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Review

Design Criteria for Planning the Agricultural Rainwater Harvesting Systems: A Review

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Abstract: The growth in world population demands greater food production. Meanwhile, rainwater-harvesting systems (RWHS) have been used since ancient times to guarantee water supply for agriculture. Therefore, this research study reviews the conditions related to RWHS, focusing on rural communities. In this review, the methodologies used for rainwater harvesting (RWH) were determined, considering the characteristics for each of the hydraulic structures to guarantee runoff collection according to the basin area. Finally, the most relevant design parameters that should be considered in the planning and integral water resource management (IWRM) are identified, such as the soil type, average rainfall, and physiographic characteristics of the basin.

Keywords: basins systems; runoff; climate change; rainwater collection system

1. Introduction

The effect of climatic variability is experienced in diverse world regions, noticing that entire populations have water shortage problems. Furthermore, local policies regarding the integral management of water resources have been limited, which has led to an increase of water shortage in urban and rural areas.

It is well known that water is an indispensable element for human life, from the biological perspective of the living organism, as well as the basis of food security and biodiversity. Nonetheless, the resource is currently threatened due to anthropogenic activities, and the previous pressure is compounded by the effect of climate change [1–3], leading to a widespread concern about the scarcity of water resources and causing researchers to worry about investigating alternatives to use to obtain and appropriately manage it.

Generally, studies have focused on the integral management of water resources, always looking for alternatives for their efficient use and involving all actors that may be exerting a pressure on the resource. The actors involved in their management are people who use the resource for subsistence, such as land owners (farmers, ranchers), users of human consumption, industry, and others [4]; or even governmental entities in charge of their management. Once stakeholders (actors) are identified in an area (river basin), possible conflicts are observed when there is a shortage of water resources due to its inequitable distribution along a river or in the basin. Similarly, conflicts could increase if deficiencies in the resource administration by government entities are added, which may include rejection by users of possible local policies in the management of the water sources, considering them inadequate as well [5].

The previous problem also involves demographic growth and the consequent increase in economic activities causing a greater resource demand and therefore an increase in its pressure [5–7].

Likewise, with climate change, there has been a shift in patterns of rainfall occurrence, resulting in dry periods with little rain or wet periods with excess rainfall [8–11], generating, on the one hand, resource availability reduction, and on the other, catastrophes with probable human and economic losses caused by floods due to precipitation increase.

Seeking to diminish the problem and its generated consequences (low agricultural production, interruptions in water supply to populations, and others), alternatives proposing to solve this type of inconveniences are presented. However, to carry out a study of the amount of water within an area, an availability analysis of water resources must be made; hydrological cycle conditions and consequently water balance must be defined, which interrelates variables of precipitation, interception, temperature, surface runoff, and potential and actual evapotranspiration.

Among these variables, precipitation is the most important when talking about climate and hydrometeorology, since it is responsible for the changes to occur in patterns related to floods, droughts, losses in biodiversity, problems related to agricultural production, as well as those to infrastructure damage [12,13]. Thereby, this variable and all those that intervene in the hydrological cycle have been studied by researchers, who have concluded that they have a stochastic behavior and are likewise affected by climatological, physiographic, and anthropic factors. Therefore, it is necessary that precipitation and runoff, which are involved in the water balance, be analyzed with statistical models that allow making predictions [14,15]. In addition, there is also a need to comprehensive study the basins considering the increase conditions in the resource demand, including its shortage and affectation in the hydraulic infrastructure built by man around the watercourses.

The studies trying to estimate the amount of water to be generated in floods or those seeking to supply water needs propose alternatives that start with the rainwater harvesting systems (also called water harvesting, rainwater collection system, and other names), which are made in geographical areas with arid (annual precipitation < 100 mm), semi-arid (annual rainfall 250–400 mm), monsoon (minimum monthly precipitation between 60 and 100 mm), and sub-humid (characterization depends of the location of the study area) [16] conditions. In each of these climatic conditions, rainwater harvesting projects were developed for urban and rural areas, considering the purposes for the water resources are to be used [17–19] as well as the problems to solve floods or droughts among them.

Once the problem is understood, researchers have considered returning to rainwater harvesting systems as an adequate solution for flood mitigation and supply. These systems have been used in the world in the past [20], and their use has now been accentuated in arid and semi-arid zones, since these have been affected by the change in rainfall patterns.

A rainwater harvesting system is a general term that is used to describe the collection and concentration of runoff or its many uses, including agricultural and domestic use [21–23]; it is also used to describe the collection and storage of water either directly in the form of precipitation and runoff, or indirectly in the form of groundwater, surface springs, or rivers [24,25].

In addition, among rainwater harvesting systems, precipitation is the main variable to obtain the amount of water resources; therefore, the solutions proposed will depend on the study area—that is, on the physiographic characteristics and existing infrastructure (urban and rural areas). In the case of the analyses developed for urban areas, there is a problem with rainwater use, since people are skeptical of this supply mode, especially in areas with low amounts of precipitation [26]. Nevertheless, rainwater use has been successful when water is captured to help maintain the hydrological cycle and used in activities in which water that is suitable for human consumption is not required [17,19,27].

In the case of rural areas, which is the focus of this study, the solutions proposed will depend on the type of supply required (population or agricultural), and the area where it will be applied (arid, semi-arid, and others). Therefore, solutions are projected from the outlook that are related to offering water resources for agricultural activities and the domestic needs of farms, allowing alternatives to counteract water scarcity, among them, collection from domestic roofs [18,26,28–32], dams, cisterns, ponds [33–36], ridges, furrows, and others. In many cases, these waters are not used for human consumption, as their physicochemical and bacteriological conditions do not comply with any international regulations regarding water potability, due to the presence of pollutants in rainwater and even from the roof material serving as catchment for the collection [37–43].

This research study reviews the conditions of rainwater harvesting systems in rural areas. First, methodologies for rainwater harvesting (RWH) are determined, considering the type of hydraulic structure used for runoff collection according to the basin area. Later, the type of soil, average rainfall, and physiographic characteristics are identified to constitute the most relevant design parameters for planning and suitable sites of the hydraulic structures that will guarantee an integral management of water resources (IMWR) in agriculture.

2. Rainwater Harvesting Structures

The techniques of water resource use are focused on, considering the use to which the resource is to be allocated and the area where it will be applied (urban or rural). Those focused on developing in rural areas are directed toward use of rainwater harvesting systems (RWHS), whose main function is to store water in the rainy season to be used in drought periods when the resource is not available. Similarly, they are also associated with the uses to which the water is to be destined, either for crops or for domestic supply on farms [44]. From the approach review made by each author on the use of water resources for domestic and agricultural purposes, five classifications or groups are made.

Group 1 included macro basins such as dams [45], small dams [46], control dams [47], reservoirs [47], cisterns [45] and nala bunds [47]. Group 2 included micro-watersheds, contemplating jessour [47], tabias [47], excavation with a dike (pits contour) [48], contour ridges [49], contour strips (runoff strips) [47], Negarim [49], dykes [48], and terraces [48]. Group 3 was named aquifer recharge and consists of gully plugs, aquifer recharge, subsurface dams, and percolation tanks [50]. Group 4 was called micro and macro basins and includes authors who used combinations of structures involved in the first, second, and third groups. Finally, Group 5 included those authors in which the use of water was made with reserve tillage, from which it drew its name. In the latter group, a mechanical device is used that develops micro reservoirs for the "in situ" uptake of rainwater to increase the retention of moisture in the soil and additionally functions to reduce soil erosion; therefore, it is very common to use in loose soils, which are characteristic of semi-arid zones [51,52].

Once the methodologies were divided into groups, the design parameters that each author used were set, as can be seen in Tables 1–5. A total of 22 design parameters were considered such as physiographic characteristics (slope, drainage network, runoff, and basin area) climatological characteristics (precipitation, relative humidity (RH), wind speed and direction, solar radiation (SR), and evaporation), soil (use, texture, coverage, depth), socioeconomics (no inhabitants, interview to stakeholders, cost, land tenure, dwelling characteristics) and distance to dwellings, crops, and streams. Alongside these parameters, the advantages and disadvantages of each of these groups were established for ease of analysis.

Table 1 shows the design parameters considered by each author for the macro-basin systems. These parameters can be obtained directly in the ground or indirectly estimated with remote sensors to later form databases managed using geographic information systems (GIS).

Similarly, GIS allows planning the river basins to establish potential sites that guarantee RWHS efficiency with dams and dikes, as well as their respective reservoirs.

Table 1. Group 1: Macro basins systems.

Author	Climatological Characteristics					Physiographic Characteristics				Soil				Socioeconomics					Distance to		
	Precipitation	Relative Humidity	Wind Speed and Direction	Solar Radiation	Evaporation	Drainage Network	Slope	Runoff	Basin Area	Use	Texture	Cover	Depth	No. Inhabitants	Interview to Stakeholders	Cost	Land Tenure	Dwelling Characteristics	Dwellings	Crops	Stream
Gupta et al., 1997 [53]	X					X	X	X		X	X	X									
Srivastava, 2001 [54]	X				X															X	
Senay and Verdin, 2004 [55]	X							X	X					X							
de Winnaar, Jewitt, and Horan, 2007 [56]	X						X			X	X	X								X	X
Forzieri et al., 2008 [57]	X						X		X	X		X				X			X		X
Roy et al., 2009 [58]	X						X	X			X										
Sturm, Zimmermann et al. 2009 [59]	X							X	X												
Al-Daghastani, 2010 [60]	X					X				X		X									
Salih and Mehdi Al-Tarif, 2012 [61]						X	X		X	X		X									
Ziadat et al., 2012 [62]							X		X	X	X	X	X				X	X			
Jayasuriya et al., 2014 [63]	X							X	X												
Jabr and El-Awar, 2004 [64]							X	X		X	X	X									
Mahmoud and Tang, 2015 [65]	X						X			X	X	X									
Adham et al., 2016 [66]	X						X				X		X			X			X		
Mekonnenet et al., 2016 [25]	X					X	X	X	X	X	X	X			X						
Sayl et al., 2016 [67]	X	X	X	X	X		X							X							
Mahmood and Hossain, 2017 [68]	X							X	X	X											
Terêncio et al., 2017 [69]	X						X				X		X	X						X	X
Terêncio et al., 2018 [70]	X						X				X		X	X						X	X

Other relevant aspects considered in the methodologies making up Group 1 are socioeconomic conditions and local characteristics from the study area, such as distance from the water collection site to the point of use, as well as technical feasibility for construction and long-term operation.

Finally, the application of processes of analytical hierarchy allow giving weight to the different attributes involved in the project by giving a different importance to each one depending on the suitability of the RWHS. Although subjectivity is diminished, it continues to exist since the weights for the process of analytical hierarchy will depend on those involved in the project.

These methodologies are generally limited to the application of RWHS solutions related to the construction of dams, dykes, and reservoirs. Likewise, in some cases, communities located in the area are not informed regarding the selection of suitable sites, nor are the sociopolitical aspects that may influence the realization and benefit of the project considered. However, the need to hold meetings with stakeholders has the disadvantage that decision making becomes a challenge when seeking a consensus to obtain the best solution [71].

Despite the advantages and applicability of the methodology in other world regions, the model must be calibrated and validated for its use.

Group 2, which includes the authors indicated in Table 2, focuses on farms requiring water supply in their crops to ensure food security of inhabitants in areas with rainfall varying spatially and temporally. As in the case of Group 1, here the use of GIS to create a digital elevation model (DEM) from topographic maps and field verification becomes a useful tool for specifying suitable sites for rainwater harvesting infrastructure with an acceptable precision. In some cases, since soil characterization information was not available, land and soil prediction models were used with adequate results and to improve the resolution of attributes that allow optimizing the identification of suitable areas.

Table 2. Group 2: Micro basin systems.

Author	**Climatological Characteristics**					**Physiographic Characteristics**				**Soil**				**Socioeconomics**					**Distance to**		
	Precipitation	**Relative Humidity**	**Wind Speed and Direction**	**Solar Radiation**	**Evaporation**	**Drainage Network**	**Slope**	**Runoff**	**Basin Area**	**Use**	**Texture**	**Cover**	**Depth**	**No. Inhabitants**	**Interview to Stakeholders**	**Cost**	**Land Tenure**	**Dwelling Characteristics**	**Dwellings**	**Crops**	**Stream**
Bhatnagar et al., 1996 [72]	X									X											
Oweis et al., 1998 [73]	X						X			X	X	X	X								
Schiettecatte et al., 2005 [74]	X							X			X										
Ziadat et al., 2006 [75]							X			X	X	X	X								
Mbilinyi et al., 2007 [76]	X					X	X			X	X	X	X								
Al Ali et al., 2008 [77]	X						X														
Bakir and Xingnan, 2008 [78]	X						X			X	X	X									
Al-Seekh and Mohammad, 2009 [79]	X						X	X			X	X									
Bekele Awulachew et al., 2009 [80]	X						X			X	X	X									
Mechlia et al., 2009 [81]	X					X	X	X		X	X		X	X				X			
Previati et al., 2010 [82]											X		X								
Al-Shamiri and Ziadat, 2012 [83]	X						X				X		X								
Krois and Schulte, 2014 [84]	X						X			X	X	X	X								
Napoli et al., 2014 [34]	X	X	X	X			X			X	X	X									
Mahmoud and Alazba, 2015 [85]	X						X	X		X	X	X									
Adham et al., 2016 [86]	X						X	X													

In addition to the GIS application, the process of selecting the location of hydraulic structures for rainwater harvesting, remote sensing, analysis and field verification, and suitability scores of physical and hydrological parameters is involved, increasing the process reliability.

Correspondingly, to determine the construction feasibility of rainwater collection structures in certain areas, the required catchment area and the respective losses in the water conduction process are considered, which will ultimately influence the construction costs of the hydraulic structure. In addition, the optimal location is determined considering the cost of a system with an efficient transport and construction of the tank in a less economic zone.

In some cases, the simplicity of the hydraulic structure that is to be built affects the number of parameters required for its location and design. In addition, the development of this type of water supply would become the basis for solving the problems related to food security and would contribute to reducing the erosion processes in the soil. Therefore, by obtaining supplementary irrigation for crops, there is an efficient use of water and a subsequent productivity increase.

Nonetheless, this group does not consider socioeconomic aspects in the design and implementation of hydraulic infrastructure for rainwater harvesting. Furthermore, some authors use suitability scores or weights [75,76], which can generate bias in decision making, despite the use of methodologies to establish selection conditions in the parameters evaluation to be scored [46,49,76,80,87,88].

Table 3. Group 3: Systems for aquifer recharge.

	Climatological Characteristics					Physiographic Characteristics				Soil				Socioeconomics					Distance to		
Author	**Precipitation**	**Relative Humidity**	**Wind Speed and Direction**	**Solar Radiation**	**Evaporation**	**Drainage Network**	**Slope**	**Runoff**	**Basin Area**	**Use**	**Texture**	**Cover**	**Depth**	**No. Inhabitants**	**Interview to Stakeholders**	**Cost**	**Land Tenure**	**Dwelling Characteristics**	**Dwellings**	**Crops**	**Stream**
Durbude and Venkatesh, 2004 [89]	X						X	X		X	X	X									
Bamne et al., 2014 [90]						X	X			X	X	X									
Sekar and Randhir, 2007 [91]	X							X		X	X	X				X					
Ramakrishnan et al., 2008 [92]	X					X	X			X	X	X									
Ramakrishnan et al., 2009 [93]	X						X	X	X												
Glendenning and Vervoort, 2010 [94]	X								X	X	X	X	X								
Glendenning and Vervoort, 2011 [95]	X				X					X	X		X							X	
Kadam et al. 2012 [96]	X					X	X	X		X	X	X							X		
Mahmoud, 2014 [97]	X				X		X	X		X	X	X									

In the specific study by Senay and Verdin [55], data resolution does not allow this methodology to be applicable to the planning and design of individual agricultural ponds, because it provides an overview of the relative differences among the regions to carry out feasibility studies in the evaluation and planning of farm ponds as a tool for water management.

As a disadvantage, the methods of this group are used to store runoff and supply water to small-scale orchards, which makes them unlikely to be used for large runoff collection areas. However, they could be replicated toward larger hydraulic infrastructure solutions, but this would require a greater number of parameters in the evaluation [54].

The used methodology enables establishing suitable sites for the location of techniques for the recharge of groundwater, guaranteeing the sustainable use of the resource in areas with little availability [97].

It is shown that remote detention, GIS, and the analytical hierarchy process are powerful tools to locate potential areas that can be used for groundwater recharge [98].

Finally, the results and databases found in the study can be used as a tool to carry out conceptual models in arid zones that present characteristics such as those analyzed [97].

In the methodology, when assigning the weight for each of the criteria, considering the rating scale, subjectivities can be incurred.

Generally, Group 4 presents several types of structures that can be used for rainwater harvesting, such as roof catchment, surface runoff to ponds and dykes with their respective reservoirs, and on-site storage systems.

A suitability score is used based on the attributes of thematic maps elaborated in a GIS and is superimposed with the hydraulic structure for the use of rainwater proposed for multicriteria evaluation. Finally, the selection of suitable areas is carried out with stakeholders [71].

Table 4. Group 4: Micro-basin and macro-basin systems.

	Climatological Characteristics					Physiographic Characteristics				Soil				Socioeconomics					Distance to		
Author	**Precipitation**	**Relative Humidity**	**Wind Speed and Direction**	**Solar Radiation**	**Evaporation**	**Drainage Network**	**Slope**	**Runoff**	**Basin Area**	**Use**	**Texture**	**Cover**	**Depth**	**No. Inhabitants**	**Interview to Stakeholders**	**Cost**	**Land Tenure**	**Dwelling Characteristics**	**Dwellings**	**Crops**	**Stream**
Banai-Kashani, 1989 [99]						X										X					
Oweis, 1999 [46]	X	X	X	X	X						X	X	X								
Prinz and Singh, 2000 [100]	X					X		X		X	X	X	X		X						
Mbilinyi et al., 2005 [101]										X	X				X						X
Mati et al., 2007 [102]	X									X	X	X	X	X							
Mwenge Kahinda et al., 2008 [87]	X										X	X	X				X	X			
Kamel and Mohammed, 2010 [103]	X								X												
Ghani et al., 2013 [104]						X		X													X
Jha et al., 2014 [105]	X					X		X		X	X	X									
Grum et al., 2016 [71]	X					X				X	X	X	X		X						
Singh et al., 2017 [106]	X					X		X		X	X										

When conducting meetings with stakeholders, the choice of analysis tools for the situation presented in terms of selecting the appropriate rainwater harvesting structure becomes a challenge, and this should not be complex in time, costs, and amount of data needed [107].

Table 5. Group 5: Reserve tillage systems (or reservoir tillage).

	Climatological Characteristics					Physiographic Characteristics				Soil				Socioeconomics					Distance to		
Author	**Precipitation**	**Relative Humidity**	**Wind Speed and Direction**	**Solar Radiation**	**Evaporation**	**Drainage Network**	**Slope**	**Runoff**	**Basin Area**	**Use**	**Texture**	**Cover**	**Depth**	**No. Inhabitants**	**Interview to Stakeholders**	**Cost**	**Land Tenure**	**Dwelling Characteristics**	**Dwellings**	**Crops**	**Stream**
Hackwell et al., 1991 [108]	X							X			X		X								
Rochester et al., 1994 [109]	X																				
Ventura et al., 2003 [110]	X										X										
Ventura et al., 2005 [111]	X																				
Patrick et al., 2007 [112]	X						X				X										
Botha et al., 2015 [113]	X									X	X	X	X								

In some of the cases raised, socioeconomic aspects are not incorporated; that is, they were limited to giving weight to each of the technical aspects considering a political decision. Likewise, it should be noted that the quality of the output data depends on the characteristics of the input data to the model—that is, whether they are third-party data or obtained from sources of reliable information.

Regarding the authors considered in Group 5 (see Table 5), this type of structure provides moisture to the soil to obtain productive crops. An increase in production is significant by using these methods. However, they require mechanization, which is not necessarily accessible to people in rural areas, and an initial investment of resources that the farmer may not be able to afford.

3. Discussion

Figure 1 shows the design parameters used by authors, it is concluded that precipitation and slope are the most relevant design parameters that should be considered, as well as the soil characteristics (use, texture, and coverage) in the rainwater harvesting structures.

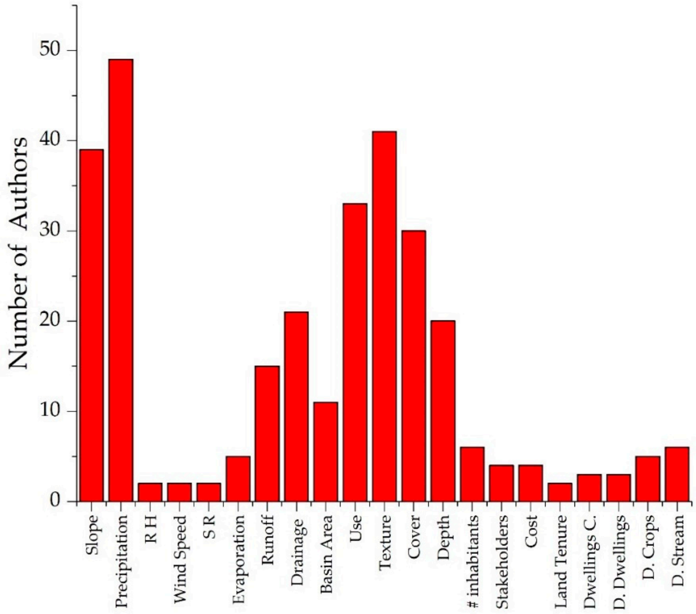

Figure 1. Number of authors per design parameter.

On the other hand, when making the division by structures, it was found that macro basins are characterized by being located at a considerable distance from harvesting areas, and therefore are generally used as supplementary irrigation. Among the advantages of this type of structures include the fact that their use can be considered variable; that is, they can be used for human consumption, agriculture, flood control, and even for hydroelectric exploitation. In most cases, these types of projects are developed in areas with agricultural potential, and therefore they are in rural areas where there may be acres of land where the required volumes of water would be stored. The most important disadvantage of macro basins is that when they are built in areas far from the water application site, it is necessary to build the required infrastructure for the water's transportation and distribution.

In macro basins, the use of GIS and multicriteria decision analysis is common, using the process of analytical hierarchy in order to prioritize areas where hydraulic structures could be located for the RWH; depending on the study area, the main characteristics to be taken into account are determined, such as runoff coefficient, drainage network, and slope [53]. In other cases, such characteristics include using thematic layers of precipitation, slope, curve number, and soil cover, use, and texture [65]. There is also a combination of GIS, remote sensing, and topographic maps to locate the ideal areas for water storage (reservoirs), with which information the optimum levels and the areas to be obtained can be established to estimate the volume of water to be collected [61]. In addition to the use of GIS and technical and social considerations, the participation of farmers (stakeholders) and field surveys are involved, where suitability is assessed by evaluating the parameters established in their methodology from Ziadat et al. [62], which are found in Table 1.

Table 1. Group 1: Similarly, the multicriteria analysis implemented in GIS with flexible weights and with suitability criteria based on physical, ecological, and socioeconomic variables can be implemented for several types of rainwater harvesting projects such as agroforestry projects, small-scale agriculture, and management of the seasonal availability of water resources [69,70]. If, added to this, the process of analytical hierarchy for the location of potential water deposits is involved, criteria that assess

the suitability for water collection are established and a reservoir suitability index is obtained that facilitates decision making for governmental entities [64,66].

With the use of remote sensing images and a digital elevation model (DEM), an analysis of the drainage network can be made, and using the curve number of the United States Soil Conservation Service, the salinity is reduced in the ephemeral currents in semi-arid zones [60].

In this sense, there are methodologies that use models with few parameters (see Table 1), which can be used in developing countries through using global data [55,67] to generate maps with water capture rates estimating the availability of runoff, evaporation losses, and the size of the basin [55].

In general terms, reservoirs include dykes or dams that allow storing water or are simply used for runoff water collection. However, in some cases, tanks of varied materials are built; that is, natural land is not used as a container, obtaining its optimal location by estimating the cost of the driving system and the tank [54].

Additionally, there are reported cases of water collection from roofs of houses to supply communities, where economic aspects are evaluated considering the possible benefits and socioeconomic characteristics of the population [59]. Remote sensing, precipitation, and water balance are also used to locate areas where domestic water collection could be done for domestic drinking water demand (drinking and cooking) or like domestic demands (drinking, cooking, and hygiene needs) [68]. In addition to domestic use, this system has been implemented for family gardens, which can be a food base for the house dwellers and even serve as an economic support, where climatic conditions, material, and roof area influence the evaluation of this methodology for rainwater use [63].

In short, the use of GIS, remote sensing, and hierarchical weighting and multicriteria analysis are important to facilitate decision making for government entities, since through them, runoff capacity is determined, planned, and evaluated for the potential use of rainwater in an area [56], even allowing the creation of computer programs with which to determine the size of reservoirs and the geometry that they should have, while also taking into account the sizes of the field and the cultivation system implemented by the farmer along with an evapotranspiration model [58].

Regarding the micro-basins (group 2), the main advantage lies in being used for crops, being the collection of water "in situ", that is, done in the same field where the plantation is made, either within the area where the plant is located or with an impluvium area that serves as a basin and is subsequently stored close to the cultivation area. Among the disadvantages, it is found that in several cases supplementary irrigation is required, such as for instance in Kharagpur, India, where the benefits of supplementary irrigation were studied in relation to the productivity and an economic analysis of profitability was made to evaluate rice production [114]. In Group 2, it is important to consider the characteristics of the soil because it is associated with agricultural productivity, which is necessary for this type of water use. Regarding the disadvantages, the types of catchment structures involved in this group cannot be used for domestic or other uses, since there is no reservoir for water storage.

Micro-basins can be used in small farms requiring water for the subsistence of their crops (e.g., rice); however, they must be supported in the supplementary irrigation, which allows savings regarding the amount of water required for cultivation [72].

Similar to Group 1, in this group, the locations of hydraulic structures for collecting rainwater for agricultural uses involving topographic data, soils, vegetation, hydrology and meteorology, can be established through using GIS and satellite images (before and after the rain) [73,78,82]. On the other hand, Ziadat et al. [75] use GIS incorporating socioeconomic aspects and criteria such as slope, depth, texture, and soil stoniness, while Mbilinyi et al. [76] also use field inspection to locate the ideal sites through criteria weighting and analytical hierarchy process. They can be refined by making the assessment at the basin level but giving emphasis at the sub-basin level and over time to understand the hydrological processes occurring in the RWHS by simulating water balance, allowing options for optimization [86].

In other cases, the aim is to determine the efficiency of rainwater harvesting systems through experimentation and using satellite images for the large-scale planning of water resources in the territory, focusing on olive crops and engaging with the stakeholders in the study area [74].

In the same way, micro-basins allow monitoring the balance of water and sediments [78], as well as runoff behavior, sedimentation, and soil moisture [79], demonstrating in these aspects the type and depth of soil influence, tillage, and the management by the farmer [82]. Identifying these sites and techniques for water conservation in soils is a useful tool for carrying out resource conservation programs involved in the integral management of water resources [84].

Generally, the methodologies related to micro-basins aim to select the ideal areas to locate rainwater harvesting sites, considering the type of hydraulic structure to be implemented [83], as well as making it financially and time-sensitive [34].

Group 3 was related to the structures for recharging aquifers, which are important for arid and semi-arid zones, where water sources are aquifers captured through deep wells. Considering this, parameters that have more weight are related to the characteristics of the soil, due to its permeability. Therefore, the infiltration capacity will depend on these to make the respective recharge.

This group also uses GIS (with thematic maps) and remote sensing to identify possible runoff areas and sites for the construction of hydraulic structures for soil and water conservation, considering the following as decision-making rules: the slope, soil permeability, and runoff, as well as integrating land-use and texture maps [89]. In addition, other methodologies follow an analytical hierarchy process with decision rules to subsequently validate the information in the field and thus verify the suitability of the implementation of the selected sites [92,93,96,97].

In addition, some authors involve topography and generate maps of the drainage network and hydrological group of the soil, superimposing them to locate the ideal sites for rainwater collection structures [92]. Others involve costs of collection and usufruct; therefore, the storage capacity and the location limit of the urban area are contemplated, as well as the cost of the land and the implementation of the rainwater harvesting system, to finally determine the economic benefit when compared to the cost of drinking water in the region [93]. It should be noted that Sekar and Randhir [93] proposed this methodology to be used in rural areas and peri-urban areas, which determines the benefit when compared to the cost of drinking water to be supplied in homes or on farms.

As well as establishing methods for selecting the right site for the construction of rainwater harvesting structures in rural areas, experimental studies are made in the field to determine the impact of groundwater recharge in the local area (zone) analyzed and in the surrounding sites [94]. In a similar manner, studying the techniques through which these types of structures for water capture impact irrigation agriculture are verified is necessary to develop a study at the sub-basin level. This allows concluding that as the area for the use of rainwater increases, it reaches a limit capacity where additional hydraulic structures do not increase the groundwater reserve but rather reduce the flow of currents [95].

In Group 4, the authors focus on diverse types of rainwater collection structures that exist (macro basin, micro basin, or aquifer recharge). They do not use a specific type of structure; instead, their focus is directed toward the suitable construction place of each, having the score of the input parameters to obtain the best performance of the RWHS.

This is how Banai-Kashani [99] affirms that there is a critical deficiency in those methodologies requiring the judgment of experts: when there are standards for the score evaluation, there are no problems when doing the weights, but when they are unfamiliar problems and the scores have not yet been defined or even existing ones are discredited, subjectivities are incurred. Considering this, the process of analytical hierarchy is used as a solution for the biases present in the expert judgment methodology to select suitable sites regardless of the type of hydraulic structure for catchment intended to be implemented in the study area [99]. Multicriteria analysis is also used, and in some cases, location restrictions and maps made with GIS are used as well to superimpose them and establish the appropriate collection sites [87,102,105,106].

The process of analytical hierarchy is supported by multicriteria analysis based on maps developed using GIS and remote sensing to locate the different suitable sites for the construction of structures for rainwater collection, being the methodology applicable to any area due to the flexibility of scores [101].

This group also analyzes the productivity of soil and amount of water retained in it, which are accompanied by supplementary irrigation, where the success or failure of these rainwater harvesting systems is marked by the socioeconomic conditions of the population to the implementation of the technique and the perception of risk and profitability of farmers [46,100]. It also facilitates its use for reforestation and the planting of fruit trees, as well as increases the productivity of arable and grazing lands, increasing yields and reducing crop losses [100].

Similarly, some authors take into consideration geometric characteristics to determine the volume of water to be captured according to a specific return period [103] and the generation of runoff [106] and even the consultation of stakeholders to obtain the most appropriate area, considering the knowledge of the population in relation to the construction of these systems [71].

The fifth group (reserve tillage systems) makes use of machinery to build footprints in the earth. This method is similar conservation tillage but generates water storage obtained by the formation of small surface deposits [109]. Essentially, the advantage of this method is that it improves soil moisture and increases agricultural productivity, which is associated with soil texture and consequently its productivity. In addition, this system is used to avoid erosion problems [51].

The group was considered especially, since in the majority field, experiments are carried out to determine productivity, contemplating the characteristics of the crop, the soil, and the precipitation in the study area. Additionally, a reduction in soil erosion is obtained with this type of RWHS.

Experimental studies have focused on determining the effect of reservoir tillage on the amount of water contained in the soil, with treatments carried out with low and high soil compaction [108,109]. Other aspects through which it is analyzed with are the slope, density of the soil, and intensities of precipitation [112].

To calculate the efficiency of reservoir tillage, this was compared with no reservoir or conventional tillage [108,110,111], zero tillage, minimum tillage, rainwater collection in the field, and Daling plowing [113].

4. Conclusions

The design parameters used were identified from the references on the methodologies carried out for RWHS in rural areas. The most relevant being the type of soil, average rainfall, and physiographic characteristics for planning and potential sites to construct rainwater harvesting structures that guarantee IWRM.

On the other hand, the challenge of these methodologies regards the data availability from the study area. In the case of rainfall, there is a problem related to the quantity and quality of the data of the weather stations located within, and sometimes the length of records is not adequate to perform a reliable variable analysis. Regarding the soil characteristics, information is scarce in developing countries, and it is necessary to apply methodologies for determination such as remote sensors, with subsequent verification and validation on the ground.

With the use of GIS and available cartography for a study area, the morphometric parameters of a river basin are estimated, which allows explaining the dynamics runoff.

Generally, the physiographic characteristics and spatial distribution of rainfall rates are fundamental to explain phenomena occurrence such as floods and erosive processes. Nonetheless, the impact of these types of events will depend on territorial management in the basin.

The application of GIS along with multicriteria analysis and analytical hierarchy processes make up a robust procedure for decision making, since the weights that are assigned to each design parameter should be considered in the RWHS selection, allowing researchers to be assertive in the choice of potential sites for the planning and construction of the runoff harvesting structures.

Climate change projections are relevant when planning rainwater-harvesting structures that guarantee the use of water resources, due to the spatial and temporal variability of the precipitation time series in the catchment.

Finally, to increase agricultural productivity, policies are required to guarantee financial support from government institutions to farmers, as well as technical training for the construction and sustainability of these systems.

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