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Sustainable Groundwater Management for Utilization in Agricultural Projects: Al-Saqi Alternative Water Project – Karbala, Iraq

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ABSTRACT

Objective: *Groundwater represents the most important source for sustaining agriculture and maintaining socio-economic development, especially in arid and semi-arid regions such as Iraq's western desert, as surface water is scarce.* ***Method:*** *Al-Saqi Alternative Water Project in Karbala province represents one of the most important projects, which depends on GW to cultivate different types of corps, has adopted the latest agricultural technologies and smart fertilization systems under the supervision of specialized companies, so that 3 main scenarios were put forward in order to get the optimal exploitation for the whole area of project (35000 dunums) with no leading to GW scarcity.* ***Results:*** *First scenario includes planting only wheat, proved to be a sustainable scenario, whereas the second one involved cultivating many summer and winter crops (each for the whole area), which showed markable risk. In the last scenario, it was assumed that a mix of summer crops is planted together evenly and so on for Winter crops, which eventually showed partial success.* ***Novelty:*** *The outcomes of this study emphasised that crop type selection and land-use plan play a vital role in maintaining groundwater sustainability.*

INTRODUCTION

Water represents one of the most important requirements to achieve economic development in general and agricultural development in particular, considering its importance in agriculture and crop production all over the world, and especially in Iraq [1].

The growth in population has led to escalating demands on available water resources, particularly to support intensive agricultural development [2]. Rapid industrial expansion and unregulated urban sprawl played an important role in this increasing demand. In semi-arid regions, such as the eastern and western parts of Iraq's Western Desert, groundwater (GW) represents the most valuable water resource, especially where surface water bodies are scarce or inaccessible. Groundwater plays a vital role in sustaining livelihoods, providing essential water for agricultural, industrial, and domestic uses [3].

Lately, the GW system in the Karbala region has witnessed significant uncalculated withdrawal, as the increased abstraction has led to signs of groundwater depletion, which was marked by negative values of storage balance as well as water table declining in some areas of the region. According to recent modeling using Visual MODFLOW Flex 7, the groundwater deficit in western Karbala was estimated to be about (-34 million m^3/year), monitoring unsustainable usage trends [4].

Due to what was mentioned, applying the modern concepts of water consumption evaluation to evaluate how much water is needed for each crop has become an important task under the nowday's situation of water crisis that is facing Iraq due to climatic changes and excessive use of upstream countries, [5].

As for the study area in this research [6], the primary source of groundwater is replenished by rainfall, while the main source of flow is groundwater extraction through wells and springs. For a certain period, the water balance between gains and losses must be determined. It is a quantitative statement describing the balance between renewable water and water consumption for a single drainage basin, implicitly necessitating the conservation of water quantities in both inflowing and outflowing drainage basins. In arid sites where groundwater layers are replenished by rainfall as acquired water, rainfall is considered the sole primary source in evaluating the water balance [7]. The aquifers holding water in the study area are confined within the Dammam Formation, which is the primary aquifer in the study area. Consequently, there is no recharge of rainfall water to groundwater in the study area because the Dammam Formation lacks extensive outcrops.

Location of the Study Area

The study area is located within the project in the western part of Karbala Governorate, specifically in the Al-Ukhaidir region, about 15 km southwest of Ain Al-Tamr city, and about 7 km to west of Al-Ukhaidir fortress

It lies between latitudes 32° 25' 00" to 32° 22' 00" N and longitudes 43° 34' 00" to 43° 30' 00" E., covering the area 35000 dunums, and situated at an altitude ranging between 61 and 95 meters above sea level, as shown in Figure 1 and Figure 2.

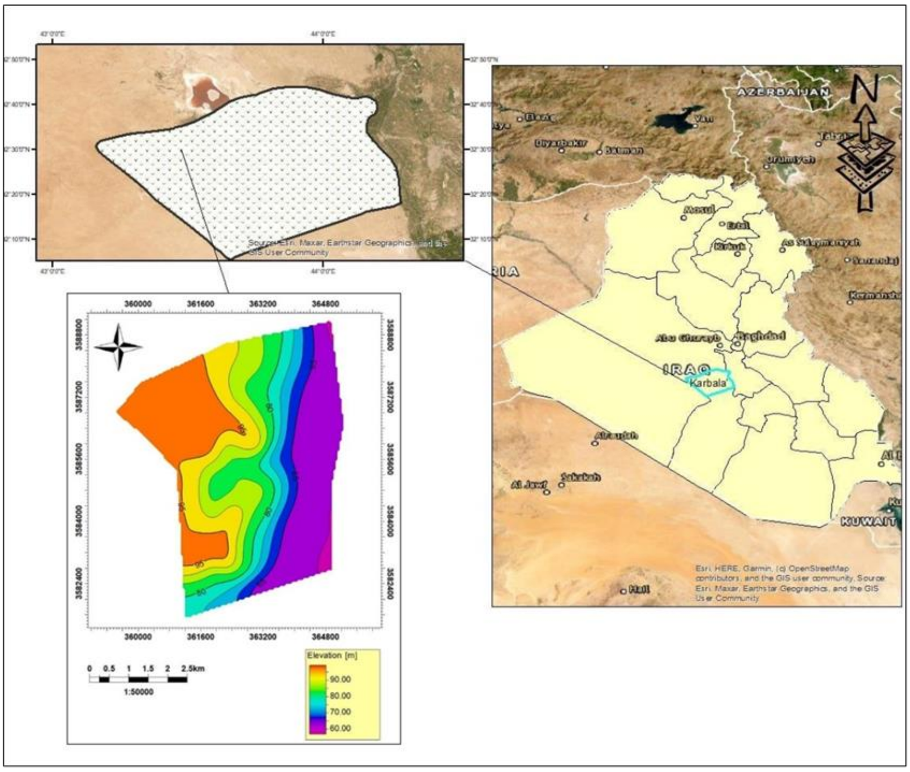

Figure 1. Location of the study area.

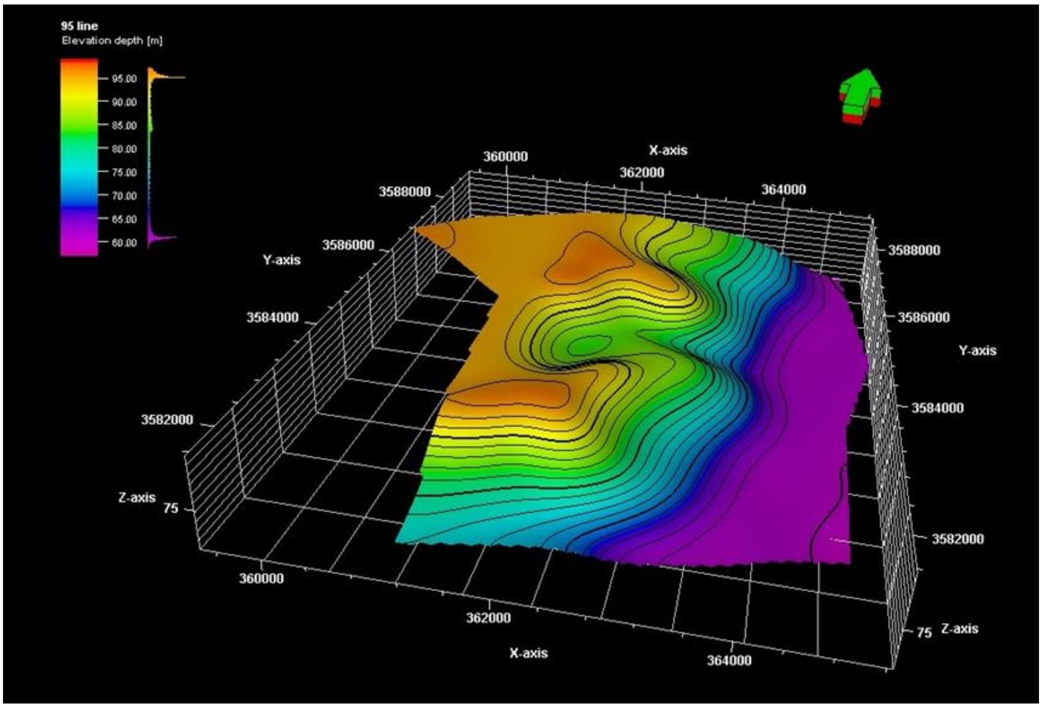

Figure 2. Elevations of the study area.

Geology of the Study Area

The study area consists mainly of the following geological formations, from older to younger, as shown in Figure 3:

- Umm Er Radhuma (E. Paleocene – E. Eocene): Dolomitic limestone with gypsum and anhydrite formation represents suitable reservoir formation in the area due to cracks, fissures and gaps [8] [9].
- Dammam (M. to L. Eocene): most important aquifer in the Iraqi desert, which consists mainly of dolomite and dolomitic limestone with marl and evaporite. [10]
- Euphrates (E. Miocene): the most extended formation in Iraq, comprises limestone and chalky limestone formation which locally contain shell coquinas and corals; they are often recrystallized and siliceous [10].
- Fatha \ Lower Fars (M. Miocene): most aerially widespread formations in Iraq, comprising numerous shallowing-upward cycles of alternating mudrocks, limestones, gypsum and/or anhydrite and halite [11].
- Quaternary Deposits

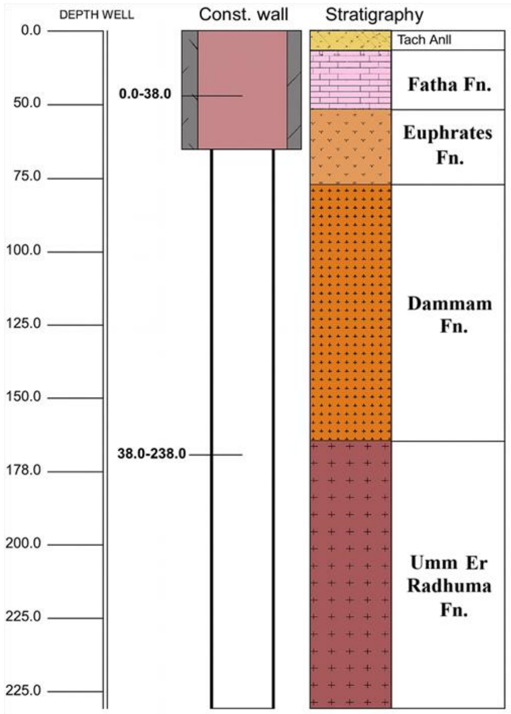

Figure 3. Geological Section of observation well no. 1 within the study area (General Commission for groundwater, 2020).

RESEARCH METHOD

1. Water Balance

Groundwater balance in the study area is calculated according to the equation of water balance [12], as follows:

$$\Delta S = \text{Input} - \text{Output}$$
$$\Delta S = Q_{in} - Q_{out}$$

Where:

ΔS: Changes in groundwater storage (m3/year)

Qin: Input discharge (m3/year).

Qout: Output discharge (m3/year).

2. Input of subsurface flow (Qin)

The recharge values for the current study area, given that the area investigated in this study overlaps with, and is considered part of, the region examined by Al-Shammari [13]. This choice is further supported by the comparable hydrogeological characteristics of the aquifer systems in both studies.

Where Q1, Q2 were:

Q1 = 10.86×106 m3/year … where Q1 is the discharge amount that flows to the area during (365) days [13]

Q2 = 19.3×106 m3/year … where Q2 is the discharge amount that flows along the study area during (365) days [13]

Therefore, the total entrances water (Qin Total) to the study area is equal to:

Qin Total = Q1 + Q2

Qin Total = (10.86 x 106) + (19.3 x 106) = 30.16 x106 m3/ year.

3. Output Discharge (Qout)

Since the study area does not feed any lakes and there are no springs in it, therefore the output discharge will represent only the water used for irrigation, which in turn defers from one crop type to another as will show later

4. Groundwater Consumption for Agricultural Purposes

The Saqi Alternative Water Project aims to address the water crisis that has begun to cast its shadow over the world in general and Iraq in particular, due to the declining water levels of the Tigris and Euphrates rivers. As a result, it has become necessary to rely on alternative water sources, specifically well water, to ensure the availability of water for the city in emergency situations. The project was implemented by the Engineering Projects Department of the Al Abbas Holy Shrine, in cooperation with the Wells Department of Karbala Province [14].

5. Utilization Scenarios

Three hypothetical scenarios have been put forward for land investment in the cultivation, where the consumption of each crop was calculated to determine its suitability. Several agricultural crops were taken for two seasons (summer and winter). Water needs for the cultivation of some crops were obtained from (Ministry of Irrigation, 1999), [15] and oral communication in (2021). In comparing the planted areas with the schedules of summer and winter crops, respectively, as shown in Table 1.

Table 1. Variation in water needs of crops over time.

Crop type	Crop consumption of water (Ministry of Irrigation, 1999) (mm/year)	Crop consumption of water in 2006 and 2007 (Al-Azawi, A. A., 2009) (mm/year)	Crop consumption of waters (Oral Communication 2021) (mm/year)
	Summer season		
Maize (summer)	2367,5	1044	1090
Maize (spring veins)	2770	-	1271
Clover	-	1668	615
Palm tree	2690	-	2235
Grapes	1881	-	-
Orchard (Citrus)	2285	-	-
	Winter season		
Wheat		586	398
Barley	-	586	398

The scenarios put in this study were as the following:

- First scenario assumed that the entire area is cultivated with only one type of crops (wheat)
- Second one is to plant the whole area with a different summer and winter crops each.

- Third scenario had 2 parts, for the summer season, the area was divided into 5 equal areas (7000 dunum for each) planted with different crop types … whereas for the winter season, the area is divided into 2 parts planted with wheat and barley.

RESULTS AND DISCUSSION

Based on the fact that the consumption of 1 mm of water for each dunum equals 1 cubic meter, the following calculations were made as shown in Table 2.

Table 2. shows the scenarios studied in the study area

Scenario	Crop type	Cultivated area (Dunum/year)	Crop Consumption of water (mm)	Annual total Consumption (m3/season)	$\Delta S = Q_{in} - Q_{out}$
Scenario 1	Wheat	35000	398	13930000	16230000
Scenario 2			**Summer Season**		
	Maize (summer)	35000	1090	38150000	- 7990000
	Maize (spring veins)		1271	44485000	- 14325000
	Clover		615	21525000	8635000
	Palm tree		2235	78225000	- 48065000
	Animal feed		2033	71155000	- 40995000
			Winter Season		
	Barley	35000	398	13930000	16230000
	Palm tree		2235	78225000	- 48065000
Scenario 3			**Summer Season**		
	Maize (summer)	7000	1090	7630000	For all crops combined is - 20548000
	Maize (spring vein)	7000	1271	8897000	
	Clover	7000	615	4305000	
	Palm tree	7000	2235	15645000	
	Animal feed	7000	2033	14231000	
	Total		50708000		
			Winter Season		
	Barley	17500	398	6965000	For both crops 16230000
	Wheat	17500	398	6965000	
	Total		13930000		

The first scenario showed accepted results as the Qin (30.16 x 106 m3/year) is larger than the Qout (16.23 x 106 m3/year).

In the second scenario, we can see a disparity of results depending on the crop type. Most summer crops are not convenient to be planted for the entire area, as they consume too much water, which leads to groundwater scarcity, except for clover, which showed promising results … as for winter crops it was only barley can be an encouraging crop

The third scenario showed different results depending on the season, for summer season it's not preferred combination of crops as they all combined consume more than (50.7 x 106 m3/year) which exceeds the input flow (Qin), whereas for Winter season the combination of wheat and barley has acceptable results as they combined consume water amount less than the input flow.

CONCLUSION

Fundamental Finding: For the calculations of each scenario, crop type and the cultivated area of crop play a crucial rule in defining the acceptance or rejection for each scenario, where we can see that the positive results from the equation ($\Delta S = Qin - Qout$) means that the scenario is suitable to be implemented on the ground, whereas for negative results means it's not a suitable scenario. **Implication:** It is suggested that different types of crops as well as different cultivation plans are put forward to get to the most ideal benefit of the project area without causing any groundwater reduction. **Limitation:** The limitation of this study is that the assessment of sustainability relies mainly on the equation ($\Delta S = Qin - Qout$), which may not fully capture all environmental, social, and technical factors affecting groundwater sustainability. **Future Research:** It is also suggested to make an annual study for the GW situation to monitor its level and reach the maximum state of GW sustainability.

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