WASTEWATER AND GROUNDWATER CONJUNCTIVE USE OPTIMIZATION MODEL IN VARAMIN IRRIGATION NETWORK

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ABSTRACT

In recent years, the use of treatment plants' wastewater, as a component of unconventional water has been considered a supplementary to groundwater resources in irrigation and drainage networks. The rate of nitrogen leaching into the soil and aquifer due to the use of chemical fertilizers and wastewater containing high nitrogen should be assessed. The wastewater due to the presence of some nutrients such as nitrogen and phosphorus can provide a significant portion of the plant's fertilizer needs, saving the cost of purchasing fertilizers. In this research, development of cropping pattern optimization model was addressed for quantitative-qualitative conjunctive use of unconventional surface water (wastewater) and groundwater. The three objectives of the model are, maximizing profits from cropping pattern, reducing nitrogen leaching and improving the rate of aquifer recharge. In order to integrated management of wastewater and irrigation water resources., A nonlinear three objectives optimization model was tested for 7 scenarios (one-objective, two-objectives and three-objectives) in water year 2012-2013 in Varamin irrigation network. Solving one-objective model by first objective (first scenario: improving of network's profit) showed the 49 percent improvement of network's net profit. The second objective (scenario: reducing of fertilizer consumption) showed the 95 percent reduction in fertilizer consumption, and the third objective (third scenario: improving the aquifer recharge) showed the 120 percent improvement in the aquifer recharge, in comparison to the current situation.

Solving the three-objectives model (seventh scenario: combined objectives of improving network's net profit, reducing of fertilizer consumption and improving the aquifer recharge) showed a 23 percent reduction in cultivated area and 71 percent of nitrogen fertilizer consumption and 13 percent of conjunctive withdrawals of wastewater and groundwater, 6 percent increase in net benefit, 29 percent increase in aquifer recharge and 22 percent increase in water productivity was achieved. Therefore, seventh scenario was chosen as the best scenario. Integrated quantitative-qualitative management of irrigation water and wastewater resources in irrigation and drainage networks in terms of controlling the environmental impacts of nitrogen leaching into the soil and groundwater environment is an important issue, the proposed three-objective model of this paper can be used to improve the performances of agriculture, environment and water resources systems in irrigation and drainage networks.

Keywords : Wastewater, Fertilizer, Nitrogenleaching, Aquifer recharge.

1. INTRODUCTION

Recently, treated wastewater has been used as an additional water supply for farming, and thus the possibly higher rate of nitrogen leaching into soil and groundwater from chemical fertilizers and treated wastewater requirements reduced. While nitrogen is one of the most significant nutrients for cropping, its abuse intensifies the risk of groundwater contamination. The applied nitrogen fertilizer should be used based on the existing nitrogen quantity in water resources and soil and the plant desires during the growing season. However, many farmers use high levels of water and nitrogen to ensure they

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meet the plant need, thus soil becomes vulnerable to leaching and transmitting nitrogen to groundwater resources (Ramos et al., 2012). The United States Environmental Protection Agency (USEPA) (1997) has indicated that one of the most significant sources of nitrate pollution is the use of nitrogen fertilizers in agricultural lands.

These fertilizers have the potential to pollute aquifers by leaching and cause adverse effects on human health. Meanwhile, many previous research studies indicate the profits of using treated wastewater in farm irrigation. For example, Oron et al. (2007), Metcalf et al. (2007), and Ghasemi et al. (2011) reported that the using treated wastewater for irrigation offers a low-cost and stable source of water, decreases the costs of treatment, saves water resources with good quality for other needs, decreases the cost of chemical fertilizers, and lessens the disaffects of treated wastewater disposal on other water resources. The World Health Organization (WHO) (2006) stated that treated wastewater irrigation at a rate of 5.1 cubic meters per year provides 225 kg of nitrogen per hectare for irrigated lands, which could reduce or entirely remove the use of organic and chemical fertilizers.

Singh et al. (2001) offered a linear programming model to optimize crop pattern in an area in India that would maximize the net benefit from available water. Khare and Jat (2006)prepared a linear economic-engineering programming to assess the conjunctive use of surface and groundwater in Indonesia using different hydrological and management constraints. Their results showed that the conjunctive use options can increase the benefits from agriculture. Davijani et al. (2016)offered a multi-objective optimization model to allocate water resources in arid regions of Iran for exploiting job in industrial, agricultural, and municipal water sectors using a PSO algorithm. Results showed that optimal allocation of water resources increased the job rate and economic benefit by 13% and 54%, respectively.

Banihabib et al. (2015)proposed a non-linear programming model of water reallocation and cropping patterns for deficit irrigation condition in the Tehran and Alborz provinces in Iran. The results of the optimization model showed that, in the most optimal state, changing the cultivated area and using deficit irrigation methods can improve the economic benefits of the agricultural sector by 36% compared to the current cropping. Karamouz et al. (2005)prepared a model for conjunctive use of surface and groundwater resources using genetic algorithms (GAs) and artificial neural networks (ANNs) with an emphasis on water quality concerns and used this method in southern Tehran (Capital of Iran).

Then, Karamouz et al. (2010) used a GA model to optimize the cropping pattern of eight irrigation networks in Tehran Province according to water allocation priorities and water accessibility. The out comes revealed that important changes must be made in the cultivated area of different crops to achieve maximum economic benefit. Alizade et al. (2012)accomplished a cropping pattern optimization in a 10-year planning period for balancing water resources in the Mashhad-Chenaran Plain in Iran. Al Khamisi et al. (2013) modeled conjunctive use of groundwater and reclaimed water (RW) in cropping rotations. The out comes showed that conjunctive use can rise cropping areas compared to using RW only. Joodavi et al. (2015) developed an optimization model for the Firouzabad ground water in Iran by considering crop patterns and conjunctive use for aquifer management.

The outcomes displayed that the optimal cropping pattern varies from the current cropping pattern and that the cultivated areas of some crops should be minimized. Singh (2012)used a linear optimization model for land and water resources to maximize net farming benefits in an area in India. Using production functions, Singh estimated the crop yield under various salinity levels in irrigation water. The outcomes showed that optimizing land and water resources would intensify groundwater use and decrease the problems of water logging and salinity in the study area. Singh and Panda (2013)prepared a linear programming optimization model for an area in India that allocates land and water resources to maximize the annual net benefit by eliminating salinity problems. Using the results of the optimization model, they applied a groundwater simulation model to find the long-term impacts of different water management strategies on the aquifer balance. Based on the outcomes, a variation in cropping patterns and an intensification in groundwater withdrawals were suggested.

In these researches, cropping pattern optimizations were provided with quantitative objectives such as an increase in benefit or groundwater balance, and the groundwater salinity was controlled by the constraints of the optimization models. Given the significance of decreasing the value of nitrogen entering to the soil and groundwater, study that optimizes the value of nitrogen leaching to soil and aquifers from the application of treated wastewater and nitrogen fertilizers is necessary. Previous studies only considered economic and water resource aspects in cropping pattern optimization, but we need to consider environmental aspects of controlling the nitrogen leaching as well.

This study has a main goal: providing the three-objective cropping pattern optimization model for quantitative-qualitative conjunctive use of treated wastewater and groundwater to maximize benefits from crop patterns, decrease nitrogen leaching, and enhancing the rate of aquifer recharge in irrigation and drainage networks.

2. METHODS

2.1 Case Study: Varamin Irrigation Network

The Varamin Plain is in northern Iran, south-east of Tehran Province. The average annual precipitation in this plain is 145 mm. The Varamin irrigation network covers an area of 52 hectares. The main channel, named OABC, has nine secondary channels that branch from the points O, A, B and C. This research considers the land served by the secondary channel, AU, which has an area of 3053 hectares. Fig. 1 shows the Varamin irrigation network and channel locations.

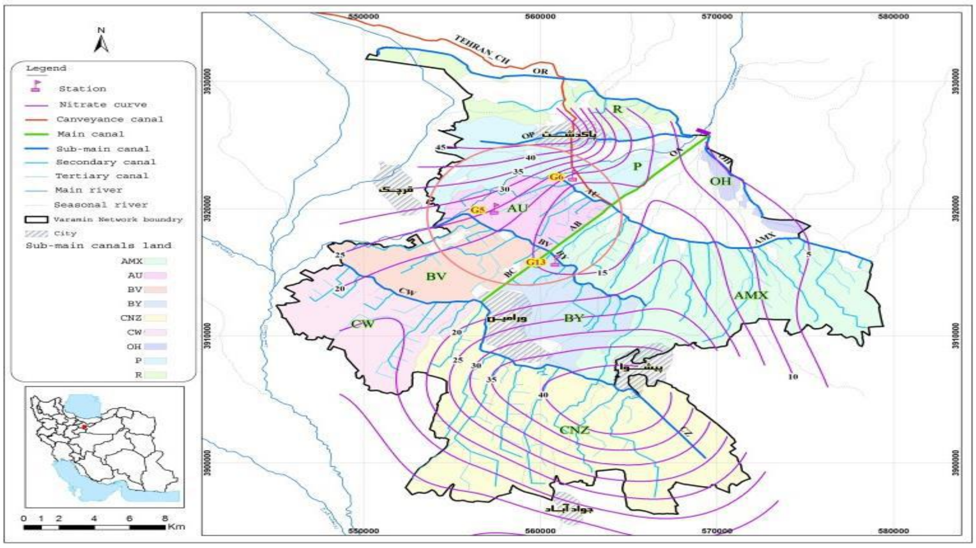

Figure 1. The location and plan of the Varamin irrigation network

2.2 Water Resources of The Varamin Network

The water resources in the area covered by the AU channel in the 2012–2013 water year are presented in Table 1.

Table 1. Water resources data in the AU channel area in 2012-2013 water year (in million cubic meters)

Month	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**Total**
Well	1.3	1.3	1.3	0.8	0.8	0.8	1.9	1.9	1.9	1.9	1.9	1.9	18
Treated waste-water	0.4	0.28	0.53	0.2	0.46	0.4	1.14	1.54	0.5	0.6	0.48	0.63	7.3
Total	1.7	1.58	1.83	0.9	1.26	1.2	3.04	3.44	2.4	2.5	2.38	2.53	25

2.3 Soil Properties

In order to evaluate soil nitrogen balance, the soil texture, nitrate, nitrogen and soil organic matters, were tested by random sampling in two stages, at the start and the end of the 2015–2016 growing season. The results are showed in Table 2.

Table 2. The values of total nitrogen, nitrate, and organic matter in soil samples in the area covered by the AU channel at the beginning of the growing season

Type of cultivation	**Total nitrogen - sample 1 (gr N)**	**Total nitrogen - sample 2 (gr N)**	**Total nitrogen - sample 3 (gr N)**	**Nitrate – sample 1 (ppm)**	**Nitrate– sample 2 (ppm)**	**Nitrate – sample 3 (ppm)**	**Organic matter†– sample 1 (%)**	**Organic matter† – sample 2 (%)**	**Organic matter†– sample 3 (%)**
Wheat	**0.043**	**0.047**	**0.041**	**23.11**	**22.91**	**23.31**	**0.862**	**0.895**	**0.862**
Barley	**0.057**	**0.065**	**0.062**	**11.74**	**13.83**	**13.8**	**1.06**	**1.09**	**1.02**
Forage maize	**0.039**	**0.041**	**0.036**	**16.67**	**16.77**	**18.15**	**0.928**	**0.596**	**0.629**
Alfalfa	**0.044**	**0.066**	**0.1**	**16.46**	**16.2**	**15.32**	**1.558**	**1.657**	**1.690**
Tomato	**0.064**	**0.058**	**0.059**	**33.47**	**28.21**	**24.2**	**1.326**	**1.209**	**1.11**

About 2% of soil organic matter is converted to nitrogen during the growing season (Clifford and Snyder, 2011).

4. MEASURING TREATED WASTEWATER AND GROUNDWATER PROPERTIES

The amount of nitrate and total nitrogen in the wastewater and groundwater was evaluated by samples taken at the upstream of the network, and the amount of nitrate in groundwater was determined by monthly sampling at the main wells in the region during 2012–2013.

The results are presented in Table 3. To extend the point measurement data from sampled wells to the entire aquifer, the nitrate iso-contours were drawn using GIS software. Detailed information on the methods used to evaluate water requirements, crop yields and fertilizer needs in the Varamin irrigation network can be found in Yousefi et al. (2016).Monitoring points and nitrate iso-contours are shown in Fig. 1.

Table 3. The amount of nitrate and total nitrogen of treated wastewater and groundwater at monitoring point

Month	October	November	December	January	February	March	April	May	June	July	August	September
Nitrate of treated wastewater - Point A- (mg/l)	88	70	10	19	103.8	77	37	29	70	31	38	36
Total nitrogen of treated wastewater - Point A- (mg/l)	28	28.8	10.5	15	39.6	29.6	23.7	21	30	19.7	23.3	24.4
Nitrate of groundwater – (G5, G6, G13)- (mg/l)	30	30	30	8.45	8.45	8.45	13.3	13.3	13.3	14.4	14.4	14.37

5. THE OPTIMIZATION MODEL FOR QUANTITATIVE-QUALITATIVE CONJUNCTIVE USE OF TREATED WASTEWATER AND GROUNDWATER

This study included developing a Nonlinear programming (NLP)by Generalized Reduced Gradient (GRG2) method that is run by Excel Solver. The optimization models were developed using three objective functions. The first objective function considers the economic view of the farmers, maximizing their profit by increasing the cultivated area for highly economically crops. The second objective function considers an environmental viewpoint of the network operation. This objective function decreases the total nitrogen leaching into the aquifer. The third objective function considers the water resource managers' concerns in network operation. This objective function improves the rate of aquifer recharge.

5.1 Objective Functions

The first objective function (Eq. 1) optimizes the farmers' benefits from crop patterns. In this objective function, the benefits from crop yields are deducted from the costs of treated wastewater and groundwater withdrawals, as well as the costs of fertilizer applied, to attain the net benefit of the cultivated area. The costs of fertilizer used include the cost of supplying nitrogen fertilizer to cover shortages of nitrogen content potentially available to the plant from treated wastewater nitrogen, groundwater nitrate, and soil nitrogen.
Maximize:

$$Z_1 = \sum_{j=1}^{5} NR_j . A_j - CCW \sum_{i=1}^{12} \sum_{j=1}^{5} VCW_{ij} - CGW \sum_{i=1}^{12} \sum_{j=1}^{5} VGW_{ij} - t\left[\left(\sum_{i=1}^{12} \sum_{j=1}^{5} TC_{ij}\right)(\mathrm{A_j}) - \left(\sum_{i=1}^{12} \sum_{j=1}^{5} TN_{ij} \left(VCW_{ij}\right) + \sum_{i=1}^{12} \sum_{j=1}^{5} Tk_{ij} \left(VGW_{ij}\right) + \left(\sum_{j=1}^{5} TM_j\right)(A_j) + \left(\sum_{j=1}^{5} OM_j\right)(A_j)\right)\right] \qquad (1)$$

where i = index for month, j = index for crop, $\mathrm{Z_1}$= net benefit from the region (IRR), IRR = Iran's currency unit, $\mathrm{A_j}$= cultivated area of the crop j (ha), $\mathrm{NR_j}$= net benefit (income minus cost) of crop j (IR/ha), $\mathrm{TC_{ij}}$= monthly required fertilizers for the crops (kg/ha), $\mathrm{TN_{ij}}$= total nitrogen concentration in treated wastewater (ppm), $\mathrm{Tk_{ij}}$ = nitrate concentrations in the groundwater (ppm), $\mathrm{TM_{ij}}$ = total nitrogen of the soil at the beginning of the growing season (kg/ha), $\mathrm{OM_{ij}}$ = soil organic matter at the beginning of the growing season (kg/ha), $\mathrm{VCW_i}$ = volume of treated wastewater used for irrigation in month i (MCM), CCW = the unit cost of canal water (treated wastewater) (IR), $\mathrm{VGW_i}$ = volume of the groundwater used for irrigation in month i (MCM), CGW = the unit cost of groundwater (IR), and t = the cost of one kilogram of consumed fertilizer (IR).

The second objective function (Eq. 2) minimizes the amount of total nitrogen leaching into the soil and groundwater environment. The difference between the input of nitrogen to the soil and its output should be minimized.

Minimize:

$$Z_2 = [(\sum_{i=1}^{12}\sum_{j=1}^{5} TN_{ij}\,(VCW_{ij}) + \sum_{i=1}^{12}\sum_{j=1}^{5} Tk_{ij}\,(VGW_{ij}) + (\sum_{i=1}^{12}\sum_{j=1}^{5} TF_{ij})(\mathrm{A_j}) + (\sum_{j=1}^{5} TM_j)(A_j) + (\sum_{j=1}^{5} OM_j)(A_j)] - [(\sum_{i=1}^{12}\sum_{j=1}^{5} TC_{ij})(\mathrm{A_j}) + (\sum_{i=1}^{12}\sum_{j=1}^{5} TD_{ij})(\mathrm{A_j}) + (\sum_{j=1}^{5} TR_j)(A_j)] (2)$$

in which, $\mathrm{Z_2}$= nitrogen leaching rate (kg/ha), $\mathrm{TF_{ij}}$= amount of fertilizer delivered to the crop (kg/ha), $\mathrm{TD_{ij}}$= denitrification in the soil (kg/ha) and $\mathrm{TR_{ij}}$= remaining nitrogen in the soil at the end of the growing season (kg/ha). The value of denitrification is calculated by Eq. 3 (Soltani et al., 2013):

$$(\sum_{i=1}^{12}\sum_{j=1}^{5} TD_{ij}) = [(\sum_{i=1}^{12}\sum_{j=1}^{5} TT_{ij}\,(VCW_{ij}) + \sum_{i=1}^{12}\sum_{j=1}^{5} Tk_{ij}\,(VGW_{ij}) + (\sum_{i=1}^{12}\sum_{j=1}^{5} TF_{ij})(\mathrm{A_j})] * (1-\exp^{(-0.01\times\Delta t)}) (3)$$

where, $\mathrm{TT_{ij}}$ = nitrate concentrations in treated wastewater (ppm) and Δt= 30 day.

The third objective function (Eq. 4) is applied for improving the rate of aquifer recharge. Groundwater withdrawal minus aquifer recharge caused by deep percolation of surface and groundwater, as well as aquifer recharge by rainfall, should be maximized.

Maximize:

$$Z_3 = \mathrm{RAL}\sum_{i=1}^{12}(VCW_i + VGW_i) + RRF\sum_{i=1}^{12} RF_i\,.\,A_i - \sum_{i=1}^{12} VGW_i \quad (4)$$

where $\mathrm{Z_3}$ = the rate of aquifer recharge (MCM), RAL = 0.374 = recharge factor for irrigation losses, RRF= 0.13 = recharge factor for rainfall and $\mathrm{RF_i}$ = rainfall amount in month i.

5.2 The Additive Weighting Method for Three-Objective Function

For solving multi-objective optimization problem, the additive weighting method was applied to integrate the results of the nonlinear programming model in this research. The general form of the weighted three-objective function is shown in Eq. 5:

$\mathrm{Z = W_1Z_1 - W_2Z_2 + W_3Z_3}\;\; (5)$

where, $\mathrm{W_1 . W_2}$ and $\mathrm{W_3}$= weights of the objective functions that were weighted equally in this study.

6. CONSTRAINTS

The constraint on the fertilizer needs of crops (Eq. 6) displays that the nitrogen fertilizer requirements of crops can be totally supplied by a combination of the fertilizer potential of treated wastewater and groundwater, the supplementary fertilizer to agricultural land, and the amounts of nitrogen and organic matter in the soil:

$$(\sum_{i=1}^{12}\sum_{j=1}^{5} TC_{ij})(\mathrm{A_j}) \le (\sum_{i=1}^{12}\sum_{j=1}^{5} TN_{ij}\,(VCW_{ij}) + \sum_{i=1}^{12}\sum_{j=1}^{5} Tk_{ij}\,(VGW_{ij}) + (\sum_{i=1}^{12}\sum_{j=1}^{5} TF_{ij})(\mathrm{A_j}) + (\sum_{j=1}^{5} TM_j)(A_j) + (\sum_{j=1}^{5} OM_j)(A_j)) \quad (6)$$

The constraint on cultivated area (Eq. 7) states that the sum of cultivated areas for crops in the Varamin irrigation network should be less than or equal to the total current cultivated area in the region:

$$\sum_{j=1}^{5} A_{ij} \leq TA_j \ (7)$$

in which TA_j is the total cultivated area.

The constraint on crop water requirement (Eq. 8) shows that the crop water requirements should be delivered monthly and consist completely of treated wastewater in conjunction with groundwater:

$$\sum_{j=1}^{5} GIR.A_{ij} - \sum_{j=1}^{5} VGW_i - \sum_{j=1}^{5} VCW_i = 0;\ \forall i \qquad (8)$$

whereGIR_i is the gross irrigation requirement?

The constraint on treated wastewater withdrawal (Eq. 9) limits the amount of treated wastewater withdrawal to the water available in canal in a specific month:

$$VCW_i \leq AVCW_i\ \forall i \qquad (9)$$

In this equation, $AVCW_i$ is the treated wastewater availability in month i (MCM).

The constraint on groundwater withdrawal (Eq. 10) limits the amount of groundwater withdrawal to the permitted groundwater withdrawal in a specific month:

$$VGW_i \leq AVGW_i\ \forall i \qquad (10)$$

in which $AVGW_i$ is the amount of groundwater availability in month i (MCM).

The constraint on changes in cultivated area of crops (Eq. 11) identifies the range of change in cultivated area of crops as between 0 and 100 based on the potential of regional production during the dry and wet years for a 10-year period:

$$0 \leq A_j \leq TA_{jmax} \quad (11)$$

where, TA_{jmax} is the maximum cultivated area of a crop in the 10-year period.

6.1 Decision Variable

The decision variables include the monthly wastewater and groundwater allocations, the annual cultivated area, and the annual amount of fertilizer given to the crops.

6.2 Suggested Scenarios

Scenarios studied in the optimization model are presented in table 4.

Table 4. Scenarios studied in the optimization model.

Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
No optimization	O.F.[2]: Z1	O.F.: Z2	O.F.: Z3	O.F.: Z1, Z2	O.F.: Z1, Z3	O.F.: Z2, Z3	O.F.: Z1,Z2,Z3

Where Z1, Z2 and Z3 are first, second and third Objective Function.

7. RESULTS AND DISCUSSION

Total cultivated area of crops in the current situation was 2120 Hectare Which by solving the one-objective, two-objectives and three-objectives optimization model, the optimum levels of cultivation area for seven scenarios are presented in table 5. Based on the results, the optimum levels of cultivation area for all scenarios in comparison with the current situation are decreased. This result could be due to consideration of allowable wastewater and groundwater withdrawal limits, limits of allowable changes in cultivated area, decreases in the total nitrogen leaching, and improvement of aquifer recharge.

Table 5. The optimum levels of cultivation area for different scenarios

Different cultivating scenarios (ha)/ Crops	Wheat	barley	Forage corn	Alfalfa	tomato	Cropping pattern
current situation	548	572	291	286	423	2120
Scenario 1	398	0	57	657	506	1636
Scenario 2	149	281	73	561	0	1064
Scenario 3	0	382	0	150	0	532
Scenario 4	184	412	37	638	58	1328
Scenario 5	230	192	18	443	18	902
Scenario 6	182	224	57	325	0	788
Scenario 7	61	786	36	675	93	1651

The comparison between the scenarios and the current situation (scenario 0) are shown in Fig. 2 for different indicators, including total cultivated area, cultivated area of crops, amounts of groundwater and surface water withdrawals, fertilizer consumption, improvement in the aquifer recharge, decrease in nitrogen leaching, total net benefit, and water consumption productivity. Note that the indicators are the ratio of optimal variables (total cultivated area, cultivated area of crops, fertilizer consumption, etc.) to the value of variables in the current situation. The results showed that the optimal cultivated areas in all scenarios were less than the scenario 0 area. This result as mentioned above could be due to consideration of allowable treated wastewater and groundwater withdrawal limits, limits of permissible changes in cultivated area, decreases in the total nitrogen leaching, and improvement of aquifer recharge. Scenarios 3,5 and 6 show more than 50% reductions. The reduction of total nitrogen leaching and the improvements in the aquifer recharge had important roles in reducing the above indicators.

The water supply from the treated wastewater was reduced in all scenarios in comparison to current situation. This is due to the treated wastewater withdrawal limits, which consequently reduce the total nitrogen leaching. The model by reducing significant supply from wastewater in scenarios 2, 4, and 6, attempt to reduce nitrogen leaching losses,

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[2] Objective Function (O.F.)

also chooses a cropping pattern which needs less nitrogen fertilizer andthus, nitrogen leaching in these scenarios are reduced.

In all scenarios, expect scenarios 1, the groundwater withdrawal was decreased compared to the current situation, which could be considered an important outcome for aquifer recovery. In scenarios 1, the model maximizes groundwater withdrawal as much as possible, to maximize income to be achieved in the region. In Scenario 3, 5 and 6 which aimed to improve the aquifer recharge, the groundwater withdrawal was minimum. The model tried to improve the condition of the aquifer by decreasing water withdrawal from the aquifer, since its balance is currently negative.

The indicator for reduced fertilizer consumption is one of the important indicators for the environment. In all scenarios, the required fertilizer was significantly reduced in comparison with the current situation. In scenarios 7, selecting the optimum combination of cultivation and meeting the three objectives together allows the fertilization potential of the wastewater and groundwater to be used. This leads to a71% reduction in nitrogen fertilizer consumption and subsequently decreasing nitrogenous leaching losses and also leads to the optimal use of wastewater fertilization potential and reduced fertilizer purchase costs.

The water consumption productivity in the models was higher than the current situation in all the scenarios. Scenario 1 had the highest benefit and water use productivity due to the selection of a cropping pattern with more economical crops. After that, scenario 5 has the highest water productivity, which is due to the selection of a cultivation pattern with high profitability and also, decreasing crop cultivation area due to improvement of aquifer balance. Scenarios 2 and 6 showed a reduced benefit and water productivity because of a significant reduction in cultivated areas to minimize nitrogen leaching. Scenarios 3 and 4 showed a reduced benefit because of a significant reduction in cultivated areas to maximize the aquifer recharge. In scenario 7, both indicators of water use productivity as well as net benefit has increased relative to the current situation.

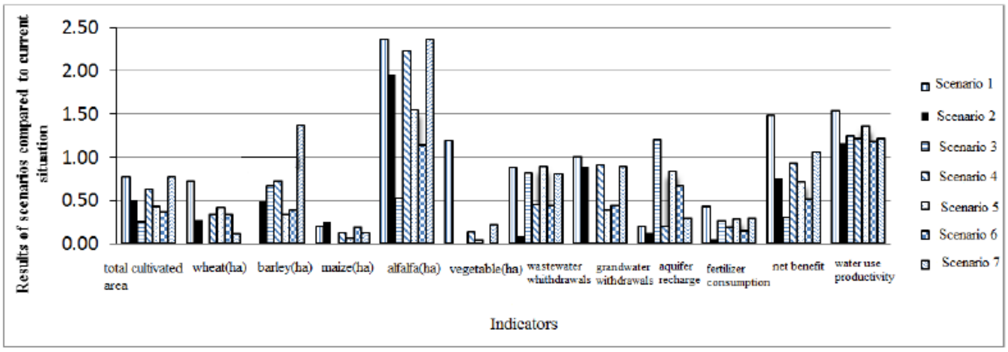

Figure 2. The results of seven scenarios indicators

8. CONCLUSIONS

The results of the three-objective optimization model for quantitative-qualitative conjunctive use of treated wastewater and groundwater showed that modifying the cropping patterns and optimal conjunctive use, in addition to efficient use of the fertilizer potential of groundwater and wastewater, reduced the amount of nitrogen leaching into the soil and groundwater and also improved the aquifer balance. Furthermore, the net profit from agricultural production, as well as the water consumption productivity, increased.In order to integrated management of wastewater and irrigation water resources, the nonlinear three objectives optimization model was run for 7 scenarios (one-objective, two-objectives and three-objectives) in water year 2012-2013 in Varamin irrigation network.

The results of various scenarios showed that based on net benefit and water use productivity index, only in first and seventh scenario, net benefit increases compared to current situation. In the first scenario, because the only goal is to raise benefit and no other indicators, such as control of leaching and improved aquifer recharge, are not improved, so this scenario, could not be selected as the best scenario, however, this scenario could be more desirable for the farmers. In the seventh scenario, 23 percent reducing of cultivated area and 71 percent reduction of nitrogen fertilizer consumption and 13 percent reduction of conjunctive withdrawals of wastewater and groundwater, 6 percent increasing of net benefit, 29 percent increasing of aquifer recharge and 22 percent increasing of water productivity have been achieved. Therefore, seventh scenario was chosen as the best scenario. Integrated quantitative-qualitative management of irrigation water and wastewater resources in irrigation and drainage networks in terms of controlling the environmental impacts of nitrogen leaching into the soil and groundwater environment is an important issue, and it is recommended that planning of water and fertilizer resources of cropping pattern using quantitative-qualitative integrated optimization models to be seen together until the economic, water resources and environmental goals of irrigation and drainage networks, to be realized simultaneously. The proposed three-objective model of this paper can be used to improve the performances of agriculture, environment and water resources management in irrigation and drainage networks.

9. REFERENCES

Al Khamisi, S. A., Prathapar, S. A., & Ahmed, M., 2013 Conjunctive use of reclaimed water and groundwater in crop rotations. J. Agricultural Water Management, v. 116, 228-234.

Alizade, A., Majidi, N., Ghorbani, M., & Mohammadian, F., 2012 Cropping pattern optimization with the aim of balancing the groundwater resources (Case Study plain of Chenaran-Mashhad) Iranian Journal of Irrigation & Drainage v. 6, no. 1, 55-68.

Anonymous, 2013 Qualitative and pollution studies in Varamin. quantitative-qualitative mathematical model of Varamin Alluvial aquifer.

Banihabib, M., hosseinzade, M., &Oladgharegoz, M. 2015 A nonlinear model development of water allocation and cropping pattern in deficit irrigation condition (Case study: Tehran and Alborz Provinces).J. Iranian Water Research, v. 9, no. 4, 139-143.

Clifford, & Snyder. 2011 NITROGEN IN SOIL ORGANIC MATTER – HOW MUCH IS RELEASED IN YOUR FIELD?: International Plant Nutrition Institute (IPNI). [Online].Available at https://ipni.net.Norcross, Georgia 30092-2844 USA.

Davijani, M. H., Banihabib, M., Anvar, A. N., & Hashemi, S. 2016 Multi-objective optimization model for the allocation of water resources in arid regions based on the maximization of socioeconomic efficiency. J. Water Resources Management, v. 30, no. 3, 927-946.

Ghasemi, S., Danesh, S., & Alizade, A. 2011 Evaluating the potential of providing irrigation water and fertilizer values of wastewater of urban wastewater treatment plants: Journal of Water and Soil v. 25, no. 5, 1172-1183.

Joodavi, A., Zare, M., & Mahootchi, M. 2015 Development and application of a stochastic optimization model for groundwater management: crop pattern and conjunctive use consideration. Stochastic environmental research and risk assessment, v. 29, no. 6, 1637-1648.

Karamouz, M., Rezapour Tabari, M. M., Kerachian, R., & Zahraie, B. 2005 Conjunctive use of surface and groundwater resources with emphasis on water quality, Impacts of Global Climate Change, 1-12.

Karamouz, M., Zahraie, B., Kerachian, R., & Eslami, A. 2010 Crop pattern and conjunctive use management: a case study. J. Irrigation and Drainage, v. 59, no. 2, 161-173.

Khare, D., & Jat, M. 2006 Assessment of conjunctive use planning options: A case study of Sapon irrigation command area of Indonesia. J.Hydrology, v. 328, no. 3, 764-777.

Oron, G., Gillerman, L., Bick, A., Mnaor, Y., Buriakovsky, N., & Hagin, J. 2007 Advanced low quality waters treatment for unrestricted use purposes: imminent challenges. J. Desalination. v. 213, no. 1-3, 189-198.

Ramos, T., Šimůnek, J., Gonçalves, M., Martins, J., Prazeres, A., & Pereira, L. 2012 Two-dimensional modelling of water and nitrogen fate from sweet sorghum irrigated with fresh and blended saline waters. J. Agricultural Water Management, v. 111, 87-104.

Singh, A. 2012 Optimal allocation of resources for the maximization of net agricultural return. J. Irrigation and Drainage Engineering, v. 138, no. 9, 830-836.

Singh, A., & Panda, S. N. 2013 Optimization and simulation modelling for managing the problems of water resources. J. Water resources management, v. 27, no. 9, 3421-3431.

Singh, D., Jaiswal, C., Reddy, K., Singh, R., & Bhandarkar, D. 2001 Optimal cropping pattern in a canal command area. J. Agricultural Water Management, v. 50, no. 1, 1-8.

Soltani, E., Soltani, A., Zeinali, E., & Dastmalchi, A. 2013 Simulation of nitrogen losses from wheat fields in Gorgan using CropSyst model. J. Soil and water conservation, v. 20, no. 4, 145-163.

USEPA, 1997 Estimated national occurrence and exposure to Nitrite in public drinking water supplies.

WHO, 2006 Guidelines for the safe use of wastewater, excreta and greywater, World Health Organization.

Yousefi, M., RahimiKhob, A., Soltani, J., Banihabib, M. E., & Soltani, E. 2016 Assessment of Nitrogen Leaching of Cropping Pattern by Soil Nitrogen Balance Equation (Case Study: Varamin Irrigation and Drainage Network), 2ndWorld.Irrigation Forum, Chiang Mai, Thailand.