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Study on the impacts of inter-basin water transfer: Northern Karun

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This study aimed to investigate the effects of inter-basin water transfer projects from Northern Karun basin to Zayanderud basin in Iran, with emphasis to Beheshtabad water transfer project. For this purpose the situation of water resources of Northern Karun basin was modeled by using WEAP model. This model was calibrated by 10 years data (1995 to 2004) and then the model was run for a 30 years period. Results showed that Northern Karun basin water resources for transferring to Zayanderud basin should be limited up to 314 million m^3 per year (MCM/year), by assuming complication of the origin basin development and considering river environment water requirement in the future. This is 46% less than the value that has been allocated by allocation committee. Results obtained from the WEAP model also indicated that the useful storage required for regulating of water resources was obtained 600 MCM as maximum value. In order to minimize social and environmental impacts of Beheshtabad tunnel, a new alternative has been introduced.

Key words: Inter basin water transferring, Beheshtabad and Kuhrang basins, WEAP model.

INTRODUCTION

Water managers and policy makers are in need to have tools at their disposal that will support them in their decision-making. This is very important for inter-basin water transfer projects. There exist today a variety of generic simulation models incorporated within interactive graphics-based interfaces that are available for studying water related planning and management issues in river basins. Sechi and Sulis (2010) Compared application of five generic models for simulating water resource systems: AQUATOOL-SimWin (Andreu et al., 1996), MODSIM (Labadie et al., 2000), RIBASIM (Delft Hydraulics, 2006), WARGI-SIM (Sechi and Sulis, 2009) and WEAP (SEI, 2005) to a multireservoir and multiuse water system in Southern Italy. While each model has its own characteristics, the proposed application comparison does not identify all the features of each model, but rather gives general information on the identification and evaluation of operating policies with the aid of these simulation models. Because the water evaluation and planning system (WEAP), is an efficient and user friendly model and it requires no additional software or cost, in this study is used.

WEAP is an exemplary application linking supply and demand site requirements. Allowing scenario analysis, changes in supply and demand structures can be simulated in order to discover potential shortages and the effects of different management strategies (Yates et al., 2005). Evaluating scenarios requires validated model results. Therefore, a challenge of many studies in which WEAP was applied is the model validation at different

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spatial and temporal scales (Al-Omari et al., 2009; Yates et al., 2009). In recent years many researchers have applied WEAP model for water resources planning and management. Ospina-Noreña et al. (2011) used WEAP model for simulating of water resources of the Sinú-Caribe river basin in Colombia to create several baseline and adaptation strategy scenarios for water supply, use and demand, and to make projections for the future including the potential impacts of climate change. The results show that the supply requirement would increase and thus unmet demand would increase more quickly under climate change conditions.

In upper Guadiana basin in Spain's inland region of Castilla La Mancha, the research focuses on the analysis of water and agricultural policies aimed at conserving groundwater resources and maintaining rural livelihoods in a basin in Spain's central arid region by using WEAP model (Varela-Ortega et al., 2011). Results showed that the region's current quota-based water policies may contribute to reduce water consumption in the farms but will not be able to recover the aquifer and will inflict income losses to the rural communities. This situation would worsen in case of drought. In South Africa, water resources in the Olifants river basin, catchment management committees (CMCs), must therefore be able to get a rapid and simple understanding of the water balances at different levels in the basin and for this purpose WEAP model was used (Levite et al., 2003). Höllermann et al. (2010) by modeling the water balance of the Ouémé–Bonou catchment with WEAP, showed that the pressure on Benin's water resources will increase, leading to greater competition for surface water. The WEAP results offer a solid basis to assist planners in developing recommendations for future water resource management by revealing hot spots of action. Harma (2011) used WEAP model to consider future scenarios for water supply and demand in both unregulated and reservoir supported streams that supply the district of Peachland in British Columbia's Okanagan basin. Results demonstrate that anticipated future climate conditions will critically reduce stream flow relative to projected uses (societal demand and ecological flow requirements). The surficial storage systems currently in place were found unable to meet municipal and in stream flow needs during "normal" precipitation years by the 2050s. Yilmaz (2010) used WEAP model as a simulation and evaluation tool to assess the performance of possible management alternatives in Gediz River basin, which is measured by nine proposed indicators. The results of the study indicated that the Gediz River basin is quite sensitive to drought conditions, and the agricultural sector is significantly affected by irrigation deficits. Raskin et al. (1992) studied on the aral sea basin water resources management. The Aral Sea, a huge saline lake located in the arid south-central region of the former U.S.S.R., is vanishing because the inflows from its two feed rivers, the Amudar'ya and Syrdar'ya, have diminished. The loss of river flow is the result of massive increases in river withdrawals in the basins. WEAP model has been applied for simulating current water balances and evaluating water management strategies in the aral sea region. The analysis provides a picture of an unfolding and deepening crisis (Raskin et al., 1992).

Purkey (2007) used WEAP model as a simulation tool to presents an overview of decision making processes ranked based on the application of a 3S: sensitivity, significance, and stakeholder support, standard, which demonstrates that while climate change is a crucial factor in virtually all water related decision making in California, it has not typically been considered, at least in any analytical sense. The authors will engage with stakeholders in these three processes, in hope of moving climate change research from the academic to the policy making arena (Purkey, 2007).

There are more studies for evaluating the effects of inter-basin water transfer projects of Northern Karun. In the past years, in order to transfer of Northern Karun basin water resources into Zayanderud basin by a total capacity of 550 MCM/year, two tunnels which named Kuhang-1 tunnel and Kuhang-2 tunnel, was constructed. These tunnels have been under operation since 1953 and 1985, respectively. In order to increase transferring the Northern Karun basin water resources, constructing of third Kuhrang tunnel with a length of 24 km had been started in 1994. Against to the first and second Kugrang tunnels, this tunnel caused many socio-economic and environmental impacts and problems because of more length and geological problems. It caused some springs such as Morvarid and Zarrin spring to be dried. Also, time and cost of the third tunnel project will be significantly increased. For example, third Kuhrang tunnel project has been under constructed since 1994 and the project cost has been increased 8 times of initial estimation. Unfortunately, despite some important springs near the tunnel have been dried due to digging of the tunnel, the tunnel has not finished yet.

In recent years forth Kuhrang tunnel which in this paper we call Beheshtabad project, has been defined to transfer of Northern Karun basin water resources to Zayanderud basin as an inter-basin water transfer project. For this purpose WEAP software has been used. Based on the obtained results from this study, some applicable recommendations are suggested in this paper.

MATERIALS AND METHODS

Study area

The study area is Kuhrang and Behesthabad basins with latitude of 3°, 50' to 32°, 35' and longitude of 50° to 51°, 25'. These basins wholly located in the area of Chaharmahal and Bakhtiyari province and they are as two sub-basin of Northern Karun basin. Beheshtabad basin with 3860 km^2 in area is the largest sub-basin in the Northern Karun basin comprising from 8 hydrologic units as shown in Figure 1 The widest plains Chaharmahal and Bakhtiyari province are located in Behesthabad basin. The Kuhrang basin with 1230 km^2 in area is also another sub-basin of Northern Karun

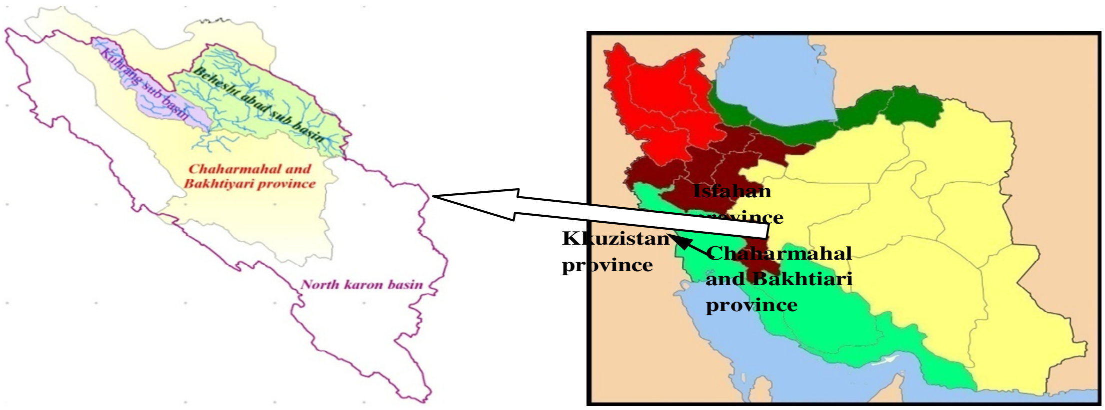

Figure 1. Study area (sub-basins of Behesht Abad and Kuhrang).

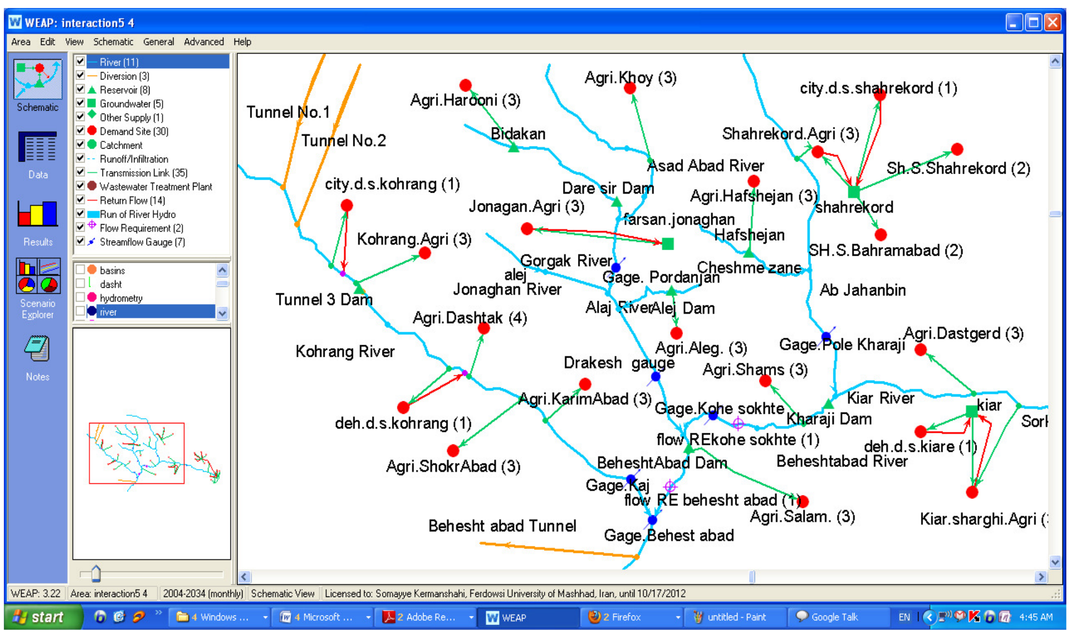

Figure 2. Configuration schematic of water resources system of Behesth Abad and Kuhrang basins.

basin. Due to high snowing, this sub-basin plays an important role in water resources of Karun and also Zayanderud basin because in the past years, there have been dug tunnels 1, 2 and 3 of Kuhrang for transferring the Kuhrang river flow to Zayandehrood basin (located in Isfahan province) with a capacity of 300, 250 and 270 MCM/year, respectively. Beheshtabad and Kuhrang rivers reach together near Ardal city in Chaharmahal and Bakhtiyari province and at this point the Karun River is formed.

In recent years the study of Beheshtabad water transfer project has been conducted for transferring an average of 600 MCM/year. This project is comprised a large dam at the point of connecting Beheshtabad and Kuhrang Rivers and a tunnel with 65 km in length which it will begin from the Beheshtabad dam site and end at Zayanderud River.

Configuration of water resources system

In WEAP model, there is used a nod-link network structure for modeling of the basin water resources. In this study, for modeling the Beheshtabad and Kuhrang basins water resources, different sites for municipal, industrial and agricultural water demand, dams reservoirs, aquifers, environmental requirement were defined as nods and different paths such as water transfer network from water supply resources to the demand sites and water return water network were used as links. Figure 2 shows the components of model in the studied basins.

Input data and model application

WEAP applications generally include several steps: (i) create a geographic representation of the area, (ii) enter the data for the different supply and demand sites, (iii) compare results with observations and if required update data and calibrate model, (iv) define scenarios, and (v) compare and present the results of different scenarios.

In this study, there was chosen 2004 as reference year and there

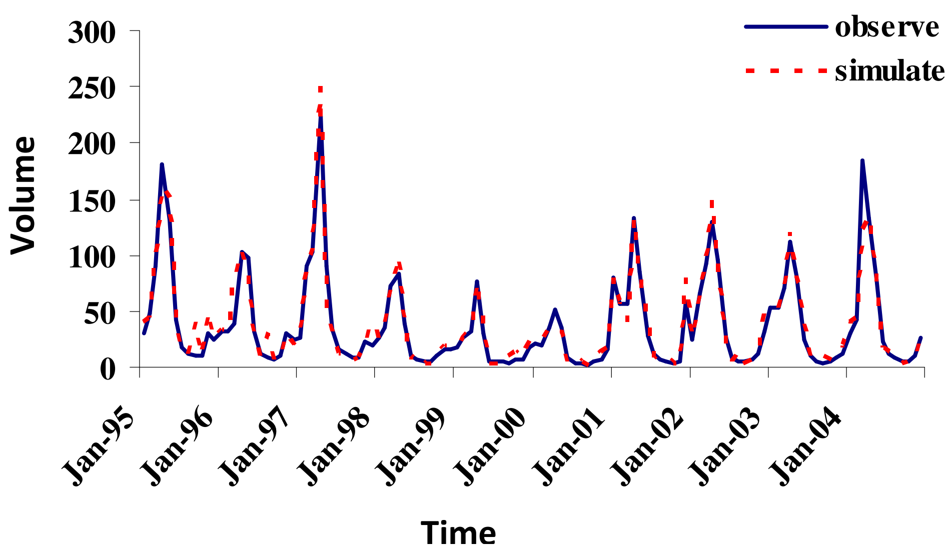

Figure 3. Observed and calculated monthly discharge.

Table 1. Error average of estimating the monthly discharge in hydrometery stations of study area.

Item	Name of hydrologic unit	River name	Hydrometery station	Error average (%)
1	Broujen-Fardanbeh	Kiar	Tang Dahano	1.25
2	Eastern Kiar	Est Kiar	Kharaji Bridge	5.52
3	Shalamzar	Shalamzar	Burnt Mountain	6.35
4	Soorashjan	Gorgak	Tang Pardanjan	7.43
5	Jonaghan	Jonghan	Darkesh Varkesh	3.08
6	Beheshtabad	Behesht Abad	Behesth Abad	2.59
7	Kuhrang	Kuhrang	Kaj	1.04

was selected 30 years statistical period (2004 to 2033) for simulations. Data for surface water resources, aquifers, dam reservoirs, water demand amount and users' priority were collected and entered in the model. In the simulation period it was assumed that inflow of rivers to be similar what happen in the past years, with due regards deterministic approach. It should be noted that the WEAP model uses a standard linear programming for resolving the water allocation problems.

It must be also mentioned that before forming the input file of the model, the existing hydro-climatology stations were homogenously tested and completed by regression method. The environmental requirement was considered with first priority in the water resources planning of river in comparing of municipal, industrial and agricultural sectors. The environmental requirement value was monthly determined as a 20% of average of river inflow (Tharme, 2003).

RESULTS AND DISCUSSION

Model calibration

For calibrating the model a 10 years period were used from 1995 to 2004. After forming the input file of model, it is necessary to calibrate the model based on the information of discharge of hydrometric stations and piezometric data of different plains in the studied area. The basis for calibration is that the percentage error of surface and groundwater water resources obtained from the model during 10 years of calibration must be less than an acceptable rate (less than 10%) in comparing of observed values.

For example, Figure 3 indicates observed and calculated monthly discharge of studied rivers. The error of estimating the monthly discharge has been calculated in hydrometery stations of study area by Equation 1 and related result indicated in Table 1.

$$E = \left| \frac{Q_{cal} - Q_{obs}}{Q_{obs}} \right| \times 100 \quad (1)$$

Where; Q_{obs} is the observed discharge, Q_{cal} is calculated discharge.

For the groundwater resources the volume of aquifer storage was also considered for calibrating of the model. The aquifer specific yield, value of groundwater recharge from precipitation, and hydraulic conductivity coefficient were considered as calibrating parameters. By changing these parameters, the error of calculating monthly groundwater storage of all aquifers within Beheshtabad

Table 2. Parameters of aquifer under study when calibration and average error of the model when estimating the volume of aquifer.

Item	Plain name	Initial volume of aquifer (M m^3)	Plain infiltration coefficient	Plain special yield coefficient (%)	Mean monthly volume of aquifer (mm^3)		Error average (%)
					Observation	Calculation	
1	Broojen	201	0.13	3	2009	204.3	4.94
2	Sefid Dasht	926	0.18	3	64.4	61.5	6.03
3	Farsan	88.1	0.27	2.2	85.8	86.6	2.66
4	Kiar	191.4	0.17	3	1788	181.3	4.5
5	Shahrekord	1332.1	0.17	4.7	1313.7	1297.8	5.2
6	Shalamzar	82	0.8	2.2	84.3	86.7	5.66

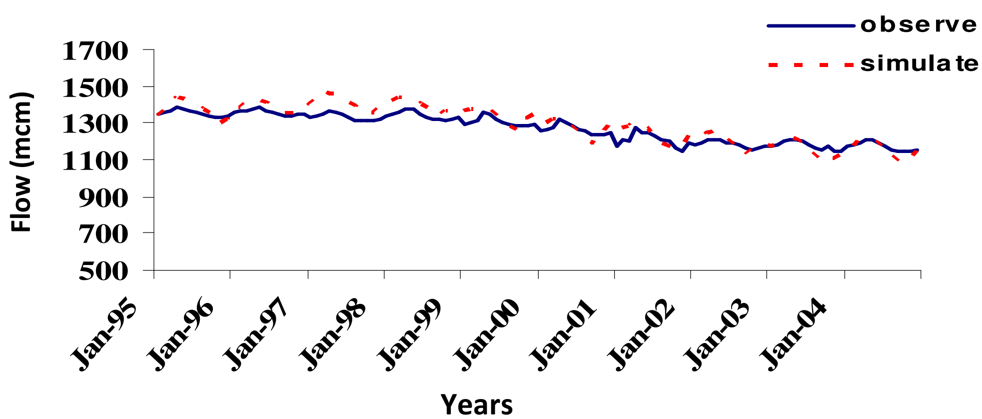

Figure 4. Observed and simulated reservoir volume in Shahr Kord plain.

basin in comparing with observed value was obtained less than an acceptable rate (less than 10%). Table 2 indicates the average model error for different plains and for example, Figure 4 shows monthly volume of the aquifer storage in Shahrkord plain obtained from the WEAP model and observed values.

Water resources evaluation

According to the calibration conducted, WEAP model was used for ultimate development scenario of the Beheshtabad and Kuhrang basins in a 30 years period (2004 to 2033) and its results were evaluated. In the ultimate development scenario, it was assumed that in the Beheshtabad basin, there were operated reservoir dams as well as artificial recharge projects as ultimate development scenario of the basin. Results obtained from the model, as illustrated in Figure 5, showed that the amount of transferable water in Beheshtabad project is averagely obtained about 470 MCM/year and it is limited to 314 MCM/year with a reliability of 90%. This is 46% less than the value that has been allocated by allocation committee. Also results showed that maximum 600 MCM storage facilities are needed for regulating of water resourced (Figure 6). It should be noted that in the conducted project study, Beheshtabad dam reservoir volume is desired about 1800 MCM, which it is overestimate.

Another important matter in Beheshtabad project is socio-economic and environment impacts and problems due to digging of 65 km tunnel because of difficult geological condition and high over load. In order to reduce tunnel impacts, many replacement alternatives can be defined. One of these options is transferring of water resources by pipeline method. In this option a pump station with a capacity of 11 m^3/s in flow rate and 26 Mw in power rate will be needed. At the end of pipeline, a hydroelectric plant with a capacity of 21 MW can be installed because of low elevation in Zayanderud river. Net consumed energy in this option was calculated about 117000 MWh/year. Full supply cost for this option was calculated equal to 15 US cent /m^3 for a discount rate of 7%. This option has no significantly socio-economic and environment impacts. Also time of executive of the project will be shorted.

Conclusion

The results of this study was conducted by general modeling of water resources of Beheshtabad and

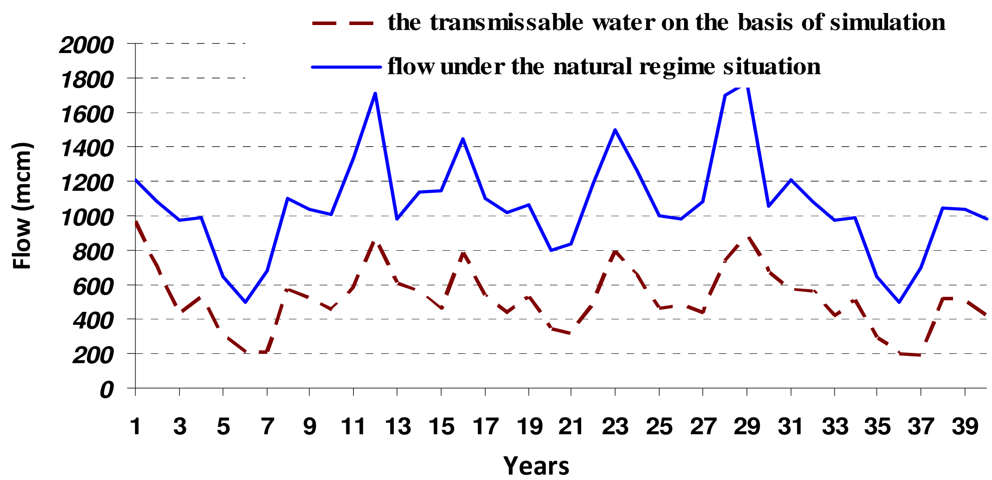

Figure 5. Changes of annual outflow of both rivers, Kuhrang and Behesht Abad in both conditions with and without ultimate development in the basin.

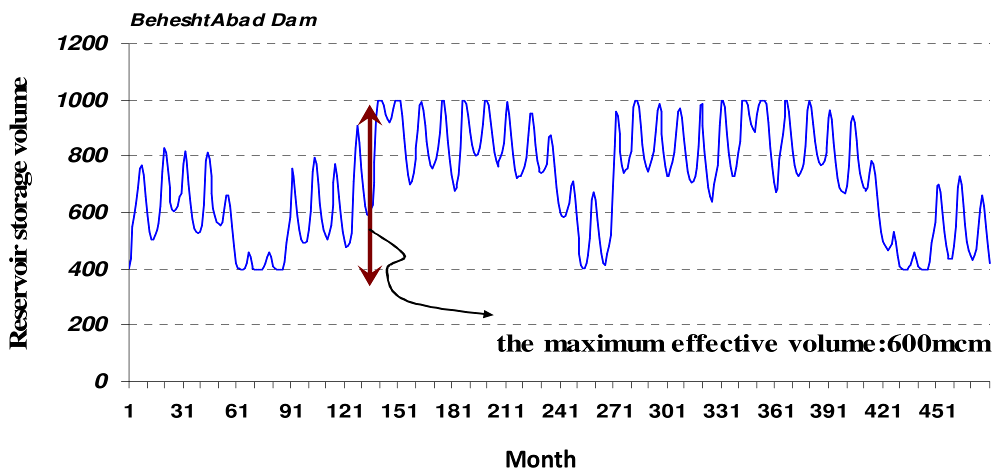

Figure 6. Changes in the water storage volume in the reservoir of Behesht Abad Dam in different months of simulation.

Koorang basins using WEAP model are as below:

1. The capacity of water transfer with a reliability of 90%. is obtained bout 314 MCM/year based on the results of model and considering the minimum Environmental requirement of downstream river and considering effect of all of the other water development projects.
2. Water transferring by tunnel will create many socio-economic and environment impacts. For example, it will drain the groundwater resources and dry the springs of region. There is considered the option of water transfer by pipeline.
3. Model results indicate that effective volume needed for storing and regulating the water is maximally equaled about 600 MCM and this figure is less than a third figure as considered by project consultant in the studies.
4. It is recommended that due to the more sensitivity of inter-basin water transfer projects, in the trend of studies, the global experiences and standards may be applied for this project.

REFERENCES

Al-Omari A, Al-Quraan S, Al-Salihi A, Abdulla F (2009). A water management support system for Amman Zarqa Basin in Jordan. Water. Resour. Manage. 23:3165-3189.

Andreu J, Capilla J, Sanchìs E (1996). AQUATOOL, a generalised decision-support system for water-resources planning and operational management. J. Hydrol. 177(3-4):269-291.

Delft H, ydraulics (2006). River Basin Planning and Management Simulation Program. Proceedings of the iEMSs Third Biennial Meeting: "Summit on Environmental Modelling and Software", Voinov, A., A.J. Jakeman and A.E. Rizzoli (eds), International Environmental Modelling and Software Society, Burlington, Vermont, USA.

Harma KJ, Johnson MS, Cohen SJ (2011). Future Water Supply and

Demand in the Okanagan Basin, British Columbia: A Scenario-Based Analysis of Multiple, Interacting Stressors. Water. Resour. Manage. DOI 10.1007/s11269-011-9938-3.

Höllermann B, Giertz S, Diekkrüger B (2010). Benin 2025Balancing FutureWater Availability and Demand Using the WEAP 'Water Evaluation and Planning' System. Water. Resour. Manage. 24:3591-3613.

Levite H, Sally H, Cour J (2003). Testing water demand management scenarios in a water-tressed basin in South Africa: Application of the WEAP model. Phys. Chem. Earth 28:779-786.

Ospina-Noreña JE, Gay-García C, Conde AC (2011). Water availability as a limiting factor and optimization of hydropower generation as an adaptation strategy to climate change in the Sinú-Caribe River basin. Atmósfera 24(2):203-220.

Purkey DR, Huber-Lee A, Yates DN, Hanemann M, Herrod-Julius S (2007). Integrating a climate change assessment tool into stakeholder-driven water management decision-making processes in California. Water. Resour. Manage. 21:315-329.

Raskin P, Hansen E , Zhu J, Iwra M (1992). Simulation of water supply and demand in the Aral sea region. Water Int. 17:55-67.

Sechi GM, Sulis A (2009). Water system management through a mixed optimization simulation approach. J. Water. Resour. Plann. Manage. 135(3):160-170.

Sechi GM, Sulis A (2010). Intercomparison of Generic Simulation Models for Water Resource Systems. International Congress on Environmental Modelling and Software Modelling for Environment's Sake, Fifth Biennial Meeting, Ottawa, Canada.

SEI (Stockholm Environmental Institute) (2005). WEAP water evaluation and planning system, Tutorial, Stockholm Environmental Institute, Boston Center, Tellus Institute.

Tharme RE (2003). A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development And Application of Environmental Flow Methodologies For Rivers. River Res. Appl. pp. 397-441.

Varela-Ortega C, Blanco-Gutierrez I, Swartz CH, Downing TE (2011). Balancing groundwater conservation and rural livelihoods under water andclimate uncertainties: An integrated hydro-economic modeling framework. Glob. Environ. Change 21:604-619.

Yates D, Sieber J, Purkey D, Huber-Lee A (2005). WEAP 21-a demand-, priority-, and preference-driven water planning model. Part 1: model characteristics. Water. Int. 30:487–500

Yates D, Purkey D, Sieber J, Huber-Lee A, Galbraith H, West J, Herrod-Julius S, Young C, Joyce B, Rayej M (2009). Climate driven water resources model of the Sacramento Basin, California. J. Water Resour. Plan. Manage. 135(5):303–313.

Yilmaz B, Harmancioglu NB (2010). An Indicator Based Assessment for Water Resources Management in Gediz River Basin, Turkey. Water Resour. Manage. 24:4359–4379.