# Selection Frameworks for Potential Rainwater Harvesting Sites in Arid and Semi-Arid Regions

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# Selection Frameworks for Potential Rainwater Harvesting Sites in Arid and Semi-Arid Regions: A Systematic Literature Review

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**Abstract:** Water shortage is a concern in arid and semi-arid regions across the globe due to their lack of precipitation and unpredictable rainfall patterns. In the past few decades, many frameworks, each with their own criteria, have been used to identify and rank sites for rainwater harvesting (RWH), a process which is critical for the improvement and maintenance of water resources, particularly in arid and semi-arid regions. This study reviews the present state of the art in rainwater harvesting site selection for such regions and identifies areas for additional research. The results of a systematic review performed based on two major databases of engineering research, Scopus and Engineering Village, are presented. Sixty-eight relevant studies were found and critically analysed to identify patterns and unique features in the frameworks used. The results of this study show that 41% of the frameworks consider both biophysical and socioeconomic criteria, whereas the remaining 59% of the frameworks depend on biophysical criteria alone. The importance of each criterion is encapsulated through a suitability score, with 21% of the frameworks using a binary (0 or 1) indicator of whether the site matches a criterion or not and the other frameworks using graded scales of differing granularities, with 52% using a low-resolution scale of 1 to 3, 4, or 5, 7% using a medium-resolution scale of 1 to 10, and a further 7% using a high-resolution scale of 1 to 100. The remaining 13% of the frameworks did not specify the scale used. Importantly, this paper concludes that all existing frameworks for selecting RWH sites are solely based on biophysical and/or socioeconomic criteria; ecological impacts, the consideration of which is vital for building RWH systems sustainably, are currently ignored.

**Keywords:** rainwater management; rainwater harvesting; arid and semi-arid regions; site selection; frameworks; stakeholder; biophysical criteria; socioeconomic criteria; ecological criteria



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## 1. Introduction

Adequate water supply is the most important requirement for human life. The demand for water has increased due to the increase in the Earth's population, from 2.5 billion to 7.35 billion between 1950 and 2015. However, more than 40% of the earth's surface is covered by arid and semi-arid regions, defined as those that receive an average annual rainfall of only about 150–350 mm and 350–700 mm, respectively [1]. Historically, arid and semi-arid regions have contained many settlements, such as those in the Middle East, Northern Africa, and Western Asia, and it is essential that rainfall and other water sources in these areas are used efficiently.

For as long as people have engaged in agriculture, they have used water harvesting to collect rainwater, floodwaters, and groundwater. People rely on water harvesting to meet their water needs where sufficient supplies for drinking water and irrigation are not easily reached [2]. Water harvesting can be classified into one of four types: fog and dew harvesting, rainwater harvesting, groundwater harvesting, and floodwater harvesting [3]. Rainwater harvesting (RWH), the subject of this paper, is the collection or diversion of rainfall runoff for productive purposes, and its use is widespread in arid and semi-arid areas [4].

The very first RWH structures were constructed in southern Jordan over 9000 years ago to provide drinking water for humans and animals [5]. Over 6500 years ago, Iraqis started to use RWH structures in a simple form in order to provide water for domestic and agricultural use [6]. Water harvesting systems were also used in China and India some 4000 years ago [7]. In the southern part of Tunisia, meskat (runoff basin that has a rectangular shape), check dams, jessour and tabias (small water bodies used to recharge aquifers) have been used, with collinaires (agricultural reservoirs) used in Algeria, and ancient hafir (artificial water catchment basin) to help meet domestic and livestock water needs in Sudan. In Niger and Burkina Faso, people have long used rock and earth bunds and stone terraces (elevated platforms on sloping ground) to harvest water. Zay (small pits) combined with bunds (ponds with a semicircular form that are used to collect rainwater) were often used in the west of Africa. These methods were critical to the successful creation of settlements in the desert [6]. In addition, the ancient Greeks demonstrated remarkable ingenuity in the advancement of hydraulic infrastructure and small-scale constructions. Notably, certain examples, such as cisterns, have maintained their full functionality even up until the 20th century [8] and are being used to address the water crises currently occurring in regions of central and eastern Greece. Losses such as evaporation from these cisterns are negligible due to their underground construction [8,9].

RWH includes all water harvesting from roofs or ground surfaces by different techniques, and is utilised for different purposes, whether agricultural, domestic, or drinking. RWH includes two main forms: rooftop harvesting and catchment harvesting [10]. Figure 1 shows the typical types of rainwater harvesting. This study was conducted for catchment rainwater harvesting systems.

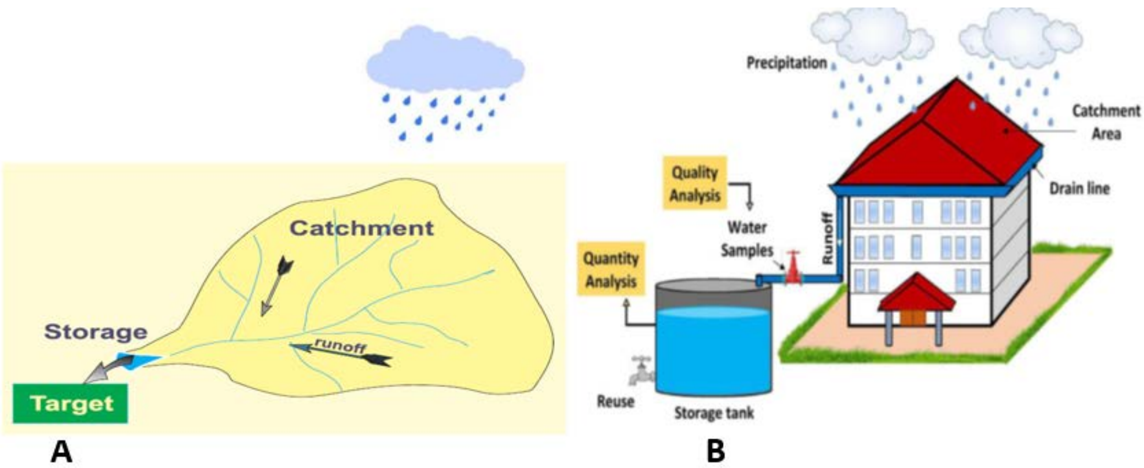


**Figure 1.** (**A**) A typical catchment rainwater harvesting system [11] (**B**) A typical rooftop rainwater harvesting system [12].

Arguably, the most important step in planning for rainwater harvesting structures is selecting the site. Identifying sites for RWH structures is a complex issue, requiring the combination of disparate criteria to produce an assessment of site suitability via a well-defined indicator-based framework, discussed in detail in Section 2. As will be discussed, a range of frameworks and criteria have been suggested for RWH site selection. The criteria can be either quantitative, i.e., measurable characteristics such as rainfall (mm) and runoff ($m^3s^{-1}$), or qualitative, i.e., those which depend on the opinion of stakeholders and experts [13].

The aim of this paper is to review the current state of the art in rainwater harvesting site selection, focusing on applications in arid and semi-arid regions, and to identify areas in which further research is necessary. A comprehensive, systematic literature review has been employed for this purpose; the first step of such a review is defining the research questions that the review is designed to answer, in this case:

1. What RWH site selection criteria have been used in existing frameworks?
2. What are the differences and similarities in the way these frameworks combine the criteria they use, i.e., their scaling and weighting methods?
3. What gaps exist in the criteria currently applied, and what future work is necessary to improve frameworks, particularly bearing in mind the need for sustainability?

The paper is divided into seven parts. Following this introduction, Section 2 describes the main principles of indicator frameworks used for RWH site selection. Section 3 provides details of the systematic literature review method applied in this study. In Section 4, an overview of the publications returned by the review search is given, with details of the important findings presented in Section 5, specifically the criteria and weighting methods currently used. Section 6 discusses the key results and puts them in context. Finally, key conclusions are drawn and summarised in Section 7.

## 2. Indicator-Based Frameworks and Their Criteria

Water resource development projects require the integration of a system that includes multidisciplinary knowledge in social sciences, economics, and agronomy [14]. Many projects related to water management around the world, costing billions of dollars, have failed due to decision makers only considering the biophysical aspects without looking at the other aspects, such as social and ecological impacts [15]. The ecological condition of a water body can be evaluated through testing of water samples for important metrics such as total dissolved solids (TDS), dissolved oxygen (DO), nitrogen (N), chlorophyll, bacterial growth, turbidity, total suspended solids, ammonia, PH, total phosphorus (TP), and salinity. It is recognised that other factors, such as the air temperature and amount of sunlight the water body receives, affect these metrics [16], and, in our opinion, should be included in assessments of site suitability. Water bodies represent a complex system in terms of the environment because they are transitional between rivers and lakse [17].

Indicator-based decision-making frameworks are an important part of ensuring that these diverse factors are adequately taken into account during the different stages of projects. The formation of an indicator-based framework has the benefit of allowing for the evaluation and clarification of multi-dimensional aspects or ideas, which cannot be evaluated directly [18]. Through collaboration between experts and stakeholders, an acceptable framework may be constructed that converts the complex issue, which contains many groups of criteria with different measures, to a single number that is easier to understand and interpret for non-experts [18] and simplifies the comparison of potential sites for experts, facilitating an objective evaluation. Any indicator framework has three main parts: headline categories (components), supporting indicators, and second-order and third-order sub-indicators [19]. Components may be seen as separate categories of indicators that reflect certain concerns or themes in response to the demands of users [20] (Figure 2).

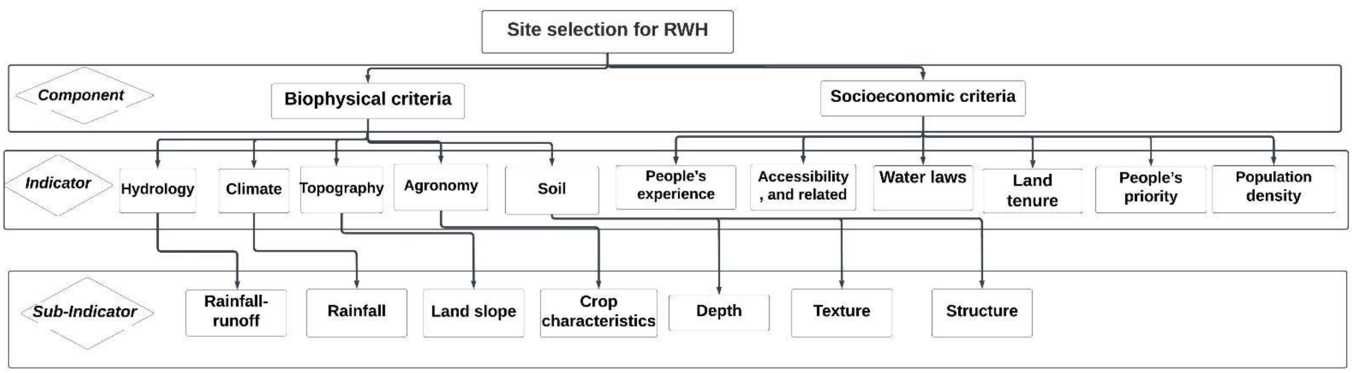


**Figure 2.** Indicators framework hierarchy for RWH site selection.

### 2.1. Indicators

Indicators are the framework's primary element, and they are often chosen based on literature review and expert opinions; their selection should be conditional on the following points [21,22]:

1. Available: the data should be easy to access or measure.
2. Measurable: the criterion may be easily measured and analysed quantitatively.
3. Repeatability: if the indicator is evaluated following the same method for the same region under the same conditions, it will provide the same result each time.
4. Validity: There must be a distinct connection between a criterion and the issue it is intended to demonstrate.

The indicators may be quantitative or qualitative. Quantitative indicators are directly measurable with a numeric value but potentially different units, such as distance to the nearest road (units of meters, m), runoff $\left(m^3s^{-1}\right)$, and slope (dimensionless). Qualitative indicators, for example subjective opinions, do not have a direct numerical value, but may be quantified using standardization.

### 2.2. Standardization of Indicators

According to Juwana et al. [19], in order to reconcile the different measures for indicators, the quantitative values should be converted to a normalized, dimensionless number, which can simplify comparison and aggregation and also aid understanding by nonexperts. This process is done using one of two standardization methods [23], one for quantitative indicators and the other for qualitative indicators:

Empirical standardization normalizes quantitative indicators by the range of values, relative to the minimum value, as illustrated in Equations (1) and (2) [23]:

$$X_i = \frac{R_i - R_{min}}{R_{max} - R_{min}} \tag{1}$$

where $X_i$ is the standardised score ($0 \leq X_i \leq 1$), $R_i$ is the raw score for the indicator, and $R_{min}$, $R_{max}$ are the minimum and maximum scores for the indicator, respectively. Equivalently, this standardisation may be scaled to the range $0 \leq X_i \leq 100$:

$$X_i = \frac{R_i - R_{min}}{R_{max} - R_{min}} \times 100 \tag{2}$$

The second method, used for producing equivalent scores from qualitative indicators, is categorical scaling. Based on pre-established criteria, the values of indicators are categorized and allocated. These classifications might be numerical, such as ranging from 1 to 5, or they can be descriptors and points of view, such as "equal importance", "moderate importance", or "strong importance", so each description in questionnaires has a number that represents the importance of this criterion. For example, if the scale for suitability is from 1 to 3, then 1 will represent "equal importance", 2 will represent "moderate importance", and 3 will represent strong importance [18]. Also, classification can take the form of Likert scale statements, whereby participants are prompted to express their degree of concurrence or discordance with a set of predetermined statements, typically spanning from "Strongly Agree" to "Strongly Disagree". The inclusion of a neutral midpoint option, such as "Neither Agree nor Disagree", may be considered in the construction of the scale. The responses are quantified using numerical values, typically within the range of 1 to 5 or 1 to 7, in order to measure the extent of concurrence or discordance [24].

### 2.3. Weighting Scheme

Weights are employed to aggregate the indicators within a framework into a resultant output index. This gives users of the framework the ability to vary the weights on the various indicators for a particular application. In order to arrive at the final index number, the weighting scheme involves multiplying each component of the indicator-based framework by a value that represents the component's significance, or weight, during each stage of the calculation.

In general, statistical methods and participatory methods are employed to assign weights to various criteria. In the statistical method, weights are assigned based on the analysis of criteria data from the literature, whereas in the participatory method, weights are assigned using questionnaires and workshops meant to gather expert and stakeholder perspectives on weighting [19].

## 3. Methodology

A systematic literature review is employed to answer specific questions by identifying, appraising, and synthesising relevant literature that fits pre-specified criteria [25]. Briefly, such a review includes a comprehensive search that concentrates on providing a summary of the existing literature on a subject and specific goals that have been established. In terms of the strategy for selecting papers, it should be transparent, with explicit inclusion and exclusion criteria for papers established prior to initiating the review. Moreover, the process of assessment of articles should be comprehensive, the selection of the information that is related to the study should be clear and specific, and the summaries of articles should be clear and based on high-quality research. The parameters of the review conducted for this paper are detailed below.

The specific questions to be answered by this review are stated in Section 1. Two databases of scientific publications were interrogated, Scopus and Engineering Village. These databases have a good search engine for complex queries and cover all the main engineering journals. To ensure reliable, high-quality sources, the scope was restricted to peer-reviewed books, articles, and conference papers. Only English-language papers were included, though with English being the language of most (if not all) of the major engineering journals, this is likely to include all important works. Details of the precise query, keywords, and filters used for each database are given in the following subsection.

Once papers were identified using the systematic literature review keywords and filters, the search was expanded to include papers that cited those papers, and that were cited by those papers. Again, these papers were filtered by relevance to the review questions.

### *3.1. Search Queries and Keyword Selection*

The search queries were designed to search the "title-abstract-keyword" fields in Scopus and (equivalently) the "subject/title/abstract-keyword" fields in Engineering Village. Three groups of keywords were used for the search queries: "scope" keywords, "target" keywords, and "methods" keywords, with keywords in each group. The groups each represent a range of possible acceptable options; therefore, the OR operator was utilized to search for one or more of the group's keywords. The search was narrowed by using AND operators between groups to ensure that at least one keyword from each group appeared in the paper.

The keywords used for the scope group were those that were primarily related to water harvesting; these keywords were used to define the broad frame from which the search should begin. Specifically, these keywords and their variations *were* "water harvesting", "rainwater harvesting", "rainwater collection", "RWH", "water storage systems" and "store precipitation".

The terms for the target group were "arid", "semi-arid", "water scarcity", "water shortage", "dry areas", "Iran", "Jordan", "Iraq", "Morocco", "Saudi Arabia", "Yemen", "Lebanon", "China", "India", "Tanzania", "Tunisia", "Pakistan", "Ethiopia", "Malawi", "Mongolia", "Egypt", "Kenya". These keywords were selected to ensure all relevant regions were captured by the search query, using aridity-related phrases and relevant country names, i.e., all countries in the Middle East, all countries in northeast Africa, and China, because most of these countries are affected by seasonal rainfall and a lack of water for people, agriculture, and animals.

The final set of keywords was related to the specific purpose of the study, and were "suitable location", "site selection", "suitable sites", "site suitability", "possible sites", "RWH sites", "potential sites", "criteria", "suitable area".

Figure 3 shows the keyword groups and their relationships. The full query strings used for each database are given in the Appendix B.

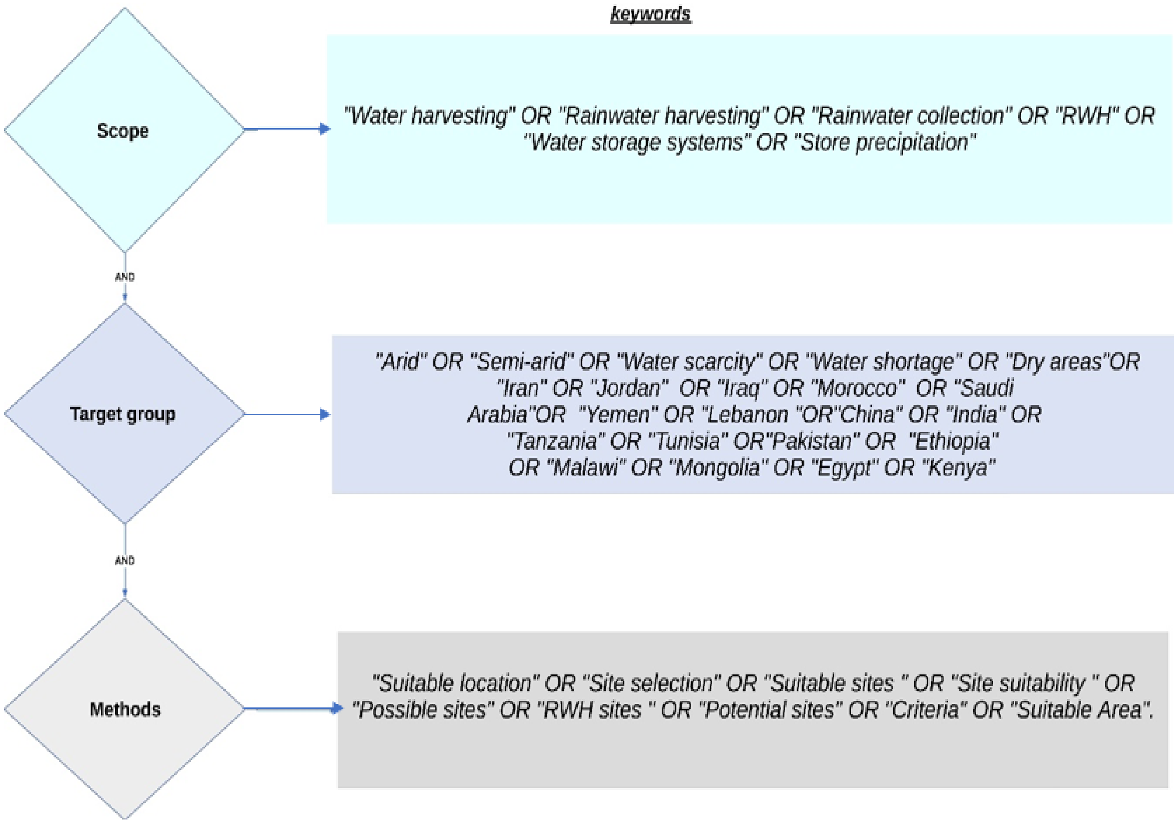


**Figure 3.** Keyword groups for this search.

### 3.2. Database Search

The Scopus and Engineering Village databases were searched on 29 October 2022, using the queries detailed in Section 3.1. These searches resulted in 244 and 312 articles, respectively. The results were collated using an EndNote library, and duplicates were automatically removed. Two hundred and sixty-two unique articles were returned by this process. To ensure relevance, the results were manually filtered based on the title and abstract, the scope of the study, and the aim of the review. This stage was conducted based on the inclusion criteria for the articles that related to site selection for rainwater harvesting; 186 articles were excluded based on these criteria.

Seventy-six articles were retained after this process, following which the remaining articles' full text was examined in detail. This final round was added to ensure that each of the 76 papers contained essential elements related to this study, such as arid and semi-arid, and that they were included in the full-text analysis. Eight articles were excluded. This process is summarised in Figure 4. Following the completion of all of the preceding processes, 68 articles were selected for in-depth review. From this review, the design and implementation of the existing frameworks were identified and analysed, along with the criteria which they use.

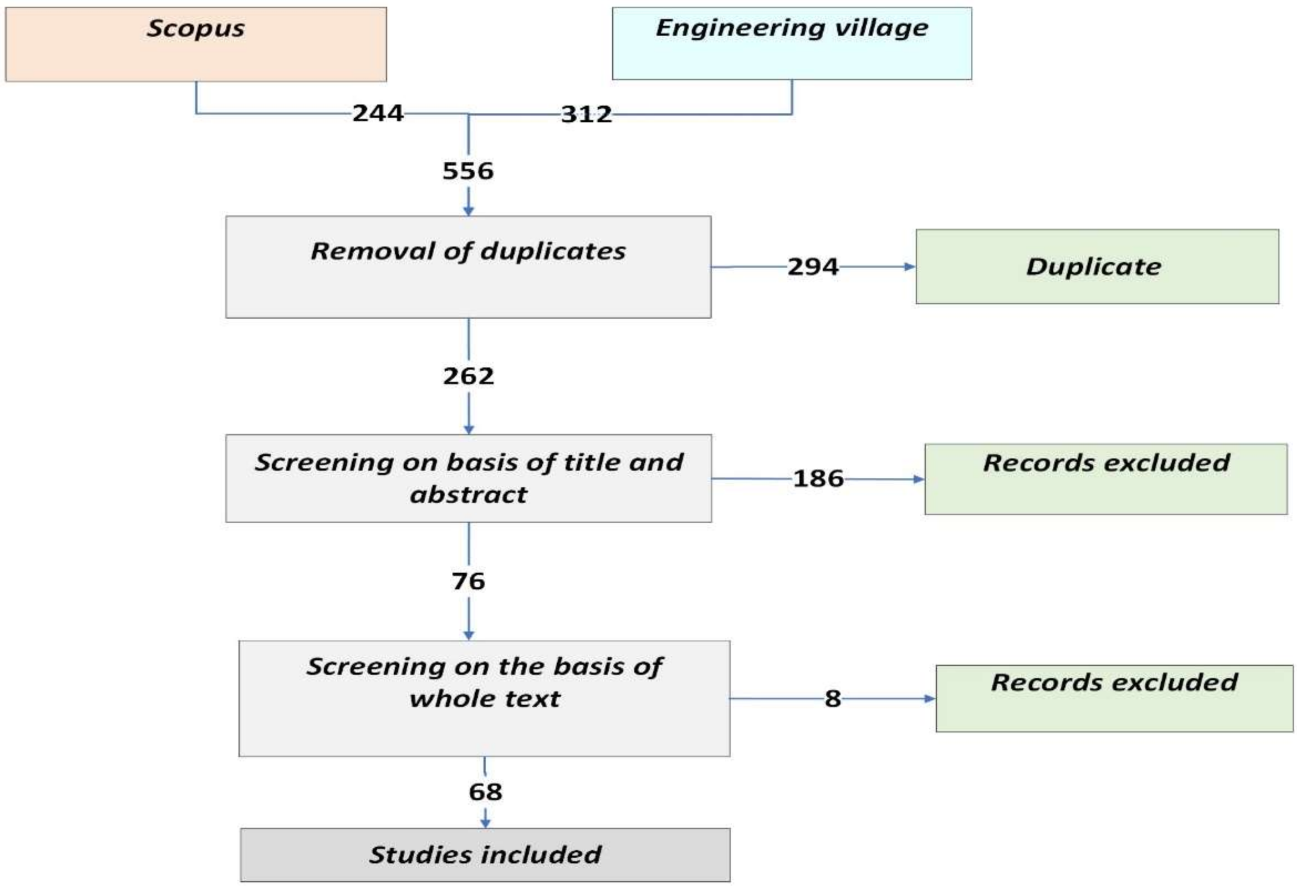


**Figure 4.** Article filtering procedure.

## 4. Overview of Retained Publications

All but three publications ([26–28]) provided author-specified keywords. "Harvesting", "rainwater", "water", "GIS" and "system" were the most frequently used keyword strings in the chosen articles, as seen in Figure 5. The word cloud depicted in Figure 5 was created using NVivo version 14, created by QSR International Software Company Pty Ltd., (The company is headquartered in Burlington, Massachusetts (US), and has branch offices in Australia, Germany, New Zealand, and the United Kingdom.), which is widely used for literature reviews and qualitative data analysis. It helps gather relevant literature from various sources like dissertations, recent journal articles, books, reliable web pages, organisational reports, and conference proceedings [29].

The country with the most publications related to RWH site selection was Iraq (12), followed by Iran (8), Egypt (7), Jordon (6), and Saudi Arabia (5); see Figure 6.

Figure 7 shows the distribution of articles by year of publication. Although the search included publications going back to 2000, all but 9 of the papers are from within the last 8 years and 36 were published in the last 3–4 years, ensuring that the results of this review are up-to-date. The growth in interest in this area of research over the last 3 years or so is also evident.


**Figure 5.** Word cloud of the author-supplied keywords (NVivo).

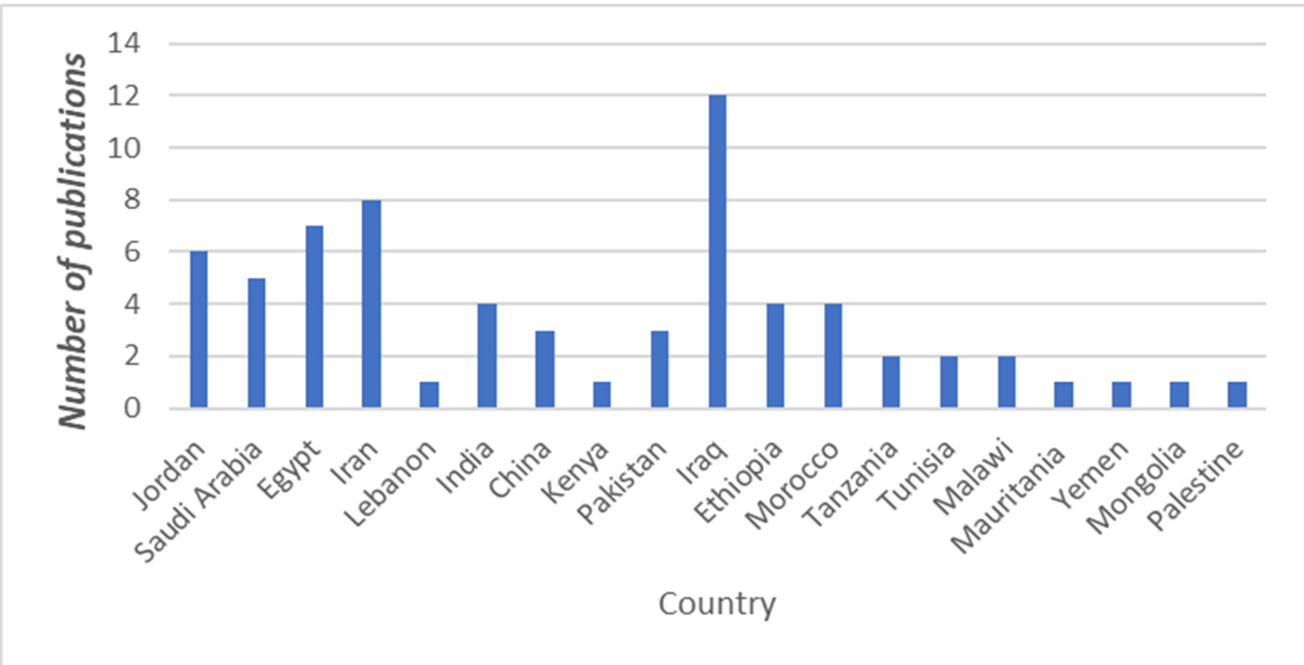


**Figure 6.** Distribution of number of publications by country.

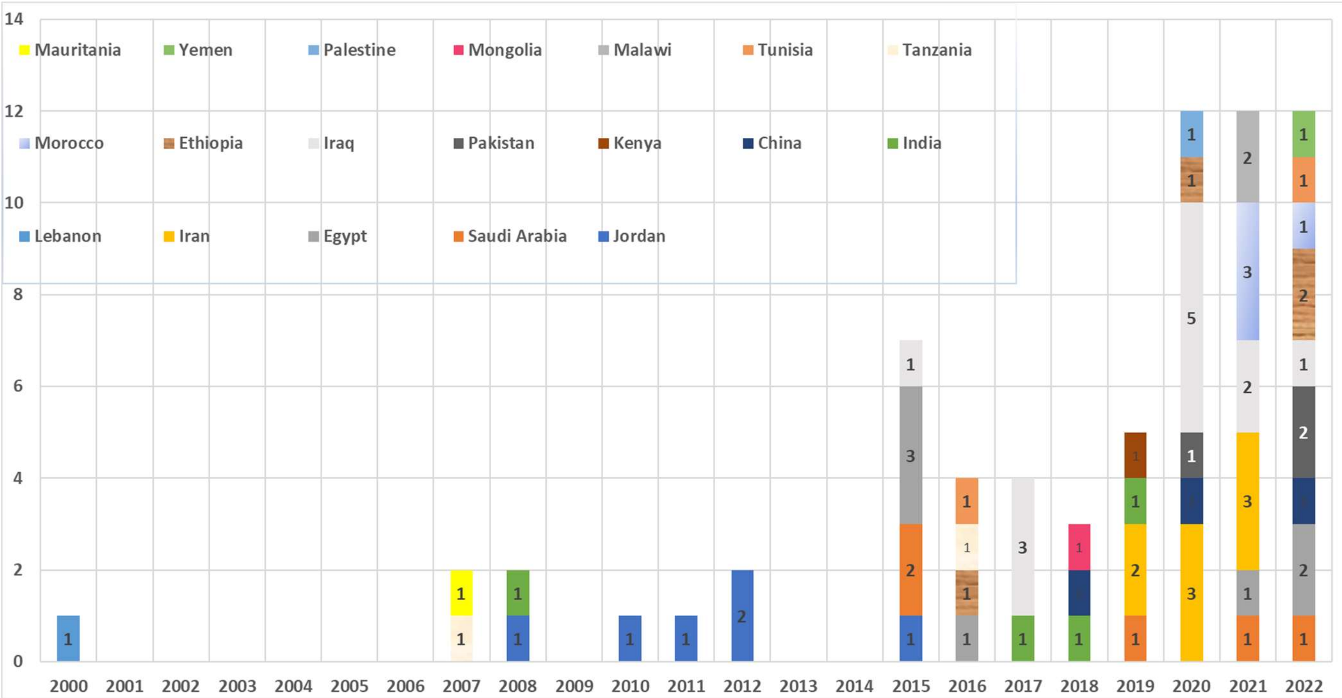


**Figure 7.** Distribution of the relevant publications by country and year.

## 5. Current Frameworks and Their Criteria

As shown in Figure 4 and explained in Section 3.2, the final number of papers matching the systematic review criteria from the two databases was reduced to 68 frameworks in the final phases that were considered for a comprehensive assessment. Each of these frameworks was designed for a distinct application at a different scale and within a unique set of local circumstances and situations. Naturally, each of these frameworks serves a unique purpose, employs a unique method of evaluation, and uses a different assessment procedure. The analysis of these frameworks was based on their country, year, keywords, classification of the criteria (biophysical and socioeconomic criteria), tools, annual rainfall, catchment area, range of the index, and methods of weighting, as shown in Table A1. The systematic literature review found that the RWH site selection frameworks use a variety of different criteria, weighting methods, and other tools.

The next section provides a detailed look at the frameworks discussed in these publications, with a focus on the criteria used and how these criteria can be combined to make a quantitative measure of site suitability.

### *5.1. Criteria Currently Used for RWH Site Selection*

Two categories of criteria have been identified for use in RWH site selection, namely, biophysical and socioeconomic. The biophysical criteria were proposed by the Integrated Mission for Sustainable Development in 1995 and include drainage system, soil texture, slope, and land use/land cover. In addition, Oweis et al. [30] introduced a second category of criteria, the socioeconomic criteria, represent by factors like land tenure. Subsequently, the Food and Agriculture Organization (FAO) [31] revised these categories to include climate (rainfall), agronomy (crop characteristics), hydrology (rainfall–runoff relationship and intermittent watercourses), topography (land slope), soil (structure, depth, and texture), and socioeconomic conditions (people's experiences, workforce, people's priorities, population density, water laws, land tenure, accessibility, and related costs).

Of the 68 publications analysed for this review, 59% use biophysical criteria alone, while the remainder used both biophysical and socioeconomic criteria. Details of each publication and their frameworks are given in the Appendix A, in Table A1.

Upon analysing the criteria used, it became apparent that various synonymous terms were used to denote equivalent criteria. In such instances, these criteria have been consolidated to achieve the merged criteria, as shown in Table 1. These criteria are categorised into two groups, namely biophysical and socioeconomic criteria.

**Table 1.** Groups of existing criteria.

| **Biophysical Criteria** | | **Socioeconomic Criteria** | |
|---|---|---|---|
| **Criteria** | **Synonyms** | **Criteria** | **Synonyms** |
| 1- Rainfall (mm) | ■ Precipitation | 1- Distance to roads (m) | |
| 2- Runoff | ■ Flow<br>■ Surface runoff<br>■ Flow distance<br>■ Discharge<br>■ Runoff depth | | |
| 3- Hydrological losses (mm) | ■ Evaporation<br>■ Infiltration | | |
| 4- Slope (%) | ■ Elevation<br>■ Digital elevation | 2- Distance to agricultural area (m) | |
| 5- Soil | ■ Soil texture<br>■ Type of soil<br>■ Soil quality<br>■ Soil depth<br>■ Curve number<br>■ Soil permeability | 3- People's priority | ■ Stakeholders' priority |
| 6- Land use/land cover | ■ Vegetation | | |
| 7- Drainage density | ■ Drainage texture<br>■ Stream order | 4- Population density | ■ Population and rural density |
| 8- Catchment area ($km^2$) | ■ Watershed area<br>■ Watershed length<br>■ Basin area | 5- Distance to urban area (m) | ■ Distance to the village<br>■ Distance to settlements<br>■ Distance to built-up areas |
| 9- Distance to wadis (m) | | | |
| 10- Distance to faults (m) | ■ Lineament density | | |
| 11- Distance to water source (m) | ■ Distance to lake<br>■ Distance to streams<br>■ Distance to river<br>■ Distance to wells | | |

#### 5.1.1. Biophysical Criteria

1- Rainfall (mm)

The volume and distribution of rainfall can vary significantly depending on geographic location, climate, and season, with higher rainfall clearly increasing the likelihood of harvesting useful amounts [32]. Rainfall measurements are based on meteorological stations, which generally measure a variety of factors, such as precipitation, wind velocity, temperature, and humidity. In arid and semi-arid regions of developing countries, many areas do not have enough meteorological stations to give detailed local data, and so interpolation from the nearest meteorological stations is used. This method does not require high costs, human resources, or time, and can therefore be applied relatively easily in developing countries such as Iraq, Yemen, Palestine, and Kenya, where limited resources and high costs have been shown to make spatial interpolation an appropriate choice to tackle this issue [33]. Out of the 68 frameworks examined, three explicitly mention the use of the inverse distance weight (IDW) interpolation method, employing data stored in a geographic information system (GIS) [1,34,35].

Catchment suitability clearly depends on the average annual rainfall and is scored based on local requirements. For instance, in Tunisia (wadi Oum Zessar), the catchments' suitability is based on five ranges of average annual rainfall (R) (mm/year), (R100, R (100–175), R (175–250), R (250–325), and R > 325), with suitability rated as very low, low, medium, high, and very high, respectively [1,36]. This classification is based on the literature and discussion with experts and stakeholders.

2- Runoff

The effectiveness of rainwater harvesting is extremely reliant on the volume of water that can be collected under a given climate. Runoff is characterised as water flow over the ground surface towards the nearest channel, such as a stream, river, etc., which occurs when the soil is saturated or when the catchment has a steep slope. Soil saturation happens through losses of infiltration, which is determined by soil texture.

The runoff volume is commonly calculated using the Soil Conservation Service Curve Number (SCS-CN) method [23]. The curve number (CN) was established by the Department of Agriculture of the United States of America and is based on soil texture, land use/land cover (LULC), and the hydrological surface conditions of the catchment. The range of the curve number is from 0 to 100, where the higher the curve number, the higher the percentage runoff and lower the infiltration, and vice versa. Runoff is calculated in accordance with Equations (3) and (4) [23,37].Runoff is calculated in accordance with Equations (3) and (4) [23,37].

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad (3)$$

$$S = \frac{25400}{CN} - 254 \quad (4)$$

where Q is the runoff depth in millimetres, S is the maximum possible retention after runoff starts in millimetres, P is the amount of rain in millimetres, and CN is the number of the runoff curve [23].

3- Hydrological Losses

Hydrological losses, which represent the percentage of rainfall that does not contribute to runoff due to evaporation and infiltration, directly impact the quantity of water that will be harvested in RWH structures. Evaporation depends on temperature, humidity, and wind, where low humidity and high temperatures lead to a high rate of evaporation. Thus, it varies with season, with annual evaporation calculated based on the average of the monthly evaporation rates [38]. Evaporation is measured based on meteorological stations [23].

The infiltration ratio depends on the soil texture, primarily based on the percentage of clay content, with high clay content reducing infiltration; see Table 2.

**Table 2.** Average values of the final infiltration rate for different types of soil [6].

| Soil Type | Infiltration Rate (mm/h) |
|---|---|
| Coarse sand | >22 |
| Fine sand | >15 |
| Fine sandy loam | 12 |
| Silt loam | 10 |
| Silty clay loam | 9 |
| Clay loam | 7.5 |
| Silty clay | 5 |
| Clayey soil | 4 |

4- Slope (%)

The suitability of a site for RWH is influenced by its slope, which affects runoff and hydrological losses. Generally, slope is defined as the ratio of the vertical change ($y$-axis) to the horizontal change ($x$-axis) between two points on the catchment. Out of the frameworks examined, 5 [39–43] out of 68 frameworks employ average catchment slope calculations based on digital elevation models (DEMs). However, the remaining frameworks do not provide a detailed explanation of the methods used for slope calculation. This omission hinders follow-up research by reviewers and compromises the transparency of a study. Rainwater harvesting is not recommended for slopes over 5% due to irregular flow and the need for expensive earthwork [36].

5- Site Soil

Soil is essential to the conservation of water within rainwater harvesting (RWH) structures, which benefits humans, animals, and agricultural activities. For example, sand-textured soils cannot be used to build RWH structures for water harvesting because of high infiltration losses, whereas a higher percentage of clay in the soil gives it a higher rank of suitability for RWH sites [32]. The existing different frameworks use different expressions for soil criteria, which are soil texture, type of soil, soil quality, soil depth, curve number, and permeability. Soil texture determines the curve number (CN), as shown in Section 2.

The suitability of the catchment area for RWH sites in terms of soil depends on the type of soil, which is classified based on the literature and experts' opinions. For example, according to research performed by Adham, A., et al. [44], conducted in the Western Desert of Iraq, it has six types of soil: clay, silty clay, sandy clay, sandy clayey loam, sandy loam, and others. The suitability of each type was rated, and adjusted based on discussions with experts, as very high, high, medium, low, and very low, respectively. The depth of the soil should permit excavation to the required level for the RWH structure. In addition, the depth of soil is a significant factor as well, which is measured based on a field test based on hammering a steel bar into the earth until it can go no further, and measuring the soil levels between successive terraces [1].

Land Use/Land Cover (LULC)

Land use/land cover (LULC) refers to the function or utilisation of the land, and affects the amount of runoff that occurs. For example, there is a link between more vegetation and more interception and infiltration, which reduces the amount of runoff [1]. In rainwater harvesting site selection, LULC classification is carried out to assess the LULC's impact on runoff; according to Adham's [1] classification, land use and land cover categories are farmland and grass, moderately cultivated land, bare soil, mountainous and water bodies, and urban areas. The suitability levels for each class were scored and adjusted based on discussions with experts, and were, respectively, very high, high, medium, low, and restricted. Bare soil refers to areas where people have overused the land, destroying the plant cover, which then allows the upper soil to be removed through natural processes [23]. Vegetation coverage rates are used to monitor changes in biomass or to identify land degradation processes. In semi-arid and arid regions, annual and seasonal changes in the quantity of vegetation cover are dramatic [32]. The selection criteria for RWH must not include farmland or urban areas, since these zones have distinct economic identities that preclude the construction of RWH buildings [32].

6- Drainage Density

Drainage density is often defined as the total length of channels (network used to transfer water to the outlet) divided by the total unit area [45]. The drainage density is inversely proportional to permeability; hence, a high drainage density indicates that a site will rank higher in suitability for RWH sites than one with a lower drainage density [46,47]. In addition, stream order is dependent on the connection between tributaries. Stream order is used to indicate the hierarchical relationship between stream segments and permits the categorization of drainage basins by size. If the number of stream orders increases, permeability and infiltration decrease, and vice versa [23]. The drainage density is calculated in arid and semi-arid regions based on a digital elevation model (DEM) [23]. The catchment area for the drainage density is inversely proportional to its permeability; hence, a high drainage density indicates that a site will rank higher in suitability for RWH sites than one with a lower drainage density [46,47].

7- Catchment Area

The catchment area for rainwater harvesting (RWH) is the surface area from which rainwater is collected and directed into a storage tank or reservoir for later use. The runoff processes are notably influenced by the basin area. Consequently, it is a crucial factor in calculating the potential for rainwater harvesting. The augmentation of the basin area results in a proportional increase in the quantity of precipitation accumulated and the maximum discharge of water [48].The catchment area for rainwater harvesting (RWH) is the surface area from which rainwater is collected and directed into a storage tank or reservoir for later use. The runoff processes are notably influenced by the basin area. Consequently, it is a crucial factor in calculating the potential for rainwater harvesting. The augmentation of the basin area results in a proportional increase in the quantity of precipitation accumulated and the maximum discharge of water [48].

8- Distance to Wadis

Wadis are the primary carriers of surface water in the region and provide the majority of surface water runoff throughout the winter months [32]. RWH structures cannot be built as part of a wadi, according to Al-Adamat [32], for financial, technical, and environmental reasons. The distance to a wadi should be more than 50 m and less than 2000 m [32,36]. This distance ensures that the RWH system can collect water from the wadi when it rains without being damaged by flash floods. It is also close enough to make it easy to collect water and move it to where it is needed [32].

9- Distance to Faults

The distance to faults and lineaments is seen as a problem when choosing a site for RWH, since faults and lineaments are like cracks and joints that increase infiltration [23,41]. The distance to the water source is a critical factor to consider when implementing RWH systems in arid and semi-arid regions. It will impact the feasibility, effectiveness, and cost of the RWH system, as well as the size and location of the collection surface. The distance to faults is measured based on a digital elevation model (DEM). The distance to faults should be more than 1000 m for RWH structures [23].

10- Distance to Water Source (m)

It is recommended that RWH zones be situated at a safe distance from natural water sources, such as rivers or lakes, to prevent obstruction of water flow and ecological disruption in the surrounding water source area [46]. The distance to the water source should be more than 1500 m [46].It is recommended that RWH zones be situated at a safe distance from natural water sources, such as rivers or lakes, to prevent obstruction of water flow and ecological disruption in the surrounding water source area [46]. The distance to the water source should be more than 1500 m [46]. Wells are very important to the local economy and society. Rainwater harvesting should be selected without including wells. The distance to the well source should be more than 500 m [32]. The distance from the water source is calculated based on remote sensing.

#### 5.1.2. Socioeconomic Criteria

1- Distance from Roads (m)

A study region's proximity to roads can present a significant socioeconomic advantage for the local community. Through these routes, they may transfer their trucks and tankers from one location to another when hunting for pasture and water for their animals [46].

Distance from roads is calculated based on remote sensing, where satellites take high-resolution photos of the Earth. These photos help locate roads, and GIS tools provide accurate measurements of distances, allowing us to quantify the separation between roads and RWH systems. The distance to roads should be more than 250 m [49]. This will avoid any potential future confrontation between the growth of the roadways and the built-up ponds [36]. A study region's proximity to roads can present a significant socioeconomic advantage for the local community. Through these routes, they may transfer their trucks and tankers from one location to another when hunting for pasture and water for their animals [46]. Distance from roads is calculated based on remote sensing, where satellites take high-resolution photos of the Earth. These photos help locate roads, and GIS tools provide accurate measurements of distances, allowing us to quantify the separation between roads and RWH systems. The distance to roads should be more than 250 m [49]. This will avoid any potential future confrontation between the growth of the roadways and the built-up ponds [36].

2- Distance from Agriculture (m)

The proximity of the RWH system sites to agricultural areas reduces the distance of pumping and diversion systems, making it the most cost-effective choice for stakeholders [50]. This criterion is measured based on remote sensing. The distance to an agricultural area should be more than 250 m. This distance is used to reduce the risk of runoff contamination by agricultural activities, such as pesticide and fertiliser use. This distance ensures that the collected rainfall is not compromised and is safe for human consumption and other household uses. The proximity of the RWH system sites to agricultural areas reduces the distance of pumping and diversion systems, making it the most cost-effective choice for stakeholders [50]. This criterion is measured based on remote sensing. The distance to an agricultural area should be more than 250 m. This distance is used to reduce the risk of runoff contamination by agricultural activities, such as pesticide and fertiliser use. This distance ensures that the collected rainfall is not compromised and is safe for human consumption and other household uses.

3- People's Priorities

People's priorities are especially significant in arid and semi-arid areas, which may help explain why so many projects failed when they did not take their priorities into consideration. A project's success can be enhanced by incorporating the community's expertise and knowledge, which align with their priorities and specific needs [51]. For example, most people in arid or semi-arid parts of Africa have lived with basic subsistence systems, which have helped them set goals for life over the years. No lower-priority tasks can be done well until all the higher responsibilities have been taken care of [51]. Also, stakeholder participation is crucial for the success and sustainability of rainwater harvesting (RWH) projects. Stakeholders are individuals or groups who have a direct or indirect interest in RWH activities, such as local communities, farmers, government agencies, and private sector organizations [52]. This criterion is calculated based on a questionnaire survey of people and stakeholders, analysing their responses to these questionnaires, and assigning a rank to each criterion based on this analysis. People's priorities are especially significant in arid and semi-arid areas, which may help explain why so many projects failed when they did not take their priorities into consideration. A project's success can be enhanced by incorporating the community's expertise and knowledge, which align with their priorities and specific needs [51]. For example, most people in arid or semi-arid parts of Africa have lived with basic subsistence systems, which have helped them set goals for life over the years. No lower-priority tasks can be done well until all the higher responsibilities have been taken care of [51]. Also, stakeholder participation is crucial for the success and sustainability of rainwater harvesting (RWH) projects. Stakeholders are individuals or groups who have a direct or indirect interest in RWH activities, such as local communities, farmers, government agencies, and private sector organizations [52]. This criterion is calculated based on a questionnaire survey of people and stakeholders, analysing their responses to these questionnaires, and assigning a rank to each criterion based on this analysis.

4- Population Density

Proximity to densely populated regions is a favourable attribute for the suggested locations. Water that has been stored is a significant resource for agricultural purposes and human settlements. Therefore, stakeholders tend to prioritise locating rainwater harvesting (RWH) systems in close proximity to densely populated regions. This approach helps minimise pumping distances, resulting in cost-effective operations [50].Proximity to densely populated regions is a favourable attribute for the suggested locations. Water that has been stored is a significant resource for agricultural purposes and human settlements. Therefore, stakeholders tend to prioritise locating rainwater harvesting (RWH) systems in close proximity to densely populated regions. This approach helps minimise pumping distances, resulting in cost-effective operations [50].

5- Distance to Urban Area (m)

One of the targets of the design of RWH structures is the local community; thus, the location of water-collection RWH structures near urban centres is vital [32,50]. The expression distance to the urban area is used in some of the frameworks as a synonym, such as distance to the village, distance to settlements, and distance to built-up areas.

Six frameworks [32,36,46,53,54] mention the limitations of criteria when applied to RWH systems in arid and semi-arid regions as follows:

- Annual rainfall should be more than 100 mm and less than 750 mm.
- The slope should be no more than 10% (not recommended for areas where the slope is greater than that).
- Soil should have a clay content of no less than 10%.
- The distance to a wadi should be more than 50 m and less than 2000 m.
- The distance to faults should be more than 1000 m.
- The distance to the water source should be more than 1500 m.
- The distance to a road should be more than 250 m.
- The distance to an agricultural area should be more than 250 m.
- The distance to an urban area should be more than 250 m and less than 2000 m.

### *5.2. Analysis of Current Frameworks' Criteria*

After merging the equivalent criteria, a survey of current frameworks led to the formation of the criteria categories shown in Figure 8, which shows the frequency of the criteria.

The term "slope" is the most frequently used, followed by "soil", "LULC", "drainage density", "rainfall", "runoff" and, "distance to roads". Word clouds were used to depict the incidence of the criteria terms as well as the frequency with which they occurred, as shown in Figure 9, where the size of the text denotes the frequency of the term [55].The term "slope" is the most frequently used, followed by "soil", "LULC", "drainage density", "rainfall", "runoff" and, "distance to roads". Word clouds were used to depict the incidence of the criteria terms as well as the frequency with which they occurred, as shown in Figure 9, where the size of the text denotes the frequency of the term [55].

Figure 10 shows the criteria that have been used in existing frameworks to identify RWH sites. Whereas 40 frameworks (59% of total frameworks) were based solely on biophysical criteria, 28 frameworks (41% of total frameworks) were based on both biophysical and socioeconomic criteria.

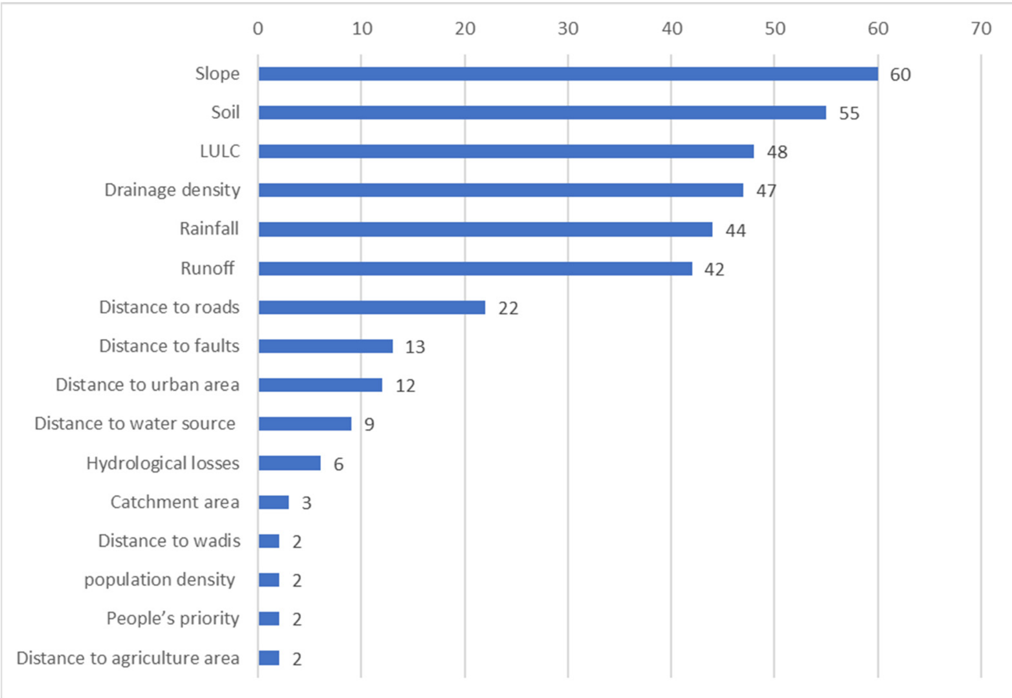


**Figure 8.** Criteria frequency in relevant frameworks.


**Figure 9.** Word cloud of the criteria based on NVivo.

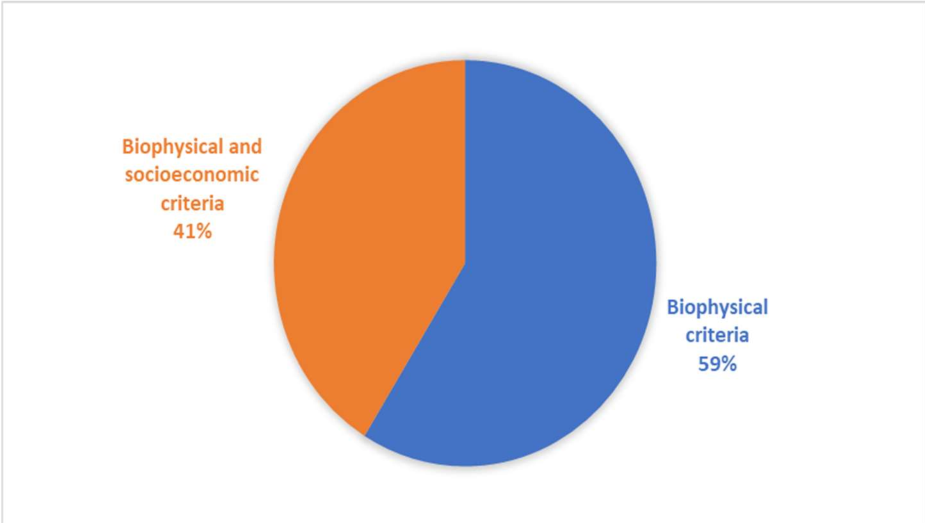


**Figure 10.** Biophysical and socioeconomic criteria.

Figure 11 shows the percentages of weights for biophysical and socioeconomic criteria that have been used in existing frameworks. Whereas the percentage of biophysical criteria weights represents 80% of the total frameworks, the socioeconomic criteria represent 20%. These percentages were calculated based on the summation of weights for biophysical and socioeconomic criteria, listed severally in existing frameworks.

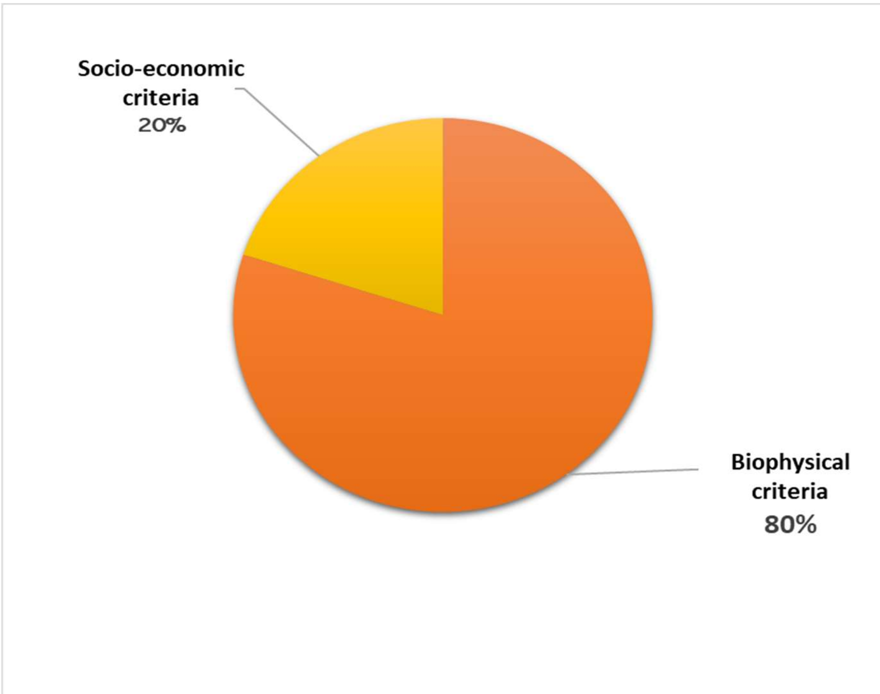


**Figure 11.** Percentages of weights for biophysical and socioeconomic criteria in existing frameworks.

### 5.3. Weighting Process and Intervals for Suitability

Based on this review, the weighted distribution scheme applied in RWH site selection frameworks can be divided into two distinct schemes:

- Equal weights: imply that each criterion in the framework is accorded the same degree of importance.
- Nonequal weights: indicate that different criteria are assigned varying levels of importance or significance within the framework. Weight for each criterion is based on

the importance of the criterion for the purpose of the framework; for example, if the slope is more important than the soil for the framework, that means the slope is given a higher weight than the soil.

Just one framework adopted equal weights, with Al-Adamat [32] arguing that a truly valid assessment system should equally balance the main elements of sustainability without introducing bias towards one aspect, especially for complex indicators. Fifty frameworks (74%) adopted unequal weights, such as [46,56–59] (Figure 12). They argue that doing so gives each criterion its importance based on its effect on the system, and also note that equal weighting does not guarantee equal importance or contribution of the indicators to the composite indicator. However, based on their research, [34,42,60], some authors concluded that the unequal weights require additional human resources and time to implement.

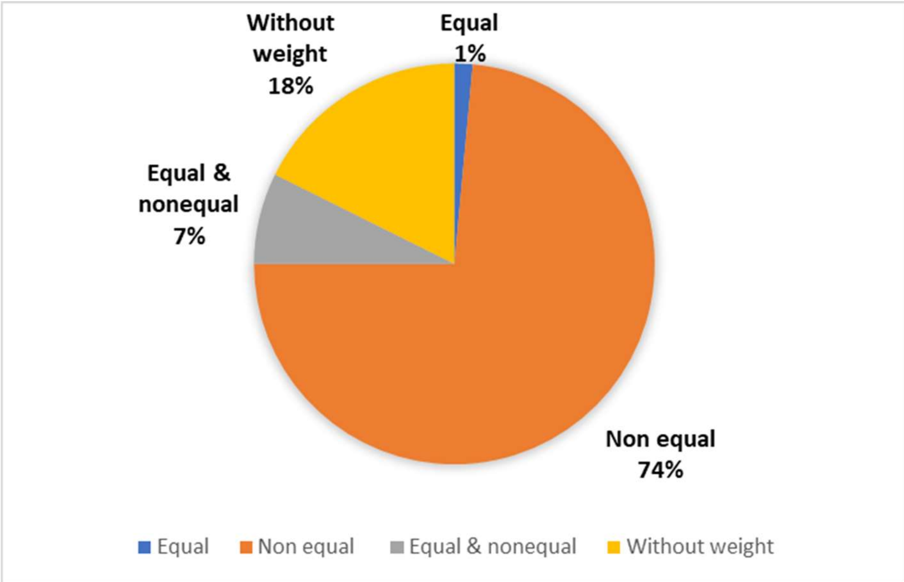


**Figure 12.** Distribution weighting scheme.

Five frameworks (7%), such as [41,61–64], used two scenarios of weights (equal and nonequal weights) in order to adjust the weight of the criteria.

This approach is utilized to compare the two scenarios and ensure that the RWH system is both safe and effective, which is essential for the sustainable utilization of rainwater resources. According to [62,63], nonequal weights offer more consistency and reliability compared to equal weights. The use of equal weights often leads to high fluctuations in the distribution criteria for the sites.

From this perspective, allocating nonequal weights to each individual criterion ensures a fair distribution of importance, thereby enhancing the accuracy and precision of the obtained outcomes.

The range of normalised weights for the criteria is shown in Table 3**.** These weights were calculated by dividing the weight assigned to each specific criterion by the sum of weights for criteria used in the same framework. The table was constructed based on extracting the different weights of different criteria from 56 frameworks; these frameworks were constructed for different purposes, i.e., drinking water, agriculture, or both, which gives every criterion a different weight. Using these weights, the calculation is based on the range of the criteria's maximum, minimum, average, and standard deviation values.

**Table 3.** Maximum and minimum weights of the existing criteria.

| Criteria | Max. Weight (%) | Min. Weight (%) | Average (%) | Standard Deviation (%) | Relative Standard Deviation (RSD) | Frequency of Criteria in Existing Frameworks |
|---|---|---|---|---|---|---|
| 1- Rainfall | 45.7 | 6 | 23.2 | 10.5 | 45.26 | 44 |
| 2- Runoff | 53 | 5.5 | 32 | 12.8 | 40.00 | 42 |
| 3- Slope | 35.4 | 6 | 19.8 | 8.3 | 41.92 | 60 |
| 4- Soil | 42.6 | 3.2 | 18.9 | 10 | 52.91 | 55 |
| 5- Land use/land cover (LULC) | 35.5 | 4 | 11.7 | 8.6 | 73.50 | 48 |
| 6- Drainage density | 41.6 | 4.1 | 14 | 9.9 | 70.71 | 47 |
| 7- Hydrological losses | 13.3 | 4.8 | 8 | 3.4 | 42.50 | 6 |
| 8- Catchment area | 22.2 | 9.81 | 14.8 | 6.5 | 43.92 | 3 |
| 9- Distance to wadis | 19 | 17 | 17.5 | 1.4 | 8.00 | 2 |
| 10- Distance to faults | 13.6 | 4.6 | 4.6 | 2.8 | 60.87 | 13 |
| 11- Distance to water source | 19.8 | 5 | 11.4 | 5.9 | 51.75 | 9 |
| 12- Distance to roads | 25 | 1.63 | 7.6 | 7.4 | 97.37 | 22 |
| 13- Distance to agricultural area | 21.3 | 4.07 | 10.4 | 8.1 | 77.88 | 2 |
| 14- People's priorities | 64.4 | 9.6 | 30 | 30 | 100.00 | 2 |
| 15- Population density | 4.3 | 2.77 | 3.5 | 1.1 | 31.43 | 2 |
| 16- Distance to urban area | 13 | 2.3 | 7.2 | 4 | 55.56 | 12 |

These values give an indication of the degree to which the weights may differ from one another, allowing for the identification of indicators with substantial variations in weight and those with consistent performance. This variation depends on how important this indicator is for the purpose of the framework and regional priorities. For example, the framework given in [42] assigned a lower weight for runoff, with a value of 5.5%, because the same soil classes exist in the regions studied. For example, the framework given in [42] assigned a lower weight for runoff, with a value of 5.5%, because the same soil classes exist in the regions studied. Lower values for this indicator indicate a higher capacity of the soil to retain precipitation, and, consequently, a reduced amount of runoff. However, the framework given in [65] allocated a higher weight to runoff because it prioritises effective management of runoff and its potential benefits for water availability. In addition, the framework given in [66] assigned a minimum weight for soil, of 3.2%, due to soil properties' generally low level of variation across the pilot region. The highest weight for soil was 42.6%, which was allocated by the framework given in [67]; the highest weight for soil in this framework was due to the fact that the purpose of this study was flood management to protect against soil erosion, and the variation in soil type in this region.The highest weight for soil was 42.6%, which was allocated by the framework given in [67]; the highest weight for soil in this framework was due to the fact that the purpose of this study was flood management to protect against soil erosion, and the variation in soil type in this region.

While the standard deviation can be used to examine the dispersion of values and identify outliers, it provides little insight into the actual values themselves [68]. For example, when analysing the weights of criteria, a high standard deviation should indicate that the weights of people's priorities (0.3) are widely spread out and that some frameworks may give this criterion significantly higher or lower weights than the mean or average value. This is in contrast to population density, which was found to have a standard deviation of 0.011, indicating that data points are generally close to the mean or average value. The relative standard deviation (RSD) is a frequently employed statistic that facilitates statistical analysis. It is calculated by multiplying the standard deviation by 100 and dividing the result by the mean value. The primary objective of the relative standard deviation (RSD) is to assess and contrast the degree of variability exhibited by data in relation to its mean value. This method offers a convenient means of evaluating the accuracy and reliability of scientific measurements [69]. This method offers a convenient means of evaluating the accuracy and reliability of scientific measurements [69].

Figure 13 shows the percentage of normalized weights for the merged criteria that are used in current frameworks. Runoff and people's priorities obtained the greatest weights, 14% and 13%, respectively. These percentages were calculated based on the average weight for each criterion in existing frameworks divided by the sum of average weights for all criteria in existing frameworks. One hundred percent is the total weight of the criteria, which represents the total importance of each criterion on the framework.

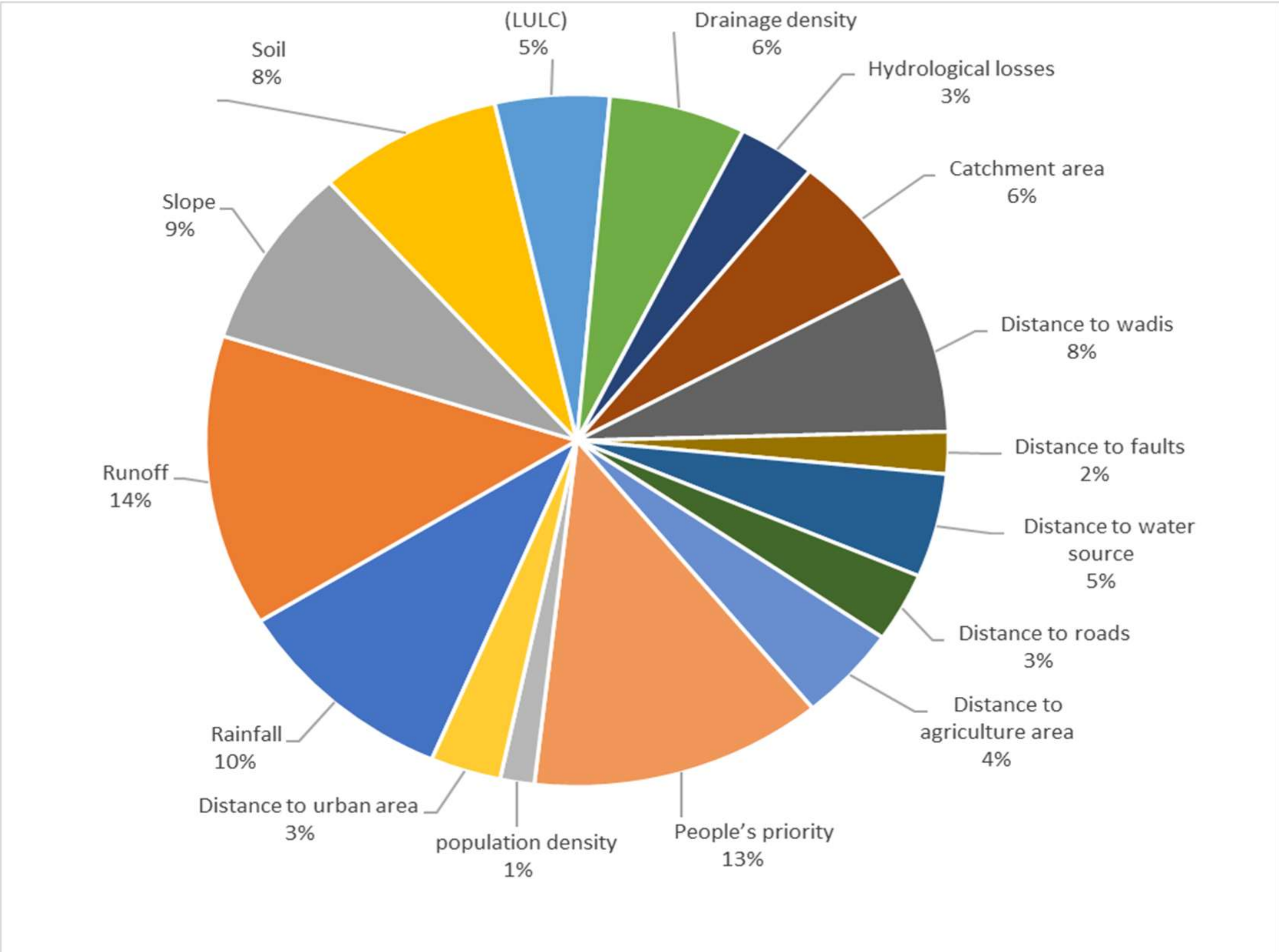


**Figure 13.** The percentages of normalised weights for the main criteria.

Figure 14 shows the intervals of the final index, which quantifies the significance of each criterion that was used in existing frameworks. A notable finding is that a significant proportion, specifically 21%, of the frameworks employ a binary (0 or 1) indicator, whereby a site is classified as either meeting or not meeting requirements. In contrast, the other frameworks utilise graded scales with varying degrees of granularity; the most common intervals used in existing frameworks are low-resolution scales of 1 to 3, 4, or 5, with 52% using them. A medium-resolution scale of 1 to 10 is used by 7%. And 7% use a high-resolution scale of 1 to 100. The rest of the frameworks, 13%, did not specify the scale used. According to the analysed frameworks, the intervals (1–5) and (0–1) seem to be the most popular options among both experts and stakeholders.

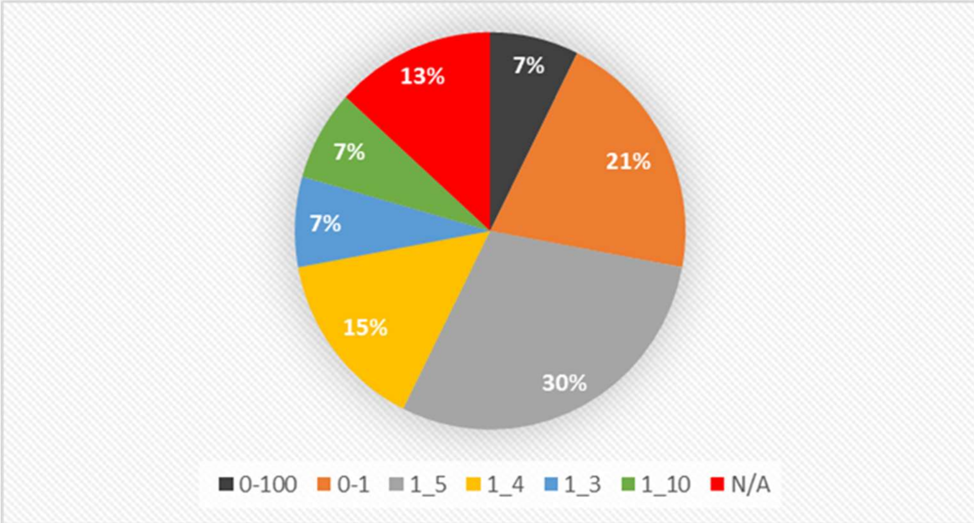


**Figure 14.** Intervals of final index value.

The advantage of using such numbers is that it makes the outcome of the entire framework simple to comprehend, not least for a wide variety of various stakeholders, and this can be accomplished without the need for a more in-depth evaluation [70].The advantage of using such numbers is that it makes the outcome of the entire framework simple to comprehend, not least for a wide variety of various stakeholders, and this can be accomplished without the need for a more in-depth evaluation [70].

From this standpoint, the higher range of interval indicates flexibility in choices. If the final index is a percentage, for instance, it may be more intuitive to report numbers between 0 and 100 than to use a different range, such as (1–3), (1–4), or (1–5), that are more commonly used for qualitative criteria.

## 6. Discussion

This research sought to identify RWH framework elements for arid and semi-arid regions based on a systematic literature review. The assessment was helpful in identifying essential qualities that a framework has to have for it to be regarded as suitable for implementation in arid and semi-arid regions. The framework's development should include participation by stakeholders, experts, etc. to identify the criteria and assign weights, and determine the appropriate number of criteria.

The findings of this review reveal that of the 68 different frameworks, 40 of them are based on biophysical criteria, and the other 28 are based on biophysical and socioeconomic criteria in site selection for RWH, as shown in Figure 11. The most common criteria that were used in existing frameworks were slope, soil, and land use/land cover. In addition, the number of criteria varied from framework to framework. The number of criteria was determined based on the size of the issue, the availability of data, and the opinions of experts and stakeholders (see Tables A1 and A2). Furthermore, the most commonly used intervals for evaluating suitability in the existing frameworks were (1–5) and (0–1); see Figure 14. The interval (1–5) provides decision makers with more options than the interval (0–1), which is more limited.

This review work contributes, although in a limited manner, to closing the knowledge gap. This research was restricted to two databases (Scopas and Engineering Village). Based on this study, it appears that the scholars, in their research in this field, have not yet investigated how ecological factors affect site selection for RWH.

## 7. Conclusions

This paper presents a systematic literature review to identify RWH sites in arid and semi-arid regions. Following the screening procedure, 68 papers met the criteria for inclusion and were deemed relevant. The purpose of this study was to discern the guiding principles of different frameworks used for identifying suitable RWH sites and to identify existing gaps in knowledge. According to this review, many frameworks have been developed for this purpose. This review helps in identifying the core components of the framework and investigating methods of data collection. In addition, the comparison between different frameworks and the identification of the similarities and differences between them help identify the gap in knowledge. This study shows that the criteria used in existing frameworks are biophysical and socioeconomic criteria, which are insufficient to achieve the pillars of the sustainability system. Forty frameworks (59 percent of the total) were founded on biophysical criteria, whereas twenty-eight frameworks (41 percent of the total) were founded on both biophysical and socioeconomic factors. In addition, "slope" was the most common criterion, followed by "soil", "LULC", "drainage density", "rainfall", "runoff", and "distance to roads", with biophysical criteria representing 80% of the weight, and socioeconomic criteria 20%; see Figure 11.

These frameworks are constructed without considering how the RWH structure's location and the duration of time it will be maintained might affect ecological aspects such as water quality and living organisms. Although rainwater is initially free of microbial contamination, it can become contaminated by human and animal activities, potentially fostering human diseases in stored rainwater due to storage conditions and posing a significant risk of infectious disease outbreaks. The quality of water in RWH structures significantly depends on the location and catchment area [71,72].The quality of water in RWH structures significantly depends on the location and catchment area [71,72].

In light of this, it is imperative to develop more comprehensive RWH system frameworks that promote sustainability, preservation of natural resources, and reduction of water pollution. A rainwater harvesting (RWH) structure is expected to align with the pillars of sustainability, including ecological considerations. Therefore, it is crucial to take into account the ecological aspects when designing such a RWH framework. As a result, ongoing efforts are being made to develop a recommended conceptual framework that effectively addresses this matter.

*Future Work*

Subsequent research will need to concentrate on developing a framework for RWH site selection in arid and semi-arid regions relying on all the factors discussed in Section 2 to ensure its practical applicability and relevance. A conceptual framework will be formulated for site selection of RWH in such regions, which will entail the following steps:

1. Identification of the most important structural criteria (biophysical and socioeconomic).
2. Formulation of a methodology to identify the most significant ecological criteria and combine them with structural criteria.
3. Engagement of stakeholders and experts to weight the criteria and validate the framework.
4. The resultant hybrid framework will be applied to a case study to demonstrate its use as a decision-support tool for potential users. The selection of the case study will be based on criteria such as its location in an arid or semi-arid region, and the availability of relevant information about the region.

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**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Summary and comparison of the key components of current frameworks.

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1- | [56] | Jordan, 2015 | Edge, Edge Contrast Proximity Index, class area proportion, class area, patch size, radius of gyration, number of patches, shape and neighbour distance (10) | (AHP) | Rainwater harvesting, analytic hierarchy process, landscape metrics | 21,565 | 250 150 | 0–1 | 12–23 °C | Nonequal | Biophysical criteria |
| 2- | [57] | Saudi Arabia, 2015 | slope, rainfall, runoff, soil texture, and land use/land cover (5) | GIS-based (DSS) | Geographic information system, in situ water harvesting, remote sensing, decision support system | | 200–600 | (1–5) | 12–23 °C | Nonequal | Biophysical criteria |
| 3- | [63] | Egypt, Sinai, 2016 | Length of overland flow, drainage density stream frequency, infiltration number, bifurcation ratio, drainage texture (6) | RS and GIS techniques | Runoff water harvesting, remote sensing, GIS weighted spatial probability modeling, watershed morphometry | 23,380.93 | 95 mm [73] | (1–4) | 23.2 °C [73] 23.2 °C [73] | Equal and nonequal weights | Biophysical criteria |
| 4- | [58] | Iran, 2020 | Proximity to qanat, slope, geomorphology, climate, land use, rainfall, geology, distance to rock source, fault, stream, well, water spring, proximity to road, proximity to village (14) | DSS, Boolean and fuzzy logic | Water harvesting, cross section, valley's profile, check dam, satisfaction, rural | | 345 | 0–1 | 11 °C | Nonequal | Biophysical and socioeconomic criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5- | [46] | Northern China, 2020 | Streams, roads, lake area, roads and railway, lake area or reservoir, built-up areas, rainfall runoff, drainage density, slope (10) | Remote sensing–based MCA, (WLC), combination with the Boolean approach in a GIS | Water management, geographic information system [74], rainwater harvesting, multi-criteria analysis, analytical hierarchy process (AHP) | 744.57 | 325.8 | (0–1) | 5.2 °C | Nonequal | Biophysical and socioeco-nomic criteria |
| 6- | [75] | Kenya, 2019 | Drainage density, lineament density, runoff depth, slope, land use/land cover, soil texture (6) | GIS and remote sensing, use of SCS-CN for runoff | Weighted overlay analysis, runoff depth, rainwater harvesting structures, SCS-CN method | | 699 mm to 1058 mm | 1–5 | 26 °C [76] 26 °C | Nonequal | Biophysical and socioeco-nomic criteria |
| 7- | [77] | Pakistan, 2020 | Slope, drainage density, geological setup, soil texture and drainage stream characteristics, runoff, land use/land cover (7) | GIS, conservation service (SCS) | Rainwater harvesting Remote sensing, GIS, site suitability | 2987 | 580 | 1–3 | 5–41 °C | Nonequal | Biophysical criteria |
| 8- | [62] | Iraq, 2017 | Slope, land use, rainfall, geological, soil type, condition, road, vegetation, village, sediment, evaporation (10) | RS, MCA fuzzy, AHP | GIS. Multi-criteria decision techniques, rainwater harvesting structure, remote sensing | 13,370 | 115 | (0–1) | 2.6–42.8 °C | Equal, and nonequal weights | Biophysical and socioeco-nomic criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9- | [59] | Egypt, 2016 | land use, land cover, slope, runoff coefficient precipitation, soil type (5) | GIS and (DSS) and remote sensing | Normalized difference, drought management, decision support system (DSS), geographic information system, vegetation index (NDVI), multi-criteria evaluation, rainwater harvesting, analytical hierarchy process (AHP) | 10,130 | 110 | 1–5 | 32 °C | Nonequal | Biophysical criteria |
| 10- | [40] | India, 2019 | Stream networks, digital elevation, soil quality (3) | GIS and digital elevation model (DEM), ArcGIS | Rainwater harvesting, DEM, India, drought | | | None | 26.98 °C [78] | Nonequal | Biophysical |
| 11- | [50] | Iraq | Land use/land cover, slope, stream orders, rainfall, soil, elevation, runoff, roads and settlements, agriculture density, livestock water demand, population and rural density (13) | GIS, multi-criteria model, (AHP) | Water harvesting, Iraq, GIS, multi-criteria, AHP | 6135.77 | 350 | 1–5 | 7.8—33.9 °C | Nonequal | Biophysical and socioeconomic criteria |
| 12- | [79] | Ethiopia, 2020 | Soil texture, runoff, slope, stakeholders' priorities, land use/land cover (5) | (SWAT), RS, MCA | Rainfall runoff, geographic information system, the Dawe River watershed, rainwater harvesting, the Wabe Shebelle River basin, soil and water assessment tool (SWAT) | 368 | 723.36–534 | 1–3 | 27.14 °C | Nonequal | Biophysical and socioeconomic criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13- | [80] | Iran, 2021 | Evaporation, rainfall, soil depth, permeability of soil, organic matter of soil, soil texture, electrical EC of soil, vegetation condition, vegetation types, percentage of vegetation, fault density, slope aspect, EC of water, groundwater, groundwater drop transport capability, drainage density, stream order, runoff, discharge management, land use, participation, alluvium thickness, distance from water resources, distance from a road, population density | Geographic Information System. | Rainwater harvesting, Shannon, TOPSIS, geographic information system, entropy | 83,000 | 115 | 1–4 | 19.17 °C [81] | Nonequal | Biophysical and socioeconomic criteria |
| 14- | [61] | Egypt, 2021 | Flood, maximum flow distance, drainage density, infiltration, slope, watershed length, watershed area, flow distance (8) | WMS and remote sensing techniques, (MPDSM) | Runoff water harvesting (RWH), remote sensing, analytical hierarchy process (AHP), multi-parametric spatial model (MPDSM), dry regions, decision | 3515 | 54.87 | 0–100 | 23.2 °C [73] 23.2 °C | Equal and nonequal weights | Biophysical criteria |
| 15- | [61] | Iran, 2021 | Temperature, precipitation, discharge, soil texture, land use, discharge density, slope, evapotranspiration (8) | GIS, (AHP), (WLC), multi-criteria decision analysis | AHP, WetSpa model, GIS, WLC, RWH | 1132 | 528.3 | 0–1 | 4.85–25.16 °C | Nonequal weights | Biophysical criteria |
| 16- | [82] | Saudi Arabia, 2021 | Rainfall, soil, slope, land use/land cover, drainage network (5) | GIS, MCDA, SCS-CN | GIS, MCDA, rainwater harvesting, suitability SCS-CN, AHP | 681 | 197 | 1–3 | 29 °C | Nonequal | Biophysical criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 17- | [83] | Morocco, 2021 | Soil texture, drainage density, slope, land use/land cover, runoff (5) | GIS-based fuzzy (FAHP), remote sensing, (DEM) | RWH Suitability, SCS-CN, FAHP, RS, GIS, Kenitra province | 3052 | 450 | 0–1 | 13.1–20.1 °C | Nonequal | Biophysical criteria |
| 18- | [53] | Iran, 2020 | Rainfall, Spatial Geographic Information, Slope, Land use/cover, Soil texture, Drainage network, Basin/sub basin, River, Road and railway, Fault, City. (10) | Best-Worst Method and fuzzy logic in a GIS-based decision support system | RWH, BWM, agriculture, decision support system | 12,981 | 125–700 | 1–5 | 15.6 °C [84] | None | Biophysical and socioeconomic criteria |
| 19- | [28] | China, 2018 | Slope and hydrological soil groups, land use, hydrological soil groups (4) | ArcGIS, SCS-CN model | --------- | 90,021 | 370 mm [84] | 1–4 | 0–7 °C | None | Biophysical criteria |
| 20- | [41] | Iraq, 2019 | Lineament frequency, drainage frequency density, slope, maximum flow distance, stream order, flood, basin area, geological condition, distance from villages, distance from main roads, geometric and morphometric, basin length, vegetation index, land use (14) | GIS techniques, (DEM), remote sensing, (SRTM) | Barrages, reservoirs, dams, hydrology, water resource, environment | 13,370 | 115 | 0–1 | 2.6–42.8 °C | Equal weight and nonequal | Biophysical and socioeconomic criteria |
| 21- | [85] | India, 2017 | Soil texture, rainfall, soil depth, land use/land cover, slope | GIS, Google Earth, remote sensing | water-harvesting runoff, remote sensing, GIS, structures' potential | 16,600 | 735 mm | NA | 11–45 °C | None | Biophysical criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 22- | [86] | Lebanon, 2000 | Slope, permeability, runoff coefficient, stream order, watershed area, soil type, rainfall (7) | Hydrologic modelling, (AHP) | Hydrologic modelling, geographic information systems, water harvesting, Lebanon, analytic hierarchy process | | 300 mm | 0–1 | 16.23 °C [86] | Nonequal | Biophysical criteria |
| 23- | [39] | Rajasthan/India, 2018 | Soil map, rainfall, drainage network, land use/land cover, depth of depression, slope, runoff (7) | MCAintegrated with RS and GIS | GIS rainwater harvesting, DEM, suitable location, surface runoff | 162 | 234.88 | 1–3 | 31.9–18.8 °C [87] | None | Biophysical criteria |
| 24- | [88] | Tanzania, 2007 | Drainage, slope, land use/land cover, soil texture, soil depth, rainfall (6) | (DSS), remote sensing | Remote sensing, rainwater harvesting, geographic information systems, decision support system, technologies | | 400–700 | 0–100 | 26.55 °C [89] | Nonequal | Biophysical criteria |
| 25- | [90] | Iraq, 2020 | Soil texture, drainage, land use/land cover, rainfall, slope (5) | RS, MCD | | 452.6 | 116 | 1–5 | 8–33 °C | Nonequal | Biophysical |
| 26- | [90] | Tunisia, 2022 | Economic, social, environmental indicators, land use, slope, stream network, road network (6) | Geographic information systems | Spatial multi-criteria, rainwater harvesting, indicator, analysis, Tunisia, composite sustainability | 361 | 157 mm. | 0–10 | −3–48 °C | Nonequal | Biophysical and socioeconomic |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 27- | [91] | Iran, 2021 | Soil type, soil depth, rainfall, land use, slope (5) | GIS, SWAT, (WLC), multi-criteria decision analysis | SWAT model, geospatial techniques, arid and semi-arid regions, rainwater harvesting, multi-criteria decision analysis | 9762 | 303 | 1–4 | 11.6–26.7 °C | Nonequal | Biophysical criteria |
| 28- | [92] | Morocco, 2021 | Land use/land cover, soil type, lithology, rainfall, hydrographic typology, slope, lineament density (7) | RS and GIS data | Remote sensing, geographic information system water harvesting structures, multi-criteria analysis, dam | 20,500 | 300 | 0–10 | 20 °C | None | Biophysical criteria |
| 29- | [93] | Saudi Arabia, 2021 | Slope, alluvial, drainage density, rainfall distribution, runoff depth, soil, closeness to streams, curve number (8) | AHP, GIS, RS. | AHP, rainwater harvesting, pairwise comparison, arid regions, suitability map | 572.17 | 95 | 1–5 | 30.8 °C [94] 30.8 °C | Nonequal | Biophysical criteria |
| 30- | [95] | India, 2008 | Geomorphology, land use/land cover, road, drainage and lineaments (5) | Remote Sensing and GIS | Rainwater harvesting site suitability | 560 | 747.52 | 0–100 Rank 1–4 | 32.1 °C | Nonequal | Biophysical and socioeco-nomic |
| 31- | [67] | Saudi Arabia, 2015 | Slope, runoff, rainfall, soil texture, land use/land cover (5) | GIS, DSS | Rainwater harvesting, GIS, multi-factor evaluation (MFE), analytical hierarchy process, decision support system (DSS) | 12,000 | 600 | 1–5 suitability | 12–23 °C | Nonequal | Biophysical |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32- | [65] | Punjab, Pakistan, 2022 | Slope, runoff depth, land use/land cover, drainage density (4) | MCA, GIS, AHP | HEC-GeoHMS, rainwater harvesting, SCS-CN modification, satellite, multi-criteria analysis, water resource management, remote sensing | 300 | 781.4 | 0–100 | 21.5 °C [96] 21.5 °C | Nonequal | Biophysical criteria |
| 33- | [36] | Northern Jordan, 2010 | Distance to international borders, distance to roads, Distance to wells, distance to wadis, distance to roads, distance to urban centres, distance to faults, soil, rainfall, slope (12) | GIS, Boolean | WLC, GIS, Jordan, ponds, Boolean, harvesting | 2611 | 600 | (1–4) | 20.36 °C [97] | Nonequal | Biophysical and socioeconomic criteria |
| 34- | [98] | Northern Ethiopia, 2022 | Land use/land cover, soil texture, project, workforce and people's priorities and water laws, rainfall, slope, runoff, implementation costs, accessibility (8) | GIS-, MCA, hydrological model | Catchment multi-criteria analysis, SCS curve number, water harvesting techniques, Werie, analytical hierarchy process, surface runoff | 1797 | 610 | 1–5 | 17 °C [99] 17 °C | Nonequal | Biophysical and socioeconomic criteria |
| 35- | [100] | Al-Qadisiyah, Iraq, 2020 | Runoff, soil, rainfall (3) | Geographical information system techniques, multi-criteria evaluation techniques | GIS multi-criteria, clean water quality, rainwater harvesting, runoff, remote sensing, water availability. | 8957.682 | 180 | (1–4) | 25 °C | Nonequal | Biophysical criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 36- | [54] | Iran, 2020 | Roads, faults, rainfall, land use, slope, soil depth, drainage density, drainage networks, RWH zones, soil type, farms and wells, urban areas (11) | MCA, hydrological models | Rainwater harvesting, decision support system, geospatial techniques, water conservation | 9762 | 262 | 0–1 | 11.6–26.7 °C | Nonequal | Biophysical and socioeconomic criteria |
| 37- | [101] | Iraq, 2017 | Land cover, surface distance to river, slope, soil, runoff (5) | GIS, fuzzy, AHP, | Analytic hierarchy process, system, Iraq, water harvesting, fuzzy logic, geographical information | 2098 | 190 | (1–5) | 23.74 and 26.43 °C | Nonequal | Biophysical criteria |
| 38- | [102] | Malawi, 2021 | Land use, soil type, slope, runoff, environmental factors, rainfall, socioeconomic factors (6) | RS, number (SCS-CN) | Harvesting technologies, rainwater, geographic information systems, service contour-tied ridging soil mulching, soil conservation | 343.1 | 700–900 | 1–5 | 12–30 °C | Nonequal | Biophysical, socioeconomic |
| 39- | [103] | Northern Ethiopia, 2016 | Soil data, drainage network, slope map, land use map, rainfall, stream order (6) | GIS-based multi-criteria analysis | Decision support suitability approach, multi-criteria analysis, indicators selection, suitability maps, participatory | 2380 | 520–680 | 1–10 | 16–20 °C | Nonequal | Biophysical criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40- | [32] | Jordan, 2008 | Distance to international borders, distance to Agricultural areas, distance to roads, distance to urban areas, distance to wells, soil, slope, rainfall, distance to wadi, distance to water pipeline (10) | GIS layers, Boolean logic to find combinations of layers | Jordan, basalt, harvesting, ponds, GIS | 56,930 | 100–300 | 0–1 (suitability) | 35–40 °C (max annual 2–9 °C (min | Equal weights | Biophysical and socioeconomic criteria |
| 41- | [104] | Mongolia, 2018 | Runoff, forest land, mining area, agricultural land, road, soil type, surface slope, precipitation, catchment slope, drainage density, settlement area, water catchment area, lake (14) | GIS, AHP, spatial multi-criteria analysis | Analytic hierarchy process, water harvesting pond, spatial multi-criteria analysis, error matrix, proper sink | 1850.09 | 250 mm | 0–1 | 0–25 °C | Nonequal | Biophysical and socioeconomic criteria |
| 42- | [35] | Northwest Ethiopia, 2022 | Soil depth, slope, rainfall, distance from settlement, lineament density, soil, land use, distance from road (8) | AHP and combined in a GIS environment | Drought-prone area, rainwater harvesting, site suitability | 7073.79 | 620 mm | (1–4) | 27 °C | Nonequal | Biophysical criteria |
| 43- | [105] | West Bank, Palestine, 2020 | {Agricultural water poverty index (AWPI)}: (agricultural access, citizens above poverty line, illiteracy, agricultural extension, agricultural resources, drainage network, irrigated areas to governorate area), rainfall, curve number, surface slope, soil texture, evapotranspiration (ET), electrical conductivity, land use (14) | GIS environment, analytical hierarchy process (AHP) | Agricultural rainwater harvesting, GIS agricultural, rainwater suitability, sustainable agriculture, water poverty, harvesting | 5860 | 153–698 | 1–10 | 23.44 °C [106] | Nonequal | Biophysical criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 44- | [34] | Wadi Oum Zessar, Tunisia, 2016 | Climate and drainage (rainfall–drainage length), structure design (storage capacity–structure dimensions ratio –CCR ratio), site characteristic (soil depth–soil texture–slope), socioeconomic (distance to settlements), structure reliability (reliability ratio), demand and supply (10) | Analytical hierarchy process (AHP) supported by a geographic information system | RWH suitability, AHP, approach, GIS | 367 | 150–230 | (1–5) | 19–22 °C | Nonequal | Biophysical criteria |
| 45- | [107] | Mharib, Jordan, 2012 | Soil depth, soil texture, land tenure, slope, stoniness (5) | GIS | Socioeconomic and biophysical benchmark suitability, watershed, land tenure, participatory approach multidisciplinary, GIS, suitability | 60 | 100–150 | none | | Nonequal | Biophysical and socioeconomic criteria |
| 46- | [48] | Sinai Peninsula, Egypt, 2022 | Slope, land use/land cover, runoff depth topographic wetness index, drainage density, distance to roads, basin area, lineament frequency density, infiltration number, flow distance, distance to built-up areas, Bedouin community, distance to roads (12) | GIS, RS, MCA, hydrological modeling | Boolean analysis, multi-criteria analysis, remote sensing, sustainable development goals | 3580 | 55.86 | 0–1 | | Nonequal | Biophysical and socioeconomic |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 47- | [108] | Maharloo-bakhtegan basin, Fars province, southern Iran, 2021 | Distance from road, slope, temperature, land use, soil type, population density, distance from lakes, elevation, precipitation, curve number (CN), geology, distance from river (13) | GIS and remote sensing techniques | Planning AIAs, optimum range artificial intelligence algorithms (AIAs), water scarcity, RWH, probability curve (PC) | 31,511 | 350–390 mm | (0–1) | 12.80–15.16 °C | None | Biophysical and socioeconomic criteria |
| 48- | [109] | ElDabaa area, Northwestern Coast of Egypt, 2015 | Landform, watershed area, rainfall amounts, geologic setting drainage lines, surface runoff, flow accumulation, flow direction, slope, morphometric parameters (10) | GIS and remote sensing | Geomorphology, rainwater harvesting, remote sensing, runoff, GIS | 770 | 164 mm | (1–5) | 22–31.6 °C 7.2–23.7 °C | None | Biophysical criteria |
| 49- | [42] | Qaradaqh basin, Sulaimaniyah city, Iraq, 2022 | Stream, geology, rain lineament, DEM, CN, land use/land cover, soil, villages, slope (10) | GIS, MCDM, AHP, sum average weighted method SAWM, fuzzy-based index (FBI) techniques | Drought crisis, water shortage, AHP, sustainable water development | 605 | 650 mm | (1–10) | 18 °C to 40 °C | Nonequal | Biophysical and socioeconomic |
| 50- | [110] | Egypt, 2015 | Slope, soil texture runoff, land use/land cover, rainfall (5) | (AHP), (DSS) 2 level (2,5) | Decision support system (DSS), geographic information system, rainwater harvesting, analytical hierarchy process (AHP), multi-criteria evaluation, (RWH) | 556,961 | 100–200 | (1–5) | | Nonequal | Biophysical criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 51- | [111] | Makanya catchment, Kilimanjaro region, Tanzania, 2005 | Production (ndiva), near water sources, e.g., stream, sloping terrain, shallow water table, Charco Dam (lambo), soils with good flat area, far from settlement, presence of conveyance system, non-saline soils, diversion canal (sasi), hard stable soils, water holding capacity, gentle slope, no rocks, ridges and border soils, water storage structure for crop slopes, soil type runoff (location of the farm) (15) | Geographic information system decision-making process, tow level (4,15) | Rainwater harvesting, indigenous knowledge, agriculture | 300 | 250 and 400 mm | (1–3) | | None | Biophysical criteria |
| 52- | [26] | Iraq, Anbar Province, Al-Muhammadi Valley, 2020 | Soil texture, drainage density, slope, vegetation cover, distance to the roads. (5) | Remote sensing, GIS | | 5332 | 115 mm | 1–4 | 0–52 °C | Nonequal weight | Biophysical and socioeconomic criteria |
| 53- | [13] | Toudgha watershed, Morocco, 2022 | Slope, drainage density, permeability, runoff depth, fracture density, rainfall, groundwater depth, closeness to stream (8) | MCDM coupled with GIS techniques, 2 level (2,8) | GIS, remote sensing, water management, rainwater harvesting, MCDM | 2296 | 40 to 345 mm | 1–5 | 18 °C | Nonequal | Biophysical criteria |
| 54- | [112] | Maysan Province, Iraq, 2020 | Stream order, roads, soil type, evaporation, slope, NDVI, precipitation (7) | GIS, Multi – Criteria Evaluation RHHS = Wci × Rsc 2 level (3, 7) | GIS, MCE, water harvesting catchment, spatial analysis, fuzzy model | 16,072 | rainfall range (14_39) mm/month | (0–1) | 23.74–26.43 °C | Nonequal | Biophysical and socioeconomic criteria |
| 55- | [113] | Kavir Area of Iran, 2019 | Soil texture, slope and drainage network, rainfall, infiltration (5) | Multi-criteria techniques | Suitability, GIS, arid land, fuzzy, AHP, runoff harvesting, MCDM | 680,000 hectares | 240 mm | (1–5) | Annual temperature of 19 °C in | Nonequal | Biophysical criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 56- | [64] | Wadi Hodein Basin, Red Sea, Egypt, 2022 | Drainage density, infiltration number, basin area, max. flow distance, flood volume, basin length, basin slope, flow distance (8) | Integration between watershed modelling and remote sensing | Remote sensing, (RWH), arid and semi-arid, rainwater harvesting regions, spatial probability model (WSPM), weighted | 11,600 | | 0–1 | 37.5–14 °C | Two scenarios Equal and nonequal weights | Biophysical criteria |
| 57- | [114] | Saudi Arabia, Riyadh, 2022 | Land use/land cover, slope, precipitation, potential runoff coefficient [17], soil texture (5) | Multi-criteria DSS, AHP | GIS, RST, arid climate, spatial distribution PRWH, MCDSS, AHP | 8500 | 150 mm | (1–5) | (28–46 °C) (15–35 °C) | Nonequal | Biophysical |
| 58- | [115] | Xinjiang, China, 2020 | Runoff, slope, crop characteristics, soil, rainfall, land use/land cover (5) | GIS, MCA | Runoff potential, ecological restoration, gully erosion, rainwater harvesting | | 400 mm | (1–5) | 10 °C | Nonequal | Biophysical criteria |
| 59- | [43] | Mediterranean region in northern Jordan, 2011 | Type of soil, vegetation, land use types, geometric, slope, sub-catchments, water drainage (6) | GIS, DEM and remote sensing technique | Management of watershed, landsat organic carbon colour, soil | 1000 | 150–650 mm | NA | 5.2–22.0 °C 2.5–28 °C | None | Biophysical criteria |
| 60- | [116] | Northeastern desert, Jordan, 2012 | Drainage networks, slope, drainage network, flow direction, runoff (5) | GIS | Flow discharge, harvesting, unit hydrograph, watershed models | | 200 mm | NA | | None | Biophysical criteria |
| 61- | [117] | Oasis zone, Mauritania, 2007 | Land cover, drainage, geomorphology, slope, geology, lineament (6) | Landsat image and GIS based on AHP | Water harvesting, GIS, remote sensing | 455,745 hac | Arid land | NA | | Nonequal | Biophysical criteria |
| 62- | [118] | Wadi Horan, Iraq, 2020 | Sediment index, cost–benefit index, hydrology index, evaporation index (4) | GIS-based multi-criteria analysis, the analytic hierarchy process (AHP), fuzzy | Harvesting, GIS, AHP, rainwater, fuzzy | | 115 mm | 1–10 | | Nonequal | Biophysical criteria |

**Table A1.** *Cont.*

| No | Reference | Country and Year | Criteria | Tools | Keywords | Catchment Area km$^2$ | Annual Rainfall (mm) | Range of Index Value | Temp °C | Methods for Weighting | Criteria Selection and Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 63- | [119] | West Bank, Palestine, 2022 | Runoff, rainfall, slope, soil texture, land use (5) | Analytical hierarchy process (AHP) methods and GIS techniques | Technique (RWH), analytical hierarchy process, the West Bank, Palestine, rainwater harvesting method (AHP), GIS | 5860 | 450 | 0–100 | | Nonequal | Biophysical criteria |
| 64- | [120] | Western Desert of Iraq, 2021 | Irrigated lands, slope, land use/land cover, residential areas, distance from roads, runoff, soil texture (7) | Boolean, (WLC) | Rainwater harvesting, earthen dam, GIS, WLC, Boolean | 1953.1 | 115 | (1–4) | 40–2.6 °C | Nonequal | Biophysical and socioeconomic criteria |
| 65- | [121] | Ghazi Tehsil, Khyber Pakhtunkhwa, Pakistan, 2022 | Elevation, land cover, rainfall, drainage and various land uses (such as roads, settlements), surface slope, geology, soil (7) | Geospatial Approach, GIS, arc GIS | SCS-CN, HMS, geospatial technology, method, harvesting, HEC-geo-weighted overlay analysis, rainwater | 348 | Semi-arid | (1–3) | 4.8–44 °C | Nonequal | Biophysical and socioeconomic criteria |
| 66- | [122] | Morocco, 2021 | Drainage density, slope, runoff, land use/land cover, soil texture (5) | GIS, FAHP | Fuzzy AHP, GIS, rainwater harvesting, SCS-CN, WaTEM/SE, DEM | 4435 | 119 to 377 mm | 1–4 | 20 °C | Nonequal | Biophysical |
| 67- | [123] | Kirkuk, Iraq, 2015 | Runoff depth, slope, drainage, land use/land cover (4) | RS, GIS, | Rainwater harvesting, remote sensing and geographic information system, multi-criteria decision analysis | 4875 | 360 mm | 1–3 | | Nonequal | Biophysical criteria |
| 68- | [124] | Sana'a Basin, Yemen, 2022 | Slope, soil type, land use/land cover, precipitation, proximity to urban areas, water wells, dams, roads, open sewage passage, wadis, drainage networks (11) | Multi-criteria analysis, analytical hierarchy process | RWH, spate, indigenous, multi-criteria, socioeconomic criteria, dry areas, systems analysis irrigation systems, limited data | 3200 km$^2$ | 240 mm | 1–5 | 20 °C | Nonequal | Biophysical and socioeconomic criteria |

## Appendix B

**Table A2.** Summary of advantages and disadvantages of existing criteria.

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
|---|---|---|---|
| [56] | Experts and stakeholders | 1- The analytical hierarchy process (AHP) was used for questionnaire output weighting.<br>2- Engagement of stakeholders—included them for indicator choice and participation in weightings. | 1- Socioeconomic and ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices. |
| [57] | Literature | 1- The range of suitability (1–5) gives flexibility in choices.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output weighting. | 1- Socioeconomic and ecological criteria were not included.<br>2- There is no mention of the number of experts. |
| [63] | Literature | 1- Applied three scenarios of weighting, which caused the differences between the results. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [58] | Literature | 1- The satisfaction of stakeholders, rural residents, and people.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output weighting. | 3- Socioeconomic and ecological criteria were not included.<br>4- The range of suitability (0–1) indicates no flexibility in choices. |
| [46] | Literature | 1- The analytical hierarchy process (AHP) was used for questionnaire output weighting.<br>2- This is a cost-effective and low-data-intensive strategy.<br>3- RWH structure types were taken into consideration. | 1- Ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices.<br>3- There was no field investigation to ensure there is no other land use conflict. |
| [75] | Availability of data | 1- The range of suitability (0–5) indicates flexibility in choices. | 2- Ecological criteria were not included.<br>3- Stakeholders and experts were not engaged. |
| [77] | Literature | 1- RWH structure types were taken into consideration. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [62] | Literature | 1- The analytical hierarchy process (AHP), fuzzy AHP, and ROM were used for questionnaire output weighting.<br>2- Four scenarios of weighting were applied to determine the differences between the results. | 1- Ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices.<br>3- Stakeholders and experts were not engaged. |

**Table A2.** *Cont.*

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
|---|---|---|---|
| [59] | Strategy of selecting criteria unclear | 1- The range of suitability (0–5) indicates flexibility in choices.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output weighting.<br>3- Two scenarios of weighting were applied to determine the differences between the results. | 4- Socioeconomic and ecological criteria were not included.<br>5- The method of weighting was unclear. |
| [40] | None | | 1- Socioeconomic and ecological criteria were not included.<br>2- The method of weighting was unclear. |
| [50] | Literature reviews | 1- The analytical hierarchy process (AHP) was used for questionnaire output.<br>2- Experts, local authorities, and the literature were used to identify the weight of the criteria.<br>3- The range of suitability (1–5) indicates flexibility in choices. | 1- Ecological criteria were not included.<br>2- The number of experts and stakeholders is unknown. |
| [79] | Literature reviews | 1- Experts and the literature were used to identify the weight of the criteria.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output. | 1- Ecological criteria were not included.<br>2- The number of experts and stakeholders is unknown. |
| [80] | Experts' opinions | 1- Experts were engaged to determine the weights of the criteria.<br>2- The range of suitability (1–4) indicates flexibility in choices. | 1- The number of criteria is too large to be implemented in a practical way.<br>2- The number of experts is unknown.<br>3- Ecological criteria were not included. |
| [61] | Literature | 1- The analytical hierarchy process (AHP) was used for questionnaire output.<br>2- The range of suitability (0–5) indicates flexibility in choices.<br>3- Experts were hired to determine criteria weights. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number of experts is unknown. |
| [60] | None | 1- The analytical hierarchy process (AHP) was used to weight output.<br>2- Experts were engaged to determine the weights of the criteria. | 1- Strategy of selecting criteria unclear.<br>2- The number of experts and stakeholders is unknown.<br>3- The range of suitability (0–1) indicates no flexibility in choices.<br>4- Socioeconomic and ecological criteria were not included. |

**Table A2.** *Cont.*

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
|---|---|---|---|
| [82] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [83] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output. | 1- Socioeconomic and ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices. |
| [53] | Literature | 1- The range of suitability (1–5) indicates flexibility in choices.<br>2- The analytical hierarchy process (AHP) was used for decision making, or experts' questionnaire output. | 1- Ecological criteria were not included.<br>2- The number of experts is unknown. |
| [28] | None | 1- The range of suitability (1–4) indicates flexibility in choices. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [41] | None | 1- The ranking process was performed based on the analytical hierarchy process (AHP), fuzzy AHP, rank order method (ROM), and variance inverse (VI).<br>2- Decision makers were engaged to identify the weighting of criteria.<br>3- Area–volume curve was used for geometric properties. | 1- Ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices.<br>3- The number of decision makers is unknown. |
| [85] | None | 1- RWH structure types were taken into consideration. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged.<br>3- There is no mention of weights for the criteria. |
| [86] | Experts and literature | 1- Experts were engaged to identify the weighting of criteria.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output. | 1- Socioeconomic and ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices.<br>3- The number of experts is unknown. |
| [39] | None | 1- This strategy saves time, reduces earthwork, and may be used for water resource management planning. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged.<br>3- There is no mention of weight for the criteria. |

**Table A2.** *Cont.*

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
|---|---|---|---|
| [88] | Not mentioned | 1- The range of suitability (0–100) gives flexibility in choices.<br>2- Employing decision support systems (DSS) to adjust suitability levels and weights based on the research area. | 1- Socioeconomic and ecological criteria were not included.<br>2- There is no specific number for decision makers. |
| [90] | Literature | 1- The range of suitability (0–100) gives flexibility in choices.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output.<br>3- Area elevation curve to estimate the best site for a dam. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [90] | Literature and experts | 1- Stakeholders and experts were engaged in identifying criteria and weights.<br>2- The number of stakeholders and experts was determined.<br>3- The range of suitability (0–10), gives flexibility in choices. | 1- Ecological criteria were not included. |
| [91] | Literature | 1- The analytical hierarchy process (AHP) was used for questionnaire output.<br>2- RWH structure types were taken into consideration.<br>3- Stakeholders and experts were engaged to identify the weighting of criteria. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number of experts is unknown. |
| [92] | Literature | 1- The range of suitability (0–10) gives flexibility in choices.<br>2- Experts were engaged to identify the weighting of criteria. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number of experts is unknown. |
| [93] | Literature | 1- The analytical hierarchy process (AHP) was used for questionnaire output.<br>2- The range of suitability (1–5) gives flexibility in choices.<br>3- Experts were engaged to identify the weighting of criteria. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number of experts was unknown. |
| [95] | Data availability | 1- The range of suitability (0–10) gives flexibility in choices.<br>2- RWH structure types were taken into consideration as criterion. | 1- Ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |

**Table A2.** *Cont.*

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
| --- | --- | --- | --- |
| [67] | None | 1- The range of suitability (1–5) gives flexibility in choices.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output.<br>3- Decision makers were involved in the weighting of criteria. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number of decision makers is unknown. |
| [65] | Literature | 1- Weights were assigned based on the literature.<br>2- The analytical hierarchy process (AHP) was used for weight output. | 1- Ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [36] | Literature | 1- Weights were assigned based on the literature. | 1- Ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [98] | Literature | 1- The range of suitability (1–5) gives flexibility in choices.<br>2- The analytical hierarchy process (AHP) was used for weights output.<br>3- RWH structure types were taken into consideration. | 1- Ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [100] | None | 1- The range of suitability (1–4) gives flexibility in choices. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [54] | Literature | 1- The analytical hierarchy process (AHP) was used for questionnaire output.<br>2- Experts were involved in the weighting of criteria. | 1- The range of suitability (0–1) indicates no flexibility in choices.<br>2- Ecological criteria were not included.<br>3- The number decision makers was unknown. |
| [101] | Literature review and available data | 1- The analytical hierarchy process (AHP) was used for questionnaires' output.<br>2- Experts were involved in the weighting of criteria.<br>3- The range of suitability (1–5) gives flexibility in choices. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number of decision makers is unknown. |
| [102] | Literature review | 1- The analytical hierarchy process (AHP) was used for weights output.<br>2- The range of suitability (1–5) gives flexibility in choices. | 1- Ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |

**Table A2.** *Cont.*

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
|---|---|---|---|
| [103] | Stakeholder workshop | 1- The analytical hierarchy process (AHP) was used for weights output.<br>2- Experts were involved in the weighting of criteria.<br>3- The range of suitability (1–10) gives flexibility in choices. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number of stakeholders is unknown. |
| [32] | Literature | 1- Weights of criteria were equally distributed in order to promote respect in all areas | 1- The range of suitability (0–1) indicates no flexibility in choices.<br>2- Ecological criteria were not included.<br>3- Stakeholders and experts were not engaged. |
| [104] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output. | 1- The range of suitability (0–1) indicates no flexibility in choices.<br>2- Ecological criteria were not included.<br>3- Stakeholders and experts were not engaged. |
| [35] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output.<br>2- The range of suitability (1–4) gives flexibility in choices. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [105] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output.<br>2- The range of suitability (1–10) gives flexibility in choices.<br>3- The weights of the criteria were based on the literature. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [34] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output.<br>2- The range of suitability (1–5) gives flexibility in choices.<br>3- Stakeholders and experts were involved in the weighting of criteria.<br>4- The number of stakeholders and experts was determined. | 1- Ecological criteria were not included. |
| [107] | Literature | 1- Discussions with owners and people to see the requirements and land tenure information. | 2- Ecological criteria were not included.<br>3- The criteria were limited. |

**Table A2.** *Cont.*

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
| --- | --- | --- | --- |
| [48] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output.<br>2- The weights were determined by the literature.<br>3- RWH structure types were taken into consideration. | 1- The range of suitability (0–1) indicates no flexibility in choices.<br>2- Ecological criteria were not included.<br>3- Stakeholders and experts were not engaged. |
| [108] | Literature | 1- Used remote sensing for locating RWH sites. | 1- Ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices.<br>3- Stakeholders and experts were not engaged. |
| [109] | Literature | 1- The range of suitability (1–5) gives flexibility in choices. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [42] | Literature and experts | 1- The analytical hierarchy process (AHP) was used for questionnaire output.<br>2- Stakeholders and experts were involved in the weighting of criteria.<br>3- The range of suitability (1–10) gives flexibility in choices. | 1- Ecological criteria were not included.<br>2- The number stakeholders and experts is unknown. |
| [110] | Literature and experts' opinions | 1- The range of suitability (1–5) gives flexibility in choices.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output.<br>3- Stakeholders and experts were involved in the weighting of criteria. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number stakeholders and experts is unknown. |
| [111] | Literature and experts' opinions | 1- Stakeholders and experts were involved in the weighting of criteria.<br>2- The number of stakeholders and experts was determined. | 1- Socioeconomic and ecological criteria were not included. |
| [26] | Literature | 1- The range of suitability (1–5) gives flexibility in choices.<br>2- Weights depend on the literature. | 1- Ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |

**Table A2.** *Cont.*

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
| --- | --- | --- | --- |
| [13] | Literature and experts | 1- The analytical hierarchy process (AHP) was used for questionnaire output.<br>2- The range of suitability (1–5) gives flexibility in choices.<br>3- Stakeholders and experts were engaged to determine criteria and weights. | 1- Ecological criteria were not included.<br>2- The number stakeholders and experts is unknown. |
| [112] | Literature | 1- Money and time needed to select the best RWH sites was saved, based on DEM and remote sensing. | 1- Socioeconomic and ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices.<br>3- Stakeholders and experts were not engaged. |
| [113] | Literature and experts' opinions | 1- The analytical hierarchy process (AHP) was used for questionnaire output.<br>2- The range of suitability (1–5) gives flexibility in choices.<br>3- Stakeholders and experts were involved in identifying the criteria and weighting.<br>4- The number of stakeholders and experts was determined.<br>(5 experts) | 1- Socioeconomic and ecological criteria were not included. |
| [64] | Literature | 1- Analysis Of Variance (ANOVA) for justifications of parameters weights | 1- Socioeconomic and ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choices.<br>3- Stakeholders and experts were not engaged. |
| [114] | Literature | 1- The range of suitability (1–5) gives flexibility in choice.<br>2- The analytical hierarchy process (AHP) was used for weights output. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [115] | Literature | 1- The range of suitability (1–5) gives flexibility in choice.<br>2- The analytical hierarchy process (AHP) was used for weights output.<br>3- Stakeholders and experts were involved in weighting of criteria. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number of stakeholders and experts is unknown. |
| [43] | Non | 1- It addresses landscape surface qualities and how built-up regions, and human building items affect surface drainage and water flow. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |

**Table A2.** *Cont.*

| Reference | Selection Process for Criteria | Advantage | Disadvantage |
| --- | --- | --- | --- |
| [116] | Non | 1- Using DEM to assess rainwater harvesting's potential. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [117] | Not mentioned | 1- The analytical hierarchy process (AHP) was used for weights output. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [118] | Not mentioned | 1- AHP, fuzzy-AHP, ROM, and VI methods were used for weights output.<br>2- area–volume curve to find height of the structure.<br>3- The range of suitability (1–10) gives flexibility in choices. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [119] | Literature and experts | 1- The range of suitability (1–100) gives flexibility in choices.<br>2- The analytical hierarchy process (AHP) was used for questionnaire output.<br>3- Stakeholders and experts were involved in weighting of criteria. | 1- Socioeconomic and ecological criteria were not included.<br>2- The number stakeholders and experts were unknown. |
| [120] | Literature | 1- The range of suitability (1–4) gives flexibility in choices.<br>2- Area–volume curve used to find height of the structure. | 1- Ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [121] | Literature | 1- RWH structure types of criteria were taken into consideration. | 1- Ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [122] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output.<br>2- The range of suitability (1–4) gives flexibility in choices. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [123] | Available data | 1- The analytical hierarchy process (AHP) was used for weights output. | 1- Socioeconomic and ecological criteria were not included.<br>2- Stakeholders and experts were not engaged. |
| [124] | Literature | 1- The analytical hierarchy process (AHP) was used for weights output.<br>2- Stakeholders and experts were involved in identifying the criteria and weighting. | 1- Ecological criteria were not included.<br>2- The range of suitability (0–1) indicates no flexibility in choice. |

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