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# Causes of Water Resources Scarcity in Iraq and Possible Solutions

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## Abstract

Iraq relies in its water resources on the waters of the Tigris and Euphrates and their tributaries. The country is located in the lower part of the catchment area of these rivers. The long-term average annual flow that enters Iraq from these rivers is about 30 BCM from the Euphrates, 21.2 BCM from the Tigris, 24.78 BCM from tributaries and 7 BCM from side valleys between Iraq and Iran. Now, the flow of these rivers is decreasing due to climate change and hydrological projects established in the upper parts of the catchment. It is indicated that precipitation will decrease by 15% - 25% during this century and that means that the flow of the Tigris and Euphrates rivers will be reduced by 29% - 73%. This will cause a grave depletion of groundwater resources. Türkiye is trying to finish building 22 dams and 19 hydropower stations. Iran built 12 dams and diverted the flow of some tributaries inside Iran and blocked all the valleys that contribute water from its land to Iraq. For these reasons, Iraq is experiencing shortages in its water resources and there is some sort of friction and conflict between riparian countries within the Tigris and Euphrates basins because each country tries to secure its water resources. In this research, the factors affecting the hydro politics within these basins are water scarcity, climate change and hydrological projects, population growth rate, energy issues, water mismanagement, economic changes, expansions of projects and technology, political issues, international water laws and public awareness. In case the situation remains as it is, Iraq will experience many problems in health, environment, economy, and security. To solve the problem of water scarcity in Iraq, two parallel lines of action are to be considered. These are: 1) Reach

agreements with Riparian Parties; 2) Develop a long-term strategy that should take the following: a) Rehabilitating of existing dams, barrages & pump stations, b) Improving the efficiency of diversion and supply, c) Using of non-conventional water resources, d) Irrigation modernization using suitable techniques, e) Developing a public awareness program, f) Developing human resources program and establishing an agenda for training, g) Developing an agricultural plan that takes into consideration the possibility of reducing crops that consume a lot of water.

## Keywords

Tigris River, Euphrates River, Iraq

## 1. Introduction

The estimated water quantity of water on Earth is 1.4 billion km$^3$ [1]. About 97% of this water is saline oceanic water, while 77% of the remainder is stored as ice, 22% as groundwater and soil moisture, and 0.35% in lakes and marshes. The percentage of water in the atmosphere is 0.04%, and then there are only 0.01% fresh water supplies in rivers [1] which provide 80% for human use. Therefore, rivers carry 0.003% of all the water available on earth [2]. On the other hand, the annual freshwater quantity required for human use is about 1000 m$^3$ annually [3].

Available facts and figures confirm that the 80 countries of the Third World that support 40% of the world's population suffer from water shortage problems which have become daily life fact. These countries experience the shortage of personal and household needs, and consequently, 1.2 billion people are suffering physically from water shortage and 1.8 billion of them lack adequate sanitation [2]. Furthermore, in the Third World, about 80% of illnesses and 30% of unnatural deaths are due to water diseases and polluted water [2]. Future predictions suggest that there will be 37 countries in 2025 having the shortage of water for all needs [4]. For these reasons, most of the countries of the world try to utilize as much as they can the water of their rivers to fulfill their demand. More than 60% of the river basins are shared by more than one state [4]. These basins are located all around the world; 57 in Africa, 35 in North and South America, 40 in Asia and 48 in Europe [2]. They cover 47% of the total land mass on the earth which includes 65% of Asia, 60% of Africa and 60% of South America. Due to the importance of water use and distribution between countries sharing the basins, 300 treaties were signed, and more than 3000 treaties included provisions relating to water. Despite these facts, coordinated and integrated management of international river basins is still rare [2]. In the Third World, the situation is the same where more than 165 river basins are shared by many countries [5]. In such basins, there is always a dominant regional power and in the case of Tigris-Euphrates basin, Türkiye, is the dominant power [2]. In the Middle East the

average annual rainfall does not exceed 166 mm/year [5]-[11]. Water allocation per capita does not exceed 500 $m^3$ in twelve countries [12] [13]. In view of these facts, water resources are very essential to life, socioeconomic development, and political stability in this region.

Iraq relies on its water resources on the waters of the Tigris and Euphrates rivers and their tributaries (**Figure 1**). The basins of these rivers are shared by Türkiye, Iran, Syria, and Iraq (**Table 1**). All these rivers originate from outside the borders of Iraq apart from the Al-Adhaim tributary where its catchment lies entirely inside Iraq (**Figure 1** and **Figure 2**). The long-term discharge of this tributary does not exceed 25 cubic meters per second. Long-term records indicate that Iraq used to receive 30 BCM of water from the Euphrates river and 21.2 BCM from the Tigris river while its tributaries contributed about 24.78 BCM [14]. In addition, 7 BCM of water was brought by small wadies from Iran [11] [14] [15] [16] [17].


**Figure 1.** Catchments of Tigris and Euphrates rivers.

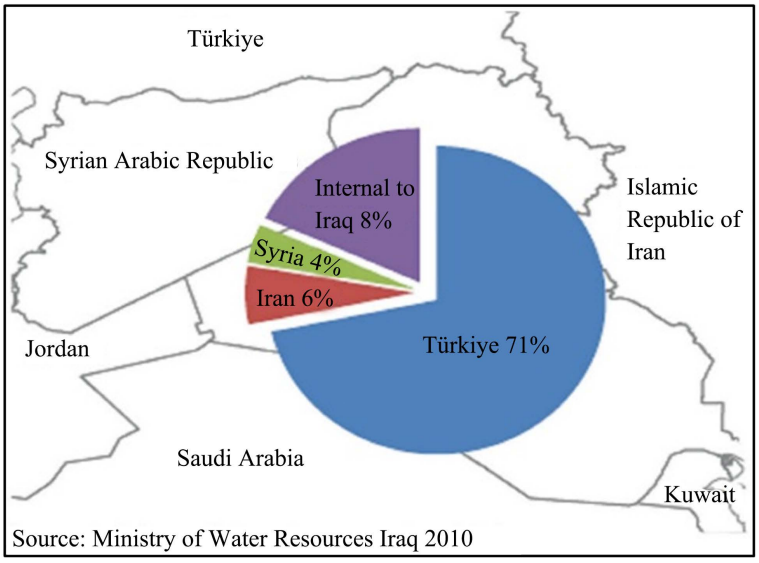



**Figure 2.** Source of water from the Tigris and Euphrates rivers and their tributaries.

**Table 1.** The catchments of the Tigris and Euphrates rivers include five countries in the middle east and southwest Asia.

| Countries | Tigris River | | Euphrates River | |
|---|---|---|---|---|
| | Catchment Area | | Catchment Area | |
| | (Km²) | (%) | (Km²) | (%) |
| **Türkiye** | 57,614 | 12.2 | 125,000 | 28.2 |
| **Syria** | 834 | 0.2 | 76,000 | 17.1 |
| **Iraq** | 253,000 | 58 | 177,000 | 39.9 |
| **Iran** | 140,180 | 29.6 | - | - |
| **Saudi Arabia** | - | - | 66,000 | 14.9 |
| **Total** | 473,103 | 100 | 444,000 | 100 |

Iraq is located at the lower end of the Tigris and Euphrates basins (**Figure 1** and **Figure 2**) and for this reason any withdrawal of water in the uppermost catchment areas affects Iraq negatively. Iraq, known historically as, Mesopotamia or the land between the two rivers, was famous for its ancient extensive irrigation works. In modern times, however, interest in hydraulic works began with the Ottoman and British forces occupying Iraq. They started monitoring the flow of the two rivers, Tigris, and Euphrates, and recording their water levels for the purpose of determining safe locations to station their armies and establish their headquarters. Some irrigation activities were also started to secure their requirement for vegetables and some other crops [18] [19] [20] [21].

After the establishment of the Iraqi national government in the early twenties of the last century, one of its main priority tasks was to stabilize and protect the population from the floods of the Tigris and Euphrates rivers that most regions of the south were exposed to during winter and spring seasons. At that period Iraq was the only outlet for the water coming from the hills in Türkiye Iran. The total water reaching Iraq was about 125 BCM/year in wet years and 75 BCM in normal years. The English engineer Sir William Wilcox, famous for his extensive experience in irrigation works in countries already occupied by the British (India, Egypt), had accompanied the British forces to Iraq and therefore made use of their water flows and level recordings. Participating with major English firms, he prepared the plans and some designs of the major hydraulic structures of the water system by utilizing all the collected data for the water inflows to Iraq (75 BCM & 125 BCM). In this plan the Tharthar natural depression was adopted as the main Tigris river flood relief reservoir, Habbaniyah Lake was taken as the main Euphrates river flood relief reservoir and finally the Southern Marshes were considered as the final location for relieving excess flood water of both rivers [18] [19] [20] [21]. The opinion was also to build a special barrage on Shatt Al-Arab river stopping sea tide from entering the Tigris and Euphrates. Its loca-

tion and specifications would be determined considering what the upstream countries will do about the construction of dams and agreements regarding water sharing.

In the seventies of the last century, when the Ataturk Dam was completed (the main reservoir of the GAP dams project series), with a reservoir capacity of 48 BCM annually signs of water scarcity began to appear clearly in Iraq and problems started between Iraq and Türkiye about water shares. In the early eighties, the water resources planning strategy was adopted for the years between 1972 and 1982 by the Ministry of Irrigation (the former name of the Ministry of Water Resources). Preparation of this strategy was entrusted to the USSR institution "Selkhozpromexport", and this has guided much of the country's policies and actions since then. The final report of 1982 called, "General Scheme of Water Resources and Land Development in Iraq—Second Stage," contained a very comprehensive compilation of data and a full account of the water resources planning up to 2000. The document covered water, salinity, soil management, agriculture and irrigation, fisheries, water supply, hydropower, flood control, erosion control, and navigation. In the 1990s, there was an initiative to update the General Scheme, called the "Third Stage", but it was unfortunately not completed [22].

One of the recommendations of the Soviet study was to gradually dry up the Hammar Marsh until the year 1990 due to the decrease in the Euphrates inflows and to consider the future of the Hawizah Marsh in the light of Iran's behavior regarding the water inflows from the eastern Iranian plateau on which the Hawizah Marsh depends to a large extent. Reliance continued on the details and programs of the Soviet study for the management of water resources in Iraq and the implementation of its programs related to the construction of reservoir dams and water harvesting dams and other projects until the year 2014.

In the year 2014, a new and quick study was prepared on the water situation in Iraq by an Italian firm, which was called "Study of Water and Wetlands in Iraq" [23]. The study relied mainly on inaccurate hypothetical assumptions in its preparation. It's considered that water income to Iraq is 35 BCM/year despite the absence of an agreement with the upstream countries in this regard (and this amount of water has not been realized since the adoption of this study).

Due to the construction of dams in the upper riparian countries the flow of the rivers decreased tremendously [14] [24] [25] [26] [27]. The decrease in flow started in mid 1970s after the construction of the Keban dam in Türkiye and the Tabaqa dam in Syria (**Figures 3-5**) [28] and continued to decrease afterwards, and this can be noticed from the Shatt Al-Arab river flow whereby the average annual flow of Shatt Al-Arab River was 919 cubic meters per second (CMS) during 1977-78 and dropped about 39 CMS in 2011 [29]. This is due to the construction of dams within the upper parts of the catchments [28]. In this work, the conflicting issues on water resources of the Tigris and Euphrates Rivers basins are discussed and possible solutions to resolve these issues are given.

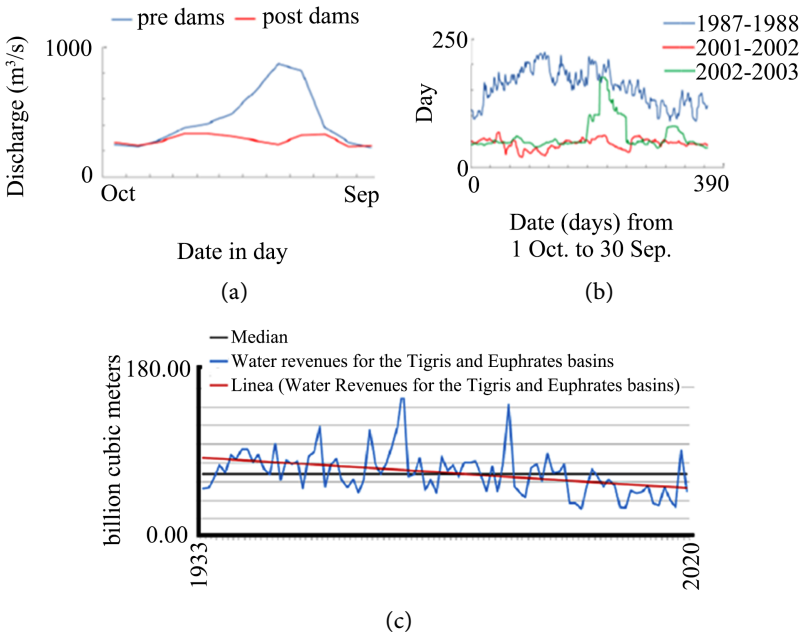



**Figure 3.** (a): The Euphrates average monthly flow at Thi-Qar station during the periods 1950-1980 (pre-dams) and 1982-1997 (post dams), (Euphrates river). (b): The average daily discharge of the Tigris river upstream of the Shatt Al-Arab river (near Qurna city) before and after the development in the basin (Modified after [25]), (Tigris river). (c): Water revenues for the Tigris and Euphrates basins 1933-2020.

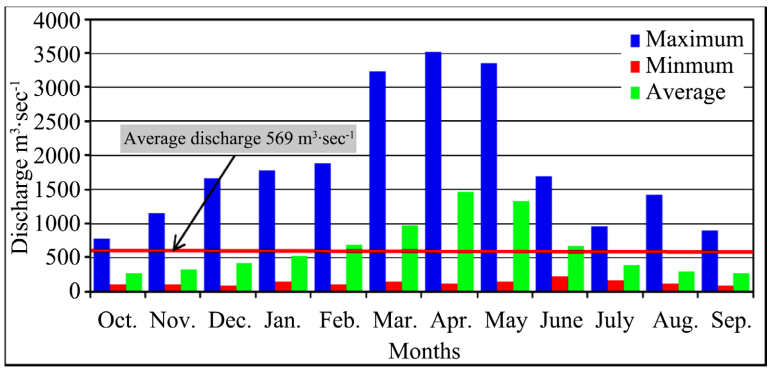



**Figure 4.** Monthly (mean, minimum and maximum) discharge of Tigris river at Mosul dam site (1931-2011), source: [30].

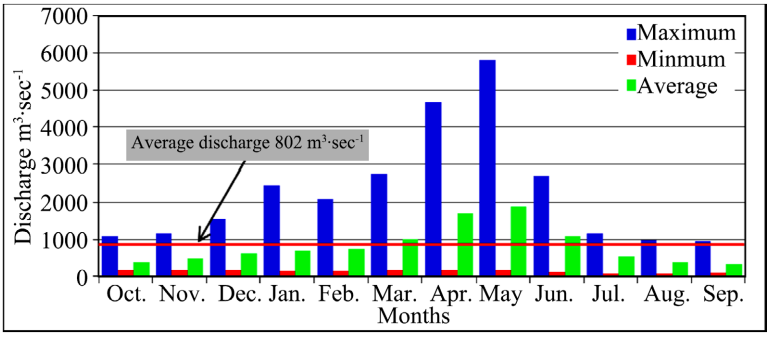



**Figure 5.** Monthly (mean, maximum and minimum) discharge of Euphrates river at Hit site (1932-1997), source: [30].

## 2. Causes of Conflict between Riparian Countries

All riparian countries within the Tigris-Euphrates basins are aware of the negative impacts of climate change. For this reason, each country tries to augment as much as it can from the available water within these basins. This has raised a few factors for conflict between these countries. These were summarized and discussed by Al-Ansari *et al.* [31] [32].

### 2.1. Water Availability

Turkish officials have always claimed that the allocation per capita is good and accepted for Iraq (see Table 2) [33] [34]. The data proposed does not consider the effect of the GAP project on the flow of the rivers and it also ignores the volume of water required to restore the Iraqi marshes. On these bases Türkiye claims that the existing water is sufficient for both Syria and Iraq [35].

### 2.2. Population Growth Rate

According to 2018 statistics, there are 221.53 million inhabitants living within the Tigris and Euphrates basins in Syria, Türkiye, Iran, and Iraq (Table 3). Since population growth rate is high in these countries, particularly in Syria and Iraq [36], it is expected that population will be 243.44 and 304.68 million in 2025 and 2050 respectively. These suggest that the increase in population is 10% in 2025

Table 2. Water allocation per capita per year in Türkiye, Syria, and Iraq, source of data a-[32]; b-[33].

| Country | Water Allocation ($m^3$/capita/year) | | | |
|---|---|---|---|---|
| | 1990 | 2000 | 2010 | 2020 |
| Türkiye | 3223 | 2703 | 2326 | 2002[a], 980[b] |
| Syria | 1636 | 117 | 880 | 760[a], 780[b] |
| Iraq | 2352 | 1848 | 1435 | 1062[a], 950[b] |

Table 3. Population characteristics within Tigris-Euphrates basins (modified from [41] [42] [43] [44] [45]).

| Country | Population (million) | Rate of Growth (%) | Projected Population (million) | | Percent Urban |
|---|---|---|---|---|---|
| | | | 2025 | 2050 | |
| Türkiye | 81.91 | 1.45 | 86.12 | 95.62<br>95.819** | 71 |
| Syria | 18.28 | 3.7 | 23.41 | 34.02<br>34.90** | 75 |
| Iraq | 39.33 | 2.78 | 47.19 | 81.49<br>83.65** | 66.9 |
| Iran | 82.01 | 1.05 | 86.72 | 93.55<br>92.21** | 73.8 |
| **Total** | **221** | | **243.44** | **304.68** | |

and 37% in 2050. In view of these figures, efforts to secure food self-sufficiency will enforce that more water to be used for agricultural purposes. Now, the allocation for water for agricultural purposes within the two basins is 84.35% (**Table 3**). Future need for water in this sector will be beyond the capacities of the two rivers to provide for these countries [36] [37]. Previously Iraq used to be grain exporter but after the Gulf war it became grain importer [38] [39] [40]. This is due to problems in salinity and water logging and deterioration of irrigation works and agriculture in general. Therefore, food security and food self-sufficiency will be one of the major concerns in Iraq in the future.

### 2.3. Energy Needs

Iraq and Iran have been oil exporters since the beginning of the twentieth century while Syria started to export oil in 2001, Türkiye, however, has no oil reserves [45]. For this reason, Türkiye is trying to use hydroelectric power to cover about 40% of its energy requirements and this will reduce its imports of oil by 28 million tons [46] [47]. One of the goals for Türkiye to achieve this is to complete the Güneydoğu Anadolu Projesi, (GAP), well known in English as the South- eastern Anatolia Project. This will decrease the flow of the two rivers to Iraq considerably, while, at the same time, it might be the goal of Türkiye to trade water against oil, as several authors have already stressed that the GAP project has number of internal and external goals [48] [49] [50] [51] [52].

### 2.4. Water Resources Management

The dominant irrigation application method used in riparian countries is "Flood Irrigation", which is characterized by high water losses. This has exasperated water scarcity problems within riparian countries [53]. In addition, water supply canals are not covered or lined which leads to increased water losses. Chemical fertilizers and pesticides are extensively used, therefore backflow from irrigated areas, added to the practice of dumping untreated or partially treated municipal and industrial waste in the rivers, have accelerated the pollution of these rivers. Consequently, water quality within the rivers in Iraq has deteriorated due to their geographic location being at the lower part of the rivers' basins. This was reported by the Consulting Engineering Bureau at Baghdad University [28] [54], and by many other researchers from Iraq.

### 2.5. Development of Economic Sector

Nearly 50% of the population from rural areas within the Tigris and Euphrates basins has already moved to urban areas due to the economic development in the Middle East which was caused by increasing oil prices. This movement had negative impacts on the water shortage problem since water consumption increased by about 10 to 12 times its normal per capita for village dwellers [36]. The standard of living in Iraq and Syria increased rapidly due to the economic developments caused by the higher oil prices [53], which in turn raised the need

for water because of these developments in the two countries, and the claimed need for Türkiye, Syria and Iraq have summed up to 149% of the total available water [45]. Lacking enough economic resources to catch up with these developments, Türkiye is trying to use its abundant water resources as a commodity for bargaining. In 1992 the president of Türkiye declared at the Ataturk dam opening ceremony that "Neither Syria nor Iraq can lay claim to Türkiye's rivers any more than Ankara could claim their oil, the water resources are Türkiye's; the oil resources are theirs. We don't say we share their oil resources, and they can't say they share our water resources" [55]. In addition, Türkiye proposed the Peace Pipeline and Manavgat River project which has its focus on trading water with Mediterranean and Middle East neighbors [56] [57].

### 2.6. Development in the Technical Sector

To augment their water resources Türkiye and Iran have built several large dams and they are planning to build more of them in the future. These dams, apart from cutting out a sizable portion of Iraq's water share, cause an increase in evaporation losses due to the high temperatures in the region. In addition, existing irrigation techniques are characterized by high water losses, and this is leading to more strain on available water resources. It is interesting to note that new techniques were tried to be used in Syria but this was met with plenty of problems as farmers were not well educated and could not understand and apply the new technologies [58] [59].

### 2.7. Political Fragmentation

Most of the Middle East was under the rule of the Ottoman Empire for the period from the thirteenth century up to the fall of this empire just after its defeat in World War I. This led to the area being taken over by Britain and France. Conflicts among different peoples inhabiting the area were less during this period. People's ethnic consciousness heightened which led to growing disparities and rivalries in the region, and all those peoples became more competitive and nationalistic after this period. The excessive use of surface water and groundwater in addition to water pollution became the prime sources of friction and tension. Examples to be mentioned are the 1967 war between Israel and the Arab states where water was one of the underlying causes, as well as the Israeli occupation of Lebanon in 1982 where they occupied the Litany River and diverted its water. Israel is extracting 40% of its water from aquifers beneath the West Bank and Gaza [44]. Similarly, a large number of dams were built on the Tigris and Euphrates in Türkiye and Iran without any consultation with Syria and Iraq, and these also raised tensions [25]. One more example is the tension between Syria and Iraq in 1974 over the Euphrates water sharing. Prediction models for future surface water and groundwater resources show their depletion in the Middle East soon [28] [60] [61] [62] [63]. This led the UN Secretary General Boutros Boutros-Ghali to say in 1985 that the next war in the Near East would not be about politics, but over water [64].

### 2.8. International Water Laws

During the meeting of the United Nations General Assembly on the 21st of May 1997 the Convention on the Law of the Non-Navigational Uses of International Watercourses was adopted with approving votes from more than one hundred UN Member States and under the sponsorship of thirty-eight governments. The Convention represents the culmination of nearly four decades of work on the topic by the United Nations and its Member States. Türkiye, China, and Burundi were, however, among the countries which voted against this law [2]. The Convention entered into force on 17 August 2014 when it became a binding law after 35 governments had ratified it which was the necessary number for this ratification. This law states the principles and mechanisms that should be followed to avoid disputes escalating to the level of acute conflicts, but it has no legally binding international obligations for countries to share their water [65]. In view of this, all agreements will depend upon the goodwill of the countries involved within the drainage basin, the degree of national interest and both internal and external power available for the country to pursue its politics [66].

### 2.9. Public Awareness Program

Although Iraq and Syria are experiencing water shortage problems now, the other riparian countries are expected to experience water shortage problems in the future also due to increasing population, expanding agriculture and industry, and climate change impacts. These issues necessitate improving the efficiency of current water supply usage to achieve secure and sustainable water quantities for future generations. The countries concerned are supposed to design a strategy for public awareness programs. This should include promotional activities, implementing the activities and monitoring and evaluating their effectiveness. Moreover, politicians, policymakers, water planners, managers, and social workers are to be educated about the importance of water conservation in the water supply sector and how it may be approached, so that they can take part in national water awareness programs and promote them to society [11].

## 3. Causes of Water Shortage in Iraq

Tensions have sometimes escalated leading to war between countries in the Middle East due to water shortage problems. As far as the Tigris and Euphrates Rivers are concerned, they are very valuable sources of water for Türkiye, Iran, Syria, and Iraq. It should be mentioned however, that these countries have never reached an agreement that gives a reasonable share of water for each of them, and they have always claimed that what they get is short of their needs and water is overexploited by the others [67] [68] [69] [70] [71] indicating that they were extremely stressed by that [68] [72].

### 3.1. Hydrological Projects in Riparian Countries

This issue has caused much strain between riparian countries in many cases all

over the world. As a result, individual countries have taken unilateral actions and implemented projects that have degraded the water resources situation in the entire basin and reduced its domestic and agricultural usefulness for the other participants. In addition, political tensions and military actions were involved in some of these situations [73]. An example of this is the military escalation in 1974 over the Tabqa Dam, when both Iraq and Syria sent troops to their common borders and nearly fighting broke between them if it were not for Saudi Arabia mediating between them to solve the matter peacefully. Another example was when Syria supported the PKK in 1987 and allowed them to have their headquarters within its territory so they could act as a proxy and attack strategic locations including hydraulic infrastructures in Türkiye without Syria being directly involved in these military actions [73]. The Gulf War between Iraq and Iran that lasted for eight years is yet one more example of water sharing conflicts which involved in this case Shatt Al-Arab River. Türkiye, being the upstream riparian for both the Tigris and Euphrates Rivers, is, on the other hand, exercising regional hegemony in its water utilization of the water resources of both two rivers. The Turkish Government believes that it has little benefit from cooperation with Syria and Iraq and it is not seriously concerned with any negotiation on this matter. If it continues such negotiations, it is just to avoid any negative criticism from the UN, EU, USA, and the world community, but in the meantime it will continue to control the water of both rivers. The same attitude applies to Iran which is doing the same thing with the tributaries of the Tigris River and Shatt Al-Arab River. Both Türkiye and Iran are taking advantage of their geographic locations, being the upper riparian countries, and are relatively the stronger political and military powers in the region which allow them to obtain their desired quantity of water.

Because of this Türkiye and Iran have continued to build dams (**Tables 4-6**) on the Tigris and Euphrates and their tributaries. Syria has also built 4 dams (**Table 6**) but due to its security problems, no new dams are to be constructed at least for the time being. All these activities have affected Iraq negatively and highly contributed to the water shortage problem in the country.

### 3.2. Climate Change

The Middle East region has been noticed to be one of the most affected areas in the world due to climate change impacts [74] [75] [76]. In this context, the temperature is rising while rainfall is decreasing (**Figure 6**). These phenomena affect all aspects of life [71]. A large volume of research has been conducted on this topic and various models were used which have all suggested the same general trends. In general, as far as the Tigris and Euphrates basins, it has been noted that during the period (1900-2009) the decrease in rainfall varied from 15% to 25% and this suggests a decrease in the flow of the Tigris and Euphrates Rivers by 20% to 73%. **Figure 6** is an example of the decrease in rainfall in Iraq which had been experienced during the period (1900-2009) [77].

**Table 4.** Dams built and planned by Iran, source [22].

| | Dam | River | Year of Operation | Height (m) | Capacity ($Km^3$) | Type |
|---|---|---|---|---|---|---|
| 1 | Karkha 1 | Karkha, Tigris | 1952 | | 7.8 | I |
| 2 | Kohrank 1 | Karon, Shatt Al Arab | 1954 | 10 | 0.32 | Diversion |
| 3 | Dez | Diz, karon, Shatt Al Arab | 1962 | 203 | 3.3 | Hp, I |
| 4 | Karon 11 | Karon, Shatt Al Arab | 1976 | 200 | 3.13 | Hp |
| 5 | Kofand down | Karon, Shatt Al Arab | 1977 | 65 | 0.071 | Hp |
| 6 | Khashlak | Serwan, Diyala, Tigris | 1979 | 89 | 0.215 | I |
| 7 | Shankasem | Barkon, Tigris | 1966 | 49 | 0.215 | I |
| 8 | Bazaft | Bazaft, Karon, Shatt Al Arab | Planned | 211 | 0.45 | Hp |
| 9 | Karkha 2 | Karkha, Huwaiza, Shatt Al Arab | 1998-2000 | 127 | 5.9 | Hp, I |
| 10 | Karkha 3 | Karkha, Shatt Al Arab | 2002 | 177 | 0.061 | I, Hp |
| 11 | Karon 2 | Karon, Shatt Al Arab | 2002 | 177 | 0.261 | Hp |
| 12 | Ghafoshan | Ghafi, Serwan, Tigris | 2004 | 123 | 0.55 | I, Hp |
| 13 | Kohrank 2 | Karon, Shatt Al Arab | 2005 | 15 | 0.01 | Hp |
| 14 | Karon 3 | Karon, Shatt Al Arab | 2005 | 205 | 2.97 | I, Hp |
| 15 | Sulaiman shah | Ghafi, Serwan, Diyala | 2006 | 50 | 0.05 | I, Hp |
| 16 | Karon 4 | Karon, Shatt Al Arab | 2010 | 230 | 2.19 | Hp |
| 17 | Upper Kofand | Karon, Shatt Al Arab | 2012 | 180 | 4.5 | I, Hp |
| 18 | Azadi | Zamankan, Diyala, Tigris | 2012 | 64 | 0.07 | D, Industry |
| 19 | Gheran | Gheran, Serwan, Diyala | 2013 | 62 | 0.11 | I |
| 20 | Semar | Karkha, Shatt Al Arab | 2013 | 180 | 3.2 | Hp |
| 21 | Gafa | Serwan, Diyala | 2013 | 86 | 0.172 | I, industry |
| 22 | Zafia | Shaheni, Serwan | 2013 | 54 | 0, 017 | I, industry |
| 23 | Azad | Serwan, Diyala | 2014 | 115 | 0.3 | I, Hp |
| 24 | Asfahan | Harod, Karon, Shatt Al Arab | 2015 | 71 | 0.05 | Drinking |
| 25 | Safelah | Lower Zab | 2017 | 79 | 0.0163 | Hp |
| 26 | Kharsan 1 | Karon, Shatt Al Arab | 2015 | 195 | 1.158 | I, Hp |
| 27 | Karsan 2 | Karon, Shatt Al Arab | Planned | 240 | 2.3 | Hp |
| 28 | Karsan 3 | Karon, Shatt Al Arab | 2015 | 176 | 1.1 | Hp |
| 29 | Zamkan | Zamkan, Diyala, Tigris | 2017 | 65 | 0.023 | I |
| 30 | Daryan | Serwan, Diyala, Tigris | 2018 | 146 | 0.316 | Hp |
| 31 | Herwa | Serwan, Diyala, Tigris | 2018 | | 0.012 | Water diversion |
| 32 | Nawsood tunnel | Water diversion to Kermanshah | 2018 | 48.3 km long | 1.0 | Water diversion |
| 33 | Azkalah | Serwan, Diyala, Tigris | 2018 | 65 | 0.03 | Water diversion |

**Continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| 34 | Saradesht | Tigris, L. Zab | 2018 | 116 | 0.0545 | Hp |
| 35 | Amer Abad | Serwan, Diyala, Tigris | 2019 | 30 | 0.018 | I |
| 36 | Ramshad | Serwan, Diyala, Tigris | 2018 | 35 | 0.006 | Water diversion |
| 37 | Bakhteyari | Karon, Shatt Al Arab | 2018 | 351 | 4.845 | Hp |
| 38 | Zalaki | Diz, Karon, Shatt Al Arab | design | 210 | 1.51 | Hp |
| 39 | Lerwa | Diz, Karon, Shatt Al Arab | design | 210 | 0.52 | Hp |
| 40 | Rodbad | Diz, Karon, Shatt Al Arab | 2017 | | 0.23 | Hp |

Hp: Hydroelectric power generation, I: Irrigation.

**Table 5.** Dams built and planned by Türkiye, source: [14].

| Dam | River | Height (m) | Purpose | Completion Date |
|---|---|---|---|---|
| Çetin Dam (Alkumru) | Tigris/ Botan | 145 | P | 2016 |
| Aslandag | Tigris/Greater Zab/Bembo | 60 | I/M/P (future) | 2012 |
| Beyyurdu | Tigris/Greater Zab/Bembo | 48 | I/M/P (future) | Under construction |
| Atatürk (Karababa) | Euphrates | 169 | P | 1992 |
| Balli | Tigris/Khabour/Hezll/Ortasu | 49 | I/M/P | Under construction |
| Batman | Tigris/ Batman | 74 | I/P | 1999 |
| Beyhan I | Euphrates/Murat | 97 | P | 2015 |
| Beyhan II | Euphrates/Murat | 62 | P | Planned |
| Birecik | Euphrates | 62.5 | I/P | 2001 |
| Burç Bendi | Euphrates/Goksu | 47 | P | 2010 |
| Cizre | Tigris/Botan | 46 | I/P | Planned |
| Çoukurca | Tigris/Greater Zab/Guzedlere | 45.5 | W/M | Under construction |
| Dumluka | Euphrates/Bugur | 30 | I | 1991 |
| Erkenek | Euphrates/Adiyaman | - | P | Operational |
| Goksu | Euphrates/Goksu | 52 | I | 1991 |
| Hecihider | Euphrates/Sehir | 42 | I | 1989 |
| Hancagiz | Euphrates/ | - | I | 1988 |
| Ilisu | Tigris | 135 | I/P/F | 2017 |
| Upperkalekoy | Euphrates/Murat | 137.5 | P | 2017 |
| Lower kalekoy | Euphrates/Murat | 115 | P | Planned |
| Karakaya | Euphrates | 158 | P | 1987 |
| Karkamis | Euphrates | 21.1 | P | 2000 |
| Kavsaktepe | Tigris/Khabour/Hezll/Ortasu | 66 | W/M | Under construction |
| Kayacik | Euphrates/Sajur | 45 | I/P | 2005 |

**Continued**

| | | | | |
|---|---|---|---|---|
| Keban | Euphrates | 207 | P | 1974 |
| Kirazlik | Euphrates/Botan | 60 | I/P | 2011 |
| Kralkizi | Tigris/Maden | 113 | I/P | 1997 |
| Mustatepe | Tigris/Khabour/Hezll/Ortasu | 34.5 | W/M | Under construction |
| Silope | Tigris/Khabour/Hezil | 79.5 | W/M/P | 2012 |
| Silvan | Tigris/Barman | 174.5 | I/P | 2017 |
| Sirrntis | Tigris/Birimse | 92 | I | 2013 |
| Sirnak | Tigris/Khabour/Hezil/Ortasu | 56.8 | W/M | 2012 |
| Uludere | Tigris/Khabour/Hezil/Ortasu | 55.5 | W/M | Under construction |

F: Flood control; I: Irrigation; M: Military; P: Power; W: Water supply.

**Table 6.** Dams built in Syria.

| Dam | River | Height (m) | Purpose | Completion Date |
|---|---|---|---|---|
| Baath | Euphrates | 14 | P, I, F | 1988 |
| Tabaqa | Euphrates | 60 | P, I | 1975 |
| Tishrine | Euphrates | 40 | P | 1999 |
| Upper Khabour | Khabour | | I | 1992 |

F: Flood control; I: Irrigation; M: Military; P: Power; W: Water supply.

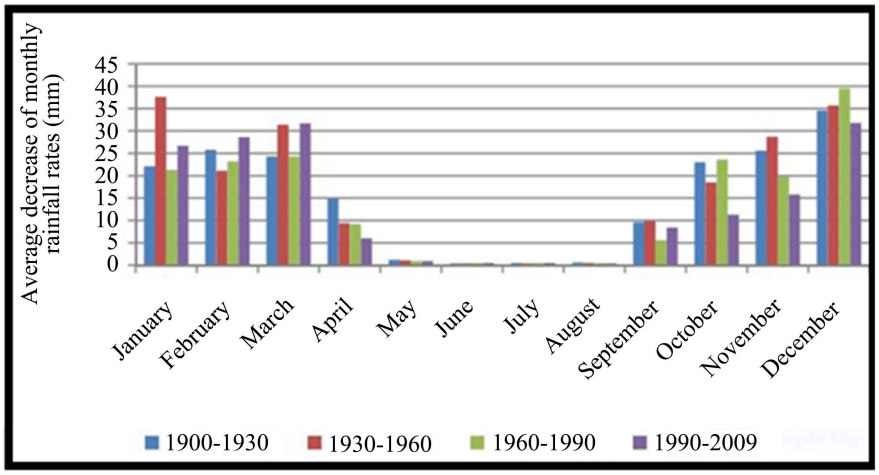



**Figure 6.** The average decrease of monthly rainfall rates for the period 1900-2009 in Iraq from [77].

This condition is having a grave depletion effect on groundwater resources, as rainfall will be decreasing in all parts of Iraq [74] [75] [78]-[90]. Climate Change has not caused a general decrease in rainfall only, but it has created the opportunity for other negative events to happen also. Even though rainfall is decreasing [77] [91]-[96], there will be certain events where intensive rainfall storms will

take place in a short period of time ((Figure 7) Such events have very negative results as they cause flash floods, destroying residential quarters, farms, and infrastructures (Figure 8) (e.g. [97] [98]). In addition, large volumes of sediments will be eroded from agricultural lands causing their damage and reducing their productivity. These sediments will be deposited in reservoirs reducing their storage capacities.

Such events can be beneficial if water harvesting schemes are constructed. In having such schemes millions of cubic meters of water can be collected and used in local areas where such water is badly needed [77] [92] [93]. Temperatures are expected to rise in Iraq at least 20˚C. This will lead to an increase in evaporation losses [75] [76]. Moreover, this, and together with rainfall decrease and increasing temperature, the natural vegetative cover will be decreased, while at the same time, the total arable land area will be reduced which will hit agriculture drastically. Similarly, the total surface area of lakes and other natural water bodies will

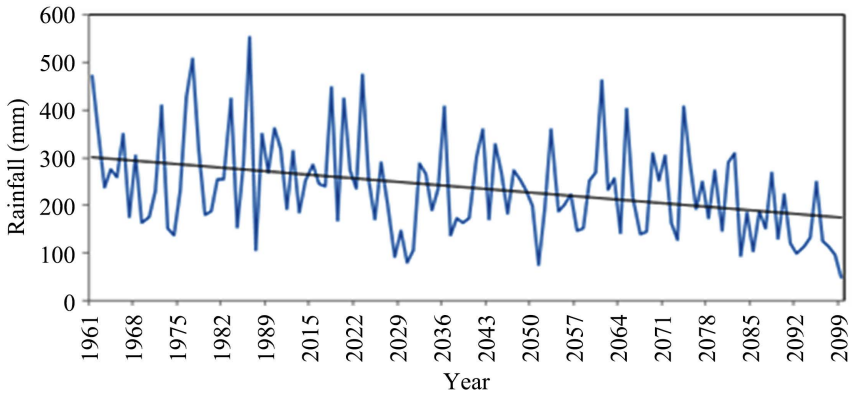



Figure 7. Rainfall decrease during 21 century in Sinjar area, Iraq, source: [78].


Figure 8. Flood in Erbil City, Iraq 17 December 2021. (a) Flooded street; (b) Damaged vehicles blocking a street; (c) Remains of muddy flood water; (d) Blocked street with mud; (e) and (f) Flooded streets; (g) Inundated cars and height of the flood water in a street in Dara Too district.

be reduced and desertification will be extended and dust storms are expected to increase to a dramatic scale not known before (**Figure 9**) [99]. According to Kurdistan 24 TV channel quoting an Iraqi expert on 06/04/2022; "Iraq will experience a massive increase in dust storms in the next 20 years."

https://www.kurdistan24.net/en/story/27876-Iraq-will-experience-massive-increase-in-dust-storms-in-the-next-20-years:-Iraqi-official

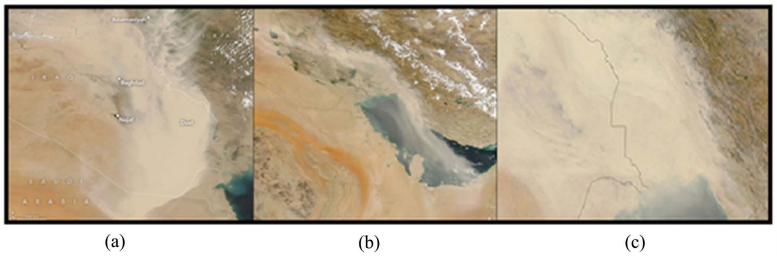
International organizations have reported that about 100,000 donums of agricultural land in Iraq are lost annually. In addition, thousands of farmers have left their lands due to water scarcity and bad water quality [14] [98]-[104].

This indicates that in case the situation remains as it is now, then Iraq will suffer from different problems such as health, energy, food, and water scarcity.

### 3.3. Water Management in Iraq

The Iraqi Ministry of Water Resources (MOWR) is following at the time being certain strategy known as the "Strategy for Water & Land Resources in Iraq" which was prepared by some Italian firms in 2014. This strategy was supposed to cover water resources utilization through the period 2015-2035. Looking at the water resources situation in Iraq now clearly shows the inefficiency and failure of this strategy. This is due to the inaccurate and erroneous basis and assumptions that the strategy had considered and adopted, which can be summarized by the following:

- Assuming the volume of incoming water to Iraq from the riparian countries is at a rate of 35 BCM annually.
- Dispensing of the Tharthar Lake as a regulating water storage reservoir and keeping it as a depression to accommodate flood peaks only.
- Benefiting from the quantities of water that Iraq is losing due to evaporation from Tharthar Lake (about four billion cubic meters) and using this quantity to replenish the marshes.
- The study adopted the hypothetical idea of transforming the marsh area into a "Garden of Eden" turning it into a global tourist attraction and a mine for fishes, game, and wild animals, and in such a case, this was supposed to give the country seven billion dollars/year in extra revenue, assuming that the productivity of one unit of water area is equivalent to several times one unit of agricultural area.



(a) (b) (c)

**Figure 9.** Dust storm (16 May 2022) Aqua MODIS image, a) dust storm covering most of Iraq; b) dust storm over the southern part of Iraq and the gulf; c) dust storm covering middle and southern parts of Iraq.

- The study takes for granted that Mosul and Haditha dams will store together the bulk of the two rivers' inflows to Iraq. This means that the maintenance of Mosul Dam foundation and the rehabilitation of its grout curtain are successfully completed, and the efficiency of this grout curtain is raised to a level exceeding 85%.
- Achieving agricultural intensification to the limit of (120%).
- This strategy has, by these erroneous assumptions resulted in wrong operation policies, which exasperated water scarcity in the country, increased the shrinkage of the agricultural land area, and caused the deterioration of water quality. This may be explained in the following:
- No scenarios were given for expected future problems in the water sector due to climate change and hydrological projects in riparian countries.
- Unfair allocation of water shares for the different governorates and for the Kurdistan region. This is a very important issue where [105] stated that if coordination does not exist between these administrative units, it will form a strategic threat to Iraq. Problems between farmers in different governorates can be solved only by giving fair and just water shares to all.
- Changing ongoing irrigation techniques that have high water losses was not proposed.
- No public awareness program was suggested for farmers and the public.
- Changing the regulations and rules concerning water resources was not mentioned.
- Restructuring the Ministry of Water Resources organization which has more than 12,000 personals according to UN reports [106] was not given any attention, although this should be considered as one of the important priorities.
- Reasonable pricing policy for water consumption rates should be adopted, while nothing was mentioned on this.
- Nothing was mentioned about developing new non-conventional water resources (e.g., rainwater harvesting, desalination and wastewater treatment and re-use) to supplement the available decreasing water resources, and no consideration for groundwater recharge was given.
- In the agricultural sector proper planning for water use is not given any attention, especially in growing water-saving crop strains and avoiding crops with high water requirements as well as using high-intensity crop rotations to make maximum use of residual soil moisture at the end of each season.
- Setting up a human resources development program was absent from this strategy.
- No calibration of the achieved results against the planned goals was done every 5 years as suggested in the main strategy.
- The strategy relied on hypothetical data and assumed that the water quantity entering Iraq from riparian countries was (35 BCM), which was not verified.
- The study relied on charts, cross sections, and investigations of rivers to determine their ability to pass water discharges and sediments which were old, and which had been mostly prepared just after the flood of 1988 and, there-

fore, do not represent the real conditions of rivers when the strategy was prepared in 2014. No attempts were made to update them.

- All field studies and investigations that were carried out later proved inaccurate, especially those related to the Tharthar channel and the volume of sediments that must be removed.
- The continued deterioration in the management of the water system in agricultural lands depending on it and the low efficiency of irrigation to less than 30%.
- The planned agricultural intensification plan was not achieved according to the study. The current agricultural intensity has not exceeded (50%), which is in contrast with the planned intensity that was taken to be (120%). Moreover, nothing in the strategy suggested the means and ways of reaching such an intensity level.
- The rehabilitation of the Mosul Dam foundation, which was done by another Italian company *i.e.*, Trevi Group, failed in getting the assumed designed grout curtain efficiency and therefore restoring the reservoir to its original designed capacity. Therefore, the assumption that both Mosul Dam and Haditha Dam reservoirs could eliminate the need for the Tharthar reservoir as a storage reservoir was not realized.
- At the same time the expansion of flooding of shallow areas in the south as marshes as proposed by this strategy had caused water losses of up to eight billion cubic meters annually as announced by the former Minister of Water Resources Al-Janabi in a lecture he gave at the American University in Sulaimaniyah.
- The outputs of this strategy did not include any guidelines for new rivers training works that take into consideration the decreasing peak discharges passing into the rivers due to the new hydrological conditions prevailing in the basin now and in the future. All such works were, therefore, carried out using obsolete data based on the 1988 flood as already mentioned above.
- As far as the southern part of Iraq, the water loses within the marshes amounting to eight billion cubic meters annually. In addition, large quantities of water were lost due to the low efficiency of irrigation of less than 30%, contrary to what was assumed to be in the strategic plan (85%). These were the main reasons for the intensification of the negative effects leading to water scarcity, shrinkage of the agricultural land area in the country, and the deterioration of water quality. This coincided with the continued decline in water inputs from the riparian countries and climate changes in the region.
- Lack of calibration of the strategic plan since its approval ten years ago. This is not usual for such plans which must be updated within suitable periods to make their outputs compatible with current situations and conditions. Otherwise, all these outputs would not be trusted and therefore looked at with suspicion. Suitable review and updating in such cases would be normally done within not more than five years.

## 4. How to Resolve Water Shortage Problem in Iraq

Iraq is located at the lowest part of the Tigris and Euphrates Rivers basins, and for this reason, it is the most affected riparian country with changes in these two rivers' water resources relative to the other two countries, namely Türkiye and Iran. This should be a strong reason to motivate the Iraqi government to take fast action to resolve problems arising from these changes such as water shortage in these countries. It is suggested that the Iraqi government should act in two parallel lines. These are:

**1) On the International Level**

It is inevitable that quick measures are to be considered to overcome the tensions and to resolve any conflict among riparian countries leading to situations such as water shortage conditions. All research prediction work indicates that most of the riparian countries will suffer in the future from such water shortage problems if the expansion of water use and declining water resources continue [107]-[113]. Experience from previous negotiations between riparian countries shows that they did not lead to many agreements. For this reason, the strategies of negotiations should be changed. In this context, Iraq should include the economic and security issues in such future negotiations.

These two factors are of prime importance for both Türkiye and Iran because their economy relies heavily on trade with Iraq, where Iraq imports an equivalent of more than 16 billion US dollars worth of goods from each of them every year. In addition, there are many companies from both Türkiye and Iran conducting work and executing projects in Iraq. These facts make the national budget of the two countries heavily dependent on what they are gaining from Iraq. As far as security is concerned, some armed opposition movements are using Iraq territory as a haven and platform to conduct attacks on civil and economic targets within Türkiye and Iran. Consequently, there are always sizable military forces from the two countries engaged in fighting these groups and conducting military and bombing raids and even missile and drones attacks within Iraqi territory targeting these groups. All these actions, while they are draining considerable manpower and economic resources, they are also posing security threats to the stability of both countries. The Iraqi government on its part can help in driving these groups from their strongholds and quell the harm they cause. If these two factors are used skillfully by the Iraqi negotiators, then it is most probable that such bargaining will get better water-sharing terms with Türkiye and Iran. To ensure the success of any agreement reached in this way and its successful implementation, a third party should be involved that can use its power to impose and implement any reached agreement. Such a party should possess political, technical, and economic powers as well as being an international powerful force to be a useful mediator. Some of the tools that can such mediators use in attracting the riparian countries to sit down for negotiation and reach good conclusions are financial and technical incentives. According to this, the best mediator or party that may be suggested would be; the World Bank, the U.S.A or the European Union.

**2) On the National Level**

A long-term strategic plan for the management of water resources should be implemented irrespective of the changes in external or internal politics and should be based on the "Resources Dependence Theory". This theory assumes that good human resources, finance, and information as well as good international relations exist [108] [109] [110] [111]. In realizing such a plan, the Ministry of Water Resources, Ministry of Municipality and Public Work, Ministry of Agriculture, Ministry of Environment, Scientific staff at universities and research institutes, Private sector, NGOs, and representatives of related regional and international organizations should all work to design such a strategy.

The suggested strategy should address the following main items:

***International and Regional Cooperation and Coordination*:**

- Institutional and technical needs for cooperation should be defined.

UN organizations and other international institutions and organizations (e.g., UNEP, UNDP, UNESCO, FAO, WMO, etc.) and Universities should be asked to share their experience in this matter.

- Benefiting from the experiences of organizations and companies in developed countries to help in giving advice for successful patterns of water management.

***Water Management Vision*:**

This should include the following:

- Existing infrastructures which should cover dams and hydraulic works on rivers and canals, water distribution networks for municipal and irrigation projects, water treatment plants, power plants as well as pumping stations, are all to be examined and rehabilitated.
- A public awareness program is very important so that all the people appreciate the serious problem they are facing.
- Training program for the use of new irrigation techniques is to be used for engineers and farmers.
- Institutional agenda including employment and training is to be defined.
- Supply and demand should be considered, and this suggests maximizing available water resources by the use of water harvesting, treated wastewater and desalinization of salty water.
- The private sector should be asked to be involved in the investment.
- To save time, efforts and money, inter-ministerial coordination should be sought and encouraged, this should include more decentralization.
- New laws and regulations that protect water resources and reduce water consumption are to be adopted.
- A new pricing policy for water use should be adopted which considers water as an economical commodity, and stringent rules for collection of the tariffs should be applied. This is done for two purposes: first, stopping wasteful usage of water and second, to use the obtained money for maintenance of water infrastructures.

***Irrigation and Agriculture*:**

- The strategic agricultural plan should be defined and put into practice and the

growing of high-water consuming plants and crops are to be restricted [114].

- Adopting the most efficient and water-saving irrigation techniques which are suitable for the local conditions of soil, water availability and quality, and crops. Traditional irrigation techniques should be abandoned because they cause a waste of water. Conserving water irrigation techniques such as drip irrigation are to be used for orchards and vegetable growing, while sprinkler irrigation is to be used on large-scale irrigation for grains and similar crops.
- Maintaining and developing of the water supply-distribution systems to reduce the losses and increase conveying efficiency. Closed conduits are to be used in irrigation conveyance systems to reduce evaporation and infiltration losses. This will have the advantage of conserving more cultivable land and protecting irrigation water from contact with the saline water table.
- Improving the drainage systems of the cultivated lands to improve soil leaching and reduce soil salinity. Also, consider the most effective modern drainage techniques such as perforated pipe field drainage systems in collecting drainage water. Returning drainage water directly to the rivers should be avoided and drainage projects like the main outfall drain (MOD) in areas lying outside the service zone of this project should be implemented.
- The use of chemical fertilizers and pesticides that can decrease the water quality shall be controlled and the return of irrigation water discharges laden with chemical residues to the rivers should be avoided.
- Institutions should reflect decentralization, autonomy, and farmer's cooperation.
- Encourage and enhance private investment in the agricultural sector.
- Public awareness program for farmers for using new suitable techniques in irrigation (drip irrigation and sprinkler irrigation).

***Water Supply and Sanitation*:**

- The efficiency of drinking water distribution networks is to be improved. This applies to both diversion and supply networks down to the point of use.
- Leakages from the sewerage networks should be inhibited and stopped. These networks must be repaired and maintained to improve their efficiency and therefore prevent them from being sources of pollution.
- Services in the water sector should be improved e.g., using Information Communication Technology (ICT). Moreover, Decision Support Systems (DSS) for better control of water management should be used.
- New sewerage systems are to be installed to connect neighborhoods that are not serviced and convey the sewage water to the sewage treatment plants to reduce the pollution of groundwater due to the leakage from old septic tanks.
- New sewage treatment plants are to be built to satisfy the increased consumption of the domestic sector. Membrane bioreactor technology can be used in these new treatment plants to reuse the treated water.
- Efficient projects should be aimed at and put into practice to prevent water losses and pollution.

***Research and Development*:**

- A comprehensive data bank must be established which includes reliable climatological, hydrological, geological, environmental and soil data to be used by researchers and decision-makers.
- Comprehensive research is to be conducted to import new technologies in water resources and agriculture which suites Iraq's environment.
- Non-conventional methods to augment water recourses are to be investigated and used. We believe that water harvesting techniques can be very effective and are relatively cheap cost-wise.
- New techniques like climate control with water recycling in Greenhouses can be tested where in such techniques the same volume of water for irrigation water can be used several times.
- Training courses are to be carried out for technicians, engineers, and decision-makers about up-to-date technologies.
- Pioneer projects which help augment water resources, develop land productivity, minimize water use and consumption are to be executed.
- Setting the outlines of public awareness programs both for water use and agricultural activities.
- Arranging with universities and institutes to set special courses in arid region hydrology.
- Prizes are to be awarded for new innovations, pioneer research and smart ideas in water resources, agriculture, and their management.
- A prudent management program for the utilization of groundwater is to be adopted to prevent its depletion and pollution.

## 5. Conclusion

Iraq's water requirements are mainly derived from the flow of the Tigris and Euphrates rivers and their tributaries. The flow of these rivers and their tributaries has drastically declined in recent years, and Iraq is facing a serious water shortage problem. The decline of flow in these rivers is attributed to three main reasons namely, climate change, the hydrological projects in upstream riparian countries, and the ongoing water management strategy of water resources in Iraq itself. To overcome this scarcity problem, a long-term strategy has to be adopted and implemented. This strategy is to be executed irrespective of what type of government is ruling the country. The strategy should consider two main lines of action. The first is to get a better and just water share for Iraq from the rivers rising in the riparian countries. The second is to change the methods and means of water resources management in the country taking into consideration the ongoing and expected future problems. To pursue the former goal, economic and security issues are to be bargained against fair water sharing in any future negotiation with the riparian countries. These issues are very important to these countries and will push them to reach an agreement with Iraq. As far as the latter one, the strategy should put a great emphasis on the rehabilitation of all existing hydrological projects, improving the efficiency of diversion and supply of water to all water users, maximizing available water resources by investing in

and using nonconventional water resources, modernizing the irrigation and agriculture sectors by using up to date methods and techniques, developing programs for public awareness and full utilization of human resource, as well as developing agricultural plans that take into consideration planting more water conserving crops while stopping growing those with high water requirements, and adopting cropping rotations that maximize yields and make best use of soil moisture stored in the root zone.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

[1] White, G.F. (1978) Resources and Needs: Assessment of the World Water Situation. Water Development, Supply and Management, UK.

[2] Elhance, A.P. (1999) Hydropolitics in the Third World: Conflict and Cooperation in International River Basins. United States Institute of Peace, Washington DC, 53-88.

[3] Gleick, P.H. (1996) Basic Water Requirements for Human Activities: Meeting Basic Needs. *Water International*, **21**, 83-92. https://doi.org/10.1080/02508069608686494

[4] Biswas, A.K. (1991) Water for Sustainable Development in the Twenty-First Century: A Global Perspective. *GeoJournal*, **24**, 341-345.

[5] Al Bomola, A. (2011) Temporal and Spatial Changes in Water Quality of the Euphrates River—Iraq. Master's Thesis, Lund University, Lund.

[6] Biswas, A.K. (1994) International Waters of the Middle East from Euphrates-Tigris to Nile. Water Resources Management Series 2.

[7] Roger, P. and Lydon, P. (1995) Water in the Arab World. Harvard University Press, Cambridge.

[8] Allan, T. (2001) The ME Water Question. I.B. Tauris Publishers, London.

[9] Al-Ansari, N. (1998) Water Resources in the Arab Countries: Problems and Possible Solutions. *UNESCO International Conference on World Water Resources at the Beginning of the* 21*st Century*, Paris, 3-6 June 1998, 367-376.

[10] Tinti, A. (2017) Water Resources Management in the Kurdistan Region of Iraq a Policy Report, Institute of Regional and International Studies (IRIS), The American University of Iraq, 20 pages. https://auis.edu.krd/iris/sites/default/files/Water%20Policy%20Report%20IRIS_FINAL%20ES.pdf

[11] Al-Ansari, N. (2016) Hydro-Politics of the Tigris and Euphrates Basins. *Engineering*, **8**, 140-172. https://doi.org/10.4236/eng.2016.83015

[12] Cherfane, C.C. and Kim, S.E. (2012) Chap. 33. Arab Region and Western Asia, UNESCWA. In: *Managing Water under Uncertainty and Risk. UN World Water*

*Development Report* 4, The United Nations Educational, Scientific and Cultural Organization, Paris, 407 pages.

[13] Barr, J., Grego, S., Hassan, E., Niasse, M., Rast, W. and Talafré, J. (2012) Chapter 7. Regional Challenges, Global Impacts. In: *Managing Water under Uncertainty and Risk. UN World Water Development Report* 4, The United Nations Educational, Scientific and Cultural Organization, Paris, 174-215.

[14] Al-Ansari, N. (2021) Water Resources of Iraq. *Journal of Earth Sciences and Geotechnical Engineering, Special Issue: Water Resources of Iraq: Perspectives and Prognosis*, **11**, 15-34. https://doi.org/10.47260/jesge/1122

[15] Al-Ansari, N.A. (2013) Management of Water Resources in Iraq: Perspectives and Prognoses. *Journal of Engineering*, **5**, 667-684. https://doi.org/10.4236/eng.2013.58080

[16] Al-Ansari, N.A. and Knutsson, S. (2011) Toward Prudent Management of Water Resources in Iraq. *Journal of Advanced Science and Engineering Research*, **1**, 53-67.

[17] Al-Ansari, N.A., Knutsson, S. and Ali, A. (2012) Restoring the Garden of Eden, Iraq. *Journal of Earth Sciences and Geotechnical Engineering*, **2**, 53-88.

[18] Cox, W. (1917) Irrigation of Mesopotamia. 2nd Edition, E&F.N. SPON Ltd., New York, 136 p.

[19] Sussa, A. (1983) History of the Mesopotamian Civilization in the Light of Agricultural Irrigation Projects, Archaeological Discoveries and Historical Sources. The Arab House for Encyclopedias, Baghdad, 572 p.

[20] Sussa, A. (1946) The Development of Irrigation in Iraq. Maṭba'at al-Ḥukūmah, al-Kuwayt, 206 p.

[21] Sussa, A. (1942) Origin of Irrigation in Iraq. Maṭba'at al-Ḥukūmah, al-Kuwayt, 206 p.

[22] Al Shami, A.M., Khoshnaw, H.A. and Barazangi, K.K. (2005) The Preparation of the World Bank's Country Water Resources Assistance Strategy (CWRAS) for the Republic of Iraq. Food and Agriculture Organization of the United Nations, Rome, 222 p. https://www.academia.edu/48048075/The_Preparation_of_the_World_Banks_Country_Water_Resources_Assistance_Strategy_for_Iraq

[23] Ministry of Water Resources (2014) Strategy for Water & Land Resources in Iraq. National Center for Water Resources Management, Baghdad, 265 p.

[24] Lahn, G. and Shamout, N. (2015) The Euphrates in Crisis: Channels of Cooperation for a Threatened River. https://www.chathamhouse.org/2015/04/euphrates-crisis-channels-cooperation-threatened-river

[25] Abdullah, A.D. (2016) Modelling Approaches to Understand Salinity Variation in Highly Dynamic Tidal River. The Case of the Shatt Al-Arab River. Ph.D. Thesis, Delft University of Technology and of the Academic Board of the UNESCO-IHE, Delft. https://doi.org/10.1201/9781315115948

[26] Al-Azzawi, S.N. (2022) Impacts of Tigris-Euphrates Headwaters Dams on Desertification in Iraq. Arab Community Organization, 1-47. https://arsco.org/article-detail-32228-4-0#:~:text=%D9%84%D9%82%D8%AF%20%D8%A3%D8%AF%D9%89%20%D8%A5%D9%86%D8%B4%D8%A7%D8%A1%20%D9%88%D8%AA%D8%B4%D8%BA%D9%8A%D9%84%20%D8%AD%D9%88%D8%A7%D9%84%D9%8A,(%D8%A7%D9%84%D8%A3%D9%87%D9%88%D8%A7%D8%B1)%20%D9%81%D9%8A%20%D8%AC%D9%86%D9%88%D8%A8%20%D8%A7%D9%84%D8%B9%D8%B1%D8%A7%D9%82

[27] Alazzawi, S.N. (2023) The Demise of Mesopotamia: The Geopolitics of Water. The

Desertification of Iraq, Global Research, 1-34.
https://www.globalresearch.ca/demise-mesopotamia-geopolitics-behind-desertification-iraq/5775765?pdf=5775765

[28] ESCWA (Economic and Social Commission for Western Asia) (2013) Inventory of Shared Water Resources in Western Asia, Salim Dabbous Printing Co., Beirut, 626 p.

[29] Al-Mahmoud, K.H. (2021) Referential Analysis of Discharge and Salinity Data in Shatt Al-Arab River. *Iraqi Journal of Aquaculture*, **17**, 11-26. (In Arabic)
https://doi.org/10.58629/ijaq.v17i1.91

[30] Issa, I.E., Al-Ansari, N.A., Sherwany, G. and Knutsson, S. (2014) Expected Future of Water Resources within Tigris-Euphrates Rivers Basin, Iraq. *Journal of Water Resource and Protection*, **6**, 421-432. https://doi.org/10.4236/jwarp.2014.65042

[31] Al-Ansari, N., Adamo, N., Sissakian, V., Knutsson, S. and Laue, J. (2018) Geopolitics of the Tigris and Euphrates Basins. *Journal of Earth Sciences and Geotechnical Engineering*, **8**, 187-222.

[32] Al-Ansari, N. (2019) Hydro Geopolitics of the Tigris and Euphrates. In: Mustafa, Y., Sadkhan, S., Zebari, S. and Jacksi, K., Eds., *Recent Researches in Earth and Environmental Sciences*, Springer, Berlin, 35-70.
https://doi.org/10.1007/978-3-030-18641-8_4

[33] Bilen, O. (2000) Türkiye and Water Issues in the Middle East. 2nd Edition, St. Martin's Press, New York.

[34] Turkish Ministry of Foreign Affairs (2012) Water Issues between Türkiye, Syria and Iraq, Department of Transboundary Waters.
https://dergipark.org.tr/en/download/article-file/817266

[35] Altinbilek, D. (2004) Development and Management of the Euphrates-Tigris Basin. *Water Resources Development*, **20**, 15-33.
https://doi.org/10.1080/07900620310001635584

[36] Drake, C. (2007) Water Resource Conflicts in the Middle East. *Journal of Geography*, **96**, 4-12. https://doi.org/10.1080/00221349708978749

[37] Sadik, A.K. and Barghouti, S. (1995) The Water Problems of the Arab World: Management of Scarce Water Resources. In: Rogers, P. and Lydon, P., Eds., *Water in the Arab World*, Harvard University Press, Cambridge, 4-37.

[38] Charrier, B. and Curtin, F. (2007) A Vital Paradigm Shift to Maintain Habitability in the Middle East: The Integrated Management of International Watercourses. In: *Water for Peace in the Middle East and Southern Africa*, Green Cross International, Geneva, 11.

[39] United Nations and World Bank (2003) Joint Iraq Needs Assessment. Working Paper. https://reliefweb.int/report/iraq/unworld-bank-joint-iraq-needs-assessment

[40] Al Ansary, K. (2015) Wheat-Importing Iraq Plans to Be Net Grain Exporter by 2017. Blooming Business, 10th June 2015.
http://www.bloomberg.com/news/articles/2015-06-10/iraq-to-become-wheat-exporter-within-2-years-trade-ministry

[41] Worldmeters (2018) Iran Population.
http://www.worldometers.info/world-population/iran-population/

[42] Worldmeters (2018) Iraq Population.
http://www.worldometers.info/world-population/iraq-population/

[43] Worldmeters (2018) Syria Population.
http://www.worldometers.info/world-population/syria-population/

[44] Worldmeters (2018) Türkiye Population.

http://www.worldometers.info/world-population/Türkiye-population/

[45] Akanda, A., Freeman, S. and Placht, M. (2007) The Tigris-Euphrates River Basin: Mediating a Path towards Regional Water Stability. *The Fletcher School Journal for Issues Related to Southwest Asia and Islamic Civilization*, Spring, Al Nakhlah, 1-12. https://ciaotest.cc.columbia.edu/olj/aln/aln_spring07/aln_spring07g.pdf

[46] Turan, I. (2004) Water and Turkish Foreign Policy. In: Lenore, M.G. and Keridis, D., Eds., *The Future of Turkish Foreign Policy*, MIT Press, Cambridge, 191-208.

[47] Bagis, A. (1989) GAP, Southeastern Anatolia Project: The Creadle of Civilization Regenerated. (Istanbul Interbank, 1989)

[48] Waterbury, J. (1993) Transboudary Water and the Challenge of International Cooperation in the Middle East. In: Roger, R. and Lydon, P., Eds., *Water in the Arab Word*: *Perspectives and Prognoses*, Harvard University, Cambridge, 39-64.

[49] Alsowdani, M. (2005) GAP Project and Its Economic Negative Implications on Syria and Iraq. Aletehad News. http://www.alitthad.com/paper.php?name=News&file=print&sid=19030

[50] Shams, S. (2006) Water Conflict between Iraq and Türkiye. Middle East News. https://www.mfa.gov.tr/data/DISPOLITIKA/WaterASourceofConflictofCoopinthe MiddleEast.pdf

[51] Alnajaf News Net (2009) The GAP Project and Its Negative Implications on Iraq. http://www.alnajafnews.net/najafnews/news.php?action=fullnews&id=31503

[52] National Defense Magazine (2009) Turkish Israeli Partnership in GAP Southeastern Anatolian Project, Official Site of the Lebanese Army. http://www.lebarmy.gov.lb/article.asp?ln=ar&id=2901

[53] Abumoghli, I. (2015) Water Scarcity in the Arab World. Eco Middle East and North Africa, August 2, 2015. https://www.worldbank.org/en/topic/water/publication/beyond-scarcity-water-security-in-the-middle-east-and-north-africa

[54] CEB (Consulting Engineering Bureau) (2011) Lakes Testing Study. College of Engineering, University of Baghdad, Baghdad.

[55] Reed, C. (2005) Paradise Lost? What Should—or Can—Be Done about "the Environmental Crime of the Century"? *Harvard Magazine*, January-February 2005. http://harvardmagazine.com/2005/01/paradise-lost.html

[56] Kolars, J. (1994) Chapter 3. Problems of International River Management: The Case of the Euphrates. In: Biswas, A., Ed., *International Waters of the Middle East from Euphrates-Tigris to Nile*, *Water Management Series* 2, Oxford University Press, Bombay, 44-94.

[57] Martin, L. and Kerids, D. (2003) The Future of Turkish Foreign Policy. MIT Press, Cambridge, 354 p.

[58] Varela-Ortega, C. and Sagardoy, J.A. (2003) Analysis of Irrigation Water Policies in Syria: Current Developments and Future Options. In: Fiorillo, C. and Vercueil, J., Eds., *Syrian Agriculture at the Crossroads*, FAO Agricultural Policy and Economic Development Series No. 8, Food and Agriculture Organization of the United Nations, Rome, 1-22.

[59] Friedman, T. (2013) Without Water, Revolution. *Sunday Review*, May 18, 2013. http://www.nytimes.com/2013/05/19/opinion/sunday/friedman-without-water-revolution.html?_r=0

[60] Bazzaz, F. (1993) Global Climatic Changes and Its Consequences for Water Availability in the Arab World. In: Roger, R. and Lydon, P., Eds., *Water in the Arab Word*:

*Perspectives and Prognoses*, Harvard University, Cambridge, 243-252.

[61] Chenoweth, J., Hadjinicolaou, P., Bruggeman, A., Lelieveld, J., Levin, Z., Lange, M.A., Xoplaki, E. and Hadjikakou, M. (2011) Impact of Climate Change on the Water Resources of the Eastern Mediterranean and Middle East Region: Modeled 21st Century Changes and Implications. *Water Resources Research*, **47**, W06506. https://doi.org/10.1029/2010WR010269

[62] Voss, K.A., Famiglietti, J.S., Lo, M.H., Linage, C., Rodell, M. and Swenson, S. (2013) Groundwater Depletion in the Middle East from GRACE with Implications for Transboundary Water Management in the Tigris-Euphrates-Western Iran Region. *Water Resources Research*, **49**, 904-914. https://doi.org/10.1002/wrcr.20078

[63] Hamdy, A. (2013) Water Crisis and Food Security in the Arab World: The Future Challenges. http://gwpmed.org/files/IWRM-Libya/Atef%20Hamdy%20AWC.pdf

[64] Venter, A. (2008) The Oldest Threat: Water in the Middle East. *Middle East Policy*, **6**, 126-136. https://doi.org/10.1111/j.1475-4967.1998.tb00300.x

[65] Morris, M.E. (1992) Poisoned Wells: The Politics of Water in the Middle East. *Middle East Insight*, **8**, 35-39.

[66] Jones, D. (2009) Iraq Reaches Water, Energy and Trade Agreements with Türkiye. Voice of America on Reliefweb 19th September 2009.

[67] Smakhtin, V., Revenga, C. and Döll, P. (2004) Taking into Account Environmental Water Requirements, Comprehensive Assessment Research Report 2, Comprehensive Assessment of Water Management in Agriculture. https://www.iwmi.cgiar.org/assessment/files/pdf/publications/ResearchReports/CARR2.pdf

[68] Aydin, M. and Ereker, F. (2009) Water Scarcity and Political Wrangling: Security in the Euphrates and Tigris Basin. In: Brauch, *et al.*, Eds., *Facing Global Environmental Change*: *Environmental*, *Human*, *Energy*, *Food*, *Health and Water Security Concepts*, Springer, Berlin, 603-613. https://doi.org/10.1007/978-3-540-68488-6_44

[69] UN (2013) United Nations World Water Development Report 4. Volume 1: Managing Water under Uncertainty and Risk. https://unesdoc.unesco.org/ark:/48223/pf0000215644

[70] UN (2013) United Nations World Water Development Report 4. Volume 2: Managing Water under Uncertainty and Risk. https://unesdoc.unesco.org/ark:/48223/pf0000217175

[71] UN (2013) Water Security and the Global Water Agenda. A UN-Water Analytical Brief. 47 p. https://www.unwater.org/publications/water-security-and-global-water-agenda

[72] Reig, P., Maddocks, A. and Gassert, F. (2013) World's 36 Most Water-Stressed Countries. World Resources Institute. http://www.wri.org/blog/2013/12/world%E2%80%99s-36-most-water-stressed-countries

[73] Berardinucci, J. (2010) The Impact of Power on Water Rights: A Study of the Jordan and Tigris-Euphrates Basins. Bachelor of Art Report, School of International Service, American University, Washington DC. http://aladinrc.wrlc.org/bitstream/handle/1961/9171/Berardinucci,%20Jessica%20-%20Spring%20'10%20(P).pdf?sequence=1

[74] Adamo, N., Al-Ansari, N., Sissakian, V., Knutsson, S. and Laue, J. (2018) Climate Change: Consequences on Iraq's Environment. *Journal of Earth Sciences and Geotechnical Engineering*, **8**, 43-58.

[75] Adamo, N., Al-Ansari, N., Sissakian, V., Knutsson, S. and Laue, J. (2018) The Future of the Tigris and Euphrates Water Resources in View of Climate Change. *Journal of Earth Sciences and Geotechnical Engineering*, **8**, 59-74.

[76] Adamo, N., Al-Ansari, N., Sissakian, V., Knutsson, S. and Laue, J. (2018) Climate Change: The Uncertain Future of Tigris River Tributaries' Basins. *Journal of Earth Sciences and Geotechnical Engineering*, **8**, 75-93.

[77] Zakaria, S., Al-Ansari, N.A. and Knutsson, S. (2013) Historical and Future Climatic Change Scenarios for Temperature and Rainfall for Iraq. *Journal of Civil Engineering and Architecture*, **7**, 1574-1594. https://doi.org/10.17265/1934-7359/2013.12.012

[78] Al-Ansari, N.A., Abdellatif, M., Ezeelden, M., Ali, S. and Knutsson, S. (2014) Climate Change and Future Long Term Trends of Rainfall at North-Eastern Part of Iraq. *Journal of Civil Engineering and Architecture*, **8**, 790-805. https://doi.org/10.17265/1934-7359/2014.06.014

[79] Al-Ansari, N.A., Abdellatif, M., Zakaria, S., Mustafa, Y. and Knutsson, S. (2014) Future Prospects for Macro Rainwater Harvesting (RWH) Technique in Northeast Iraq. *Journal of Water Resource and Protection*, **6**, 403-420. https://doi.org/10.4236/jwarp.2014.65041

[80] Al-Ansari, N.A., Abdellatif, M., Ali, S. and Knutsson, S. (2014) Long Term Effect of Climate Change on Rainfall in Northwest Iraq. *Central European Journal of Engineering*, **4**, 250-263. https://doi.org/10.2478/s13531-013-0151-4

[81] Abbas, N., Wasimi, S.A. and Al-Ansari, N.A. (2017) Impacts of Climate Change on Water Resources of Greater Zab and Lesser Zab Basins, Iraq, Using Soil and Water Assessment Tool Model. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, **11**, 808-814. https://doi.org/10.17265/1934-7359/2016.12.009

[82] Abbas, N., Wasim, S.A. and Al-Ansari, N.A. (2016) Impacts of Climate Change on Water Resources in Diyala River Basin, Iraq. *Journal of Civil Engineering and Architecture*, **10**, 1059-1074. https://doi.org/10.17265/1934-7359/2016.09.009

[83] Abbas, N., Wasim, S.A. and Al-Ansari, N.A. (2016) Assessment of Climate Change Impacts on Water Resources of Khabour in Kurdistan, Iraq. *Journal of Environmental Hydrology*, **24**, Paper 10. https://doi.org/10.17265/1934-7359/2016.12.009

[84] Abbas, N., Wasim, S.A. and Al-Ansari, N.A. (2016) Assessment of Climate Change Impacts on Water Resources of Lesser Zab, I, Kurdistan, Iraq. *Journal of Engineering*, **8**, 697-715. https://doi.org/10.4236/eng.2016.810064

[85] Abbas, N., Wasim, S.A. and Al-Ansari, N.A. (2016) Assessment of Climate Change Impacts on Water Resources of Al-Adhaim, Iraq. *Journal of Engineering*, **8**, 716-732. https://doi.org/10.4236/eng.2016.810065

[86] Abbas, N., Wasimi, S. and Al-Ansari, N.A. (2016) Climate Change Impacts on Water Resources of Greater Zab River, Iraq. *Journal of Civil Engineering and Architecture*, **10**, 1384-1402. https://doi.org/10.17265/1934-7359/2016.12.009

[87] Abbas, N., Wsaimi, S., Al-Ansari, N. and Sultana, N. (2018) Water Resources Problems of Iraq: Climate Change Adaptation and Mitigation. *Journal of Environmental Hydrology*, **26**, Paper 6.

[88] Osman, Y., Abdellatif, M., Al-Ansari, N.A., Knutsson, S. and Aljawad, S.B. (2017) Climate Change and Future Precipitation in Arid Environment of Middle East: Case study of Iraq. *Journal of Environmental Hydrology*, **25**, paper 3.

[89] Osman, Y., Al-Ansari, N.A., Abdellatif, M., Aljawad, S.B. and Knutsson, S. (2014) Expected Future Precipitation in Central Iraq Using LARS-WG Stochastic Weather Generator. *Engineering*, **6**, 948-959. https://doi.org/10.4236/eng.2014.613086

[90] Osman, Y., Al-Ansari, N.A. and Abdellatif, M. (2019) Climate Change Model as a Decision Support Tool for Water Resources Management: A Case Study of Greater Zab River. *Journal of Water and Climate Change*, **10**, 197-209. https://doi.org/10.2166/wcc.2017.083

[91] Zakaria, S., Al-Ansari, N. and Knutsson, S. (2013) Rainwater Harvesting Using Recorded and Hypothetical Rainfall Data Scenarios. *Journal of Earth Sciences and Geotechnical Engineering*, **3**, 21-42.

[92] Al-Ansari, N.A., Abdulatif, M., Zakaria, S., Mustafa, Y. and Knutsson, S. (2015) Future Prospects for Macro Rainwater Harvesting (RWH) Technique in North East Iraq. *International Symposium on Energy Challenges and Mechanics*, Aberdeen, 8-10 July 2015, 403-420.

[93] Zakaria, S., Al-Ansari, N., Knutsson, S. and Al-Badrany, T. (2012) ARIMA Models for Weekly Rainfall in the Semi-Arid, Sinjar District at Iraq. *Journal of Earth Sciences and Geotechnical Engineering*, **2**, 25-55.

[94] Al-Ansari, N.A., Knutsson, S., Zakaria, S. and Ezildeen, M. (2015) Feasibility of Using Small Dams in Water Harvesting, Northern Iraq. *International Commission on Large Dams* "*ICOLD*" *Conference*, *Hydropower* 15, Stavanger, Norway, 15-16 June 2015, 199-217.

[95] Zakaria, S., Al-Ansari, N.A., Mustafa, Y., Mohammed, D.A., Knutsson, S., Ahmed, P. and Ghafour, B. (2013) Rainwater Harvesting at Koysinjaq (Koya) Kurdistan Region, Iraq. *Journal of Earth Sciences and Geotechnical Engineering*, **3**, 25-46.

[96] Zakaria, S., Al-Ansari, N., Ezz-Aldeen, M. and Knutsson, S. (2012) Rainwater Harvesting at Eastern Sinjar Mountain, Iraq. *Journal of Geosciences Research*, **3**, 100-108.

[97] Zakaria, S. (2014) Rainwater Harvesting (RWH) North of Iraq. PhD Thesis, Department of Civil, Environmental and Natural Resources Engineering, Lulea University of Technology, Lulea.

[98] Zakaria, S., Al-Ansari, N.A. and Knutsson, S. (2012) Rainwater Harvesting and Supplemental Irrigation at Northern Sinjar Mountain, Iraq. *Journal of Purity*, *Utility Reaction and Environment*, **1**, 121-141.

[99] Sissakian, V.K., Adamo, N. and Al-Ansari, N. (2023) The Severe Consequences of Climate Change in Iraq: A Case Study. *Journal of Engineering*, **15**, 242-260. https://doi.org/10.4236/eng.2023.154019

[100] Sissakian, V.K., Al-Ansari, N., Adamo, N., Ahad, I.D.A. and Abed, S.A. (2022) Flood Hazards in Erbil City Kurdistan Region Iraq, 2021: A Case Study. *Engineering*, **14**, 591-601. https://doi.org/10.4236/eng.2022.1412044

[101] Mohammed D.S. (2022) Iraq Will Experience Massive Increase in Dust Storms in the Next 20 Years: Iraqi Official. Kurdistan24. https://www.kurdistan24.net/en/story/27876-Iraq-will-experience-massive-increase-in-dust-storms-in-the-next-20-years:-Iraqi-official

[102] International Organization for Migration Iraq (IOM) (2020) Water Quantity and Water Quality in Central and South Iraq: A Preliminary Assessment in the Context of Displacement Risk. https://environmentalmigration.iom.int/sites/g/files/tmzbdl1411/files/documents/water-quantity-and-water-quality-in-central-and-south-iraq-final_0.pdf

[103] Al-Ansari, N., Abbas, N., Laue, J. and Knutsson, S. (2021) Water Scarcity: Problems and Possible Solutions. *Journal of Earth Sciences and Geotechnical Engineering*, **11**, 243-312. https://doi.org/10.47260/jesge/1127

[104] Norwegian Refugee Council (2021) Water Crisis and Drought Threaten More than 12 Million in Syria and Iraq.

https://www.nrc.no/news/2021/august/water-crisis-iraq-syria/

[105] UNICEF (2021) Running Dry: Water Scarcity Threatens Lives and Development in Iraq. https://www.unicef.org/iraq/press-releases/running-dry-water-scarcity-threatens-lives-and-development-iraq

[106] US National Intelligence Council (2021) Climate Change and International Responses Increasing Challenges to US National Security through 2040. https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf

[107] Lorenz, F.M. (2008) Strategic Water for Iraq—The Need for Planning and Action. *American University International Law Review*, **24**, 257-299.

[108] Frenken, K. (2009) Irrigation in the Middle East Region in Figures—AQUASTAT Survey 2008. Food and Agriculture Organization of the United Nations, Roma. https://www.researchgate.net/publication/276058258_Irrigation_in_the_Middle_East_region_in_figures_-_AQUASTAT_Survey_2008

[109] Maddocks, A., Young, R.S. and Reig, P. (2015) Ranking the World's Most Water-Stressed Countries in 2040. World Resources Institute. http://www.wri.org/blog/2015/08/ranking-world%E2%80%99s-most-water-stressed-countries-2040

[110] Jason, H. and Nancy, F. (2014) Resource Dependence and the Exits of Young Firms. *Entrepreneurship Research Journal*, **4**, 323-349. https://doi.org/10.1515/erj-2013-0063

[111] Pfeffer, J. (1987) A Resource Dependence Perspective on Interorganizational Relations. In: Mizruchi, M.S. and Schwartz, M., Eds., *Intercorporate Relations: The Structural Analysis of Business*, Cambridge University Press, Cambridge, 25-55. https://doi.org/10.1017/CBO9780511570841.002

[112] Hillman, A.J., Withers, M.C. and Collins, B.J. (2009) Resource Dependence Theory: A Review. *Journal of Management*, **35**, 1404-1427. https://doi.org/10.1177/0149206309343469

[113] Harkins, J. and Forster-Holt, N. (2014) Resource Dependence and the Exits of Young Firms. *Entrepreneurship Research Journal*, **4**, 323-349. https://doi.org/10.1515/erj-2013-0063

[114] Adamo, N., Al-Ansari, N., Sissakian, V., Laue, J. and AlKhanfar, S.A.A. (2023) Virtual Water Trade and Food Security for Iraq. *Journal of Engineering*, **15**, 417-430. https://doi.org/10.4236/eng.2023.157032