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INTERNATIONAL WATER MODEL UNDER PRODUCTIVITY CONDITIONS: THE CASE OF THE TIGRIS AND THE EUPHRATES

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ABSTRACT: Allocation of international water resources needs to play a vital role in the shared river basins. An environmental and reliable framework involves not only the competing parties divided by geography and national boundaries but also spatially - variable environmental parameters such as water productivity in agriculture. In international rivers, the inflow of turbid materials from the drainage basins of the upstream definitely affects water quality at the downstream. Consequently, emerging global challenges, such as climate change, water scarcity, and population growth have to meet rising demand over time. The Tigris and Euphrates (as a case study) give us a good example of the water system in a region politically unstable. Although a number of studies on water resources allocation modeling, such as ITETRBM and WATER-Model, have analyzed the geographic nature of basins, success in achieving sustainable development calls for an optimal water allocation model. Based on water productivity conditions, and to achieve stable, long-term cooperation among riparian countries and sustainable use of the water resources, international Water Model Under Productivity Conditions (WMUPC) gives us an optimal solution. In order to show the impacts of water quality changes on downstream users, these results are presented via histogram. The significant finding, under previous conditions, is the water quantity available in downstream will be less than the quantity required.

Keywords: International Water Resources, Spatial Equilibrium Analysis, The Tigris and the Euphrates

1. INTRODUCTION

Freshwater is an indispensable resource for human life. It is used for different purposes: irrigation, industry, energy production etc., but the intensity of its use varies according to climatic conditions, economic development, urbanization, etc. More than 286 international watercourses cross the boundaries of two or more countries [1]. The Tigris and the Euphrates are the largest two rivers in the Middle East. Their basins span notably three countries, Iraq, Turkey, and Syria, including more than 126 million people, which cover 1.4 million km^2 and produce around 70 km^3 of river discharges each year [2].

By water resource allocation, international rivers developments, including their basins within various riparian, can obtain extremes of cooperation or dispute. It is generally accepted that conflicting demands over the Tigris and the Euphrates will intensify. Yet, although the importance of recent water allocation models, such as ITETRBM and WATER-Model, the literature on international water resources allocation modeling is still far from an encompassing complex environment common factor. Therefore, many rivers basins all over the world, in particular for the regions that are historically unstable, are not able to establish a long-term cooperative agreement between the riparian.

Thus, the proposed water model will be a valuable tool, among other quantitative models, for estimating an optimum water resource management. Directly and indirectly, it also provides the potential for water conservation concerning the crops grown under various environments.

2. NEEDS FOR NEW WATER MODEL

The appearance of international water disputes, especially in unstable politically and economically regions, raises concerns for the future. The disputes clearly stem from the mismatch between demand and supply of water. The climate challenge currently carries very serious issues which call for a strategic focus on water resources management. Due to low precipitation, Iraq depends exclusively on the Tigris and the Euphrates waters [2]. If projected climate change has played, and still, a role in reducing the water flow of these two rivers, the dams which control the rivers flow in the upstream riparian also have negative impacts, not only on the volume of the rivers' waters but also on their quality levels.

Although water use efficiency may be defined quite differently by the farmers and by the rivers' basins authorities, the components required to improve productivity and efficiency are essential in making most effective use of this vital source in any agriculture areas [7]. The difficult issue of water productivity is to determine the optimum amount of water used for agriculture. In the definitions, this amount could be expressed by the amount of water needed for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout the growing cycle [8].

Inferior water quality will have a serious impact on land and water productivity. The decline of water quality needs to be addressed and to be included in any allocation model. Due to environmental concerns and the rising complexity of water demands, realize a water model under productivity conditions needs to explain the basin's real water availability and to confront population growth and development.

3. WATER MODEL DESIGN

The linear water model WMUPC illustrates the international Water Model Under Productivity Conditions. In contrast to the other two preceding water models, the WMUPC model can be used to analyze the reduction of water quantity as a reason for quality fall. This model facilitates efficient analysis of integrated water management among the different riparian not only for the present but also for the future. Its actual scope covers the Tigris and the Euphrates basins.

Moreover, WMUPC has the ability to be developed to cover not only other international watercourse but also to add any other environment parameters on specific regions and countries.

The difficult point of determining the optimum amount of water for any riparian countries can be solved by calculating the amount that’s saved through optimized irrigation. Accordingly, the optimum amount of water can be used more profitably to irrigate supplemental lands. It will be that which produces a maximum crop yield, per unit of land or per unit of water, depending on food produced by the best use of water. In this case, it would be easier to achieve the desired and rational use of international water resources [9].

3.1 Boundary conditions

For the international basins, the optimal model of water will depend on a mix of factors, including hydrologic characteristics, quality of water entering the basins, the water volume that will travel down towards the downstream riparian and by taking into consideration the constant riparian water rights. It is important to recognize that the upstream country, Turkey in the case of the Tigris and the Euphrates, will always have a different agenda for the river that it shares with other countries, Iraq and Syria. Thus Turkey will have easy access to better quality water sources.

The Tigris and the Euphrates take their sources in Turkey, pass through Syria and enter Iraq from the north and north-west. The characteristics of these two rivers vary from upstream to downstream according to the zones crossed by them. The variability of climatic conditions in each riparian country, such as temperature and precipitation, has played an important role in modifying water resources qualitatively and quantitatively. Therefore, changes in water properties by adding the agricultural drainage water, particularly near the northern border of Iraq, will seriously affect the water stress in this country.

For agriculture country, good quality of water for irrigation is a prime requisite. There is a continuous debate on whether the riparian have to respect water quality in an international watercourse or just use any quantity of water without taking into consideration the water demands of downstream water users. Nevertheless, as long as the water of good purity helpfully affects the productivity of the land, the poor quality of the water negatively affects the productivity of the land. This change can be expressed mathematically by in the WMUPC water model.

3.2 Structure of the WMUPC

WMUPC is inspired by the Inter-Temporal Euphrates and Tigris River Basin Model ITETRBM and from Water Allocation of the Tigris and Euphrates Rivershed WATER-Model, which developed by [3] and [4] respectively. Without consideration of water quality requirements, these models aim to allocate water resources in the international rivers among Turkey-Syria-Iraq through a network of supply and demand nodes. However, due to water quality changes, ignoring these changes will increase certainty the conflicts, and significantly reduces the chance of successful negotiations along the international rivers. In an optimistic manner, the WMUPC allocates all nodes of water demand and supply by comprising water quality indicators.

A hydraulic network of supply and demand nodes was established and illustrated, as an example of the case study, among Iraq, Syria, and Turkey. All of the variables pertaining to water volume in various regions and sub-regions of the Tigris and the Euphrates, such as the volume of inflow, outflow, and water consumption for agriculture, municipal and industrial, were determined during a certain period of time. The relationships between the unknown variables and the given variables were expressed by a number of functions of the given variables.

The mathematical details of the WMUPC are based on quantitative outcome variables as follows:

$$D = \varepsilon\,(\sum TTWi + \sum Qi + \sum TRWi) - Evj - \sum TAMIWj - GFj \quad \forall\, i,j \in n \quad (1)$$

Subject to:

$$\sigma = \sum SW - \sum TAMIW / \sum SW \quad (2)$$

$$\varepsilon = k - \sigma \quad (3)$$

where D is the quantity of water Demand; TTW refers to the Total Tributary Water; Q is the Quantity of water inflow; TRW indicates to Total Return Water; Ev expresses the loss of Evaporation; TAMIW is the Total Agricultural, Municipal and Industrial Water withdrawal; GF assigns the Groundwater Feeding; I, is the demand and j is the supply nodes of the total nodes n; σ refers to the adjustability ratio of water resource; SW is the Storage Water quantity; and ε ascribes water's adeptness and its productivity, which depends on a constant factor k =1 in this paper.

The water productivity term is used in a variety of ways and there is no single definition that suits all situations [5]. Therefore, the concept of water productivity has been used sometimes as a measure of the ability of agricultural systems to convert water into food, and sometimes used to evaluate the function of irrigation systems as the amount of crop per drop [6]. By taking a look at literature, the concept of water productivity has been developed by some researchers, and it is well known that this concept can be accepted by the community [10].

Consequently, the water's adeptness quantitative symbol ε is developed here to simulate the impacts of irrigation on the water resources system, such as the side effects of increasing the Total Dissolved Solid TDS, the impact of biological oxygen demand BOD, dissolved oxygen DO etc. of the rivers.

The problem of estimating water productivity could become more complex for large areas. The discrepancy of the meaning of water productivity between different users, especially in international river basins, will complicate the model considerably. To simplify this, water productivity can be assessed by subtracting the value of water adjustability, which is demonstrated here by the symbol ε. This step will help us to illustrate the reduction of productivity of the water resource.

3.3 Model network applications

The WMUPC contains 63 demand and 45 supply nodes similar to the first version of the figure, which is developed by [1]. In order to understand more about the geographical distribution of water resources, the typical allocations of demand and supply nodes are illustrated schematically in Fig.1.

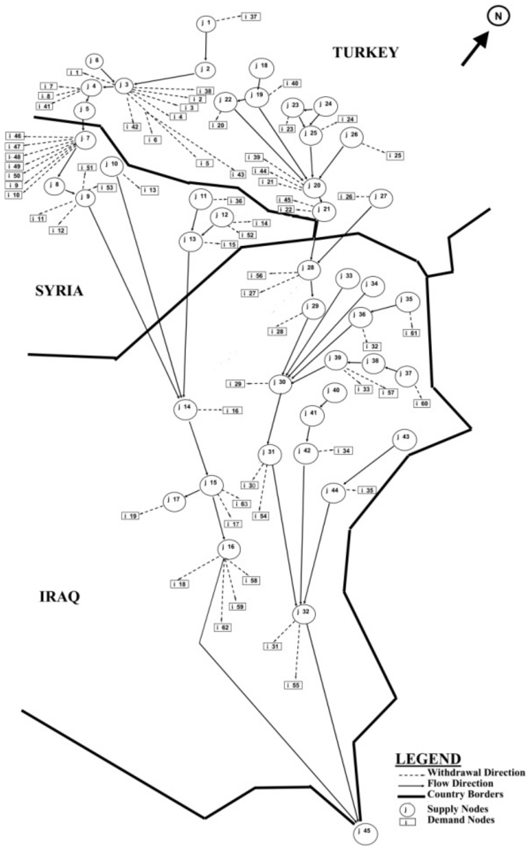

Fig.1 Network structure of the international Water Model Under Productivity Conditions WMUPC of the Euphrates and Tigris Rivers which is modified from [1] with kind permission from the authors.

In order to be more confident of WMUPC outcomes, the model should be calibrated and verified to a satisfactory accuracy. Thus, the model details are improved and amended significantly in accordance with the actual water nodes distribution the main riparian countries in the Tigris and the Euphrates basins.

The WMUPC model measures the relations between the proposed demand and supply nodes of two periods, both lasting for about six months. Rainy period is ongoing from January till June, while nearly no rainfall can be seen in the dry season from July to December. The storage option in the reservoirs enables the model to simulate water amount for the included periods which could satisfy the minimal demands. Water inflows depend on tributary inflows in addition to backflow water coming from upstream nodes. While water outflows depend on evaporation losses as well as agricultural, domestic and industrial water withdrawal which are illustrated by a number of supply nodes.

To indicate water productivity and quality effectiveness at downstream nodes, at this stage of research, there is a need to highlight water use in various productive and consumptive activities. Consequently, to find out the true figure of how water quality is affecting its productivity at each node, further research needs to be conducted to assess that in more detail. It is clear, however, the highest level of water use efficiency, reasonably achievable by the upstream countries, Turkey and Syria in this case. While water use efficiency in the downstream countries, like Iraq, will be the lowest level.

Differences between water lack and water abundance within the given three countries (Iraq, Syria, and Turkey) were observed. To summarize and simplify the results, the indication of water productivity, across different sections of the rivers, could hypothetically be equivalent to ε in the WMUPC model.

4. RESULTS AND DISCUSSION

In the simulation of WMUPC model, the sensitive parameters listed in this water model were selected for the Tigris and the Euphrates rivers among the riparian countries, in addition to water use for domestic, agricultural and industrial purposes, including water quality indicator facing water productivity.

The domestic and industrial sectors in Iraq, Syria, and Turkey offer a large return rate of water for irrigation purposes. So, in case of low water flows in an arid zone like Iraq, only the minimum agricultural water demands are met. Therefore, the country is suffering from a critical lack of water as shown in Fig.2.

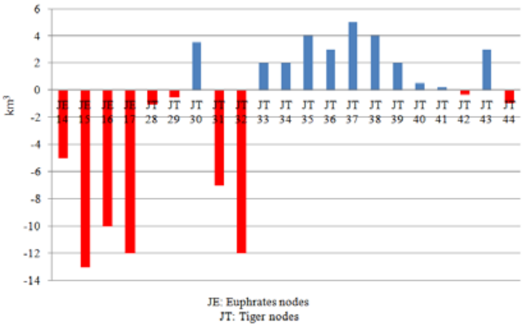

Fig.2 Water lack and abundance in Iraq.

In Iraq, the clear indication of the impact of changes in water quality on land, although a pretty good amount of water, is the significant decrease in land productivity, for example, the number of date trees decreased from 33 to 13 million between 1950 and 2010; the number of sandstorm between 1951 and 1990 was about 24 days/year, while the Ministry of the Environment in Iraq records 122 sandstorms and more than 280 dusty days from 2000 to 2010 in addition to the prolonged drought and desertification [2].

Recently, during the summer of 2018, Iraqi farmers faced severe drought after low winter rainfall with increasing salinity problems in irrigated areas in the country. Unfortunately, due to rapidly falling water levels in the Tigris and the Euphrates rivers on which the farmers depend, in addition to the lack of funds targeting the vital infrastructure, the development of the agricultural became more difficult in the short and medium-term.

While in the case of high water flows in a humid zone as Turkey, the minimum agricultural water demands almost are satisfied and will easily meet the requirements of the irrigation. Thanks to dam construction in the Euphrates and Tigris in the upstream, however, increases the water welfare and could thus foster water abstraction in Southeast Anatolia Region which is bordered by Syria to the south, and Iraq to the southeast.

In terms of irrigation, Turkey is able to irrigate about 1.8 million hectares of land, near the borders of Iraq and Syria in southeast Anatolia, which is the equivalent of 9.7 percent of Turkey's total surface [11]. Accordingly, the significant increase in the irrigated area shows the weight of water abundance in Turkey as shown by the outcomes of the WMUPC in Fig.3.

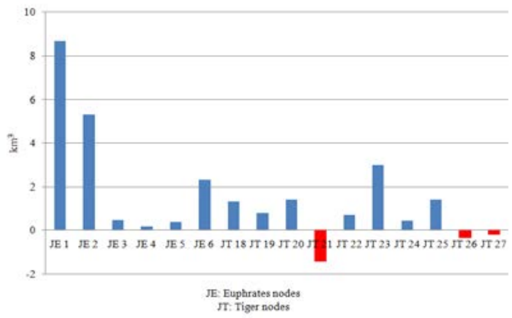

Fig.3 Water lack and abundance in Turkey.

On the other hand, by the development of this region (Southeast Anatolia Region), Turkey also aims to increase its electricity production by 45% of the total economically exploitable hydroelectric potential in the country. As the Southeastern Anatolia Project GAP (Güneydoğu Anadolu Projesi) is one of the largest power generating, when all dams and hydropower plants are completed, 27 billion kWh of electricity will be generated annually [12].

In regard to water lack and abundance in Syria, the situation is different as between the situation in Iraq and Turkey. The lack of water in Syria is slightly better than that observed in Iraq, while water levels have been falling for a few months as shown in Fig.4. So, in the case of low water flows in the country, only the minimum agricultural water demands are met.

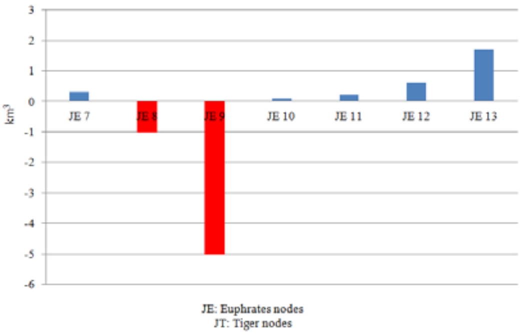

Fig.4 Water lack and abundance in Syria.

In the current war in Syria, some analysts have argued that factors related to agricultural failure and water shortages have played an important role in water-related conflicts [13,14]. These conflicts are contributing to the deterioration of social structures in many forms, including disputes over access to water and the use of water as a weapon by the targeting of water infrastructure and systems either during terrorist actions or during the action of coalition force actions.

Thus, the outcomes of the WMUPC show that water productivity is responsible for water welfare, even though if this issue has a small interest in all riparian countries so far. Highlighting the importance of these results and the importance of water productivity, as mentioned above, isn't in the sense that the water quantity is a less important quality. The WMUPC is established here to increase focus attention on both water quality and quantity.

5. CONCLUSION

The asymmetries driven by population growth, observed climate change, economic competition, and agriculture evolution, over the last century, are highlighting the importance of water efficiency evaluation. The quantification of the lack or the abundance of international waters, due to changes in water quality, is applicable by the modeling of water under productivity conditions WMUPC. So, the calculations show the ability to reflect water quality changes along any river to a valuable amount of water quality.

A shortcoming of this model is that the water productivity values do not cover the actual value of the nodes in this case study. However, the impact of different water uses and the effects of water quality changes have recently become more observable in downstream countries. Therefore, a comprehensive database needs to be established in order to evaluate and analyze variations of water productivity. Furthermore, if the objective is finding an effective international water allocation tool, the WMUPC enables to represent an alternative mechanism for fulfilling the dispute of water sharing among any riparian.

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