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WATER RESOURCES PROBLEMS OF IRAQ: CLIMATE CHANGE ADAPTATION AND MITIGATION

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Iraq is suffering from water scarcity, and future predictions indicate that it could get worse due to changing climate. Arguably, climate change is one of the greatest challenges confronting this region it could have significant adverse effects on water resources and hence the environment and economy, particularly in the agricultural sector. This study considers possible adaptation and mitigation measures that could be undertaken in response to climate change. To overcome this problem, adaptation measures at farm and government level were conferred. Farm-level adaptation comprises adopting crop modification, soil conservation, irrigation, changing crop calendar and planting of trees. The government role is to ensure success of these adaptation measures. The government should get involved and support the farmers financially and technologically.

INTRODUCTION

Although climate change is a physical process linked with alterations in climatic variables, it also involves social processes associated with the way society evolves over time. Climate change has impacts on social, economic, and environmental systems and forms scenarios for water, food and health security (Bryan et al. 2009). The capability of mitigating and adapting to climate change depends largely on proactive approaches adopted by diverse socioeconomic groups existing in various geographical circumstances (Deressa et al. 2009). Climate change can intensify the vulnerability of the society. It may lead to aggravated water scarcity, exposure to diseases and undermining of growth opportunities.

Most of the countries in the Middle East suffer from aridity (Al-Ansari and Knutsson, 2011; Al-Ansari, 2013; Al-Ansari et.al. 2014 a,b). It is also among the most venerable regions the potential impacts of climate change (WRI, 2002; IPCC, 2007; Tolba and Saab, 2009). Future expectations, suggest that the region will suffer from higher temperatures and intense heat waves affecting inhabitants and crop yields, and affecting marine ecosystems and fisheries (Al-Ansari and Knutsson, 2011; Al-Ansari, 2013). High temperatures will cause more droughts and greater flooding, sea level rise, more intense cyclones and new areas exposed to different waterborne disease (Al-Ansari, 2013).

One of the expected effects is the sea level rise in the northern part of the Gulf that will affect the southern part of Iraq (Dasgupta et al., 2007 and Tolba and Saab, 2009). In addition, the flow of rivers is also expected to decrease by the end of 21st century (Arnell; 2004).

The impacts of climate change in northeast Iraq (Figure 1) including Kurdistan region will be varied geographically (Abbas et al. 2017a). The southern parts, which includes Daylia and Al-Adhiam, are projected to be the most impacted by droughts and shortened growing seasons (Abbas et al. 2016). Extreme droughts have categorized the region in the last three decades as shown in the finding of Abbas et al. (2017a) and the results were in line with the report of UN-ESCWA and BGR (2013). Severe drought has caused a reduction in agricultural production, especially in the areas of rain-fed crop, this in turn, caused a noticeable reduction in farmers' income. One-third of Iraq's cereal production is produced under rain-fed conditions in the north (FAO, 2008). Water scarcity can be a cause of conflict (Center for Naval Analyses, 2017). This study looks at the concept of vulnerability in the context of climate change and its three features (exposure, sensitivity and adaptive capacity), and discusses adaptation and mitigation measures that should be taken into account to respond to climate change, and thus, secure and sustain water for present and future generations at all levels.

STUDY AREA

The Tigris River has five major tributaries namely Khabur, Greater Zab, Lesser Zab, Al-Adhiam and Diyala Rivers (Figure 2). These tributaries are located in the left bank of the Tigris River and have significant contribution to Tigris flow. The catchment areas of Rivers Khabur and Greater Zab are shared between Iraq and Turkey while Rivers Lesser Zab and Diyala catchment areas are shared by Iraq and Iran (Figure 2). Al-Adhaim River catchment lies entirely in Iraq (Figure 2).

The Khbour River rises from the Eastern Anatolia Region in Turkey, flows to the south crossing Turkey-Iraqi border and then to the west through the Zakho City, finally it joins the Tigris River at a small distance to the south (Figure 2). The basin is highly mountainous, with various elevations ranging from 300 to 3300 m above the sea level. Many springs rise in the basin. Mean annual temperature is 10°C and mean annual rainfall 780 mm. Greater Zab River is the major Tigris tributary in terms of

Figure 1. Location of Iraq within the Middle East.

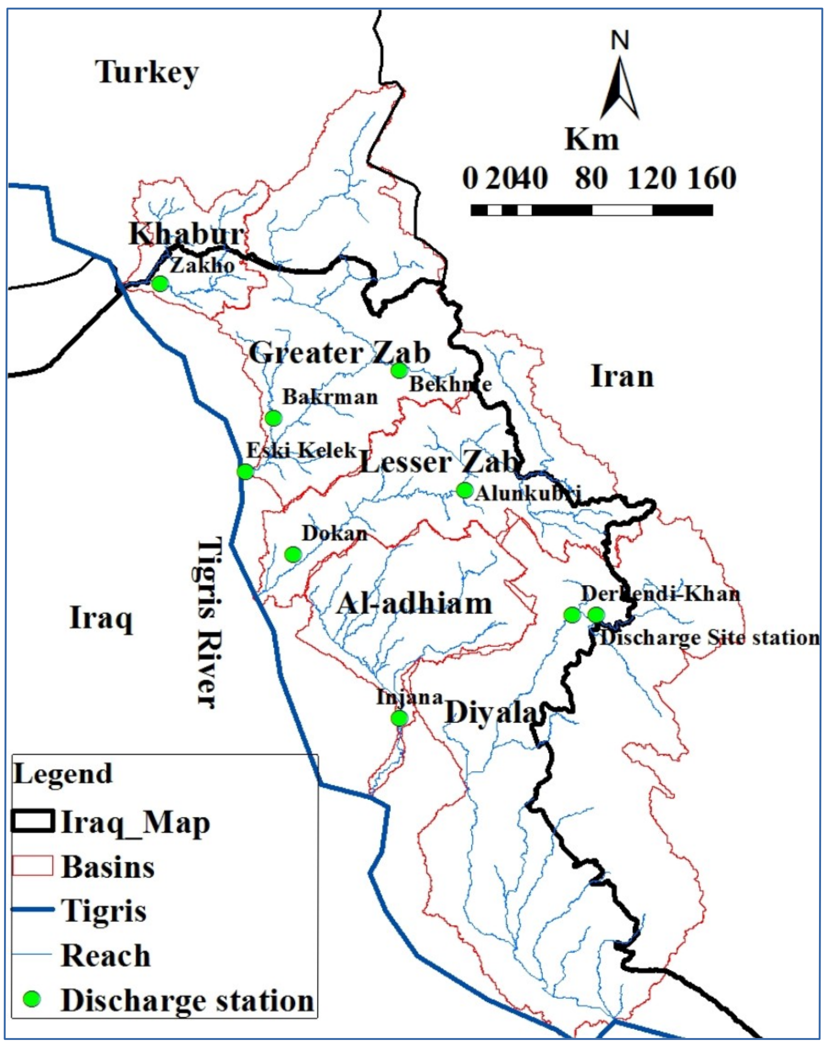

Figure 2. Location of the study area.

Table 1. Main tributaries of the River Tigris

River	Catchment (km^2)				Length (km)
	Total	Turkey	Iran	Iraq	
Feesh Khabur	6143	57%	-	43%	181
Greater Zab	26310	35%		65%	462
Lesser Zab	19,780	-	24%	76%	456
Al-Adhaim	13,000	-	-	100%	330
Diyala	33,240	-	25%	75%	445
Source of data: UN-ESCWA, 2013; Mahmoud, 2010 ; Ministry of Water Resources in Iraq, 2010; USGS, 2012					

water harvest. It originates from the Ararat Mountains in Turkey and runs in the central northern part of Iraq and then links the Tigris River South of Mosul City (Figure 2).It comprises four main tributaries, namely, Shamdinan, Haji Beg, Rawandooz and Khazir-Gormal rivers (Kafia et al. 2009). Based on some estimates, the Greater Zab contributes to 35% of Tigris flow (UN-ESCWA and BGR 2013). As Khbour Basin, Greater Zab basin is mountainous with many springs and most of the precipitation including snowfall falls in winter and spring (Abdulla and Al-Badranih 2000). Mean annual precipitation is 570 mm and mean annual temperature is 14.3^0C.

Further south of Mosul, Lesser Zab (known also as little or lower Zab) links the Tigris River. It originates from north-eastern Zagros Mountains in Iran, adjacent the Iraqi border. The Lesser Zab joins the Tigris at Fatah (Figure 2). Its average discharge contribution to the Tigris River is about 191 m^3/sec (UN-ESCWA and BGR 2013). Al-Ansari et al. (2014) state that the main contribution to Tigris discharge originates from the Greater and Lesser Zab Rivers, which is estimated about 50-60% of total Tigris flow. Mean annual precipitation is 670 mm most of which falls in winter, and spring with fewer snowfalls compared to the Greater Zab River. Mean annual temperature is 16°C.

Al-adhaim or Nahr Al Uzaym is located in northeast Iraq, rises from hilly and mountainous areas in Iraq. The basin is characterised by limited rainfall and no snowfall. The basin is fed by rainfall only. Therefore, the occurrence of effective flow is during the wet season (Al-Kadhimi et al. 2013, Abdulla and Al-Badranih 2000). It links Tigris River approximately 13 km downstream of Balad city. Mean annual precipitation for the Al-adhaim basin ranges from 200 mm, and mean annual temperature 28°C.

Diyala River originates in the Zagros Mountains in Iran, shaping the Iran-Iraq border for more than 30 km. Its main tributaries are the Sirwan, Tanjeru and Wand Rivers (Al-Faraj and Scholz 2014). The Diyala River links Tigris River 15 Km south of Baghdad. More dams have been built along the Diyala River compared to other Tigris tributaries. Three dams have been built within Iraqi part (Derbendikhan Dam, Hemrin Dam, Diyala Weir) for a multi uses. In spite the construction of these dams, no significant influence on flow volumes and flow regime has been detected (UN-ESCWA and BGR 2013). Mean annual precipitation is 420 mm and mean annual temperature is 36°C.

THE CONCEPT OF VULNERABILITY

IPCC's Third Assessment Report (TAR) defines vulnerability as the level to which a system is prone to or incapable of tackling with adverse impacts of climate change, including climate variability and extremes. The vulnerability in the context of climate change has three components, which are exposure, sensitivity and adaptive capacity (Figure 3) (Fellmann 2012). For example, farming vulnerability to climate change can be described as being exposed to increased temperatures and decreased rainfall and thus, reduction in water resources. The sensitivity of crop yields is described as how they would be affected due to these changes. Adaptive capacity is expressed as the capability of the farmers to adjust to the impacts of the exposure and sensitivity, for instance, by growing plant varieties that are more drought-resistant.

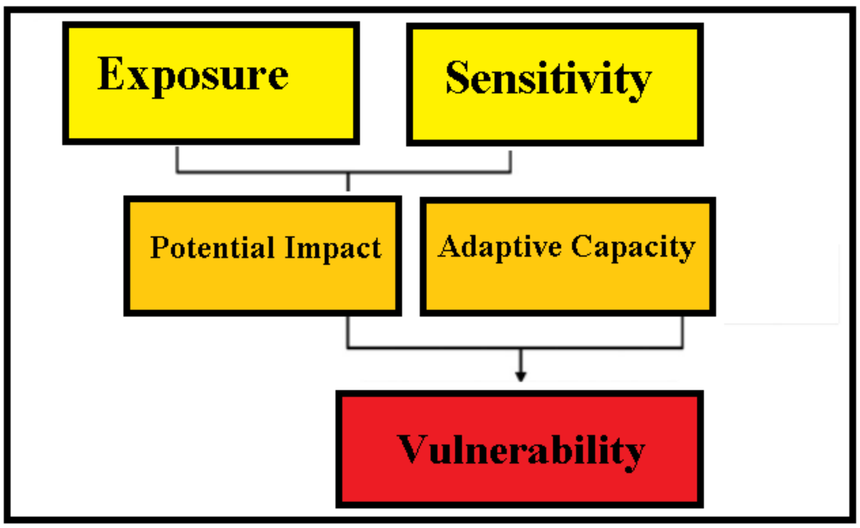

Figure 3. Vulnerability and its components (Fellmann 2012).

The possible impacts of climate change on any system can be described by both exposure and sensitivity factors. Nevertheless, it has been established that despite a system being considered as greatly exposed and/or sensitive to climate change, it does not necessarily indicate that it is vulnerable (IPCC 2007, Fellmann 2012). The reason is that both exposure and sensitivity do not account for the capability of a system to adjust to climate change, while vulnerability is the remaining effect after adaptation is conducted (Figure 3). Consequently, the adaptive capacity of any system impacts its vulnerability to climate change by controlling exposure and sensitivity (Adger et al. 2007, Fellmann 2012).

CONCEPT OF ADAPTIVE CAPACITY

Adaptive capacity has been described by IPCC (2007) as the possible ability of a system to adapt successfully to climate change. Recent studies stress the significance of socio-economic aspects for the adaptive capacity of a system, particularly underlining the essential part of organizations, authorities and management in defining the capability of responding and adjusting to climate change (Williamson et al. 2012). Consequently, the adaptive capacity of any system is essentially designed by socio-economic actions, and it affects both the social features and biophysics of a system (IPCC 2007). The main role of adaptive capacity in prompting vulnerability is shown in Figure 4.

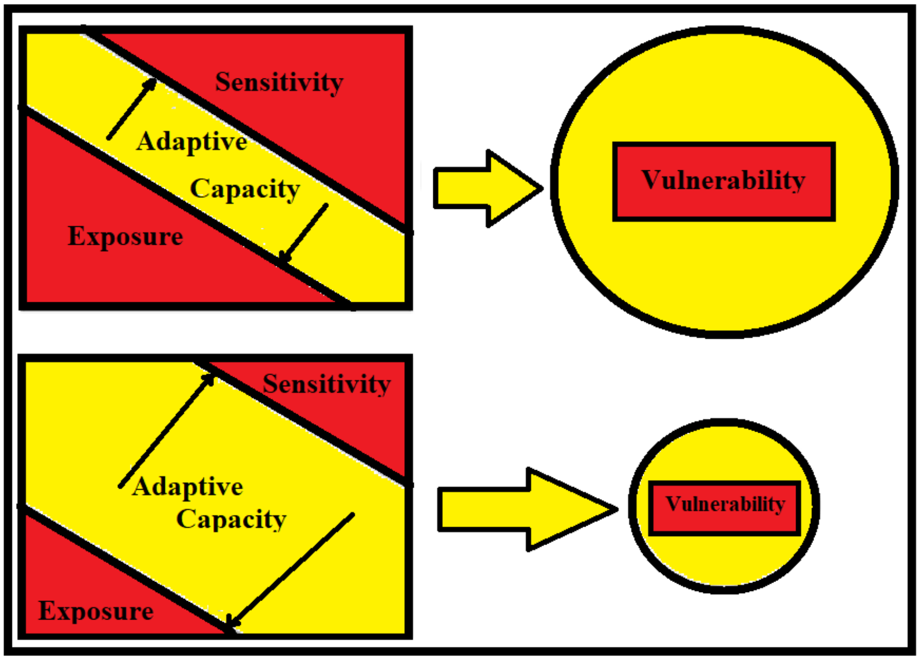

Figure 4. The basic role of adaptive capacity in influencing vulnerability (Fellmann 2012).

Iraqi's agriculture is the most fragile sector and is negatively affected by climate change (UN-ESCWA and BGR 2013). Without appropriate adaptation strategies to climate change, there is the potential to stifle economic development and aggravate already persistent difficulties (Fellmann 2012). Logically, therefore, adaptation is increasingly being considered as one of the possible strategies to diminish the adverse effect of climate change (Adger et al., 2007). Especially, a country such as Iraq needs to take into consideration the best management of water resources and agricultural activities since climate change will definitely affect agricultural production the most (Abbas et al, 2017b).

AGRICULTURAL ADAPTATION TO CLIMATE CHANGE

Generally, agricultural adaptation includes two forms of amendments in plant production systems. The first strategy is enhanced agricultural diversification through, for example, using drought tolerant varieties to temperature stresses. The second policy emphasizes plant management practices, for instance, managing critical plant growth stages by not coinciding with severe climatic events such as mid-season droughts. According to Orindi and Eriksen (2005), shifting the duration to plant growth period and altering implanting the plant growth period and altering implanting and harvesting dates is one of the plant management measures that are used in plant adaptation to climate change. The adaptation processes for this study are inferred from focus groups in the Iraqi region on examining farmers' views to climate change and their actions to respond to the adverse effects of climate change. From their answers, planting trees; crop modification; altering planting dates and soil conservation are considered as the main adaptation policies that farmers recognized as proper for rain-fed plants.

A. Adaptation to climate change at Farm level

In order to adapt and respond efficiently to climate change, farmers must initially observe that changes are occurring. Most of the farmers have noticed that the climate has become hotter and drier and the water resources have decreased significantly. The farmers' observations are in line with the results of this study. They have been struggling to adjust with such extreme weather conditions, especially for farmers who live in the south of the northern region of Iraq. The following are the adaptation measures to climate change that farmers believe to be proper approaches.

Crop Modification: Farmers grow crop varieties that have the ability to survive in harsh weather conditions. In addition, growers plant early ripening crop varieties and grow drought tolerant crops and crops that are resistant to temperature stresses. These are significant forms of plant protection against rainfall variations (Orindi and Eriksen 2005). Furthermore, planting diverse crop varieties in the same field or various plots with different crops moderates the risk of whole crop failure because diverse crops are influenced differently by climate conditions, and thereby, provides some minimum certain revenues for livelihood security (Orindi and Eriksen 2005).

Soil Conservation: Soil conservation practices are to increase productivity on-farm (Gebrehiwot and van der Veen 2013). Decreasing rainfall and increasing prolonged periods of drought, due to climate change, are highly likely to reduce crops. Increasing soil health and fertility leads to increased crop productivity, thus serve to moderate the impact of climate change on agricultural productivity.

Irrigation: Improving the usage of water irrigation has proven as efficient practices to confront unreliable rainfall conditions. Using irrigation is likely to improve agricultural productivity through complementing rainwater during dry periods (Orindi and Eriksen 2005). In addition, using irrigation systems may enable framers to grow crops such as vegetables in low rainfall fields and during the dry season and drought events. This could be considered as a substitute source of food and revenue when rain-fed crops are unsuccessful. In some parts, flood waters are impounded and utilized for developing crops after the floods have regressed (Gebrehiwot and van der Veen 2013). Generally, improvement of the irrigation water usage enables farmers to avoid crop losses in areas exposed to frequent drought (Orindi and Eriksen 2005).

Changing Planting Dates: Early and late growing plants is another policy to adapt to climate change. This approach enables farmers to protect sensitive growth stages to safeguard these critical stages from coinciding with severe climatic conditions.

Planting Trees: This strategy includes growing trees in a farm to function as a shade against severe hot weather. Growing trees and afforestation enhances agricultural productivity, as it usually contributes to climate change alleviation through improved carbon sequestration (Gebrehiwot and van der Veen 2013).

B. Adaptation measures at local government

The local governments in this region should adopt a multi-step framework to cope with the adverse impacts of climate change, which includes;

B.1. *Water Management Strategy View*

Long run integrated national water resources management, and plan should be considered by all authorities concerned including the Ministry of Water Resources, Ministry of Agriculture, Ministry of Environment and water resources experts at universities.

Rehabilitate the infrastructure of water treatment plants and irrigation and drainage pumping stations.

Use alternative water resources such as recycled waste water by establishing recycling water plants.

Increase public awareness about the climate change and its impact. Use of the social media is one of the great ways to educate the population about the adverse impacts of climate change and the importance of water conservation strategies. According to Al-Ansari at el. (2014a), many people, especially in developing countries are not aware of how climate change would affect their lives. Therefore, working with media, the governmental authorities concerned can spread their message easily and quickly. Conducting effective environmental education campaign, in addition, is of importance for raising the public awareness towards climate change issues and its mitigation practices. Furthermore, the concerned agencies and authorities can use the classrooms to introduce this subject to the students. According to UNEP, educating children and young population about environmental issues is vital to long-term achievement. This will enable them to acquire a sense of responsibility. Thus, they can play an essential role in educating their community about this issues in the absence of public awareness about the significance of appropriate water management and the impacts of governmental decisions of the long term assurance of water resources are one of the major problems in the Middle East (Al-Ansari and Knutsson 2011).

Since agriculture is the biggest water consumer in the Iraqi northeast region, educating farmers on the usage of modern irrigation systems that are appropriate for arid climate can be a great measure to avoid water losses.

B.2. ***Research and Development***

Creating an inclusive data set, which comprises weather, hydrological, topographical, soil and plant cover data that can be utilized by researchers. So, they can conduct research to introduce new technologies in water resources and agriculture, which is suitable for Iraqi environment.

Conducting modelling research that predicts the impacts of climate change on various sectors of life.

B.3. ***Regional Cooperation***

Collaboration amongst riparian countries. Iraq, Turkey, Iran and Syria should organize their efforts to find realistic arrangements among riparian countries on water asset distribution.

The UN organizations such as UNESCO and International organizations such as FAO, WMO and international universities should be involved to assist the region with their experience and expertise in this matter.

B.4. ***Irrigation and Agriculture***

Abandoning conventional irrigation systems such as furrow system to avoid wasting water and adopting effective irrigation systems that are appropriate for the types of the soils, water accessibility and quality and crop yields. For example, Sprinkler irrigation is appropriate for grains whereas drip irrigation is suitable for orchards such as grape using saline water and both practices are much better than furrow irrigation.

Improving and maintaining the transmission water systems to reduce water losses and increase transmission effectiveness. Using closed channels reduces evaporation and infiltration losses and it prevents irrigation water from coming into contact with the saline water table.

Enhancing the drainage systems of agricultural lands to improve soil percolation and reduce soil salinity.

Reducing chemical fertilizers and pesticides usage, which deteriorate the water quality.

CONCLUSIONS

Adaptation to climate change is the modification of a system to mitigate the impacts, take advantages of new opportunities and/or to cope with the consequences. It is understood that even with very strict policies to control emissions, greenhouse gases are likely to continue to grow in concentrations. As climate change impacts a whole gamut of sectors, in particular, agriculture and water, the effects are also pervasive affecting national food security and farmers' lives. Therefore, it is imperative that every country draws mitigation and adaptation policies to cope with the climate change impacts anticipated. Adaptation in the agricultural sector is vital to warrant food security and protects the source of revenue of the poor whose main livelihood derives from farming. In this study, adaptation measures at farm and government level were discussed. Farm-level adaptation includes adopting crop modification, soil conservation, irrigation, changing crop calendar and planting of trees. However, to ensure success of these adaptation measures, the government should get involved and support the farmers financially and technologically. The government should adopt a multi-step framework to cope with the adverse impacts of climate change that involves water management strategy, research and development, regional cooperation, new irrigation and agriculture technologies. The outcomes of this study may prove useful to support decision makers in planning relevant adaptation and mitigation measures, and thus decrease, the adverse impacts on water resources in the basin.

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