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Roof Rainwater Harvesting in Central Mexico: Uses, Benefits, and Factors of Adoption

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Abstract: This study was carried out in rural communities in the state of Guanajuato, in central Mexico. A questionnaire was directly applied to users of rainwater (RW) to identify the uses, water consumption, and perception towards RW and traditional supply sources, for the purpose of evaluating the relevance of RW in different situations as an alternative supply, as well as the factors that affect the adoption and use of this source. RW turned out to be the users' main water source, and functions as a tool to increase the knowledge and perception of the rainy season and other factors. The respondents identified at least one benefit from the use of RW; the most important benefits were the watering of plants and gardens, avoiding the purchase of water from tank trucks, avoiding the need to fetch water, among others. In the localities studied, where the traditional water supply is either deficient or totally lacking, the use and acceptance of RW has increased. Economic support and training to install systems were key factors for those systems' installation in the communities. These findings may assist future projects to promote the use of RW harvesting at the domestic level and increase the water supply.

Keywords: rainwater harvesting; uses; water supply; benefits; rural

1. Introduction

Between the decades of the 1950s and the 1970s, the population in Mexico went from being rural to concentrated in urban centers, generating an increase in the demand for water and natural resources. Thus, the percentage of the population with piped water and sanitation became higher in urban areas than in rural areas, where now the piped water coverage is 87%, compared to 97% in urban areas. Regarding sanitation coverage, the difference is larger: 97.4% in urban areas and 77.5% in rural locations [1].

With this growth, and taking into account the country's natural water distribution, the water availability per capita in Mexico has decreased. Aside from the increase in demands for all water uses, the extraction of ground and surface water resources has caused environmental, social, and economic damages. Despite the pressure exerted on water resources, the need to provide water for different purposes must be addressed in a sustainable way, incorporating the management of water demand.

The state of Guanajuato is located in central Mexico, and is comprised of 46 municipalities. 70% of the total population lives in urban areas and 30% in rural areas [2]. In the same way as the national population, the population in the state moved from rural to urban areas between the 50s and the 70s. As a result, the urban population is concentrated in only 1.6% of all of the state's localities [2].

The main water source in the state is groundwater (65%). Although agriculture is the principal use of water, the public supply depends on groundwater for 82% of its consumption [1]. In the state of Guanajuato, 20 aquifers have been defined—14 of them are overexploited [3]. Water extraction restrictions have been imposed since 1948, and they now cover almost all the state's sources of water. Therefore, it is important to propose and evaluate sustainable water supply alternatives.

Rainwater harvesting (RWH) is a technique used to collect and store rainwater (RW), e.g., from buildings, rock catchments, and land or road surfaces [4]. RWH is an alternative water supply that offers diverse benefits, such as low impacts, optimal usage of water resources within a framework of sustainable development, low cost, accessibility, and easy installation and maintenance at the household level [5–8]. It is simple, and could be one of the most adaptable methods for mitigating water scarcity [9,10]. It also has high water-saving potential, and the possibility of an alternative water supply reduces pressure on aquifers and surface water sources [10,11].

RWH is currently a practice used around the world to supply different water needs. However, it is a particularly important alternative for supplying water for domestic and irrigation uses [12].

RWH plays an important role in increasing water security for individuals and governments [11]. In Mexico, it has been promoted as an alternative water supply, and is seen as a strategy in the National Water Plan to increase the percentage of the population with easy access to drinking water, as well as improve the efficiencies of water services in the municipalities [13]. As such, in recent years the implementation of RWH has been driven by private foundations, civil associations, governmental programs, and academic sectors. Moreover, taking into account the need to provide water to rural populations, and considering the technical and economic difficulties involved in conventional means of supply, the National Water Commission (CONAGUA) developed the National Program for Rainwater Harvesting and Eco-techniques in Rural Areas [14].

As a result, this practice is currently applied in different states of the country, including Mexico State, Guanajuato, Queretaro, Michoacan, Morelos, Zacatecas, San Luis Potosi, and others. The uses of RWH are mainly for domestic supply, irrigation, sanitary uses, and in some community cases, the water receives formal treatment to become drinkable. Rural areas predominate in the use of this resource, but in urban areas it is mainly used for sanitation, watering, and cleaning; potable uses are accepted in some primary schools.

In the context of water resource shortages, the development of strategies and systems to identify alternative water resources will become critical, as will the improvement of water resource management and planning [10]. Thus, taking into account the water situation in Mexico and in the state, and considering RWH as one of the strategies that provides an alternative water resource, it is relevant to identify the factors that affect the use and promotion of this practice.

In Mexico, studies have been done to assess the reliability of RWH for reducing water consumption in buildings, taking into account consumption and the viability of RWH [15]. A recent study [16] took a regional approach to determine the municipalities in Mexico that would benefit from the installation of domestic rainwater harvesting systems (DRWHS), considering water access, precipitation, marginalization, and the expected level of service.

Nevertheless, some aspects, such as user behavior, the demand model, and social acceptance continue to be considered as hard to quantify [17], even as they are seen as key factors in the implementation, use, and extension of RWH at any level.

Acceptance, adoption, economic or financial support, willingness to use, and other factors related to RW have been studied in countries where it is widely used, such as India, Spain, Australia, the UK, Brazil, and Bangladesh [18–24]. These factors are identified as determinant variables in the success of RWH systems (RWHS) use; therefore, knowledge of the particular characteristics of a population makes a difference in the introduction of alternative water sources such as RW.

In Mexico, few studies have been undertaken to gauge the social acceptance and willingness to use RW and its harvesting. Mexico has the circumstances to exploit the technology of DRWHS, given its geographic conditions and its shortcomings in water supply [16]. Thus, considering the current popularity of RWH as an alternative water source in urban, peri-urban, and rural areas, it is important to determine whether or not, in the introduction of new water supply schemes, social and environmental aspects should be considered as drivers to obtain the intended results and adoption of technologies, according the particularities of communities.

The objective of this study is to identify determinant factors that affect the use and adoption of RW and RWHS in rural communities, in order to obtain information that will facilitate the promotion and extension of RWH.

2. Materials and Methods

This study shows the results obtained from a research study carried out between 2016 and 2017, in 13 rural communities located in four municipalities of the state of Guanajuato. The rural communities were selected on the basis of their use of roof RWHS at the domestic level. Thus, taking into account the promotion of RWH, governmental and non-govermental programs related to this topic were found in the state. According to the plan used for RWHS implementation (considering environmental education, level of commitment, training, and other technologies to improve their quality of life) localities of RWHS users were selected in or near natural protected areas. The categories of the state's natural protected areas of the studied localities are: Conservation Reserve, Ecological Preservation Area, and Area of Sustainable Use. The purpose of the first category is to conserve and maintain natural processes and environmental services; Cuenca de la Esperanza and Pinal del Zamorano are in this category [25,26]. Cuenca de la Soledad and Presa de Neutla are established as areas of Ecological Preservation, with the objective of restoring and increasing the original functions and processes of the area [27,28]. The third category corresponds to areas that produce goods and services that meet the economic, social, and cultural needs of the population, based on the sustainable exploitation of compatible uses; Peña Alta is classified in this category [29].

According to their characteristics (water supply, physical characteristics, support program, among others), the selected communities were classified into five Localities. Table 1 shows the name of the communities, the municipality, and the name of natural protected area of the location and the number of questionnaires applied. The locations of the communities are shown in Figure 1.

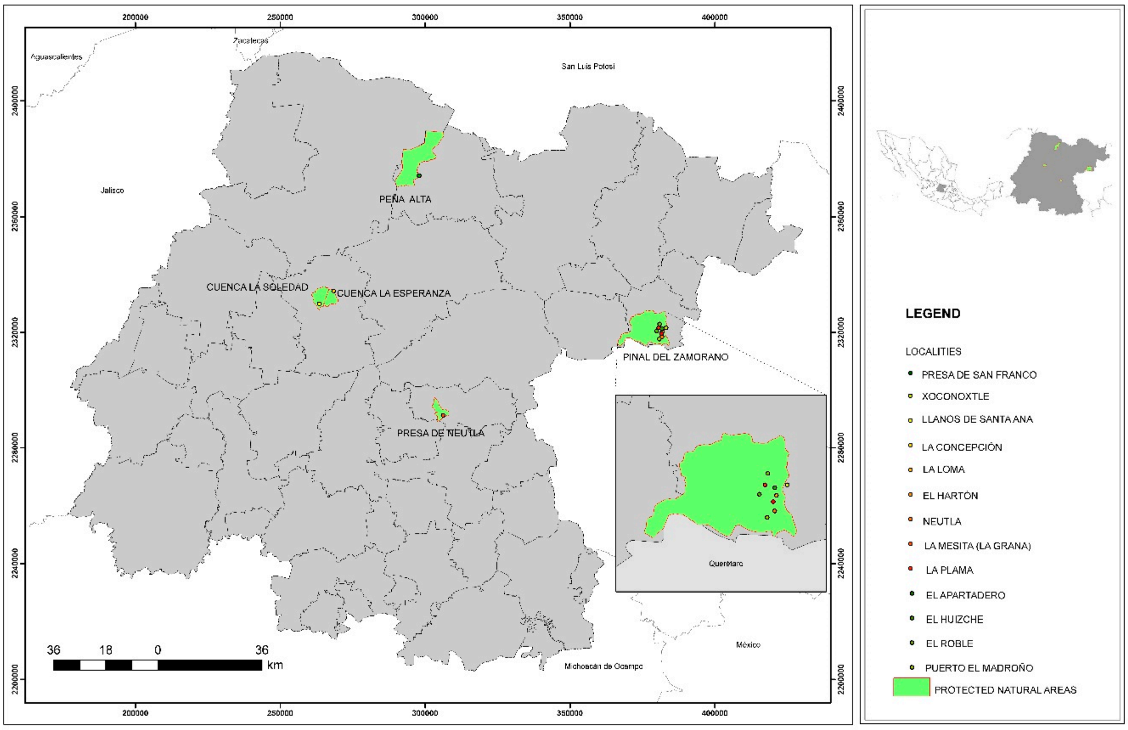

Figure 1. Location of studied communities.

Table 1. Classification of Localities of study: location, natural protected area, and questionnaires applied.

Classification of Localities	Name of Rural Communities	Municipality	Natural Protected Area	Questionnaires Applied
Locality 1	La Concepción	Guanajuato	Cuenca de la Esperanza	26
Locality 2	Llanos de Santa Ana	Guanajuato	Cuenca de la Soledad	7
Locality 3	Xoconostle, La Loma, El Hartón, La Mesita, La Palma, El Apartadero, El Huizache, El Roble, Puerto del Madroño	Tierra Blanca	Pinal del Zamorano	29
Locality 4	Neutla	Comonfort	Presa de Neutla	5
Locality 5	Presa de San Franco	San Diego de la Unión	Peña Alta	9

A questionnaire was designed to obtain information about water uses, characteristics, installation, maintenance, cleaning practices of the RWHS, the benefits perceived from its use, among others topics. The questionnaire contained four major sections. The first asked for the respondents' general information (gender, age, inhabitants per household), and about the physical characteristics of the dwellings (size and roof material).

The next section is related to water use and considered traditional, RW, and other sources, as well as the volume of water. The third segment of the questionnaire dealt with the occurrence of the rainy season and its relation with the filling of cisterns, knowledge about the users' system, practices such as first flush diversion, and the identification of odors and colors in stored water, among others.

The last section was related to the installation, operation, and maintenance of the systems, as well as the perceived benefits and disadvantages derived from the use of RW.

The questionnaire design took into account the experience of an expert on the characteristics of the natural protected areas, and of the personnel that implements the RWHS in the communities and provide the initial training in RWH and other eco-techniques. The characteristics of the communities were considered, and visits to the study areas were carried out before the application of the questionnaires. Local authorities or influencers from within the communities were approached by the personnel that implemented the systems to facilitate the openness of the RW users; in most cases, they were present during the field work, which led to a low rate of refusal.

Data were collected with a direct application of the questionnaire to the users of DRWHS. The questionnaire was applied by visiting each household of the identified beneficiaries, covering more than 80% of the users in each community; a total of 76 questionnaires were applied. Exceptionally, in the case of Locality 3, some users were gathered together in one place to facilitate the process, due the isolation of their houses. For the application of the questionnaire, a group made up of 15 elements had a previous process of training in environmental education and RWH, as well as an introduction to the studied areas and the objective of the questionnaire. The number of pollsters sent depended on the area, the isolation of the dwellings, and the possible respondents.

3. Results

3.1. Identifying Data

Respondents' information (gender, average age, and average size of household) per locality can be found in Table 2. Out of the total respondents, 76% were female; the range of female ages varied from 16 to 77 years old (average 43.2 years old). Localities 2 (67%) and 3 (47%) had the highest percentage of females over the age of 50. Male ages varied from 16 to 90 years old; the average was 47.7 years old. The oldest population is in Locality 3, where only one male respondent was under the age of 40.

Table 2. Gender, average age, and average size of household of respondents of the questionnaire per Locality.

Variable	Female	Male	Average Age (Years)	Average No. of People Living in Household
Locality 1	80.8%	19.2%	39	7.6
Locality 2	85.7%	14.3%	50.6	5.7
Locality 3	65.5%	34.5%	51.1	5.7
Locality 4	100%	-	35	4.8
Locality 5	77.8%	22.2%	38	4.7

The roof areas varied from 9 to 210 m^2. The average roof areas were 57.7 m^2 (Locality 1), 100.0 m^2 (Locality 2), 26.6 m^2 (Locality 3), 34.9 m^2 (Locality 4), and 51.3 m^2 (Locality 5). From all the roof materials registered, sheet metal (55.8%) was the most common material, followed by concrete (41.6%); the use of tiles occurred in Localities 3 and 4, with a small percentage of usage (2.6%). The types of roof per Locality are shown in Figure 2. The most common roof material in the Localities were concrete and sheet metal, which have a high runoff coefficient (0.9–0.95) [30].

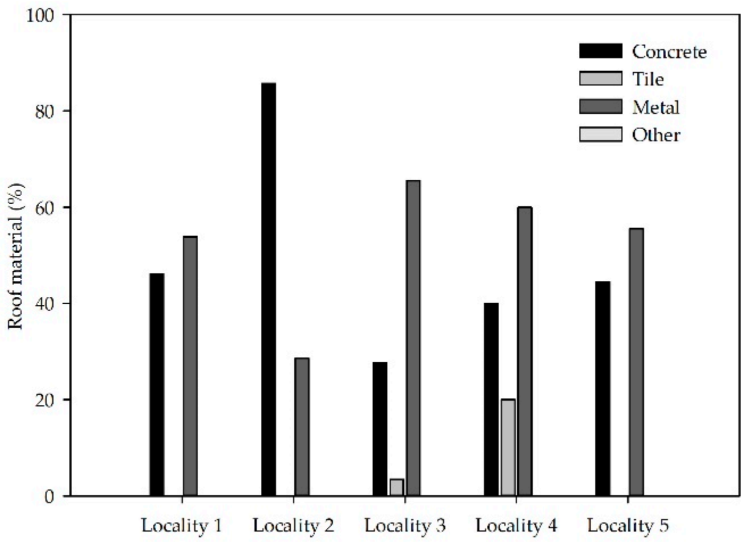

Figure 2. Roof material.

3.2. Water Use

Table 3 includes data related to water consumption, water use per capita, the main water source per Locality, and treatment applied to drinking and cooking water. The first variable considers the household use of water. 100% of the respondents answered this question for Localities 2–5, and 92.3% answered for Locality 1. The relationship between the number of habitants per dwelling and the dwelling's water use is shown in the second variable. Concerning the main supply source, eight types of supply were identified. RW was the main source, with 36.8% of the total answers. Particularly in Localities 1 and 2, RW was the main source. In the former, before the installation of RWHS, the only water available came from a spring (and had to be fetched) and from the purchase of water from tank trucks; currently, the latter option is still an important source. In Locality 3, before the installation of RWHS, the population had water from a spring piped to their dwellings and had a monthly water allotment assigned, which was related to the amount of water used (the highest of all the Localities). In the same locality, 3.4% of respondents did not know the main source of supply. Locality 4 is the only one where RW was not considered a main water source by the respondents; the RWHS serves to provide a complementary water supply. The main source continues to be water extracted from hand-dug wells, the same as before the implementation of RWHS. In Locality 5, water piped into the dwellings continues to be the main source, with a small percentage that considers RW as the main source.

With respect to habits related to water for drinking and cooking, the consumption of water without treatment (34.9%) and water with chlorine disinfection (33.7%) are the most common practices for all the respondents; these practices are used in all five Localities. Boiling water is used by 14.5% of all RWHS users in four of the Localities. The purchase of bottled water (20 L jugs) follows, with 13.3% of total respondents, and then the use of filters as the least-used alternative (3.6%), found only in Locality 3.

Table 3. Water use per capita, main water sources, and drinking water treatment.

Variable	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
Water use (m^3/month)	2.3	2.7	7.7	6.2	5.1
Per-capita water use (L/person/day)	12.3	16	57.6	42.6	40
Main water source					
Rainwater	53.8%	71.4%	27.6%	-	11.1%
Spring (carrying)	3.8%	-	-	-	-
Tank truck	42.3%	-	-	20%	-
Piped water	-	-	-	-	88.9%
Piped spring water	-	-	69%	-	-
Hand-dug well	-	-	-	80%	-
Reservoir	-	14.3%	-	-	-
River	-	14.3%	-	-	-
Drinking water treatment					
Boiling	10.7%	30%	16.7%	-	10%
Filters	-	-	10%	-	-
Chlorine	28.6%	10%	53.3%	40%	10%
Bottled water (20 L)	3.6%	40%	-	20%	50%
No treatment	57.1%	20%	20%	40%	30%

The water uses per Locality, according to the source, are shown in Table 4, where the traditional source is defined as the most common supply method (spring, piped water, tanker, and dam) without the alternative sources such as RW or reuse. The traditional sources were water purchased from tank trucks in Locality 1 (70.6%), water from a reservoir (40%), water from a spring or river (40%) in Locality 2, water piped from spring (100%) in Locality 3, water from hand-dug well (over 80%) in Locality 4, and piped water in Locality 5. Regarding the other alternatives, the main source in this category was the reuse of water, with 57.1% of the total answers. But the respondents also considered bottled water (14.3%), water from springs and rivers (16.7%), tank truck water (7.1%), and water from reservoir (4.8%) as "other sources", those that are not the most commonly used. The uses considered were drinking and cooking (DC); washing dishes (WD); personal hygiene (PH); toilet (WC); washing clothes (WCL); watering gardens, plants, and vegetable beds (WGO); watering animals and pets (AP); and other uses (O).

About the quantity of water, WCL was the use with the greatest consumption (52%), followed by WD (13%), and PH (11%). WGO, DC, and AP were identified as the uses with the least consumption of water.

Regarding water uses, in Localities 1 and 2, as mentioned before, RW was the main source; thus, for all the uses (including DC) RW has a high percentage of usage—over 61.5% for Locality 1 and over 71.4% for Locality 2. Localities 3, 4, and 5, where RW is not considered the main source by the majority of respondents, and there are well-established traditional sources, such as water piped into dwellings or hand-dug wells, presented higher usage of traditional sources than the other alternatives for all uses, except WGO and AP. For those uses, RW was preferred. In these Localities, the use of water for DC from traditional sources was over 80% and less than 30% from RW. But in Localities 1 and 2, RW was used for this purpose by 88.5% and 100% of respondents, respectively.

From Table 4, it is possible to see that Localities 1, 2, and 3 took advantage of the other sources for all the uses shown, as opposed to Localities 4 and 5, where other sources of water were consumed for four of these uses. Reused water was the most-used alternative source, and it was utilized in all the Localities for WGO.

Table 4. Water uses per Locality according the water source.

Locality	Water Source	Use							
		D&C	WD	PH	WC	WCL	WG&O	A&P	O
Locality 1	Traditional	42.3%	50%	53.8%	26.9%	53.8%	30.8%	50%	-
	RW	88.5%	73.1%	73.1%	65.4%	69.2%	76.9%	61.5%	-
	Other	11.5%	3.8%	7.7%	3.8%	11.5%	30.8%	11.5%	-
Locality 2	Traditional	57.1%	71.4%	85.7%	71.4%	85.7%	71.4%	85.7%	-
	RW	100%	100%	100%	71.4%	100%	85.7%	85.7%	-
	Other	42.9%	14.3%	14.3%	42.9%	14.3%	71.4%	14.3%	-
Locality 3	Traditional	79.3%	75.9%	79.3%	44.8%	72.4%	55.2%	62.1%	-
	RW	41.4%	55.2%	51.7%	37.9%	58.6%	86.2%	65.5%	3.4%
	Other	6.9%	6.9%	6.9%	6.9%	6.9%	27.6%	3.4%	-
Locality 4	Traditional	80%	100%	80%	40%	60%	60%	40%	-
	RW	20%	20%	60%	-	80%	80%	40%	-
	Other	20%	-	-	-	80%	60%	40%	-
Locality 5	Traditional	88.9%	100%	100%	100%	100%	66.7%	55.6%	-
	RW	22.2%	66.7%	55.6%	55.6%	66.7%	66.7%	66.7%	-
	Other	22.2%	-	-	11.1%	-	88.9%	22.2%	-

Concerning the use of RW, the satisfaction using this source is high regardless of what it is used for: 92.3%—Locality 1; 96.6%—Locality 3; 100%—Locality 2, 4 and 5.

3.3. *Rainwater Harvesting*

Knowledge of individuals' environmental perceptions helped to identify alternatives that would improve the use of natural resources and the implementation of concrete actions that allowed for better management, conservation, and rehabilitation of these resources [31]. Thus, for the purpose of gauging environmental perceptions, the questionnaire included open questions concerning the knowledge of the rainy season and precipitation events, as well as questions about the harvesting process and practices (volume of cisterns, duration of collected RW, identification of odor and colors in stored water, among other factors). The objective of this section was to identify factors that could be applied to improve future RWH projects or to promote them in other communities.

The first question in this section—"How many times does the cistern fill with RW?"—referred to the precipitation events per year that generated the roof runoff needed to fill each respondent's tank. These events occur between 3 and 1.8 times per year, according the respondents, from May to August for the most part; a small percentage of respondents did not know the period of occurrence (Locality 1, 10%; Locality 2, 7%; Locality 3, 4%; Locality 5, 9.1%). Table 5 presents the months in which the rainy events are identified. The rainy season in the areas of study begins in May and ends in October; the highest concentration of the precipitation occurs in three months (June–August), when more than 70% of the annual precipitation falls and the maximum precipitation events occur.

Regarding the volume of the tank, more than 80% of the respondents knew its capacity (10 m^3 in Localities 1, 3 and 5; 5 m^3 in Locality 2; and 10 and 12 m^3 in Locality 4); only in Locality 5 was the knowledge about the tank volume smaller (55.5%). The material of the cistern was ferro-cement in Localities 1, 3, 4 and 5; only Locality 2 had high-density polyethylene tanks.

RWH is a complementary water source for the communities of study, according to the results, with 39% of the responses reflecting the use of RW during the whole year, particularly in the Localities where it is considered the main water source. The next most frequent durations of RW are 3 months (11% of total responses) or 6 months (12.5% of total responses), when users take advantage of RW.

Table 5. Occurrence of rain events that fill the cistern, according the respondents.

Variable	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
Identified months of occurrence of rain events that fill the cistern					
January	2%	7.1%	-	-	-
February	-	-	-	17%	-
March	-	7.1%	-	-	-
April	2%	7.1%	1.6%	-	-
May	3.9%	7.1%	4.8%	83%	-
June	27.5%	28.6%	22.2%	-	18.2%
July	33.3%	21.4%	27%	-	9.1%
August	19.6%	14.3%	23.8%	-	36.4%
September	2%	-	11.1%	-	9.1%
October	-	-	4.8%	-	9.1%
November	-	-	1.6%	-	9.1%
December	-	-	-	-	-

There are practices that could improve the quality of harvested water, such as first flush deviation [32,33] and the maintenance and cleaning (MC) of systems (roof, pipes, tank, etc.). Two closed questions asked about those aspects: "Do you deviate the first flush before storage?" and "have you detected odor and color in the stored RW?" The majority of respondents (60.8%) deviated the first flush; the lowest ranges were found in Localities with less experience using the systems (Locality 4 and 5). Regarding the identified quality of water (odor and color), Locality 2 showed the highest percentage of detection of these parameters, and from the Table 3 it can be seen that this Locality has the second highest percentage in the purchase of bottled water. In the other Localities, the identification of the quality of water is less frequent.

The cisterns in the Localities of study serve as storage receptacles for any water source when RW is not available, but they can also store a mixture of water from different sources. Therefore, the questionnaire included the open questions: "How many times do you fill your cistern with water from another source?" and "What is this other water source?" Localities 2 and 3 presented the highest percentages of not filling the tank, with 71.4% and 72.4% respectively.

From the small percentage of respondents that filled their tanks with other water sources, water from tank trucks was the most popular option. The main sources of Table 2 were also the sources for filling the respondents' RWHS cisterns. Most of the respondents also have other tanks to store water, with smaller capacities, such as 200 L. Table 6 integrates the results of the section.

Table 6. RWHS knowledge, practices (first flush deviation, average times per year cistern is filled with RW, and other water source), and perceived RW quality.

Variable	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
Times per year cistern is filled with RW	2.3	3	2.5	1.8	2
Knew times cistern filled	96.2%	100%	75.9%	100%	77.8%
Knew cistern volume	92.3%	85.7%	93.1%	80%	55.5%
First flush deviation	53.8%	85.7%	79.3%	20%	11.1%
Identification of odor and color	15.4%	28.6%	13.8%	20%	11.1%
Filled cistern from other source	38.5%	14.3%	17.2%	80%	62.5%
Average times filled from other source per year	4.2	4	5	1	1
Water source for filling					
Tank truck	100%	100%	40%	60%	-
Piped water	-	-	-	-	100%
Piped spring water	-	-	60%	-	-
Hand-dug well	-	-	-	40%	-

3.4. Installation, Maintenace, and Cleaning of Rainwater Harvesting Systems

The success of an RWHS program depends on the interest, enthusiasm, and active support of the users [34]. Considering the support and participation of beneficiaries, seven questions were included in this section to take into consideration parameters related to the installation, operation, and maintenance of RWHSs. There were three closed questions: "Do you see the installation of a RWHS in your dwelling as a positive thing?" "Did you participate in the installation of the RWHS?" and "Does your RWHS receive M&C?" There were also open questions about who provides the MC and the cost of these activities. The results are presented in Table 7.

All the respondents considered that having installed a RWHS was positive for them, and 92% of all beneficiaries participated in the installation of their system; the lowest percentage of participation was found in Locality 3, with 86.2%. About the MC, 92% answered that they provide these services to their system; the same Localities that had the lowest percentage of participation in the installation were the Localities with the least MC. These activities were identified as cleaning the roofs, pipes, and cisterns, and filling and preventing cracks in cisterns. Regarding the person who performs these activities, the owners of the dwellings carry out the MC, and of the total responses for this answer (58), 36.8% of the MC is performed by a female of the family, 32.8% by males, and 31% answered that the whole family participates. Table 7 shows the results per Locality.

The respondents of Localities 4 and 5 did not identify the cost associated with the MC; as mentioned before, in these Localities the installation of the RWHS is relatively recent. Also, as previously mentioned, the main actions considered in MC are cleaning roofs, pipes, cisterns, and filling and preventing the cracks in cisterns. Thus, the expenses related to these activities include soap and chlorine in all the communities, and to a lesser extent, paint and resin.

With regard to the operation of the system, respondents were asked: "How well does your RWHS work?" They had four answer choices: "excellent", "good", "regular" and "bad". No one answered that the operation of their system was bad—most of the respondents (50.7%) thought the system had a good operation, and 38.7% rated it excellent. The rest gave it a regular evaluation. All the respondents thought that RWH is a practice that should be implemented in other communities.

Table 7. Rainwater harvesting perception and factors of installation, maintenance, and operation of the systems.

Variable	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
It was positive to install RWHS	100%	100%	100%	100%	100%
Participated in the installation	92.3%	100%	86.2%	100%	100%
Provides MC	88.5%	100%	89.7%	100%	100%
Who performs MC?					
Female	36.4%	50%	25%	40%	20%
Male	31.8%	33.3%	30%	60%	60%
Family	31.8%	16.7%	45%	-	20%
The MC does not represent an expense	77.8%	40%	24.1%	100%	100%
Cost of MC, (mean), EUR	0.36	1.6	7.18	-	-
Operation of system					
Excellent	38.5%	71.4%	27.6%	40%	44.4%
Good	46.2%	28.6%	58.6%	60%	44.4%
Regular	15.4%	-	13.8%	-	-
Bad	-	-	-	-	-
RWH should be implemented in other communities	100%	100%	100%	100%	100%

3.5. Benefits

The ability to deliver water to households "without walking" is considered the most important feature of RWHS at a domestic level, particularly where women and children have to walk long distances to fetch water [4]. Other important benefits are the water quality in places with pollution (natural or anthropogenic), the savings, and the economic advantages because of the reduction in the amount of water purchased from public systems, among others [10]. Thus, an open section to allow the respondents' description of the benefits and disadvantages derived from the use of RWHS was considered in the questionnaire.

The benefits perceived from the use of RW and from RWHSs are presented in Figure 3. From the total responses, the most important benefits identified were the watering of ornamental plants and backyard gardens (15%); at the same level, the respondents identified the benefit of "I do not buy water" (from tank trucks). The second most important benefit, according to all the respondents (13.2%), was "I do not carry water", the availability of water all year, and the quantity of water. Other benefits identified were that RW increases the quantity of available water—"I have more water" (10.8%); reduces women's work—"I wash clothes in the house" (7.8%); "I have water in the house" (7.2%); the "quality" of water (5.4%); improving "health" or decreasing illness (2.4%); and finally, "watering animals" (0.6%).

Concerning the results per Locality (Figure 3), in Locality 1 all the benefits except the watering of animals and pets were identified; in this Locality, more than half of the respondents (53.8%) recognized "I do not carry water" as a benefit of the use of RWHSs, followed by "I do not buy water". It should be remembered that in this Locality, tank truck water is the second water supply, and the other alternative of supply is carrying water from the spring; thus, benefits of "washing clothes in the house" and "watering plants and gardens" are related to this condition, because the irrigation of plants without a water supply is considered squandering, and clothes are ordinarily washed in the stream. Other benefits were identified to a lesser degree, including "knowledge of the origin of water and the needed water quality for watering plants and gardens" (4.6%), and "less time spent and effort" (3%), in relation to walking to the spring or river to fetch water. Locality 2 shows as the major benefits "quality" and "I do not buy water", with 42% each. In Locality 3, 44.8% of the respondents answered that watering plants and gardens is a benefit derived from the use of RWHSs. In this locality, backyard gardens are common, because the implementation of gardens is the first part of the support program to increase the quality of life in the area; the main products are vegetables. "Quantity and the availability all year" is another benefit (27.6%). The other benefit is "prevention and tranquility" (4.5%) and that the respondents "do not use spring water" (4.5%), as a way to save water.

With respect to Locality 4, only six benefits are identified. The main one is "I do not buy water" with 80% of the respondents recognizing it as a benefit, while 60% identify "I do not carry water"; this related to the main water source, water from hand-dug wells (which must be carried in buckets, in some cases) and to a lesser extent, water from tank trucks. 80% of the respondents have a garden and 40% of the respondents identified irrigation as a benefit; the other benefits are the cisterns as a structure to store water from any source (14.3%), the increase of uses (7.1%) and "I avoid the risk of washing clothes at the hand-dug well" (7.1%). As for Locality 5, there are six main benefits identified, as shown in Figure 3, in a smaller percentage than in the other communities.

In relation to the identified disadvantages, more than 80% of the total responses for this section mentioned that there were no disadvantages concerning the use of RW or RWHSs (Locality 1, 79.2%; Locality 2, 85.7%, Locality 3, 77.8%, Locality 4, 100%; Locality 5, 100%). In Locality 1 the disadvantages recognized were related to the system, including low capacity of capture, finishing of the tank and leaks, and the space used for the cistern. In Locality 2, people mentioned the space used for the cistern, and in Locality 3, the cleaning of the cistern and the quality of water.

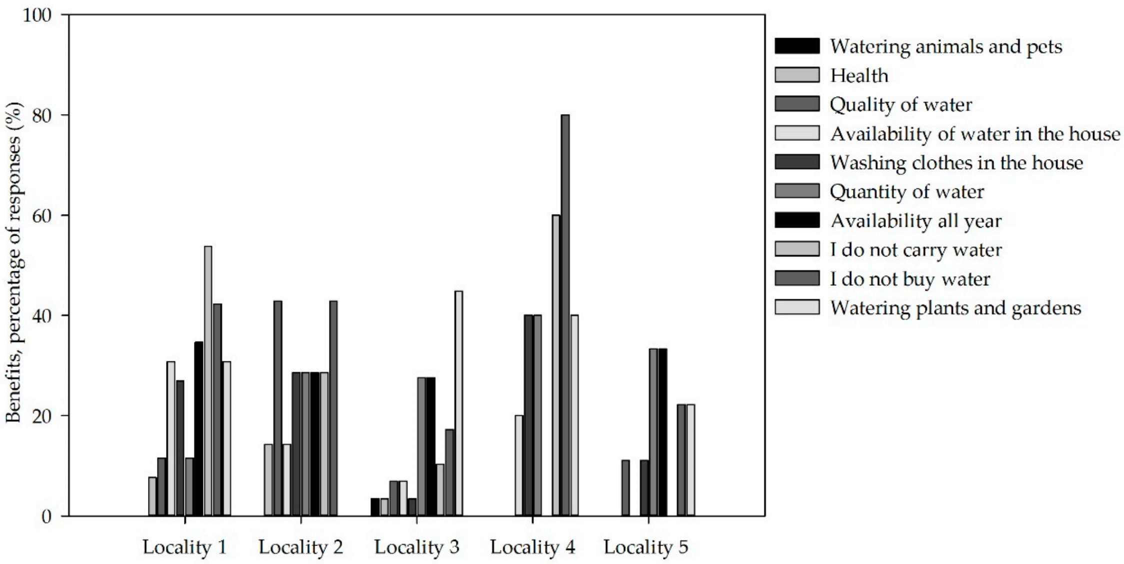

Figure 3. Benefits identified by the respondents of the use of rainwater harvesting.

4. Discussion

This study was carried out in 13 rural communities grouped in five Localities on the basis of their characteristics, where water is supplied in different ways: piped from underground and surface sources; fetched from hand-dug wells and from a river, spring, or reservoir; and finally, purchased from tank trucks. In these localities, governmental programs implemented RWHSs as a way to increase the water supply and services for the beneficiaries.

A questionnaire was applied to RWHS users to identify their water preferences and consumption, their willingness to use RW, their practices for the operation and maintenance of the system, the benefits perceived from the use of RW, among others, for the purpose of evaluating the relevance of RW in different situations as an alternative water supply, and its level of adoption by the communities.

Eight water sources were identified, and RW proved to be the main source, when all the responses were considered. But taking into account the Localities and their particularities showed that the Localities without a well-established supply source in dwellings, or without any supply at all, were more open to using RW (Localities 1 and 2).

About the perception of water quality, it was identified that most of the respondents (65.1%) drink water with some treatment (boiling, filters, and chlorine) or bottled water. But, in Locality 1, 57.1% of the respondents drank water without treatment, RW was identified as the main water source, and drinking and cooking were the main uses of RW in this Locality. Nevertheless, Locality 2, which is closest to Locality 1, has the highest identification of odor and color in RW and also the highest percentage of first flush deviation, the lowest of filling with other sources and the highest of purchase of bottled water; it is also the only locality that uses high-density polyethylene tanks for RW storage, and DC is one of the main uses for RW. Thus, the perception of RW quality differs between these Localities, highlighting the different perceptions of water quality by respondents in close localities, as well as the importance of quality analysis to discern actual water quality. In view of the fact that the quality of harvested RW depends, as mentioned earlier, on natural as well as anthropogenic factors (pollution, regional economic activities, materials and system management, among others), the knowledge of water quality could permit the identification of particular factors affecting RW, and determine the appropriate management and practices related to RWHSs and water use.

When it comes to RWH as a tool for increasing the knowledge and perception of rain and the environment, and for improving the use of water resources, the findings suggest that according to the precipitation data in the studied areas, the population identified the months when this kind of event is most likely to occur, and the usual number of rain events per year that can fill the cistern with the runoff generated in the roof area. About the knowledge of the time when RW is used, the answers coincide with the monthly water consumption for the Localities where RW is the main source, and considering the uses of RW in the other Localities.

Experience in the use of RWHS improves the operation and utility of the systems. The Localities with the longest time using their systems had a higher percentage of deviation of first flush, and a lower percentage of filling the cisterns from other sources. With respect to participation in the installation, the Localities with the lowest participation were the Localities with the least MC. MC is provided at a slightly higher percentage by females followed by males, but it is also considered an activity in which the whole family collaborates.

All the respondents identified at least one benefit derived from the use of RWH; the specific benefits identified depended on the characteristics of the community and its traditional water supply. Considering the number of benefits, there is no meaningful difference by gender. In the type of benefits there are small differences. The main benefits are identified by both genders to the same degree, but the watering of animals is a benefit identified only by men, and more women identified the increase in the quantity of water and in health. The disadvantages identified from the use of RWH are related to the cisterns: the space needed, capacity, cleaning and maintenance.

In the Localities where RW is the main source and there is no supply inside or near dwellings and the process implies fetching water or purchasing it from tank trucks, D&C, PH and WD are the uses of RW with the greatest acceptance, as opposed to the Localities where there are other established alternatives of water supply, where the most accepted uses are WG&O and WCL.

The findings reported for the willingness to use RW for diverse activities show that in Brazilian semiarid localities the use of RW for drinking reached 90% [35], but in studies carried out in Malaysia and the UK, the acceptance of drinking RW reached 17% [36], and 38% in urban areas [24]. In the first case, the main source of drinking water is RW and they are rural localities; in the other cases, the studies were carried out in urban areas. The findings in this research show that in Localities where RW is the main source, its use is higher for D&C than in Localities where there are other supply sources; for example, in Localities 1 and 2 RW and its acceptance for D&C match the results found in the Brazilian localities. In Localities 3, 4 and 5, the acceptance of this use is lower, ranging from 41% to 20%. Thus, RW acceptance in the Localities for these uses is related to the water supply and restricted access. These factors are considered in other research as determinants for the adoption of DRWHSs [37].

The watering of gardens (acceptance: 80.73% [36]; 89% [24]) and the WC (acceptance: 49.54% [36]; 93% [24]) are the most accepted uses reported for studies carried out in urban areas. For this study, the watering of gardens is the most accepted use for all the Localities (80%), and in the case of WC, in the Localities of study the use of dry toilets is common. Concerning bathing and PH, the findings showed acceptance or a perceived benefit among 8.26% and 62% in urban areas [24,36]. From the total answers of this study, the acceptance for PH is 68%, but in particular, Localities 1 and 2 present the greatest acceptance, as previously stated.

Thus, RW is a main water source and preferred over other sources in the cases where there is a deficient supply or water must be fetched or purchased from tank trucks. Where there are better supplies, RW is accepted but not as much as the traditional supply, and it is considered a complementary water source or as a way to increase the activities that otherwise are limited, such as the watering of plants and gardens.

In the communities of study, RW was used in an informal and limited way before the implementation of the systems. RW was collected from gutters in buckets and in small tanks, and thus, only a small quantity of the runoff was stored, and not during the entire rainy season. All the RWHS in the Localities were implemented with the support of government programs for materials and training, and in most cases with the beneficiaries providing the labor. Hence, the willingness to implement a formal system is related to the economic support provided. This was found as a determinant factor for propitiating the installation of RWHSs in other studies [18,35,38]. Thus, the respondents did not see the installation cost as a disadvantage, because they did not perceive it, and the maintenance cost is minimal. But, the absence of formal systems installed without support evidences the restrictive factor of cost as a disadvantage of RWH in the communities.

RWH is accepted in all the Localities and provides diverse benefits, but some of the findings, such as the importance of analyzing the current water supply before promoting RWH, the benefits of RW that are perceived, and the implementation of the most suitable system (dimension and material of tank, as in Locality 2, where RW is the main source and people have the smallest tank capacity) may assist future projects in rural areas of the region. The participation in the implementation of the systems could improve the MC and operation of RWHSs; thus future projects could develop these local capacities to improve the adoption and maintenance of the systems.

5. Conclusions

RW is an alternative water supply that offers diverse benefits, and in recent years has been promoted to improve the availability of water for different purposes, particularly in rural areas. Nevertheless, certain factors could favor the expansion of RWH, and improve and maximize the adoption, use, and benefit of systems.

This study provides some social factors of RWHS users that could be useful to consider in the expansion and adoption of RW. The relevance consists of the evaluation of the use of RW in different contexts, to identify such aspects as the influence of the water supply in the acceptance of RW, the willingness to use RW, practices and benefits of users of RWHSs, among others.

Thus, the results suggest that when RWH is promoted, the current water supply should be considered. Water availability and the supply service determine the uses to which water will be put: non-potable uses are accepted in all localities, whereas potable uses are most accepted in localities with fewer supply alternatives. For the localities of study here, the more deficient or lacking the traditional water supply, the greater the use and acceptance of RW. Participation in the implementation of RWHS improves the management and utility of systems through MC. Economic support for the localities of study was a determinant factor in the implementation of RWHSs; thus, the development of programs to support this type of water supply is essential, along with the consideration of environmental, social, and technical aspects.

The benefits perceived by RW users agree with some identified in other studies, which increases our knowledge and posits RW not only as a supply alternative, but also as a tool to increase users' perception of their environment and other benefits according the characteristics of the community and its water supply.

Thus, RWH is a useful water supply alternative; however, the specific characteristics of localities and other social factors determine the success of the introduction of this practice.

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