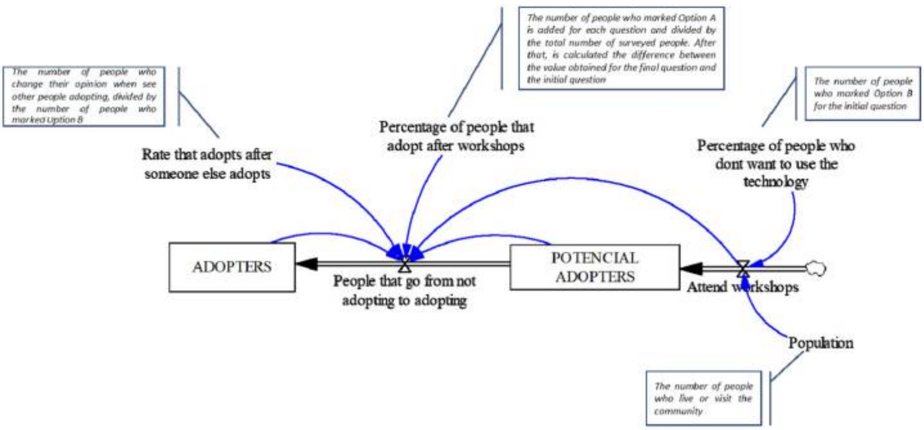
After applying the questions, the number of people who marked option A is added for each question and divided by the total number of surveyed people. The difference between the value obtained for the final question and the initial question, multiplied by 100, is considered the percentage of increase of awareness in the community after knowing the possible consequences between whether adopting the technology or not.

PM – relate in a model the variables of the water-consuming activities and the variables of the technology and its adoption to analyze possible future behaviors

Having identified the activities related with the water expenditure, the appropriate technology for reduction in water consumption, and the adoption that this would have, the model can begin to be developed using system dynamics. It is recommended to use the model of Figure 3, based on the Bass model, to model the adoption of the technology. This model was constructed in the software Vensim, whch is a free modeling software. It is important that stakeholders who have access to the internet download the software from http://vensim.com/free-download/http://vensim.com/free-download/ and make the model, following the instructions presented at http://vensim.com/building-a-simple-vensim-model/. Other software to create system dynamics models also can be used.

PE – empowerment of the technology to reduce water consumption.

After the values of the variables were introduced in the model, the amount of water that could be saved if the technology is assessed. Then, there are some questions that the community and the users should answer to begin the self-building process:



Notes: ***Attend_workshops*** *= Population * percentage_of_people_who_dont_want_to_use_the_technology*; ***People_that_go_from_not_adopting_to_adopting*** *= POTENTIAL_ADOPTERS * Percentage_of_people_that_adopt after_workshops + (ADOPTERS/Attend_workshops) * rate_that_adopts_after_someone_else_adopts * POTENTIAL_ADOPTERS*; ***Percentage_of_people_that_adopt_after_workshops*** *= Percentage_of_people_that_develop_awareness_through_workshops * Percentage_of_people_that_adopt_after_developing_awareness*

Figure 3.
Model for adoption of the technology

- Is it significant and sufficient the amount of water saved?
- Do we think that this kind of technologies help to reduce water consumption? Why?
- What materials do we need to start building the technology?
- Do we have some of the materials that we need to build the technology? Where are they? How can we get them if we do not have them?
- When and how are we going to start technology building?

Once the technology has been built, it should be overseen and monitored. For this, some of the questions that should be answered to self-evaluate the process are as follows:

- What kind of lessons do you think that a process like that leaves to the community?
- Have we used the technology? Why?
- Do we consider that these kinds of technologies are easy to replicate?
- After the building experience, have we made concrete actions which permit the water reduction? Has the technology building process contributed in the design and implementation of these actions?

Application case

The methodological proposal was applied as a study case in Reserva el Encenillo located in the Guasca municipality, in the Guavio province in Cundinamarca. The Guavio province comprises the municipalities of Guasca, Gachetá, Ubalá, Gachalá, Junín, Guatavita, La Calera and Gama. It is a region that has on its surface hydro tributaries and paramos. This territory supplies 70 per cent of the water consumed in Bogotá and 20 per cent of the energy of the country (Cámara de Comercio de Bogotá, 2010). This fact leads part of the population to mistakenly assume that there is an abundance of the hydro resource, which is not the case due to factors such as the climate change and unregulated economic development that has a negative impact on the hydro resources of these regions and endangers its hydro sustainability (IDEAM, 2014).

Reserva el Encenillo is a biological reservoir that seeks to preserve the Encenillo woods, as well as their fauna and flora, particularly some bird and vegetal species, which are unique to the region. The reservoir is located in the Pueblo Viejo sector, in the vereda[1] La Trinidad of the Guasca municipality on the Cundinamarca department. It covers an area of 18,679 hectares, it has an altitude of 2,800 to 3,200 MAMSL, and temperatures ranging between 4°C and 21°C (Fundación Natura de Colombia, 2016).

The reservoir has a visitors center and an administrative headquarters with auditorium, bathroom facilities, dining area and a small eco store with souvenirs from Encenillo. It also has six walking paths, camping zone, carries out several activities such as bird watching, company's events, environmental education and lectures on biodiversity and hydro resources conservation, among others. If an activity requires water, it is gathered from the nearby springs, and they do not pay a significant amount for its use (Fundación Natura de Colombia, 2016).

Reserva el Encenillo was interested in engaging in water-saving practices to be consistent with its mission and with the lectures offered about the proper use of the hydro resource. They did not have any kind of tools that allowed them to measure the quantity of water they were using, and they thought that this type of tool could generate a positive impact regarding the reduction of water consumption and the awareness of the visitors.

Specifically, the goal was to make Reserva Encenillo became a space for the students, teachers and community in general to be acquainted with the technology, create awareness about the importance of the correct use of water and start acting according to these using technologies which reduce water consumption. In the study case, it was working with 1,500 students from Cundinamarca who were part of Strengthening of the Community's Management of the Hydro Resource Project of Gobernación de Cundinamarca (Cundinamarca Governorate).

Below, the development of the methodology is described in detail.

PW – identify stakeholders and the activities related with the waste of water in the study site and establish their values

As Hesamamiri and Bourouni (2016) mention, to model a system, an analyst should start by defining the problem or the issue at hand and identifying the scope, the boundaries of the study and the stakeholders (Table V). Initially, by means of interviewing an employee of the reservoir and the person in charge of it, the activities of the reservoir involving water consumption were identified; afterward, the variables that affect these activities were identified, and their values were calculated in a participatory way with the reservoir's members. Table VI presents this information along with the measurement method.

PA – measure the adoption that the technology would have based on the awareness generated

Out of the technologies for reducing the consumption of water proposed in the theoretical framework, dry toilet technology was chosen in the study case because in this particular case, all the criteria had the same degree of importance for the stakeholders. This technology (like the rainwater gathering and the fog collection systems) fulfilled all the relevant criteria for the implementation of a technology in a rural area (Table VII). It is important to mention that, for completing the comparison table, was taken in to account the opinion of the stakeholders and the community.

The reason that the dry toilets system was chosen over the rain water gathering and the fog collection systems is that, among the three systems, this was the only one that leads to a reduction of water consumption because, as it was explained before, it does not use water for discharge. Hence, it generates a water consumption reduction of approximately 3,536 liters per month, assuming that all the visitors use this toilet and taking as reference the 2014 monthly average number of visitors, 325 people:

$$\textit{Water used per toilet per person} = \textit{Water used per flush}$$

$$* \textit{Average number of times a person uses the toilet during the day}$$

$$* \textit{Average number of person in a month} = 5.44\frac{l}{flush} * 2\frac{flushes}{person} * 325\frac{people}{month} = \frac{3536\ l}{month}$$

Table V. Water expenditure activities in the Encenillo reservoir

	Actors
1	Gobernación de Cundinamarca
3	Administrator of Reserva Encenillo – Fundación Natura member
4	Employee of the reservoir
5	1,500 students of secondary education institutes from Cundinamarca
6	Teachers of secondary education institutes from Cundinamarca
7	Professors and students of Universidad de los Andes and Universidad Minuto de Dios
8	Funcener (foundation with experience in the field of renewable energies)

Activity	Variable	Units	Value	Measurement method
Crops irrigation	Water used per crop	Liters/crop	10	Interview with an employee from Reserva Encenillo
	Number of crops	Crops	1	Interview with an employee from Encenillo Reservoir
Cleaning	Water used in cleaning	Liters/ cleaning	98	Volume measured after using the storage tank
	Number of cleanings	Cleanings/ month	8	Interview with an employee from Reserva Encenillo
Cattle feeding	Water consumed per animal	Liters/day. Animal	80	Interview with an employee from Reserva Encenillo
	Number of animals	Animals	60	Interview with an employee from Reserva Encenillo
Toilet flushing	Water used per toilet flush	Liters/flush	5,44	Measurement of the volume of water used per flush through the methodology proposed in the design stage
	Average number of flushes per person	Flushes/ person	2	Observation during a visit to the Reserva Encenillo
	Average number of visitors	Visitors/ month	325	2014 data supplied by the Fundación Natura
Handwashing	Average time to wash hands per person	Minutes/ person	0.16	Times measured in the Reserva Encenillo during a visit from university students
	Water consumed per time using the sink	Liters/ minute	1,98	Bathroom sink flow rate according to the methodology proposed in the design stage
	Average number of visitors	Persons/ month	325	2014 data supplied by the Fundación Natura
Shower	Average time in the shower per person	Minutes/ person	10	Supposition based on observation
	Water consumed per time in the shower	Liters/ minute	2,16	Shower flow rate according to the methodology proposed in the design stage
	Average number of visitors	Persons/ month	325	2014 data supplied by the Fundación Natura
	Average percentage of visitors that stay overnight	NA	0.05	Interview with an employee from Reserva Encenillo
	Time that cold water comes out before the hot water comes out	Seconds	10	Times measured in the Reserva Encenillo
Dish washing	Time the water faucet is turned on for washing dishes in a day	Minutes	15	Interview with an employee from Reserva Encenillo
	Water used for washing dishes per time the water faucet is turned on	Liters/ minutes	3,36	Kitchen sink flow rate according to the methodology proposed in the design stage

Table VI.
Water expenditure activities in Reserva Encenillo

Based on the Technologies Assessment for Provision of Essential Services in Institutional Housing report Alcaldía Mayor de Bogotá (2010), the different scenarios proposed were evaluated to determine which one presented the best toilet proposal for implementation. The scenario number five was chosen because:

(1) it does not use water for the evacuation of the excreta;
(2) a disposal in situ of the excreta is considered; and
(3) there are conditions suitable for the use of the soil for graywater treatment

Hence, it was decided that the most appropriate toilet technology to develop in the Reserva el Encenillo was a dry toilet similar to a VIP latrine (ventilated improved pit). This type of latrine uses a ventilation tube to prevent foul odors, and it is not expensive, and it is easy to build. However, the technology that was to be implemented was not the latrine but a dry toilet because, unlike the latrines, dry toilets allow for a separation of feces and urine, which prevents foul odors and permits to use afterward the urine as fertilizer and the feces as compost.

To assess the average adoption among the community, a sample of 150 students involved in the Strengthening of the Community's Management of the Hydro Resource Project was taken into consideration; this sample corresponds to 10 per cent of the total of participants. In total, 90 students were asked to answer the two questions related to the dry toilet technology (Tables III and IV). The results obtained are shown in Figure 4.

Regarding the initial question, Figure 4 shows that, in the beginning, 21 per cent of the families surveyed preferred the dry toilet, and that this percentage increased to 79 per cent (an increase of 58 per cent) after they knew that this type of toilet may result in an improved water supply in the future, in comparison with the conventional toilet. Based on these particular awareness results, it can be argued that, through a training process that informs of the consequences of the wrong management the hydro resource, it achieved an increase in the water-saving awareness and the adoption of the technology which permits it.

PM – relate in a model the variables of the water-consuming activities and the variables of the technology and its adoption to analyze possible future behaviors

To relate the variables of the water-consuming activities to the variable of the adoption of the technology (Table VIII) and the variable of total water consumption, and to understand

Table VII. Technologies and criteria in the study case

Technology	Replicate	Low cost	Easy to build	Easy installation
Dry toilets	Yes	Yes	Yes	Yes
Rain water gathering system	Yes	Yes	Yes	Yes
Shower cold-water diverter system	Yes	Yes	No	Yes
Faucet aerators	Yes	Yes	No	Yes
Water meters or counters	Yes	Yes	No	Yes
Fog collection systems	Yes	Yes	Yes	Yes

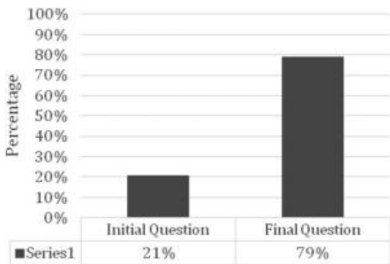


Figure 4. Water-saving awareness regarding the use of dry toilet

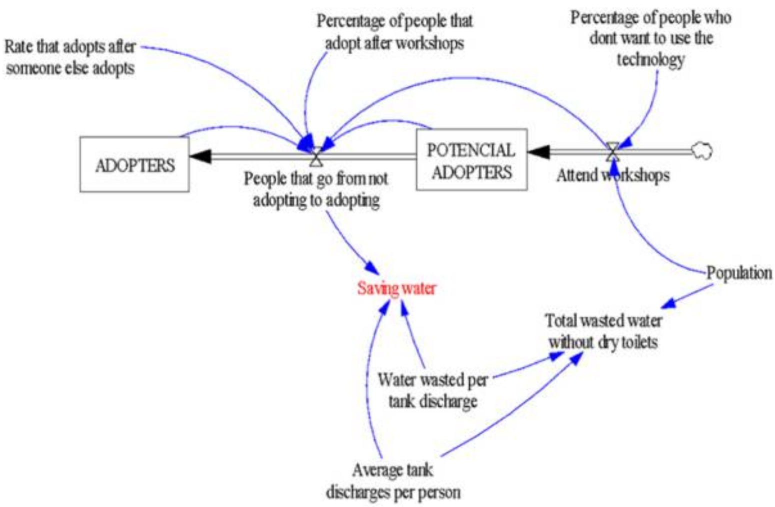
the implications of decisions, a model in Vensim was developed with different stakeholders (Figure 5). Based on this model, some figures of the current water consumption in the Reserva el Encenillo were obtained. The yearly average water consumption is almost 50,000 liters in the Reserva Encenillo; whereas Figure 6 shows that the implementation of this technology would lead to a saving of approximately 35,000 liters per year.

PE – empowerment of the technology to reduce water consumption

To self-build the dry toilet in the Reserva Encenillo, the questions proposed in the design stage were answered. Initially, a design in Sketchup was proposed (Figure 7); it used cement and brick as the main material for the structure. Based on the advice of Funcener, a foundation dedicated to the research, development and production of knowledge and experience in the field of renewable energies applied to projects that impact positively the

Variable	Units	Value (%)	Measurement method
Percentage of people who adopt after workshops	Percentage	58	Survey conducted with 150 persons
Rate of people who adopt after someone else adopts	Percentage	0	Supposition
Percentage of people who do not want to use the technology (in a beginning)	Percentage	79	Percentage obtained based on the initial question (Table III). It corresponds to the percentage of people that prefer the conventional toilet

Table VIII.
Variables of adoption of the technology



Notes: ***Total wasted water without dry toilets*** *= Population * Water wasted per tank discharge * average tank discharges per person;* ***Saving water*** *= People who go from not adopting to adopting * Water wasted per tank discharge * Average tank discharges per person*

Figure 5.
Model of the water saved due to dry toilet, Reserva Encenillo

Figure 6.
Water saved by the dry toilet

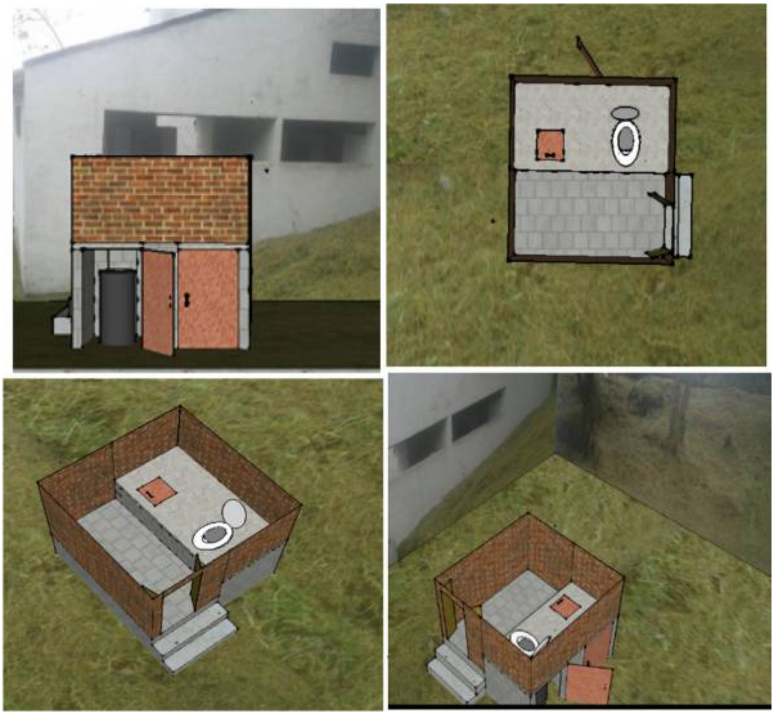


Figure 7.
Initial model of dry toilet in Sketchup

environment and human ecology projects (Funcener, 2015), and that has considerable background in dry toilets, it was decided to use the earthship technique for building the dry toilets. The earthship technique is based on taking advantage of the soil properties and in the utilization of recycled materials for construction. Therefore, not only is water being saved but also there is a good management of solid waste.

For the new design, it was proposed to replace the brick with wood and the cement with tires, soil and mud. In this way, the materials available in Reserva El Encenillo were taken into consideration, and tires, which are usually regarded as thrash and piled up in the streets, were taken advantage. The self-build of the technology in Reserva el Encenillo began on 15 May 2015, with advisory from Funcener. It is described as a self-build process because the community by itself started the building of the dry toilet. That day, a workshop took place, organized by the Project for the Strengthening of the Community's Management of the Hydro Resource, with the participation of members from the community and representatives from the institutions attached to the project. Among the latter, there were coordinators, teachers and students from educational institutions who up to that moment had stood out due to their performance in the project. The workshop began with a context presentation to inform the participants of the objectives of the workshop, followed by a theoretical explanation of what is a dry toilet, its utility and how to use it. After this first part, a practical workshop was carried out in which the building of the dry toilet took place, through workstations in which the stakeholders interacted and made use of the different materials to achieve it (Plate 1).

After the construction of the dry toilet, different members of the region have visited Reserva Encenillo and have had the opportunity to see the dry toilet. According to the reservoir's administrator, this kind of technologies "Provide an opportunity to reflect on the cost of using water in bathrooms and offer alternatives to reduce water consumption". Furthermore, he also recognized that cultural change is hard, especially in regions where water supply is not a main concern. He also added: "It is necessary to increase the awareness that reducing water consumption will not only result in a personal but a collective benefit". On the other hand, one of the teachers who participated in the dry toilet building considered that the experience brought out the following aspects:

> Team work, positive attitude, caring for each other and for the environment, positive thinking about the future of future generations, search for innovative and creative thoughts, importance of learning about our environment, reusing, and conservation.

Plate 1.
Building of the dry toilet

She also mentioned:

> This type of technology not only contributes to water-saving but also to create a culture of love towards the nature. In the aftermath of this experience, we started to work on the acquisition of habits among students and their families in order to change the mindset of waste and contamination. I am certain that if we aim at developing a cultural change, as well at incentivizing creativity and originality among our students, they will come up with excellent environmentally-friendly projects that will build up a better future for humanity and for the planet. In our school, we cultivated onions, carrots, coriander, lettuce, and radish using rainfall water.

She concluded by saying:

> For the construction of the dry bathroom we used non-contaminating materials and reused those that do contaminate (tires, for instance). Teachers and students made the most of our knowledge in mathematics (direct and indirect measurements), language (not only verbal but corporal communication), geography (location), and biology (we observed different species in their natural environment and recognized biotic and abiotic factors). For me, one of the most important field of study that was brought during this experience was the one of Ethics: the fact of making students and teachers interested in a true problematic of the community – 'the water in today's world' – is certainly a highlight of the project.

Conclusions

This paper contributes to the understanding of the dynamics of water saving through participatory design technologies. The results of the implementation of a device for the efficient use of the hydro resource in a Colombian rural region show the need of considering both social and hydrodynamic aspects for the design and building of the device. Additionally, the involvement of the communities in the decision-making processes, in the design of the technology and in its building is crucial for the replicability of the technology. Thus, to obtain successful results in the implementation of water-saving technologies, their design must consider the complexity of the relations between the stakeholders and technology to evaluate future implications, and it must be implemented in a participative way. PAWAME is a systemic methodology that could be developed in different rural context where the most important topic is to promote the adoption through the collective participation.

The implementation of a systemic methodology for the reduction of water consumption in rural areas is an example of how a transition from a rural region to a socially and environmentally sustainable system can be achieved and replied. Additionally, it promotes an interdisciplinary approximation that poses innovative and holistic questions based on a solid conceptual framework. Further studies could improve on this methodology, through the implementation of technologies in different rural and urban contexts.

Note

1. Political division within a municipality.

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