Iraq Water Resources Planning: Perspectives and Prognoses

Nadhir Al-Ansari, Ammar A. Ali, Sven Knutsson

***Abstract*—**Iraq is located in the Middle East. It covers an area of 433,970 square kilometres populated by about 32 million inhabitants. Iraq greatly relies in its water resources on the Tigris and Euphrates Rivers. Recently, Iraq is suffering from water shortage problems. This is due to external and internal factors. The former includes global warming and water resources policies of neighbouring countries while the latter includes mismanagement of its water resources.

The supply and demand are predicted to be 43 and 66.8 Billion Cubic Meters (BCM) respectively in 2015, while in 2025 it will be 17.61 and 77 BCM respectively. In addition, future prediction suggests that Tigris and Euphrates Rivers will be completely dry in 2040.

To overcome this problem, prudent water management policies are to be adopted. This includes Strategic Water Management Vision, development of irrigation techniques, reduction of water losses, use of non-conventional water resources and research and development planning.

***Keywords*—**Iraq, Tigris River, Euphrates River, water scarcity, water resources management.

I. Introduction

IRAQ is one of Middle East and North African region countries (MENA) (Fig. 1). This region is characterized by its water shortage problem [1]-[4] where at least 12 countries have acute water scarcity problemswith less than 500 m^3 of renewable water resources per capita available [5], [6]. The largest consumer of water across the region is agriculture where it accounts for 66% of demand [7] and therefore the water shortage problem cannot be objectively analyzed nor adequately addressed without a thorough consideration of agriculture [8]. If we consider 10% transfer of water away from agriculture would produce a 40% increase in domestic water supply for Jordan [8]. Reference[9] argues that rather than diverting precious water to agriculture this water could be saved by importing the food/grain. However, this is not the case in many Middle Eastern countries which have unrealistic aspirations of food self-sufficiency and in it would require a most fundamental change in national outlook [10]. Reference[8] emphasized that the extent of the problem is so severe that "the future challenges in meeting the growing demands for water are beyond the capabilities of individual countries". Future predictions suggest more shortages [11]-[13], [4] and depletion of groundwater resources [14], [15].

Nadhir Al-Ansari is with Department of Civil, Environmental and Natural Resources Engineering, Lulea University of Technology, 97187, Sweden(e-mail: nadhir.alansari@ltu.se).

Ammar A. Ali is with Department of Civil, Environmental and Natural Resources Engineering, Lulea University of Technology, 971 87, Sweden (e-mail: ammar.ali@ltu.se).

Sven Knutsson is with Department of Civil, Environmental and Natural Resources Engineering, Lulea University of Technology, 971 87, Sweden (e-mail: sven.knutsson@ltu.se).

Iraq covers an area of 433,970 square kilometers populated by about 32 million inhabitants. Due to the presence of the Rivers Tigris and Euphrates, Iraq was an exception till the 1970s [16], [17],[4]. It was considered rich in its water resources compared with other countries where the annual allocation per capita reached 6029 m^3 in 1995 and expected to be 2100 m^{3}in 2015 [18]. In other countries as an example, it is 170, 1112, 2162 and 1752 in Jordan, Egypt, United States and Canada respectively [19]. Recently, it is suffering from water shortage problems [4],[20]–[23], [16]. Reference [24] reported that the Tigris and Euphrates Rivers will be completely dry by 2040.

In this research, an attempt is made to discuss this problem and suggest ways and means of overcome the water crises in Iraq.

II. Climate

The climate of Iraq is mainly of a continental, subtropical semi-arid type. The temperature during summer is usually over 43°C during July and August and drops down to 20°C and 16°C during the day and night respectively in winter time.

The average annual rainfall is 154 mm, but it ranges from less than 100 mm over 60% of the country in the south up to 1200 mm in the northeast. The rainy season is restricted between Octobers to April [16], [25], [26]. While the overall average evaporation and evapotranspiration are of the order of 1900 m per year.

III. Hydrological Scheme and Water Resources of Iraq

Tigris River rises from Turkey and passes through Syria and enters Iraq at the north. It flows for 1418 km inside Iraq (77% for the total length of the river). It has five tributaries inside Iraq (Al-Khabour, Upper Zab, Lower Zab, Al-Udhaim and Diyala). The total catchment areas are shared by Turkey, Syria, Iraq and Iran [17], [28]. Tigris River mean discharge at Mosul city prior to 1984 was 701m^3/s and dropped to596 m^3/s afterward. This implies a 15% decrease of the river discharge (Fig. 2).

Euphrates River also rises from Turkey, flows through Syria and enters Iraq from the northwest border. It does not have any tributary inside Iraq, except small seasonal wadies from the west. The catchment areas are distributed among Turkey, Syria, Iraq and Saudi Arabia [16], [27]. The mean daily discharge of Euphrates River at Hit and Haditha cities has dropped from 967m^3/s (prior to 1972) to 553m^3/s (after 1985). The percentage decrease in river discharge is 43% (Fig. 3).

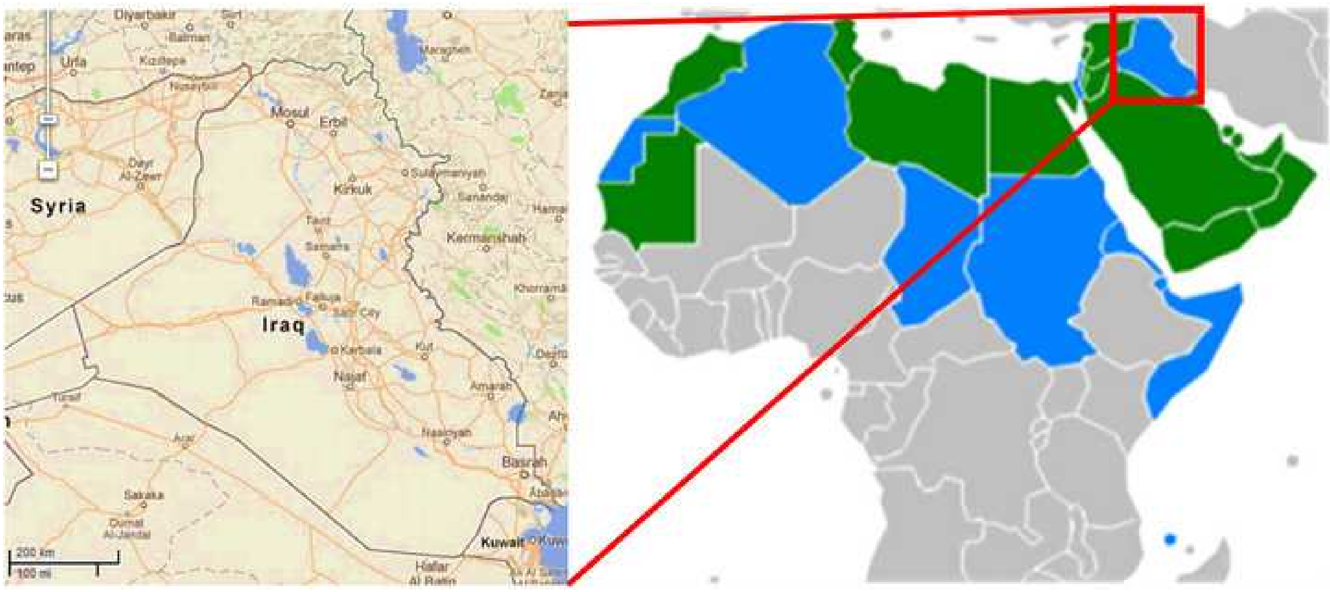

Fig. 1 Location of Iraq in the MENA region

Shatt Al-Arab River forms at Qurna where the Tigris and Euphrates Rivers join together, and it flows into the Gulf. It drains an area of 80800 km^2 and flows for 110 km. Two main tributaries (Suwaib and Karun) join the main course of the river. Most of the flow of these tributaries is halted by the Iranian water projects now.

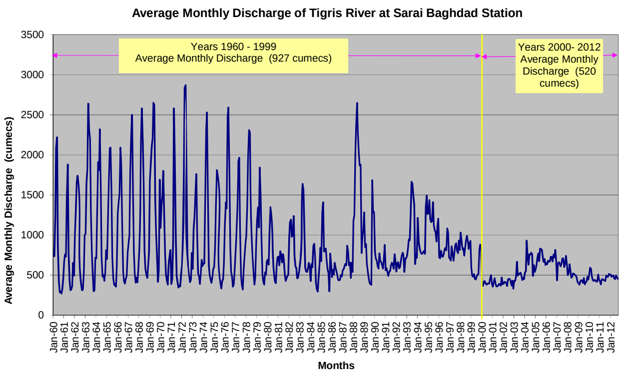

Fig. 2 Average monthly recorded discharges of Tigris River at Sarai Baghdad station for the period 1960-2012 [28]

Iraq started controlling its water resources since 1939 when the first barrage was constructed at Kut on Tigris River. The idea of building dams in Iraq started in the first half of the twentieth century. Primarily it was to protect Baghdad the capital and other major cities from flooding. The first big dam (Dokan) was constructed in 1959 on the Lesser Zab River. Later, dams and regulators were constructed for irrigation and power generation purposes [29], [30]. The natural depressions are included within the hydrological scheme as flooding escapes such as Al-Therthar depression.

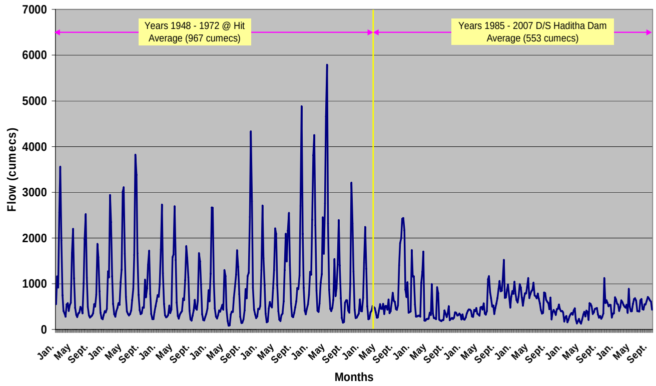

Fig. 3 Average monthly recorded discharges of Euphrates River at Hit and Haditha stations for the period 1948-2007 [28]

The Iraqi Government realized the process of building dams should be speeded up due the huge increase of water demand and the threat of halting water of the rivers by Turkey and Syria. The process stopped in the 1990s due to the second Gulf war and UN sanctions. None of these dams was filled to its maximum storage capacity during the twenty first century. This is due to the depletion of flow in the Euphrates and Tigris Rivers due to the Turkish and Syrian dams. It is noteworthy to mention that Haditha dam is almost of no use now due to the severe depletion of the Euphrates flow.

As shown before, the rivers Tigris and Euphrates form the main water resources of Iraq. Most of the water from these rivers comes from Turkey (71%) followed by Iran (6.9%) and Syria (4%). The remainder, only 8%, is from internal sources [31]. The average annual flow of the Euphrates and Tigris is estimated to be about 30 km3 (which might fluctuate from 10 to 40 km^3) for the former and 21.2 $km^3$for the latter when they entering Iraq. Tigris River tributaries in Iraq contribute 24.78 $km^3$of water and there are about 7 $km^3$of water brought by small wadies from Iran, which drains directly towards the marsh area. Euphrates River doesn't have tributaries inside Iraq. Groundwater resources are estimated about 1.2 BCM and form about 2% of the total water resources of Iraq [25].

According to the negotiations between riparian countries, Iraq is supposed to receive 58% of the Euphrates flow, which crosses the Turkish- Syrian border, while Syria receives 42%. Turkey promised in the past to secure minimum flow of 15.8km^3/year at its border which gives Iraq 9 km^3/year. Up to now there has been no agreement between the three countries concerning the Euphrates and Tigris water. Present estimates indicate that Iraq is receiving only about 0.03 km^3/year of the Euphrates water [16].

IV. Water Consumptions

The World Bank mentioned that the population of Iraq was 20.4 million in 1995 with a growth rate of 3.6% for the period 1980-1990 and expectation to be about 32 million in 2012. Population density ranges from 5 to 170 inhabitants/km^{2}in western desertic and the central part of the country respectively [16]. Agriculture has high priority for the Iraqi people since one third of the inhabitants live in rural areas [32] and they usually work as farmers and livestock breeders.

The total water withdrawal in Iraq in 1990 was about 42.8 km^3, which is used for agricultural (90%), domestic (4%) and industrial (6%) purposes [3], [8], [25], [33]. It is obvious that most of the water consumption goes for the agriculture since the percentage of the agricultural land is 19-25% (8.2 - 11.5 million ha) of the total area of Iraq. But according to the recent estimates, the percentage of consumed water for agriculture is slightly reduced to 85% [16]. This amount is used for an area of 8.2 million ha, which forms 70% of the total cultivable area. About 40% - 50% of this area is irrigable, while the remainder is rain fed and only 7% is of the area is supplied by ground water. Considering the soil resources, about 6 million hectares are classified as excellent, good or moderately suitable for flood irrigation.

The irrigation potential is 63%, 35% and 2% for the Tigris, Euphrates and Shat Al-Arab Rivers respectively. Irrigation consumptive use reached 39 km^{3}in 1991 and in 2003/2004 it was 22 km^{3}equivalents to 44 km^{3}of water derived, assuming 50% irrigation efficiency. Real efficiency might be 25-35%. Existing data estimates that the contribution of the agricultural sector was only 5% of Gross Domestic Product (GDP) which is usually dominated by oil (more than 60%). About 20% of the labour force is engaged in agriculture [16].

It should be mentioned however, that the demand of the industrial sector decreased with the progress idling of the industrial capacity. Hydropower use including the evaporation from reservoirs reaches 10/annum BCM. Potable water usage in Iraq is about 350 liters/capita/day for the urban areas [34] and it used to reach 100% and 54% the urban and rural areas in 1991. The situation deteriorated in both quantity and quality afterwards and 33% of the population do not have access to water and sanitation. Current estimates indicate that water supply to urban areas is 94% and in rural areas is 67% [32]. Water services are limited to few hours per day and its quality does not meet WHO standards or Iraqi national water quality standards.

References [24] and [35] estimate indicated that available water in Iraq reached 75 BCM (2400 m^3 per person per year) which is more than neighboring countries with the exception of Turkey.

V. Water Demands

A comprehensive study is conducted in Iraq by MWR under title “The strategic study for Iraqi water resources and lands” to evaluate the current water resources and their future prediction. The aims of this study are poverty reduction, economic improvement, and agricultural investment to achieve self-sufficiency and improve patterns of agriculture and irrigation as well as water management to ensure the sustainability of good quality of water [31].

All the iterations to estimate the water demands have not ignorable amount uncertainty. However, they shall take in consideration the current effective use for water and the efficient management measures for future demands.

VI. Irrigation

The cropped land is about 1.9 million ha in recent years out of 4 million ha arable lands. According to Iraqi Ministry of Planning (MoP), Iraq is planning to increase the agricultural area cropped by wheat and barley achieving 2017 by 14% and 21% respectively [36]. In case all arable land is cropped then the water requirement is 50 BCM, assuming good irrigation efficiency.

VII. Potable Water and Sanitation

The demand was about 11 MCM/day in 2011, while the domestic water shortage was 1.7 MCM/day [34]. Iraqi government hopes to ensure water supplies to 91% of the population by 2015 [24]. The scenarios given by reference [34] are based on lower ongoing consumption level from 350 to 200 liter/capita/day and with expected population of more than 34 million in 2015, the potable water demand will range between 8 and 13 MCM/day (Table I) depending on overall (treating, conveying and distribution) efficiency. An additional 5 BCM of water required in sanitation sector due to the fact that the infrastructure is out of service losses have increased.

VIII. Energy and Industry

With the increase of Iraq population, urgency increased for electricity production. The estimate of the increase in power demand is 24% by 2017 [36]. Installation of more thermal power plants, which are the popular electricity sources in Iraq, to replenish electricity shortage requires more water demand.

Iraq has six hydroelectric stations installed in dams, but their operation plans are influenced by the available storage in the reservoirs and the operation rule curves of these reservoirs. None of these hydropower stations are operated at its maximum capacity till now.

Many of the Iraqi industries starting from 2003 or earlier, which are considered as water consumers is out of duties or need rehabilitation campaigns to be functional from 2003 or earlier. No documents found stating the quantity of water consumed by these industries. Iraqi government is looking for external investments for these industries [37] and in case they do that, extra water demands will be impose on the water resources of the country.

IX. Restore Marshes

The Iraqi marsh lands, which are known as the Garden of Eden, cover an area about 15000-20000 km^2 in the lower part of the Mesopotamian basin. During the previous regime, some of the marshes were partially dried while the remainder dried totally. Many agricultural projects were established on the dried lands at that time covering 1920 km2 distributed over three provinces. After 2003 and with the help of other countries and international organizations, a new program started to restore the Iraqi marshes [17]. It is believed that 70% - 75% of the original areas of the marshes can be restored. Restoring the marshes requires 13 BCM without improving the quality of water in the marshes and extra 5 BCM to improve it [25].

TABLE I
Expected Population and Potable Water Demand for Different Water Shares and Different Distribution System Efficiency

Water share (l/capita/day)	Year	Population (million)	All population Demand (MCM/day)	91% population Demand (MCM/day)	Real water demand (MCM/day)			
					Efficiency 50 %	Efficiency 60 %	Efficiency 70 %	Efficiency 80 %
350	2012	32	11.2	10.192	20.384	16.98667	14.56	12.74
	2015	34.98	12.243	11.14113	22.28226	18.56855	15.9159	13.92641
250	2012	32	8	7.28	14.56	12.13333	10.4	9.1
	2015	34.98	8.745	7.95795	15.9159	13.26325	11.3685	9.947438
200	2012	32	6.4	5.824	11.648	9.706667	8.32	7.28
	2015	34.98	6.996	6.36636	12.73272	10.6106	9.0948	7.95795

X. Overall Estimations

The World Bank estimated the overall water required to be 75 to 81 BCM [25]. In 2010, reference [24], estimated the overall water demand excluding restoring the marshes is about 73 BCM and the available water is about 59-75 BCM. If the situation remains as it is, the Iraqi water supplies will drop to 43 BCM by 2015 and to 17.61 BCM in 2025 and the demand is 77 BCM or 66.85 BCM at the least. According to reference [25], the Iraqi water deficit in 2030 will reach 25.55 BCM (37%) where the expected supply is 44 BCM only.

XI. Water Sacristy in Iraq

Iraq is facing serious water shortage problem as part of regionally problem. The cause of this problem is attributed to external factors (Global climatic change and abusive water policies by riparian countries) and internal factor (poor management of water resources).

XII. Global Climate Change

MENA region is among the most vulnerable in the world to the potential impacts of climate change [38].The most significant changes in MENA region which already suffers from aridity (Fig. 4), recurrent drought and water scarcity are the increased average temperatures, less precipitation and more erratic, and sea level rise (SLR).

Records of temperature highs in 2010 show that five countries from MENA region including Kuwait (52.6 °C), Iraq (52.0 °C), Saudi Arabia (52.0 °C), Qatar (50.4 °C), and Sudan (49.7 °C) were among the top 19 countries effected [39]. The drought will affect the agricultural life and water supply at MENA region [40]. This is due to the fact, that most of the agricultural areas of MENA region are rain-fed [41]. For example about one-third of Iraq's cereal production (wheat and barley) is produced under rain-fed conditions at northern part of Iraq [42].

CGCM3.1 (T47) model with A2 scenario was chosen in order to simulate the average monthly temperature and rainfall on Iraq for the historical period 1900-2009, and for mean future projected temperature and rainfall till the period 2099 [43]. The results of simulation and prediction are shown in Fig. 5 and 6.

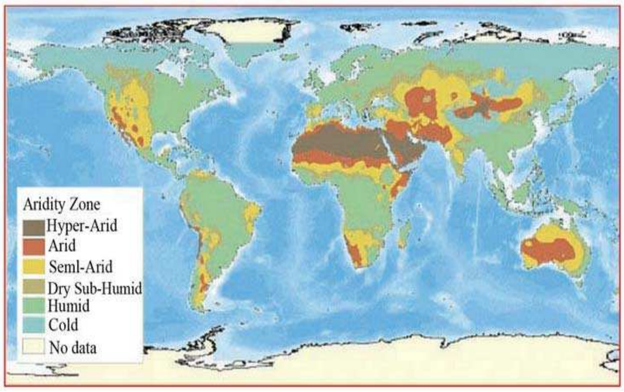

Fig. 4 Aridity zones of the world [48]

A comparison between the values of annual temperatures (Fig. 5) shows that the increase of annual temperature was limited during the historical period 1900-2009, but the increase is more noticeable during the period 2020-2099. Rainfall trend (Fig. 6) expects that rainfall will increase till 2039 followed by decrease till 2099. The future predicted part in Fig.6 shows that an increase and decrease of the total summation of the rainfall (average annual) through the four periods of 2020-2039 (175.41mm), 2040-2059 (150.96mm), 2060-2079 (134.59mm), and 2080-2099 (135.31 mm) in Iraq.

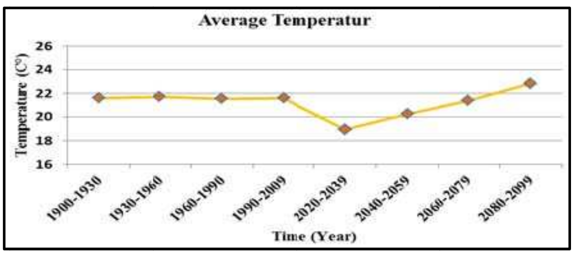

Fig. 5 Average annual temperature over the historical and future study periods

It should be mentioned however, that the general trend is decreasing but annual rainfall is expected to highly fluctuate round the general trend.

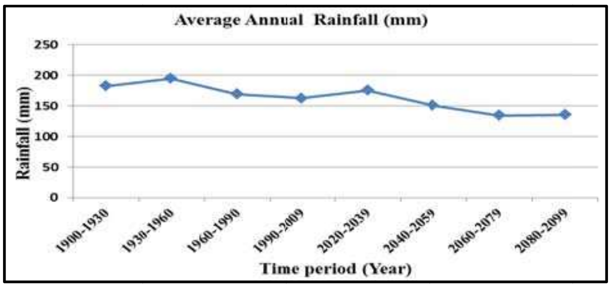

Fig. 6 Average annual rainfall (mm) over the study historical and future periods

Dust storms may lead to aerosol pollution which change cloud properties and then reduce precipitation in the polluted region. In the desert land, the limited precipitation will help to produce more dry soil which leads to produce more dust in the air [45]. Reference [46] indicated that there are eleven factors that affect the frequency of dust storms phenomenon in Iraq, the most factor affective was relative humidity while the evaporation and clouds quantity were the lowest. For the past few years, Iraq was experiencing plenty of dust storms (Fig. 7 and 8).

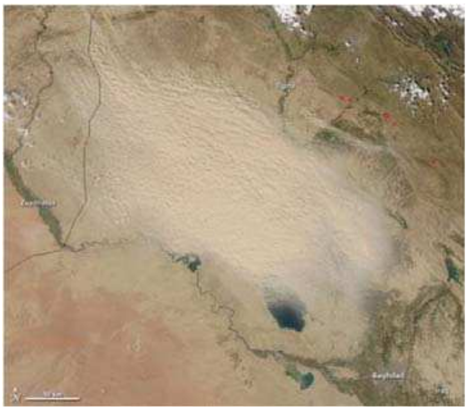

Fig. 7 An aerial view of a dust storm. Note it had started just in the north-western borders of Iraq (March 3, 2011) [47]

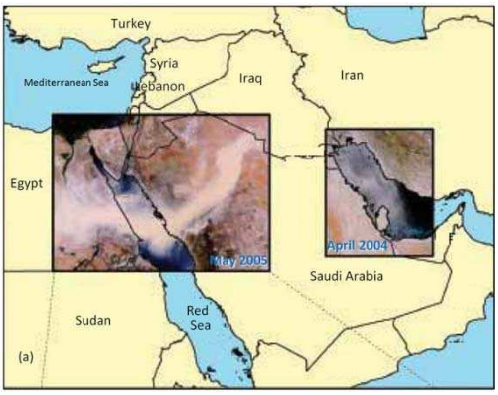

Fig. 8 A thick dust moving from southwest of Iraq passing Saudi Arabia and then the Red Sea to reach Egypt (in 2005) [48]

XIII. Water Policies of Riparian Countries

All landowners whose property adjoins a body of water or river have the right to make reasonable use of it and the right to access for swimming, boating and fishingas it flows through or over their property. If water is lacking to satisfy all landowners, rations are generally fixed in proportion to frontage on the water source [49].

Many studies tried to draw figures for the water requirement for Turkey, Syria and Iraq (the riparian countries) from Euphrates and Tigris Rivers. Estimates for required water from Euphrates River to irrigate all the cultivated lands along it are 15.7, 11 and 13 km^3 for Turkey, Syria and Iraq respectively. It should be mentioned however that, other authors had cited different figures for the water requirement for Turkey, Syria (7.95 km^3) and Iraq (19 km^3) [50].

During the 1970s Syria and Turkey started to construct dams on the Euphrates and Tigris Rivers which caused a major decrease in the flow of the rivers [4], [16] as well as deterioration of the quality of their water [51].

XIV. Turkish Water Projects (GAP Project)

In 1977, the Turkish government set a huge project referred to as Southeastern Anatolia Project (GAP) [52]. The component of the project includes 22 dams and 19 hydraulic power plants which are supposed to irrigate 17000 km^2 of land [53]. The project is supposed to develop the southeastern provinces which cover 9.7% of the total area of Turkey which forms 20% of the agricultural land of the country. The overall volume of water to be captured is about100 km^3 (while the required water to irrigate the supposed area is about 29 km^3) which is three times more than the overall capacity of Iraq and Syrian reservoirs. Despite the continuous claims of the Turkish Government that GAP is purely development project, it seems that there are number of internal and external goals involved [54]-[58]. When GAP project is completed, then 80% of the Euphrates water will be controlled by Turkey [59]–[61].

When Ilisu dam on Tigris River is operating then, Iraq will receive only 9.7 km^3[74]. This implies that 47% of the river flow will be depleted. This in turn means that 696000 ha of agricultural land will be abandoned due to water scarcity [16]. Recent reports state that Tigris and Euphrates rivers will be completely dry by 2040 [24].

XV. Syrian Water Projects

Syria built three main dams along Euphrates River with a total storage capacity of 16.1 km^3 for irrigation and electricity generation.

Syria used to receive 21 km^3/year of the Euphrates water prior 1990 which dropped to 12 km^3 in 2000 onward (40% reduction). As far as Iraq is concerned, the volume of water received dropped from 29 km^3 before 1990 [63] to 4.4 km^3 (85% reduction) now. Due to this reduction in water shares, the agricultural used land in both countries had been reduced from 650000 ha to 240000 ha. In addition, the quality of water deteriorated due to back water irrigation directed toward the main channel in its upstream reaches [16].

Syria is planning to double its irrigated area (740000 ha). This will increase its water withdrawal from 5 km^3 to 9 km^3 [25].

XVI. Iranian Water Projects

In addition to the above, Iran had recently diverted all perennial valleys running toward Iraq inside Iran. Furthermore, water of Karkha and Karun Rivers had been almost completely diverted inside the Iranian borders and no water is contributing to Shatt Al-Arab River from these tributaries (Fig. 9).

Shatt Al-Arab River is formed after the confluence of Tigris and Euphrates Rivers at Qurnah in Iraq. Karun and Karkha Rivers usually contributes 24. 5 and 5.8 billion cubic meters (BCM) annually respectively. This forms about 41% of the water of Shatt Al-Arab. The decrease of the water discharge of the Tigris and Euphrates Rivers and the diversion of the water of Karun and Karkha tributaries caused the salinity to increase to 2408 mg/l in 2011[64].

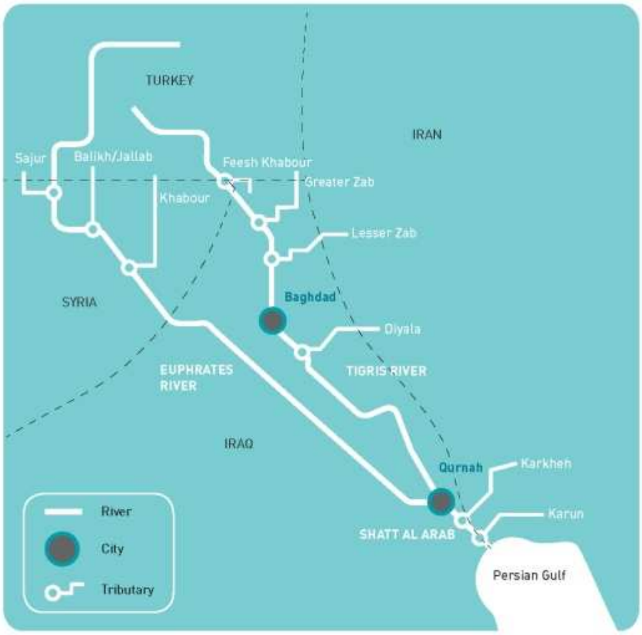

Fig. 9 Schematic diagram of Tigris, Euphrates and Shatt Al-Arab Rivers system [64]

XVII. Water Resources Mismanagement

World water crisis is believed to be due to the fact that water of the world is running out. But it is not absolute scarcity; in fact, it is mainly one of mismanagement, such as, inefficient and inequitable irrigation schemes, leaky water mains and wasteful overconsumption [65].

Freshwater mismanagement is widespread in developing countries. Iraq suffers from many problems in its infrastructures whether those related to water losses through conveying or distribution networks, water overuse in old irrigation schemes, and pollutes fresh water sources by back water from irrigation and sanitation.

The main factors affecting water resources management in Iraq are as follow:

XVIII. Potable Water Distribution Networks

Reference [66] indicated that 79% of the population has access to drinking water (92% in urban and 57% in rural areas). The same survey showed that 21% have no access to drinking water, 16% have daily problems, 7% have weekly problems, 15% have less than weekly problems and only 41% have reliable source.

The efficiency of the distribution network is very poor (32%) [25]and it is deteriorating with time. For this reason water allocation per capita is decreasing with time since 1980 [67].

Quality of drinking water does not meet WHO standards or Iraqi national water quality standards [68]. Leakage, in both potable water distribution and sewage systems causes high contamination. In view of this situation large number of the population are suffering from various disease [24], [66], [69].

XIX. Sanitation

About 92% of the population of Iraq are living in households using improved sanitation and 82% of this category use flush toilets connected to sewage systems or septic tanks or latrines [66]. Most of the sewage treatment plants and septic systems do not function properly and as a result, there is an overflow of the effluent into the environment [70].

Only 14 cities out of 252 urban centres have a wastewater treatment plant [25]. Wastewater treatment capacity reaches 350000 m^3/day and this serves 8% of the population. Most if not all the sewerage systems required replacement, rehabilitation and upgrading. Leakages in wastewater systems threaten the public health as well as contaminated groundwater sources.

It should be mentioned however that 70% of the sewage water is discharged untreated directly to the rivers [25]. This value of effluent estimated over 0.5 MCM/day.

XX. Irrigation Schemes

Almost 60 percent of all draw freshwater in the world consumed in irrigation uses [71]. Different irrigation schemes are used along the history of agriculture; some are suitable and efficient for certain conditions (crops requirements, available water, topography... etc.).

Three major irrigation schemes (surface, sprinkle and drip) are mainly used in Iraq with different presence. Farmer’s awareness of water scarcity, financial and technical assistance of the government to the agricultural sector and the size of the privet investments are the factors that influence the growing use of more efficient irrigation techniques in Iraq.

Water consumption in surface irrigation, which is one of the oldest irrigation techniques ever used, is less efficient and water losses in such system are large compared to other systems. In this system, water is lost by leakage, evaporation and percolation. Problems of waterlogging and high salinity in soil are very common if the drainage system is inefficient [72].

Low-pressure sprinkler system is more efficient where much less water is lost due to evaporation and air-blown losses [73].Drip irrigation is much more efficient than traditional systems. It increases crop yields and decreases water, fertilizer, and labour requirements with proper management [71].

XXI. Drainage and Salinity

The major aims of drainage are to prevent waterlogging, control salinity and acidity as well as increasing cultivable areas [74]. Flushing the soil after every growing cycle reduces the level of the accumulated salts. But the drained water from the agricultural lands usually contains high amount of leached salts and over need fertilizers. Excessive use of chemical fertilizers without investigating the real requirements of the soil works as a source of pollution of water resources when the drained water returns to the rivers.

When the quality of irrigation water is deteriorated (saline water), the productivity of crop yields will be low and the range of crops diversity will be narrow. Even if the quantity of irrigation water is increased (which is already not available) to reduce the osmotic pressure on the plants, the results are worse on the soil by adding more salts.

The expansion of drainage of irrigated lands in Turkey and Syria caused deterioration of the water quality of the rivers. This can be noticed from the levels of the salinity or Total Dissolved Solids (TDS) in Euphrates River at the Syrian-Iraqi borders. Where TDS level now is 600 mg/l which is already higher that the recommended level for irrigation (Fig. 10) and it increases to more than 1200 mg/l (minimum) downstream at Samawah [25], [33]. Tigris River is in better situation relative to the Euphrates River (Fig. 15). TDS values of the Tigris water at the Turkish Iraqi border are 280 - 275 mg/l and it reaches more than 1800 mg/l in Basra [33]. The situation might be worse on the tributaries where TDS values in the Diyala River reaches 3705 mg/l [75].

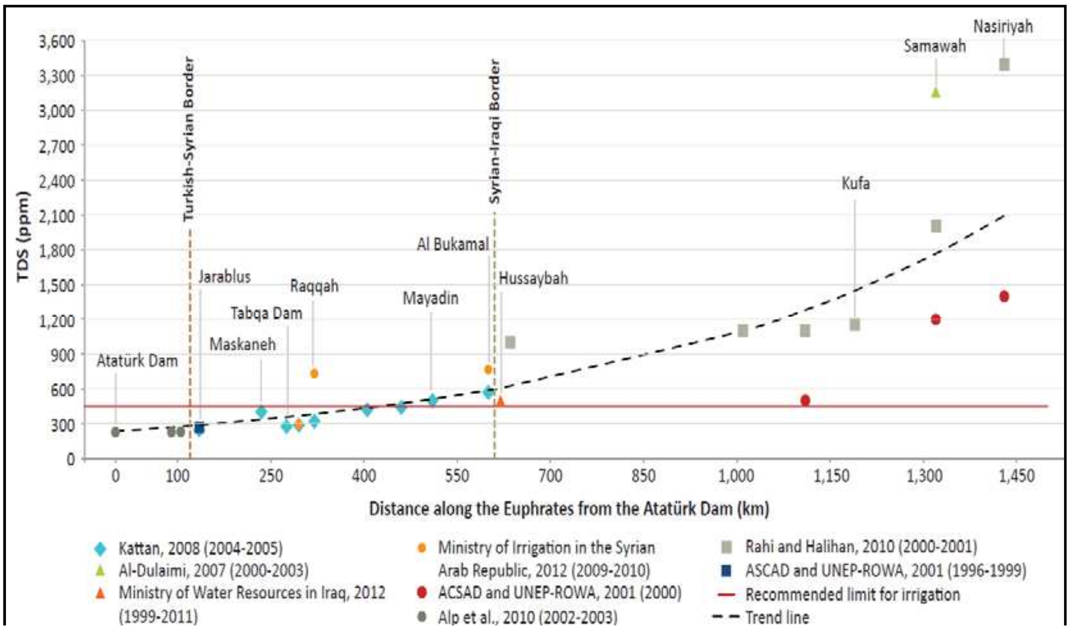

Fig. 10 Salinity variation along Euphrates River since 1996 [64]

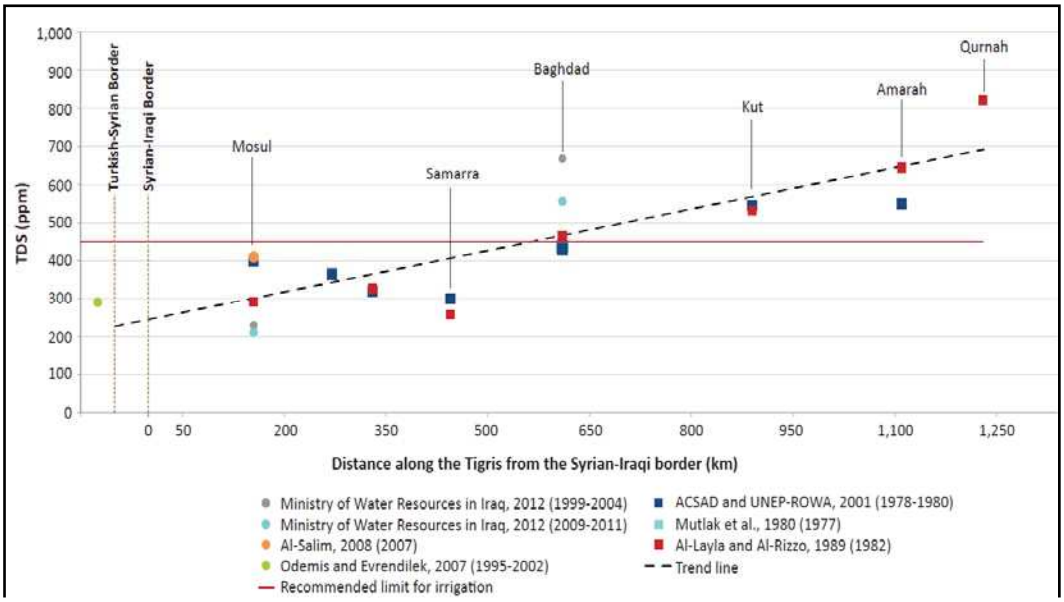

Fig. 11 Salinity variation along Tigris River before 1983 and after 1995 [64]

Inside Iraq, the source of most of the back irrigation water is from irrigation projects (1.5 million ha) that are located in the central and southern parts of the country. Back irrigation water from these projects is directed to the main outfall drain which drains to the gulf in order to reduce the soil salinity [76]. Even with these drainage measures, the salinity increases along the courses of the two rivers in conjunction with decreases in their discharges (Fig. 12 and 13), which represents overstress for the agricultural sector especially in the southern part of Iraq. Significant increase in Tigris River's salinity starts from Baghdad downward due to the negative effect of the feedback from Tharthar depression toward Tigris River (Fig. 14). Recent estimates indicate that 4% of irrigated areas are severely saline, 50% are of medium salinity and 20% are slightly saline [4].

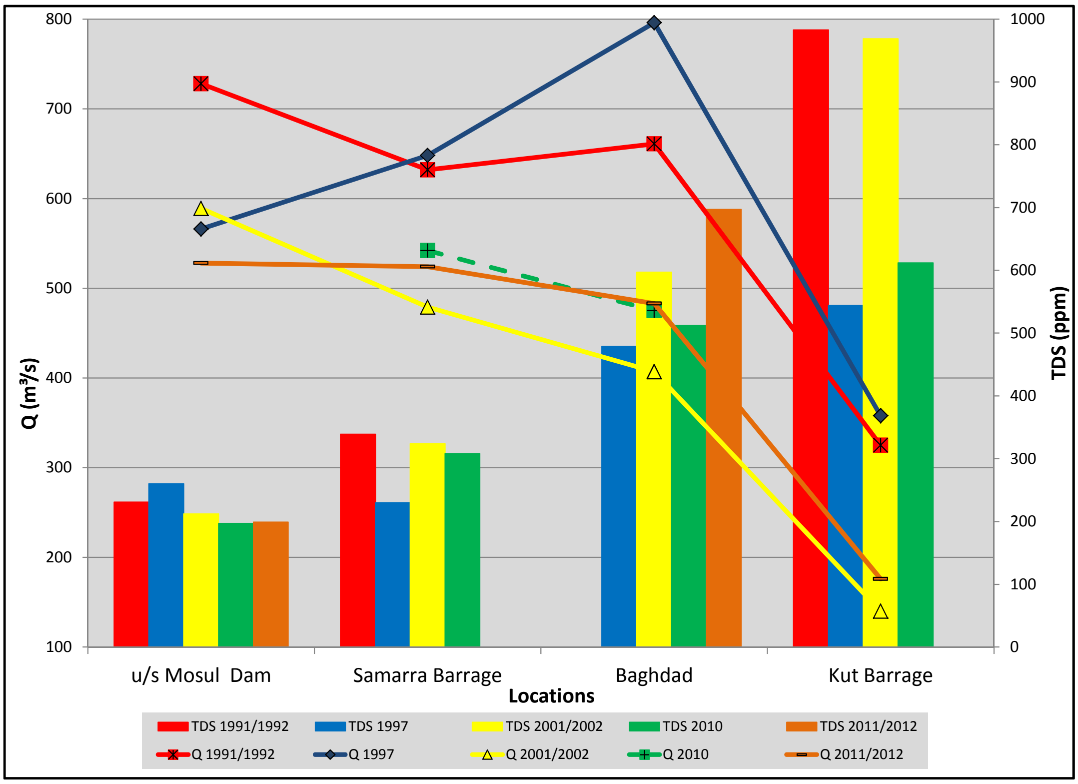

Fig. 12 Variation of Discharges (Q) and Total Dissolved Solids (TDS) along Tigris River inside Iraq

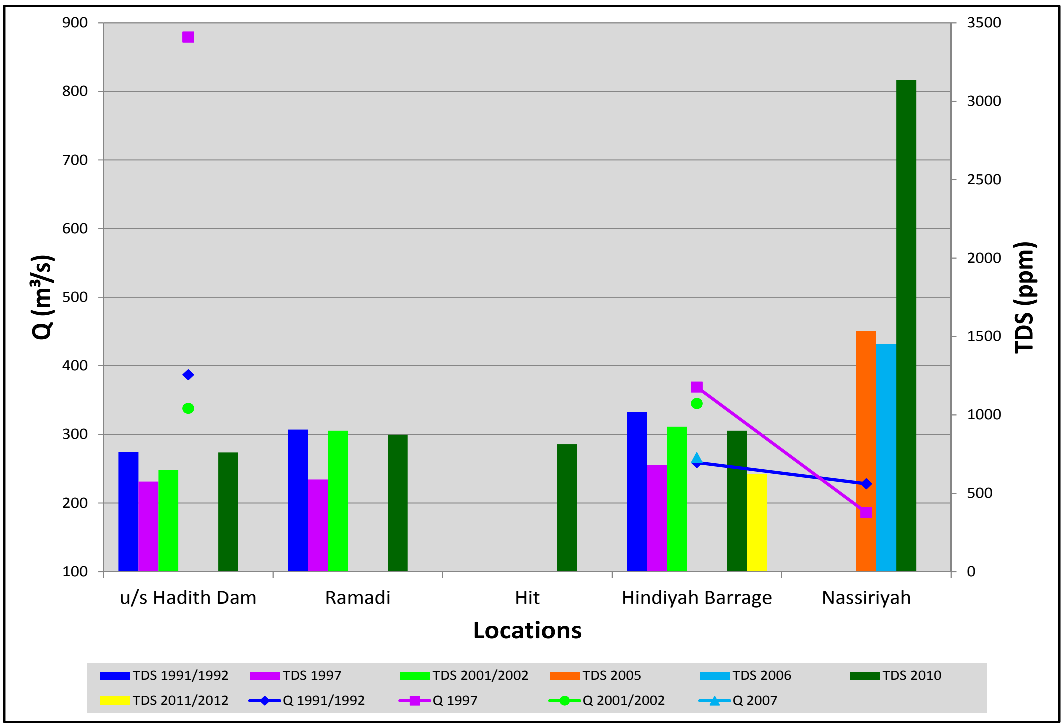

Fig. 13 Variation of Discharges (Q) and Total Dissolved Solids (TDS) along Euphrates River inside Iraq

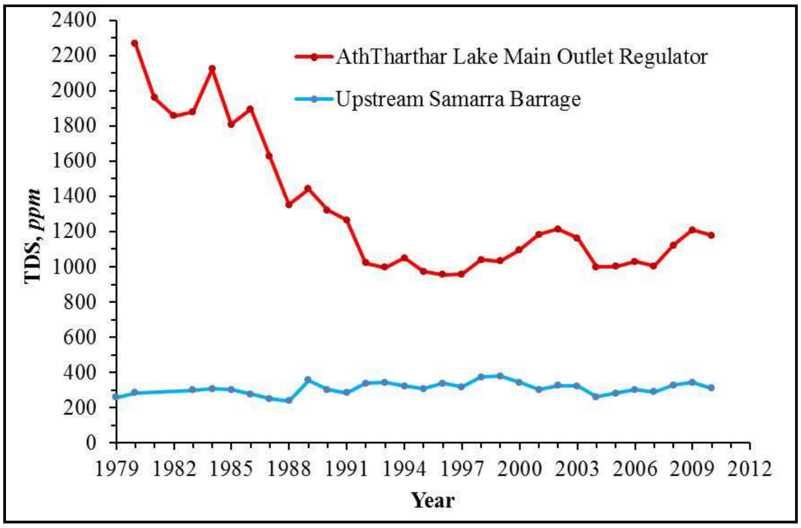

Fig. 14 Total Dissolved Solids concentration at Samarra Barrage (the supplying point to Tharthar depression) and at the outlet of the depression [77]

XXII. Desertification

Large areas of Iraq are facing serious problems of desertification due to declining water flow, repeated frequency of drought [78] and increasing water salinity. During the Gulf wars, huge number of palm and other kinds of trees were destructed which were acting as natural barriers against the expansion of desertification. At least 75% of the area of Iraq has been substantially affected by desertification (Fig. 15) [79].

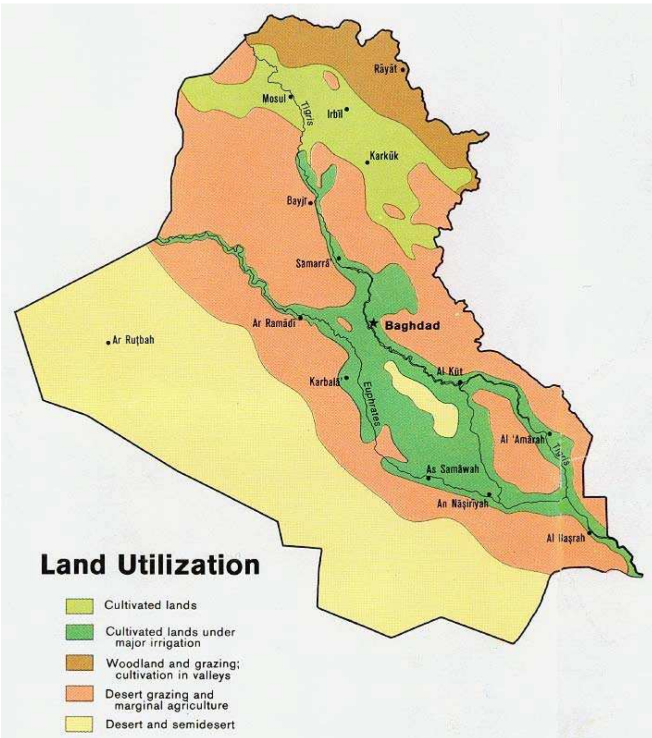

Fig. 15 Land utilization in Iraq [80]

Between 2007 and 2009, 40% of cropland area experienced reduced crop coverage and 20,000 rural inhabitants left their homes [68].

Iraq is facing water scarcity problem due to various factors. Some of these factors cannot be solved independently or in short term actions or planning like global climatic change and abusive water policies by riparian countries. In addition, these themes are to be addressed with regional and international cooperation.

XXIII. Conclusions

The increasing of climate temperature and decreasing precipitation reduces the quantity of the internal water resources and increase the desertification in Iraq which already reached 75%.

Turkish water projects (GAP, Ilisu…etc.) will control 80% of the Euphrates water and 47% of Tigris River flow to Iraq. At least, 696000 ha of agricultural land will be abandoned influenced by these projects. The diversion of the water of Karun and Karkha tributaries inside the Iranian borders caused very high increase of the salinity in Shatt Al-Arab.

About 85% of the withdrawal water is consumed in agriculture. Where, only 1.9 million ha out of 4 million ha of arable land are cultivated in recent years. Even with the degradation in the productivity of the industrial sector, the hydropower consumption including the evaporation from reservoirs reaches 10 BCM/annum. A plan to reduce the domestic consumption from 350 to 200 liter/capita/day is proposed parallel with other plans to supply potable water to 91% of the population by 2015.

Other issues of water scarcity problem can be solved independently in relatively short period of time. These are related to mismanagement of water resources inside Iraq, such as water losses in the distribution networks, overuse of water by inefficient irrigation systems, pollute water resources by sewage feedback, increase water salinity…etc.

Iraq suffers from many problems in its infrastructures whether those related to water losses through its water distribution networks, water overuse in old irrigation schemes, pollutes fresh water sources by back water from irrigation and sanitation.

The efficiency of the distribution network is very poor (32%) and it is deteriorating with time. Quality of drinking water does not meet WHO standards or Iraqi national water quality standards and the high contaminated leaked sewage water threatens potable water networks.The estimated effluent that discharged untreated directly to the riversis over 0.5 MCM/day.

The expansion of drainage of irrigated lands in Turkey and Syria will cause a further deterioration in the water quality of the rivers. The TDS level of Euphrates River at Syrian-Iraqi borders is 600 mg/l which already higher that the recommended level for irrigation and increases to more than 1200 mg/l (as minimum) downstream at Samawah. Tigris River is relatively better than Euphrates at the borders, but the salinity increases significantly starting from Baghdad downstream by the influence of the feedback from Tharthar depression which is highly saline. The situation is worse on Diyala River where its TDS level reaches 3705 mg/l.

It had been noticed by various researchers and organizations that the problem is becoming more alarming with time where the gap between supply and demand is increasing.

The supply of Tigris and Euphrates Rivers will be 43 and 17.61 BCM in 2015 and 2025 respectively while the demand is estimated to be between 66.8 to 77 BCM respectively. In addition to all of this, it had been reported that Tigris and Euphrates discharges will continue to decrease with time and they will be completely dry by 2040.

XXIV. Recommendations

All the previous facts enforce the Iraqi government to take quick, prudent and firm action. The action should address the following points:

A. *Strategic Water Management Vision Should Include*

- Integrated long term “National Water Master Plan” is to be designed and put in practice immediately. Such plan should be the outcome of the work of the Ministry of Water Resources, Ministry of Municipality and Public Work, Ministry of Agriculture, Water Resources staff at Universities, private sector, NGO’s and representatives of regional and International organizations concerned.
- Rehabilitation of infrastructure which should cover water treatment plants, power plants as well as pumping stations.
- Public awareness program is vital so that all the people appreciate the serious problem they are facing.
- Defining institutional agenda including employment and training.
- Supply and demand should be considered. In this context new non-conventional water resources (water harvesting, treated waste water) are to be used.
- Private sector is to be enhanced to be involved in the investment.
- Inter-ministerial coordination is very important. This will save time, effort and money. More decentralization including budget in irrigation, water supply and sanitation sectors are to be practiced.

B. *Regional Cooperation and Coordination*

- Defining institutional and technical needs for cooperation.
- Cooperation on trans-boundary resources. Iraq, Turkey, Iran and Syria are to coordinate their efforts to reach reasonable agreements with riparian countries on water quotas.
- UN organizations (e.g. UNEP, UNDP, UNESCO etc.) and International institutions and organizations (FAO, WMO etc.) and universities should be asked to give their experience in this matter.
- Cooperation with other countries, organizations and companies in developed countries to help in giving advice for successful patterns of water management to get benefit from their experiences.

C. *Irrigation and Agriculture*

- The most efficient irrigation techniques that is suitable for the local conditions of soil, water availability and quality, crops … etc. should be used. Traditional irrigation techniques should be abandoned because they cause waste of water. Drip irrigation is convenient for orchards using salty water while sprinkler irrigation is suitable for grains and both of them are more conservative than surface irrigation.
- Maintaining and developing the conveying systems to reduce the losses and increase conveying efficiency. Closed conduits are considered as conveying system that reduces evaporation losses and infiltration losses. It is also conservative in land use and protects irrigation water from contact with saline water Table.
- Improving the drainage systems of cultivated lands to improve soil leaching and reduce soil salinity. Also considering the most effective modern drainage techniques such as perforated pipe drainage system in collecting and FITO treatment in treating drainage water. Return drainage water to the rivers directly should be avoided and drainage projects are to be implemented (like the main outfall drain in the areas lying outside the service zone of this project).
- Reduce using chemical fertilizers and pesticides that can decrease the water quality when back irrigation water discharges to the rivers.
- Using FITO treatment with drainage water and sewage water to reuse it in restoring the marshes as well as the available fresh water.
- Institutions should reflect decentralization, autonomy and farmer empowerment.
- Enhance private investment in the agricultural sector.
- Public awareness program for farmers to use new suitable techniques in irrigation (drip irrigation and sprinkler irrigation).
- Partially built dams should be completed and measure is to be taken to build the suggested dams and irrigation projects. This will increase the storage capacity of dams about 27 km^3.

D. *Water Supply and Sanitation*

- Improving the efficiency of drinking water distribution networks specially diversion and supply down to the point of use which is most cost effective.
- Repairing the leakages from the sewerage networks and improving their efficiencies to prevent any source of pollution from these networks.
- New efficient projects should be put in practice to prevent water losses and pollution.

- Improving services e.g. using ICT.
- Install new sewerage systems to connect the neighbors that not serviced and convey the sewage water to the sewage treatment plants to reduce the pollution of groundwater from the leakage from old septic tanks.
- Install new sewage treatment plants to satisfy the increased consumption of domestic sector. Membrane bioreactor technology can be used in these new treatment plants to reuse the treated water.

E. Research and Development

- Establishing a comprehensive data bank which includes reliable climatological, hydrological, geological, environmental and soil data to be used by researchers and decision makers.
- Conducting research to import new technologies in water resources and agriculture which suites Iraq environment.
- Non- conventional methods to augments water recourses are to be used. We believe that water harvesting techniques can be very effective and are relative cheap cost wise.
- Carry out training programs for technicians, engineers and decision makers about up to date technologies.
- Execute pioneer projects which help in augmenting water resources, developing land productivity, minimizing water use and consumption.
- Setting the outlines of public awareness programs both for water use and agricultural activities.
- Giving advice to universities and institutes to set special courses in arid region hydrology.
- Awarding of prizes for new innovations, pioneer researches and smart ideas in water resources and their management.
- Groundwater resources are still not exhausted, big efforts should spend to manage prudent using of this source and protect it from all kinds of pollution.

REFERENCES

[1] Rogers, P. and Lydon, P., eds., 1994, Water in the Arab World, Massachusetts, Harvard University Press, USA.

[2] Biswas, A.K., ed., 1994, International Waters of the Middle East–From Euphrates, Tigris to Nile, Oxford University Press, Bombay, India.

[3] 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 21st Century 3-6 June, Paris.

[4] Al-Ansari, N., 2013, Management of Water Resources in Iraq: Perspectives and Prognoses, J. Engineering, V.5, 8, 667-68.

[5] Cherfane C. and Kim S., 2012, Arab region and Western Asia, UN-ESCWA, in Managing Water under Uncertainty and Risk, UN World Water Development Report 4, Chapter 33.

[6] Barr, J., Grego, S., Hassan, E., Niasse, M., Rast,,W. and Talafré, J., 2012. Regional challenges, global impacts, in Managing Water under Uncertainty and Risk, UN World Water Development Report 4, Chapter 7.

[7] Hiniker, M., 1999, Sustainable Solutions to Water Conflicts in the Jordan Valley. Geneva: Green Cross Internationa.

[8] Sadik, A. and Barghouti, S., 1994, The water problems of the Arab world: Management of scarce water resources, In Rogers, P. and Lydon, P. (eds.), Water in the Arab World. Massachusetts, USA: Harvard University Press. 4-37.

[9] Postel, S., 1992, Last Oasis – Facing Water Scarcity, World watch Institute WW Norton & Co., New York.

[10] 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. Geneva: Green Cross International. 11-1.

[11] Bazzaz, F., 1993, Global climatic changes and its consequences for water availability in the Arab World, in Roger, R. and Lydon, P. (Ed.), Water in the Arab Word: Perspectives and Prognoses, Harvard University, 243- 252.

[12] Al-Ansari, N., Salameh, E. and Al-Omari, I., 1999, Analysis of Rainfall in the Badia Region, Jordan, Al al-Bayt University Research paper No.1, 66p.

[13] 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, last access: 23-August-2013.

[14] Chenoweth, J., Hadjinicolaou, P., Bruggeman, A., Lelieveld, J., Levin,Z., Lange, M., Xoplaki, E. and Hadjikakou1, M., 2011, Impact of climate change on the water resources of the eastern Mediterranean and Middle East region: Modeled 21st century changes and implications, J. Water Resources Res.,V. 47, W06506, 1-18.

[15] Voss, K., Famiglietti, J., Lo, M., de Linage, C., Rodell, M. and Swenson, S., 2013, Water Resources Research, V.49, 904-914.

[16] Al-Ansari, N. and Knutsson, S., 2011, Toward Prudent management of Water Resources in Iraq, J. Advanced Science and Engineering Research, V. 1,53-67.

[17] Al-Ansari, N., Knutsson, S. and Ali, A., 2012, Restoring the Garden of Eden, Iraq, J. Earth Science and Geotechnical Engineering, V. 2 , No. 1,53-88

[18] Nimah, M., 2008, Water Resources, Report of the Arab Forum for Environment and Development, in Tolba, M.K. and Saab, N.W., Arab Environment and Future Challenges, Chapter 5, 63-74.

[19] The Economist, 1993, Pocket world in Figures, 3rd Edition, the Economist Books Ltd. London, p. 82.

[20] Al-Ansari, N., Abdellatif, M., Ali, S. and Knutsson, S., 2014a, Long Term Effect of Climate Change on Rainfall in Northwest Iraq, Accepted Central European Journal of Engineering.

[21] Al-Ansari, N., Abdellatif, M., Al-Khateeb, M. and Knutsson, S., 2014b, Desertification and Future rainfall trends north Iraq, 8th edition of the international scientific Congress of GIS and geospace applications Geotunis 2014 April 02 to April 06, 2014 Tunis/ Hammamet

[22] Al-Ansari, N.A., Abdellatif, M., Zakaria, S., Mustafa, Y. and Knutsson, S., 2014c, Future Prospects for Macro Rainwater Harvesting (RWH) technique in north east Iraq, J. Water Resource and Protection, V. 6, No. 5, 403-420.

[23] Al-Ansari, N.A., Abdellatif, M.,Ezeelden, M.,Ali, S. and Knutsson, S., 2014d, Climate Change and Future Long Term Trends of Rainfall at North-eastern Part of Iraq, Accepted J. Civil Engineering and Architecture.

[24] United Nations (UN), 2010, Water Resources Management White Paper, United Nations Assistance Mission for Iraq, United Nations Country Team in Iraq, 20 p. http://iq.one.un.org/documents/100/white%20paper-eng_Small.pdf

[25] World Bank, 2006, Iraq: Country Water Resources, Assistance Strategy: Addressing Major Threats to People's Livelihoods, Report no. 36297-IQ, 97p.

[26] Al-Ansari, N., Assaid, H. and Salim, V., 1981, Water resources in Iraq, J. Geol. Soc., V15, pp35-42.

[27] University of Victoria, 2010, Dams in the Tigris Euphrates river basins, online map, http://hdl.handle.net/1828/2400 , last access: 29-January-2013.

[28] Al-Shahrabaly, Q.M., 2008, River discharges for Tigris and Euphrates gauging stations, Ministry of Water Resources, Baghdad (in Arabic).

[29] General Commission for Dams and Reservoirs, 2009, Official website, Iraqi Government, http://www.mowr.gov.iq/arabic/dams/small%20dams%20under%20dicition.php

[30] Iraqi Parliament, 2009, Dams of Iraq, Official website of the Iraqi Parliament, http://www.irqparliament.com/vb/showthread.php?t=30387

[31] Ministry of Water Resources-Iraq, 2014, the strategic study for Iraqi water resources and lands, in Arabic, http://www.mowr.gov.iq/?q=node/902, last access: 26-June-2014

[32] World Bank, 2014, Country at a Glance: Iraq, http://data.worldbank.org/country/iraq, last access: 16-June-2014.

[33] Al-Ansari, N., 2005, Applied surface Hydrology, Al al-Bayt University publication.

[34] Ministry of Municipalities and Public Work-Iraq, 2011, Water demand and supply in Iraq: Vision, Approach and Efforts, GD for water http://www.mmpw.gov.iq/

[35] Stockholm International Water Institute (SIWI), 2009, Water resources in the Middle East, Background Report to Seminar on Water and Energy Linkages in the Middle East, p. 9.

[36] Ministry of Planning-Iraq, 2013, National Development Plan 2013-2017, Baghdad.

[37] Ministry of Industry and Minerals-Iraq (MIM), 2008, Industrial Investment Opportunities in Iraq, Investment Department, Baghdad.

[38] Arab Forum for Environment and Development (AFED), 2009, Impact of Climate Change on Arab Countries, ISBN: 9953-437-28-9, http://www.afedonline.org.

[39] Verner, D. and El-Mallah, F., 2011, Adaptation to a Changing Climate in the Arab Countries MNA Flagship Report. Sustainable Development Department, Middle East and North Africa Region.

[40] Medany M., 2008, Impact Of Climate Change on Arab Countries, in Tolba, M.K. and Saab, N.W., Arab Environment and Future Challenges, Chapter 9, 127-136.

[41] Oweis, T. and Hachum A., 2004, Water Harvesting and Supplemental Irrigation for Improved Water Productivity of Dry Farming Systems in West Asia and North Africa, "New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress, 26 Sep-1 Oct, 2004, www.cropscience.org.au, Brisbane, Australia.

[42] Food and Agriculture Organization (FAO), 2008, Irrigation in the Middle East region in figures – AQUASTAT Survey 2008 Water Report 34, 2009, ftp://ftp.fao.org/docrep/fao/012 /i0936e/i0936e08.pdf

[43] DAI CGCM3 Predictors, 2008, Sets of Predictor Variables Derived from CGCM3 T47 and NCEP/NCAR Reanalysis, version 1.2, Montreal, QC, Canada, 17 pp.

[44] World Resources Institute (WRI), 2002, Drylands, People, and Ecosystem Goods and Services: A Web-based Geospatial Analysis, http://www.wri.org.

[45] Rosenfeld, F., Rudich, Y. and Lahav, R., 2001, Desert dust suppressing precipitation: A possible desertification feedback loop, Geophysics, V. 98, 11, 5975-5980.

[46] Al-Bayati , F., 2011, Climatic conditions and their impact on the geographical distribution of the dust storms Empirical Study at Al-Anbar province, Anbar University, Journal for the Humanities, (1), 2011.

[47] Sissakian, V., Al-Ansari, N. and Knutsson, S., 2013, Sand and dust storm events in Iraq, J. Natural Science, 5,10, 1084-1094.

[48] Ghoneim, E., 2009, Remote Sensing Study of Some Impacts of Global Warming on the Arab Region. In Tolba, M. and Saab, N. (edit), Arab Environment Climate Change, Report, The Arab Forum for Environmentand Development (AFED), Chapter 3: 31-46 .

[49] Guerin, K., 2003, Property Rights and Environmental Policy: A New Zealand Perspective, New Zealand Treasury Working Paper 03/02, Wellington.

[50] Kamona, H., 2003, The effect of Turkish water policy on Iraq, AlSabah Iraqi news net, 17/05/2003, Baghdad, Iraq.

[51] Kamel, A., Sulaiman, S. and Mustaffa, S., 2013, Study of the Effects of Water Level Depression in Euphrates River on the Water Quality, J. Civil Engineering and Architecture, V.7, 2, 238-247.

[52] GAP, 2006, South-eastern Anatolia Project: latest situation, http://www.gap.gov.tr/English/Genel/sdurum.pdf

[53] Unver, I., 1997, Southeastern Anatolia Project (GAP), International Journal of Water Resources Development, V. 13, N. 4, 453 – 484.

[54] Shams, S., 2006, water conflict between Iraq and Turkey, Middle East News, http://www.mokarabat.com/m1091.htm

[55] Alnajaf News net, 2009, The GAP project and its negative implications on Iraq, http://www.alnajafnews.net/najafnews/news.php?action=fullnews&id =31503

[56] Waterbury, J., 1993, Transboudary water and the challenge of international cooperation in the Middle East, in Roger, R. and Lydon, P.(Ed.),Water in the Arab Word: Perspectives and Prognoses, Harvard University, 39-64.

[57] Alsowdani, M., 2005, GAP project and its economic negative implications on Syria and Iraq, in Al-Itehad News, http://www.alitthad.com/paper.php?name=News&file=print&sid=190 30

[58] 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

[59] Beaumont, P., 1995, Agricultural and environmental changes in the upper Euphrates catchment of Turkey and Syria and their political and economic implications, Applied Geography, Volume 16, Issue 2, April 1996, 137-157.

[60] Alyaseri, S., 2009, GAP project: Dangerous consequences on life in Iraq, Official site of Iraqi Council for Peace and Unity, http://www.marafea.org/paper.php?source=akbar&mlf=copy&sid=11 556

[61] Robertson, C., 2009, Iraq Suffers as the Euphrates River Dwindles, The New York Times, http://topics.nytimes.com/topics/reference/timestopics/people/r/campb ell_robertson/index.html?inline=nyt-per

[62] Alalaf, I., 2009, Ilisu dam and its effect on man and environment in Iraq and Turkey, Batnaya, http://www.batnaya.net/forum/showthread.php?s=9bd97aa8bfae0b9b 35554d8ce6c2787e&p=151263#post151263.

[63] Majeed, Y., 1993, The central Regions: Problems and Perspectives, in Roger, R. and Lydon, P. (Ed.), Water in the Arab Word: Perspectives and Prognoses, Harvard University, 101-120.

[64] UN-ESCWA and BGR, 2013, Inventory of Shared Water Resources in Western Asia, United Nations Economic and Social Commission for Western Asia and BundesanstaltfürGeowissenschaften und Rohstoffe, Beirut.

[65] International Rivers Network (IRN), 2003, A Crisis of Management:Real Solutions to the word’s Water Problems, Berkeley. http://www.internationalrivers.org/files/attached-files/wwf3.2-crisis_0.pdf

[66] Multiple Indicator Cluster Survey (MICS), 2007, IRAQ: Monitoring the situation of children and Women, Final Report, http://www.childinfo.org/files/MICS3_Iraq_FinalReport_2006_eng.p df

[67] World Bank, 2013, Food and Agriculture Organization, AQUASTAT, Renewable Internal,

[68] Inter-Agency information and Analysis Unit (IAU), 2011, Water in Iraq Factsheet, http://www.iauiraq.org/documents/1319/Water%20Fact%20Sheet%20 March%202011.pdf

[69] A Climate for Change, 2012, Water supply and sanitation in Iraq, http://www.aclimateforchange.org/profiles/blogs/water-supply-and-sanitation-in-iraq

[70] UNICEF, 2003, Iraq watching briefs, Water and Environmental Sanitation, 64p. http://www.unicef.org/evaldatabase/files/Iraq_2003_Watching_Briefs .pdf.

[71] United State Geographical Survey (USGS), 2005, Irrigation water use, http://water.usgs.gov/edu/wuir.html, last access: 24-June-2014.

[72] Walker, W., 1989, Guidelines for designing and evaluating surface irrigation systems, FAO IRRIGATION AND DRAINAGE PAPER 45, FAO, Rome.

[73] United State Department of Agriculture (USDA), 1991, Section 15: Irrigation, National Engineering Handbook, Soil Conservation Service.

[74] Ritzema, H. and Braun, H., 1994, Environmental Aspects of Drainage, chapter 25 in Environmental Drainage Principles and Applications, International Institute for Land Reclamation and Improvement (IILRI), Publication No. 16, 1041-1065, Netherland.

[75] Jawaheri, E. A. and Alsahmari, R. A., 2009, Water problems of Iraq and possible solutions, Journal of Law and Politics, V 2, 1, 9-61.

[76] Merry, M., 1992, Iraq builds “Third River” project despite no-fly zone and embargo, Executive Intelligence Review, Vol. 19, No. 46, Washington, D.C.

[77] Consulting Engineering Bureau (CEB), 2011, Lakes testing study, College of Engineering, University of Baghdad, Baghdad.

[78] Ali, S. M., Qutaiba, A. S., Hussan, M. and Al-Azawi, F. W., 2013, Fluctuating rainfall as one of the important cause for desertification in Iraq, Journal of Environment and Earth Science, V. 3, 2, 25-33.

[79] Al-Saidi, A. and Al-Juaiali, S., 2013, The Economic Costs and Consequences of Desertification in Iraq, Global Journal of Political Science and Administration, Vol.1, No.1, pp. 40-45, UK.

[80] Food and Agriculture Organization (FAO), 2005, Country profile: land use and water resources, http://www.fao.org/ag/agp/AGPC/doc/Counprof/Iraq/Iraq.html, last access: 24-June-2014.