Optimization of water quantity and quality in Mahabad River by SWAT model

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Abstract

Water quantity and quality joint operation is a new method in the present dams' operation research. This paper coupled a water quantity and quality joint operation model (WEAP) and a genetic algorithm, with the Soil and Water Assessment Tool model. Together, these tools are used to explore a reasonable operation of dams and floodgates in a basin scale. Mahabad River Catchment in the Urmia Lake basin was selected as a case study that caused a 33% increase agricultural efficiency, and enhanced by 51% in terms of biological reservoir water quality. The results showed that the coupled model of Mahabad River Catchment more realistically simulates the process of water quantity and quality control by dams and floodgates. This integrated model provided the foundation for the research of water quantity and quality optimization on dam operation. The results also suggested that current water quality of Mahabad River can improve following the implementation of the optimized operation of the main dams and floodgates. By pollution control and water quantity and quality joint operation of dams and floodgates, water quality of Mahabad river changed significantly, and the available water resources increased by 14.2%, and 10% at the downstream sites of Mahabad River Reservoir, and Yusefkand floodgate, respectively. The method played an active role in improving water quality and water use efficiency in Mahabad river basin. The research can provide the technical support for water pollution control and ecological restoration in Mahabad River Catchments.

Keywords: Water Quantity; Mahabad River Catchments; Yusefkand floodgate; SWAT model.

1. Introduction

One of the tasks of government is to supply urban drinkable water (fresh) with desirable quality. Quality of water reservoir is one of the most important elements in water consumption, and Mahabad dam in Iran is located over Mahabad River lower than the junction of two other rivers, Kavter and

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Baytas. Mahabad River is spillway basin of Urmia Lake of Mahabad dam. Urmia Lake is becoming crisis of water shortage now and its purpose is supplying urban drinkable water and water for agriculture in Mahabad plain. The urban drinkable water changed to light yellow in 2005. To solve this problem, different studies suggested transforming the situation of pipe basin of powerhouse, but the problem appeared again in 2011. In all lakes, the quality of exist water differs from entrance water, and lakes are growing old by a natural process. This process occurs by gradual entrance of organic and inorganic nourishing substances with inflow. The lakes are contained few nutrients in the period of youth and little accumulation of water plants and seaweeds, but the lakes are receiving the nutrients from drainpipe of basins, industrial actions, agricultural, tourist, discharge of sewage and etc . After that, the growth of water plants is aggravated and the growth of phytoplankton is increased with time and biological fertility, which caused to darkness and tend to becoming green water lakes.

Water quantity and quality joint operation of dams and floodgates are the most effective approaches to control water pollution and ecological restoration in dam-crowded basins (Zhang *et al.*, 2011). Dams are important to meet water and energy requirements, and they sustain economic growth (Feder, 2004; Wei *et al.*, 2009). Although the large dams constructed all over the world can be considered as huge storages, dam construction changes river flow and may increase pollution in the rivers. These changes frequently make the rivers dry, more sedimentation, drop-in environmental quality, and reduce in biodiversity (Topping *et al.*, 2000; Jansson *et al.*, 2000; Ewa and Grazyna, 2002; Onema *et al.*, 2006). Runoff from agricultural terrains is usually enriched with sediments, pesticides, and nutrients, while runoff from extended urban areas contains different contaminants such as heavy metals, hydrocarbons, and chloride (Huber, 1993). Significant reduction in the loads from point sources during years could increase the relative significance of diffuse sources of pollution in Swiss waters (Prasuhn and Sieber, 2005). Restricting the methods of measurement and amount of time – consuming parameters and expensive in quality, are the main reasons to simulate qualitative processes. A method is needed to be able to generalize available statistics for the places where the measurement is impossible. In recent years, inverse modeling (IM) has become an accepted method for calibration (Gupta *et al.*, 2003). IM is concerned with the problem of making inferences about physical systems from measured output variables of the model (e.g., river discharge, sediment concentration).

Soil and Water Assessment Tool (SWAT) is a river basin scale model with strong physical mechanism (Srinivasan *et al.*, 1998; Neitsch *et al.*, 2002). A number of simulators such as SWAT, Hydrologic Simulation Program FORTRAN (HSPF) (Bicknell *et al.*, 2001), and SHETRAN (Ewen *et al.*, 2000) were used in the study. Several comparisons of these models showed reasonable results in simulating discharge, and sediment (Borah *et al.*, 2004; Singh *et al.*, 2005). Quantitative and qualitative were simulated with SWAT model, and quality and quantity of water were improved by optimum exploitation from dam and hydraulic establishment. Using the integral management of aquifer basin, the effect of the lake age was examined. They found that lakes where there are a lot of humanity activities severely could have a tendency toward nourishing regardless of the age of water-bearing layers.

1.1. Description of study area and Mahabad dam

Mahabad dam has geographically located in 45º 43′ 30″ E and 36º 46′ 30″ N and about 1 km away from the west of Mahabad city in Iran (Figure 1). A study related to this dam was started in 1962 and the construction of the diversion tunnel was performed. The research was finished and put into operation with initial volume of 230 million m^3 with an altitude of 47.5m from the base level and a crown length of 700m with the maximum of depth 41m and the length of lake in a normal level is 11 km (Gholizadeh *et al*., 2010).

Mahabad dam is one of the aquifer basins leaded to Urmia Lake. The lake is situated in the west of Simineh River basin and the east of Little Zab River basin. The region is a mountainous and full slope area. Minimum and maximum altitude from free level of seas in Urmia Lake basin are about 1268m, and 1778m, and the basin area is nearly 1486 km^2. Territorial use on dry farming on higher part and lower part of the dam are respectively 9%, and 20%. The jungle on higher and lower parts are 0%, and 2% and also for pasture land these amounts are in that order of 46% and 86%.The aquaculture in higher part and lower part of dam are 2% and 22%, and residential are 0.2%, and 2%. Mahabad River is formed from the conjunction of two original rivers called Kavter and Baytas, on the northeast of Mahabad city.

The rivers of Kavter and Baytas consist of sub–branches, and are supplied by snow melting in highlands in the aquifer basin. The rivers of Kavter and Baytas are providing water for Mahabad River about 80% and 20%, respectively. According to available statistics from hydrometric stations, in a period of 25 years, annual average of discharge for Kavter river was about equal to 8 m^3/s and for Baytas river was about 1.7 m^3/s, so that the aggregate of intakes was calculated about 9.7m^3/s for Mahabad River. The average volume of water intake of Mahabad Dam was about 298 million cubic meters (mcm) in the year.

2. Materials and methods

2.1. SWAT model description

SWAT is a semi-distributed, time continuous watershed simulator operating on a daily time step. It is developed for evaluating the management and climate effects on water supplies, sediment, and agricultural chemical yields in watersheds and larger river basins (Srinivasan *et al*., 1998). The model allows simulating a high level of spatial detail by dividing the watershed into many sub-watersheds. The main SWAT modules contain hydrology, weather, erosion, plant growth, nutrients, pesticides, land management, and stream routing. The program is presented with an interface

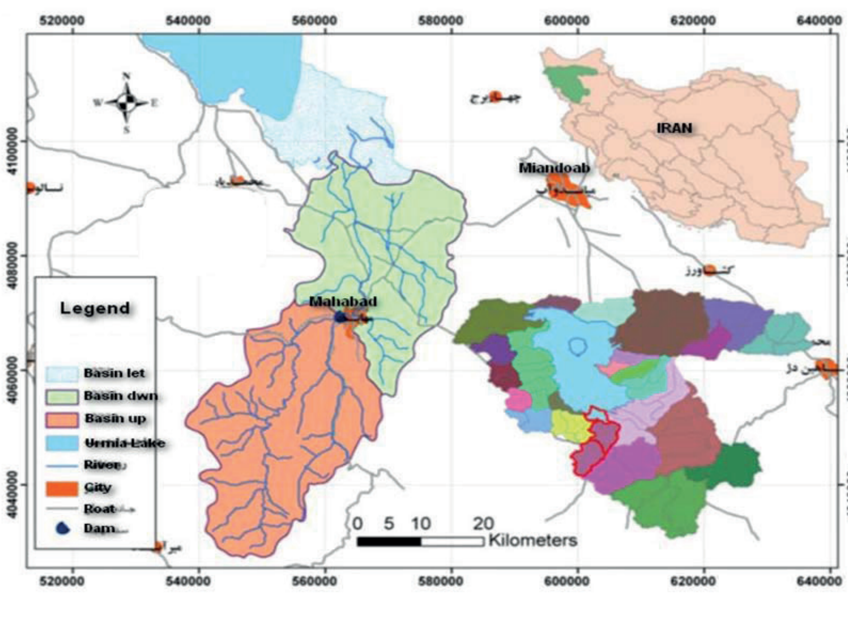

Figure 1. Location of Mahabad River Catchment in Urmia Lake basin and Mahabad City (in Iran), and the corresponding monitoring sections

in Arc View GIS (Di Luzio *et al.*, 2002; Winchell *et al.*, 2008) for the definition of watershed hydrologic features and storage, as well as the management of the related spatial and tabular data. Each sub basin is further discredited into a series of hydrologic response units (HRUs), which are unique soil-land use combinations. Soil water content, surface runoff, nutrient cycles, sediment yield, crop growth and management practices are simulated for each HRU and then aggregated for the sub basin by a weighted average. Physical characteristics, such as slope, reach dimensions, and climatic data are considered for each sub basin. For climate, SWAT uses the data from the station nearest to the centroid of each sub basin. Calculated flow, sediment yield, and nutrient loading obtained for each sub basin are then routed through the river system. Channel routing is simulated using the variable storage or Muskingum method (Abbaspour, 2007).

The water quantity and quality optimal operation model of dams and floodgates based on SWAT contains three parts (Figure 2). The first part is the distributed hydrology and water quality model coupling the operation of dams and floodgates. This part is the base of the whole model and is helpful to recognize hydrologic and pollutant variation at the basin scale and provide all the boundary conditions for dam operation. The second part is the optimal operation model of dams and floodgates, which will be developed to reach two objectives, namely, maximizing available water resources and minimizing water pollution. The third part is to couple and resolve distributed SWAT model and the optimal operation model of dams and flood gates. The hydrologic cycle of the SWAT model is based on the water balance equation, which considers the unsaturated zone and shallow aquifer above the impermeable layer as a unit (Zhang *et al.*, 2011).

In stream water quality module (QUAL2K) is a 1-dimensional, steady state, for well mixed channels (laterally and vertically). Constituents modeled include: ammonia, nitrate, organic and inorganic phosphorous, algae, sediment, pH and pathogens. To model a SWAT constituent using QUAL2K, choose "Modeled in QUAL2K" in the Calculate by column. To model any elements in QUAL2K, water temperature must be modeled in QUAL2K. QUAL2K will calculate water temperature for each

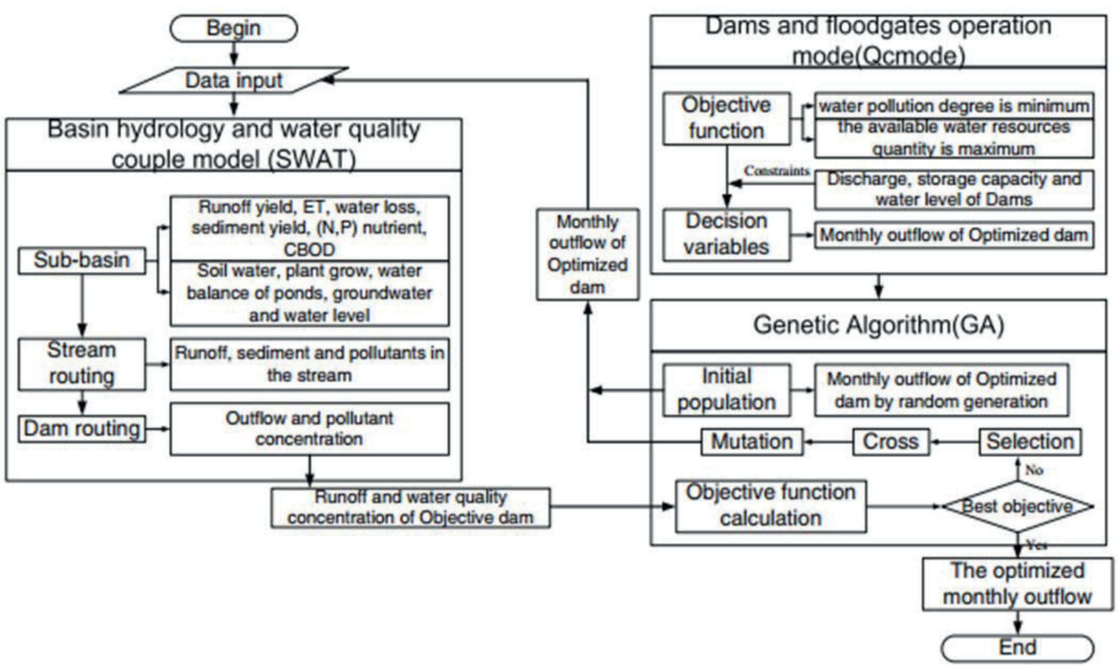

Figure 2. SWAT model flowchart (Zhang *et al.*, 2011)

river based on SWAT climate data (air temperature, dew point, wind speed, and cloud cover and shade fractions) input in the Data view (under the Climate tab). For each constituent modeled in QUAL2K, the corresponding QUAL2K constituent is chosen in the Link to QUAL2K Constituent column.
The pollutant balance equation is:

$$v(\frac{dc}{dt}) = W(t) - Qc - vcAi \quad (1)$$

$$Msettling = vcA_s dt \quad (2)$$

where v is the water volume in the dam; c is the concentration of a certain pollutant; dt is the length of the time step; W (t) is the amount of pollutant entering the water body; Q is the rate of water flow exiting the water body; Msettling is the mass of pollutant lost by settling; v is the apparent settling velocity; and A_i is the area of the sediment–water interface.
The objective of dams operation mode is to simulate and contrast the water quantity and quality processes in different scenarios of multi-dams' operation based on distributed SWAT to control the water pollution and increase the quantity of available water resources. Optimal Velum of the dam and reservoir modeling of the Mahabad basin monthly output in the WEAP to pest software, Yusefkand conduct that results in txt format was introduced as an input file for SWAT. SWAT output results in various scenarios to determine the optimal amount of water for WEAP monthly output volume of the dam and reservoir seal was introduced at the end of each month.

2.2. Model solution

The solution of the Pest-SWAT model is a complicated multi-constraints and nonlinear task. GA is employed to resolve this difficulty (Holland 1975). In the model, some key parameters have been set, including the maximum number of generations, the number of variables (monthly outflow), the probability of crossover, and the probability of mutation, for which values are 10, 10, 1, and 0.2, respectively.

Table 1. Hydrologic and water quality sensitive parameters of SWAT model of Mahabad River Catchment

Data type	Scale	Source	Data description
Topography	1:250,000 (grid, 76 m)	Continuous	Elevation, Channel slopes, Lengths
Land use map	1:250,000	Institute of Geographic Science and Natural Resources Research	Land use classifications
Soil map	1:250,000	Institute of Geographic Science and Natural Resources Research	Soil physical properties such as bulk density, texture, saturated conductivity, etc.
Weather	3 stations	Mahabad Weather Bureau	Daily precipitation, wind speed, maximum/minimum temperature relative
Hydrology Dam	2 stations dam	Mahabad Hydrologic Mahabad Hydraulic	Station monthly outflow The reservoir's design data attribute parameters
Environment		Mahabad Hydraulic	Water quality standard The outlets and the discharge data Monthly water quality monitoring data

2.3. Data collection

Historical data were collected from the meteorological, hydrologic, environment protection, urban development, economic, and agriculture departments in Mahabad City. For the hydrologic simulation, the 5-year (2007 and 2011) of daily meteorological data (precipitation, wind speed, maximum and minimum temperature, and relative humidity) was collected from 3 stations and monthly outflow data of Mahabad River Reservoir and Yusefkand floodgate. The annual runoff with the different assurance rates (P = 75% and 95%) for Mahabad River Reservoir, and Yusefkand floodgate were gathered. For the water quality simulation, the annual treatment capacity of the main sewage treatment plants, the pollution discharge data from the outlets, and the water quality monitoring data in Mahabad River Reservoir and Yusefkand floodgate in 2011 were collected. Moreover, the basin attributes information of DEM, land use map; soil map, dams, and floodgates regulation were also gathered. All the data used for this research are shown in Table 1.

2.4. Model setup

The catchment was divided into 15 sub-basins according to hydrologic stations, water quality stations, the position of dam and floodgate, the water function zones, and the discharge zones. The sub-basin threshold area was 5,000 (ha). Mahabad floodgate was selected as the outlet of the whole basin. The hydrologic response unit (HRU), which is a unique combination of soil and land use overlay in the sub-basins (Neitsch *et al.*,

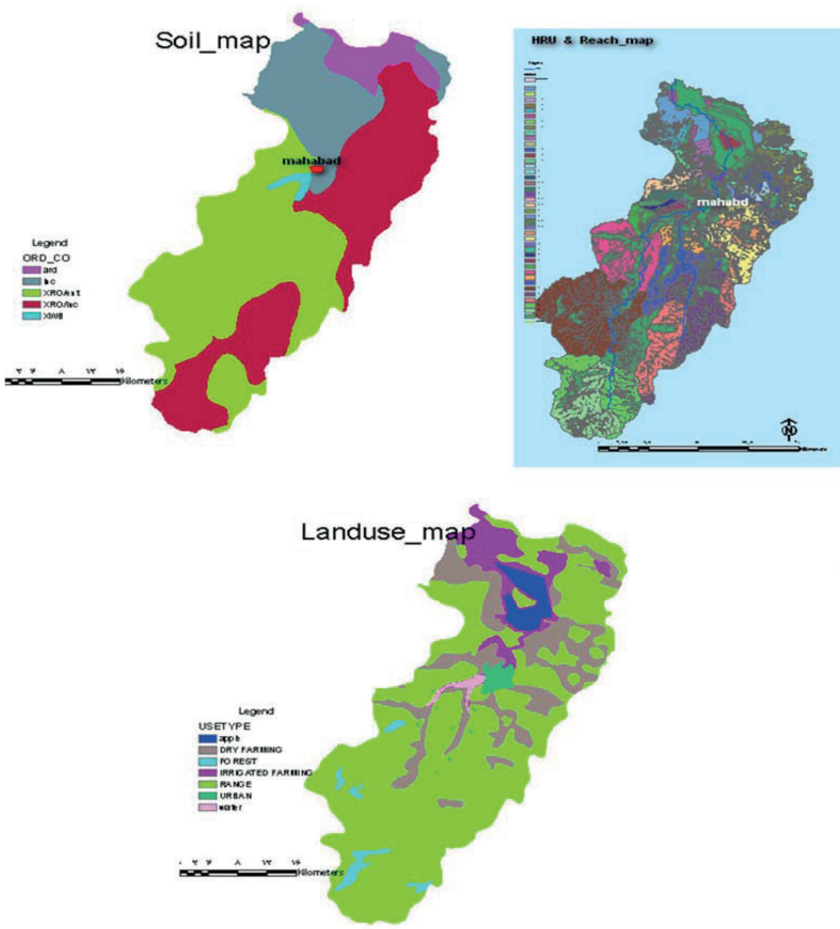

Figure 3. Digitized land use, soil type and streams, the sub-basin delineation, and location of dams and floodgates, sewage outlets and sewage treatment plants

2002; Fechrul *et al.*, 2006), is the minimum calculative smallest unit of hydrologic process. With a threshold value of 25% for land use and soil types, the total number of HRUs was 146 (Figure 3). The calibration process was begun by initially including some 40 parameters in the response of all four variables to changes in each parameter was plotted. This helped to identify the insensitive parameters (causing no or very small changes to variables), the sensitive parameters to all four variables, and the parameters that were sensitive to sediment only, total phosphorus only, and nitrate only (Table1).

Twenty-eight sensitive parameters (six hydrologic parameters and twenty-two water quality parameters) that may have a potential influence on river flow and water quality were selected (Srinivasan *et al.*, 1998; Eckhardt and Arnold, 2001; Lenhart *et al.*, 2002; Van Griensven *et al.*, 2006; Barlund *et al.*, 2007; Carney, 2009). The ranges of these parameters were obtained from the SWAT manual (Neitsch *et al.*, 2002). The hydrologic parameters were calibrated to match the simulated and observed monthly flow data at Mahabad River Reservoir and Yusefkand floodgate from 2007 to 2011. Runoff with different assure rates at Mahabad River Reservoir, Yusefkand floodgate were used for validation. For the water quality parameters, the observed data of ammonia nitrate (NO3), phosphorus (P), dissolved oxygen (DO) and chemical oxygen demand (COD) at Mahabad River Reservoir and Yusefkand floodgate were used for calibration (Table 2).

Several evaluation indices, including the relative error (re), correlation coefficient (r), and Nash–Sutcliffe coefficient (NSE) were used to evaluate the model performance (Romanowicz *et al*,. 2005). For the runoff simulation, if the correlation coefficient and Nash–Sutcliffe efficiencies can range from $-\infty$ to 1. An efficiency of 1 (NSE = 1) corresponds to a perfect match of modeled discharge to the observed data (Table 3). An efficiency of 0 (NSE = 0) indicates that the model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero (NSE < 0) occurs when the observed mean is a better predictor than the model or, in other words, when the residual variance described by the numerator in the expression above is larger than the data variance expressed by the denominator (Nash and Sutcliffe, 1970). Because the error of runoff simulation directly affects on the simulated results of water quality and the monitoring data is limited, if the relative error is between −30% and 30% and the correlation coefficient is greater than 0.40 for water quality, the prediction was considered "acceptable."

3. Results and Discussion

3.1. Calibration and validation

At Mahabad River Reservoir, the observed monthly inflow is set as the objective for calibration, and the observed outflow is used as an input of SWAT model, and the outflow simulation code is changed to the measured monthly outflow in the control file (IRESCO = 1). This is a suitable method to avoid the effect of simulated error on runoff simulation at the downstream (Zhang *et al.*, 2011). For water quality simulation, the observed monthly values at upper stream of the reservoir are considered. Mahabad River Reservoir is located at the upper stream of Mahabad River, and its main purpose is to ensure the irrigation and drink water for Mahabad demand. If the maximum flow is assumed to an outlier, and consequently the statistical analyses of the 2010, at Kavter and Baytas river inflow and outlet of the Mahabad dam and Yusefkand, floodgate, and basin outlet, the observed and monthly relative error of simulation (0.07, 0.03, 0.01, 0.19, 0.05) and NSE coefficient (0.97, 0.89, 0.99, 0.93, 0.99) increase significantly (Table 4 and Figure 4).

To examine the volume and portion of nourishing substances intake into the Mahabad dam reservoir in every river embranchment of Kavter and Baytas, the intake discharge and density values, total nitrogen (TN) and total phosphorus (TP) in the entrance stations of the Mahabad dam, Kavter (SW3) and Baytas (SW7) have been presented. To calculate

Table 2. Hydrologic and water quality sensitive parameters of SWAT model of Mahabad River Catchment

Model processes	Name	Description	Range of values	Fil
Hydrology	CN2	SCS runoff curve number	(43, 96)	.mgt
	ESCO	Soil evaporation	(0.005, 0.845)	.hru
	EPCO	Plant evaporation	(0.005, 0.845)	.hru
	SOL_AW	Available water capacity of	(0.10, 0.25)	.sol
	SOL_K	Soil conductivity (mm/h)	(0.05, 1.68)	.sol
	SOL_Z	Soil depth	(96, 1040)	.sol
Water quality	BSETLR	COD settling rate in reservoir	(−100, 100)	.lwq
	NSETLR	Nitrogen settling rate in reservoir	(−500, 5.5)	.lwq
	RK1	CBOD deoxygenation rate at 20◦C	(0.0, 3.4)	.swq
	RK3	Settling loss rate of CBOD at 20◦C	(−0.10, 0.36)	.swq
	BC1	Rate constant for biological oxidation of ammonia nitrogen at 20◦C	(0.05, 0.10)	.swq
	BC3	Local rate constant for hydrolysis of organic nitrogen to NH+ 4 at 20◦C	(0.20, 0.40)	.swq
	ERORGN	Organic nitrogen enrichment ratio	(1.8, 3.5)	.hru
	ECBOD	cbod enrichment ratio	(0.1,1.5)	.hru
	PSP	Phosphorus availability index	(0.5, 0.7)	.bsn
	ERORGP	P enrichment ratio with sediment loading	(2.0, 4.0)	.hru
	BC4	Rate constant for mineralization	(0.3, 0.5)	.swq
	RS5	Organic P settling rate	(0.08, 0.1)	.swq
	RCN	Nitrogen in rain	(1.3)	.bsn
	UBN	Nitrogen uptake distribution parameter	(9.4)	.bsn
	GWNO3	Concentration of NO3 in groundwater	(0.3, 0.5)	.gw
	ERORGN	Organic N enrichment for sediment	(2.75)	.hru
	NPERCO	Nitrate percolation coefficient	(0.223)	.bsn
	USLE_P	support practice factor	(0.6, 0.1)	.mgt
	USLE_C	water erosion factor, AGRR	(0.03, 0.3)	.crp
	USLE_C	water erosion factor, PAST, ORCD	(0.07, 0.2)	.crp
	USLE_C	water erosion factor, FRST	(0.0, 0.1)	.crp
	USLE_K	soil erodability factor	(0.19, 0.5)	.sol

Table 3. The evaluation indices

Definition	Reference	Comments
$re = \frac{\sum_{i=1}^{m} \lvert O_i - S_i \rvert}{\sum_{i=1}^{m} (O_i)}$	Relative error	The optimal statistical value is close to 0
$r = \frac{\sum_{i=1}^{m} (O_i - \bar{O})(S_i - \bar{S})}{\sqrt{\sum_{i=1}^{m} (O_i - \bar{O})^2 . \sum_{i=1}^{m} (S_i - \bar{S})^2}}$	Correlation coefficient	The optimal statistical value is close to 1
$NSE = 1 - \frac{\sum_{i=1}^{m} (S_i - O_i)^2}{\sum_{i=1}^{m} (S_i - \bar{O})^2}$	Nash-Sutcliffe coefficient (Nash and Sutcliffe, 1970)	The optimal statistical value occurs when the value is 1

which O is the observed value; $\bar{O}$ is the average of observed values; S is the simulated value; $\bar{S}$ is the average of simulated values

Table 4. Simulated results of water quantity in some main cross-sections

	Runoff									
	Kavter (sw3)		Baytas (sw6)		Mahabad Dam outlet		Yusefkand floodgate		Basin outlet	
	Original	Simulation	Original	Simulation	Original	Simulation	Original	Simulation	Original	Simulation
Average	1.32	1.41	0.44	0.46	5.18	5.15	0.55	0.63	0.67	0.70
Extent (%)	-6.80		-3.25		0.55		-18.58		-5.20	
re	0.07		0.03		0.01		0.19		0.05	
r	0.98		0.97		0.99		0.99		0.99	
NSE	0.97		0.89		0.99		0.93		0.99	

the nutrient balance, discharge and concentrations of outflow nitrogen and phosphorus of the reservoir have also been estimated. Based on the Trophic State Index (TSI), average concentrations of TN and TP of the dam reservoir are calculated as follows:

$TSI\ (TN) = 14.43 \ln (TN) + 54.45$ (in mg/lit)

$TSI\ (TP) = 14.42 \ln (TP) + 4.15$ (in µg / lit)

The TSI index for the Mahabad dam reservoir is estimated on the base of nitrogen 85, and phosphorus 169. Considering the values in Table 3, in terms of eutrophication, the Mahabad dam reservoir is in the state of hypertrophic. Table 5 demonstrates the classification of qualitative situation of tank and nutrition of Mahabad dam based on the TSI parameter.

3.2. Optimal operation of dams and floodgates

Calculating the minimum water flow requires

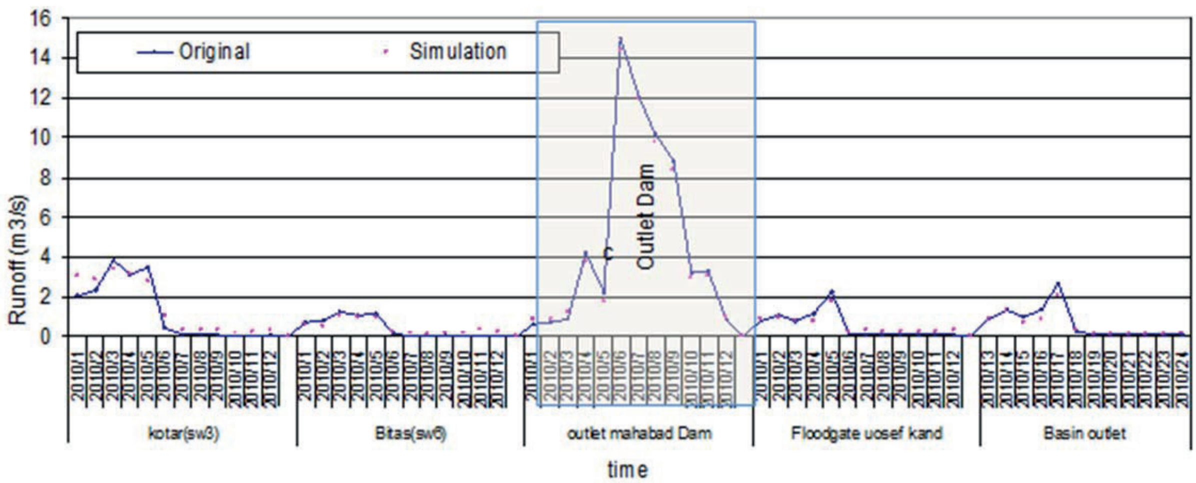

Figure 4. Monthly observed and simulated runoff

Table 5. The classification of qualitative situation of tank and nutrition of Mahabad dam on the basis of TSI parameter

Parameter of Water Quality Concentration in the lake	The average	TSI index Oriented repository		Nutrition
TN (mg/lit)	8.53	85	H	Too bad
TP (μg/lit)	90.16	169	H	Too bad

which O is oligotrophic; M is Mesotrophic; E is Eutrophic; and H is hypertrophic

the optimal operation of dams and floodgates. The theory of minimum of flow power equal to principles of thermodynamics for prevention from trapping of deposits in the tank of dam is in from of the following equation. It is calculated based on the Anandol studies, and the fixed quantity (Q*S= const = a min= 0.006) is remaining fixed in order to determining the longitudinal profile in total in Mahabad River reservoir and it has more popular form in most of natural water canal.

$$Q*S=a\ min$$

$$IF\ \left(\frac{dQ}{dx} \to 0\right) \qquad Q*S= const = a\ min= 0.006$$

$$\frac{dA}{dx} = \left(\frac{A}{Q}\right)\left(\frac{dQ}{dx}\right) + \left(\frac{A}{3P}\right)\left(\frac{dp}{dx}\right)$$

So:

$$S = \left(\frac{1385.5 - 1317.5}{1100}\right) = 0.0037$$

$$(g*D*S)^{1/2} = const \quad , \quad const=(9.81*0.001*0.00375)^{1/2}=0.006$$

$$Q*S=a\ min,\ Q*(0.0037)=0.006,\ Q=1.6\ (m^3/s)$$

where D is the depth; S is longitudinal slope, Q is water discharge flow with value of 1.6 m^3/s for Mahabad dam that is the minimum of discharge needed for least trapping of deposits in tank and most exhaustion of deposit. It can be concluded that increasing the rate of phosphorus deposit as a factor for limiting nourishing in the tank. So, it would be possible to prevent from intense nourishing and extreme subsidence of quality, particularly during water inversion in thermal layer of tank. The deposited sea-foam is entered to the dam water by water discharge. The discharge (Q) of water can discharge intake deposit, sea-foam, and also extra phosphorus from tank. While preserves existing capacity of the tank, prevents extreme eutrophication and a sharp drop in the quality of nutrition, especially during water inversion that disturbs the thermal layer and caused the sediments entered into the water. The center of irrigation basin and imbibing in Mahabad dam is situated in fixed level of 1333m from the open sea level. The tank has been having thermal layer from the beginning of spring to the middle of autumn. The water entrance to the tank is low from the beginning of summer to the end of autumn and the oxygen in tank is used with crucial organisms' activities.

The central layer contains of the best quality for water deduction. In order to taking water with best quality in thermal layer, the below layer must be placed at a level of less than 1330m. As it was explained earlier, in the end of summer and beginning of autumn, the level of upper layer is lower than the tank dewatering level, therefore, the volume of water in tank must be managed in this issue. The results in the text format was introduced as an input file to the SWAT model, and the model output in various scenarios was used for optimization process to calculate the optimum value of monthly water outflow from dam and dike, and volume of dam in the end of each month.

3.3. Calibration

The calibration of sensitive parameters is performed manually and the degree of each parameter in Table 2 is changed. After model run, the resulted changes in the model output is reviewed and re-examined, this process is repeated for 2010 till to find an acceptable model output, and the model is performed again for validating the model for 2011.

3.4. Validation results

The diagrams in Figure 6 indicate the simulation of volume of nitrogen, solution of oxygen, oxygen needed for chemical and phosphorus in validation stage. In rivers of entrance of tank in embranchment of Kavter and Baytas rivers and the exit of basin in end of Mahabad River, the exit of Mahabad dam and the exit of deviational wall of Yusefkand and diagram of volume of tank has been introduced and resultant and assessed parameters of model is able to observe in Table 6. The current operation of dams and floodgates involves always keeping them closed in the nonfood season to store water for irrigation. During the flood season, however, Mahabad dam and Yusefkand floodgates are usually open to discharge water for flood control. By two scenario analysis from Mahabad River Reservoir, and Yusefkand floodgate, the water quality condition and the water resources quantity will be improved significantly after the implementation of water quantity and quality optimal operation of dams and floodgates (Tables 6 and 7). In the first scenario, the volume of water in tank is managed to such that upper layer of lower layer doesn't reach to the level of 1330m. The results in shape of text format from input file is presented and the results of output in various scenarios to calculate optimum value of monthly outflow water from dam and dike and volume of dam in the last days of each month will increased in the non-flood season to increase fluidity of rivers and improve water quality, while the runoff will decreased in flood season to store the less polluted water for utilization. Thus, the water quantity internal annual distribution will be more reasonable by the optimization operations. In the next, scenario in the pollutant sources reduction scenario, the main pollution sources of the indiscriminate use of chemical fertilizers and livestock waste, according to the cultural and economic status of people living in the catchments area, there is very little possibility of reducing pollution sources. According to the model calibration results for 2011, the optimization of operations in terms of quality and quantity of Mahabad dam output and in the downstream of Yusefkand River improved for nitrate (NO_3) from 4.2% to 75.3%, phosphate from 4% to 42%, DO from 3.4% to 42%, and for COD from 21.4% to 51.1% (Figures 5 and 6).

In the study area, runoff is extremely sensitive to CN, ESCO, and SOL−AW (Table 2), which are related to Eco-morphology, soil, melting snow, and land use. The land use categories in the model are pasturage, forest, agricultural land, and urban, but

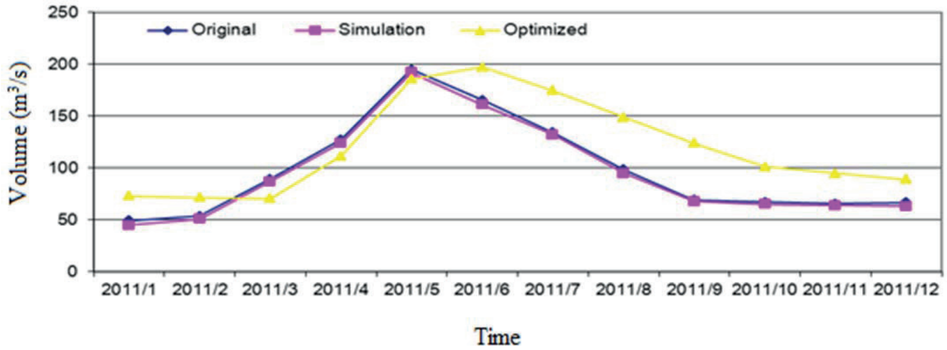

Figure 5. Volume in the main sections in the reservoir pollution reduction scenario

the soil variation is rather limited, including only cinnamon soil and moisture soil. Most runoff are generated on pasturage, urban and agricultural land, and forest, because the average values of CN in urban, pasturage, and agricultural land are 92.51, 79.4 and 89.36, respectively, while in forest is only 73.3. The water storage volume is greater in the upper stream (Kavter and Baytas); thus, the values are less, and these parameters are reasonable in Mahabad River Catchment. The results indicate analytics with the exception of underestimated simulated concentrations of P in January and December at basin outlet and DO in Yusefkand floodgate, the simulation results are acceptable considering the error of runoff simulation and the shortage of water quality observation data (Figure 7).

The optimal rule of Yusefkand floodgate is as follows: increasing outflow by 400% before the flooding time, increasing outflow by 8% in the flooding time, and decreasing outflow by 13% after the flooding time. The total annual average outflow of Yusefkand floodgate increased by 83 %, CO2 by 36.3% and NO2 by 23% decreased.

The optimal management of Mahabad River Reservoir is as follows: increasing permanently the bottom gate outflow by 2 m^3/s before the irrigation season and in the flooding time, and decreasing outflow by 15.3% after the flooding the irrigation season time, the available water resources increased in Mahabad Reservoir about 29.2%, NO2, P, and CO2 decreased about 73.2%, 84.3%, and 6.1%, and DO increased about 27.3%. In the basin outlet, the total annual average outflow of outlet increased by 8.3 %, and CO2 and NO2 decreased about 36.3%, and 23%. According to the long-term Mahabad River flow River Dam in Table 3 is provided, the resulting data shows that the average river is more than 250 million cubic meters.

In this scheme, the water requirement of the plant Han and gardens in different months on average per hectare by applying irrigation efficiency in the face of water research area equal to about 40% and mechanized irrigation of about 70% hectare achieved with regard to the composition of the culture in the current state of the network and the automation calculated in Table 8. Crop water needs of different products in different conditions are given. Water savings to improve the environmental situation there led to the Urmia Lake.

Conclusions

Water quantity and quality joint operation in the integrated basin management and will provide a new approach optimal operation to water environment improvement and ecological restoration. In this study, the water quantity and quality operation mode of dams and floodgate by pest, and genetic algorithm were coupled with the SWAT model. The optimization of dam and floodgate operation at the basin scale overcame the limitation of the

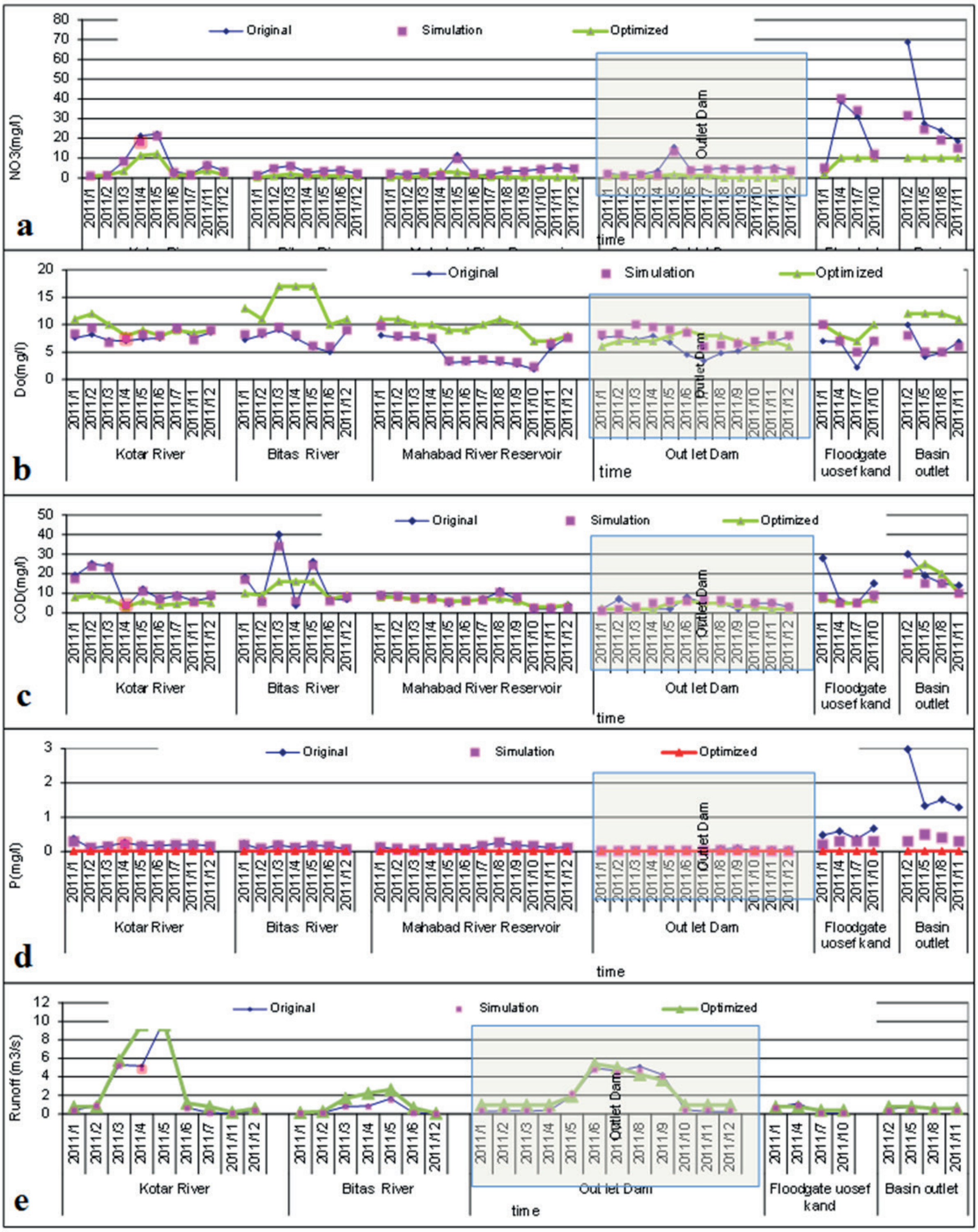

Figure 6. Contrasting the optimized results with the original and simulated concentration and values of water quantity and quality at the upper and downstream of the main objective dam and floodgate in the current and discharge pollutant a) NO3; b) DO; c) COD; d) P; e) Runoff

Table 6. The optimized results with the original and simulated in the different dams in the pollutant discharge reduction scenario

	Runoff			NO_3			DO			COD			P		
	Original	Simulation	Optimized	Original	Simulation	Optimized	Original	Simulation	Optimized	Original	Simulation	Optimized	Original	Simulation	Optimized
	Kavter River														
Average	6.78	6.49	8.44	7.69	6.99	4.13	7.84	8.14	10.18	12.56	12.13	5.78	0.20	0.18	0.01
Extent (%)	4.20			9.01			-3.93			3.36			13.11		
re	0.04			0.09			0.04			0.03			0.13		
r	1.00			0.99			0.82			1.00			0.99		
NSE	1.00			0.97			0.61			0.98			0.59		
	Baytas River														
Average	1.36	1.22	2.83	3.54	3.35	0.99	7.38	7.91	14.57	15.43	14.39	11.86	0.14	0.24	0.01
Extent (%)	10.31			5.48			-7.20			6.76			-67.33		
re	0.10			0.05			0.07			0.07			0.67		
r	1.00			1.00			0.97			0.99			-0.42		
NSE	0.98			0.97			0.79			0.93			-0.19		
	Dam Outlet														
Average	5.00	4.93	5.83	4.65	3.94	1.08	6.40	7.14	7.50	4.05	4.58	3.33	0.04	0.03	0.01
Extent (%)	1.51			15.28			-11.50			-13.17			19.15		
re	0.02			0.15			0.11			0.13			0.19		
r	0.99			0.98			0.95			0.79			0.83		
NSE	0.99			0.89			0.69			0.38			0.57		
	Yusefkand floodgate														
Average	1.35	1.13	1.50	20.48	22.75	8.00	5.80	7.25	8.50	13.50	9.63	6.00	0.53	0.33	0.01
Extent (%)	16.67			-11.11			-25.05			28.70			38.39		
re	0.17			0.11			0.25			0.38			0.97		
r	0.99			0.99			0.73			0.83			-0.66		
NSE	0.88			0.97			0.20			-1.45			-0.12		
	Basin outlet														
Average	1.65	1.19	1.75	34.65	25.75	10.00	6.46	6.08	8.00	19.65	15.98	18.75	1.78	0.99	0.01
Extent (%)	28.03			25.67			6.00			18.70			44.44		
re	0.28			0.26			0.06			0.19			0.44		
r	0.60			0.99			0.99			0.96			0.81		
NSE	0.03			0.24			0.35			0.26			0.06		

Table7. Probability to bring the annual flow in Mahabad River

Yearly (mcm)	Yearly (m3/s)	September	October	November	December	January	February	March	April	May	June	July	August	Perhaps percent
522.46	16.57	0.77	0.9	2.28	8.87	38.09	56.45	36.63	18.3	17.65	10.8	6.8	1.27	10%
380.67	12.07	0.48	0.59	1.69	5.9	27.8	45.88	24.6	14.31	9.56	7.86	5.12	1.07	20%
257.36	8.16	0.31	0.38	1.05	4.08	19.2	32.72	17.8	8.93	5.64	4.48	2.7	0.64	50%
174.07	5.52	0.18	0.22	0.77	3.09	12.49	25.47	13.54	4.31	2.79	2.06	1.01	0.33	75%
154.44	4.9	0.14	0.18	0.66	2.22	11.64	23.8	11.55	3.14	2.49	1.83	0.81	0.3	80%
97.26	3.08	0	0.01	0.16	1.1	6.77	17.31	7.44	1.76	1.13	0.81	0.36	0.17	90%

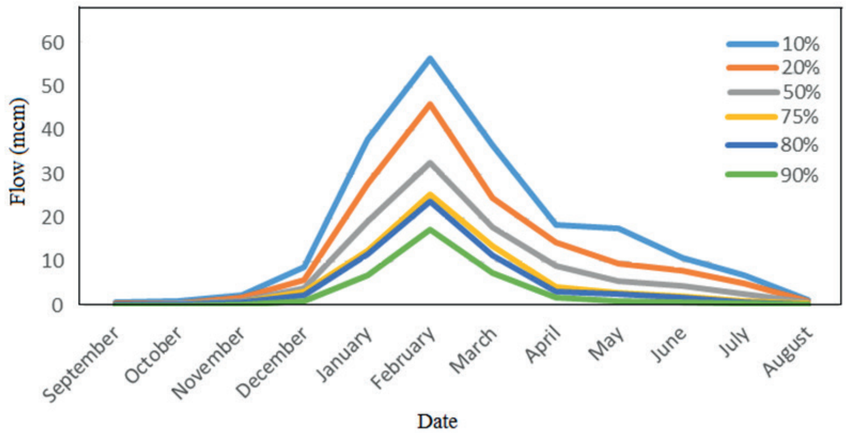

Figure 7. The probability of the Mahabad River's annual flow

method of former reservoir operation and extended the reservoir operation module of SWAT model. It has been applied successfully in Mahabad River Catchment of the Urmia lake watershed in Mahabad City, West Azerbaijan Province, Iran.

Acknowledgements

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Table 8. Mahabad plain crop water requirement and irrigation networks

m3/month/ha		wheat	barley	pea	sugar beet	rape	maize	vegetable	alfalfa	apple	grape	peach	total
Mahabad	pattern%	19.52	12.3	0.5	3.05	4.07	2.15	0.44	28.66	27.2	1.02	1.09	100
April	Net requirement	587	587	39	16	587	9	0	32	154	103	154	2268
	Gross requirements	903	903	60	25	903	14	0	49	137	92	137	3223
May	Net requirement	902	750	495	135	912	63	385	180	563	388	559	5332
	Gross requirem	1388	1154	762	208	1403	97	592	277	501	345	498	7225
June	Net requirement	480	163	1606	1044	636	921	1352	826	1187	1005	1134	10354
	Gross requirements	738	251	2471	1606	978	1417	2080	1271	1057	895	1010	13774
July	Net requirement	24	0	723	1684	242	1658	1711	1364	1520	1372	1430	11728
	Gross requirements	37	0	1112	2591	372	2551	2632	2098	1353	1222	1273	15242
August	Net requirement	0	0	0	1793	0	1708	1032	1630	1574	1441	1430	10608
	Gross requirements	0	0	0	2758	0	2628	1588	2508	1402	1283	1273	13439
September	Net requirement	0	0	0	1414	0	942	0	1423	1201	1081	430	6491
	Gross requirements	0	0	0	2175	0	1449	0	2189	1069	963	383	8229
March	Net requirement	241	241	0	405	241	0	0	931	167	114	0	2340
	Gross requirements	371	371	0	623	371	0	0	1432	149	102	0	3418
February	Net requirement	191	192	0	0	191	0	0	0	0	0	0	574
	Gross requirements	294	295	0	0	294	0	0	0	0	0	0	883
January	Net requirement	30	32	0	0	30	0	0	0	0	0	0	92
	Gross requirements	46	49	0	0	46	0	0	0	0	0	0	142
December	Net requirement	7	9	0	0	7	0	0	0	0	0	0	23
	Gross requirements	11	14	0	0	11	0	0	0	0	0	0	35
November	Net requirement	85	90	0	0	85	0	0	0	0	0	0	260
	Gross requirements	131	138	0	0	131	0	0	0	0	0	0	400
October	Net requirement	225	232	0	0	225	0	0	0	0	0	0	682
	Gross requirements	346	357	0	0	346	0	0	0	0	0	0	1049
Net requirement (m3/year/ha)		2772	2296	2863	6491	5489	5301	4480	6386	6366	5504	5137	Total required annual gross weight
Net requirement (m3/year/ha)		4265	3532	4405	9986	4855	8155	6892	9825	5668	4901	4574	
Net requirement (m3/year/ha)		6930	5740	7157.5	16227.5	13722.5	13252.5	11200	15965	15915	13760	12842.5	
Net requirement (m3/year/ha)		9.16	4.78	0.24	3.35	2.17	1.92	0.33	30.97	16.95	0.548	0.548	70.99
Net requirement (m3/year/ha)		14.88	7.766	0.39	5.44	6.14	3.13	0.54	50.33	47.62	1.54	1.54	139.34

Table 8. Mahabad plain crop water requirement and irrigation networks

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