

Improving the Cultivated Area for Ramadi Irrigation Project Using Water Evaluation and Planning Model (WEAP)

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Received: 2/9/2020

Accepted: 10/10/2020

ABSTRACT

In this study, a water evaluation and planning WEAP model was utilized to improve the Ramadi irrigation project with 28342 hectares and 326 million m³ annual budget for the period (2018-2019). The results showed that the total water used was 111.5 million m³/year representing 34.2% of Ramadi irrigation budget. The annual production was 39.3 million Kg/year for Ramadi irrigation, and the total economic returns was 16.04 million \$/year. The study proposes two scenarios to improve the cultivated area. The first scenario increases water volume of the current year from 111.5 million m³/year to 272.12 million m³/year, which caused an increase in annual productivity from 39.3 million Kg/year to 144.57 million Kg/year, and economic return rose from 16.04 million \$/year to 65.25 million \$/year. The second scenario recorded an increase in the annual production for the current year from 39.3 million Kg/year to 192.27 million Kg/year and economic return from 16.04 million \$/year to 86.79 million \$/year when using additional pumps for project 2, 3 and project 5. Also, the convey loss increased from 16.72 million m³/year for the current year to 48.47 million m³/year when applying the second scenario, which equals 15% from the water budget of Ramadi irrigation.

Keywords:

Improve cultivated area; Improve economic returns; Ramadi irrigation project; WEAP-model

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1. INTRODUCTION

Water is an essential part of the ecosystem; it is a natural resource that cannot be recycled. It has a social and economic significance depending on the quality and quantity of the available water [1]. The water demand is divided into agricultural, domestic, and industrial demand. Agriculture has the largest water share in the various regions of the world-about 70% to 90% in arid and semi-arid regions [2]. The population increase requires providing more water with food to meet local demands.

Due to the limited water resources, it was necessary to achieve a water-management that ensures meeting the water demands of the population [3,21], by raising the efficiency of crop production and saving more water (García *et al.*, 2020).

The Euphrates River is considered the main water resource that provides the water demands for agriculture within the study area.

The water imports of the Euphrates River are shared between Anbar Governorate and the others Iraqi governorates.

The reduction in water imports of Euphrates River leads to reducing the cultivated area within the study area. At the same time, a population growth of about 2% according to the Anbar Statistics Directorate, requires more water supply with more available food.

The Ramadi irrigation project is 28342 hectares with an annual budget of 326 million m³/year, with few cultivated areas. It represents 35% of winter crops, 3.46% of summer crops and 0.39% permanent crops, which makes it to necessary to increase the cultivated area to achieve more economic returns with food for population instead of importing crops from outside the governorate or the country.

Some programs like CROPWAT and SIM DUAL appeared during past periods are used to evaluate water consumption of crops. These

programs deal with field only, which makes it necessary to find a system that deals with all water resource elements [5]. The water evaluation and planning WEAP model comes as a development of these programs, with different tools and methods. It uses assumptions and means to improve the water management of the region. The WEAP model was one of best programs that have set of options and features necessary for water management [6].

2. MATERIALS AND METHODS

2.1 Study area

The study area located between 33 ° 26' 84 " N to 33 ° 22'15.46" N Latitude and 43 ° 35'36.63 "E to 42 ° 57'59.50" E longitude with elevation 53 m above the sea level as shown in Figure 1. It extends from Abu Tayban west of Ramadi on the right Euphrates River and to end at Al-Malahma to the left of the Euphrates River, east of Ramadi.

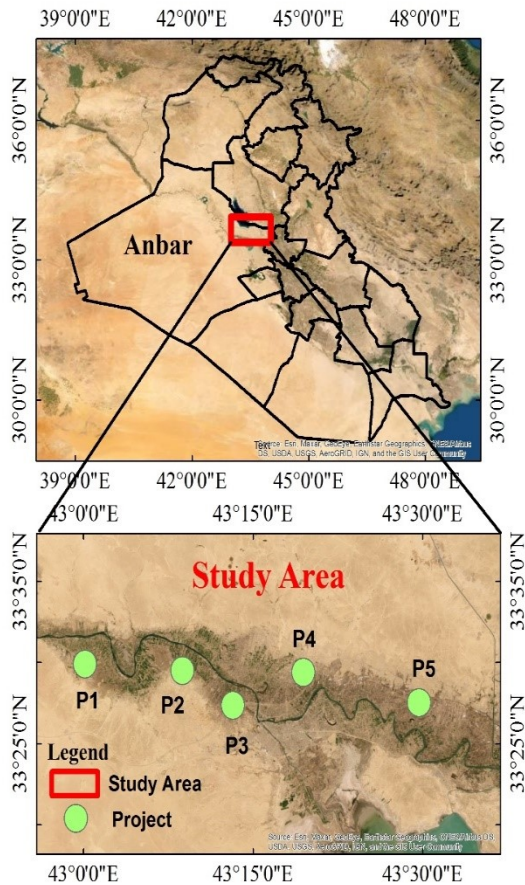


Figure 1. Map of the study area

Ramadi city is the capital of Anbar Governorate and has an important and strategic location, about 108 Km west of Baghdad. It bordered by Salah Al-Din Governorate from the north and northeast, Karbala Governorate from

the south and southwest and Hit District from the west [7]. The study area has several water bodies as Tharthar Lake to the north and Habbaniyah Lake to the east of Ramadi city which are used during water shortages periods while Razazah Lake is used for flood protection. Al-Warar stream to the west of Ramadi is used to transport water from the Euphrates River by Al-Warar regulator to Habbaniyah Lake by Al- Warar stream.

2.2 Irrigation sector

The Ramadi irrigation has five irrigation projects as in Figure 1. Each project serves several agricultural districts.

Euphrates River is the main source to supply water requirements of crops for each project using pumps establish on the banks of the River. The cultivated area for each irrigation project represented by winter crops as wheat, barley, and Bersame with summer crops as sweet pepper, potato spring, cucumber, sesame, sunflower, tomato, and watermelon, also trees as palm, grape, olives, and citrus in addition to others crops as in Table 1.

The surface irrigation is considered the main method used in each irrigation project with high water losses about 45% that are not reusable for agricultural. The conveying channels in each irrigation project are lined with losses of about 15% [8]. The cultivated area in Table 1 was taken from Irrigation Directorate of Anbar, 2019.

Table 1. Cultivated area for each project

| Project | Area (ha) | Cultivated area | | |
|----------|-----------|-----------------|----------------|-------------------|
| | | Winter Crops % | summer Crops % | Perennial crops % |
| Projec1 | 3667 | 27.6 | 1.7 | 0.34 |
| Projec2 | 2675 | 66.2 | 6.5 | 0.47 |
| Projec3 | 2500 | 58 | 4.5 | 0.75 |
| Projec4 | 8250 | 44.2 | 3.18 | 0.34 |
| Project5 | 11250 | 18.1 | 3.29 | 0.34 |
| Sum | 28342 | 35 | 3.46 | 0.39 |

2.3 Climates conditions

The climate of the study area is arid and semi-arid; with a limited amount of rainfall- not enough to meet the water requirement of crops [9]. The study area is characterized by the length of the summer season that extends from March to the beginning of October with high temperatures as in Figure 2. The wind differs according to the regions that come from it. The wind passes through the water bodies is characterized by moderate temperatures and high humidity, while the wind that comes from desert areas is characterized by high temperatures and low

humidity [10]. The daily climate data of the study area was collected from the Iraqi Meteorological Organization and Seismology, 2019.

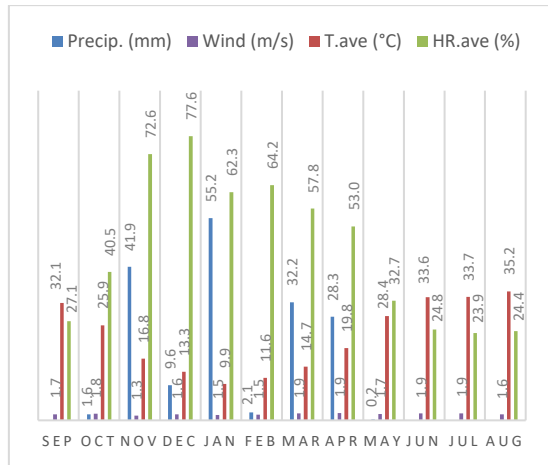


Figure 2. Daily Climate Data from (2018-2019)

2.4 WEAP modelling process

The WEAP model calculates Reference Evapotranspiration (ET₀) using Penman-Monteith equation [11], which assumes the reference surface is green grass with 12 cm high and 70 s/m resistant with an albedo of 0.23 according to the following:

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

Where ET₀ represents the reference evapotranspiration (mm day⁻¹), R_n represents net radiation at the surface of the crop (MJ m⁻² day⁻¹), G represents the density of the soil heat flux (MJ m⁻² day⁻¹), T represents average temperature of the daily air at a height of 2m (°C), U₂ represents the speed of wind at 2m height (m s⁻¹), e_s represents the vapor pressure of the saturation (kPa), e_a represents the actual vapor pressure (kPa), e_s - e_a saturation vapor pressure deficit (kPa), D represents the curve of the slope vapor pressure (kPa °C⁻¹), and g represents the psychrometric constant (kPa °C⁻¹).

The model was provided by Characteristics of crops as planting and harvesting, Basal crop coefficient, depletion factor of the crop, and maximum height as in Figure 3 [11]. The daily climate conditions as precipitation, temperature, wind speed, humidity, elevation above sea level, latitude and longitude of the study area as in Figure 4. The climate conditions effects on the planting and harvesting of crops, which are divided into summer and

winter crops with trees. Also, the climate data used to correct values of Basal crop coefficient (K_{cb}) and depletion factor of the crops that taken from FAO-56 [11].

The Dual-K_c is the approach used by WEAP model, which is considered more complicated than the simple approach, where the crop coefficient (K_c) is divided into the "Basal" crop coefficient (K_{cb}) and the (K_e) coefficient that represents the evaporation from the soil [12] as in Figure 3. The total crop Evapotranspiration (ET_c) is calculated as the result of multiplying the reference Evapotranspiration (ET₀) by the sum of two coefficients (K_{cb} + K_e) according to the following equation [13]:

$$ET_c = (K_{cb} + K_e)ET_0 \quad (2)$$

However, this equation requires adjusted values of (K_{cb}) that is taken from FAO-56 using equation (3), while the daily values (K_e) coefficient using daily water balance for topsoil layer as in equation (5).

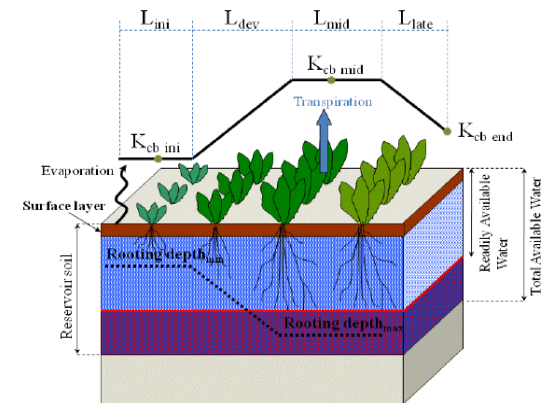


Figure 3. Growth stages of crop [14]

$$K_{cb} = K_{cb} (Tab) + [0.04(U_2 - 2) - 0.004(RHmin - 45)] \left(\frac{h}{3}\right)^3 \quad (3)$$

Where K_{cb} (Tab) represents the standard K_{cb} value taken from FAO-56 for stage mid and end stage, U₂ (m/s) represents the average of wind speed during the mid or last stage, and h represents the height of the crop during the stage, which is calculated by equation (4).

$$h_i = \frac{K_{cbi}}{K_{cb\ mid}} h_{max} \quad (4)$$

Where h_i represents the crop height on day i in (m), K_{cbi} represents the crop basal coefficient on day i, K_{cb mid} represents the crop basal coefficient

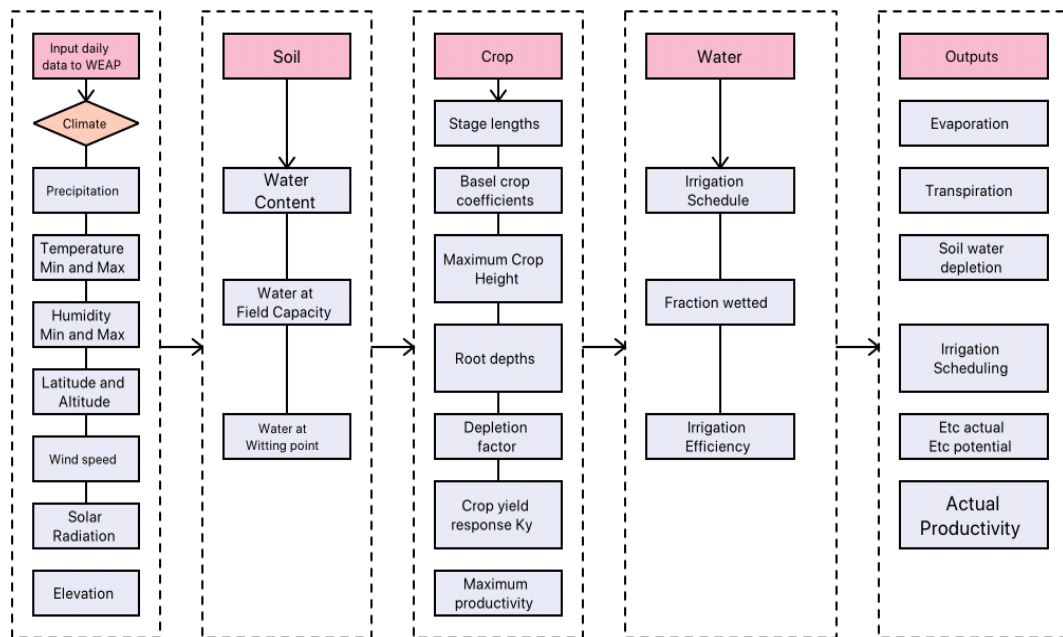


Figure 4. Steps represent the process of WEAP-model

at the mid stage, and h_{max} represents the height of crop at mid stage in (m).

The water balance was applied for topsoil layer to calculate the daily depletion as following [11]:

$$D_{e,i} = D_{e,i-1} - (P_i - RO_i) - \frac{I_i}{f_w} + \frac{E_i}{f_{ew}} + T_{ew,i} + DP_{e,i} \quad (5)$$

Where $D_{e,i-1}$ represents the cumulative depletion depth at the end of previous day $i-1$ in (mm), $D_{e,i}$ represents the cumulative depletion depth at the end of day i in (mm), P_i represents Precipitation on day i in (mm), RO_i represents the amount that exceeds the infiltration of soil and causes runoff on a day i in (mm), represents the irrigation depth on day i that infiltrates the soil (mm), E_i represents the evaporation on day i (i.e., $E_i = K_e ET_0$) (mm), $T_{ew,i}$ represents the depth of transpiration from the exposed and wetted fraction of the soil surface layer on day i (mm), $DP_{e,i}$ represents the deep percolation loss from the topsoil layer on day i if soil water content exceeds field capacity (mm), F_w represents the surface of the soil moistened by rain or irrigation (0.01 – 1), and F_{ew} represents the exposed soil and wetted which be subjected to solar radiation (0.01 – 1).

2.4.1 Irrigation supplied

Irrigation is used to supply water at a suitable time when the amount of rainfall is not

enough to meet the water requirement. Irrigation is provided according to characteristics of crops, climate conditions during the growth period, soil texture and the irrigation efficiency [15].

In optimal irrigation, WEAP model supplies the water to crops before exceeding the readily available water (RAW), which represents the amount of water used by crop without any stress. RAW equals to the total available water (TAW) multiplied by the depletion factor of crop during the growth stage.

$$TAW = 1000 (\theta_{FC} - \theta_{WP}) Z_r \quad (6)$$

Where TAW represents the total available water in soil (mm), θ_{FC} represents the water content at field capacity in ($m^3 m^{-3}$), θ_{WP} represents the water content at wilting point in ($m^3 m^{-3}$), and Z_r represents the effective rooting depth in (m).

$$RAW = P TAW \quad (7)$$

Where RAW represents the readily available water, P represents the depletion factor of crop, and TAW represent the total available water. The total amount of water with irrigation losses can be calculated using the following formula [16]:

$$d_g = \frac{d_n}{E_a} \quad (8)$$

Where d_g represents the gross irrigation in (mm), d_n represents the net water requirement of crop in (mm), and E_a represents application efficiency.

2.4.2 Yield module and its parameter

The productivity of crops under surface irrigation method (Kg/ha) was taken from Central Statistical Organization, Iraq 2018 [17], with the unite price for each crop as in Table 2.

The marketing value of crops calculated using WEAP model is by multiplying cultivated area by the yield productivity with the unit price as in the following formula:

$$MV = Y_a * Area * Price \tag{9}$$

Where MV represent total market value of crop (\$), Y_a represents actual yield in (Kg/ha), Area represents cultivated area in (ha), Price represents unit market price of crop in (\$/kg).

Water productivity of crops is defined as the ratio between crop yields (Kg /ha) on the total water applied during the crop season, by irrigation and rainfall [18]. Water productivity of crops can be calculated using the following formula [19]:

$$WP = \frac{Y_a}{TWU} \tag{10}$$

Where Y_a the yield of crop (Kg/ha), and TWU represents the total water applied, which include effective rainfall and losses of irrigation method with net depth irrigation of crop in (m^3).

Table 2. Yield of crops in central of Iraq, with unite price [17]

| Crops | Surface (Kg / ha) | Price (\$ / Kg) |
|---------------|--------------------|-----------------|
| Wheat | 2779 | 0.363 |
| Barley | 1419 | 0.309 |
| Maize | 5444 | 0.467 |
| Cucumber | 10056 | 0.434 |
| Eggplants | 16264 | 0.433 |
| Kidney beans | 5020 | 1.188 |
| Potato Spring | 26983 | 0.476 |
| Sesame | 893 | 1.499 |
| Sunflower | 2226 | 0.725 |
| Sweet Pepper | 8710 | 0.518 |
| Tomato | 26866 | 0.393 |
| Watermelon | 19225 | 0.348 |
| Berseem | 12441 | 0.359 |
| Broad bean | 5802 | 0.516 |
| Cauliflower | 8632 | 0.388 |
| Potato autumn | 26983 | 0.476 |

| | | |
|--------|-------|-------|
| Citrus | 4004 | 1.257 |
| Grap | 11800 | 0.713 |
| Olives | 17211 | 1.257 |
| Palm | 9872 | 1.022 |

3. Results and discussion

The results shows that the total reference evaporation calculated using Penman-Monteith Equation is 1745 mm / year.

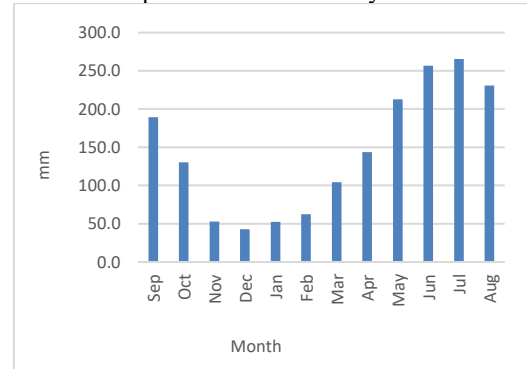


Figure 5. Monthly reference evapotranspiration

There was increasing from March with 104 mm/month to reach a peak value at July with 266 mm /month while was decreasing during the period from September with 189 mm/month to reach the minimum value at December with 43 mm /month as shown in Figure 5. The increase in irrigation water requirements in summer was due to hot months, for example the wheat crop evapotranspiration (ET_c) was 43 mm and 103mm for initial and development stage. The mid stage that extends from February until mid-April recorded 282 mm with 146 mm for end stage until harvesting at mid-May as in Figure 6.

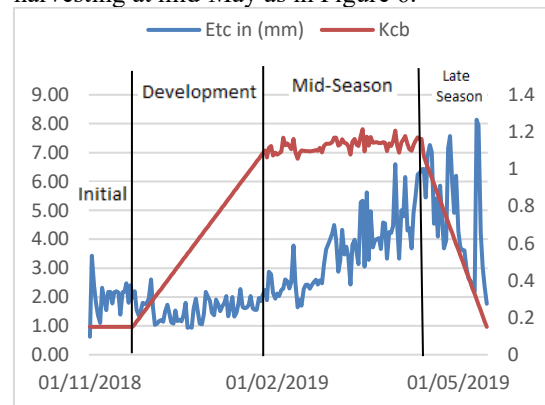


Figure 6.Wheat crop evapotranspiration (ET_c) for project I

The water supplied to crop before exceeding the readily available water (RAW), to avoid water stress during the growth season of crops and achieve optimal irrigation as in Figure

7. Where the differences in (TAW) leads to different (RAW) of Ramadi irrigation projects. The (RAW) depends on the total available water (TAW) with depletion factor of crop (p) during the growth stage.

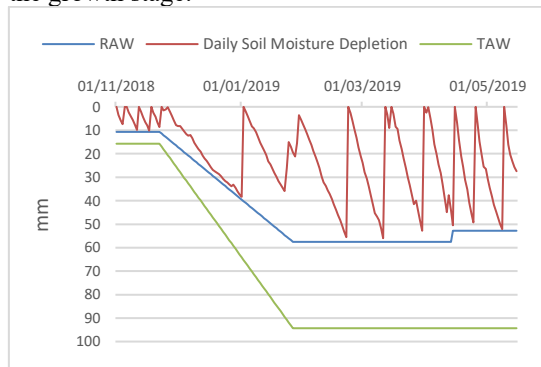


Figure 7. Daily soil depletion with total and readily available water of wheat within project1

The water requirements of each project in Figure 8 were calculated according to the cultivated area with the water requirement of crops for each project as in Table 3.

In November, Strategic crops wheat and barley with winter crops are cultivated, therefore there was water requirement of 8.6 million m^3 during this month by multiplying gross irrigation depth by irrigated area. The water demand declined to 1.8 million m^3 for December where the month is cold, the evaporation is minimum, and the rainfall contributes in irrigation. The water supply increased during March and April with 20.8 million m^3 and 22 million m^3 respectively as in Figure 8, where winter and summer crops need more water demand with increasing (ET_c) and low depletion factor of crops. In May, the water supply started to decline with the harvesting of strategic crops wheat and barley until reaching the minimum water supply in august 0.5 million m^3 .

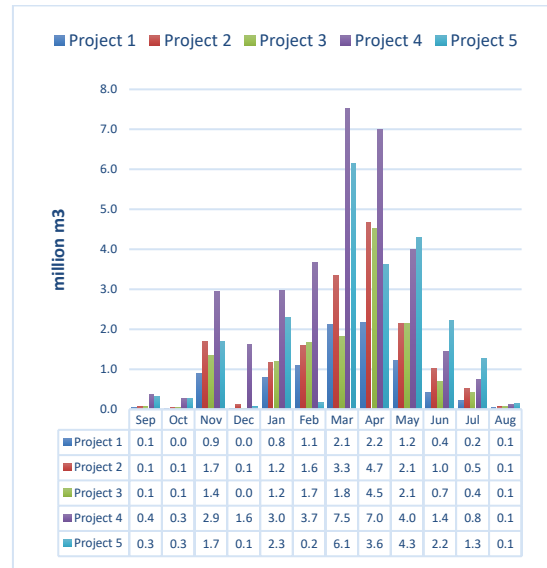


Figure 8. Water requirement for each project (with feild losses)

Table 3. Gross irrigation depth of crops in (mm)

| Crops | Pro.1 | Pro.2 | Pro.3 | Pro.4 | Pro.5 |
|---------------|-------|-------|-------|-------|-------|
| Wheat | 780 | 758 | 821 | 787 | 758 |
| Barley | 632 | 658 | 669 | 645 | 671 |
| Maize | 1707 | 1795 | 1789 | 1792 | 1727 |
| Cucumber | 1401 | 1402 | 1411 | 1445 | 1400 |
| Eggplants | 1161 | 1218 | 1216 | 1233 | 1154 |
| Kidney beans | 778 | 819 | 800 | 821 | 779 |
| Potato Spring | 1470 | 1441 | 1449 | 1476 | 1415 |
| Sesame | 1625 | 1582 | 1628 | 1621 | 1619 |
| Sunflower | 1647 | 1718 | 1625 | 1699 | 1646 |
| Sweet Pepper | 1752 | 1768 | 1758 | 1755 | 1750 |
| Tomato | 1519 | 1570 | 1527 | 1591 | 1554 |
| Watermelon | 1544 | 1571 | 1539 | 1602 | 1488 |
| Berseem | 1070 | 1097 | 1074 | 1034 | 1021 |
| Broad bean | 553 | 588 | 554 | 592 | 558 |
| Cauliflower | 1026 | 1016 | 967 | 999 | 983 |
| Potato autumn | 712 | 769 | 713 | 701 | 704 |
| Citrus | 3309 | 3399 | 3420 | 3429 | 3303 |
| Grap | 2389 | 2452 | 2361 | 2526 | 2454 |
| Olives | 2511 | 2762 | 2618 | 2832 | 2539 |
| Palm | 3688 | 3681 | 3644 | 3713 | 3719 |

The Total water supply represents the total water provided from the river to each project included the field efficiency of 55% and the conveyance efficiency of lined canal of 85% [8] as in Table.4.

Table 4. Total water supply from river for each project in (million m^3) / year

| Project | Pumps (m^3/s) | Volume without losses | Field losses | Convey losses | Water supply |
|---------|-------------------|-----------------------|--------------|---------------|--------------|
| Pro.1 | 3.3 | 5.00 | 4.09 | 1.6 | 10.7 |

| | | | | | |
|-------|------|-------|-------|-------|-------|
| Pro.2 | 2.16 | 9.06 | 7.41 | 2.91 | 19.4 |
| Pro.3 | 2.14 | 7.71 | 6.31 | 2.47 | 16.5 |
| Pro.4 | 8.2 | 18.00 | 14.72 | 5.77 | 38.5 |
| Pro.5 | 8.8 | 12.39 | 10.14 | 3.97 | 26.5 |
| Sum | 24.6 | 52.15 | 42.67 | 16.72 | 111.5 |

The different in water requirement of the projects in Table 4 is related to the cultivated area for each project as in Table 1. The largest water supply was to project 4 and project 5 with 38.5 million m^3 /year and 26.5 million m^3 /year respectively. It is related to the largest area, which is 8250 ha and 11250 ha for project 4 and project 5 with cultivated area of winter and summer crops of 58% with 4.5% for project 4 and 44% with 3.18% for project 5 as in Table 1.

The amount of water used in production in Table 5, represents the sum of the gross irrigation depth of crop with the effective rainfall, and the result is multiplied by cultivated area of crop.

Table 5. Total water used in production in (million m^3 /year)

| Crops | Pro.1 | Pro.2 | Pro.3 | Pro.4 | Pro.5 |
|---------------|-------|-------|-------|-------|-------|
| Wheat | 8.71 | 15.33 | 12.24 | 27.16 | 16.36 |
| Barley | 0.96 | 2.21 | 1.59 | 5.93 | 0.83 |
| Maize | 0.66 | 1.81 | 1.14 | 1.42 | 3.85 |
| Cucumber | 0.04 | 0.12 | 0.08 | 0.31 | 0.23 |
| Eggplants | 0.03 | 0.10 | 0.07 | 0.26 | 0.20 |
| Kidney beans | 0.02 | 0.07 | 0.04 | 0.17 | 0.13 |
| Potato Spring | 0.04 | 0.12 | 0.08 | 0.32 | 0.26 |
| Sesame | 0.04 | 0.13 | 0.09 | 0.34 | 0.27 |
| Sunflower | 0.05 | 0.14 | 0.09 | 0.36 | 0.29 |
| Sweet Pepper | 0.05 | 0.16 | 0.11 | 0.40 | 0.34 |
| Tomato | 0.04 | 0.13 | 0.09 | 0.33 | 0.27 |
| Watermelon | 0.04 | 0.13 | 0.09 | 0.34 | 0.26 |
| Berseem | 0.04 | 0.06 | 0.04 | 0.48 | 0.40 |
| Broad bean | 0.02 | 0.04 | 0.02 | 0.29 | 0.24 |
| Cauliflower | 0.03 | 0.05 | 0.04 | 0.42 | 0.33 |
| Potato autumn | 0.02 | 0.04 | 0.02 | 0.28 | 0.25 |
| Citrus | 0.11 | 0.11 | 0.16 | 0.25 | 0.32 |
| Grap | 0.08 | 0.08 | 0.12 | 0.18 | 0.24 |
| Olives | 0.08 | 0.09 | 0.12 | 0.20 | 0.27 |
| Palm | 0.12 | 0.12 | 0.18 | 0.27 | 0.37 |

In Table 5, the total water used in production represents the sum of the gross irrigation of crops with effective rainfall, product by the cultivated area of the crop within the project. The water productivity was different between irrigation projects as in Table 6 due to the different soil texture of each project, which caused differences in water supply and as a result, differences in water productivity.

Table 6. Water productivity of crops (kg / m^3)

| Crops | P.1 | P.2 | P.3 | P.4 | P.5 |
|---------------|------|------|------|------|------|
| Wheat | 0.28 | 0.27 | 0.28 | 0.28 | 0.31 |
| Barley | 0.19 | 0.16 | 0.17 | 0.18 | 0.17 |
| Maize | 0.30 | 0.30 | 0.30 | 0.29 | 0.30 |
| Cucumber | 0.75 | 0.67 | 0.63 | 0.68 | 0.74 |
| Eggplants | 1.33 | 1.30 | 1.29 | 1.31 | 1.40 |
| Kidney beans | 0.50 | 0.57 | 0.75 | 0.59 | 0.69 |
| Potato Spring | 1.75 | 1.83 | 1.88 | 1.75 | 1.77 |
| Sesame | 0.05 | 0.08 | 0.06 | 0.06 | 0.07 |
| Sunflower | 0.20 | 0.14 | 0.13 | 0.14 | 0.14 |
| Sweet Pepper | 0.60 | 0.50 | 0.45 | 0.50 | 0.47 |
| Tomato | 1.75 | 1.69 | 1.67 | 1.67 | 1.70 |
| Watermelon | 1.25 | 1.23 | 1.11 | 1.18 | 1.27 |
| Berseem | 1.00 | 1.00 | 1.00 | 0.98 | 1.00 |
| Broad bean | 1.00 | 0.75 | 1.00 | 0.76 | 0.75 |
| Cauliflower | 1.00 | 0.80 | 0.75 | 0.76 | 0.82 |
| Potato autumn | 4.00 | 3.25 | 4.00 | 3.61 | 3.44 |
| Citrus | 0.09 | 0.09 | 0.13 | 0.12 | 0.13 |
| Grap | 0.50 | 0.50 | 0.50 | 0.44 | 0.46 |
| Olives | 0.63 | 0.56 | 0.67 | 0.60 | 0.59 |
| Palm | 0.25 | 0.25 | 0.28 | 0.26 | 0.24 |

Table 7. Total Production and economic return in (million)

| Projects | Production (Kg/year) | Total returns (\$/ year) |
|-----------|----------------------|--------------------------|
| Project 1 | 3.4 | 1.37 |
| Project 2 | 6.4 | 2.56 |
| Project 3 | 5.1 | 2.05 |
| Project 4 | 13.8 | 5.58 |
| Project 5 | 10.5 | 4.47 |
| Sum | 39.3 | 16.04 |

The total production for the current year was 39.3 million Kg/year with economic returns of 16.04 million \$/year as in Table 7. The total water supply from the river was 111.5 million m^3 /year, represented by the gross irrigation with conveyance losses of 16.72 million m^3 /year. The conveyance losses were not used in production due to water productivity including water applied in field with the effective rainfall.

The total water supply from the river was 111.5 m^3 /year, and equal 34.2% from water budget from Euphrates, which was 326 million m^3 /year. The economic returns from project 4 and 5 were the largest compared to the other projects, and the reason related to the large cultivated area of these projects compare to the other projects as in Table 1. Although the few cultivated area for project 4 and 5, but it was the largest plants with crops. There for the total

economics returns were 5.58 with 4.47 million \$/year on respectively.

| | | | | |
|-----|-------|------|------|-----|
| Sum | 28342 | 67.7 | 13.4 | 2.6 |
|-----|-------|------|------|-----|

3.1 Improve cultivated area

The water budget for the irrigation project was 326 million m^3 / year and the amount of water used in irrigation was 111.5 million m^3 / year including all losses. The percent of unused water was 65.8%. Therefore it was necessary to improve the cultivated area to achieve more production with more economic returns.

The additional cultivated area as in Table 9 increased the irrigation volume by 144% from 111.5 million m^3 /year to 272.12 million m^3 /year. The economic returns increased by 307% from 16.04 million \$ /year to 65.24 million \$/year as in Table 10. The unused water reached 54 million m^3 /year, which equals to 17% from water budget and to use it, more pumps are required for the projects.

3.1.1 First scenario

Improving the cultivated area for Table 1 was without adding new operation pumps for projects with evaluating the annual production and economic returns.

Table 10. Total Production and economic return in (million)

Table 8. The percent of Increasing in cultivated area of projects

| | Winter crps | | | Summer crops | | Tress |
|-------|-------------|--------|-------|--------------|-------|-------|
| | Wheat | Barley | Other | Maize | Other | |
| Pro.1 | +4% | +15% | +25% | +2% | +20% | +4% |
| Pro.4 | +10% | ----- | +24% | +1% | +15% | +2% |
| Pro.5 | +30% | +5% | +7% | +2% | +5% | +3% |

| Projects | Total water supply with losses (m^3) | Production (Kg/year) | Total returns (\$/ year) |
|-----------|--|----------------------|--------------------------|
| Project 1 | 46.92 | 28.83 | 13.33 |
| Project 2 | 19.37 | 6.42 | 2.56 |
| Project 3 | 16.49 | 5.09 | 2.05 |
| Project 4 | 94.78 | 60.94 | 27.4 |
| Project 5 | 94.55 | 43.29 | 19.9 |
| Sum | 272.12 | 144.57 | 65.25 |

The increase in cultivated area in Table 8 is based on the Priority of saving water. For example, the barley crop needs gross irrigation depth of 632 mm/year and 672 mm/year for project 1 and 5, respectively. Therefore, the increase was 35% and 5% for project 1 and 5 respectively. As well for wheat crop, it needed gross irrigation of 821 mm and 758 mm for project 3 and 5, respectively. Therefore, it increase by 30% for project 5.

3.1.2 Second scenario

In this scenario new pumps were added to use all water budget of Ramadi irrigation project. The pumps increased from 2.16 to 3.16 m^3/s , 2.14 to 3.14, and from 8.8 to 10.8 for projects 2, 3, and 5 respectively.

The cultivated area in Table 8 did not increase for Project 2 and 3 because the pumps were not enough to cultivate more crops. This required increasing the pumps for the project to cover all demand during all months, where the need occurred during hot months with increased crops water requirements. The water discharge of pumps for projects 1, 2, 3, 4, and 5 were 3.3, 2.16, 2.14, 8.2, and 8.8 m^3/s , respectively.

Table 11. The percent of Increasing in cultivated area of projects under second scenario

Table 9.Total cultivated area of Ramadi irrigation project by scenario 1 after Improving

| | Area (ha) | Cultivated area after applied First scenario | | |
|-------|-----------|--|----------------|-------------------|
| | | Winter crops % | Summer crops % | Perennial crops % |
| Pro.1 | 3667 | 71.6 | 23.7 | 4.34 |
| Pro.2 | 2675 | 66.2 | 6.5 | 0.47 |
| Pro.3 | 2500 | 58 | 4.5 | 0.75 |
| Pro.4 | 8250 | 78.2 | 19.18 | 2.34 |
| Pro.5 | 11250 | 60.1 | 10.29 | 3 |

| | Winter crps | | | Summer crops | | Tress |
|-------|-------------|--------|-------|--------------|-------|-------|
| | Wheat | Barley | Other | Maize | Other | |
| Pro.1 | +4% | +15% | +25% | +2% | +20% | +4% |
| Pro.2 | ----- | ----- | +20% | ----- | +5% | ----- |
| Pro.3 | ----- | ----- | +10% | ----- | +18% | ----- |
| Pro.4 | +10% | ----- | +24% | +1% | +15% | +2% |
| Pro.5 | +30% | +10% | +17 | +2% | +5% | +3% |

Table 12. Production of projects with economic return in (million)

| Projects | Total water supply with losses (m^3) | Production (Kg) | Total returns (\$/ year) |
|-----------|--|-----------------|--------------------------|
| Project 1 | 46.92 | 28.83 | 13.33 |
| Project 2 | 26.20 | 14.65 | 6.21 |
| Project 3 | 26.56 | 14.21 | 6.25 |
| Project 4 | 94.78 | 60.94 | 27.40 |
| Project 5 | 128.68 | 73.64 | 33.60 |

| | | | |
|-----|--------|--------|-------|
| Sum | 323.14 | 192.27 | 86.79 |
|-----|--------|--------|-------|

Table 13. Total cultivated area of project by second scenario after Improving

| | Area (ha) | Cultivated area after applied second scenario | | |
|-------|-----------|---|----------------|-------------------|
| | | Winter crops % | Summer crops % | Perennial crops % |
| Pro.1 | 3667 | 71.6 | 23.7 | 4.34 |
| Pro.2 | 2675 | 86.2 | 11.5 | 0.47 |
| Pro.3 | 2500 | 68 | 22.5 | 0.75 |
| Pro.4 | 8250 | 78.2 | 19.18 | 0.34 |
| Pro.5 | 11250 | 75.1 | 10.29 | 3.34 |
| Sum | 28342 | 76 | 15.8 | 2.1 |

4. Conclusion

1- The water used for Ramadi irrigation project represent 34.2% from Ramadi irrigation budget from Euphrates River.

2- Despite of, the total water requirement increased by 144% from 111.5 m^3 /year to 272.12 m^3 /year, the economic returns increased by 307% from 16.04 million \$ /year to 65.24 million \$.

3- When using additional pumps for project 2 and project 3 by 1 m^3 /s and 2 m^3 /s for project 5, respectively, the economics return increased by 441% from 16.04 million \$ /year to 86.79 million \$ / year.

4- The convey loss increased from 16.72 million m^3 /year to 48.47 million m^3 /year, when applied second scenario.

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تحسين المساحة المزروعة لمشروع الرمادي الاروائي باستخدام نموذج تخطيط وتقييم المياه (WEAP)

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المخلص

في هذه الدراسة تم استخدام نموذج تقييم وتخطيط المياه (ويب) لتحسين المساحة المزروعة لمشروع الرمادي الاروائي بمساحة 28342 هكتار وحصه مائيه سنويه 326 مليون م3/بالسنة. أظهرت النتائج أن إجمالي المياه المستخدمة بلغت 111.5 مليون م3/بالسنة وهو ما يعادل 34.2% من الحصه المائيه المخصصه للمشروع الاروائي. حيث بلغ الإنتاج السنوي 39.3 مليون كغم/بالسنة للمشروع مع عائد اقتصادي 16.04 مليون دولار/ بالسنة. اقترحت الدراسة سيناريوهين لتحسين المساحة المزروعة. أدى السيناريو الأول إلى زيادة حجم المياه المستخدمة للعام الحالي من 111.5 مليون م3 / سنويًا إلى 272.12 مليون م3 / سنويًا ، حيث أدى إلى زيادة الإنتاجية السنوية من 39.3 مليون كغم / سنويًا إلى 144.57 مليون كغم/سنويًا ، وكذلك ارتفاع العائد الاقتصادي من 16.04 مليون دولار إلى 65.25 مليون دولار في السنة. سجل السيناريو الثاني زيادة في الإنتاج السنوي من 39.3 مليون كغم / إلى 192.27 مليون كغم / بالسنة مع زيادة العائد الاقتصادي من 16.04 مليون دولار / سنويًا إلى 86.79 مليون دولار / سنويًا عند استخدام مضخات إضافية للمشروع 2 و 3 والمشروع 5. كما زادت خسارة النقل من 16.72 مليون م3/ بالسنة للعام الحالي إلى 48.47 مليون م3/ بالسنة عند تطبيق السيناريو الثاني ، وهو ما يعادل 15% من الحصه المائيه لمشروع الرمادي الاروائي.

الكلمات الداله :

تحسين المساحة المزروعة ، تحسن العائدات الاقتصادية ، مشروع الرمادي الاروائي ، نموذج ويب