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Reuse Wastewater By Using Water Evaluation And Planning (WEAP) (Ramadi City–Case Study)

Isam M. Abdulhameed[1], Sadeq O. Sulaiman[2,] Abu Baker A. Najm[3]

[1]The Upper Euphrates Basin Developing Center, University of Anbar, Iraq

[2, 3]Dams and Water Resource Department, College of Engineering, University of Anbar, Iraq

[3]Corresponding author: abubaker_ded@uoanbar.edu.iq

Abstract. Managing water resources is important with the increasing population, especially in arid and semi-arid regions. It is necessary to treat wastewater and greywater to saving more water amount and increase agriculture density. The current study forecasts the amounts of wastewater and greywater for Ramadi city during the next years (2020-2040). Also, the study proposes the possibility of reusing these amounts as a renewable water resource. These liquid wastes consist of 99.9% water and only 0.1% of solids. The study proposes using the treated wastewater to plant a green belt around the city to reduce the impact of dust storms and use the greywater in irrigating vegetables and fruits. The study was used water evaluation and planning (WEAP) to evaluating water amounts and reused wastewater in the current and future years. The results were indicated the domestic water returns for the current year to Euphrates River is 63 million m^3/year, with 11.7 million m^3/year of greywater, which covers about 22% of Ramadi irrigation requirements. The future domestic water would increase by about 24% to reach 78.4 million m^3/year at 2030 and 95.5 million m^3/year at 2040, while the greywater rising to 21 million m^3/year in 2030, and 34.3 million m^3/year in 2040.

1. Introduction

Treated wastewater use in agriculture contributes to saving water and expanding agricultural areas to produce various crops. It reduces costs related to fertilisers' production and use, where the necessary elements for plants exist in water use [1]. Water resources are considered one of the main pillars for achieving economic, industrial, and agricultural life for the human. Water is important in all demand sites, especially the agricultural. Globally, agriculture consumes more than 70% of the available freshwater resources, and reach in some developing country to 95% [2] which is more than the other demands as domestic and industrial. This water not well use by farmers, where there is wasteful water [3]. Therefore, an agricultural policy must be applied that works to manage water resources well. Population increases lead to the demand for food production increases; thus, water demand increases [4]. Wastewater is a sustainable water source for agricultural purposes and can solve the difference between water demand and supply. The wastewater treated can release a tremendous amount of fresh water for irrigation to meet the growing freshwater needs in villages and cities in developing countries [5].

During the past decades, using wastewater in agriculture has increased considerably due to increased agricultural area and population density with the limited water resources available in most world countries [6]. Reduce traditional water sources depletion, especially those used in agriculture, as most

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countries consume between 60 - 93% of the total water consumption in agriculture [7]. Agriculture is the main water consumer, followed by domestic, industrial, and tourism uses. Therefore, it is necessary to raise water use efficiency, and additional traditional and non-traditional water sources should be found. Among the non-traditional sources are wastewater treatment and reuse [8]. Wastewater contains elements and minerals; some of them are beneficial to the plant and leads to an increase the productivity, but the other may be harmful to the plant and soil, as well as animals and humans, depending on the water quality, soil properties, and climatic conditions [9].

It is important to use additional water irrigation sources like treated wastewater, with the increasing water demands, where the study area has growth ration 2% according to the central statistical of Anbar, 2019. Also, dams construction by upstream countries of turkey and Syria reflected negatively on Euphrates River water imports [10], [11]. In this study, the water evaluation and planning (WEAP) was used to evaluate the water demand with water consumption in Ramadi city as a case study as in Figure 1. The Ramadi city has a limited water budget from Euphrates River (418 million m^3/year). Agriculture has 78% of this budget, while the domestic and industrial represent 18.8% and 3.2%, respectively. Therefore, the study estimates the water demand for domestic and industrial according to population growth and industrial for the period 2020-2040. It was suggested to use wastewater and greywater to increase agricultural density in Ramadi irrigation project. In this study, the impact of groundwater and capillary rise on crops was ignored. Also, the effect of water quality and deficient irrigation was neglected.

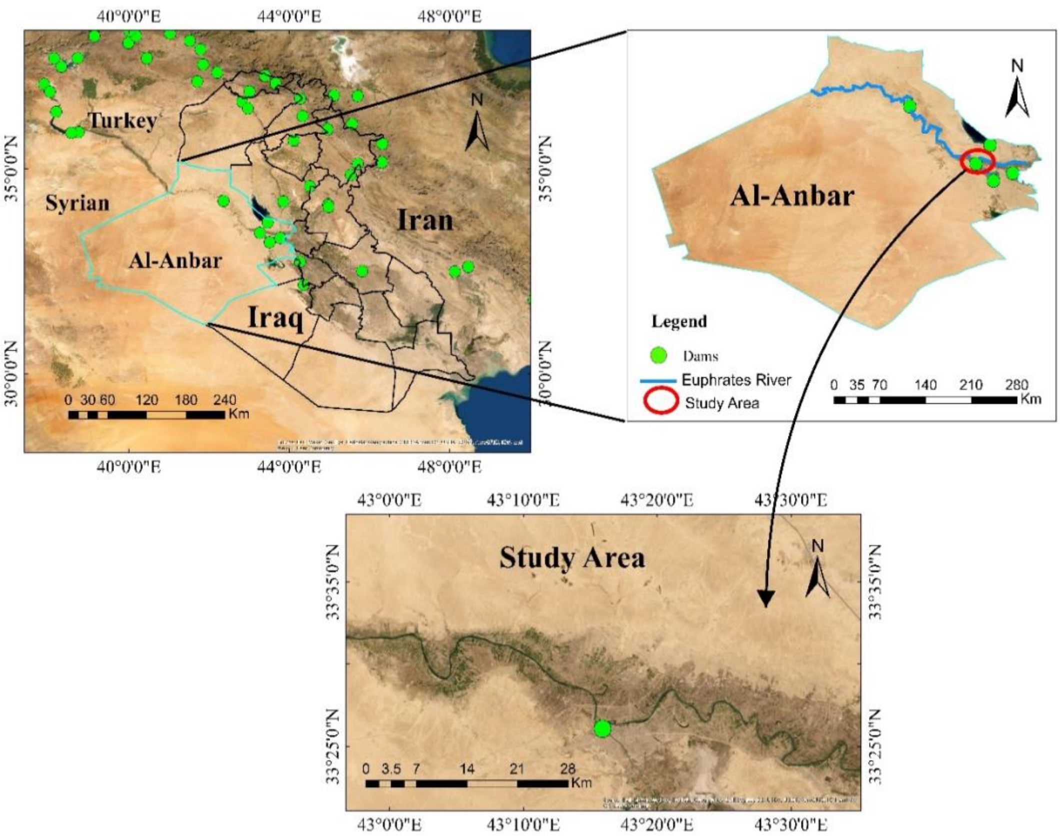

Figure 1: Map of the study area.

2. Material and Methods

WEAP model is used to managing treated wastewater and greywater for agriculture purposes in Ramadi city. The daily climate data was collected from the Iraqi Meteorological Organization and Seismology for 2019. The crop characteristics were collected from FAO-56 [12]. The cultivated area and pumps

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water discharge data for demand sites were taken from Irrigation Directorate of Anbar, 2019, and Anbar Water Directorate, 2019. The population census for previous years with the growth rate was taken from Anbar Statistics Directorate.

WEAP model provides water supply performance according to Priority by using number 1 - 99. For example, in Figure 2 and Figure 3, the water supply performance for project 1 and project 2 has been appointed from the wastewater treatment using number 1. In contrast, number 2 represented the second water source to supply water demand for crops [13]. Crops water requirements calculate by the WEAP model based on (FAO 56, dual Kc, daily) method. The K_c coefficient defines as the crop coefficient, which uses to calculates the crop evapotranspiration (ET_c) from reference evapotranspiration ($ET_c = K_c * ET_0$). This method bases daily climate conditions, crop characteristics, soil texture [13], [14]. The Penman-Monteith equation is used to calculate the Reference Evapotranspiration (ET_0) by the following formula:

$$ET_0 = \frac{0.408\Delta\,(R_n - G) + \gamma \frac{900}{T_{mean} + 273} U_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,U_2)} \tag{1}$$

Where ET_o refers to Reference evapotranspiration (mm day-1), R_n refers to net radiation at the surface of the crop (MJ m-2 day-1), G refers to the density of the soil heat flux (MJ m-2 day-1), which can be neglected (G=0), T_{mean} refers to the average temperature of the daily air at the height of 2m (°C), U2 refers to the wind speed at 2m height (m s-1), $e_s - e_a$ refers to saturation vapour pressure deficit (kPa), Δ refers to the slope vapour pressure curve (kPa /°C), and γ refers to psychometric constant (kPa /°C).

For the domestic demand, the WEAP requires the population growth rate and the population census. The model estimates the population census for the future year using "Growth Form" within the expression builder as in equation (s). The model used the annual per unit activity according to water demand and consumption as in Table 1. The amount of water returning to the river without treatment is about 80% of the domestic water supply [15].

The industrial facilities of the study area are various in water demand. It can be classified into small and medium facilities represented by sand, gravel, and car washing factories with total annual demand 396,250 m^3/year in 2018 [16] . The large facilities such as ceramics and glass have the greatest demand; of about 0.4 m^3/s according to State Company for Glass and Refractoriness, 2020.

$$\text{Annual Demand} = \sum (\text{Total Activity x Water Quota}) \tag{2}$$

Table 1: Domestic projects within the study area.

Project	**Operating Hours Per Season**		**Operation Power (m^3 / Hour)**	
	Summer	**Winter**	**Summer**	**Winter**
Big project	24	14	6000	3000
Modern Project	24	14	600	600
Qasrel-Adala	24	14	750	750
Water stations	6	3	12120	12120

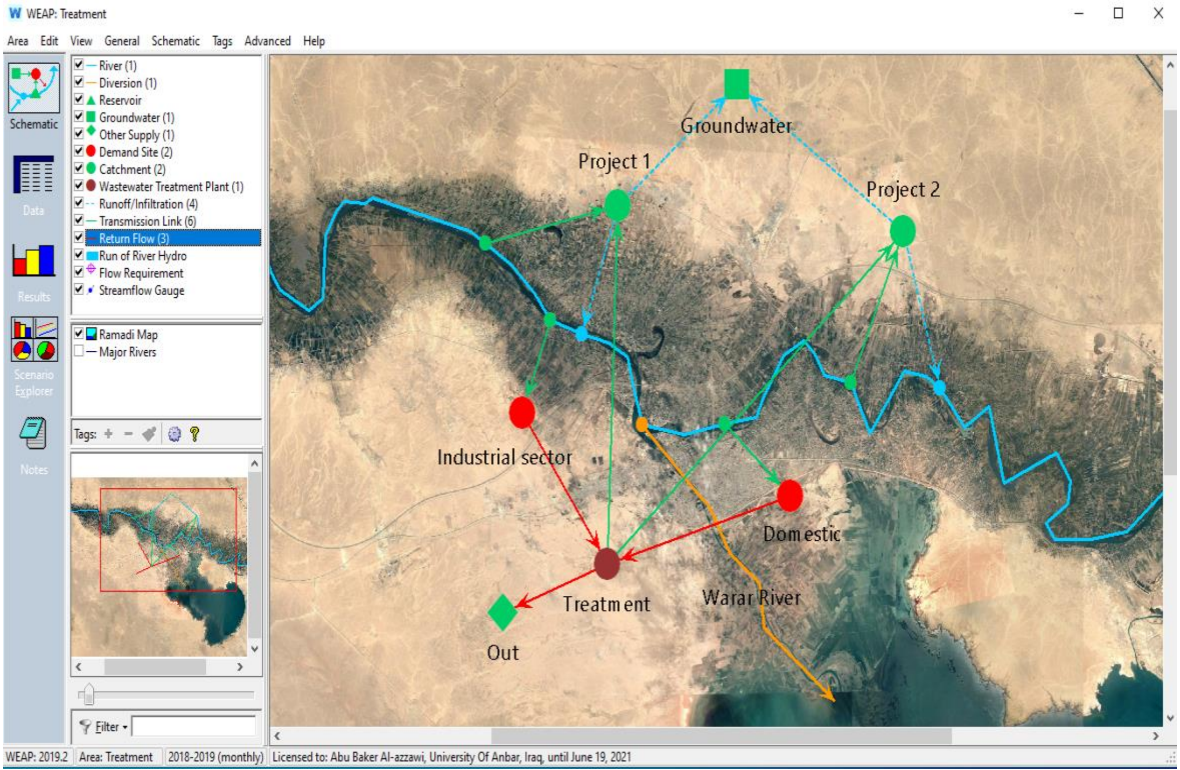

Figure 2: Represents the study area within WEAP-Model.

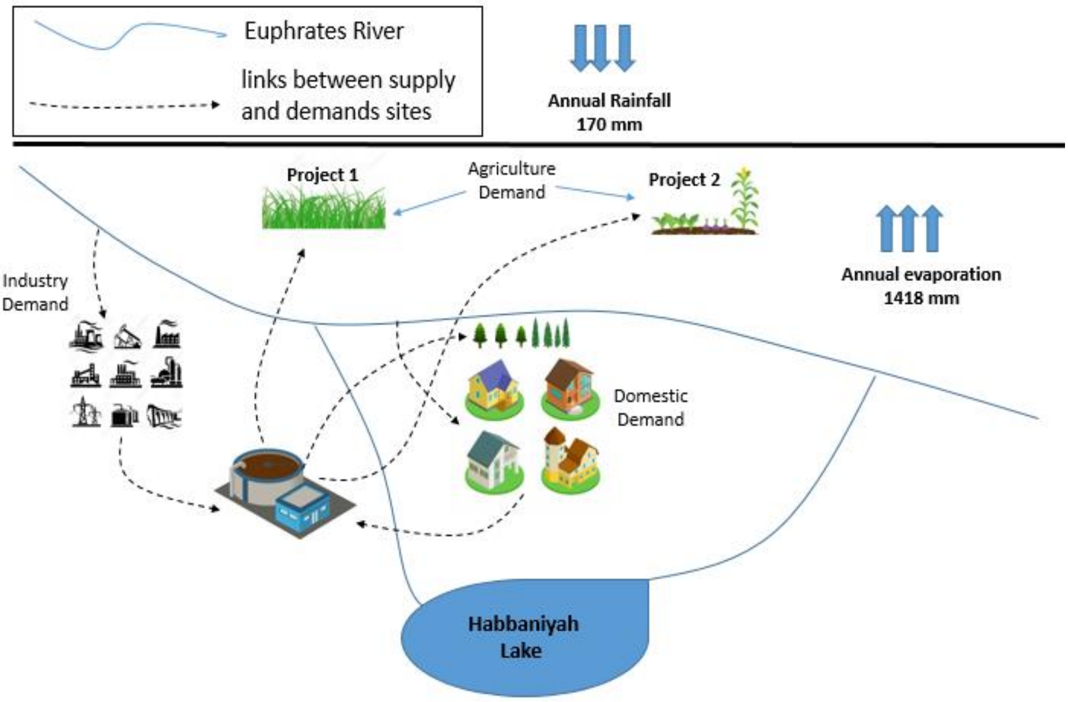

Figure 3: Supply and water demands sites of the study area

3. Results and Discussion

The domestic demand was 571 L / capita per day from March to September, which decreased to 223 L / capita per day from December to February. The water demand is different between months according to increased temperature, which causes an increase in water use by the population. During the season, the average water demand was 485 L / capita per day, while the total per capita was 177.1 m^3 / year. The total monthly domestic demand was, as shown in Figure 4. The increase in water demand for the period (2020-2040) was depended on the population growth rate (2%).

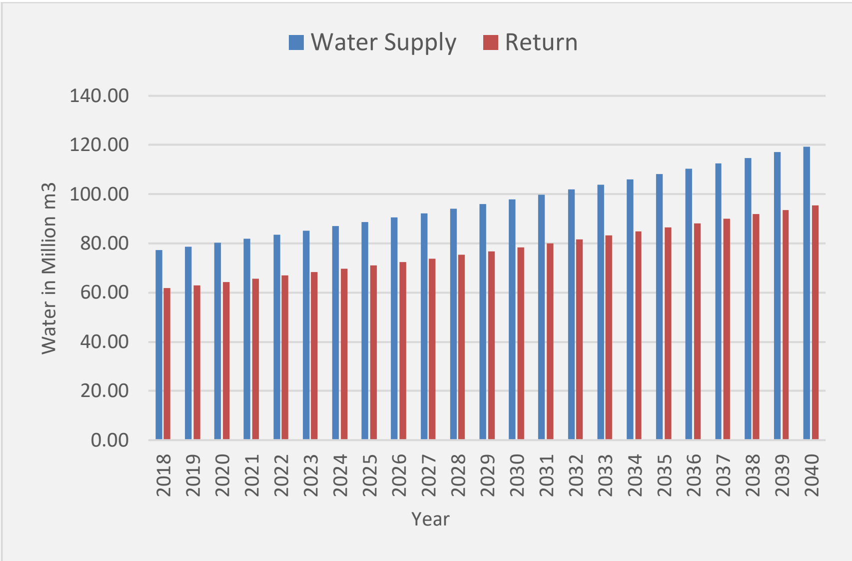

Figure 4: Domestic water demand (2018 – 2040)

Industrial demand was a small volume as compared with the domestic demand. Most establishments within the study area are sand washing, gravel, block factories, or car washing with the relative amount of water. In contrast, the glass and ceramic factory with a demand of about 0.4 m^3/sec, which represents the most significant water demand in the industrial demand. The total water demand for the industrial was as shown in Figure 5. The total water returns from domestic and industrial were, as shown in Figure 6.

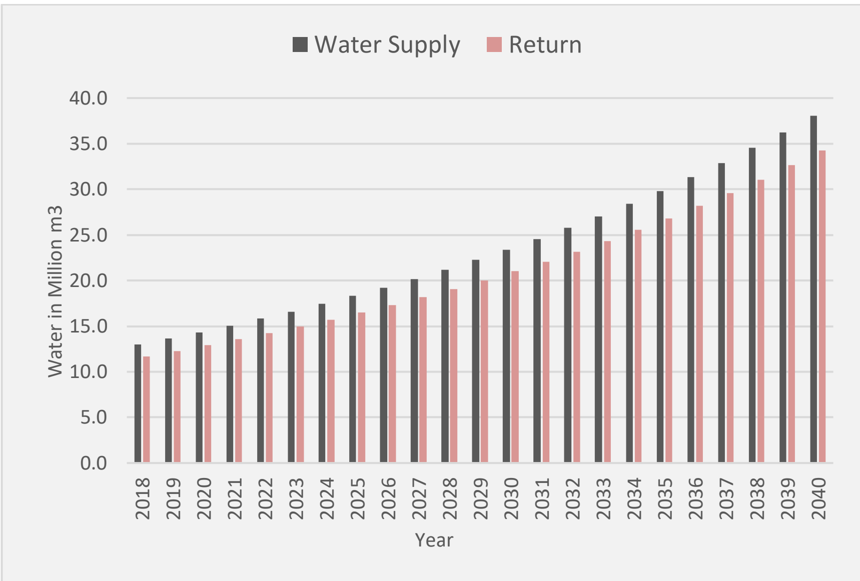

Figure 5: Industrial water demand (2018 – 2040)

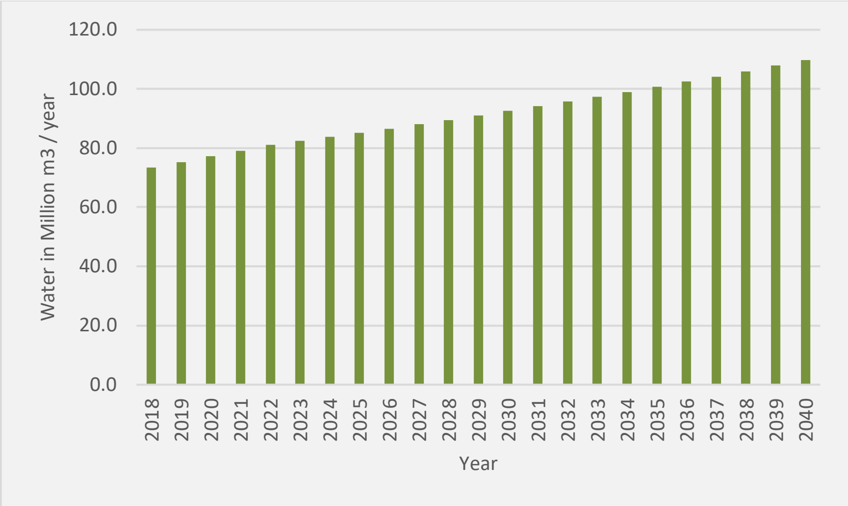

Figure 6: Total return from industrial and domestic

The total irrigation demands were 55 million $\boldsymbol{m^3}$/year as in Table 2 and Table 3, which equals 74.8% from the total return in 2018 that be 73.5 million $\boldsymbol{m^3}$/year. The water return must be treated by secondary treatment before uses in irrigated crops. The greywater that equals 11.71 million $\boldsymbol{m^3}$/year for 2018, enough to covers 21.3% from water demand of irrigation project (55 million $\boldsymbol{m^3}$/year). The remaining water demand of irrigation 78.7%, can be covered after treated wastewater under secondary treatment, with costs 7.5 cents / 3.785 $\boldsymbol{m^3}$.

Table 2. Project cultivated area for (2018-2019)

Project	**Area (ha)**	**Cultivated area (%)**			
		Winter Crops %	**Summer Crops %**	**Perennial Crops %**	**Density (%)**
Pro. 1	2500	58	4.5	0.75	63.25
Pro. 2	8250	44.2	3.18	0.34	47.72
Sum	10750	47.4	3.5	0.4	51.3

Table 3: Total water supply from the river with all losses in (million /year)

Projects	Field losses (m^3)	Conveyance Losses (m^3)	Total volume (m^3)
Project 1	6.3	2.47	16.5
Project 2	14.7	5.77	38.5
Sum	21	8.24	55

Where the cost of primary and secondary treated equals 7.5 cents / 3.785 m^3 [17].

$$\frac{3.785\ m^3}{7.5\text{ cents}} = \frac{43.29 \text{ x } 10^6\ m^3}{\text{cost}} \qquad (3)$$

Treated cost = 857,794 dollars

Therefore the water remains from total returns (73.5 million m^3/year for 2018, will be 18.5 million m^3/year that can be treated as primary stage only. The treated water can be used to make a border of ornamental trees around the city of Ramadi to reduce dust storms. Where the cost of primary treated be 3.5 cents / 3.785 m^3 [17].

$$\frac{3.785\ m^3}{3.5\ \text{cents}} = \frac{18.5\ x\ 10^6\ m^3}{\text{cost}} \qquad (4)$$

Treated cost = 171,070 dollars

The water demand for trees according to Iraqi Water Resources Directorate, 2019, is 32620 m^3 / hectare. Therefore, the area that can be planted with trees around the city is 567.14 hectare.

The number of trees planted per hectare is 125, with spacing 10 × 8 m. This result leads to the total tress that can be planted around the city equals 70893 trees.

The domestic returns have been increased by 15% (from 61.8 to 71 million m^3/year) for the period 2018 - 2025, following by 32% (from 72.4 to 96 million m^3/year) for the period 2026-2040. Furthermore, the industrial water return was 41% for 2018 - 2025, with increases by 98% for the period 2026-2040. This result means increasing the cultivated area and expanding the green areas around the city, as in Figure7.

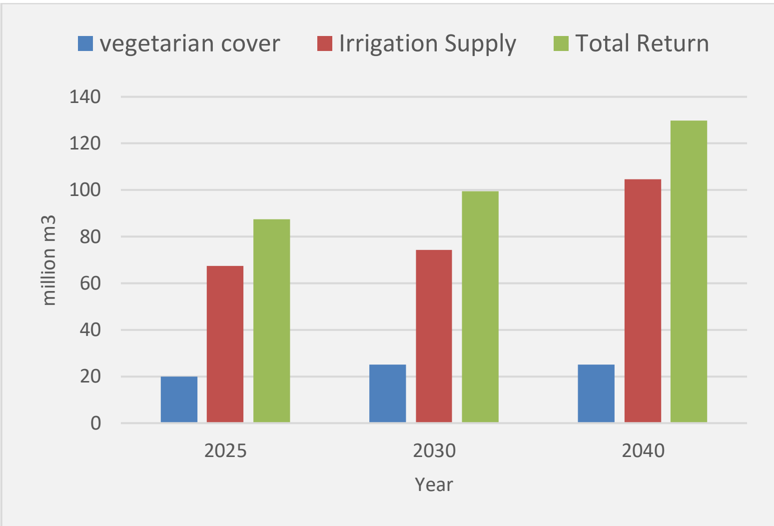

Figure 7: Water supply with a return to the river

In the first case, the water return of 2025 was 87.45 million m^3/year, as shown in Figure 6. Suppose we use 20 million m^3/year to extend the vegetation cover with increasing population. The remaining amount of water 67.45 million m^3/year can be treated using the secondary treatment, which contributes to increasing the plant density by 22.6% (from 51.3 % to 62.9 %). In the second case, the water return of 2030 was 99.39 million m^3/year, as shown in Figure 6. The water used to extend the vegetation cover was 20 million m^3/year. The remaining amount of water 67.45 million m^3/year can be treated and contributes to increasing the plant density by 23% (from 51.3 % to 68.4 %). In the last year 2040, the agricultural density increasing to 97.7% with 25 million m^3/year for vegetarian cover.

4. Conclusions

Wastewater reuse in agriculture is important management for the sustainable use of the limited freshwater resource due to the potential economic and environmental benefits. It is necessary to support wastewater reuse projects in the study area, with the population water demand grows. The study referred to several important points:

1- The population growth rate causes more water demand with more wastewater return to the river. The industrial water demand also increased with industrial activity growth, which causes more greywater that returns to the river. The future domestic water would increase by about 24% to reach 78.4 million m^3/year at 2030 and 95.5 million m^3/year at 2040, while the greywater rising to 21 million m^3/year in 2030, and 34.3 million m^3/year in 2040
2- The treated water contributes to increasing the agricultural density by 22%, 33% and 97% for 2025, 2030 and 2040 respectively.
3- Water treatment costs are low compared with the extended plant density, which means increased production and increased economic return for the region.

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