ENERGY AND AGRICULTURAL POLICIES OVER THE TRANSBOUNDARY SURFACE WATER RESOURCES

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ABSTRACT

Allocation of transboundary water resources involves not only the competing parties divided by geographic and administrative boundaries (regional, national and local boundaries) but also various sectors (agricultural, urban, and industrial etc.) and various time periods (monthly, seasonal, annual). This study uses the Inter-Temporal Euphrates and Tigris River Basin Model (ITETRBM), which is a linear programming model maximizing net economic benefit derived from energy generation, agricultural and urban uses after conveyance costs. While optimally allocating water resources, The ITETRBM enables to pursue various sensitivity analyses in order to measure the impacts of annual changes in energy and water demand over the countries (Turkey, Syria, Iraq) and sectors (agriculture, urban) in the Euphrates and Tigris River Basin (ETRB). The results present that i) energy and agriculture are two different sectors potentially compete one other, and ii) that competition opens a wide spectrum of water and energy policies in the basin among all countries. The spectrum of policies may cover the issues of a) time preferences of energy generation via hydroelectric power plants especially in the relatively cold upstream countries and b) utilization of alternative energy recourses and their preferential uses in upstream and downstream countries. While managing agriculture and energy sectors, an integrative approach potentially brings a superior allocation solution that provides higher welfare to the basin countries.

Keywords: Linear programming; Energy versus agriculture; Transboundary water resources allocation; The Euphrates and Tigris River Basin.

1. INTRODUCTION

In the today's era, where the global climatic change is being discussed, the rational and equitable use of water resources of the world has an increasing importance. Especially, for the regions where the water is scarce, scientific approaches to handle issues of managing scarce water resources are both technical and political necessity. The water resources not acknowledging human made political and administrative boundaries (Dellapenna 2007) have a potential to bring many parties into collaboration and peace, but also, have a potential to take them to the conflict, even war. Transboundary water resources issues are not limited to the Euphrates and Tigris River Basin (ETRB), which is the topic of this study, but also are relevant to 261 surface water resources basins in the world (Dinar et al. 2007).

The political boundaries, not only create artificial thresholds or barriers to efficient and effective use of water resources, but also cause competition and conflicts over the allocation of them among multiple parties. Overcoming these barriers and thresholds can only be possible via an integrated water resources basin management approach. Founding an integrated water resources basin management organization is relatively easier when the stakeholders are in the same country, where there exist an agreed legal system. But resources allocation at the international level is a daunting task due to absence of an agreed international legal system and enforcement power. Handling the issues and laying out the possibilities through a scientific methodology will always contribute to the negotiation and agreement of all parties.

Allocation of transboundary water resources are not only among the geographically identified parties but also among the various sectors, even among different time periods due to periodical fluctuations in year(s). While the process of allocation taking place simultaneously in these three dimensions, the policies of water uses affect directly and indirectly all parties and sectors in the basin. This study uses the Inter-Temporal Euphrates and Tigris River Basin Model (ITETRBM), which is a linear programming model (Kucukmehmetoglu 2009). The fluctuations in annual energy demand are incorporated into the optimization model, and their effects on water resources allocations among parties (Turkey, Syria, Iraq) and sectors (energy, urban and agriculture) are analyzed over the case of the Euphrates and Tigris Rivers.

2. LITERATURE

In the literature, the studies on the transboundary resources allocation can be classified into two broad categories of *verbal* and *technical* studies. While the *verbal* literature focusing on the legal and political aspects of the issues, the *technical* one dwells on the quantitative modeling aspects. It is noteworthy to mention that these studies are not totally mutually exclusive, and the quantitative models support verbal studies and enable parties understand the nature of the problems.

At the international level, though have not been accepted by all countries, the most well-known legal document is *"the Draft Articles on the law of the non-navigational uses of international watercourses"* by the UN in 1994. Some of the studies outlining the legal framework are Dinar et al. (2007), Margesson (1997), Wolf (1997), Flint (1995), Tanzi (1997a & 1997b) and Arcari (1997). The policy oriented studies are mostly on the specific topics and/or basins. Some of those are Kolars & Mitchell (1991), Biswas (1994), Kliot (1994), and Naff (1994).

The *technical* studies can be classified into two headings: The first one is based on *optimization* leading efficient uses and allocation of limited water resources; and the second one is on the *game theory* that systematically lists the strategies of involving parties. Those strategies formulize and enlist the individual, sub-group, and grand coalition behaviors of involving parties with their associated benefits and costs. The first optimization study, though is not on water resources allocation, is developed by Samuelson (1952), and later Takayama & Judge (1964) elaborate mathematical modeling aspects of the literature. Then, the developed models has been a base on a hypothetic water resources model by Flinn & Guise (1970). Later, Booker & Young (1994), Becker (1995), Rogers (1969, 1993), Dinar & Wolf (1994a, 1994b), and Kucukmehmetoglu & Guldmann (2004) have developed specific models focusing on transboundary water resources allocation issues of various basins in the world. In the mean time, there are also increasing number of game theoretic analyses built on or be complementary parts of optimization researches. The first game theoretic model is developed by Rogers (1969). Afterward, Rogers (1993), Dinar & Wolf (1994a, b), Kucukmehmetoglu & Guldmann (2004), Kucukmehmetoglu (2009), Kucukmehmetoglu et al. (2010), and Wu & Whittington (2006) have pursued various studies on cooperative game theoretic aspects of the water resources allocation issues.

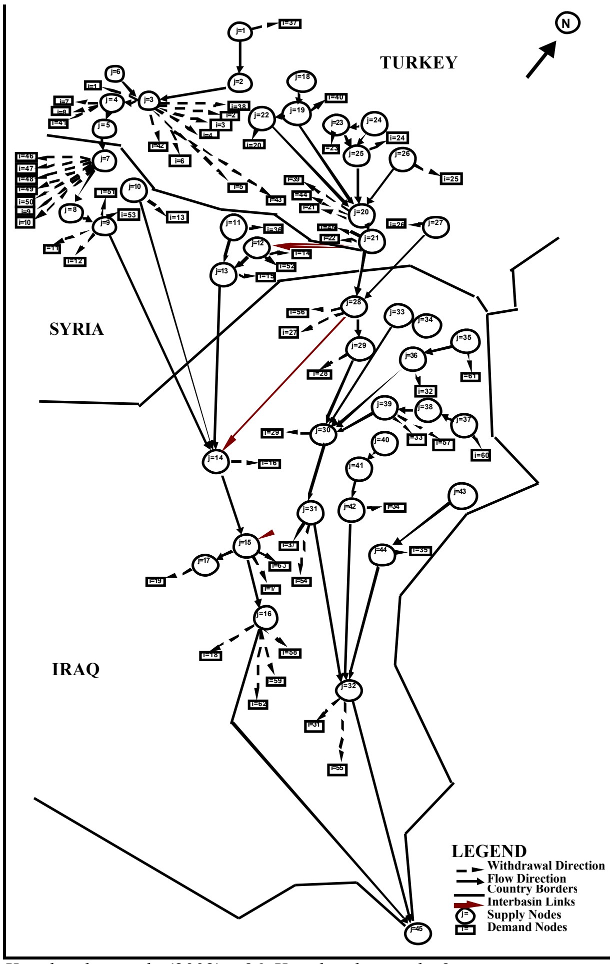
Kucukmehmetoglu (2002) has developed the first game theoretic transboundary water resources optimization model on the Euphrates and the Tigris. This study is followed by i) Kucukmehmetoglu & Guldmann (2004) that is a slightly modified version of Kucukmehmetoglu (2002) for an academic publication; ii) Kucukmehmetoglu & Guldmann (2010) that generates three party Pareto frontier i.e. tradeoff surface (PFS) among the three riparian countries, and tries to find politically acceptable allocation via analyses using political weights and marginal values impacts of countries each other; iii) Kucukmehmetoglu (2009) that evaluates the impacts of built-up active reservoir capacities for an inter-temporal allocation, measures the potential benefits of them to the upstream and downstream countries, and presents the political advantages of built reservoirs to the owner of these reservoir and to the basin during water shortage; iv) Kucukmehmetoglu et al. (2010) that aims at finding the most acceptable allocation scenario by means of a developed *fuzzy logic* model considering the variations in annual tributary flows and game theory based allotments from the varying core solutions.

Beyond these researches, this study methodologically evaluates the likely impacts of changes in national energy demands on agriculture, and presents the possible competition between agriculture and energy sectors. In the analyses, the advantages and disadvantages of an integrated and disintegrated basin management to the parties and to the overall performance of basin are presented. Finally, considering their outcomes, a series of policy suggestions are proposed.

3. THE INTER-TEMPORAL EUPHRATES & TIGRIS RIVER BASIN MODEL (ITETRBM)

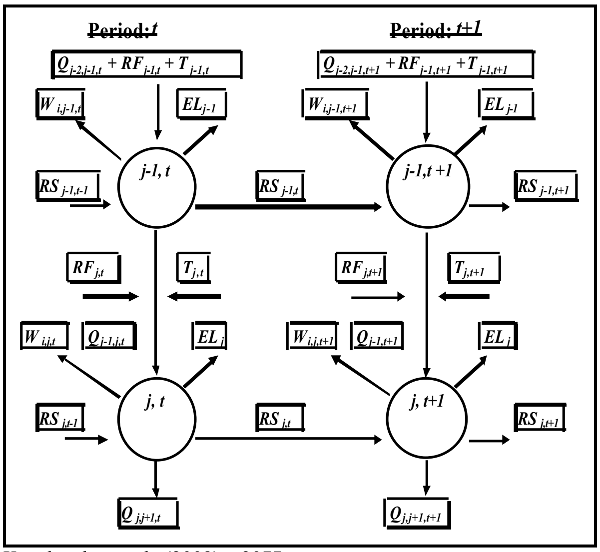
The ITETRBM is an optimization model, which is inspired from the Colorado River Institutional Model (CRIM) developed by Booker and Young (1994). Their work aims at allocating scarce water resources among the states by fulfilling the international allocation agreements with Mexico. Similarly, the ITETRBM optimally allocates scarce water resources in the ETRB among Turkey-Syria-Iraq. The used model is a linear programming model that has similar character with Becker (1999) in terms of the nature of objective function. As an extension of the ETRBM, the ITETRBM enables inter-temporal water resources allocation among the multiple periods by means of reservoirs in the basin (Kucukmehmetoglu 2009). By this model, the potential political and economic advantages of the reservoirs are presented, and alleviation of water shortage by the water stored in rainy season is shown in the economic terms.

The network structure of the ITETRBM: The ITETRBM contains 63 demand and 45 supply nodes. Their allocations by countries and schematic structure of the ITETRBM are presented in Figure 1. Among demand nodes, the 37 of them are assigned to agriculture, and remaining the 26 of them are to the urban demand nodes. The 24, 16, and remaining 23 of these demand nodes are respectively in Turkey, Syria, and Iraq. Similarly, the 15, 7, and remaining 22 of the supply nodes are respectively in Turkey, Syria, and Iraq. In order to transfer water from the Tigris to the Euphrates, there are three inter-basin links, one of which is from Turkey to Syria (21→12) and the remaining two are in Iraq (28→14 &, 31→16) (Figure 1).



Kucukmehmetoglu (2002) p.96, Kucukmehmetoglu & Guldmann (2004) p.786.

Figure 1 – The network structure of the ITETRBM



Kucukmehmetoglu (2009) p.3077.

Figure 2 – The flow balance in the ITETRBM

The mathematical character of the ITETRBM: The ITETRBM is an improved version of the original ETRBM in Kucukmehmetoglu (2002) via incorporation of time dimension. The basic model, while maximizing net economic benefit, optimally allocates water resources among energy, urban, and agricultural uses net of conveyance costs. The inter-temporal nature of the model enables to store water during wet seasons for dry periods. As used in Kucukmehmetoglu (2009) and Kucukmehmetoglu et al. (2010), Equation (1) with alternative (a,b) and partial forms (c,d,e) is the objective function to be maximized subject to constraints presented by Equations (2)-(5) in the ITETRBM.[1] As presented in Kucukmehmetoglu et al. (2010), the mathematical details of the ITETRBM with updates in energy price parameter (P_{et}) are as follows:

Maximize

$$NEB = \sum_t \{ \sum_{i \in ag} V_{ag} \cdot \sum_j W_{jit} - \sum_{j,\, i \in ag} C_{ag} \cdot D_{ji} \cdot W_{jit} + \sum_{i \in ur} V_{ur} \cdot \sum_j W_{jit} - \sum_{j,\, i \in ur} C_{ur} \cdot D_{ji} \cdot W_{jit} + \sum_{j,l} P_{et} \cdot E_j \cdot Q_{jlt} - [(Q_{28,14,t} \cdot C_{ss} \cdot L_{28,14}) + (Q_{31,16,t} \cdot C_{ss} \cdot L_{31,16}) + (Q_{21,12,t} \cdot C_{ss} \cdot L_{21,12})] \} \quad (1a)$$

equivalently (assuming $WG_T = WG_S = WG_I = 1$)

$$NEB = NEB_{TSI} = WG_T \cdot NEB_T + WG_S \cdot NEB_S + WG_I \cdot NEB_I \quad (1b)$$

where:

$$NEB_T = \sum_t \{ \sum_{i \in TA} V_{TA} \cdot \sum_j W_{jit} - \sum_{j,\, i \in TA} C_{TA} \cdot D_{ji} \cdot W_{jit} + \sum_{i \in TU} V_{TU} \cdot \sum_j W_{jit} - \sum_{j,\, i \in TU} C_{TU} \cdot D_{ji} \cdot W_{jit} + \sum_{j,l} P_{TEt} \cdot E_j \cdot Q_{jlt} - [(Q_{28,14,t} \cdot C_{ss} \cdot L_{28,14}) + (Q_{31,16,t} \cdot C_{ss} \cdot L_{31,16}) + (Q_{21,12,t} \cdot C_{ss} \cdot L_{21,12})] \} \quad (1c)$$

$$NEB_S = \sum_t \{ \sum_{i \in SA} V_{SA} \cdot \sum_j W_{jit} - \sum_{j,\, i \in SA} C_{SA} \cdot D_{ji} \cdot W_{jit} + \sum_{i \in SU} V_{SU} \cdot \sum_j W_{jit} - \sum_{j,\, i \in SU} C_{SU} \cdot D_{ji} \cdot W_{jit} + \sum_{j,l} P_{SEt} \cdot E_j \cdot Q_{jlt} - [(Q_{28,14,t} \cdot C_{ss} \cdot L_{28,14}) + (Q_{31,16,t} \cdot C_{ss} \cdot L_{31,16}) + (Q_{21,12,t} \cdot C_{ss} \cdot L_{21,12})] \} \quad (1d)$$

$$NEB_I = \sum_t \{ \sum_{i \in IA} V_{IA} \cdot \sum_j W_{jit} - \sum_{j,\, i \in IA} C_{IA} \cdot D_{ji} \cdot W_{jit} + \sum_{i \in IU} V_{IU} \cdot \sum_j W_{jit} - \sum_{j,\, i \in IU} C_{IU} \cdot D_{ji} \cdot W_{jit} + \sum_{j,l} P_{IEt} \cdot E_j \cdot Q_{jlt} - [(Q_{28,14,t} \cdot C_{ss} \cdot L_{28,14}) + (Q_{31,16,t} \cdot C_{ss} \cdot L_{31,16}) + (Q_{21,12,t} \cdot C_{ss} \cdot L_{21,12})] \} \quad (1e)$$

Subject to:

$$\sum_i W_{jit} + \sum_l Q_{jlt} + EL_{jt} + RS_{jt} = \sum_i RF_{ij} \cdot (\sum_j W_{jit}) + T_{jt} + \sum_l Q_{ljt} + RS_{jt-1} \qquad \forall j \;\&\; t \quad (2)$$

$$Min_{agt} \cdot S_i \le \sum_j W_{jit} \le Max_{agt} \cdot S_i \qquad \forall\, i \in ag,\ \forall\, t \quad (3)$$

$$Min_{urt} \cdot S_i \le \sum_j W_{jit} \le Max_{urt} \cdot S_i \qquad \forall\, i \in ur,\ \forall\, t \quad (4)$$

$$RS_{jt} \le RC_j \qquad \forall j \;\&\; t \quad (5)$$

where Equation (1a) represents the objective function in terms of the net economic benefits, *NEB*. $V_{ag[ur]}$ is the unit value of water to agriculture [urban]; W_{jit} is the amount of water transferred from node *j* to node *i* in period *t,* and $\sum_j W_{jit}$ shows the amount of water used for agricultural

[1] For variables, parameters, and indices in the model please refer Appendix A.

[urban] activities at node i at time t. The total value of the water at i and time t is $V_{ag[ur]}\cdot\sum_j W_{jit}$, and the total value of the water to all agricultural [urban] nodes is expressed as $\sum_{i\in ag[ur]} V_{ag[ur]}\cdot\sum_j W_{jit}$. D_{ji} and $C_{ag[ur]}$ are the distances between the nodes, and the transportation cost per unit distance, respectively; the total cost of transporting water to node i is $\sum_j W_{jit}\cdot D_{ji}\cdot C_{ag[ur]}$, and the total water transportation cost to all agricultural [urban] nodes is $\sum_{i\in ag[ur]}\sum_j W_{jit}\cdot D_{ji}\cdot C_{ag[ur]}$. Although the unit cost/benefit values change from country to country and season to season, due to the data unavailability, they are considered herein as constants, but with the data availability such changes can be incorporated into the model without additional difficulty. Thus, in period t, the net benefits of water usage in the agricultural [urban] sector is,

$$\sum_{i\in ag} V_{ag}\cdot(\sum_j W_{jit}) - \sum_{j,\, i\in ag} C_{ag}\cdot D_{ji}\cdot W_{jit} \quad (6)$$

$$\sum_{i\in ur} V_{ur}\cdot(\sum_j W_{jit}) - \sum_{j,\, i\in ur} C_{ur}\cdot D_{ji}\cdot W_{jit} \quad (7)$$

P_{et} is the unit market price of generated energy in period t; E_j is the amount of energy generation per unit of water release at node j; and Q_{jlt} the flow of water into downstream node l from node j at time t; $P_{et}\cdot E_j\cdot Q_{jlt}$ shows the value of the energy generated at node j during water release to downstream node l, Hence, the total value of generated energy in the basin at time t is,

$$\sum_{j,l} P_{et}\cdot E_j\cdot Q_{jlt} \quad (8)$$

For the inter-basin water transfer links and their associated costs, let Q_{jlt} be the flow of water from node j into downstream node l at time t, D_{jl} the distance between the supply nodes, and C_{ss} the transportation cost per unit distance and amount between the two river basins. As there are only three links, they are explicitly represented by the corresponding node indices for period t. These costs are assigned to water recipient country. Let $Q_{21,12,t}$ be the water flowing at time t from the Tigris in Turkey, to the Euphrates in Syria, over the link from nodes $j=21$ to $j=12$, and $Q_{28,14,t}$ and $Q_{31,16,t}$ the water flows over the links from node $j=28$ to $j=14$ and from node $j=31$ to $j=16$, both from the Tigris to the Euphrates within Iraq. Let L_{jl} be the length of links from node j to node l. The transportation cost for link j-l is, then, computed as $Q_{jlt}\cdot C_{ss}\cdot L_{jl}$. At time t, the total inter-basin link cost is then calculated as follows.

$$(Q_{28,14,t}\cdot C_{ss}\cdot L_{28,14}) + (Q_{31,16,t}\cdot C_{ss}\cdot L_{31,16}) + (Q_{21,12,t}\cdot C_{ss}\cdot L_{21,12}) \quad (9)$$

The sum of benefits and costs in Equations (6)-(9) constitutes the objective function as given in Equation (1a). Later, in order to differentiate energy prices for different countries, the same objective function is divided into three mutually exclusive parts reflecting the country benefits separately. Then, indices are adjusted regarding the country sunsets: *TA(i)* is indices for agriculture in Turkey, *SA(i)* for agriculture in Syria, and *IA(i)* for agriculture in Iraq; In the same way, *TU(i)* is indices for urban in Turkey, *SU(i)* for urban in Syria, and *IU(i)* for urban in Iraq. Equation (1b) is for separate country benefits with weight multipliers (WG_T, WG_S, WG_I), which may take 0 or 1. In order to obtain the same net economic value from Equations (1a) and (1b), weights are required to be 1 for each country. These weights are used to include or exclude country or countries from objective functions. Equations (1c)-(1e) are the country details of Equations (1a) and (1b) as their country subsets. Those separated objective functions also enable to assign different energy prices in different countries: *TEt* is indices for energy price in Turkey at time *t*, *SEt* for energy price in Syria at time *t*, *IEt* for energy price in Iraq at time *t*.

Equation (2) and Figure 2 present the water balance and its diagrammatic form. Water leaving node *j* at time *t* (the left hand side of the equation) is made up of reservoir evaporation EL_{jt}, reservoir storage for use in the next period, RS_{jt}, water withdrawal for agricultural and urban uses W_{jit}, and water release to downstream nodes Q_{jt}, which is equal to $\sum_l Q_{ljt}$. The total water delivery to demand node *i* at time *t* is $\sum_j W_{jit}$, which is the sum of the deliveries W_{jit} from all supply nodes *j* to node *i* at time *t*. Accordingly the total amount of water leaving node *j* at time *t* is given as,

$$\sum_i W_{jit} + \sum_l Q_{jlt} + EL_{jt} + RS_{jt} \qquad (10)$$

Right hand side of Equation (2) shows the water inputs to supply node *j* at time *t*, which are the sub-drainage basin inflows T_{jt}, the water stored (i.e. transferred to period *t*) in the reservoir *j* from earlier period at time *t-1* RS_{jt-1}, the total of return flows from the upstream withdrawals to supply node *j* at time *t* ($RFT_{j-1,t}$) taken as the sum of the products of return flow rates (RF_{ij}) and withdrawals ($\sum_j W_{jit}$) at node *i* at time *t* $\sum_i RF_{ij} \cdot \sum_j W_{jit}$, and water from upstream nodes *l* to *j* at time *t* $\sum_l Q_{ljt}$. As can be seen visually in Figure 2, the total input at node *j* at time *t* is,

$$\sum_i RF_{ij} \cdot (\sum_j W_{jit}) + T_{jt} + \sum_l Q_{ljt} + RS_{jt-1} \qquad (11)$$

Equations (10) and (11) make the water balance constraint in Equation (2) for each supply node *j*, at time *t*. Equations (3) and (4) are designed to control the minimum and maximum total water withdrawal at node *j* at time *t*, $\sum_j W_{jit}$. S_i is a size parameter for demand node *i* refers hectare for agricultural nodes or inhabitants for urban nodes. Min_{agt} and Min_{urt} are minimum usage rates to sustain agricultural and urban activities, and Max_{agt} and Max_{urt} are maximum usage rates to prevent excessive withdrawals at time *t*. In the model application, Min_{agt} and Min_{urt} are set to be zero in order to prevent negativity and not to force irrational water withdrawals, such as providing water for far away demand nodes. The ITETRBM optimizes only available resources to measure the impacts of available water resources in the basin. Given that RC_j is the reservoir capacity for each node j, and RS_{jt} is the water stored in reservoir node j at time t for the next period, Equation (5) provides a reservoir capacity constraint at node j at time t. A total list of indices, variables, and parameters are presented in Appendix A. Assumptions concerning the basic system parameters and the necessary data for model execution are presented in Appendix B similar to Kucukmehmetoglu (2002, 2009), Kucukmehmetoglu & Guldmann (2004).

Data & Assumptions: Except the differences in the number of the period and associated periodical differences in demands, tributary flows, evaporation levels, time based parameters, all data sources and assumptions remain the same as in Kucukmehmetoglu (2009). They are as follows: It is assumed in the ITETRBM that the planned dams are completed and all irrigable lands are developed by the year 2040. Current populations are projected to the year 2040, assuming that the current growth rates remain constant (Kucukmehmetoglu 2002). For the inter-temporal nature of the ITETRBM the year is divided into periods (for this study 12 months). In the process of developing the ITETRBM, due to the lack of adequate data on the Euphrates and the Tigris, some of the necessary parameters are adopted from earlier studies conducted in some of the Middle East countries and the U.S.A. The *supply* figures are derived from Kolars (1986, 1992, 1994), Kolars & Mitchell (1991), Kliot (1994), and Bağış (1989); the demand figures are drawn from Bağış (1989), Kolars & Mitchell (1991), Kolars (1994, 1992, 1986), Kliot (1994), FAO (1993), Altinbilek (1997), and www.library.uu.nl/wesp/populstat/Asia/ ; agricultural and urban water use figures are adjusted from the studies of Howitt et al. (1982), and Dinar & Wolf (1994a); the cost of water transfers and energy are drawn from Hirshleifer et al. (1969), Gibbons (1986), and Bilen (1994). Adding time dimension to the model requires additional data: *Reservoir capacity* figures are obtained from Altinbilek (1997, 2004) and UNEP (2001), *tributary flows by periods* from Kliot (1994), *seasonal evaporation figures* from a study done over the Nile by Hurst (1952), *urban and agricultural demand figures* by periods from İlhan & Utku (1998) and İstanbul Su ve Kanalizasyon İdaresi (İSKİ) (2004). Detailed explanations on these parameters are available in Appendix B. Additional major assumptions are as follows: The base model does not consider geographic variations in the values of urban and agricultural consumptions, energy prices, and transportation costs. These variables also vary with time, technology, alternative energy resources availability, levels of economic and socio-cultural development and their characteristics. Due to linear nature of ITETRBM, it is necessary to enforce withdrawal limit of each demand node to eliminate excessive and irrational water withdrawals. These limits are designed on per capita and hectare bases for urban and agricultural demand nodes, respectively.

4. MODEL APPLICATIONS

In the ITETRBM application process, the temporal nature of the model covers 12 consecutive monthly periods that the first month is November, and the last month is October. The single year model uses only active reservoir capacities (ARC) filled by accumulated water in that year. For the analyses, whatever accumulated in that year is used in the same year without extending into multiyear temporal allocations. In the evaluations, as can be seen in Table 1, there are two scenario dimensions: The first one is the ***management*** (by rows), and the second one is the ***energy demand*** (by columns).

Table 1 – Model application scenarios

Management Scenarios	Energy Demand Scenarios	
	C: Constant in the Basin	**V**: Variable in the Basin
I: Integrated	**IC**	**IV**
D: Disintegrated	**DC**	**DV**

The ***management*** dimension contains of two scenarios: The *first* scenario is the integrated (I) one (Figure 3a) that assumes the ETRB is managed by a single authority, and all resources are optimally used without considering countries and their priorities; the *second* scenario is the disintegrated (D) one that first Turkey uses the resources in the basin considering her priorities, then Syria, and then Iraq (Figure 3b). For the sequential optimization runs presented in Figure 3b, only country based subsets, parameters, and variables are used for sequential country optimizations (1st Turkey, 2nd Syria, and 3rd Iraq). Besides, the return flows from upstream countries and water releases from their border are considered as inputs for the relevant downstream country (first Syria, then Iraq).

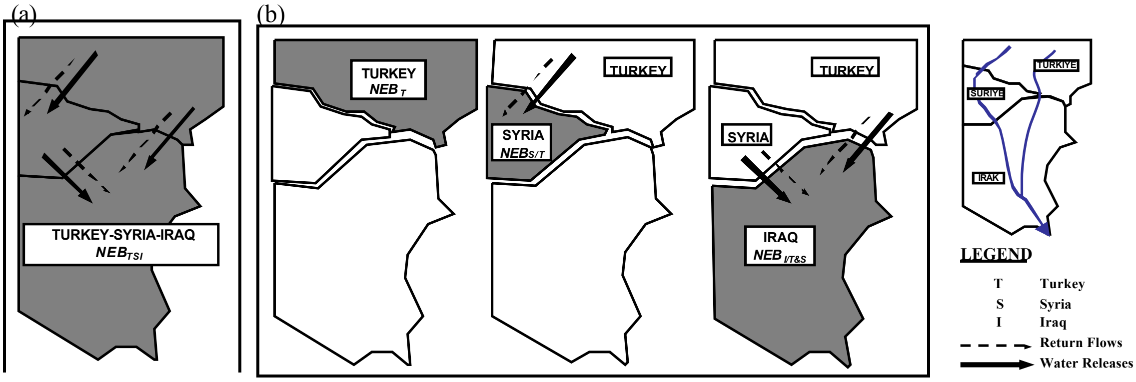


Figure 3 – Management scenarios for ETB: (a) Integrated; (b) Disintegrated
(Derived fom Kucukmehmetoglu et al. 2010)

The ***energy demand*** dimension contains two scenarios: The *first* scenario assumes that there is an invariant energy price (P_{et} is constant - C) throughout the basin; the *second* scenario assumes that upstream country Turkey is an energy poor country, and during low temperature the energy prices increases (P_{TEt} is variant - V). In contrast, the downstream countries are energy rich countries that any changes in the temperature do not have any price effect. The rule for energy price change in Turkey is: Considering the monthly average temperature figures between year 1970 and 2000, for those months in which average temperature is below 15˚C, energy prices ($25 MWh) is increased. The temperature elasticity of energy price is assumed to be -1, and then the computed prices are shown in Table 2.

Table 2 – Energy price scenarios

Average Temperature (˚C)*	Nov *t=1* 8.3	Dec *t=2* 4.1	Jan *t=3* 1.9	Feb *t=4* 2.9	Mar *t=5* 6.3	Apr *t=6* 11.7	May *t=7* 16.3	Jun *t=8* 20.7	Jul *t=9* 23.9	Aug *t=10* 23.5	Sep *t=11* 19.7	Oct *t=12* 14.3
Price (P_{TEt} = $-MWh)**	36.2	43.2	46.8	45.2	39.5	30.5	25.0	25.0	25.0	25.0	25.0	26.2
Price (P_{SEt} = $-MWh)	25	25	25	25	25	25	25	25	25	25	25	25
Price (P_{IEt} = $-MWh)	25	25	25	25	25	25	25	25	25	25	25	25

*Source: http://www.dmi.gov.tr/FILES/ziraat/2008yiliSicakliklarininAnalizi.pdf. (Last access October 2010)
** Turkey's energy prices are derived with respect to the average temperatures (1971-2000).

In the model application section, primarily a base model assuming an *integrated basin* (I) and *constant energy prices* (C) is used, and its results are presented as a benchmark in order to show the impacts of alternative management and energy scenarios.

4.1. Benchmark Model Results

The benchmark model assumes that there is an integrated (I) the Euphrates and Tigris Basin (ETRB) disregarding country specific objectives. November is the first period to accumulate water in the ARC, and October of the following year is the last period (12^{nd} month). Monthly the ITETRBM results are presented in Tables 3-4 and Figures 4-8.

The benchmark model results are presented in *three* steps: In the *first* step, there are monthly water allocations and accounting balance results; In the *second* step, there are monthly economic benefits with their associated sources; In the *last* step, there are country based monthly economic benefits with their sources. These results later are used as a reference to make various sensitivity analyses.

Table 3 – Monthly water balances (black-incoming & red-outgoing) ($10^6 m^3$)

Periods	Tributary inflows to ARC	Return flows	Water ready to use in ARC	Withdrawn water	Stored water in ARC	Evaporation form ARC	Releases to the Gulf	Continuity balance
Nov	2573	681		1273	0	1922	59	0
Dec	3302	794	0	1597	681	1685	133	0
Jan	4236	586	681	987	2433	2001	83	0
Feb	5260	573	2433	910	4674	1127	1555	0
Mar	7079	699	4674	1242	10017	907	287	0
Apr	10324	1249	10017	2930	17749	657	255	0
May	15379	2636	17749	6887	27382	939	556	0
Jun	15437	4310	27382	11611	32951	1251	1316	0
Jul	9242	5242	32951	14245	30453	1534	1204	0
Aug	4203	6594	30453	18129	18179	1722	3221	0
Sep	2663	6293	18179	17270	5845	1940	2080	0
Oct	2220	3332	5845	8838	0	2033	526	0
Nov			0					
Total	**81920**	**32988**	**150364**	**85918**	**150364**	**17716**	**11274**	**0**

Basin-Wide Water Use Figures: Table 3 shows both *incoming* and *outgoing* water from supply nodes with their sources, and Figure 4 visually presents the same values. The incoming waters (in black) are tributary inflows, return flows from withdrawals, and incoming (stored) water from earlier periods. The outgoing waters (in red) are water withdrawals, evaporation from the reservoirs, water stored in the reservoirs for the uses of next periods, and water releases to the Gulf. In Figure 4, the values above the zero show the incoming water, and the values below zero present the outgoing water from the reservoirs. The bars presenting tributary inflows and water withdrawals are not perfectly symmetric along the zero line, because the stored water in winter and spring is used in the coming summer and fall. In the mean time, the accumulated (stored) water figures presented in green line is perfectly counterparts with the blue line showing accumulated (stored) water ready to use with only one month lag. The accumulated water in the ARC enables seasonal shifts in water uses presented by bars. The same figure also presents, monthly return flows, evaporation levels, and water releases to the Gulf. At the end of the 12 periods, all incoming water is used, water in ARC is totally consumed, and system's *in* and *out* balance reaches to zero.

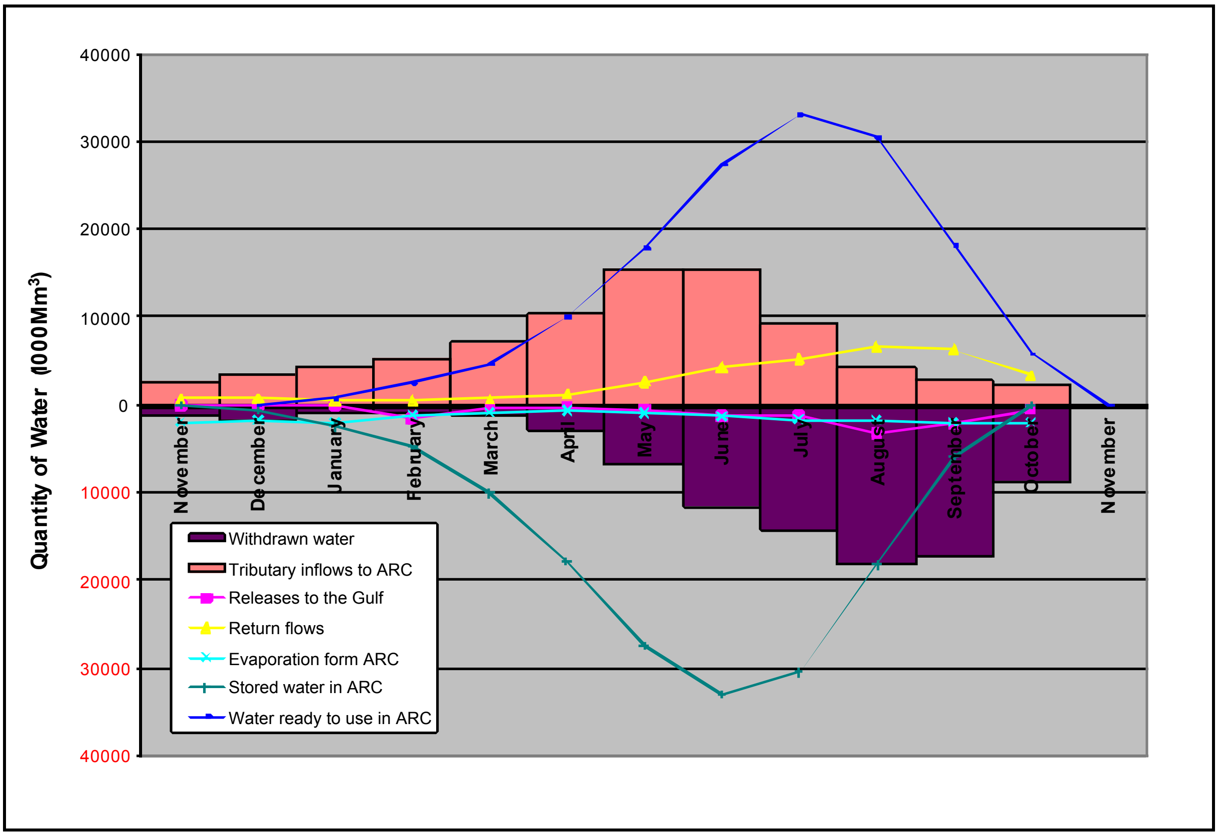


Figure 4– Monthly in and out balances

Basin-Wide Economic Benefit Figures: Table 4 and Figure 5 present the net economic benefits from the application of the ITETRBM with their sources and associated costs. As designed in the basic optimization model, the net economic benefit is derived from energy generation, urban and agricultural water withdrawals. Since energy is generated directly from water releases from reservoirs, energy components of the benefits do not have any cost component; however, urban and agricultural withdrawals have associated water conveyance costs as a function of distance. Net economic benefit from water withdrawal is estimated after water conveyance costs.

The Net Economic Benefit (NEB) from the ITETRBM is found to be $2892.8x10^6$ (Table 4). As can be seen from Table 4 and Figure 5, economic benefits from the urban uses present a uniform distribution between months; however, energy and agricultural water use benefits indicate a synchronized seasonal fluctuation regarding the water demand in agriculture. During the water scarce period, the energy generation benefits increase due to uniformly priced energy. Uniform energy price in a year makes the optimization model delay hydroelectric generation until water is deficient in agriculture (in summer and autumn). In other words, water releases from the upstream dams take place during the water scarce periods in order to be able to convey water to downstream agricultural districts.

Later in this study, uniformity assumption of the energy value is relaxed and its effects on agriculture are measured.

Table 4 – Monthly economic benefits with respect to their sources ($$10^3$)

Periods	Net Economic Benefit		Sources of the Net Economic Benefit							
			Benefit				Transport Cost			
			Water Withdrawal		Energy		Urban		Agriculture	
	($)	%	($)	%	($)	%	($)	%	($)	%
Nov	95793	3.31	97120	3.28	28778	2.48	14059	7.24	10258	1.00
Dec	118145	4.08	105136	3.55	40924	3.53	14042	7.23	13874	1.35
Jan	117506	4.06	91467	3.09	46213	3.98	14382	7.41	5792	0.56
Feb	144138	4.98	93567	3.16	78587	6.77	23679	12.20	4337	0.42
Mar	168064	5.81	104504	3.53	98896	8.52	27084	13.95	8250	0.80
Apr	224548	7.76	135299	4.57	133441	11.50	13362	6.88	30831	3.01
May	216720	7.49	234721	7.93	77848	6.71	13464	6.93	82385	8.03
Jun	325805	11.26	358657	12.12	125801	10.84	14722	7.58	143931	14.03
Jul	275946	9.54	427429	14.45	40153	3.46	15351	7.91	176285	17.19
Aug	420179	14.53	522403	17.66	140078	12.07	14892	7.67	227411	22.17
Sep	582916	20.15	500675	16.93	314041	27.07	14841	7.64	216959	21.15
Oct	203031	7.02	287199	9.71	35488	3.06	14284	7.36	105372	10.27
Total	**2892791**	**100**	**2958176**	**100**	**1160249**	**100**	**194162**	**100**	**1025684**	**100**

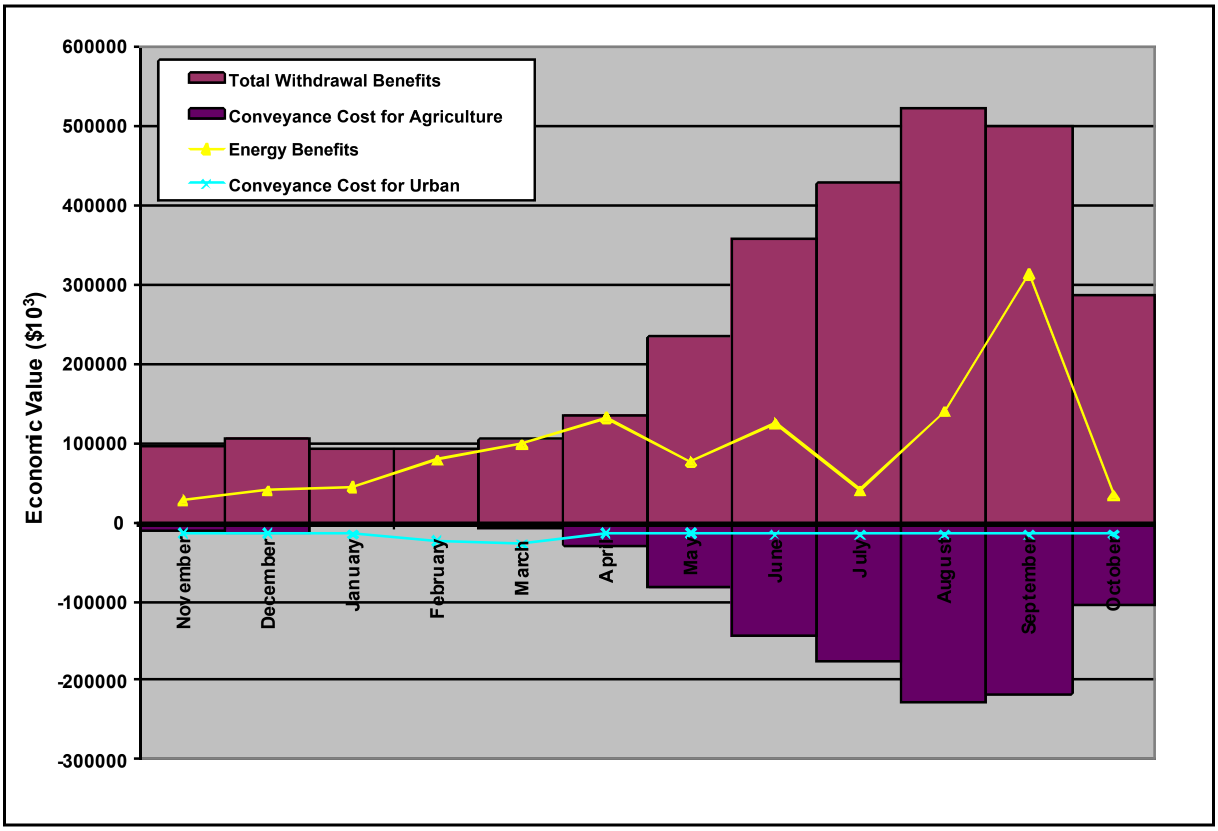


Figure 5– The monthly changes in economic benefits with respect to their sources

Distribution of the Economic Benefits among Countries and Between Sectors: So far, aggregate measures of economic benefits and water recourses allocations are presented. In this section, first country based monthly allocation of the benchmark model benefits then their associated sources are presented in Figures 6 and 7, respectively. Figure 7 also provides monthly water withdrawals by countries. Figures present that Turkey and Iraq obtain most of their benefits during partially autumn and heavily summer and fall periods. These benefits can be mainly attributed to energy generations for Turkey and agricultural water withdrawals for Iraq (Figure 7). The difference between Iraq and Turkey is clearly identified by the blue and purple bars indicating energy and agricultural benefits, respectively. Syria is different from both Turkey and Iraq that she obtains benefits from both energy and agriculture. It can be concluded that an integrated basin management makes Turkey an energy generating and Iraq an agricultural country. Though the highest total net economic benefits are generated from the basin-wide optimization disregarding country specific unilateral objectives, this scenario requires voluntary participation of upstream country Turkey with a rational compensation payment

(Kucukmehmetoglu 2010). The integrated basin model forces Turkey minimally withdraw water in favor of overall performance of the basin and, specifically, downstream countries.

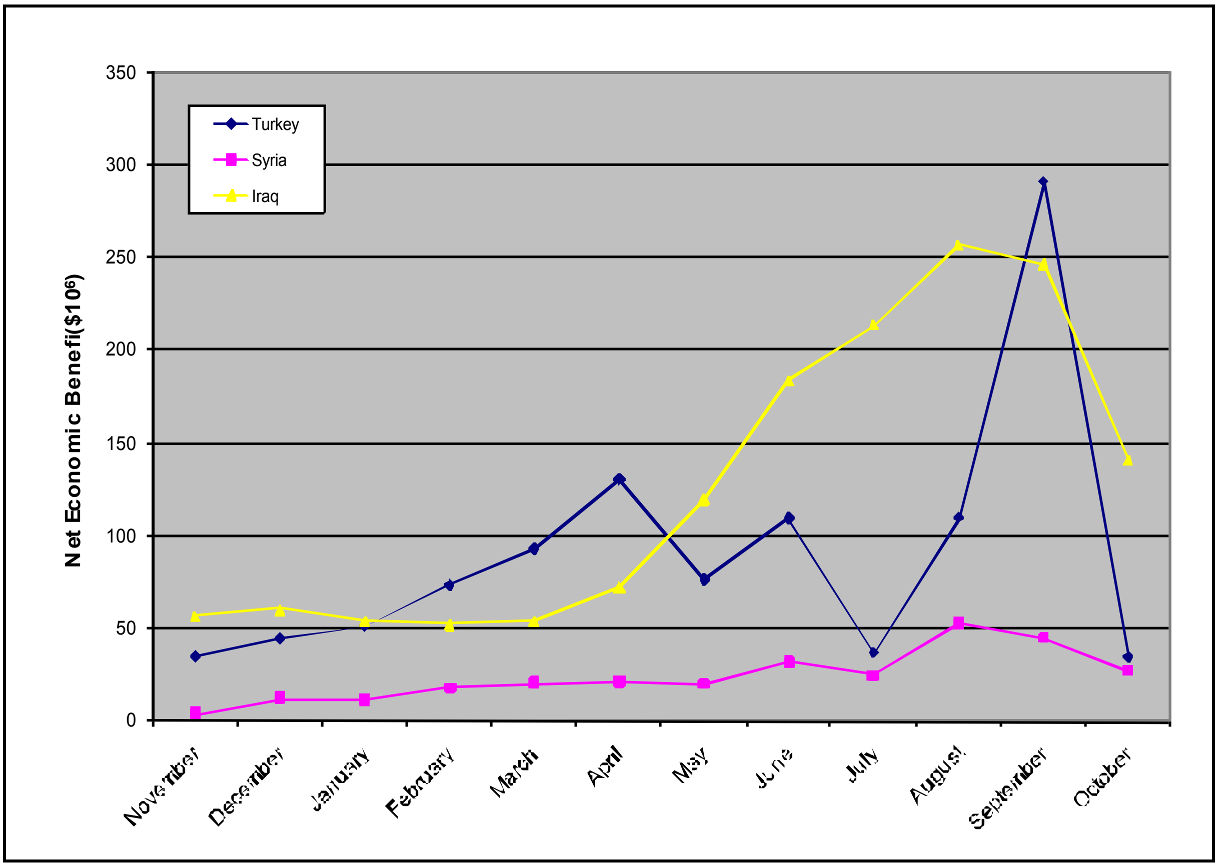


Figure 6– Net country benefits by months

4.2. Impacts of Energy Demand Changes on Agriculture under Various Management Scenarios.

In this section, under the integrated and disintegrated basin management scenarios, the impacts of changes in energy demand over a year on agriculture are the bases for analyses. Based on scenarios identified in Table 1 and Figure 3, Table 5 is prepared to show the marginal impacts of scenario changes on net economic benefits and water uses. In order to convey the marginal changes to the reader, obtained values are indexed to the benchmark model assuming integrated basin and uniform energy prices (not considering any changes in energy demand over the year). Benchmark model values are also presented in the same table to the reader to convey the magnitude of values. Figure 8 presents the graphic equivalence of Table 5 with actual values. The results are as follows:

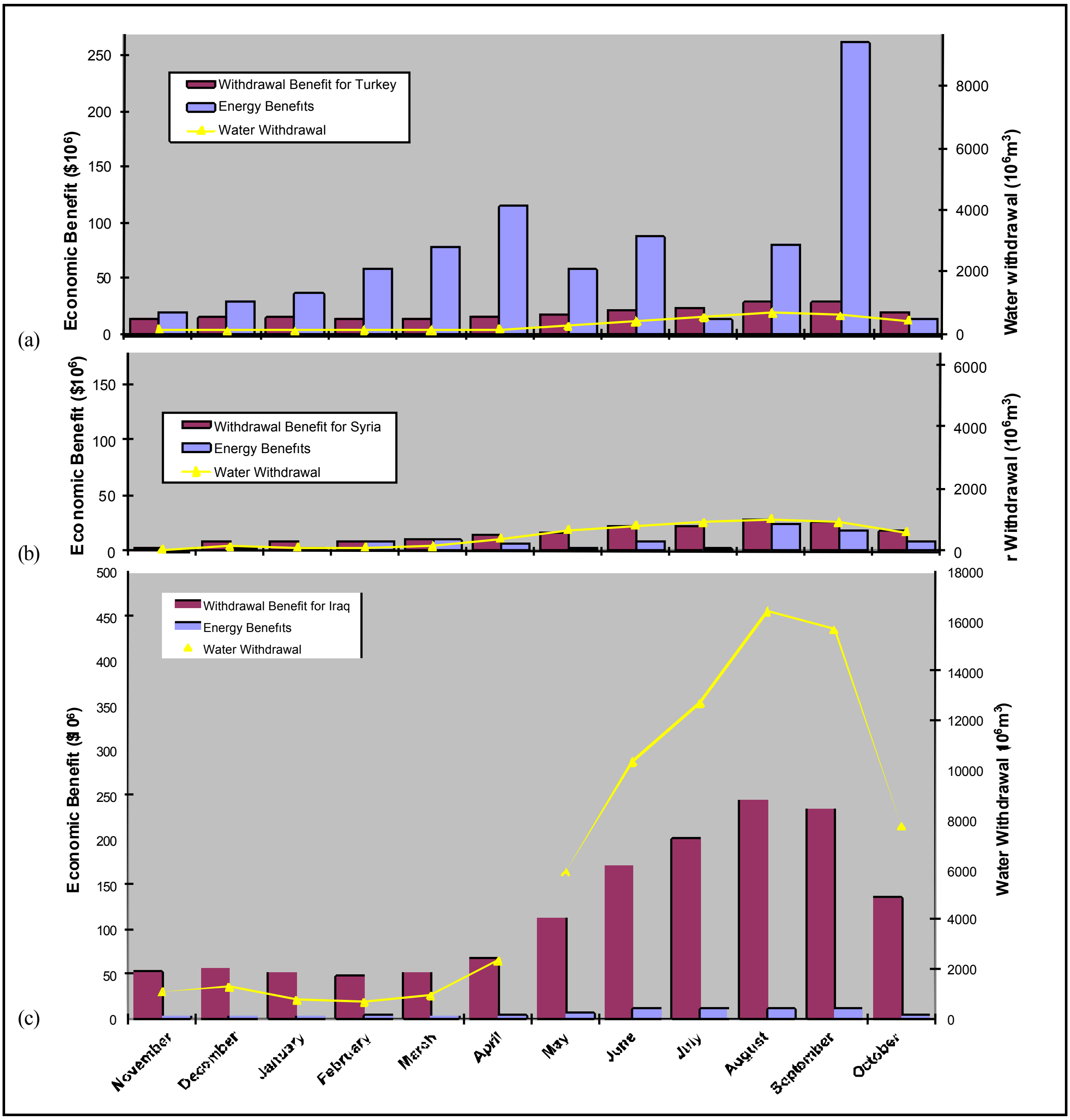


Figure 7 – Monthly net economic benefits of the countries by their sources and monthly water withdrawals: Turkey; (b) Syria; (c) Iraq

- ***Comparison of ICand DC Scenarios:*** For an integrated system, the winner of the scenario is, mainly the basin itself as a whole, and specifically downstream country Iraq. As can be seen in Table 5, while Iraq's benefit is declining (100.0→93.5) in the disintegrated basin management, Turkey and Syria's net economic benefits are increasing (respectively 100→102.7, 100→100.6). In the same scenario, the decrease in energy benefits in the upstream Turkey and Syria refers to increases in agricultural withdrawals, which mean less water for energy generation. The upstream water uses have mainly negative agricultural and partially energy effects on Iraq.
- ***Comparison of IC and IV Scenarios and Comparison of DC and DV Scenarios:*** In the scenarios encountering the impacts of energy price changes (higher energy prices when temperature decreases below 15℃ in upstream Turkey), there are similar impacts in both integrated and disintegrated managements; however, the decrease in agricultural benefits is much more for the disintegrated scenarios in Iraq (100→80.3) in Table 5. The reason for that during cold weather period Turkey rationally uses (releases) the water from their reservoirs for the benefit of energy; conversely, in this process, water releases take places from reservoirs in Turkey much earlier than the period needed for Iraq. It is noteworthy that in an integrated basin management the reservoirs in Turkey have positive economic contribution to the downstream countries at the expense of her own unilateral benefits.
- ***Water Withdrawals and Water Releases for Energy Generation:*** Table 5 provides water withdrawals for urban and agriculture. The changes in energy demand have limited impact on urban water withdrawals as compared to agricultural uses. The reasons for that the economic values of water in urban area are 6 times and the return flow rates are 2.3 times more than the values in agriculture. It is clear that in an integrated basin management Iraq utilizes her agricultural potent at the expense of agricultural withdrawals in Turkey. In the meantime, increasing energy demand in Turkey does the similar effects on agricultural withdrawals. By assumption, the invariant agricultural productivity assumption makes both upstream and downstream lands indifferent, but unused water has potential of generating energy until reaching to the Gulf from head losses. Unless Turkey's losses from an integrated basin management are compensated, Turkey would rather rationally prefer acting unilaterally to take advantage of her upstream water contributing position. Higher winter season energy demands in Turkey lead untimely water releases beyond the water holding capacity of

downstream countries and cause losses from potential benefits in agriculture. In this process, the upstream reservoirs in Turkey, on the other hand, enable inter-temporal water resources allocations by delaying water flows, and provide benefits to the downstream countries.

Table 5 – The indexed results of various management and energy demand scenarios : Net economic benefits and water withdrawals in reference to the benchmark model (Index=100)

Net Economic Benefit ($) & Withdrawal ($Mm^3$)			Assumption for Energy Price			
			C: Constant in the Basin		V: Variable in Turkey ($\varepsilon_{p,\circ c}=-1$)	
			I: Integrated (IC)	D: Disintegrated (DC)	I: Integrated (IV)	D: Disintegrated (DV)
Turkey	benefit	*Total*	1087379 ≡ *100*	*102,7*	*119,1*	*123,7*
		Withdrawal	191083 ≡ 100	133,4	99,1	132,3
		Agriculture	50393 ≡ 100	226,7	96,7	222,3
		Urban	140690 ≡ 100	100,0	100,0	100,0
		Energy	896297 ≡ 100	96,1	123,3	121,9
	water	*Total*	3764 ≡ *100*	*247,9*	*97,7*	*241,8*
		Agriculture	2529 ≡ 100	320,2	96,6	311,1
		Urban	1235 ≡ 100	100,0	100,0	100,0
Syria	benefit	*Total*	292640 ≡ *100*	*100,6*	*100,0*	*95,7*
		Withdrawal	161445 ≡ 100	105,5	100,0	95,3
		Agriculture	83396 ≡ 100	103,7	100,0	99,7
		Urban	83837 ≡ 100	100,0	100,0	84,3
		Energy	131195 ≡ 100	94,6	100,1	96,2
	water	*Total*	6092 ≡ *100*	*103,2*	*100,0*	*98,3*
		Agriculture	5272 ≡ 100	103,7	100,0	99,9
		Urban	821 ≡ 100	100,0	100,0	88,6
Iraq	benefit	*Total*	1512772 ≡ *100*	*93,5*	*100,0*	*84,6*
		Withdrawal	1380015 ≡ 100	93,3	100,0	82,7
		Agriculture	826436 ≡ 100	91,8	99,9	80,3
		Urban	553578 ≡ 100	100,0	100,0	91,8
		Energy	132758 ≡ 100	95,5	100,5	103,8
	water	*Total*	76061 ≡ *100*	*91,9*	*99,9*	*80,0*
		Agriculture	71635 ≡ 100	91,4	99,9	79,2
		Urban	4426 ≡ 100	100,0	100,0	92,1
Turkey-Syria-Iraq	benefit	*Total*	2892791 ≡ *100*	*97,7*	*107,2*	*100,4*
		Withdrawal	1732542 ≡ 100	98,9	99,9	89,4
		Agriculture	960225 ≡ 100	99,9	99,8	89,4
		Urban	778105 ≡ 100	100,0	100,0	92,5
		Energy	1160249 ≡ 100	95,9	118,1	116,9
	water	*Total*	85918 ≡ *100*	*99,5*	*99,8*	*88,4*
		Agriculture	79436 ≡ 100	99,5	99,8	88,0
		Urban	6482 ≡ 100	100,0	100,0	93,2

IC: Integrated Management; Constant Energy Demand in the Basin
DC: Disintegrated Management; Constant Energy Demand in the Basin
IV: Integrated Management; Variable Energy Demand in Turkey
DV: Disintegrated Management; Variable Energy Demand in Turkey

Table 5 presents that agriculture is the primary sector being affected from management and energy demand scenarios. In order to present the country based monthly effects of changes, Figures 8a,b,c are prepared. Analyses are as follows:

- ***Impacts of Management Strategies (Integrated and disintegrated):*** As compared to the disintegrated basin management, the integrated basin management causes significant economic benefit decreases in Turkey between April and October. In contrast, in Iraq, during August and September (Figure 8), when water is short, there are significant agricultural economic benefit increases in the integrated basin management. Syrian benefits are almost indifferent due to her intermediate geographic location in the basin. In the water withdrawal values, the scenarios assuming changes in energy demand hardly results in alterations in water withdrawals for the countries in the integrated management scenario alone; however, these alterations are prominent in Iraq when the basin management is disintegrated. Especially, during June-September (Figure 8), water withdrawals in Turkey and Iraq present significant changes.
- ***The Impacts of Energy Price Changes in the Upstream Turkey for the Integrated Basin Management Scenarios:*** In Figures 8a, b, c, it can be seen that the changes in the energy prices in the upstream country Turkey do not cause significant changes in water withdrawals for the integrated basin management scenarios. The reason for that the integrated basin management still considers the valuable water uses in agriculture at the downstream countries. Also, it is still possible to generate energy while transferring water to the downstream agricultural zones.
- ***The Impacts of Energy Price Changes in the Upstream Turkey for the Disintegrated Basin Management Scenarios:*** In the disintegrated basin management scenarios, the energy price changes in upstream country Turkey make her unilaterally adapt to new situations to generate maximum net economic benefit. That means more water releases during low temperature periods to generate energy, and untimely more water intakes to the downstream countries beyond their ARC enabling to postpone water withdrawals to the high water demand periods. The disintegrated basin management puts Iraq in a passive position, and her water withdrawal therefore declines (100→80.3, in Table 5).

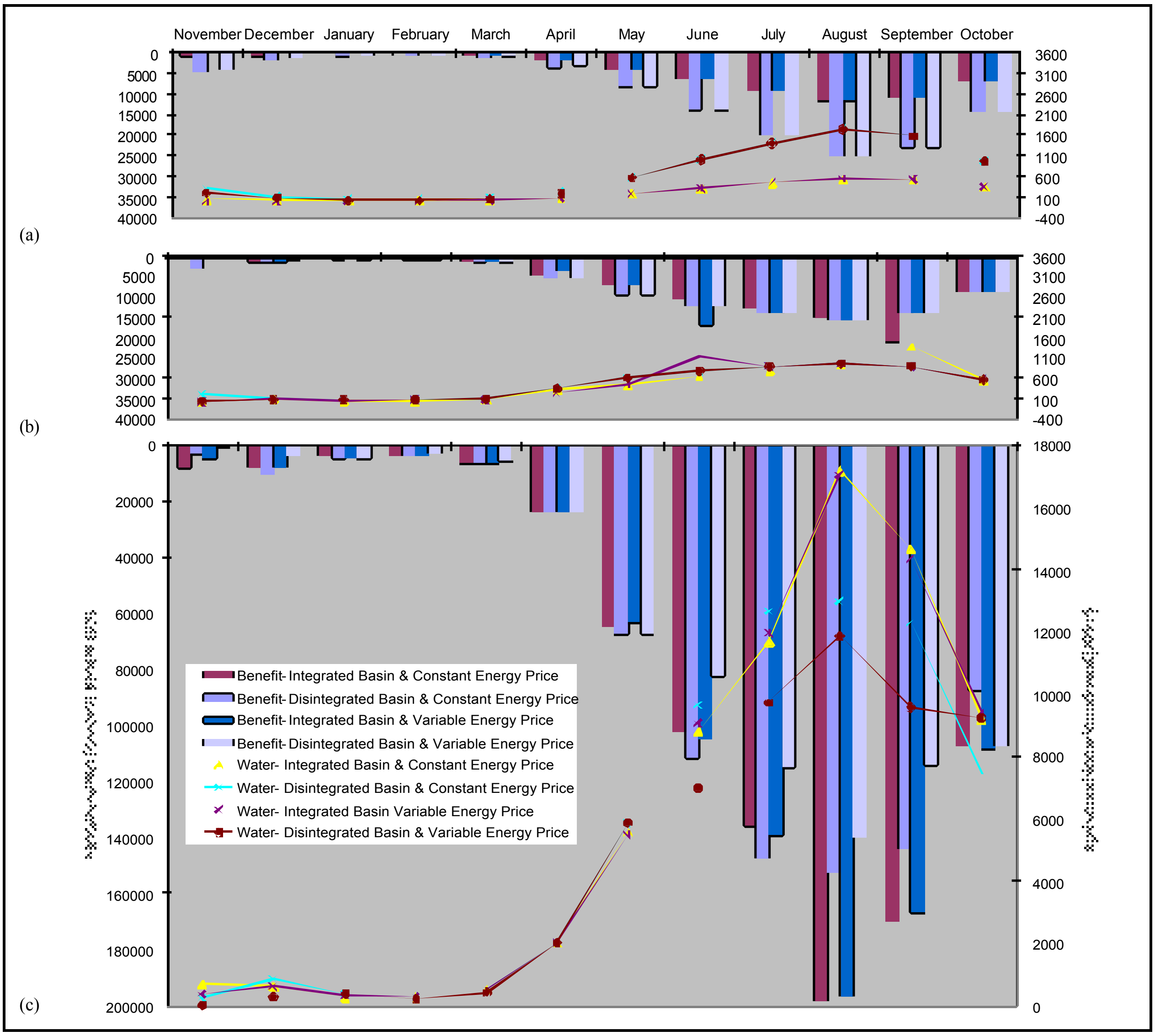


Figure 8– Net economic benefits and total water withdrawals under effects of varying energy demands in Turkey: (a) Turkey; (b) Syria; (c) Iraq

For agriculture and energy sectors, there are several conclusions can be derived:

- Regarding the total net economic benefit generated from the basin, it is certain that integrated basin management is superior to the disintegrated basin management. Because, in the disintegrated basin management, the upstream optimization behaviors create certain preconditions to the downstream countries, the total net economic benefits derived from the basin becomes an outcome of partial country based optimizations. Thus, the sum of partial optimization results never exceeds the total net economic benefits derived from the integrated basin management (IC:100→DC:97,7; IV:107,2→DV:100,4).

- The changes in the upstream energy demand and their negative impacts on downstream countries can be resolved by means of alternative energy policies. For example, during cold periods or untimely energy demand changes, the inclination to the hydroelectric energy sources can be prevented by providing alternative energy sources. The energy rich downstream countries may rationally provide or subsidize energy to the upstream country to maximize their economic benefits from the basin. Similarly, any alternative energy source investments in the upstream county Turkey can be promoted and/or subsidized by the negatively affected downstream counties in order to attain timely water releases from the upstream reservoirs.
- It is noteworthy that the integrated basin management uses the ARC in Turkey for the overall benefit of the ETRB. In any consideration of integrated basin management, authorities should consider the monetary costs born to the upstream country Turkey from the construction of reservoir infrastructure.

Though the case study is designed to encompass a single year 12 period optimization model, at the brim of the Global Climatic Change, the existence of reservoirs can be further evaluated for the multiple year fluctuations in rainfalls in the ETRB. The ITETRBM is technically capable of measuring these impacts and creates a base for further sophistications in any parameters and functional relations.

5. CONCLUSION

The scenarios has shown that integrated basin management are always more productive and superior to the any disintegrated basin management. Therefore, coordination among all parties, which can be provinces, regions, and countries in a basin, is an absolute necessity.

As a result of sensitivity analyses, Turkey's energy policy is a direct concern of Iraq as a downstream country of the ETRB. The water releases in Turkey during the cold weather periods to generate energy have negative effects on Iraq. In these effects, Turkey has two different roles: In the *first* one, the ARC built in and by Turkey enables to store water and actualizes inter-temporal water resources allocations. The built infrastructure provides significant economic benefits to the basin and especially to the downstream countries. In the *second* one, the water releases in Turkey during cold weathers to generate energy result in excess of water intake beyond the ARC of downstream countries to be able to make inter-temporal resources allocation in their land. This prevents the downstream countries have *additional* net economic benefits from the water stored at the upstream country Turkey.

For agricultural and energy policies, two assertions can be made:

- The energy (petroleum and natural gas) rich downstream countries (Syria and Iraq) may have effect on closing the upstream country Turkey's energy deficits during cold weather, and in this way, they may have a positive effect on the timing of water releases for their beneficial uses in the downstream regions.
- Similar to increasing energy demand during cold periods, the hot periods may show other higher energy demands for air conditioning and cooling. This shows that heating is not the only sources of energy demand; therefore, these policies needs to be adopted with respect to the countries' level of development, socio economic dynamics of the region, and climatic changes.

Integrated basin management not considering the separating impacts of borders can be pursued only when the necessary compensation mechanisms are developed for those who lose benefits for higher benefits of whole and others. The upstream and downstream concern is the main dilemma for an integrated basin management. It is noteworthy that unless the concerns of upstream country Turkey are addressed, the downstream countries' concerns cannot be addressed properly due to geography based sequential utilization of water resources in the ETRB.

It is usually expected that any water development project will improve the countries' economic prosperity; however, water should not be considered the only way of economic growth and development in the region. Other areas of trade and development should be used for the welfare gain of the region, so that the alternative areas of coalitions might bring parties act in a partnership in activating the regional water resources potentials. In other words, water resources allocation should not be the only base of cooperation, but should be a limited part of regional economic coalition and perspective. In that way, many specific energy and agricultural problems can be solved simultaneously.

Finally, to achieve an integrated basin management and to develop exact policies throughout the basin, there is need to have a detailed database infrastructure. But, primarily, there is need to have coordinated actions of provinces, regions, and countries in the basin. That is a political, economic, socio-cultural necessity of the parties involved in the ETRB.

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APPENDIX EK A

Indices

i:	demand nodes (1 to 63)
j & l:	supply nodes (1 to 45)
t:	periods (1 to 12)
ag:	set of agricultural demand nodes
ur:	set of urban demand nodes
st(j), *ss(j)*, *si(j)*:	the supply node subsets for Turkey, Syria, and Iraq, respectively
TA(i), *SA(i)*, *IA(i)*:	sunsets for the agricultural demand nodes for Turkey, Syria, and Iraq, respectively
TU(i), *SU(i)*, *IU(i)*:	sunsets for the urban demand nodes for Turkey, Syria, and Iraq, respectively
TEt, SEt, IEt:	energy price subsets at time *t* for Turkey, Syria, and Iraq, respectively

Variables

NEB:	total benefit net of transportation costs	($)
NEB_{TSI} :	net economic benefit of Turkey, Syria, and Iraq in the grand coalition (=*NEB*)	($)
Q_{jlt}:	inter-nodal flow (node *j* to node *l*)	(Mm^3)
W_{jit}	water transferred from supply node *j* to demand node *i* at time *t*	(Mm^3)
NEB_T:	net economic benefit of Turkey, all countries acting independently	($)
$NEB_{S/T}$:	net economic benefit of Syria given Turkey's action, all countries acting independently	($)
$NEB_{I/T\&S}$:	net economic benefit of Iraq given first Turkey's and then Syria's actions, all countries acting independently	($)

Parameters

C_{ag}:	agricultural water transport unit cost	($ per Mm^3-km)
C_{ur}:	urban water transport unit cost	($ per Mm^3-km)
V_{ag}:	agriculture water unit value	($ per Mm^3)
V_{ur}:	urban water unit value	($ per Mm^3)
C_{ss}:	internodal water transport unit cost	($ per Mm^3-km)
D_{ii}:	distance from supply node *j* to demand node *i*	(km)
D_{jl}:	distance from supply node *j* to supply node *l*	(km)

L_{jl}:	length of link from supply node j to supply node l	(km)
P_{et}:	energy price for electricity at time t	($ per MWh)
E_j:	electric generation rate for node j dam	(MWh per Mm^3)
Min_{ag}:	minimum agricultural consumption rate	(Mm^3 per ha)
Max_{ag}:	maximum agricultural consumption rate	(Mm^3 per ha)
Min_{ur}:	minimum urban consumption rate	(Mm^3 per inhabitant)
Max_{ur}:	maximum urban consumption rate	(Mm^3 per inhabitant)
EL_{jt}:	reservoir evaporation loss at supply node j at time t	(Mm^3)
RF_{ijt}:	return flow rate from demand node i to supply node j at time t	
RS_{jt-1}	water stored at time $t-1$ to transfer time t in the reservoir j	(Mm^3)
S_i:	size of demand node i (hectare for agricultural nodes, inhabitants for urban nodes)	
T_{jt}:	tributary inflow at node j at time t	(Mm^3)
RC_j:	reservoir capacity at node j	(Mm^3)

APPENDIX B: DATA AND ASSUMPTIONS

As detailed for the ETRBM in Kucukmehmetoglu (2002, 2009) and Kucukmehmetoglu & Guldmann (2004), and Kucukmehmetoglu et al. (2010) the demand-supply data various system parameters and assumptions are as follows:

Supply Data

- Data on the water contributions of each riparian country are available in Kolars (1986, 1992, 1994), Kolars and Mitchell (1991), Kliot (1994), Bagis (1989). From those figures, for each tributary of the Euphrates and the Tigris a tributary flow amount is derived.
- The return flow rate is assumed 35% for agriculture, and 80% for urban use.
- Evaporation rates (per-km^2) from the reservoirs are computed for the three riparian countries based on observed annual evaporation figures given the reservoir surface areas for the major reservoirs in the Euphrates basin (Altinbilek, 1997) and then the estimated evaporation rates are applied to the other reservoirs.

Demand Data

- Total planned irrigable land areas for each riparian country are available in the literature, with: 1,770,956 ha for Turkey, 1,040,000 ha for Syria, and 5,833,000 ha for Iraq, or a total of 8,643,956 ha for the whole region along the two rivers. Those values are assigned to 21 agricultural districts (nodes) in the Euphrates basin, and 16 in the Tigris basin.
- Irrigable areas are only available at country or regional level for Syria and Iraq. The delineation of irrigation districts was made using existing irrigation maps.
- Due to a lack of spatial information, agricultural productivity (V_{ag}) is assumed to be the same throughout the region, and crop diversity and double cropping options are ignored.
- The agricultural districts are located close to the two rivers, with the water conveyance distance varying mostly between 4 and 40 km.
- There are 8 urban demand nodes in Turkey (South Eastern Anatolia Region), 8 in Syria, and 10 in Iraq. These nodes are constituted by cities having 100,000 or more inhabitants. Historical population data for these cities, from 1965 to 1995, have been used to estimate populations in year 2040.

Agriculture and Urban Water Values

- Agriculture and urban water values are derived from Dinar and Wolf (1994b) and Howitt, Mann, and Vaux (1982), and the following values are selected: V_{ur} = \$150,000/Mm^3, V_{ag} = \$25,000/Mm^3.

Maximum and Minimum Consumption Rates

- Using the upper-bound estimate of Dinar and Wolf (1994a), Max_{ag} = 0.020 Mm^3/ha is selected as the upper bound of water withdrawal and Max_{ur}=0.000106 Mm^3/capita is selected as the upper water use rate. Because some districts may not be irrigated and some urban areas are not served, minimum withdrawals are chosen to be Min_{ag} = 0.0 Mm^3/ha and Min_{ur}=0.0 Mm^3/capita.

Water Transportation Costs

- Each demand node is assigned to the most accessible supply node that distances are strait line distances measured through map analysis. Then transportation costs are derived from Hirshleifer et al. (1969) as C_{ag}=\$850/Mm^3-km for agricultural uses, C_{ur}=\$4,958/Mm^3-km for urban uses, and C_{ss} = \$850 per Mm^3-km for inter-basin links.

Electricity Generation

- The average electric generation rate is known as 0.87 kWh per foot-head and acre-feet of water (Gibbons, 1986). This value have been converted into electricity generation per Mm^3 of water released from the head of the dam. The literature provides head heights of dams from the riverbed on the main branch of the Euphrates (Bilen, 1994). The head heights for the other dams are estimated to range between 20-35 m, in view of the change in elevation through Syria and Iraq.

Additional Data and Assumptions needed for the ITETRBM

For each reservoir, there are two types of water holding capacities: dead and active reserves. While the dead reserve capacity has no use for energy generation and water distribution, the active one is critical for inter-temporal allocations. Those active reservoir capacities are almost completely available in Turkey and partially in Syria and Iraq (Altınbilek 1997, 2004; UNEP 2001). In Turkey, the total active storage capacity is 63.3 Mm^3. The 47.6 Mm^3 of this total is in the Euphrates, and the remainder 15.7 Mm^3 in the Tigris basin. In the Euphrates basin, in Syria and Iraq, the known total active storage capacities are respectively 9 and 10.4 Mm^3. In the Tigris basin of Iraq, the only available active reservoir capacity is Mosul Dam with 8.2 Mm^3. The remainders, in Iraq and Syria, are derived by multiplying total storages by the average ratio of active reservoir capacities to total storage in the basin. This ratio is obtained from available reservoir figures in the basin. The computed average ratio is .52, and the calculated ranges of the ratios vary from .40 to .80. In the text, the reservoir capacities refer only the active reserve capacities but not the dead reserves.

- 12 monthly periods ($t=1 \rightarrow 12$) are selected for the application of inter-temporal allocation.
- Kliot (1994: p.106, 107) provides monthly variations of the Euphrates and the Tigris in graph form. These figures are aggregated into the 12 working periods and their ratio is used as multiplier for the tributary flows used in Kucukmehmetoglu (2002). These multipliers are mT_1 ... mT_{12}, and they can be used to compute periodically defined tributary flows for each supply node as $T_{jt} = T_j \cdot mT_t$.
- The water demand is expected to vary from dry to rainy season. The values of water used in these 12 monthly periods are the same, but quantities demanded are different. Therefore, adjustments ofthe maximum withdrawal limits for the 12 periods are needed. In the literature, İlhan & Utku (1998) provide monthly variations of water demands in the GAP area of Turkey. The monthly figures are converted into 12 water demand multipliers, by computing the monthly ratios of water demanded in the total annual demand ($mMax_{ag1}$ ... $mMax_{ag12}$), then these ratios are used as multiplier to adjust maximum water withdrawal limits Mm^3 per-ha in agriculture ($Max_{agt} = Max_{ag} \cdot mMax_{agt}$). The same procedure is applied for maximum urban water demands Mm^3 per-inhabitant by using monthly Istanbul metropolitan area water use figures (İSKİ, 2003) to obtain the periodical water demand ratios ($mMax_{ur1}$ … $mMax_{ur12}$). Then conversion is done by multiplying the maximum urban water demands Mm^3 per-inhabitant by these multipliers ($Max_{urt} = Max_{ur} \cdot mMax_{urt}$).
- The constant evaporation values in Kucukmehmetoglu (2002) need to be apportioned into 12 periods. The necessary multipliers are adapted from the graph provided by Hurst (1952) for the Aswan Dam over the Nile. Monthly evaporation figures are aggregated into 12 periods, and then the ratios of periodical to annual evaporation total are calculated (mEL_1 … mEL_{12}). Then the constant evaporation values are apportioned to periods by using these ratios as multipliers ($EL_{jt} = EL_j \cdot mEL_t$).
- Energy values are assumed to be the same throughout the year in calculating the economic benefits from water releases from reservoirs. But this assumption is relaxed in this research for the analyses.