An-Najah University Journal for Research – A
Natural Sciences

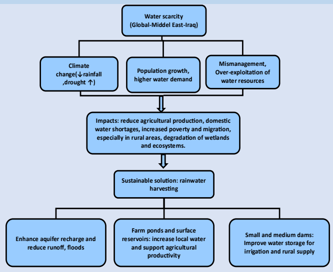
Water Scarcity and Rainwater Harvesting Technology in Different Regions in the World: State of the Art

Istabraq H. Sbekhan[1,*] & Yousif H. Al-Aqeeli[1,2]

(Type: Review Article). Received: 18th Oct. 2025, Accepted: 7th Dec. 2025, Published: ××××, DOI: https://doi.org/10.xxxx

Accepted Manuscript, In Press

Abstract: Given the close relationship between water scarcity and water harvesting using various methods, this study monitors and presents a set of research related to both topics. Research on these two topics was presented in three sections, organized according to the climate changes that occur in different geographical locations on the Earth's surface. The first section represents studies conducted in various countries worldwide, excluding those in the Middle East. In contrast, the second part symbolizes the research completed in the Middle East, excluding Iraq, and the third part includes a group of studies conducted in Iraq. This research will offer an understanding of the influence of climate change that leads to water scarcity, as well as harvesting measures to address this issue.



Keywords: Water Scarcity, Rainwater Harvesting, Climate Change, Iraq, Sustainable Water Management.

Introduction

One of the most significant environmental and social issues confronting the world in the twenty-first century is water scarcity [1]. When there is a greater demand for fresh water than there is supply, resulting from population growth, growing living levels, and climate change, unmet needs arise. This is known as water scarcity [2]. The shortage of water has complex, interrelated effects, one of which is environmental impact, as evidenced by the fact that since the beginning of the 20th century, the world has lost almost half of its wetlands, resulting in biodiversity loss and degradation of environmental services [3]. The economic and social effects of water scarcity include lower food security, reduced crop production, higher food prices, and increased reliance on imports, which are particularly prevalent in arid rural regions [4]. The issue of water and quality is one of the most important topics of the eighth phase of the International Hydrological Program (IHP-VII), "Water security: Responding to local, Regional, and Global challenges (2014-2021)", which addresses water scarcity and quality. Additionally, it is a significant theme of the International Association of Hydrological Sciences (IAHS) Decade of Science 2013-2022, "Panta Rhei-Everything Flows," which focuses on research projects pertaining to societal and hydrological change [5]. The Arab world is most negatively impacted by the lack of water, with countries such as Jordan, Egypt, and Iraq being among the worst affected. As a case in point, Jordan is one of the poorest nations globally in regard to water resources, considering the per capita allocation of renewable water does not exceed 135 cubic meters per annum. This ranks it far below that of absolute scarcity. This has been attributed to high population growth, almost complete dependence on over-tapped groundwater, and climate change's impact, that is leading to more instances of droughts and water evaporation [6]. In light of these growing difficulties, new research shows that freshwater availability in the Middle East has drastically reduced by three-quarters since 1950 and that it is likely to fall by another half by 2030. The most common use of water resources in most countries in the area is agriculture, with over 90 percent of the total water consumed in countries like Iraq, Iran, and Saudi Arabia. This means that this sector is the most at risk of the impact of water shortages and climate change. Staying with the Standardized Aridity Index (SAI), analysis carried out on the period 1979-2017 shows that the region fell into an unprecedented drought period as early as 1999, which is still ongoing today, not forgetting the gradual increase in severity of droughts as noticed in the years 2008, 2010, and 2017 [7]. Water scarcity can be practically solved using rainwater harvesting due to the rising water demand, the dropping water table, and the common droughts attributed to climate change. This system is a reliable source of clean water, and the communities, especially those in rural and remote settlements, are more independent because it is challenging to implement conventional water supply projects in these areas due to high costs and inaccessible maintenance. Rainwater harvesting is also significant because an individual can capture and store rainwater during the rainy seasons and tap the same wealth in times of droughts. It mitigates the impact of drought, enhances the capacity of groundwater reservoirs, and makes water resources more sustainable. It also causes less surface water runoff, as well as the ensuing Flooding, soil erosion, and pollution

1 Dams and Water Resources Engineering Department, College of Engineering, University of Mosul, Mosul, Iraq
* Corresponding author email: istabraq.23enp88@student.uomosul.edu.iq, istabarak@gmail.com
2 Dams and water resources research center, University of Mosul, Mosul, Iraq
E-mail: y.alaqeeli@uomosul.edu.iq, ysifokaily@gmail.com

of waterways and riverways. It eases the strain on the municipal water supply system and assists in equilibrating the hydrological cycle by assisting groundwater recharge. Rainwater that is collected is sometimes of excellent quality with fewer salts and harmful minerals compared to some water bodies on the surface, and therefore, a good alternative when there is a proper collection and maintenance system [8].

This paper seeks to summarize some of the most critical studies on this issue of water scarcity by exploring the natural and artificial causes, such as changes in the climate, population increase, and the misallocation of available water resources, in combination with their health, economic, and environmental consequences. The paper then directs its attention to the process of rainwater harvesting as one of the available practical solutions, exploring its methods and possibilities.

Literature review

Over the last few years, the scientific field has witnessed the publication of numerous research papers and studies on the subject of water scarcity and its consequences, as well as proposed solutions to address the issue using rainwater harvesting technology. To gain an overall understanding of the subject matter in this paper, it has been divided into several sections in the literature review.

Review of water scarcity

According to scientific research, the world is facing a rising water supply shortage, together with its multidimensional and cross-dimensional economic and environmental effects. This must be fully conceptualized by classifying the literature review to achieve a thorough and progressive analysis.

Earlier scientific research associated with water scarcity and its global impacts

According to [9] indicates that Kenya is in deep water distress, such that its per capita renewable water supply is smaller than 1,000 m³/year. This is due to rapid population growth, pollution, environmental changes, and poor management, especially in rural and arid regions that rely on non-enhanced water sources. Scarcity of water affects health and food security. The largest portion of freshwater is used by agriculture, and water scarcity, which is worsened by a high rate of population increase and climate change, is a threat to food security and agricultural productivity [10]. It is required to increase the efficiency of water use, implement modern methods of irrigation, and think over other sources of water, in order to alleviate the crisis and promote agricultural sustainability. [11] Survey, official reports, and other forms of studies done on Pakistan's Thar Desert's water shortage have shown that 91 percent of the population either uses and depends on poor-quality groundwater most of the time, and only 6 percent of the population gets piped water. The majority of homes lack access to water beyond the WHO standard, with 70 percent having an average of 50 liters and 85 percent having less than 10 liters per head. Such scarcity has been a negative experience for agriculture, livestock, and the health of people, especially women. The research suggests that there should be better infrastructure, increased water distribution, encouragement of rainwater harvesting, solar desalination, and local community involvement in water management. [12] attempted to investigate the changing pattern of water scarcity in the world between 1901 and 2090 based on a per capita freshwater availability index by the study of six global hydrological models. The study noted that the main factor that will continue to exacerbate the lack of water availability is the increase in population, with East and West Africa being given priority consideration, which requires intervention and solid adaptation plans for managing water resources among the most vulnerable.

[13] suggested a water scarcity index from a pragmatic viewpoint that places primary emphasis on meeting human demands. The index integrates three primary factors: the total of accessible water for resources, water utilization efficiencies, and the ratio of domestic consumption to overall water use. The index aims to determine the daily typical amount of water availability for usage in the home, taking into account both population size and the time factor, in a manner that accurately reflects the capacity of water resources to meet people's basic daily needs in a particular region. The following is the formulation of the indicator equation:

WSI= (TWR* WUE*PDW) / (Number of Days Per Year * Population)

All of the water that is available for use in a certain location at a specific moment is referred to as total water resources, or TWR. The ratio of available water to actual water supply is known as water usage efficiency, or WUE. Proportion of domestic water (PDW): The percentage of domestic water usage in total water use is reflected in the percentage of domestic water consumption. According to the minimum 50 liters (0.05 cubic meters) of basic daily needs per person, the index rates the scarcity limits to four principal categories:

- No pressure: Over 0.2 m3 per person per day
- Pressure: 0.1- 0.2 m3 per person per day
- Scarcity: This ranges between 0.05- 0.1 m3 per person per day
- Total lack: Scarcity of smaller than 0.05 m3 per person per day

The index was expanded to the 2021 data in the administrative regions of China, and a significant variation was highlighted in space: the high-water scarcity area comprises the northern regions and big cities, including Beijing, Tianjin, and Shanghai, whereas the other regions of the South (including Qinghai and Tibet) had surplus amenity of water. Such differences can be explained mainly by the fact that the North is more industrialized and densely populated. The research underlines the simplicity of the index and its application in making decisions on water management.

The deficit between 1980 and 2013 of blue water (surface water and groundwater) was studied by [14] in China, India, and the United States, combining 2,443 sub-basins, considering the need for water in the industrial, agricultural, urban, and energy industries. The demand for blue water grew by 60-70 per cent in China, 71-83 per cent in India, and 22-27 per cent in the US; it was mainly because of irrigation, and in 2015, it comprised 80, 95, and 81 per cent of the demand in China, India, and the US, respectively. It was found that 32 percent of Chinese, 61 percent of Indian, and 27 percent of the US sub-basins experienced water shortage of four months or more, depending on the seasons, particularly in the major agricultural areas, mainly the North China Plain in China, Northern and central India, and the western US.

Scientific studies on water scarcity and its repercussions at the regional level (the Middle East)

[15] have conducted a water footprint analysis of the water crisis in Jordan. They discovered that Jordan experiences extreme water shortages (blue water consumption represents 69 percent of the available resources), large groundwater withdrawal (groundwater depletion is almost twice the renewable

level), and more pollution than the resources can deal with (pollution index 1.13). Another aspect that emerged from the study was the significant reliance on external sources of water, with eighty-six percent of the water consumed being imported. The researchers suggested that they should shift to demand management, reduce excessive water depletion, upgrade water use efficiency, and reuse water to make water resources sustainable. The analysis of [16] revealed that climate change and misuse, especially overuse of groundwater in Saudi Arabia, have contributed to water scarcity in the country because of population increase and agricultural activities. The author observed that the use of desalination, food imports, and wastewater reuse has contributed to alleviating the crisis. Yet, these are inefficient in a longer perspective as they are associated with environmental and health hazards; choosing more sustainable options and greater collaboration of international action is needed to maintain water and health security in light of the changing climate. Research [17] revealed that Sudan is one of the countries that experiences severe water shortage because of unequal distribution of resources and population growth. They cautioned that sustaining such a condition will pose a hidden disaster to the water crisis in the future. They suggested enhancing water management and setting water irrigation and rainwater harvesting methods in order to realize water security. [18] clarified that Jordan is facing a severe water shortage as the per capita water consumption decreased by 3,600 m³/year to 140 m³/year, and this makes it the fourth lowest level in the world. This can be attributed to an increase in population, influx of refugees, exhaustion and salination of groundwater basins, and a 22 percent reduction in rain. The researcher forebade that the per capita share would decline to 91 m³/year in the absence of adequate interventions. [7] demonstrated that Iraq, Iran, and Saudi Arabia are facing significant water stress because over 90 percent of existing water is used in agriculture. The research forecasted that by 2030, the demand and supply of water would increase by 20 to 40 percent, and the supply would increase by 12 to 40 percent, respectively, specifically in Iran and Iraq, where the decreasing rainfall would likely form adverse effects on the agricultural output. in a research study [19] aimed at quantifying the economic impact of water shortage growth of Saudi Arabian agriculture. The findings revealed that a scarcity of water means a reduction in cultivated land and the productivity of farm produce, thereby lowering the growth of Gross Domestic Product. [20] investigated changes in water and vegetation in Iran in the last twenty years and found that the scarcity of water resources has not been caused by rainfall deficiency but the intensive development of agricultural lands and unsustainable groundwater extraction. The agricultural activity has been advancing at a rate of around 27,000 km². It has intensified in 48,000 km², thereby increasing the degradation of the vegetation cover and translating 40,000 km² of natural lands into barren ones. The ability of agricultural governance and high demand triggered the crisis, and it is recommended that there should be approximately 10,000 km² of land has been degraded. [21] examined the issue of water scarcity in Egypt, determining that Egypt has already surpassed the stage of absolute water scarcity, with the most significant challenges being concentrated in semi-arid and arid regions. The research results indicated that the crisis is not merely limited to low volume or poor quality of water, but is further compounded by mismanagement, increasing population pressure, aging infrastructure, and intensifying demand for water resources. The researchers recommended introducing integrated management policies, including community sensitization, developing a water knowledge base, reforming the institutional framework, and subsidy rationalization, for the attainment of water security and sustainability in Egypt.

Scientific studies on water scarcity and its implications at the local level (Iraq)

According to [22], research on the growing water scarcity in the Erbil Basin is accurate. The research revealed that the groundwater depletion was at a rate of 0.22 meters annually owing to excessive consumption, the expansion of wells, and the population. He cautioned that prolonging this condition without proper management would further exacerbate the shortages and endanger the region's water security. [23] revealed that the issues of water scarcity in Iraq have contributed to the reduction of farmlands, agricultural yields, and agriculture's share in GDP, which poses threats to food security and stability. The scientists suggested collective water governance, integration of advanced irrigation tools, and modification of agricultural habits in order to improve water usage efficiency. The average daily per capita share of drinking water in Thi-Qar was indicated in a study [24] that evaluated water scarcity in Thi-Qar Governorate, Iraq, using GIS and climate datasets. The results indicated that Thi-Qar's daily per capita potable water consumption was 284 liters, which falls short of the average for the country of 340 liters. The annual per capita available water in Thi-Qar Governorate was only 1,390.95m³, less than the Falkenmark Index threshold for water scarcity. In addition, 6% of months between 1998 and 2018 experienced water shortage and were unable to meet demand. The reduction in marshland area is also quite drastic when viewed on satellite images, which illustrates its impact on both the environment and society. The study carried out by [25] was focused on water scarcity in Erbil. The findings showed an extreme depletion of water resources and a shortage of per capita water supplies to less than the lowest mark of the Falken mark indicator, validating that the condition of apparent water scarcity prevailed. Among the strategies highly recommended in the study are the creation of a groundwater reservoir, increased storage, and using contemporary irrigation methods to enhance water sustainability in the area. Iraq is already facing the rising water scarcity because of the reduced water flows in the Tigris and Euphrates Rivers, which are majorly attributed to the upstream dam construction, global warming, and internal mismanagement. This crisis has increased due to the declining rainfall, temperatures, population and agricultural expansion. These challenges can only be addressed by sustainable management of water resources and agreements with upstream countries [26]. [27] conducted a study of the possible impact of the issue of climate change and the absence of sources of fresh water on the energy resources of Iraq. They communicated that the decline in rain, the increase in evaporation, and the construction of dams in neighboring countries have resulted in a significant decline in water resources, which poses a significant threat to both agriculture and energy. The study confirmed that poor governance and high demand triggered the crisis, and it recommended enhancing the management of resources and infrastructure to increase the sustainability of water and energy in Iraq. [28] carried out the study on the sub-basin of Erbil. Its findings revealed a notable drop in rainfall, humidity, and high temperatures, as well as increased evaporation, resulting in a large annual water deficit and rising water scarcity. This endangers water security in the region, underscoring the need to manage resources effectively and adapt to climate change. [29] compared population and water demand in Erbil Governorate and demonstrated that urbanization and the rapid increase of population have led to extremely high growth in water demand, accelerating groundwater dependency. The study demonstrated that groundwater in the Erbil Plain has lost 20 to 50 m due to over pumping and decreased rainfall. The researcher further found that the city is well below international per capita consumption levels, indicating that high levels of consumption are contributing to the aggravation of water scarcity conditions. The study highlighted the importance of developing policies that will help manage water resources more sustainably and effectively, addressing this growing problem. [30] conducted research into the effects of water shortage on the Kirkuk Irrigation Project. The results showed a steep rise in water volumes due to climate change, with dams and mismanagement as major contributing factors, and this reduced yearly discharge from 104.5 to 30 m³/sec from 1996 to 2023, and reduced the per capita percentage of water below the minimum point of the Falken mark index, indicating an absolute shortage of water and the decline of agriculture and water security in the region. A study considered water scarcity in Erbil and found that overexploitation of groundwater, especially when it is the sole source, combined with population and urbanization growth, has resulted in widespread depressions of water levels and wells running dry. Water scarcity in the region is accelerated by limited resources, rising demand, drought and global climate change. Sustainable solutions that the study advises include wastewater management, and reuse of treated wastewater to irrigate crops to lessen the pressure on the traditional water sources [31].

[32]The research shows that water scarcity in West Bank is due to the interaction between various factors, the first of which is the fact that consumption of domestic water continues to rise, the second one is the scarcity of traditional water sources, and the third is the escalation of the effects of climate change in the arid and semi-arid areas. This, in turn, creates an acute imbalance between the supply and demand of domestic water, which is approximately 32 million cubic meters in 2017 on the territory of the West Bank, which indicates how significant the water deficit of the population is, especially in the most water-deficit regions.

Review of rainwater harvesting and its significance

Since research indicates that rainwater harvesting can play a crucial role in addressing the water shortage problem by providing both economic and ecological benefits, the use of rainwater harvesting will likely reduce water shortages. In its comprehensive elaboration, the literature must be systematically reviewed and categorized into key themes that give a thorough comprehension of the subject.

Review of rainwater harvesting and its significance on a global level

Rainwater harvesting is a worthwhile technology in Malaysia for reducing the use of traditional water and reducing water shortages. Still, the cost of systems and low community awareness limit their uptake. The system is worthwhile in supplying water, providing economic benefits, and combating floods, but its widespread implementation must be fostered through incentives and conducive policies [33]. Researchers have demonstrated that rainwater harvesting dams are effective because in the Mai Gobo region of Ethiopia, the construction of the dams has boosted agricultural water productivity, areas under irrigation, and water security among the small farmers, making agricultural incomes in arid and semi-arid climates rise [34]. Rainwater harvesting is an available and sustainable technology, in favor of complementing the agriculture business of irrigation, and giving a boost to the conventional water sources, particularly in situations of water shortage. Even though the technology is associated with positive environmental changes and changes in agriculture, it has been plagued with problems of quality, price versus affordability, proper support, and regulation. The leaders of research and adoption in the field are India, China, the United States, South Africa, and the Netherlands, since, in these countries, new technologies were developed [35]. [36] researched the possibility of rainwater harvesting to help solve the water scarcity problem in arid and semi-arid regions of Africa. It has been found that the construction of ponds, mini dams, and reservoirs, either to store water, makes agriculture more intensive, offers drinking water, alleviates flooding, and leads to increased food security. Locating rainwater harvesting technology in rural communities: The first aspect highlighted in the study was the need to involve local people, offering them the right technical services and policy regulations, while addressing the challenges of volatile rainfall, installation and maintenance costs, and applying water harvesting technology sustainably. As proven by [37], traditional water resources cannot be relied upon anymore in the face of increasing demand, climate change, and population and economic growth. Rainwater harvesting dams can be used as a viable alternative to mitigate drought, especially in arid and semi-arid zones, where the harvested water is utilized for irrigation of agricultural fields, animal farming, and other purposes. These dams have various regulating functions depending on the rainfall, soil type, topography, and site design, and they are therefore a good water resources control measure in limiting the impact of water shortages. The analysis on rainwater harvesting done by [38] on Karkar Basin revealed that the creation of the earth dam led to better irrigation, more acquisition, and income, as well as the transformation of agriculture to multi-seasonal agriculture, which boosted the water and food security and rural development.

Review of rainwater harvesting and its significance at the regional level (Middle East)

A study in the Oum Zser Valley of south-east Tunisia found that rainwater harvesting systems, analyzed by [39] using GIS and AHP, were moderately effective in reducing drought and water scarcity in arid areas. Most sites achieved a mean performance, and site characteristics, such as soil type, depth, and distance from populations, were the decisive factors. The approach also revealed weaknesses and proposed cost-cutting enhancements to help boost local agriculture and improve harvest efficiency within the regions. A key aspect of their optimization is the appropriate storage capacity relative to runoff potential from each catchment. A calculation of the annual potential for collection from runoff can be done by

$V_1 = 0.001 \times A \times C \times P$

V_1: Annual potential runoff in m³.

C: The mean annual runoff coefficient.

P: the mean annual precipitation(mm).

A: The catchment area (m²).

This computation assures that each structure for harvesting is sized to harvest as much water as can reasonably be captured, given the available runoff, without either under-sizing (leading to water loss) or unnecessarily oversizing (which would be financially burdensome). Reaching the balance assures efficient and sustainable water resource management, which is essential for agricultural productivity and resilience within a dry land environment. Collecting rainwater through the utilization of small and medium dams is the solution to alleviating water scarcity in the dry Arab world by increasing stored water, preserving agriculture, and reducing flood risks. Nine potential locations for dams were chosen based on rainfall, topography, soil, and proximity to urban centers and roads in a study conducted using GIS and multi-criteria decision making in Karak, Jordan, demonstrating that these dams are an effective and low-cost method of enhancing water availability and sustaining rural development [40]. [41] proposed building small concrete dams on Lebanon's mountains to harvest millions of cubic meters of water that each year is lost from the rivers. Using GIS, they identified good sites and stressed that such dams are cheap, simple to apply, and bear low environmental and social risks. [42] used GIS and MCDA in the West Bank in Palestine and found that 61% of the land is plagued by high agricultural water scarcity, 65% is excellent for collecting rainwater, and 40% of the land represents optimum opportunities to enhance agriculture and food security in the most vulnerable locations.

The research [43] examined the efficiency of collecting rainwater in Mashhad, Iran, as a green method of decreasing water shortages in dry lands. The study demonstrated that it is feasible to harvest rainwater from urban areas and accumulate it in special tanks for a secondary source of irrigation. The extracted water has high quality to fair and suitable for irrigation. However, the researchers recommended additional treatment if the water is to be used for drinking purposes due to contamination with microbial and chemical pollutants that exceeded drinking water safe limits. The Researchers [44] have developed an intelligent rainwater harvesting system in Palestine to reduce water deficiency. The system has the capacity for automatic water quality monitoring and detection of leaks, and uses high-tech digital infrastructure and cooperation among citizens. The system was implemented in a neighborhood in Jenin and fulfilled 41% of household demand for water, providing an operable alternative that reduces reliance on groundwater. [45] used advanced techniques to identify the best spots for rainwater harvesting in Wadi Hodein, which is part of the Eastern Desert in Egypt. They demonstrated that with low slopes and surface runoff collection, it is ideal to build reservoirs and dams. This was to combat the scarcity of water as well as promote sustainability in dry conditions. [46] researched water harvesting in Jordan and concluded that the light strike water harvesting in the highlands is more fruitful than large dams. This water harvesting will offer cleaner and purer water, will support and take care of farming, and will also reduce floods. It can, however, lower lowland groundwater recharge. They proposed sponsoring small-scale collecting initiatives.

Review of rainwater harvesting and its significance at the local level (Iraq)

[47] was utilizing the GIS and various evaluation models to pick the most appropriate rainwater harvesting locations in Erbil Governorate. The outcomes indicated that the area was highly and well-suited at 36 per cent. He suggested building smaller and medium-scale dams in six areas of a capacity of about 165 million m³ to boost water security and fight drought. Still, before the proposal was to be implemented, it had to be studied in the field and socially. [48] utilized a WMS model and the SCS-CN approach to calculate rainwater harvesting from small dams in northern Iraq, specifically in Nineveh, Erbil, and Sulaymaniyah. The study indicated the potential to harvest more than 75 million m³ annually, specifically in Sinjar Mountain, Koya, and Sulaymaniyah. The study advocated the use of this technology to alleviate the issue of water shortages and cultivate agriculture, with the need to select areas based on engineering and hydrological considerations. They employed remote sensing, GIS, and multi-criteria analysis to find the best sites of rainwater harvesting in Kirkuk. Also, they determined the sites where agricultural ponds and small dams can be constructed, and this would help to manage the available water as well as offer a good solution to the water shortage in arid regions [49]. A study [50] showed that rainwater harvesting tanks in Sinjar are efficient and economical, with over 100 years of lifespan and very high sediment retention efficiency. Thus, harvesting is a feasible solution to the problem of water scarcity in semi-arid and arid regions. To identify suitable locations to implement rainwater harvesting in Iraq in the Western Desert, [51] combined slope, runoff depth, land cover, soil texture, and stream order in ArcGIS-based modeling. The findings indicate that the most appropriate sites are within the downstream and are characterized by low-intense slopes, soil of clay-like properties, and dense stream settings, allowing the maximum gathering of water and recharge of the groundwater. As shown in Figure 1, the GIS-based analysis presented the spatial distribution and suitability of potential dam sites, which would help in the practical planning of water resources management in arid regions.

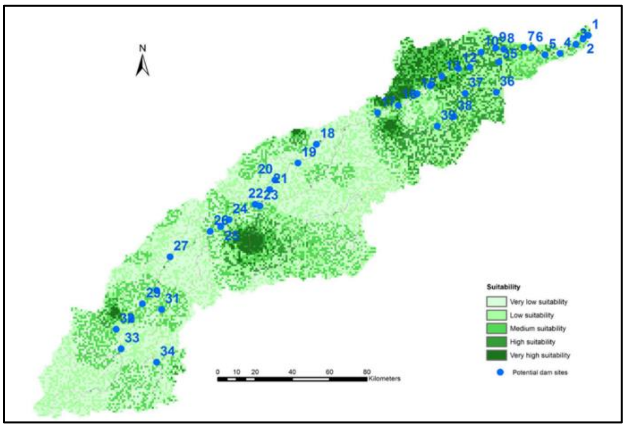


Figure (1): Map of suitability for locating possible dams.

The research by [52] employed remote sensing, GIS, and SCS-CN model methods to determine ideal sites of water harvesting dams and ponds of Al-Qadisiyah, to extend resource management, and minimize the impact of water shortage in deserts. [53] employed remote sensing and geographic information systems in the detection of more appropriate rainwater harvesting systems in the Muthanna Governorate, wherein roof water collection systems, semicircular dams, and ponds were identified as the most appropriate and efficient to be implemented, with the capability of providing household consumption water and agricultural water, thereby improving water security within the desert region. The spatial analysis of the [54] study was conducted to distinguish the most suitable sites to construct rainwater harvesting basins in Maysan Governorate using geographic information systems (ArcGIS) and remote sensing. The fuzzy analysis was used to develop a suitability map, which was done after considering several factors: slope, soil type, rainfall rate, evaporation, vegetation cover, and the lowest distance to the roads. The findings showed 11 convenient locations, which are found on the northwestern side of the governorate, that can be used in irrigation works and the improvement of groundwater recharge. Possible rainwater harvest locations are presented in Figure 2. This map is a geographical spread of the proposed sites and shows the place of optimal basins with regard to the suggested levels of suitability as used in the study. This plays a role in facilitating planning and decision-making in order to increase water security in arid and desert areas. Introducing rainwater harvesting in such places is a successful initiative in alleviating cases of water shortage since it results in augmenting water stores and enhancing water safety in desert and arid regions.

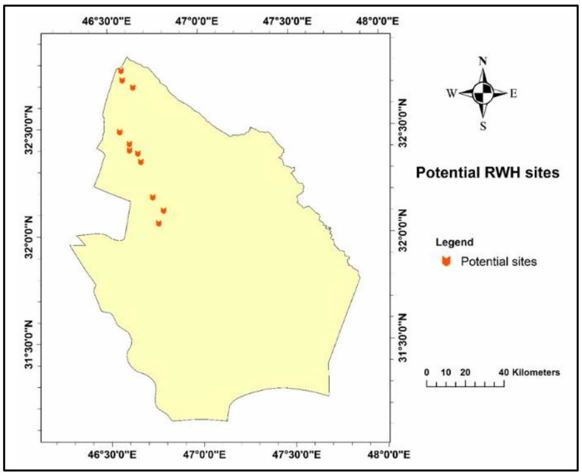


Figure (2): map of optimal rainwater harvesting locations.

[55] used GIS and remote sensing approaches to determine the most suitable locations in the western desert of Iraq, to conduct water harvesting and groundwater recharge improvement. The researchers suggested wells and infiltration reservoirs, as well as small dams. The approach taken by the researchers was very precise and well applicable in terms of cost and soundness in terms of technical suitability in terms of choosing the apt locations. [56] Apply GIS to determine the location to harvest the rainwater in Diyala because of water scarcity and climate change. They relied on satellite images, topographic models, climatic data, and selected six key criteria as the foundation of their work. The findings indicated that it becomes clear that the eastern region of Diyala is the most appropriate region to harvest, and the land use criterion was most significant. Tools have also been identified and proven useful in facilitating faster and easier water resources planning in the semi-arid areas.

In a GIS framework, the AHP approach has been used in a study [57] in order to choose the best rainwater collecting locations in the Labbad Basin west of Samarra; ten spatial indicators have been considered in the process. The study identified seven candidate sites where the small surface dams could be built to store rainwater and surface runoffs to irrigate food produced, provide drinking water, and recharge the groundwater. One of the strategies that fought water shortage and drought in the area was harvesting.

The study calculated the most suitable site where dams can be constructed to store the surface runoff water in the Qashan Himy Basin, located in the northeast of Iraq, and release the water in the mountains of the country in an attempt to tame the problem of water scarcity in the mountains. The output displayed that such plants boost water security since it is possible to store rainwater that can be utilized in the case of droughts [58]. [59] conducted a study that applied the use of remote sensing and satellite imaging to define rainwater harvesting areas in Nineveh. The findings showed that the described technique is sustainable and can be used to effectively reduce water shortage, increase food security, and counteract the consequences of global warming.

Five locations in Wadi al-Muhammadi, western Iraq, were also chosen for the construction of harvesting dams. Of these locations, the percentage of surface runoff was 99%, with an average runoff of 4.65 million m^3/year. According to the recommendation of the researchers, sites with a high index should be chosen to increase water security and contribute to farming [60].

In another study [61], hydrological models with GIS methods were involved in the major sites to construct dams for rainwater harvest in Al-Abyad Valley in Western Iraq. The researchers estimated about 1,045 million m^3 of storage capacity of water in the proposed dams, which would enhance the water quality of Lake Razzaza, minimize losses of surface water, and enhance water security. The study by [62] was founded on GIS methods and multi-criteria analysis to determine the most preferable locations to install the rainwater harvesting systems in the Erbil Basin. It showed that the proportion of highly suitable to moderately suitable was 37 and 26, respectively. As proposed in the research study, there should be the construction of three dams with a total capacity of approximately 35 million m3 to enhance the control of water supplies in desert areas.

In research that used an AHP model with ArcGIS, rainwater harvesting in Basra Basin was identified as a viable way to enhance water security in arid areas as well as the south and southeast of the Basra Basin where 33.6 percent of the land has been reported as having the possible potential of being rated as very good potential; it helps ease the burden of tapping into the conventional sources of water and will also help in practice of agriculture and the domestic utilization of water [63].

Conclusion

1. Current studies have shown that water scarcity is a rising environmental, economic, and social challenge, particularly in arid and semi-arid regions such as the Arab world. The primary causes of this are climate change, population, mismanagement of water resources, and low-quality water, leading to food insecurity, reduced agricultural production, and high poverty and migration levels.
2. The results indicate that the most affected sector by water scarcity is agriculture, where more than 90% of water resources are used in some countries. This aggravates the crisis, with falling rainfall and increasing drought. The sharp decline in per capita water availability and severe degradation of ecosystems, particularly marshlands, have been observed, along with mounting pollution and loss of biodiversity.
3. Rainwater harvesting technologies, particularly small and medium-sized dam construction, have emerged as effective and beneficial means of enhancing water and food security. Studies have confirmed that the technologies are significant in supplementing the storage of water, nourishing agriculture, easing flood risks, and promoting groundwater recharge, with promise for highly efficient use at relatively low investment levels in rural and remote areas.
4. Research has concluded that the overcoming of the water scarcity issue requires adopting integrated approaches that harmonize sustainable water resource management, rainwater harvesting technology utilization, and infrastructure development, while supporting country and subregional policies for maximizing water use efficiency and enhancing the deployment of harvesting technologies based on consideration of hydrological, engineering, and social aspects of each region to achieve a long-term sustainable positive effect.

In accordance with a thorough review of literature, we suggest the installation of rains water harvesting dams. These interventions are critical in reducing the water shortage in the regions where there are low water resources and enhancing stability of the local population, who may not need to migrate to places where there is more water. It has been proven through empirical evidence that rainwater harvesting dams are beneficial ecologically and economically, they improve water security and are a long term, sustainable solution, especially in arid and semi-arid areas.

Methodology

Literature review was carried out in an organized way to maintain the methodological transparency and exhaustive coverage of pertinent studies. The search was conducted using certain keywords, namely, the following: water scarcity, water shortage, and rainwater harvesting in the largest academic databases like Google scholar, Elsevier, and ResearchGate. The publications reviewed belonged to 2015 up to 2025. The selection criteria were based on the focus on the works that made a direct reference to the notion of water scarcity and studies that were able to examine the causes and the results of water scarcity in the context of different sectors. When it came to the rainwater harvesting, the special attention was paid to the studies that considered it as the method of reducing the water shortage, and to the studies that discussed the design and functionality of the rainwater harvesting dams, reservoirs, and associated storage facilities.

Disclosure Statement

– **Ethics approval and consent to participate:** Not applicable.
– Consent for publication: Not applicable.
– **Author's contribution:** The authors confirm their contributions to the paper as follows: study conception and design: Istabraq H. Sbekhan, Yousif H. Al-Aqeeli. Literature search analysis and interpretation and writing: Istabraq H. Sbekhan. critical revision, methodological guidance: Yousif H. Al-Aqeeli. Draft manuscript preparation: Istabraq H. Sbekhan, Yousif H. Al-Aqeeli. All authors reviewed the results and approved the final version of the manuscript.
– **Funding:** Not granted funding.
– **Conflicts of interest:** The authors declare that there is no conflict interest regarding the publication of this article.

Open Access

References

1] Biswas A, Sarkar S, Das S, Dutta S, Banerjee K, Gupta D, et al. Water scarcity: A global hindrance to sustainable development and agricultural production – A critical review of the impacts and adaptation strategies. 2025;3: e4:1-22. https://doi.org/10.1017/wat.2024.16

2] Shemer H, Wald S, Semiat R. Challenges and Solutions for Global Water Scarcity. Membranes (Basel). 2023;13(6) :612. https://doi.org/10.3390/membranes13060612

3] Faisal Abass Padder, Asif Bashir. Scarcity of Water in the Twenty-First Century: Problems and Potential Remedies. MEDALION J Med Res Nursing, Heal Midwife Particip. 2023;4(1):1–5. https://medalionjournal.com

4] Jahura S, Islam MS, Mostafa MG. Impact of water scarcity on rural livelihood in the drought-prone region: A review of global perspectives. Indones J Soc Sci. 2024;16(1):1–13.

5] Liu J, Yang H, Gosling SN, Kummu M, Flörke M, Pfister S, et al. Water scarcity assessments in the past, present, and future. Earth's Future. 2017;5(6):545–59.

6] Abuhalaweh N. Water scarcity in Jordan: Sustainability issues and information drought. Grenfell Campus, Memorial University. 2017; Available from: https://core.ac.uk/display/211574685

7] Procházka P, Hönig V, Maitah M, Pljučarská I, Kleindienst J. Evaluation of water scarcity in selected countries of the Middle East. Water (Switzerland). 2018;10(10):1–18. https://doi.org/10.3390/w10101482

8] Sakati SN, Mallongi A, Ibrahim E, Budimawan, Stang, Palutturi S, et al. Utilization of Rainwater as Consumable Water with Rainwater Harvesting Methods: A Literature Review. Pharmacogn J. 2023;15(6Suppl):1254 -1257. https://doi.org/10.5530/pj.2023.15.227

9] Mulwa F, Li Z, Fangninou FF. Water Scarcity in Kenya: Current Status, Challenges, and Future Solutions. Open Access Library Journal. 2021;08(01):1–15. https://doi.org/10.4236/oalib.1107096

10] Ingrao C, Strippoli R, Lagioia G, Huisingh D. Water scarcity in agriculture: An overview of causes, impacts and approaches for reducing the risks. Heliyon [Internet]. 2023;9(8):e18507. Available from: https://doi.org/10.1016/j.heliyon.2023.e18507

11] Hirani, J. D., & Ali M. Water Scarcity in Desert Belts in Pakistan: A Case of Thar Region 1Jhaman. Ann Hum Soc Sci [Internet]. 2023;4(3):1–11. Available from: https://ojs.ahss.org.pk/journal/article/view/21/69

12] Liu C, Xu C, Zhang Z, Xiong S, Zhang W, Zhang B, et al. Modeling hydrological consequences of 21st-century climate and land use/land cover changes in a mid-high latitude watershed. Geosci Front [Internet]. 2024;15(5):101819. Available from: https://doi.org/10.1016/j.gsf.2024.101819

13] Liao R. Water scarcity assessment index from the realistic perspective of human basic water requirements. Environ Sustain Indic [Internet]. 2024;22(April):100404. Available from: https://doi.org/10.1016/j.indic.2024.100404

14] Deng Q, Sharretts T, Ali T, Ao YZ, Chiarelli DD, Demeke B, et al. Deepening water scarcity in breadbasket nations. Nat Commun. 2025;16(1):1110.

15] Schyns JF, Hamaideh A, Hoekstra AY, Mekonnen MM, Schyns M. Mitigating the risk of extreme water scarcity and dependency: The case of Jordan. Water (Switzerland). 2015;7(10):5705–5730. https://doi.org/10.3390/w7105705

16] DeNicola E, Aburizaiza OS, Siddique A, Khwaja H, Carpenter DO. Climate change and water scarcity: The case of Saudi Arabia. Ann Glob Heal [Internet]. 2015;81(3):342–53. Available from: http://dx.doi.org/10.1016/j.aogh.2015.08.005

17] Li Y, Tang C, Xu L, Ye S. Using System Dynamic Model and Neural Network Model to Analyze Water Scarcity in Sudan. IOP Conf Ser Earth Environ Sci. 2017;73: 012013. https://doi.org/10.1088/1755-1315/73/1/012013

18] Al-ghussain L. Water Scarcity and Sustainable Water Solutions in Jordan. SEES 503 Term Paper, Middle East Technical University Northern Cyprus Campus; 2017.

19] Alrwis KN, Ghanem AM, Alnashwan OS, Al Duwais AAM, Alaagib SAB, Aldawdahi NM. Measuring the impact of water scarcity on agricultural economic development in Saudi Arabia. Saudi J Biol Sci [Internet]. 2021;28(1):191–5. Available from: https://doi.org/10.1016/j.sjbs.2020.09.038

20] Behling R, Roessner S, Foerster S, Saemian P, Tourian MJ, Portele TC, et al. Interrelations of vegetation growth and water scarcity in Iran revealed by satellite time series. Sci Rep [Internet]. 2022;12(1):1–22. Available from: https://doi.org/10.1038/s41598-022-24712-6

21] ElZein Z, Abdou A, Säumel I. Lessons learned from water-scarce cities: Proposed policies toward an integrated urban water management in Egypt. Frontiers in Water. 2022; 4:981261. https://doi.org/10.3389/frwa.2022.981261

22] Mawlood DK. Sustainability of Aquifer and Groundwater Condition in Erbil Basin/ Iraq. Zanco J Pure Appl Sci. 2019;31(6). :51-60. https://doi.org/10.21271/ZJPAS.31.6.6

23] van Vliet MTH, Jones ER, Flörke M, Franssen WHP, Hanasaki N, Wada Y, et al. Global water scarcity, including surface water quality and expansions of clean water technologies. Environ Res Lett. 2021;16(2):024020. https://doi.org/10.1088/1748-9326/abbfc3

24] Ethaib S, Zubaidi SL, Al-Ansari N. Evaluation of water scarcity based on GIS estimation and climate-change effects: A case study of Thi-Qar Governorate, Iraq. Cogent Eng [Internet]. 2022;9(1). Available from: https://doi.org/10.1080/23311916.2022.2075301

25] Abdullah AI, Mohammed AH. Water Scarcity in Erbil City: Problems and Innovative Solutions. In: 4th International Conference on Communication Engineering and Computer Science (CIC-COCOS'2022) [Internet]. Cihan University; 2022. p.105–13. Availablefrom: https://conferences.cihanuniversity.edu.iq/index.php/COCOS/22/paper/view/760

26] Hommadi AH, Al-ansari NA, Obaidy A Al, Obied WK, Abdul-ghni RN, Abed SA. Evaluating Water Scarcity Indices for Cultivation Region in Sadat Al-Hindya, Babylon, Iraq: A Case Study.Engineering.2023;15:647-662. https://doi.org/10.4236/eng.2023.1510045

27] Marcellin MC, Pavur G, Loose DC, Cardenas JJ, Denehy D, Almashhadani M, et al. Risk Model of Climate Change and Water Scarcity for Energy Resources of Iraq. 2023;1–20. Available from: https://doi.org/10.21203/rs.3.rs-3581219/v1

28] Hamed MH. Climate Parameter Uses as Indices For Assessment of Climate Change and Water Balance in Erbil Sub-Basin, North Iraq. Iraqi J Sci. 2023;64(9):4518–4537. https://doi.org/10.24996/ijs.2023.64.9.19

29] Sissakian V. Population Growth in Erbil Governorate and Water Consumption. A Case Study. J Duhok Univ. 2023;26(2, Special issue):110–8. ttps://doi.org/10.26682/csjuod.2023.26.2.12

30] Salah Yaseen R, Ridha Faris M. Water Scarcity Effect on Kirkuk irrigation project. IOP Conf Ser Earth Environ Sci. 2024; 1374:012065.https://doi.org/10.1088/1755-1315/1374/1/012065

31] Ahmed B, Aziz SQ, Ismael SO, Dizayee KK. Wastewater Management as a Part of the Solution for the Water Resources Problem in Erbil City. Zanco J Pure Appl Sci. 2024;36(5):95–103. https://doi.org/10.21271/ZJPAS.36.5.9

32] Al-sulttani A, Al-Akaam I. Spatial Variation of Groundwater Suitability for Drinking and Irrigation by Using GIS - East of Tharthar Lake, Iraq, a case Study. An-Najah Univ J Res B(Humanti).2018;32(7):1337-1360.

33] Lani NHM, Yusop Z, Syafiuddin A. A review of rainwater harvesting in Malaysia: Prospects and challenges. Water (Switzerland). 2018;10(4):1–21. https://doi.org/10.3390/w10040506

34] Villani L, Castelli G, Hagos EY, Bresci E. Water productivity analysis of sand dams' irrigation farming in northern Ethiopia. 2018;112(1):139–60. https://doi.org/10.12895/jaeid.20181.726

35] Velasco-Muñoz JF, Aznar-Sánchez JA, Batlles-delaFuente A, Fidelibus MD. Rainwater harvesting for agricultural irrigation: An analysis of global research. Water (Switzerland). 2019;11(7).https://doi.org/10.3390/w11071320

36] Umukiza E, Ntole R, Chikavumbwa SR, Bwambale E, Sibale D, Jeremiah Z, et al. Rainwater Harvesting in Arid and Semi-Arid Lands of Africa: Challenges and Opportunities. Acta Sci Pol Form Circumiectus. 2023;22(2):41–52.

37] Ertop H, Koci˛ecka J, Atilgan A, Liberacki D, Niemiec M, Rolbiecki R. The Importance of Rainwater Harvesting and Its Usage Possibilities: Antalya Example (Turkey). Water 2023, 15, 2194. https://doi.org/10.3390/w15122194

38] Tiwari A. Rainwater Harvesting through Check Dams for Integrated Watershed Management in Karkara Basin: A Geographical Analysis. Int J Soc Impact. 2024;9(3).

39] Ammar A, Riksen M, Ouessar M, Ritsema C. Identification of suitable sites for rainwater harvesting structures in arid and semi-arid regions: A review. Int Soil Water Conserv Res. 2016;4(2):108–20.

40] Rida Al-Adamat, Al-Shabeeb AAR, Al-Fugara A, Al-Amoush H. The Use of Vector-Based GIS and Multi-Criteria Decision Making (MCDM) for Siting Water Harvesting Dams in Karak Governorate/ South Jordan. 2017;7(6):28–35.

41] Hamze Y, Oil KA. Water Conservation in Arid Countries, Small Friendly Environmental Lakes and Dams, Research Study of a Small-Scale Experimental Dam Project on a Small River. SciFed J Glob Warm. 2017;1(1).

42] Shadeed S, Judeh T, Riksen M. Rainwater harvesting for sustainable agriculture in high water-poor areas in the West Bank, Palestine. Water (Switzerland). 2020;12(2):1–16.

43] Ranaee E, Abbasi AA, Yazdi JT, Ziyaee M. Feasibility of rainwater harvesting and consumption in a Middle Eastern Semiarid urban area. Water (Switzerland). 2021;13(15):1–23.

44] Judeh T, Shahrour I, Comair F. Smart Rainwater Harvesting for Sustainable Potable Water Supply in Arid and Semi-Arid Areas. Sustain. 2022;14(15).

45] Aly MM, Sakr SA, Zayed MSM. Selection of the optimum locations for rainwater harvesting in arid regions using WMS and remote sensing. Case Study: Wadi Hodein Basin, Red Sea, Egypt. Alexandria Eng J [Internet]. 2022;61(12):9795–810. Available from: https://doi.org/10.1016/j.aej.2022.02.046

46] Salameh E, Yaseen MA haj. Hydrologic, Environmental, and Socioeconomic Relevance of Small-Scale Water Harvesting: Small-Scale Versus Large-Scale Water Harvesting, the Case of Jordan. 2025;13(6):221–40.

47] Hameed HM. Student thesis series INES nr 271 Water harvesting in Erbil Governorate, Kurdistan region, Iraq Detection of suitable sites using Geographic Information System and Remote Sensing. 2013;(271).

48] Al-Ansari N, Knutsson S, Zakaria S, Ezzeldin M. Feasibility of using small dams in water harvesting, Northern Iraq. Hydropower'15. 2015;4(6):15–6.

49] Buraihi FH, Shariff ARM. Selection of rainwater harvesting sites by using remote sensing and GIS techniques: A case study of Kirkuk, Iraq. J Teknol. 2015;76(15):75–81.

50] Mohammad EM, Al-ansari N, Knutsson S. ESTIMATING LIFE SPAN OF RAINWATER HARVESTING RESERVOIRS IN SINJAR AREA, IRAQ. 2016;24:1-10

51] Adham A, Naba K, Abed R, Arbi M, Wesseling JG, Riksen M, et al. A GIS-based approach for identifying potential sites for harvesting rainwater in the Western Desert of Iraq. Int Soil Water Conserv Res [Internet]. 2018;(July). Available from: https://doi.org/10.1016/j.iswcr.2018.07.003

52] Al-khuzaie MM, Janna H, Al-ansari N. Assessment model of water harvesting and storage location using GIS and remote sensing in Al-Qadisiyah , Iraq. Arabian journal of Geosciences.2020;13:1154. https://doi.org/10.1007/s12517-020-06154-4

53] Al-khafaji DS, Abdulkareem AK, Al-kubaisi QY. Determining the Best Rainwater Harvesting System in Al-Muthanna Governorate, Iraq. 2022;63(6):2755–63.

54] Alwan IA, Aziz NA, Hamoodi MN. Potential Water Harvesting Sites Identification Using Spatial Multi-Criteria Evaluation in Maysan Province, Iraq. Imzahim. 2020;

55] Al-shammari MMA, Õ AMA Shamma, Almaliki A, Hussain HM, Yaseen ZM, Armanuos AM. Integrated Water Harvesting and Aquifer Recharge Evaluation Methodology Based on Remote Sensing and Geographical Information System: Case Study in Iraq. 2021;(February).

56] Al-khafaji DS, Abdulkareem AK, Al-kubaisi QY. Rainwater Harvesting Using GIS Technique: A Case Study of Diyala Governorate, Iraq. 2021;3(2).

57] Mohmmed SJ, Hassan MA. Assessment of the possibility of water harvesting for the Al-Labad Basin - west of Samarra , using artificial intelligence technology , watershed modeling (WMS). 2022;6(May):1035–1054.

58] Al-kakey O, Othman AA, Al-mukhtar M, Dunger V. Proposing Optimal Locations for Runoff Harvesting and Water Management Structures in the Hami Qeshan Watershed, Iraq. ISPRS Int J Geo-Inf. 2023;12(8):312. https://doi.org/10.3390/ijgi12080312

59] M.Aliyas I, Alrawi AT, Mohammed MF. RAINWATER HARVESTING: AN EFFECTIVE SYSTEM FOR ACHIEVING FOOD SECURITY. 2024;(March). https://doi.org/10.69557/ujrra.v1i2.29

60] Al-Kubaisi MHD, Al-Kubaisi QY. Delineation of Suitable Rainwater Harvesting Sites in Wadi Al-Mohammadi, Iraq. IOP Conf Ser Earth Environ Sci. 2024; 1300:012021. https://doi.org/10.1088/1755-1315/1300/1/012021

61] Mohammed HA, Abed BS. The Feasibility of Constructing Rainwater Harvesting Dams and Their Storage Capacity in Al-Abyadh Valley, West of Iraq, Haneen. J Eng. 2025;31(3):96–112.

62] HAJANI E, K SISSAKIAN V, MUSA I, AATROOSHI S, DOUVEN W, MASIH I. Water harvesting in Erbil Watershed, Kurdistan Region of Iraq. J Earth Syst Sci. 2025;134(68). https://doi.org/10.1007/s12040-025-02530-4

63] Najm aT, Lee W Koon, Abbas AA, Ramli S. Enhancing Rainwater Harvesting Sustainability in the Al-Basrah Basin, Iraq: A Two-Phased Approach Combining GIS-AHP for Site Suitability and Fog Computing for Dynamic Management. J Comput Cogn Eng.2025; 00:1–15. https://doi.org/10.47852/bonviewJCCE52024444