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Evaluation Water Consumptive in Western Asia by Mathematical Model

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Abstract- Significant problems of water shortage and deteriorating water quality are contributing to a growing water crisis in many countries such as western Asia. This situation requires creative solutions to achieve sustainable resources management. In the Western Asia irrigation (agricultural sector) extraction have bad major impact on the water resources environment. Finding ways to meet agricultural demands and also achieve positive environmental and economic outcomes requires the aid of modeling tools to analyze the impact of alternative policy scenarios. These scenarios seek to asses the impact of option for allocation of limited water resources between agricultural production and the environment. This study presents a novel approach for optimizing these objectives by combining system dynamics and constrained linear objective optimization approaches. The network simulation optimization model NSOM has been coupled with a linear programming mathematical algorithm model. This paper concludes that system dynamic optimization approaches is a useful tool for agricultural water use. NSOM has the capability to compare the simulation and optimization dynamic results synchronized in time for each variable involved in the model. The comparison shows that VENSM optimizer does achieve the same results. Rationalization water consumptive require a lot of researches to achieve objectives by using scientific means.

Index Terms- Mathematical model, Evaluation, Water, Western Asia, Consumptive.

I. INTRODUCTION

Integrated water management in sectional level using is the best strategy to improve water benefit and optimize the use of the available water resources. The chief limiting factors for increased water production are the availability of suitable water. Water problems are rapidly increasing in many parts of the world such as in western Asia (ESCWA) region, the real crisis in water uses is a creeping crisis which needs a sustainable response at present [1].

Increasingly, researcher and policy makers are advocating sustainable development as the best approach to day's and future water problems [2]. The consumptive sector to water in ESCWA region were: agricultural; industrial and domestic; the agricultural sector consumes about 80%; industrial 8%; domestic 10% such as in table 1 of total available water resources in region, agricultural water consumptive requirement depend on many factors such as temperature, humidity rain fall and evaporation. Typically agricultural patterns and agriculture decisions are affected by several factors such as climatic forecasted growing condition and water allocation. Taking in to consideration this approach, the agricultural pattern of the different cultivated crops under a given allocation is a variable that can be used to improve the productivity of consumed water. The overall goal of this study is to evaluation consumptive sectors in such manner that the optimal pattern is achieved by minimizing the water deficit (difference between available water and total water requirement) in an agriculture area while maximizing the economic return. The current study is carried out on regional scale at an sectors consume water. The model determines the optimal water use in sectors with maximize the net return and minimize use. The study has been performed using the system dynamics programming tool VENSIM with an optimizer algorithm.

The network simulation optimization model NSOM are developed to determine the amount of water demand foe each case. Development mathematical model to generate optimal water uses has been performed by researchers since 1970. Most of the optimization models have adopted linear programming (LP), Quadratic programming (QP) and Dynamic programming (DP) approaches.

II. PROBLEM FORMING

A water resources were bio factor to life stability in nature , water form 75% of earth surface , the percentage of potable water in the world was 2% that require rationalization scientific care from pollution , depletion and activation the water circulation in nature by decreasing atmospheric pollution which increasing average of rain water, that consider first renewed source.

The environmental situation in world was connecting circle. Which any defect in ecological balance on local, territorial and international levels will be invert to other resources and on sustainable development, life stability. Finally, appearance great environmental problems in by the reason of demography increasing, technological development, non rationalization natural resources such as a water, and human activities increasing, where water exposed to great crisis. Western Asia include 13 Arabic countries in ESCWA organization which intending on territorial ecology for organs countries.

This region characterize with hard ecological conditions, consider the great region in water depletion by reason of high temperature and its average variation between winter and summer seasons which reaches 40 C$^{\circ}$, lowest rain water in the most countries less than 155 mm yearly, evaporation increasing and fastness wind blowing. This leaved negative elicit such as: drying, desertification increasing. This require researchers attention to study water depletion in the region by laying capability scientific strategy plans to solving water problems and protect water from pollution and depletion further to diagnosis exhaustive sector, also how to find solving to ensure sustainable development and balance achievement to water in this region by evaluation traditional, nontraditional water resources, with harvesting rain water. The current study include analysis water consumptive due to sector using of water such as, agricultural, industrial and domestic using. Agricultural sector was great consumptive of water but was non capability in economic production by comparing with water consumptive which reaching 80% from total available water. The aim of study how calculate the amount of consumptive water by using mathematical formulation to reach optimization water using.

III. SYSTEM DYNAMIC

Sector water demand managements is a difficult variable to impact due to the pressure of uncontrolled variable factors such as climatic conditions. Difficulties increase further when economic and environmental perspectives are integrated with realities of biophysical processes. The dynamic character of contributing variables and how they affect water use in the future is not captured through traditional modeling approaches. Although the application of optimization techniques has been a major field of research in water resources planning for many years, their successful adaptation to practical water allocation problems has not been validated in practice, partly due to the fact that most applications dealt with oversimplified systems [3,4].

Therefore; there is a need to explore new tools to represent the complex relationship found in water system. One promising option in system dynamics (SD), a feedback-based, object-oriented approach. Although not a novel approach, system dynamic offers a new way of modeling the future dynamics of complex system [4]. System dynamics is based on a theory of system structure and a set of tools for representing complex system and analyzing their dynamic behavior. A network simulation optimization model (NSOM) problem of effectively has been developed to test the feasibility and issues in applying system dynamics to the purpose of model is to analyses the historical water allocation for an agricultural use with un the constraints of environmental flow rules based on economic rationale . The model uses VENSIM™ as a software development tool to configure the water balance network model. The outputs of NSM model are total cost, total yield, total return, irrigation demand, gross margin, losses, surface water use, ground water Fundamentally, a water balance must be determined which can best match the demand and environmental flows within system constraints [5].

IV. NSOM MODEL FORMULATION AND APPLICATION

The objective function of the NSOM model is formulated to know the relation between several water resources, sector consumptive, ecological water resources, renewed water, minimize the amount of water with maximize advantages (maximize net return), which were as the followings:

Total water resources (T) =traditional water (tr) + non traditional water (nt)

$$T = \sum_{i=1}^{n} tr + \sum_{j=1}^{m} nt$$

Where i, j=1, 2, 3….. n, m

Traditional water (tr)=surface water (S)+ground water (G)

$$tr = \sum_{i=1}^{n} S_i + \sum_{j=1}^{m} G_j$$

Where i, j=1, 2, 3….. n, m

.Non traditional water (nt)=treating waste water (w)+desalinated water (D)

$$nt = \sum_{i=1}^{n} W_i + \sum_{j=1}^{m} D_j$$

Where i, j=1, 2, 3….. n, m

Total consumptive water(c) = agricultural consume. (A) +industrial consume. (I) + domestic consume (D)

$$C = \sum_{i=1}^{n} A_i + \sum_{j=1}^{m} I_j + \sum_{k+1}^{q} D_k$$

Where i, j, k =1, 2, 3….. n, m, q

Agricultural consumptive water = Area of crop(a) × quantity of water use (q)

$$ACW = \sum_{i=1}^{n} a_i + \sum_{j=1}^{m} q_j$$

Where i, j=1, 2, 3….. n, m

Industrial consumptive water=number of factories (N) ×quantity of water use (*q*)

$$ICW = \sum_{i=1}^{n} (F_i \times \sum_{j=1}^{m} q_j)$$

Where i, j=1, 2, 3….. n, m

Domestic consumptive water=number of domestic (d) × quantity of water use (*q*)

$$DCW = \sum_{i=1}^{n} (d_i \times \sum_{j=1}^{m} q_j)$$

Where i, j=1, 2, 3….. n, m

Total consumptive water

Where i, j=1, 2, 3….. n, m,

Sector consumptive percentage of water $= \frac{type\ of\ sector\ consumptive\ water}{total\ consumptive}$

a - % Agricultural consumptive water $= \frac{A}{T} \times 100$

b - % Industrial $= \frac{I}{T} \times 100$

c - % domestic= $\frac{d}{T} \times 100$

Ecological water resources = Available water (Aw) – loosing water (Lw)

$$= EWR = \sum_{i=1}^{n} \sum_{j=1}^{m} (AW) - \sum_{j=1}^{m} (LW)$$

Where i=1, 2, 3….n, j=1, 2, 3…m

Optimization irrigation = Evaporation + Exhaustive(Ex)

$$OI = F(N)$$

Year capita share of water $= \frac{Available\ water}{Number\ population}$

a – water pressure =F(population growth)

$$wp = F(p)$$

Percentage rain water to renewed water $= \frac{Rain\ water}{Total\ water} \times 100$

Percentage traditional water resources $= \frac{traditional\ water}{available\ water} \times 100$

Percentage nontraditional water $= \frac{nontraditional\ water}{available\ water} \times 100$

Water deficit = available water ≥ Consumptive water

Density of water consumptive $= \frac{yearly\ capita\ \ share\ of\ total\ consumptive\ water}{yearly\ capita\ \ share\ of\ renewed\ water} \times 100$

Arid factor (A)=F(Environmental factors)

A=F(E)

Desertification (D) =F (arid) =F (A)

Pollution (P) =F (human activities)

P=F (H)

Maximum net benefit (MNB) $= \sum_{c=1}^{n} yc \times pc \times Ac - \sum_{c=1}^{n} c_1 w_x \times Q \times A$

Where y_c=yield of crop
p_c=crop price
A_c=crop area
c_1w_x= cost of water
Q=quantity of water (MWN)

Minimizes water neck = $= \sum_{c=1}^{n} I_C \times A_c \sum_{c=1}^{n} I_c \times A_c$

I_c= crop irrigation water demand need
A_c= crop area
MR (maximizes ratio) =MNB/MWN
Where: MNB – maximum net benefit
MWN – minimizes water need

Area Availability to total area

$$= \sum_{C=1}^{n} A \leq TA$$

The sum of all crop area is equal or less the total farm area, where TA is the total area.
Water demand to water Availability

$$= \sum_{C=1}^{n} i_c \times A_C \leq WA$$

Where i_c water need of chop total irrigation water needed should not exceed total water available for the irrigation area.

Hydrological sustainable development= F (pollution + depletion)

= F (p + D)
The effecting factors in water resources were pollution and depletion

V. Discussion and Results

Clear from this study the water resources suffers from two problems, pollution and depletion, which requires to find suitable solving by researchers to protect water resources. Western Asia characterize great arid region in world, that must be laying strategy plans and integrated water management in sector using. Figure 1 shows consumptive water resources in many sectors such as agricultural industrial and domestic consumptive water. On territorial level the consumptive of agricultural was 80%, industrial was 8%, domestic was 10%, other 2% [6]. From figure 1 possible doing analysis to knowing consumptive water in ESCWA region which were 13 countries, this shows in figure 2 which clear watery consumptive percentage in 13 countries, the great consumptive country in potable water was Kuwait 90% and the lowest country Syria 8% , possible obtaining agricultural using water , the great consumptive country was Yemen 89% and the lowest in Kuwait 4%, possible calculate industrial water consumptive , which shows, the great consumptive industrial water in Egypt 15%, the lowest was in Oman 1.2% .

The conclusion of this study, a system dynamic optimization programming model has been developed to determine the optimal water use against two objectives: to maximize the net profit and minimize the amount of water used. The agricultural sector was a chief consumptive, this require to be less by rationalization and using scientific means in agricultural production such as sprinkler and drip irrigation which irrigated crops due to water necessity with optimization water using.

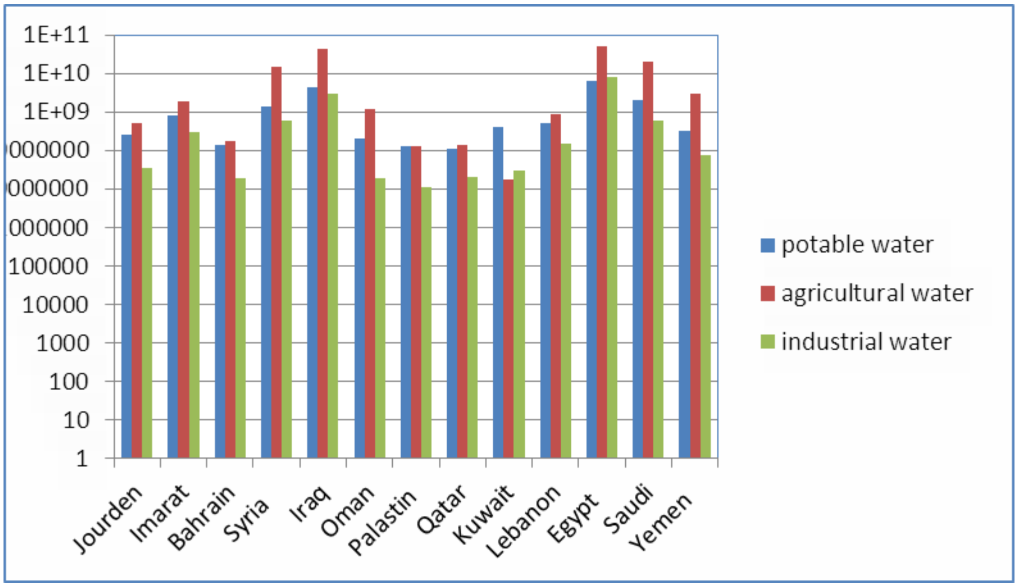

Figure 1 The water sector consumptive in ESCWA region(million M³/year in 2003 y

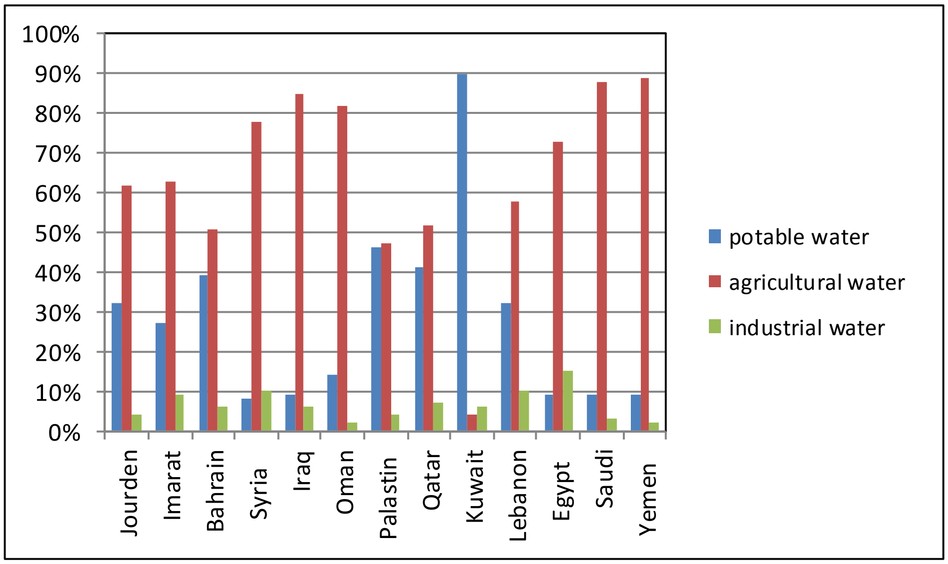

Figure 2 Percentage of water consumptive in ESCWA region

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