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The Impact of Water Scarcity on Food Security in Iraq

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Abstract: Iraq is part of the Fertile Crescent with the two large rivers: Tigris and Euphrates and their tributaries that secure the required quantity and quality of water to the Iraqi population for their different uses; including agriculture, industry, and other domestic requirements. During the last decades, however, the quantity and quality of water in these rivers decreased causing water scarcity in the country. This scarcity is having severe impacts on food security in Iraq since large cultivated areas in different parts of the country that grow different agricultural products have been abandoned due to lack of water. The worsening situation is attributed mainly to global climate changes including decreasing rainfall amounts, increase in air temperature, and insufficient water inflows in the two main rivers and their tributaries. This last issue is exasperated by the unfair water sharing policies of the riparian countries namely Turkey and Iran. In writing this article relevant data from different sources were used. Numerous published reports and papers dealing with this important issue were consulted, while at the same time, the long experience of the authors in these very important issues was also drawn upon to elucidate the difficulties that are current today and those expected in the future in this field.

Key words: Water scarcity, food security, agricultural yield, global change, dry marshes, fertile crescent.

1. Introduction

Water scarcity is the lack of freshwater resources to meet the standard water demand. It is also called "water stress", and "water risk". There are two types of water scarcity: physical water scarcity and economic water scarcity [1]. Physical water scarcity is where there is not enough water to meet all demands, including that needed for ecosystems to function. Arid areas for example Central and West Asia, and North Africa often suffer from physical water scarcity [2]. Yet, economic water scarcity is the result of a lack of investment in infrastructure or technology to draw water from rivers, aquifers, or other water sources, or insufficient human capacity to meet the water demand [1].

Food security means the availability of food in a country (or region) and the ability of individuals within that country (or region) to access, afford, and source adequate foodstuffs. According to the UN (United Nations), food security means that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life [3].

It is the responsibility and preparedness of the Iraqi government to assure food security for the Iraqi people living in Iraq, whereas, in the Kurdistan Region of Iraq, it is the added responsibility of the Kurdistan Regional Government. In both cases, the Ministry of Trade is carrying out the responsibility, besides the local governments in the governorates. Large relevant food stores and grain silos were constructed in the main cities and towns in each governorate to save the imported foodstuff from different countries, especially Turkey, and Iran, and to store the harvested wheat, and barley.

The organization of the various Ministries within the government assigns to the Ministry of Agriculture the duty of sponsoring the agricultural sector and, therefore dealing with all matters related to the

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improvement of local production of crops and animal husbandry products. This includes among other things drawing the annual agricultural plans, recommending the best crop rotations and types of products needed, in addition to helping farmers with loans, fertilizers, good variety seeds, and technical support and advice. The Ministry of Water Resources on the other hand has the obligation of securing irrigation water commensurate with the farmers' needs in the required quantities and quality. In this, the Ministry must fight water scarcity by improving water management practices and reducing waste. Moreover, the Iraqi Government have to use maximum effort for securing better water sharing terms of the Tigris and Euphrates water resources with the riparian countries, namely Turkey and Iran. Environmental and natural factors can contribute greatly to the water scarcity problem leading to food insecurity. Natural and environmental factors such as climate change impacts can play a negative in aggravating the water scarcity issue and shrinkage of good cultivable lands. The responsibility for carrying out all mitigation efforts lays with all Government departments at all levels acting in liaison, being Ministries, Government of the Kurdistan Region, or local governments in all the country's governorates and localities.

When the people in it at any time have the physical, social, and economic ability to have the required amount of food that can be enough for an adequate and healthy life [3]. Although Iraq is considered part of the fertile crescent; it is suffering from water scarcity for a few years, which has harsh impact on food security.

2. Materials and Methods

In writing this article, relevant data from different sources were used. Numerous published reports and papers dealing with this important issue were consulted, while at the same time, the long experience of many Iraqi experts and the writers themselves in these very important fields was also drawn upon to elucidate the difficulties current today and those expected in the future. Photographs shown (Fig. 1) illustrate some of the harsh consequences of water scarcity in different parts of Iraq which no doubt will have negative impacts on food security in the country. Among these, there are dried streams, shrinking marshes, abandoned agricultural lands, dry water channels, and perished animals (Fig. 1). These impacts, especially as related to food security, are discussed hereinafter, and certain recommendations for solutions are presented to ensure food security in Iraq and to overcome the problem of water scarcity.

Many photos are also presented from different parts of Iraq that elucidate the harsh consequences of water scarcity and its impact on food security. Many photos are also presented from different parts of Iraq that elucidate the harsh consequences of water scarcity and its impact on food security (Fig. 1). In view of this situation, this problem is discussed and suggestions are given to resolve the problem.

3. Water Scarcity

Iraq is known to be among five countries worldwide suffering from climate change and its consequence on water scarcity. Climate change is predicted to increase the challenges and constraints to the efforts of ensuring adequate water supply, which is necessary to meet these growing regions, and is likely to continue attempts to reduce total and per capita water availability to dangerous low levels [4]. Iraq is one of the countries of the EMR (Eastern Mediterranean Region), which is predicted to "essentially run out of water" [5].

In semi-arid regions, water scarcity is aggravated, threatening food production and ecosystems [6]. However, arid and semi-arid regions (like Iraq) are already notoriously known for their water scarcity and water stress. This is attributed, apart from the negative climate change impacts, to their competing use in agriculture and industries and to the rapid population growth, such that water supplies are being depleted faster than they are being replaced by precipitation.

It is worth mentioning also, that Iraq suffers greatly from poor agriculture practices which need extremely high quantities of water, and its population growth rate is one of the highest in the world today. In the former case, the majority of farmers are still using conventional and ancient irrigation methods. Quoting one Iraqi water management expert only about 70%-80% of the rainwater is utilized for agricultural purposes. With the same amount of water, the cultivated areas can be 15 times more than what is being cultivated now; if modern irrigation methods are used (Interview on Al-Sharqiyah TV Channel, 25 March 2023). In the latter case, the

Fig. 1 Photos indicating water scarcity, (a) and (c) dry branch of the Euphrates River, (b) dry main irrigation canal, (d) shrinking marsh, (e) perished water buffalos, and (f) dry lined concrete irrigation canal.

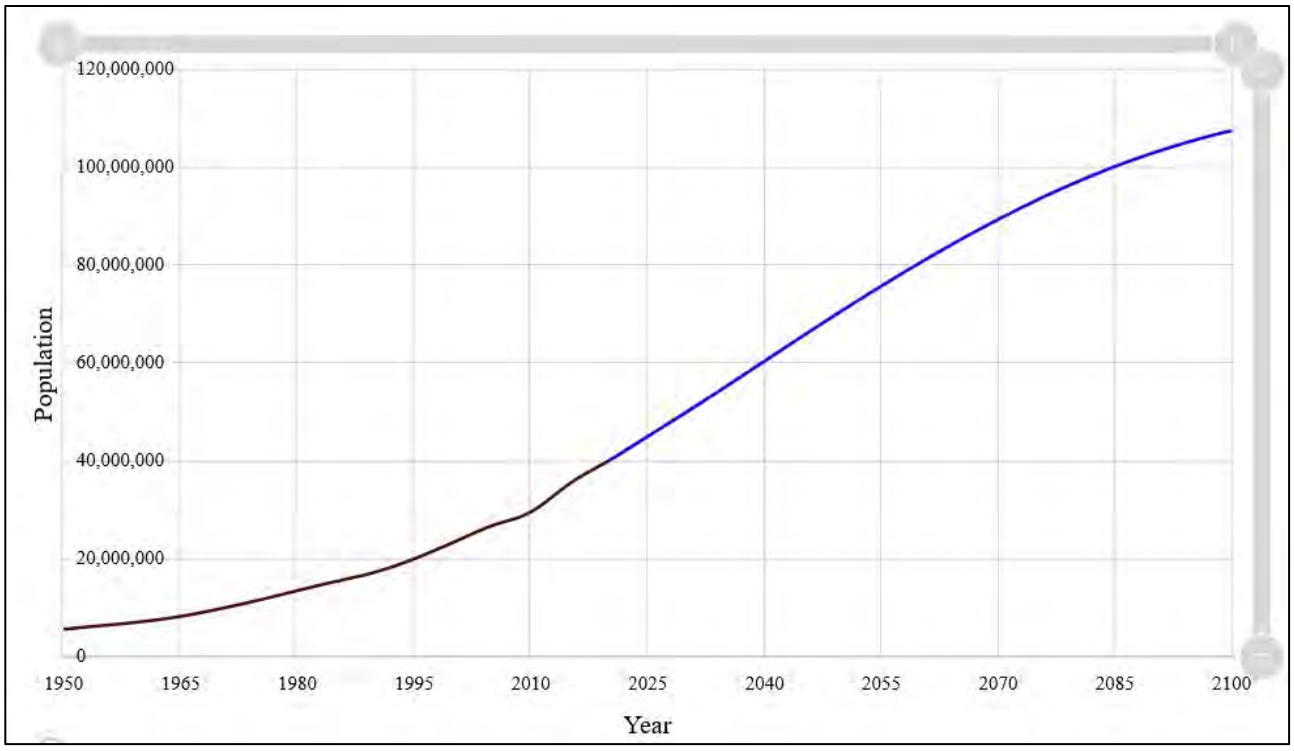

Fig. 2 Population growth in Iraq [7].

Table 1 Population of Iraq with increasing rates (1990-2050) [7].

No.	Year	Population	Increasing rate (%)	Yearly change	Density (P/km^2)
1	1990	17,419,113	2.29	372,663	40
3	1995	20,149,338	2.95	546,045	46
4	2000	23,497,585	3.12	669,649	54
5	2005	26,922,284	2.76	684,940	62
6	2010	29,741,976	2.01	563,938	68
7	2015	35,572,261	3.64	1,166,057	82
8	2020	40,222,493	2.49	930,046	93
9	2025	45,187,256	2.36	992,953	104
10	2030	50,193,756	2.12	1,001,300	116
11	2035	55,342,596	1.97	1,029,768	127
12	2040	60,583,723	1.83	1,048,225	139
13	2045	65,809,029	1.67	1,045,061	152
14	2050	70,940,126	1.51	1,026,219	169

population is increasing at an enormous rate (Fig. 2). The current population of Iraq is 42,891,566 as of March 28, 2023, based on interpolation of the latest UN data. This figure is projected from 41,179,350 countries/territories. Iraq also ranks 14th among 51 countries in Asia [7] in this matter. The rate of growth of the population is also increasing (Table 1).

With such an increase in population and decrease in water resources, Iraq will face serious problems within 2-3 decades, and meet with grave problems in food security. This will be exasperated by low incoming flows in rivers and declining precipitation, and the loss of large agricultural land areas. Moreover, livestock resources will decrease enormously. Animal breeders have started already leaving rural areas and migrating to the nearest towns and cities. This also will cause serious problems for the government due to the demographic changes that will occur in the community,

not to mention also the added negative impacts on municipal water and electricity supplies, health, and housing conditions in these towns and cities.

4. Water Management

Although the main causes of water scarcity in Iraq can be attributed to (1) climate change and related droughts and floods, (2) increased human consumption, (3) an increasing use of water by the other riparian countries of the Tigris and Euphrates rivers, (4) poor water management policies and practices, however, however, this factor remains as the most important factor contributing to this scarcity among the other factors that were mentioned. Poor water management is manifested in: (1) overuse and wastage of water by farmers due to ignorance and negligence, (2) use of ancient irrigation practices that reduces water application efficiency to almost 30%; not switching to modern water-saving methods such as drip and sprinkler irrigation, (3) overuse of aquifers and its consequent slow recharge (Internet data, 2023a), (4) bad government planning and reluctance to invest more in this sector. All these make Iraq one of the worst countries as far as water management is concerned as testified by many water and economic experts and environmental activists (Interviews in Al-Sharqiyah TV Channel, January-April 2023). This was confirmed by the UN Secretary-General António Guterres during his visit to Iraq who declared that water scarcity is a real problem in Iraq (1 March 2023).

A good example of poor water management in Iraq is what happened during the heavy rain showers that occurred on 26 and 27 March 2023 in Iraq. All Iraqi cities and towns were almost inundated, and all governmental offices (apart from security and basic services), schools, and universities were closed (Fig. 3). The same heavy rain showers were repeated on 11 and 12 April 2023, and maximum rainfall was at Tuz Kurmatu town 216 mm northern part of Iraq, whereas the minimum was in Hilla city (68 mm) central part of Iraq.

Fig. 3 The consequences of the floods in Iraq on 26-27 March 2023.

These enormous quantities of rainfall instead of being trapped and saved in proper simple hydraulic structures to be used in coming dry months for different uses, water was left to run as flash floods in rivers, streams, valleys, and depressions (Fig. 4) causing enormous damages to infrastructure (Fig. 5), inundation of agricultural fields, and drowning thousands of sheep and cattle in different parts of Iraq (Fig. 6).

One significant matter showing poor water management in Iraq is the haphazard and unscientific operation of some of the reservoirs and dams commissioning. An example of this can be seen from the use of Al Tharthar reservoir for the dual purposes of flood control and irrigation water storage which results from lacking enough water storage capacity in the dams located on the upper reaches of the Tigris River and its tributaries. During large floods and flash floods, excess freshwater from the Tigris, Upper Zab, and Lower Zab rivers is diverted to Al-Tharthar Depression, which is the largest natural depression in Iraq [8, 9] through the Samarra

Fig. 4 Flash floods during 26-27 March 2023.

Fig. 5 Damages of the flash floods during 26-27 March 2023 in the eastern part of Iraq.

Fig. 6 Perished sheep, (a) due to drought in the southern part of Iraq, drowning sheep due to flash flood on 26-27 Match 2023, (b) and (c) in the southern and western parts of Iraq, respectively.

barrage and the related Tharthar flood channel. The salinity of the water in this depression, however, ranges between 5,000-1,0000 ppm [10]. This is attributed to the dissolution of the exposed thick gypsum beds in the depression and surrounding areas [11]. Accordingly, the diverted fresh water is mixed with this saline water causing considerable deterioration of its quality. Despite that, this water is returned to the Tigris and Euphrates Rivers during the summer months using two separate canals to supplement irrigation needs in the lower Tigris River basin. This, however, is leading to increased salinity in both rivers which means increased chances of Land Salinization in the middle and south of Iraq. Moreover, the large surface area of the depression leads to high rates of evaporation and therefore, loss of large quantities of water, and an even higher concentration of salts in the water of Al-Tharthar Depression. Poor planning indicating poor water management has led the MOWAR (Ministry of Water Resources) recently to stop the construction of the Makhool Dam on the Tigris River which was intended to give among other benefits increased total flood water storage capacity on the river therefore, limiting the use of Al-Tharthar Reservoir and its damaging impacts to a minimum.

Other actions which can help to improve water management and reduce the expected water scarcity impacts on Iraq may be: (1) wide scale application of modern irrigation methods and abandoning wasteful traditional methods, (2) taking actions to improve water quality in the rivers, (3) recycling of all municipal sewerage water to eliminate contamination of natural rivers and streams and add more water to these resources, (4) introduction of water desalinization, (5) application of rainfall harvesting methods wherever possible to reduce flash flood damages and recharge groundwater aquifer and for better surface water utilization, (6) invest much more on the water sector than what is presently done, (7) continue negotiation with Turkey and Iran for better water sharing terms of the Tigris and Euphrates waters. This may be done keeping in mind the mutual economic and security interests of all these countries.

5. Food Security

In Iraq, the central government and local governments in all governorates are responsible for supplying various foodstuff items to low-income families either directly through special rationing cards or through supplying foodstuffs at subsidized prices in special governmental markets. However, in both cases, no proper quality foodstuffs are supplied. Therefore, people are compelled to buy their requirements from local markets with higher prices; accordingly, the majority of the Iraqi people are not able to buy their actual needs.

Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996) [12]. This definition gives rise to four dimensions of food security: (1) availability of food, (2) accessibility (economically and physically), (3) utilization (the way it is used and assimilated by the human body), and (4) stability of these three dimensions [12].

Mainly four measurements have been developed to capture the access component of food security; these include [13]:

(1) Household Food Insecurity Access Scale

This scale measures the degree of food insecurity (inaccessibility) in the household in the previous month on a discrete ordinal scale. According to a Baghdad Municipality source on 6th March 2023, the Municipality collects 10 tons of food remains daily, which comes to 0.5 kg of food remains per person per day, while millions in Iraq suffer from poverty.

(2) Household Dietary Diversity Scale

This scale measures the number of different food groups consumed over a specific reference period (24 h/48 h/7 days). Unfortunately, no such data are available, apart from what was mentioned by an economic expert (20th January 2023), i.e., 85% of the foodstuff is imported because agricultural activities in Iraq are not enough.

(3) Household Hunger Scale

This scale measures the experience of household food deprivation based on a set of predictable reactions, captured through a survey and summarized in a scale. According to one civil activist Mrs. Manal Al-Ubaidi (22 March 2023), a few million Iraqis are living below the poverty line, she added that there are no accurate data to indicate the exact number and in which governorate; however, she added that Al-Samawa Governorate is the most suffering from poverty as compared to other Iraqi governorates.

(4) CSI (Coping Strategies Index)

This index assesses household behaviors and rates them based on a set of varied established behaviors on how households cope with food shortages. Although there are no available numerical data, however, from following the local markets in different Iraqi cities and towns, it can be recognized that people are suffering from high inflation rates, which was 8.2% in January 2023. Therefore, families could not buy enough food this year (April 2023) as compared to last year. The President of UNDP (United Nations Development Programme) in Iraq, Mr. Auke Lootsma, declared in one TV interview on 6th April 2023, that Iraq is facing big problems with water scarcity, drought, and food security (Al-Sharqiyah TV Channel, Iraq, 6 April 2023).

The following aspects have strong and direct relationships with food security. Missing some of them will affect the possibility of securing necessary food and healthy nutrition for the people.

5.1 Availability

Food availability relates to the supply of food through production, distribution, and exchange [14]. Food production is determined by different aspects including: (1) land ownership and use; (2) soil management; (3) crop selection, (4) breeding, and management; livestock breeding and management; and (5) harvesting [15]. From the presented data on food availability in Iraq, there is a continuous deterioration in the type, quantity, and quality of produced food in Iraq. This is mainly due to water scarcity and poor water management. Farmers and animal breeders are either suffering from droughts (Fig. 1) or the loss of their cattle (Figs. 1e and 6). Accordingly, migrating from rural areas to nearby towns and cities, or they are not getting enough crop yield from their farms due to poor management causing continuous degradation of soil and diminishing of irrigation water supply. Some of them are even suffering from inundation of their farms due to flash floods or flood water contaminated with oil causing losses of cattle (Fig. 7).

5.2 Access

Food access refers to the affordability and allocation of food, as well as the preferences of individuals and households [14]. The inability to access food due to poverty [16] is one of the main problems in Iraq. The high inflation rates, unemployment, and damaged farms are all reasons for the increase in poverty which leads to difficulties in accessing enough food. Moreover, people who were living in rural areas and used to have

Fig. 7 The central part of Iraq, polluted flood water by crude oil caused damage to large agricultural lands.

food satisfaction from their own farms and animal breeding are not able to have this luxury now, due to water scarcity in the main two rivers Tigris and Euphrates, and decreasing rainfall rates due to climate change which have caused their immigration and abandoning of their farms.

5.3 Utilization

The next pillar of food security is food utilization, which refers to the metabolism of food by individuals [17]. The Iraqi Government started after 1991 supplying necessary food commodities with reasonable amounts of calories to the majority of the people through a special rationing program. After 2003, however, the supplied qualities, quantities, and types of the rations deteriorated enormously. The metabolism of food by a considerable part of Iraqi individuals fell accordingly below the rates required to ensure a healthy life.

5.4 Stability

Food stability refers to the ability to obtain food over time. Food insecurity can be transitory, seasonal, or chronic [15]. In Iraq, food stability can be considered transitory. This can be attributed to different weather conditions in different parts of Iraq as far as temperature and rainfall amounts are concerned. Different types of vegetables and other agricultural products are grown in different parts of Iraq during different months. Therefore, some of these products ripen at certain times in different parts of Iraq causing surpluses and/or deficiencies in certain other parts. This is a direct result of the absence of efficient marketing and suitable storage facilities. Moreover, imported food materials such as some vegetables, fruits, dairy products, and meats are available sufficiently only during limited periods of the year. The absence of rational importation policies and proper planning that is based on market research whether by the Ministry of Agriculture and/or the Ministry of Trade causes shortages of these commodities and instability of food supplies in different periods of the year.

5.5 Sustainability

Sustainability refers to the long-term ability of food systems to provide food security and nutrition in a way that does not compromise the economic, social, and environmental bases that generate food security and

nutrition for future generations [18]. In Iraq, current policies, short-sightedness, and lack of rational planning related to future food security indicate that future generations will face serious problems to secure healthy food with relevant nutrition and metabolism. Many scientific published articles point out that in 2040-2050 Tigris and Euphrates rivers flows will be reduced to almost nothing. These articles go further to explain the reasons behind this tragic situation which are summed up by climate change impacts and the unfair sharing policies of the riparian countries. This only means the interruption of the food chain supply produced locally and food supply sustainability shall be hit [19-24]. There is, of course always the argument that Iraq can import its food needs from other countries.

6. Land Degradation and Reclamation

6.1 Land Degradation

Land degradation is defined as "A process in which the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land" [25]. It is viewed as any change or disturbance to the land perceived to be deleterious or undesirable [26]. In Iraq, land degradation began to gather momentum in 1991 when the UN imposed stringent economic sanctions on Iraq. This degradation is increasing enormously nowadays, especially in central and southern parts and even more in the Euphrates River basin. In northern Iraq (Kurdistan Region of Iraq) causes of land degradation stem out of unlawful deforestation and overgrazing of lands resulting in reducing the vegetative cover of soil. In general, degradation is the result of: (1) decrease in annual rainfall rates, (2) decrease in water flow in rivers; some of them are almost dry (Fig. 1), (3) increasing salinity in the rivers [27], (4) increasing desertification due to climate change impacts [27], (5) creeping of sand dunes on agricultural lands and absence of efforts to stop them. All these factors caused the rural population to abandon their agricultural land leaving it to more disuse and desertification.

The Ministry of Water Resources (previously the Ministry of Irrigation) in Iraq had numerous large land reclamation and amelioration projects during the last century in central and southern parts of Iraq. Most of these projects with all existing facilities were abandoned and their infrastructures were ruined after 1991 due to the UN economic embargo on Iraq. This has resulted in great damage to agricultural lands, especially where reclamation works were unfinished. Farmers in many parts started using saline water from drain canals for irrigating their farms which increased the salinity of the soil even more than the previous levels and decreased the productivity of the cultivated lands appreciably. The loss of large quantities of different crops contributed to the reduction of food security in Iraq and increased imports of these crops from neighboring countries instead of exporting them as was the case during the last century. The decrease in the river's flows due to the reasons known and the decreased rainfall due to climate change caused a decrease in the water supply to the fertile soil reducing its productivity.

Another significant issue of land degradation is deforestation. In the northern part of Iraq, more trees were cut to supply firewood while overgrazing of good lands is going on unhindered. Similarly, in the southern and middle parts, extensive date palms and fruit orchards were removed and good cultivable lands were all used for building residential complexes. This has resulted in the loss of large areas that were previously producing good quantities of crops for food and other uses.

6.2 Land Reclamation

Iraq was one of the pioneering countries in the Middle East to start land reclamation through the construction of hydraulic structures like the Dokan, Derbendi-Khan, Mosul, and Haditha dams to avoid flooding and inundation of agricultural lands, besides generation of electrical power, and supplying water for irrigation through giant irrigation projects were also

aimed at during the last century. The official policy of the government was to have all the irrigation canals lined down to the field outlets thus limiting seepage losses on one hand and reducing salinization of land to bear a minimum on the other. Further to that Iraq initiated and completed huge land reclamation projects in the middle and southern parts of the country in lands where salinization was already high to improve its productivity. This was achieved by digging extensive drainage canal networks and installing closed field drains. The whole saline drainage water was to be discharged in the Arabian Gulf via the MOD (Main Outfall Drain) extending from North West of Baghdad and ending in Khor Al Zubair (Fig. 8).

Until 1991, there were tens of such large land reclamation projects planned and completed by the Ministry of Irrigation (presently, Ministry of Water Resource). The total area covered by these projects mounted to 11 million donums i.e., 2.75 million hectares (one donum equals 2,500 m^2 or quarter hectare).

Fig. 8 Map showing rivers, dams, and the MOD.
(Modified from the Main Drain Channel [28]).

After 1991 almost the whole system was ruined and infrastructures collapsed due to negligence, lack of maintenance, and corruption and only 5.1 million donums were left under cultivation. No real efforts were done to restore the previous situation and after 2003, only 100,000 donums were reclaimed by 20 foreign companies with a cost of $2,000-2,500 US per donum, an exceptionally high cost compared to world's standards according to a hydraulic engineering expert (TV interview on 26 January 2023). Each land reclamation project included concrete irrigation canals; some of them were covered to decrease evaporation and modern irrigation techniques; like drop, and sprinkler irrigation were used.

Due to water scarcity and because of the many reasons already presented, especially poor water management practices, most of these giant reclamation projects were abandoned. Only 7% of the farmers were left in these rural areas in 2004 compared to the previous level. Currently, only 3% of farmers have remained. This large migration from rural areas to cities and towns caused a great loss in agricultural productivity and undermined food security in Iraq which is expected as the only natural outcome in such conditions, according to the same source mentioned above.

7. Discussion

The impacts of water scarcity on food security in Iraq have been very harsh during the last few decades; more can be said and discussed on this matter in the following.

7.1 Water Management

Water management in Iraq is in a very poor state today. This has been reported by a great number of Iraqi specialists and water resources experts in published papers and articles and through the media. This state is caused by: (1) lack of experience among the present senior staff in the Ministry of Water Resources, and the Ministry of Agriculture, (2) shortage of water inflows of the rivers; due to reasons such as climate change and the newly constructed dams in Turkey and Iran outside any agreement between the riparian countries, (3) absence and/or wrong water management policies adopted by the Ministry of Water Resources, (4) use of old conventional irrigation methods by the farmers in the absence of modernization schemes implemented by the government, (5) growing to a great extent of crops with high water footprints such as rice and corn, and (6) violating the water rights allocated to farmers by the irrigation departments in the governorates and exceeding these shares in a wasteful manner.

To overcome the abovementioned poor water management problems, it is necessary to resort to some drastic solutions and take some painful decisions, such as: (1) deeper consultation with highly qualified water, agriculture, and environment experts to utilize their experiences in water management fields and sound agricultural practices including the selection of crops with low water footprints and protection of the aqueous environment from salinization and chemical contamination. This has to be done by the Ministry of Water Resources, Ministry of Agriculture and Ministry of Environment together; (2) imposing strict policies on farmers who exceed their water rights or grow crops that are not recommended by the agricultural authorities, (3) encouraging those farmers who use modern irrigation methods by giving them incentives such as generous loans, modern irrigation equipment, and fertilizers, (4) banning the growing of such crops as rice and other crops with high consumption of water, (5) distribution of government cultivable lands to all farmers who pledge to use modern irrigation methods and continue to do so, (6) carry out serious negotiations with Turkey and Iran to obtain equitable and fair water sharing of the Euphrates and Tigris rivers with their tributaries waters, (7) taking serious legal actions against water resources pollutants whether Individuals, Private Sector entities, or even Government authorities, such as the Ministry of Industry and the Ministry of Health. This must be applied also to the Ministry of

Municipalities if it fails to construct and operate properly enough sewerage treatment plants for the treatment of all untreated outflows. Enforcing such regulations shall be taken diligently by the Ministry of Environment, and (8) keeping salinity and chemical levels to acceptable values in the Transboundary Rivers must be taken seriously by the Iraqi Government in any future negotiation with the riparian countries Turkey, Iran, and Syria.

7.2 Land Reclamation

There are currently, some attempts in the central part of Iraq to cultivate some lands by farmers utilizing groundwater for irrigating small plots (Fig. 9). Those farmers started reclamation of barren lands by growing wheat, barley, and vegetables using modern irrigation techniques (Figs. 9a and 9b). In this work, solar cells (Fig. 9c) are used for generating electrical power to run water pumps and for other domestic uses. They also are breeding cattle, deer, and sheep (Figs. 9d, and 9e). Moreover, they have started small canning projects such as tomato paste and date syrup production (Fig. 9f).

To improve land reclamation efforts in Iraq, the Ministries of Water Resources and Agriculture have to cooperate more in their attempts to improve land

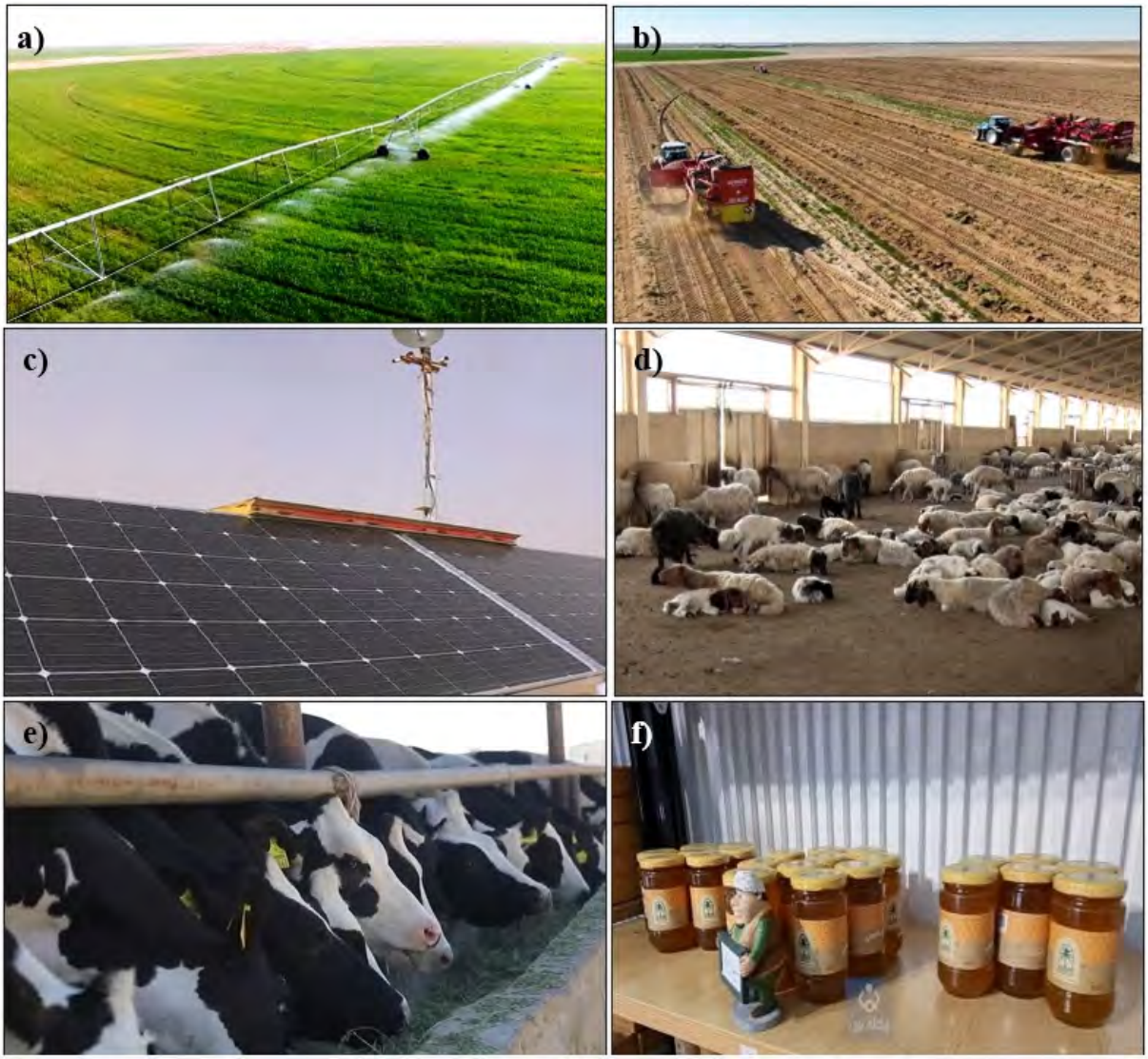

Fig. 9 Land reclamation, (a) miodren irrigation, (b) modren plowing technique, (c) solar cells, (d) bred sheep, (e) beginning cows, (f) canning of date syrup.

reclamation as common work in expanding the cultivated areas with the existing or even lesser expected quantities of water resources in the future. This will reflect in more crop yields and serves to improve the food security situation.

In an interview with one prominent Iraqi hydraulic engineer and reclamation expert Dr. Kana'n Abdul Jabbar, that was aired on 26th January 2023, the following actions should be performed in land reclamation works if such works are to have any meaningful effect on the general food security situation in Iraq: (1) maintaining the MOD (Fig. 8) and all other main and secondary drains in the country by continuous dredging of the accumulated sediments and clearing them from growths of reeds and other infesting plants and deleterious materials. Maintenance of all field drains in already reclaimed lands should also be done regularly; (2) maintaining all already lined irrigation canals and lining all new ones and adopting this as a fixed policy to reduce seepage losses and to protect the integrity of these canals, especially in areas whose soils are characterized by high contents of soluble salts, (3) using closed piping systems for secondary irrigation canals and lateral wherever possible to minimize seepage and evaporation losses, (4) imposing rational agricultural policies compatible with the present and expected future water scarcity situation by the Ministry of Agriculture and instructing all farmers to follow the guidelines stipulated by these policies to improve water application methods and improve soil properties. One such guideline is to use suitable cultivation rotations and intensities that save irrigation water and preserve and improve soil qualities. An example of this is to have, for example, 80% of their lands to be used for winter crops and 20% of them for summer crops. Examples of crop types that may be encouraged are legumes and alfalfa which have good financial returns and improve at the same time the nitrogen content of the soil, (5) banning irrigation with saline drain water except when highly tolerant crops are grown and after scientific evidence proves that such use is harmless to the yield and will not leave lasting damage to the land. According to the same expert quoted above, no less than 42 million donums of land can be cultivated if such actions are put into application.

7.3 Population Growth

Iraq is experiencing now one of the highest population increase rates in the world. In 2020, the population in Iraq was 40,222,493 with a rate of 2.49% and a density of 93 persons/km^2, in 2050 it will be 70,940,126 with a rate of 1.5% and a density of 169 persons/km^2 (Table 1) [7]. If the same rates continue without any limiting actions and living conditions remain as of today, securing enough food for such a population will be very big challenge to the Iraqi Government. It is predicted that in 2050, the Tigris and Euphrates rivers will almost not exist due to a variety of reasons [19]. Therefore, the government has to control overpopulation by applying any possible rational policy; otherwise, it will become impossible to secure enough food for everybody and poverty will certainly increase and the possibility of famine will be great.

To overcome this unacceptable population increase in Iraq, the government has to encourage recently married couples to limit the number of children to only two maximum following the birth-control policy, especially in rural areas. At the same time, it is important that the government has to initiate family planning education centers and even establish birth control clinics to help in this effort of reducing population growth rate. A good example is the policy followed in China [29].

7.4 Improving Flash Floods Control

Although Iraq is facing water scarcity due to the aforementioned reasons, however, large flash floods may still occur many times in a single year as a result of climate change. The quantities of flood water are usually enormous. For example in March 2023, through only two rainy days the reserve in the Mosul Dam

reservoir became 7.5×10^9 m^3, in the Tharthar Depression 10×10^9 m^3, in the marshes 5×10^9 m^3, in Al-Adaim Dam Reservoir 0.75×10^9 m^3 and as the total amount in Iraq is predicted to be 39×10^9 m^3. However, large dykes and other relevant hydraulic structures such as check dams should be constructed to use the flood water that can be stored from these floods and to control such preventing their damaging consequences. Otherwise, the flood water will flow in Wadis, inundate farms, cause damage to infrastructures (Figs. 3-6), and may even cause human casualties.

8. Conclusions

Water scarcity impacts food security in Iraq very harshly. Despite two main rivers, Tigris and Euphrates with their tributaries flow in Iraq, the country however suffers from severe water scarcity. Therefore, agricultural lands are decreasing drastically causing a decrease in crop production, which leads to big problems in food security and other problems in the Iraqi community. One of the main reasons for water scarcity, besides climate change, is poor water management. Yearly, an increasing number of flash floods occur in different parts of the country, especially the eastern, where tens of rivers, streams, and valleys flow from the highlands in Iran toward Iraq. The flood water flows without any control causing damage to the infrastructure, inundation of agricultural lands, and perishing of cattle. The quantities of flood water can be used in drought months if they are controlled and stored properly. Other significant points that contribute to increasing the problems of food security and poverty are the drastic increase in the population, and transferring agricultural lands to residential sites.

Author Contributions

Mr. Varoujan Sissakian, Professor Nadhir, and Mr. Nasrat Adamo analyzed and interpreted the acquired data (Section 3).

Professor Jan Laue and Mr. Nasrat Adamo contributed to collecting data (Section 4).

Mr. Varoujan Sissakian, Mr. Nasrat Adamo, Professors Nadhir Al-Ansari, and Jan Laue wrote the paper (section 5).

Mr. Varoujan Sissakian performed the fieldwork.

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Data Availability Statement

All used data are presented in the manuscript. However, data will be made available on request from the corresponding author.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Additional Information

No more information.

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