Optimal Policies for Conjunctive-Use and Cropping Pattern for Al-Wand Basin

Amer Hassan Al-Haddad **Zainab Kadhim Jabal**
College of Engineering-University of Baghdad
Ameralhaddad1950@yahoo.com zainabkadham@yahoo.com

Abstract

Applying conjunctive use between surface water and ground water is getting widely used at many regions in the world, due to the increasing need of water resources, especially when large quantities of water and for long time are used for irrigation purposes to meet agricultural production requirements.

The linear programming has been formulated to optimize the optimum allocation of water. An economic analysis of conjunctive use for Al-Wand project in Iraq has been done for a certain cropping pattern using two scenarios of management and operation of ground water and surface water. One suggested scenario was to use ground tank to save the water during the period of water excess to be used during the shortage period. The other scenario was to operate the reservoir dam to supply the water requirements during the agriculture years. The main concerns of this research were: the fluctuation of the ground water and how to estimate the deficit of yield which is caused by using the decreased water in irrigation. The economic analysis has been done by calculating the overall cost and the annual estimation of return. It can be concluded that the operation of surface water at (60 and 70%) from total available surface is a compromise, because some of the water still flow in the river and canals and the ground water reservoirs were not affected especially its storage capacity.

Keyword: water requirement, conjunctive use, linear optimization, recharge of ground water.

1. Introduction

When the water used during the growing season is not adequate for the development of plants growth, its yield may be effected. So, the quantity and the time of water application are important to guarantee that they get maximum yield. The irrigation engineering tries to cover the shortage of designed water requirements by finding other sources of water to cover this shortage. One of these sources is the ground water which must be suitable in terms of quantity and quality to provide the water required by crops to grow without suffering of water stress during its growth stage.

1.1 Conjunctive use

The conjunctive use is a way to satisfy the best use of water by linking between surface water and ground water. The conjunctive use is intended to increase the irrigation water required and to improve the efficiency of operation and management of natural water resources systems to satisfy the equilibrium strategy for hydrologic cycle balance by the management of outlet (uses) and inlet (sources) for resources to meet their purposes.

Kubba [1] presented a linkage between the economic model and the hydrologic model to give an optimum plan to manage irrigation water and to increase agricultural production in Kasra region in Iraq. He analyzed the aquifer's behavior under different pumping operations using numerical simulation model for ground water. Two models in Cosatal river basin in Orissa state, India was develop as a try to increase the crop rice production. The ground water balance model with optimum cropping pattern was apply as an effective management between ground and surface water. Also, the model used for saline and non-saline type of soil and for two cultivated land rained and irrigated, and for two seasons monsoon and winter **[2]**. Genetic Algorithm in conjunctive use formulated a model to optimize the water resources allocation connecting between surface water and ground water to indicate a suitable crop pattern. The economic function considers the maximizing the net benefit which main parameters are pumping cost, crop agriculture cost, water table fluctuations and crop yield reduction. The suggested model was applied in Varamin plain, Iran **[3]**.

The conjunction between surface water and ground water connected to decrease the salinity of irrigation water and to avoid soil salinization. Fixed rotational canal in Punjab Pakistan with ground water resources were applied in study area. When ground water was rising in the upstream areas and aggravating salinity problem in the tail area. From the options to solve the salinity of water is mixing ratios of surface water and ground water to reach the acceptable salinity levels as guidelines **[4]**. The optimal cropping pattern for connecting between ground and surface water used a dynamic programming for single crop and linear programming for multiple crops in Nadiad branch canal of mahi (Gujarat, India) as a command study area **[5]**.

1.2 Ground Water

The hydrologic cycle in nature gives accurate explanation of the balance of ground water and surface water components; the two resources are connected and cannot be disconnected. At any natural basin the components might affect the assumption of the researchers and boundaries of any program technique. In this study the components that affect the ground water reservoir are: Recharge, Discharge and Ground reservoir storage.

Recharge of groundwater is the process of transferring water into the soil after be infused (saturated zone) making an availability of water reservoir **[6]**. Ground water recharge is a key component of any ground water model, and accurate quantification of recharge values. It is an imperative parameter to take proper management and the protection of availability of ground water resources **[7]**. The main estimated parts of recharge are: precipitation, base flow from rivers or lake, deep percolation from irrigation, and excess of soil moisture content. Water table fluctuation (WTF) method was used to estimate the recharge, specific yield and change in water level must be available during a period as requirements of this study. There are many methods used water level to estimate the recharge of ground water, but these methods based on Darcy equation. The simple and insensitivity of mechanics in (WTF) method makes it useful especially when water moves through unsaturated zone **[7]**.

The storage of ground water is the volume of water existing in the effective voids of geological layers in unconfined aquifer. The storage of ground water differs from aquifer to another due to the quantity and percentage of their volumes. There are two types of storage: Renewed Storage has a dynamic objective and a function of time, and is affected by natural boundaries of layers and Fixed Storage has volumetric of porosity quantity and a function of properties of geological layers dimensions (pressure and pores) **[8]**. Where the ground storage would determine by depending on the recharge which reaches to aquifer that's mean is Renewed Storage has been estimated in this research.

The subsurface storage of ground water was present by two possibilities: the first one is the artificial recharge, whereas the second is the use of ground water as an alternate source of surface water. The artificial recharge is expensive and it is carried out with wells through infiltration ponds and the water that is recharged to be desalted and treated to prevent clogging **[9]**. The recharge of ground water in Eastern United states was estimate by using four methods which are Daily Water Balance, Unsaturated-Zone drainage, Equations of Rovabaugh, and Water-Table Fluctuations method. These methods can be used to estimate base flow for a study area **[10]**. The Evaluation for a recharge of ground water in arid and semi – arid was present by selecting four methods to calculate the recharge of ground water. They are: Fluctuating of water table, Water balance of the basin, Numerical modeling, and Balance of chloride ion mass in unsaturated zone and the region of study in the plateau of Karbala **[11]**.

1.3 Mathematical Optimization

The mathematical programming (Optimization) is the way to select the best elements to help in working out a certain criteria from a set of available alternatives. Maximizing and minimizing problems are the types of optimization. In applied mathematics the generalization of optimization theory and techniques are used. The goal of using the optimization is to find the best available values for objective function (or a group of constraints) or for different types of objective function.

Linear programming shows the fact the line for the objective function must be optimized and for all the constraints which are linear in sets of the decision variables. Feasible solution satisfy when the solution is found in decision variables of the constraints and objective function, by practice in algorithms can be appear move on feasible solution until the objective function has been optimized as maximized or minimized **[12]**.

2. The Area of Study

The main properties of the study area can clarify by explain the geography, climate and Geology.

2.1 Geography

The study project is situated in the eastern part of Iraq, in Diyala Governorate. It is located in the middle of Iraq with border crossings with Iran (Monthiriah and Mandali) and the shortest road to Baghdad and near the Iranian border and north–west of the town Khanaqin. The project is located between (34° 18'), (34° 30') north latitude, and (45° 12'), (45° 24') east longitude, **Fig. 1**. Al-Wand River passes through the study area. It is one of the most important tributaries of Diyala River in the southern part. The area of the basin which feeds Al-Wand River is about (3340 km^2). In Iran the basin area is about (2780km^2), and about (560km^2) inside Iraq. There are five irrigation branches which branch off Al-Wand River and irrigate agricultural land and orchards in the area of Khanaqin and its height boring area after breaking threat of Khanaqin. It meets Diyala

River at (5*km*) upstream the town of Jalula **[13],** see **Fig. 2**.

Al-Wand Dam is situated across Al-Wand River at (7*km*) from south east Khaniqin city and at (6*km*) from borderline between Iraq and Iran. The purpose of the constructed Al-Wand dam is to control the water supply from Iranian border, and to protect Khaniqin and other cities from flood.

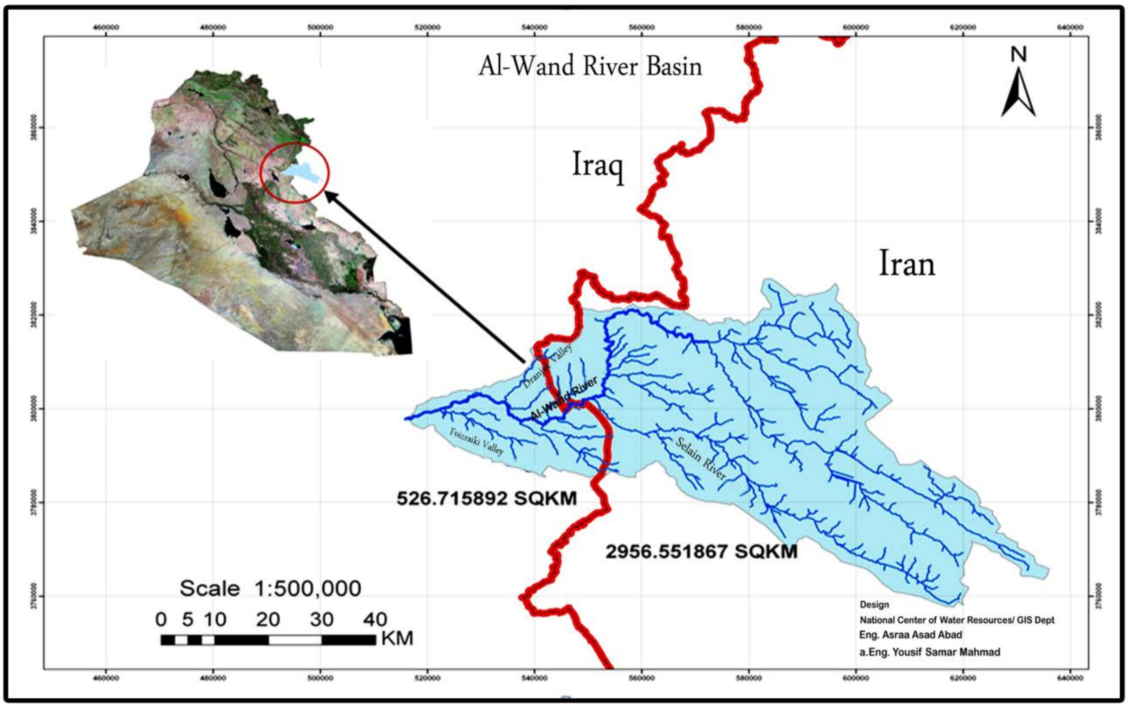

Figure 1: The geographic and basin of Al-Wand River, **[13]** .

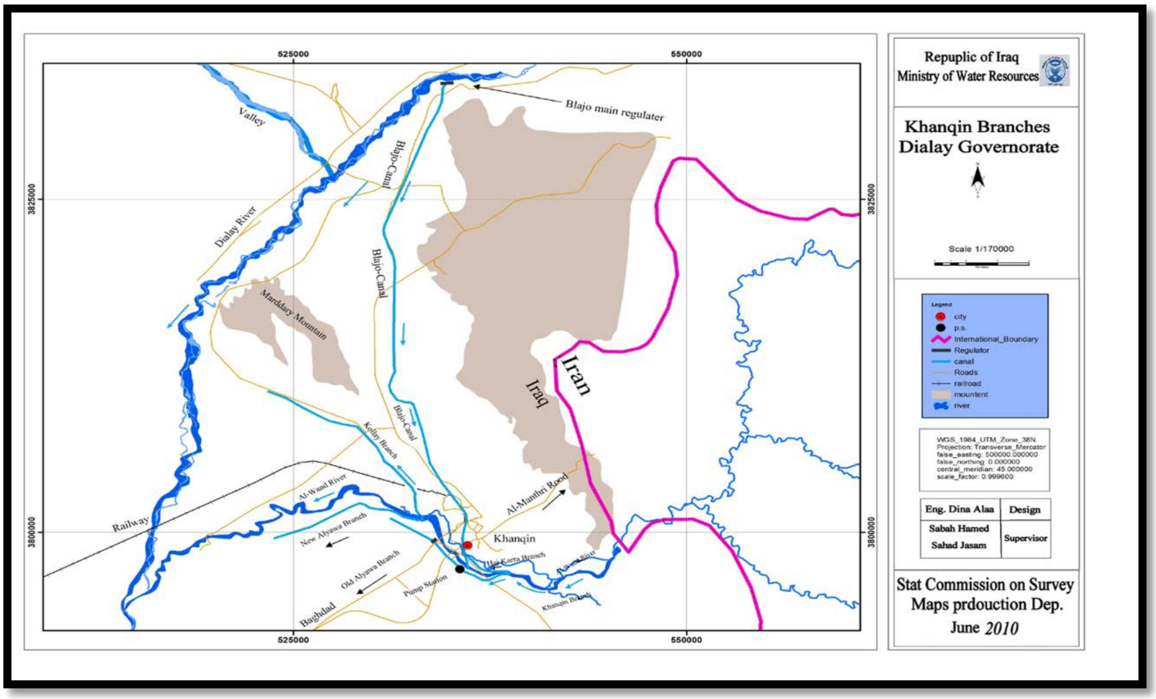

Figure 2: The details the Blajo canal between Al-Wand River and Diyala River, **[13]**.

2.2 Climates

The main climatic features of the region of the project are long in winter and hot summer. The climatic data recorded in Khanaqin Meteorological Station, which is located quite near to the irrigated area on (34° 18') latitude and (45° 26') longitude. The parameters of climate can be illustrated as annual average for 20 years. The annual rainfall average during this period is 283 *mm*, and the humidity is equal to (48.52%) as average for period (1981-2000), and the averages of temperature in winter is (12C°), and (33C°) in summer and during the same interval. The average wind speed is (2.18 *m/s*), and the annual average of evaporation for interval (1988-2008) is (260*mm*).

2.3 Geology

Al -Wand River valley basin is characterized as a valley created due to the erosion. It consists of deposits of Quaternary Age almiosin which is a type of (almarl) and sandstone. The most tracts of Al -wand River basin is an alluvial deposit, ranging from depths of (1.5–10*m*) which is resulted from the historical phases of the age of the river and the transmission of these materials through runoff and floods on the river. Gypsum is found in Almarl stones and sandy stones at ground bases in the form of small isolated pools and tests have shown that these stones were not self-executing and zaoian for gypsum or access filter. Due to the investigation of ground water from the wells which are excavated in the area, the aquifer is unconfined which means it spreads between Iraq and Iran.

Due to Al-Wand River suffers from scarcity of water during certain months due to the policy of the Iranian government. The discharge of the river is not sufficient to cover the human needs and the agriculture purposes. The Iraqi experts solved this problem by creating Blajo lined canal as a by – pass connects Diyala River and Al-Wand River near Khanagin and for this reason is called (Blajo-Al-Wand) Project, **Fig. 2**. Because of the increase in the population and irrigation requirements, an increase in the deficit of water requirements for irrigation and human needed during certain months appeared especially during the summer months, at Al-Wand River and Blajo canal. The farmers use the ground water as a standby source of water to cover their need for irrigation, and for human and animal purposes. The government drilled many wells, and distributed it's around project area. Cropping pattern at (Al-Wand – Blajo) project is shown with details in **Table. 1**. **Table. 2**, shows the monthly average discharge of Al-Wand River and Blajo canal.

Table 1: The cropping pattern and its intensity in the study area, **[13]**.

No.	Branch	Net Area(*ha*)	Intensity of crops as percentage %					
			Wheat	Barley	Veget.	Field	Fruit	Total
1.	Haje Karra	157.5	0	0	0	0	80	80
2.	Old Alyawa	1231.5	29	29	4	15	3	80
3.	New Alyawa	1037.25	29	29	5	15	2	80
4.	Kollay	5570	30	30	5	15	0	80
5.	Khanaqin	1842.25	28	28	4	15	5	80
6.	Al-Wand River	500	30	30	5	15	0	80

Table 2: The average of monthly discharges of Al-Wand River, and Blajo Canal**[14]**.

Month	Average discharge (m^3/s)	
	Al-Wand River	Blajo Canal
Jan	11.42	4
Feb	9.14	4
Mar	6.7	4.4
Apr	4.06	4.4
May	2.5	4.4
Jun	2.12	5.2
Jul	1.55	5.5
Aug	0.94	6.6
Sep	3.8	4
Oct	4.24	3.9
Nov	15.9	3.5
Dec	16.01	4

3. Mathematical Model

Mathematical model is formulated from the equations and scientific basics of the research objectives. The scientific basics can be divided into three levels: the first level is the calculation of water requirements; the second level is the formulation of conjunctive use, and economic analysis; the third level includes the formulation of optimization basics of the objective functions and their constraints, **Fig. 3** shows the flow chart steps of mathematical model.

3.1 Calculation of Water Requirements

In this level weighted of actual crop evapotranspiration determined due to the change in planted area for each crop, from equation:

$$WET_{cib} = \left(\sum_{c=1}^{n} (ETa_{ic} * NA_c) \right) / \left(\sum_{c=1}^{n} NA_c \right) \quad (1)$$

Where:

WET_{cib} = monthly average weighted of actual crop evapotranspiration for certain cropping pattern during i^{th} month for each branch, (*mm / month*),

NA_c = net area which planted with c^{th} crop, it is equal $NA * PA_c$, (*hectare*),

NA = net irrigated project area, (*ha*),

PA_c = percentage of area planted with the crop c^{th},

n = number of crops in adopted crop pattern,

b = branch number index, and

c = crop index.

The effective rainfall calculated by using (USDA) method, which depended on the long term of climate and soil moisture data. The analysis was done by collecting years of precipitation which were record at 22 experimental stations. To avoid the high degree of complexity for using the way of balancing the soil moisture by adding the effective rainfall or irrigation water for two days sequential and subtracting the consumptive use from the supplying water **[15]**, the effective rainfall using to calculate the net water required which present as below:

$$NI_{i\ req} = \sum_{b=1}^{m} \sum_{c=1}^{n} C * (NA_c * (WET_{cib} - ER_{ib})) \quad (2)$$

where:

$NI_{i\ req}$ = net volume of water required during the i^{th} month for all branches, (m^3),

ER_{ib} = monthly effective rainfall during the i^{th} month, (*mm/month*), and for each branch in study area, and

C = conversion factor.

Leaching requirement, human need and animal purpose percentages added to calculate the total water requirement of the study area:

$$TWQ = NQ_{i\ req} * (1+A) / PE * (1 + HN) \quad (3)$$

where:

TWQ = total water requirement, m^3/s,

$NQ_{i\ req}$ = monthly water required for each branch, m^3/s,

A = leaching requirement percentage,

PE = project efficiency, and

HN = human and animal needed percentage.

3.2 Calculation of conjunctive use

The second level of calculation is the conjunctive – use is a way to operate the two resources surface water and ground water to satisfy the optimum operation of irrigation project, and to maximize the benefit of agriculture yield. The surface resources of irrigation water may be rivers, reservoirs of dams or lakes. Ground water may be used as a second resource of irrigation water. The wells are distributed around the project area, knowing that each well had a different water supply capacity. In this research the ground water was a standby to surface water, and the ground water would be used when there is a deficit in the water requirement that might be covered by surface water.

Two scenarios used as a reasonable solution for deficit water requirement which are floor tank used to collect water during the months which are not needed to deliver irrigation water from the ground water reservoir because the surface water is sufficient to cover all water requirements. The water yield from wells may not meet the deficit of water requirement when of needed, and also the wells capacity does not meet the need with the time of irrigation due to wells discharge. The second scenario is used the operation reservoir dam to cover the deficit of water requirement was to use the water saved at the reservoir of dam as another alternative of ground water. Floor tanks can be used to collect the water to satisfy the shortage of the irrigation water. This scenario allowed us to use ground water when the operation of dam didn't cover all the need for water requirements.

The shortage in water requirement may be appear when using the one of two scenarios, the reason for that was the resources of water (surface water and ground water)did not cover the all water requirement, this shortage affected in yield production which was formulated for each crop as shown below:

$$S_c = (s * r_c) / r_t \quad (4)$$

where:

S_c = percentage of shortage for each crop, (%),

s = shortage of irrigation water calculated as discharge, (m^3/s),

r_c = root depth for each crop, and

r_t = total root depths for all crops in study area.

3.3 Economic Analyses and Optimization

One of the important parameters to make economic analyses of studies is the yield of crops, which gives the gross return of the project. This yield will be affecting by the availability of the irrigation water as a main parameter, and will be optimum when it is available and sufficient during the growth stages of the crop or for all crops. The yield function is a function that explains the variation of yield that is affected by the water supply only. The optimum amount of water supplies to the crop must meet the maximum consumptive use, consequence there is maximum yield which derivative from **[16]**:

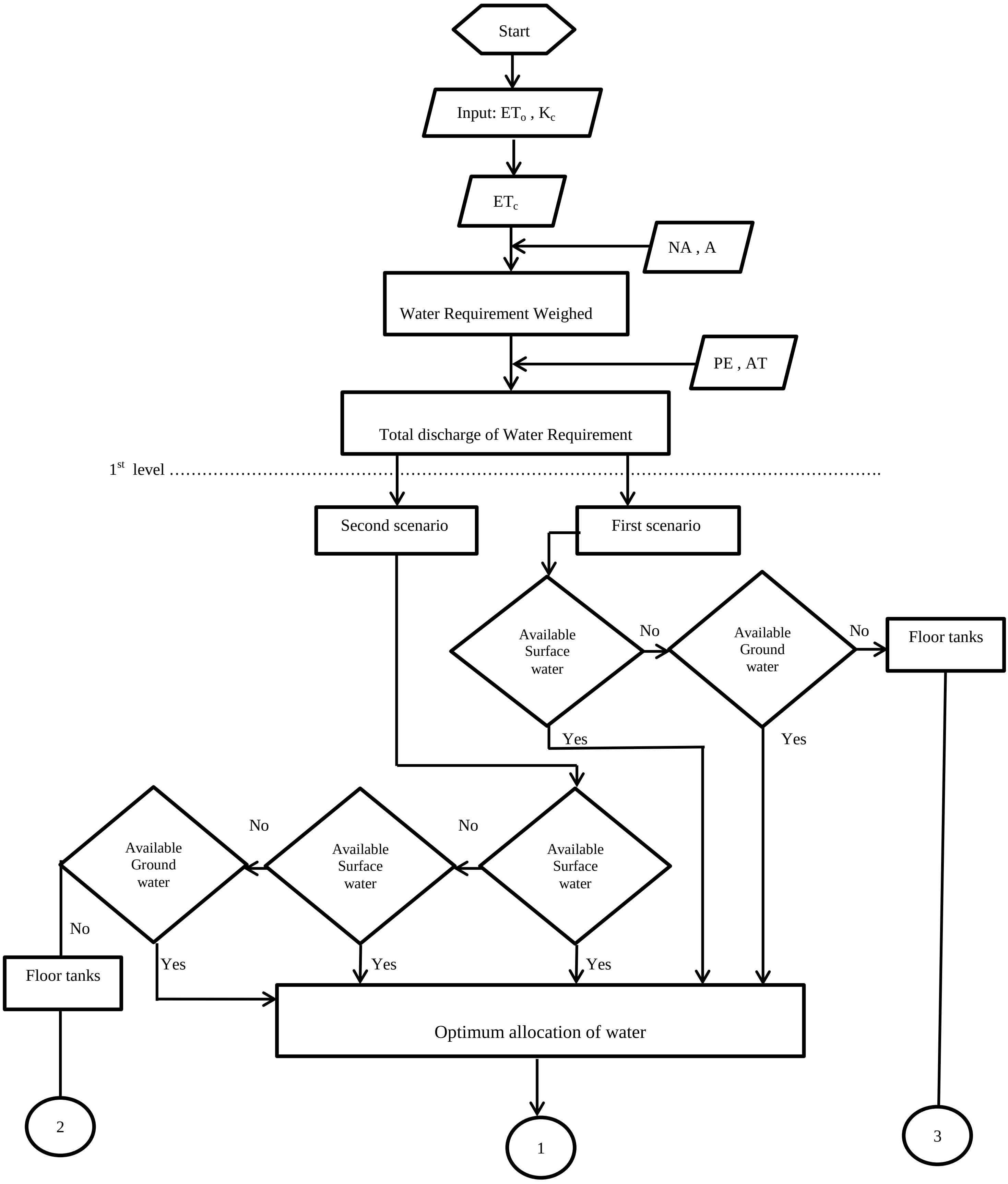

Figure 3: Flowchart illustrates the main steps of mathematical model of conjunctive use.

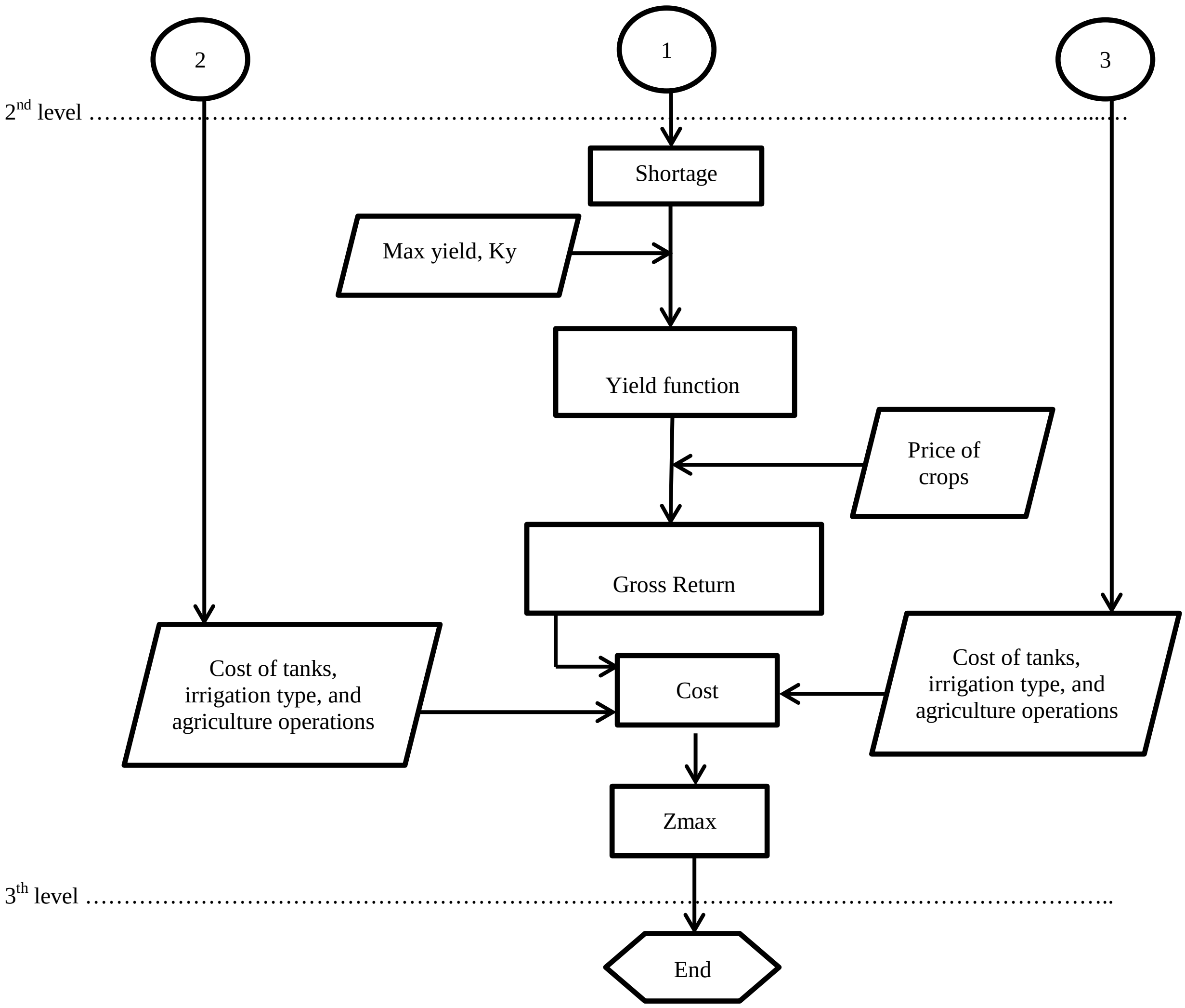

Figure 3 : continued

$$Y_a = Y_m * (1 - Ky * (1 - s_1)) \quad (5)$$

where:

Y_a = actual yield in, (*kg/ha*),

Y_m = maximum yield in (*kg/ha*), which depended on the data of region,

Ky = response factor of water for each crop which depends on the stage of crop growth,

s_1 = percentage of deficit from optimum water supply ($ET_a < ET_m$), $s_1 = 1 - s$,

ET_a = actual evapotranspiration for each crop, (*mm*), and

ET_m = maximum evapotranspiration for each crop, (*mm*).

The main objective is maximizing the net benefit which becomes the objective function of this research, and this is:

$$Z_{max} = G.R - \sum C \quad (6)$$

$$Z = NA * Y_a * P_c - (C_1 + V_S * C_2 + V_G * C_3 + C_4)$$

Constraints:-

$$\sum NA_c = AT$$

$$V_S \geq 40\% \; V_{S\,(ava.)}$$

$$V_G \leq \Delta S$$

where:

AT = total area of project, *ha*,

V_S = volume of surface water that is used in irrigation, (m^3),

V_G = volume of ground water that is used in irrigation, (m^3), and

ΔS = renewed storage of ground water, (m^3), which presented as below:

$$\Delta S = R * AT * C \quad (7)$$

where:

C = conversion of unit factor,

R = recharge water of aquifer, (*m*), which presented from (WTF) method **[7]** as below:

$$R = S_y * \Delta h \quad (8)$$

where:

S_y = specific yield, and

Δh = fluctuation of water level.

4. Results and Discussion

MATLAB is the software program that is used to formulate all scientific basics of Mathematical model. The possibilities of MATLAB are employed to optimize the conjunctive use between surface water and ground water at Al-Wand project. Water requirement can be calculated when all the necessary data must be available as soil physical properties, cropping pattern, the characteristics of the crops, and calculated reference evapotranspiration for the area of study, the crop coefficient and reference evapotranspiration values, also must be available to determine the weighted evapotranspiration. The value of calculated effective rainfall obtains from (USDA) method which is more suitable to indicate the monthly effective rainfall; (USDA) method took into account all the conditions of the agricultural cover and the type of the soil because it depends on water a requirement which is affected by the crop type.

To estimate the supplementary water needed to cover optimum water requirements by using the ground water, in cases of surface water deficit. Conjunctive use suggested a different percentage of using available surface water to indicate the needed amount of ground water to cover the residual deficit of water requirements. **Fig. 4** and **Fig. 5** showed the relation between total water requirement and available surface water in the study area for operation of surface water is (100%), (40%), respectively from available surface water.

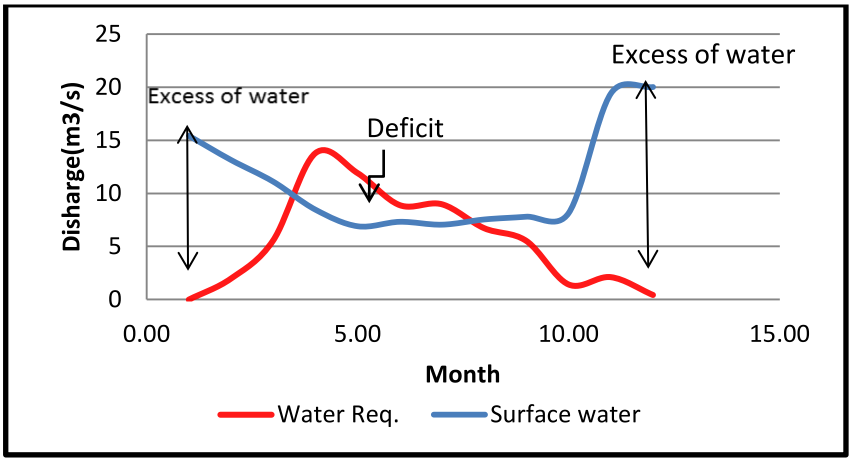

Figure 4: Water requirements discharge with percentage of available surface water 100 %.

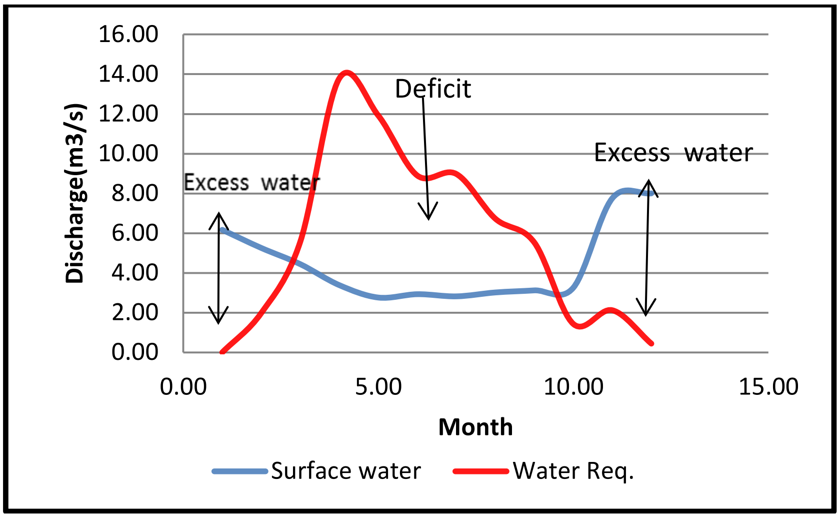

Figure 5: Water requirements discharge with percentage of available surface water 40 % .

4.1 First scenario

The source of ground water is the way to supplement surface water of irrigation to meet water requirements. In this research, the deficit of surface water source can be covered by ground water to satisfy the water requirements. This scenario gives a chance to irrigate the cultivated area at the suitable time of irrigation, and present the assumptions:

1. The supply of surface water was constant during the agricultural year.
2. The designed volume and number of tanks depend upon the predicted larger deficit of water requirement. **Table. 3** show the predicted larger volume of deficit (residual) and number of tanks for each. **Fig. 6** represent the amount of shortage of water required for different percentages of deficit. This may be due to undesirable distribution of the surface water and ground water during the agricultural year.

The total area of the project is about 10181*ha*, the recharge from ground water 28.85*mm* and the grand average of ground storage is about 3039028.5m^3 were calculate by (WTF) method. **Table.4** showed the annual net return before and after using ground water.

Table 3: Number of tank required due to larger value of water deficit.

Deficit percentage	Largest volume (LDm^3)	Volume of one tank (vm^3)	Number of tank (*NT*)
0	14224550.79	1000	14224.55
10	16417382.79	1000	16417.38
20	18610214.79	1000	18610.21
30	20803046.79	1000	20803.05
40	22995878.79	1000	22995.88
50	25188710.79	1000	25188.71
60	27381542.79	1000	27381.54

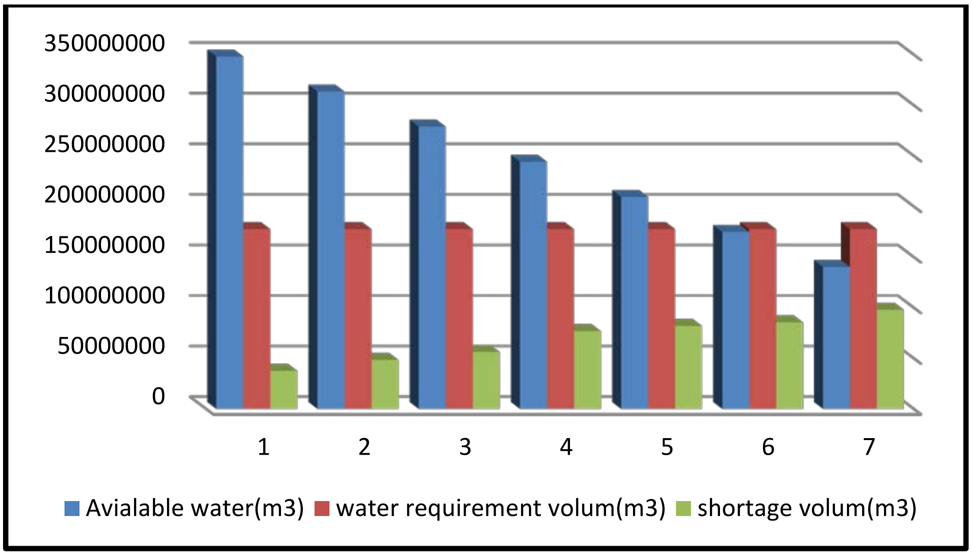

Figure 6: Annual volume of water requirement, available water (surface and ground) and of shortage.

Table 4: Annual net return for each suggested deficit of water requirement after using optimization model (without and with using ground water).

Deficit (%)	Volume of surface water ($V_S\ m^3$)	Volume of ground water ($V_G\ m^3$)	Z_{max}* (*ID*)	Z_{max}** (*ID*)
0	174674880	1418342.4	4755275707	un bounded
10	157207392	1418342.4	4743981771	un bounded
20	139739904	1418342.4	4737415529	un bounded
30	122272416	1418342.4	4728310341	un bounded
40	104804928	1418342.4	4719467802	un bounded
50	87337440	1418342.4	4709749764	un bounded
60	69869952	1418342.4	4700119276	un bounded

Z_{max}* net return without using ground water.
Z_{max} ** net return with using ground water.

4.2 Second scenario

The second scenario used the possibility of using the capacity of water that was saved in the dam reservoir to cover the water deficit of water requirements, and for trying to improve the conjunctive use of ground water with surface water for the study area. All the values of the suggested deficit underlying the storage of dam, which means no shortage, may appear during the agricultural year and the water that is stored in the reservoir will cover any shortage suggested in water requirements. That means there is no need of ground water for suggested cropping pattern, **Fig. 7**.

The economic analysis for second scenario followed to any engineering project is to be desirable when it gives a profit at the end of each agricultural year, and this profit depends on the cost of project operation and the amount of return. **Table. 5** showed the net return before and after using operation of Al-Wand dam.

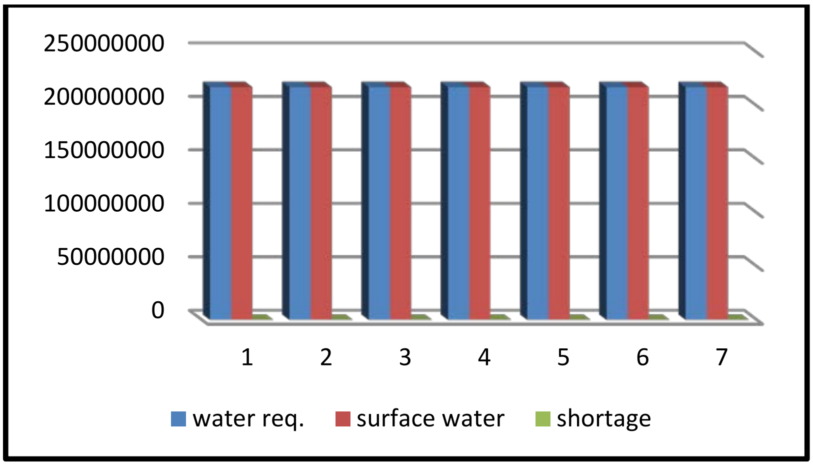

Figure 7: Water requirement with available surface water (dam operation).

Table 5: The expected annual net return and percentage of improvement.

Deficit (%)	Volume of surface water (*VSm*^{3})	Volume of ground water (*VGm*^{3})	Z_{max}* (*ID*)	Z_{max}** (*ID*)
0	217520640	0	4461869077	7133565000
10	217520640	0	4450575141	7133565000
20	217520640	0	4444008899	7133565000
30	217520640	0	4434903711	7133565000
40	217520640	0	4426061172	7133565000
50	217520640	0	4416343134	7133565000
60	217520640	0	4406712646	7133565000

Z_{max}* net return before using operation of dam.
Z_{max}** net return after using operation of dam.

5. Conclusions

1. The results of the first scenario show, the using of available surface and for all percentage of using did not cover all the calculated requirements, the shortage in water requirement decreases as the use of the amount of available surface water increases, so the results indicate the needed of using ground water.
2. The yield of ground water from the wells at the project may be not meeting the time and intervals of irrigation when we suggested applying the conjunctive use due to low production of water. Construct the tanks to save water were very expensive that gave the results of objective function unbounded due to high cost of operation.
3. Any deficit in water requirements given a deficit in yield this principle effects directly on the results of project yield, so high deficit (low surface water used) gave low yield.
4. The second scenario was the possibility of Al-Wand dam operation, and by using the capacity of dam reservoir. The results show that, all the water requirement were cover if we built a schedule of water supplying from the dam with proper time that meeting the date and time of supplying irrigation water to meet water requirements. This operation gave an optimum yield during the agricultural year.

5. From all results of cases study the compromise operation of Al-Wand project is by using (60-70%) of available irrigation water (surface and ground water) which gave less reduction in yield and maximum benefit as compare with other operation.

6. Recommendations

1. Pumping test must be conducted for all suggested cases to clarify the drawdown for each well when using ground water for irrigation and indicate the capacity of aquifer in the study area.
2. Irrigation scheduling should be applied to study on the conjunctive –use method and on the production of the project.
3. Another cropping pattern should be applied to satisfy an optimum operation and optimum yield.
4. The properties and the quality of ground water and surface water should be studied to see whether they are suitable for agriculture and human uses, and to prevent any soil salinization.

References

[1]. Kubba, F, A, (1998), "Conjunctive use of ground water and surface water in the western desert of Iraq, case study, Kasra area", Ph. D. Thesis submitted to Irrigation and Drainage Engineering Department, University of Baghdad.

[2]. Seith, L, N, Kumar, D, N, Panda, S, N, and MAL, B, C, (2002), "Optimal crop planning and conjunctive use of water resources in a Coastat river basin", Water Resources Management: Kluwer Academic publishers. Printed in the Netherlands, vol. 16, p. 145 –169.

[3]. Karamouz, M, Ahmad, A, and Nazif, S, (2009), "Development of management schemes in irrigation planning: economic and crop pattern consideration", Transaction A: civil Engineering. SID. Irr, vol. 16, no. 6, p. 457 – 466.

[4]. Qureshi, A, S, (2014), "Conjunctive water management in the fixed rational canal system: a case study from Punjab Pakistan", Irrigation and Drainage Systems Engineering, vol. 3: 122 doi 10. 4172/2168 – 9768. 10001222.

[5]. Aparnathi, M, G, and Bhatt, D, K, (2014),"Linear programming model for optimal cropping pattern for economic benefits of Mrbc command area", International Journal for Innovative Research in Science and Technology, vol. 2349, no. 6010, p. 47 – 54.

[6]. Freeze, R, A, and Cherry, J, A, (1979), "Ground water", prentice – Hall, Engle wood Cliffs, NJ, 604 p.

[7]. Healy, R, W, and Cook, P, G, (2002), "Using ground levels to estimate recharge", Hydrogeology Journal, DOI 10. 1007/s10040–001 – 0178 – 0, p. 91 – 109.

[8]. Al-Jawaid, S, B, (1999), "Development the advantage of ground water in Iraq", Not Emitted Research, (Language Arabic).

[9]. Sahuguillo, A, (2002), "Ground water – conjunctive use of surface water and ground water", Encyclopedia of life Support Systems (EOLSS), vol. 3.

[10]. Risser, D, W, Gburek, W, J, and Folmar, G, J, (2005), "Comparison of methods for estimating ground water recharge and base flow at as small watershed underlain by fractured bedrock in the eastern United States", U. S. Geological Survey Scientific Investigations Report, vol. 5038, 30 p.

[11]. Ramadhan, A, A, Ali, M, H, and Al-Kubaisy, R, K, (2013), "Evaluation of ground water recharge in arid and semi-arid regions case study of Dibdiba formation in Karballa – Najaf plateau", Iraqi Journal of Science – University of Baghdad, vol. 54, no. 4, p. 902 – 910.

[12]. Postolache, R, (2007), "Linear and nonlinear optimization programming", National Science Foundation, DUE 06/8252.

[13]. National Center for Water Resources Management, Ministry of Water Resources, (2015).

[14]. Stat Commission on Operating of Irrigation and Drainage Projects, 2015.

[15]. Dastane, N, G, (1978), "Effective rainfall in irrigated agriculture", Food and Agriculture Organization of the United Nations, via delle terme dicarcalla, 00/00 Rome, Italy.

[16]. FAO, 1986, "Yield response to water", paper No. 33, Rome.

Nomenclature

WET_{cib}	= monthly average weighted of actual crop evapotranspiration for certain cropping pattern during i^{th} month for each branch, (*mm / month*).
NA_c	= net area which planted with c^{th} crop, it is equal $NA * PA_c$, (*hectare*).
NA	= net irrigated project area, (*ha*).
PA_c	= percentage of area planted with the crop c^{th}.
n	= number of crops in adopted crop pattern.
b	= branch number index.
c	= crop index.
$NI_{i\ req}$	= net volume of water required during the i^{th} month for all branches, (m^3).
ER_{ib}	= monthly effective rainfall during the i^{th} month, (*mm/month*), and for each branch in study area.
C	= conversion factor.
TWQ	= total water requirement, m^3/s.
$NQ_{i\ req}$	= monthly water required for each branch, m^3/s.
A	= leaching requirement percentage.
PE	= project efficiency.
HN	= human and animal needed

	percentage.
S_c	= percentage of shortage for each crop, (%).
s	= shortage of irrigation water calculated as discharge, (m^3/s).
r_c	= root depth for each crop.
r_t	= total root depths for all crops in study area.
Y_a	= actual yield in, (*kg/ha*).
Y_m	= maximum yield in (*kg/ha*), which depended on the data of region.
Ky	= response factor of water for each crop which depends on the stage of growth.
s_1 =	= percentage of deficit from optimum water supply.
ET_a	= actual evapotranspiration for each crop, (*mm*).
ET_m	= maximum evapotranspiration for each crop, (*mm*).
AT	= total area of project, *ha*.
V_S	= volume of surface water that is used in irrigation, (m^3).
V_G	= volume of ground water that is used in irrigation, (m^3).
ΔS	= renewed storage of ground water, ($m^{\cdot}$).
C	= conversion of unit factor.
R	= recharge water of aquifer, (*m*).
S_y	= specific yield.
Δh	= average fluctuation of water level.

السياسة المثلى للربط بين المياه الجوفية والسطحية لدورة زراعية لحوض نهر الوند

عامر حسن الحداد **ينب كاظم جبل**
جامعة بغداد/كلية الهندسة

الخلاصة

استخدام الربط الامثل بين المياه الجوفية والسطحية اصبح اكثر انتشاراً في مناطق عديدة من العالم نتيجة لزيادة الحاجة الى الموارد المائية وخصوصاً عند استخدام كميات كبيرة من المياه ولفترة طويلة لغرض توفير الاحتياجات المائية للانتاج الزراعي. البرمجة الخطية استخدمت للحصول على افضل تخصيص مائي للربط بين المياه السطحية والجوفية لمشروع نهر الوند في العراق الذي حدد بدورة زراعية وذلك من خلال استخدام اسلوبين في ادارة وتشغيل مصادر المياه السطحية والجوفية. احد الاساليب المقترحة هو انشاء خزانات ارضية لحفظ المياه من المصادر الجوفية للاوقات التي تتوفر فيها المياه والتي تزيد عن الحاجة وفي اوقات عدم الحاجة الى تلك المصادر واستخدامها في اوقات العجز المائي. الاسلوب الاخر المقترح هو تشغيل سد الوند لغرض توفير الاحتياجات المائية وخلال سنة زراعية. من اهم الاعتبارات التي استخدمت في هذا البحث هو تذبذب مناسيب المياه الجوفية ، والنقص في الانتاج صيغ نتيجة لاستخدام النقص المائي في الارواء .

التحليل الاقتصادي نفذ من خلال تقدير الكلف الكلية والعائد الكلي لسنة زراعية ومن خلال النتائج التي تم الحصول عليها. من ذلك نستنتج ان تشغيل الماء السطحي بنسبة (70-60%) من مجموع الماء السطحي المتوفر يعتبر حل وسط ولان كمية المياه تبقى في الانهار والقنوات والذي لا يؤثر على سعة الخزين الجوفي.

الكلمات الرئيسية: الاحتياجات المائية، الربط الامثل بين المياه السطحية والجوفية، البرمجة الخطية، تغذية المياه الجوفية.