Resistive Economics
International Journal

The Open Access Journal of Resistive Economics (OAJRE)/
Volume 5, Number 2, 2017 Published Online July 01
E-ISSN: 2345-4954 http://oajre.ir

Original Article

Pages: 20-31

Economic Valuation of Water Resources Using the Evaluation And Planning System "Weap"

(Case Study: Masouleh River)

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Received: 2017/02/28 Revised: 2017/04/25 Accepted: 2017/06/03

ABSTRACT: A high amount of water demand nearby Masouleh River in the Guilan province of Iran – in spite of high flow rate of this river – is supplied by Sepidroud Dam and a significant amount is supplied from underground water that finally it leads to the Anzali Wetland. A part of the surplus water of this river is wasted, evaporated or changed to flood water. WEAP software submits a model for simulation of flow rates and water demand in the future. In the designed model, it was determined that the amount of lack of rural water need will increase from 27.76 million square meter to 32.67, and lack of agricultural water will decrease from 153 million square meter to 96.6, during next 25 years. Additionally, in this research, software efficiency for economic evaluation was studied, based on exciting economic data. The results gained from the designed model indicated that in the economic discussion, benefit rate is 28$ per square meter in 2011 and 29.5 $ in 2035. Through comparing of expenses between different scenarios, the scenario of "change of priority of supply resource of agricultural water need", submits the minimum amount (24$) and the scenario of "growth population", submits the maximum amount (29 $) per square meter.

KEYWORDS: Economic evaluation, Masouleh River, WEAP Water Evaluation and Planning System, Water Resources Management, Sustainable Development.

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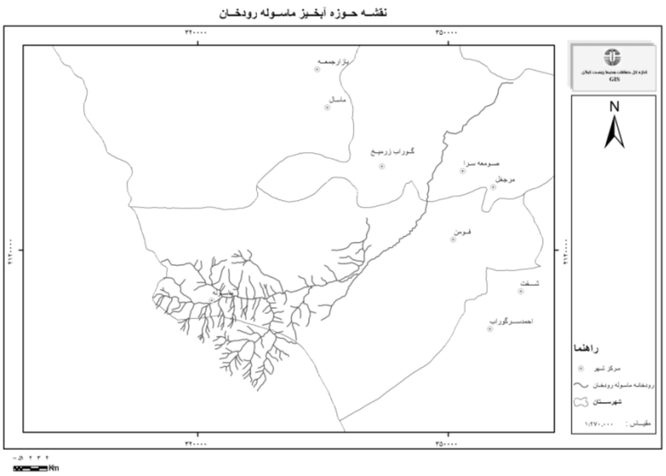
1. INTRODUCTION

The existing evidences indicate that water resources' status is critical. This matter needs necessity of more consideration to water resources management and optimization of utilization (Arabi and et al, 2008). Although, management of cultivation water consumption is presented, only in 20% of the world cultivable lands but 50% of world food requirements of the current population is provided from these lands. In Iran, about 60% of lands are under water cultivation that provides 90% of state foodstuffs production (Ghaemi and Hossein Abadi, 2003). Regarding to unsuitable local distribution of rain in the country and lack of time accordance of raining with irrigation season, water crisis is a serious problem. Certainly in a near future, Iran would encounter lack of renewable water resources for continuation of agricultural activities and providing its necessities. Consequently, in order to counter with this crisis, water resources must be managed through the most economized and executable methods (Shamsaei, 2003).
Application of surface running waters is in two sections of domestic consumption, irrigation, industrial and urban consumptions as well as breeding of aquatics, resource of surface waters and wetlands. Quantity and quality of surface waters are managed with management methods similar to the adjacent and upper lands (Droogers et al, 2011). Limited resources of water have caused some worries about provision of water with favorite qualification. Implementation of sustainable strategies of water consumption has caused increasing pressure for planners of water resources management. WEAP wholly acts in the framework of a tool for analyzing of water resources policies and planning. The gained results are a complete useful tool to study different options of water management and development (Yates et al, 2009). Water Evaluation and Planning System (WEAP) has been designed with the objective of sustainable management of water resources through description of different long-term scenarios, in this regard, in the year 1989. The first major application of WEAP has been formed by Raskin and et al in Aral Sea in the year 1990 (Mahamadu et al, 2011). WEAP software, a model for simulation of the amount of water flow and demand in future, submits water supply and demand system. In this system, different rules and regulations related to water resources, such as surface and underground waters, water demand, reusing the consumed water, sewage treatment and transfer and as well as evaluation of real value of water resources and valuing them on the basis of real cost caused for the environment, may be studied (McCartney et al, 2011). Cost estimation and assessment of environmental advantages are not simple. Assessment of environmental items with the real economical meaning of markets has not been fulfilled, and if some efforts are fulfilled for estimation of these types of costs, the related results are not accepted by everyone. Important specification of environmental expenses is that, they will happen in future and sometimes so far from now and as the time horizon will be longer, dimensions of these expenses are appeared so greater (Karimzadegan, 2010). Existing defect in establishing the relation between markets and environment has caused to give up valuable natural resources in lieu of receiving a trifling amount. Masouleh is a watery and permanent river in Guilan Province (Map 1). Origin of this river is in 3,000m height of the region. Its length is about 60 kilometer that more than 35 kilometer thereof flows in plain (Kankash Omran Consulting Engineers Co., 2009). Hypothesis of this research is that with consideration to the present information and using the WEAP software, economical evaluation is possible in the limitation of Masouleh River in order to manage an important water resource.



Map1. Masouleh Basin and River (Guilan Environment Protection Agency, 2013)

2. MATERIALS AND METHODS

Region of the Case Study is Masouleh River. Masouleh River, as the most important agricultural water supply of Formant Plain, located at the north side of the Country and west side of Rasht County in Guilan Province, is one of the main and permanent rivers in the region. Drain basin of this river is located at the north part of the country and a part of drain basin grade 2 of Talesh-Anzali that is ended to Anzali Lagoon in the north, Great Sefidroud Drain Basin in the south, Ghalehroudkhan River Drain Basin in the earth, and Roudbar River Drain Basin in the west. This river is ended to Anzali wetland after passing through Masouleh, Fouman and Someesara Cities. Basin of this river has an area equal to 426.77 square kilometer. About 96% of water is consumed for agriculture and 4% is used for potable and industrial consumptions. (Sazeh Pardazi Iran Consulting Engineers Company, 2010). Masouleh River Basin Information consisting regional information (Ghalehroudkhan, Kasma and masal Stations), monthly and annually hydrometric statistics (Chomesghal, Koumadoul and Zoudel Stations), monthly and annually average flow rate (Komadol Station) have been collected and classified from Guilan Province Regional Water Co., for the Water Years of 1986 to 2011 that have been presented in Table No. 1.

Table No. 1. Average Annual and Monthly Flow Rate in Masouleh River, Komadol Station (Guilan Regional Water Co., 2013)

Annual	Sep	Aug	Jul	Jun	May	Apr	Mar	Feb	Jan	Dec	Nov	Oct	Water year
3.64	7.57	2.02	2.72	1.68	3.74	7.93	7.19	3.61	1.49	0.761	3.01	2	2010-2011
3.81	2.42	0.90	1.11	1.78	7.58	5.69	4.93	3.87	3.00	4.78	4.25	5.45	2009-2010
4.77	4.20	2.83	1.64	3.79	6.45	6.02	4.25	5.91	4.66	6.33	8.33	2.88	2008-2009
2.66	2.12	1.98	3.36	1.29	1.86	3.85	6.16	3.35	2.35	3.28	1.07	1.25	2007-2008
5.26	1.43	2.05	5.28	3.83	10.40	14.90	6.52	3.82	3.85	4.54	2.75	3.72	2006-2007
3.03	2.38	0.71	1.25	1.42	4.65	3.77	3.24	7.07	2.15	2.63	5.04	2.08	2005-2006
5.80	3.52	0.97	1.83	5.18	6.50	9.67	16.60	4.73	5.44	4.35	3.44	7.34	2004-2005
6.15	4.68	3.46	4.24	4.66	11.90	12.40	4.90	5.19	4.75	9.02	4.19	4.37	2003-2004
5.18	6.17	1.89	3.04	7.31	13.10	12.50	7.64	2.99	5.13	1.58	0.49	0.37	2002-2003
4.66	3.77	1.02	1.15	2.77	11.60	7.90	3.20	1.70	2.20	6.50	6.00	8.10	2001-2002
3.89	1.82	0.80	0.95	1.56	2.17	5.15	4.69	3.83	2.78	4.51	9.83	8.57	2000-2001
4.07	3.96	0.16	0.82	1.09	2.52	10.40	7.38	5.56	3.20	4.74	5.51	3.47	1999-2000
3.21	2.21	1.01	1.55	1.97	5.41	4.90	2.17	2.70	2.70	3.70	4.09	6.16	1998-1999
5.43	6.89	1.61	2.55	2.25	5.59	14.30	10.80	5.01	3.14	5.96	3.31	3.74	1997-1998
4.58	10.60	2.97	5.15	1.53	3.91	8.47	5.52	2.63	1.35	2.37	5.10	5.40	1996-1997
5.18	1.22	3.37	2.00	2.86	9.12	17.00	6.29	6.67	1.55	1.28	4.49	6.28	1995-1996
3.67	1.53	1.42	1.84	1.47	4.64	3.08	3.39	2.31	2.37	8.54	11.30	2.17	1994-1995
6.27	3.79	2.04	5.13	2.84	5.97	7.66	8.83	3.46	7.77	9.38	10.50	7.90	1993-1994
4.75	5.48	1.83	3.55	4.73	7.16	7.24	5.84	3.01	3.12	4.69	3.93	6.47	1992-1993
2	3.14	2.54	3.69	5.41	14.40	12.20	6.66	3.27	2.60	2.21	2.36	5.32	1991-1992
3.34	2.13	0.78	1.19	1.96	3.89	9.07	7.68	2.44	2.51	1.15	2.48	4.84	1990-1991
4.69	4.13	2.94	2.06	2.65	10.40	12.90	6.87	3.83	1.77	2.20	4.53	2.01	1989-1990
4.29	1.85	0.94	0.86	1.43	5.17	10.60	10.40	4.15	2.47	1.59	4.54	7.48	1988-1989
6.16	4.13	3.16	1.09	1.79	6.36	11.70	11.20	5.85	4.43	3.54	10.90	9.72	1987-1988
3.57	5.40	1.17	0.63	1.00	2.70	5.19	4.09	2.53	4.87	6.52	5.92	2.86	1986-1987

WEAP "Water Evaluation and Planning System" is able to manage limited water resources among agricultural demands, industrial needs, urban necessities and environmental needs. In this software, there are some schematics to show river, demand points, water going and returning flow, drain domain, underground waters and so on that through installation of each one in the model, new data can be inserted. The sample Model for the region of case study has been shown in Fig. 1. In the presented model, Masouleh Basin, Sefidroud Network Basin, Masouleh River, three demand points (agricultural, industrial and rural), environmental minimum need point and supplier resources (river, underground water and Sefidroud Dam), have been identified. Minimum environmental need has been defined at the end of direction of River Flow in the connection point of the river to Anzali wetland.

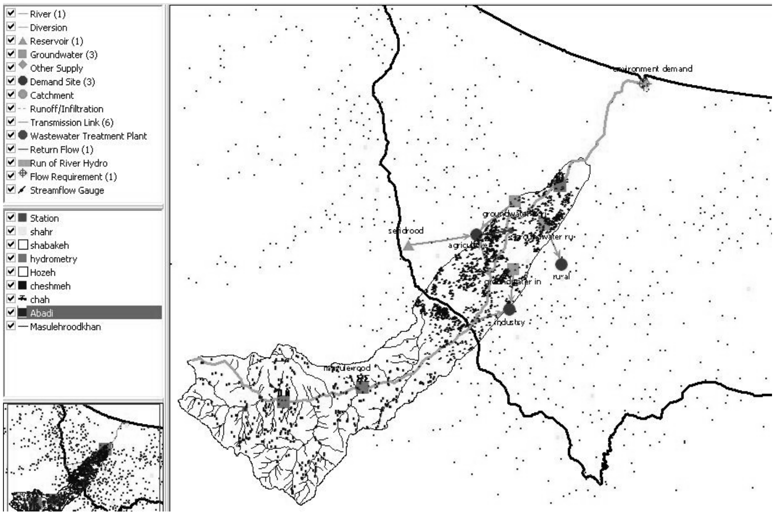


Fig.1. Model presented for Region of Case Study by WEAP Software

Minimum environmental need was calculated with evaluation of 10% of average water of the River from Sept. 23 to Mar. 20 and 30% of average water of the River from Mar. 21 to Sept. 22. (Fig. 2). The scenarios have been designed based on the existing conditions and their effects were studied on the amount of water availability and consumption in future. Through considering the existing data (25 years, 1986-2011), time distance has been considered from 2012 to 2035 in designing of scenarios. Consequently, the Software can predict the conditions up to the year 2035. Through providing the scenario tree, some scenarios may transfer some specifications and conditions to other scenarios. Heritage scenario is the same subset of a scenario that means specifications and conditions of the previous scenario can be transferred to another, additionally new conditions may be described for it or new data may be inserted.

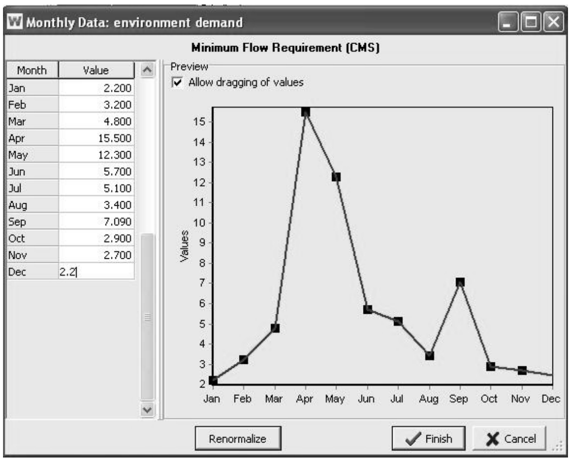


Fig.2. A scheme on inserting the monthly data of minimum environmental needs

The designed scenarios consist of:

- Reference scenario: this scenario is formed by data of the years 1986-2011 (heritage of this scenario has been considered from the base year). Rate of population growth in this scenario is calculated similar to base year with rate equal to 0.7%.

- Scenario for change of priority of water supplier for agriculture: this scenario is a subset of reference scenario. Priority for supplying of water need from surface water resource, underground water and dam, are separately determined. The first priority is considered for river due to high capacity of watering, the second and third priorities are considered for underground water and canal on Sefidroud Dam.

- Scenario of Population Growth: Information heritage in this scenario is from reference scenario. In this scenario, it is supposed that with consideration to increasing development in the boundaries of Masouleh Roudkhan, population growth will be increasingly, too, rate of population will increase from 0.7% to 2% in the year 2011. Through assumption the flow of constant input of water to the region, rate of population growth is estimated 2% up to year 2035 that rate of unsupplied demand and need are studied.

2.1. Method of Economical Evaluation in WEAP System

A- Through applying this model, five types of expenses for water resources systems may be defined: 1- constant expenses of annual operation, 2- variable expenses for annual pumping, 3- expenses for replacement and improvement of planned capital, 4- connection expenses, and 5- costs to eliminate noises. Constant expenses of annual operation are gained through calculation the difference of variable expenses of human resource and pumping expenses from annual budget. It will be predicted that in those projects that development is associated with wide extent, calculation of expenses for replacement and improvement of capital is necessary, too (Cubed and Davis, 2008).

B- WEAP System may design three models of expenses and incomes. Expenses consisting of: 1- expense of preliminary investment, 2- constant expense of operation and maintenance, 3- variable expense of operation and maintenance of incomes consisting of: 1- constant incomes, 2- variable incomes, 3- incomes raised from electricity production.

WEAP may study the average expense of water and also effective factors on changes of monthly or annually expenses. Monthly changes in average of water expense is raised from changes of remainder of water consumption (especially in agriculture section), while the constant expenses are without changes. Annual changes are raised from change in expenses in preliminary investments (Cubed and Davis, 2008).

In the present research, modelling of income has been fulfilled on the basis of data related to the existing point of rural district need (such as income of water sales dollar/square meter). In modelling of electricity-water storages, the related data can be inserted (such as incomes gained from electricity production) and the related results will be calculated. Through inserting the data, current expenses and incomes may be compared that net value of the project is determined. Current value of the net expenses may be compared with incomes and economic success of the system may be calculated. If the current value of the net expenses will be less than net value of incomes, system will have less profit, and if the current value of net expenses will be more than net value of incomes, system will have more profit in comparison with average expenses of the project.

Existing data in studying of the region consist of: A- Amount of water-rights of operation in Masouleh Roudkhan: traditional stream, every hectare 125,900.—Rls, integration method, every hectare, 251,800.—Rls, concrete channel method (modern method), every hectare, and 377,000.—Rls. in the study area for pressurized irrigation, water-right is received based on irrigation of modern method (Sazehpardazi Consulting Engineers, 2007). B- Evaluation the income in the agriculture and industry sections: harvesting from rice paddies is 3.5 to 5 Tons (2 Tons per hectare) that through deduction of wage of rice-threshing worksites will be 1,900 Kg. Tourism application is 5.9 hectares that along with forest area, equal to 44.06 is allocated in the boundary of river direction to recreation and tourism regions. Economic structure of the region consisting of agriculture, animal husbandry, agricultural services and workers resources in the area of 1,503.77 hectare in the margins of Masouleh Roudkhan, is 18,900 hectares of pasture and forest lands that more than 5,600 Tons of UN husked rice, 180 Tons of tobacco and about 275 Tons summer-corps are produced. Incomes of tobacco and silk-worm are variable and due to low production are not so important. Domesticated animals of the region are more than 17,596 heads but there is not definite amount of production of meat and domesticated animals products, therefore the related economic income may not be calculated (Sazehpardazi Consulting Engineers, 2007).

2.2. Calculation of Profit and Expense at Agricultural Section

Variable Operational Expense: about 7,500 Dollars have been considered for expenses of leakage-finding, keeping and maintenance (Cubed and Davis, 2008).

Constant Operational Expense: This section of expense, was calculated based on the method of expenses in shade, due to lack of real data (Karimzadegan, 2010). Total annual expenses of human resource (833,000.—Dollars) and pumping expense (460,000.—Dollars) were deducted from annual budget (1,300,000.—Dollars) and constant operational expense (4,000.—Dollars) was calculated (Karimzadegan, 2010) (Cubed and Davis, 2008).

Variable Profit: in order to profit calculation, at first, the amount of income must be determined and deducted from the amount of expense. About 6.9 Dollars for each square meter was calculated that this amount must be deducted from variable operational expense for each square meter. Consequently, variable profit is calculated equal to 6.8 Dollars for each square meter.

7500\$÷1641 ha=4.5 \$/ha

4.5÷12000cm=0.000375 \$/cm

6.9-0.000375=6.8 \$/cm

Constant Profit: constant profit was calculated equal to 132,203.—Dollars per year for total agricultural plots of the region, from difference of annual income (136,203.—Dollars) and constant operational expense (4,000.—Dollars).

3. CONCLUSIONS

- Comparison between reference scenario and changing priorities for agricultural water supply needs scenario: as it has been presented in Diagram 1, the amount of agricultural need reaches from 7.1 million square meters at the reference scenario to 3.7 million square meters at the scenario of change of priority of agricultural water supplier. Totally in 25 years, lack of water need will decreased as from 153 million square meter to 96.6.

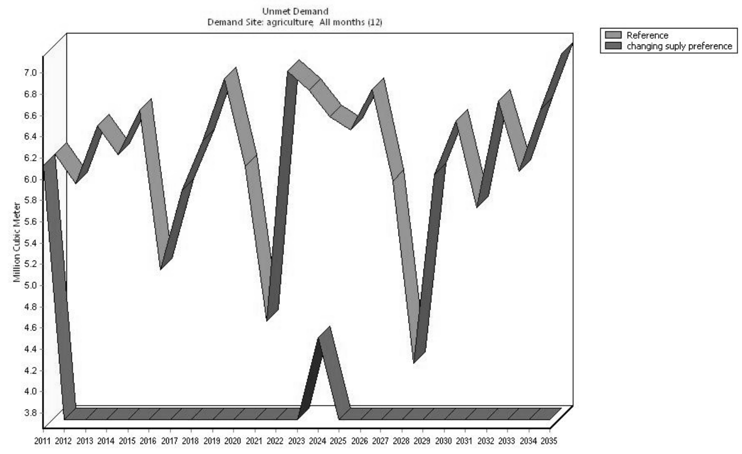


Diagram1. Comparison of Lack of Water between Reference Scenario and change of priority of agricultural water supplier (years 2012 to 2035)

- Comparison between Reference Scenario and Scenario of Population Growth: unsupplied needs are observed due to difference of water needs suppliers and demands. On the basis of Diagram 2, lack of rural districts' needs reach from 1.21 million square meters at reference scenario to 1.64 at scenario of population growth. Totally in 25 years, lack of water will increase as from 27.76 million square meter to 32.67.

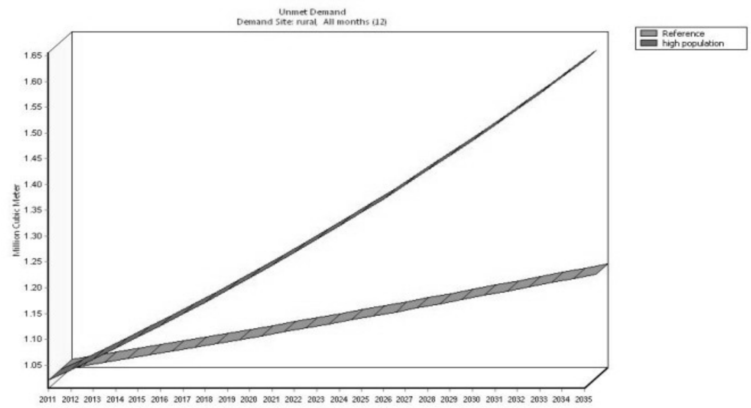


Diagram2. Comparison of Lack of Water between Reference Scenario and Scenario of Population Growth in Rural Districts' Needs (2012 to 2035)

- Economic evaluation in WEAP System: results of economic evaluation of the years 2011 and 2035 have been presented in Diagrams No. 3 and 4. In economic discussion, the amount of profit for each square meter of water in the year 2011 is about 28 Dollars, and in the year 2035 is about 29.5 Dollars. Comparison of the expenses between different scenarios indicates that the scenario of change of water supplier priority has minimum profit (24 Dollars) and the scenario of population growth has the maximum profit (29 Dollars) for each square meter of water. Results of average monthly expense of water in each square meter per years 2011 and 2035 have been presented in Tables No. 2 and 3.

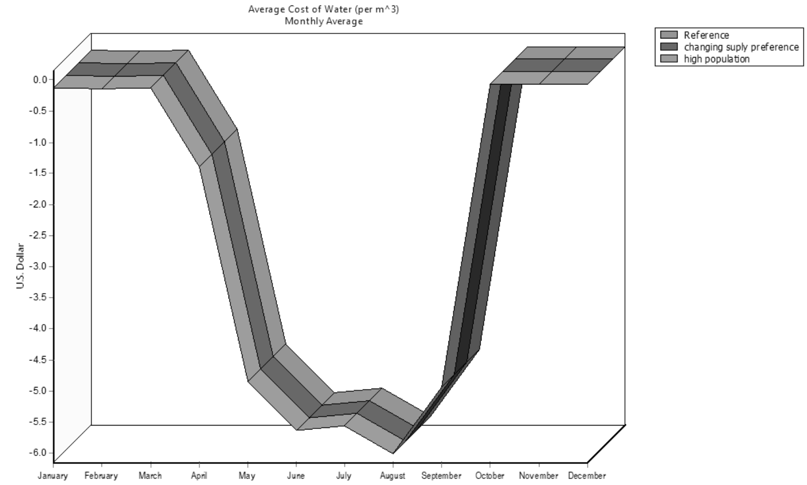


Diagram3. Comparison of average expense between scenarios in the year 2011

Table No. 2. Average monthly expense of water per each square meter in the year 2011

Chart | Table | Map

Average Cost of Water (per m^3) (U.S. Dollar)

All months (12) ☑ Monthly Average Selected Scenarios (3/5)

	January	February	March	April	May	June	July	August	September	October	November	December
Reference	-0.1	-0.1	-0.1	-1.4	-4.8	-5.6	-5.6	-6.0	-4.9	-0.1	-0.1	-0.1
changing suply preference	-0.1	-0.1	-0.1	-1.4	-4.8	-5.6	-5.6	-6.0	-4.9	-0.1	-0.1	-0.1
high population	-0.1	-0.1	-0.1	-1.4	-4.8	-5.6	-5.6	-6.0	-4.9	-0.1	-0.1	-0.1

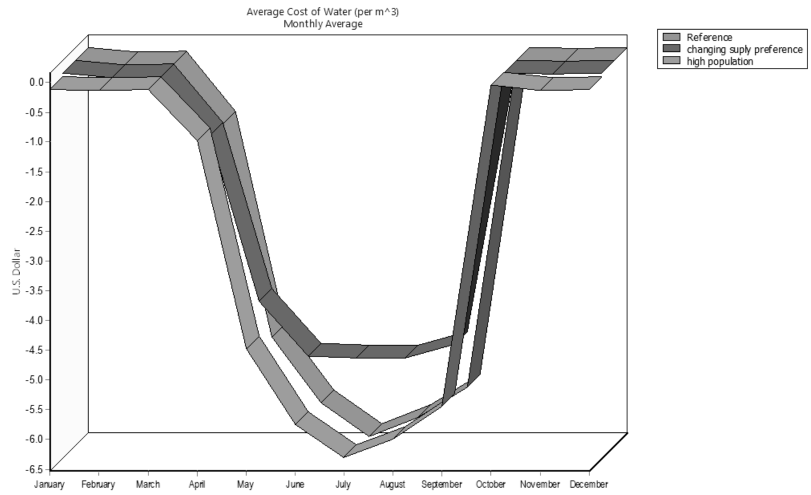


Diagram4. Comparison of average expense between scenarios in the year 2035

Table No. 3. Average monthly expense of water in each square meter in the year 2035

Chart | Table | Map

Average Cost of Water (per m^3) (U.S. Dollar)

All months (12) ☑ Monthly Average Selected Scenarios (3/5)

	January	February	March	April	May	June	July	August	September	October	November	December
Reference	-0.1	-0.1	-0.1	-1.1	-4.7	-5.8	-6.4	-6.1	-5.6	-0.1	-0.1	-0.1
changing suply preference	-0.1	-0.1	-0.1	-1.1	-3.9	-4.8	-4.8	-4.8	-4.6	-0.1	-0.1	-0.1
high population	-0.1	-0.1	-0.1	-1.0	-4.5	-5.8	-6.3	-6.0	-5.4	0.0	-0.1	-0.1

. M.Cubed, Davis, CA defined five types of water system annual expenses in the years 2007 and 2008 using WEAP Model for the town of Sharon, Massachusetts and studied the operation constant expenses, pumping variable expenses, replacement expenses and development of planning capital, connection expenses and harvesting expenses and predicted water system expenses for the year 2014. In the research on Masouleh Roukhan, the pumping variable expenses and harvesting expenses were studied in the network of this basin. In the case of development of water transfer in the basin of case study, operational constant expenses and connection expenses must be calculated, too. Calculation of the other cases has been calculated through the Expense in Shadow Method. George et al have used the modeling method in uniting the allocation network model and social expenses and studied the physical and economic results of allocation of water in Musi river basin (one of the sub-basins of Krishna Basin in India). This Model studied on the relationship between calculated surface and underground waters resources in the hydrologic, surface and underground viewpoints, for the first time that water transfer from agricultural resources to urban application is increasing in future; therefore cultivable regions will be decreased. Simulation in Masouleh river basin indicated that in the case of population growth, water demand will increase. But due to pollution of the river water, the amount of underground water harvesting will be increased. On the other hand, as noticeable amount of agricultural necessities are supplied from underground waters, if population growth would not be correctly managed, population in this region may cause to decrease the under cultivation area due to water shortage.

4. DISCUSSION AND CONCLUSION

In the map of Masouleh River Basin, some points have been studied and applied in modelling: - layout of demand points has been fulfilled based on existing natural conditions in the region and manner of point's position with consideration to the direction of river flow. – Layout of the points has been fulfilled because of applying of water of Sefidroud Dam. – In order to design the different scenario, water supplier has been determined based on division of natural locations on the map. – At the end of the river direction, and at the location of connection to Anzali wetland, the point of minimum environmental need was determined. Evaluation of the water volume that must normally be entered to Anzali wetland, confirms that river pollution removing is important.

- Input flow rate to the software was extracted from Komadol Station (this station has the minimum distance to the demand points, in comparison with the other stations and the most important input branches to the river is located before this station. Therefore, input flow rate of this drainage is calculated, too).

Simulation at Masouleh River Basin indicated that: - through comparison between reference scenario and the scenario for change of priority of agricultural water supplier, it was determined that the amount of agricultural need reaches from 7.1 million square meter at the reference scenario to 3.7 million square meter at the scenario of change of priority of agricultural water supplier. During 25 years, lack of water need will decrease as from 153 million square meter to 96.6.

Through comparison between reference scenario and scenario for population growth, it was observed that lack of rural districts' needs reach from 1.21 million square meters at reference scenario to 1.64 at scenario of population growth. During 25 years, lack of water will increase from 27.76 million square meter to 32.67. – Economic evaluation at WEAP System indicates that the amount of profit for each square meter of water in the year 2011 is about 28 Dollars and in the year 2035, is about 29.5 Dollars. Through comparison of the expenses between different scenarios, it is indicated that the scenario of change of water supplier priority has minimum profit (24 Dollars) and the scenario of population growth has the maximum profit (29 Dollars) for each square meter of water.

ACKNOWLEDGMENTS

None.

ETHICAL CONSIDERATION

Authenticity of the texts, honesty and fidelity has been observed.

AUTHOR CONTRIBUTIONS

Planning and writing of the manuscript was done by the authors.

CONFLICT OF INTEREST

Author/s confirmed no conflict of interest.

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