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Investigation of Data Mining Method in Optimal Operation of Eyvashan Earth Dam Reservoir Based on PSO Algorithm

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ABSTRACT

Today, Metaheuristic Algorithms are considered one of the most important and appropriate methods to achieve good solutions and optimization. In this research, a Particle swarm optimization (PSO) algorithm with a nonlinear objective function has been used to optimize the reservoir water allocation of the Eyvashan earth dam based on the reservoir water balance for irrigation periods (2014-2020). The results show that the highest agricultural demand downstream of the dam in June was 8.96 (MCM). The amount of reservoir release calculated by the model to meet the water requirement downstream of the dam (37.80MCM) is much more optimal than the total amount of downstream needs (41.03MCM). Also, the minimum amount of water shortage due to severe drought while controlling floods is easily possible due to the reservoir's useful volume and the reservoir's annual flow. According to the PSO model, in each period of operation of Eyvashan earth dam, about 7.9% can be saved in the reservoir release for the needs of downstream agriculture in the months of high water consumption in summer.

Keywords: PSO algorithm, optimization, Eyvashan earth dam, Metaheuristic methods

1. INTRODUCTION

In recent years, with the increase in population, the increasing need for water, limited water resources, and its uneven distribution and excessive consumption of these limited resources have increased the need for water resources. Iran is located in one of the driest regions of the world, and the average rainfall of the country is 250 mm (one-third of the world average), about 71% of which is directly out of reach due to the high potential for evaporation in the country. Therefore, with increasing population and limited quantities of water resources, targeted management of water resources is increasingly essential. By predicting the reservoir volume of dams, in addition to managing the exploitation of required water resources, natural disasters such as floods and droughts can be predicted and controlled. For optimal operation of the dam reservoir, the number of objective functions and variables required to meet the designed need must be optimized. In recent years, various methods and algorithms have been used for optimization, which has also made significant progress. In this regard, metaheuristic methods have been considered as one of the most important and appropriate methods to achieve good and close to absolute optimal solutions. Among the metaheuristic methods, the particle swarm optimization

(PSO) algorithm, modeled on the mass movement of birds and fish, can be used in many engineering optimization problems, such as dam reservoir optimization. This method, with its ability to adapt to unforeseen changes, is a good alternative to experimental and regression models for estimating the behavior of water resources. Shourian and Mousavi (2006), in a study, used the PSO algorithm for the optimal operation of the Bakhtiari Dam reservoir for hydroelectricity and presented their reports based on the output of this model [1]. Ye et al. (2019), used the PSO algorithm for wastewater treatment network planning. The results indicated PSO algorithm the better performance with the proposed approach than the genetic algorithm in terms of efficiency in finding the solutions, computational requirements, and overall costs of the network [2]. Li et al. (2020), studied the groundwater contamination source identification based on a hybrid particle swarm optimization-extreme learning machine The results showed that compared with the ELM, the PSO-ELM could establish the surrogate model with higher accuracy [3]. Cyriac and Rastogi (2013) investigated the basic concepts and successful application of the PSO algorithm in water resource optimization. Some studies have also been performed on the application of different methods for operation optimization under drought conditions [4]. Joodavi et al. (2020), studied the Deriving optimal operational policies for off-stream man-made reservoirs considering conjunctive use of surface- and groundwater at the Bar dam reservoir. The results showed the reliability of conjunctive use of surface and groundwater in water-scarce areas by exploiting reservoir infrastructures with relevant leakage losses [5]. Taghian et al. (2014) presented a hybrid model of MOPSO and fuzzy logic to optimization of reservoir operation and to minimize drought effects. The results showed that the developed model had a good performance on reservoir operation in drought and normal conditions [6]. Yousefi et al. (2018), used the PSO algorithm for conjunctive of treated wastewater and groundwater. The results showed using the MOPSO algorithm, forming Pareto front, and then using TOPSIS to select the optimal solution from among the non-dominated solutions showed that the benefits obtained from optimizing cropping patterns, water consumption productivity, and aquifer recharge were increased by 7%, 47%, and 15%, respectively Researchers investigated the hybrid SWMM and particle swarm optimization model for urban runoff water quality control by using green infrastructures (LID-BMPs) [7]. Taghizadeh et al. (2021), studied the hybrid SWMM and particle swarm optimization model for urban runoff water quality control by using green infrastructures (LID-BMPs). Results showed that by the application of these single BMP types, the whole basin’s concentrations of total suspended solids (TSS), total phosphorous (TP), and total nitrogen (TN) were reduced by 97%, 68%, and 72%, respectively [8]. Xiang et al. (2017), studied the seepage safety monitoring model for an earth rock dam under the influence of high-impact typhoons based on a particle swarm optimization algorithm. The results showed that the present model has a higher fitting accuracy and can simulate the uprush feature of the seepage pressure during the typhoon perfectly [9]. Zhang et al. (2011) used the improved PSO algorithm (IPSO), which is a combination of PSO and genetic algorithms, to optimize hydropower in a multi-reservoir system. The convergence time of the IPSO algorithm was better than the PSO algorithm and comparable to the dynamic sequential approximation algorithm (DPSA). The results showed that this algorithm could have more effective and efficient results [10]. The GA model was developed by Paliwal et al. (2017) for Jayakwadi-I reservoir, Maharashtra, India, to derive optimal releases and performance indices [11]. The PSO algorithm is an effective optimization method developed in recent years with the advantages of fast convergence and high accuracy (Kong et al., 2017) [12]. Yang et al. (2019) studied improved PLS and PSO methods-based back analysis for the elastic modulus of the dam. The results showed that the statistical model established by BE-PLS has high fitting precision and that the new PSO algorithm improves the global optimization ability and convergence speed and can avoid falling into the local solution [13]. Mehdipoor et al. (2011) state that the main reason for using meta-exploration algorithms in multi-objective problems is to compare near-optimal solutions. They used PSO multi-objective algorithm to optimize the operation of the Bazaft Dam reservoir and provided optimal answers for easier decision-making and selection [14]. Rezaei et al. (2017) studied an alternative multi-objective PSO algorithm for conjunctive water use management. The results showed proposed algorithm is capable of finding the unique optimal solution on the Pareto-front to facilitate decisions to address large-scale optimization problems [15]. Mirzaie et al. (2021), investigated the fuzzy particle swarm optimization for conjunctive use of groundwater and reclaimed wastewater under uncertainty. The results indicated that the net benefit increased up to 16% without increasing the cultivated area in the fuzzy MOPSO model [16]. Bilal et al. (2020) Have conducted studies on reservoir optimization using the PSO algorithm [17]. The most important advantages of PSO can be simple concepts, easy to use, good ability to control parameters and computational efficiency. Given the research background, the particle swarm algorithm is efficient in dam reservoir optimization. Therefore, this research has attempted to optimize the Eyvashan earth dam reservoir using the particle swarm algorithm (PSO).

2. MATERIALS AND METHODS

2.1. EYVASHAN EARTH DAM- CASE STUDY

Eyvashan earth dam has located 1.5 km from the upstream of the village of Eyvashan and about 57 km from Khorramabad in the coordinates of 48°49'2" and 33°28'31" degrees north, located on the Hood River. The Hood River drainage basin area up to the axis of the Eyvashan earth dam is 120 km2. The dam is a rock fill-earth dam type with a vertical clay core that has a height of 62 m (1804 masl, meters above sea level), a crest height of 1868 masl, and a normal elevation of 1864 masl. Fig 1, presents the location and reservoir of Eyvashan earth dam.

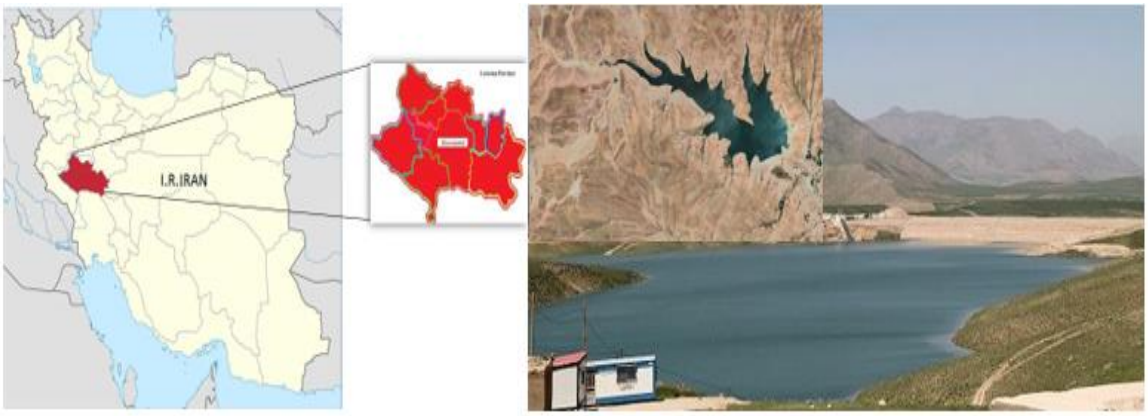


Figure 1. The location and reservoir of Eyvashan earth dam

The volume of the reservoir in the normal water level of the dam is 51.75 MCM, and the area of the lake at a normal level is 2.3 km2. Also, the volume of the reservoir at the level of 1817 (masl) in the Minimum operating level of the dam is 1.5 MCM. In addition, the volume of adjustable water is 45 MCM.

2.2. SURFACE-VOLUME RELATIONSHIP OF EYVASHAN DAM RESERVOIR

The water level in the dam reservoir is considered a function of water storage volume. According to the surface-volume curve (Figure 2), Equation 1 for the Eyvashan dam reservoir is a nonlinear function and of the second degree.

$$A_t = 5.44S_t^2 + 9.02S_t - 1.138, (R^2 = 0.998) \quad (1)$$

Concerning (1), At is the area of water in the dam reservoir in period t, and St is the volume of water storage in the dam reservoir in period t. Since the coefficient R2 has an acceptable value and close to 1, so the analysis of the reservoir can be done with high confidence. Figure 2 shows the area, volume, and height of the Eyvashan earth dam curve.

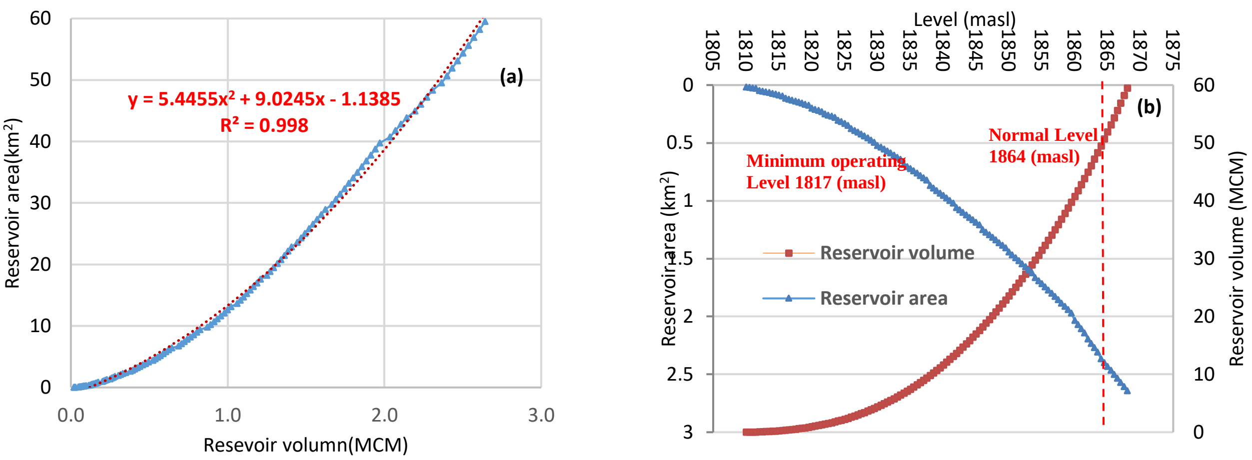


Figure 2. a) Surface and volume relationship b) Level and volume of Eyvashan earth dam reservoir in different levels

2.3. ANNUAL INFLOW DISCHARGE OF EYVASHAN EARTH DAM

To evaluate the annual discharge and to identify the wet and drought periods of the study area, the long-term rainfall statistics of Dehno, Zagheh, and Kakareza stations were examined. Table 1 shows the annual rainfall figures of the regional stations in the joint period 1990 to 2020. According to this table, it can be said that 2018-2019 was the rainiest year and 1996-1997 were the least rainy years in the region.

Table 1. Annual rainfall in different stations of the region (2020-1990)

Station	Dehno	Zagheh	Kakareza
1996-1997	262.1	257.5	146
2018-2019	654	985	681.7
MXR (mm)	680	1020	773
MIR (mm)	258	257.5	137
MER (mm)	458	638	488.8
MAX-MIN (mm)	422	762.5	636

MXR: Maximum Rainfall, MIR: Minimum Rainfall, MER: MER: Mean Rainfall

According to Table 2, the average annual discharge and flow of the river at the site of Eyvashan Dam is equal to 1.28 cubic meters per second, which is equivalent to a volume flow of 41.5 million cubic meters per year. Figure 3 shows the amount of discharge to the reservoir of Eyvashan Dam in the years 1970 to 2000.

Table 2. Average long-term flow rate of the inlet of Eyvashan dam reservoir

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annually
QMAX (m3/s) 1976-1977	1.08	1.91	4.24	6.50	4.74	1.96	0.55	0.29	0.17	0.23	0.63	0.95	1.94
QMIN (m3/s)-1996-1997	0.29	0.52	1.16	1.77	1.29	0.53	0.15	0.08	0.05	0.06	0.17	0.26	0.53
QMEN (m3/s)	0.7	1.24	2.75	4.22	3.08	1.27	0.36	0.19	0.11	0.15	0.41	0.62	1.26

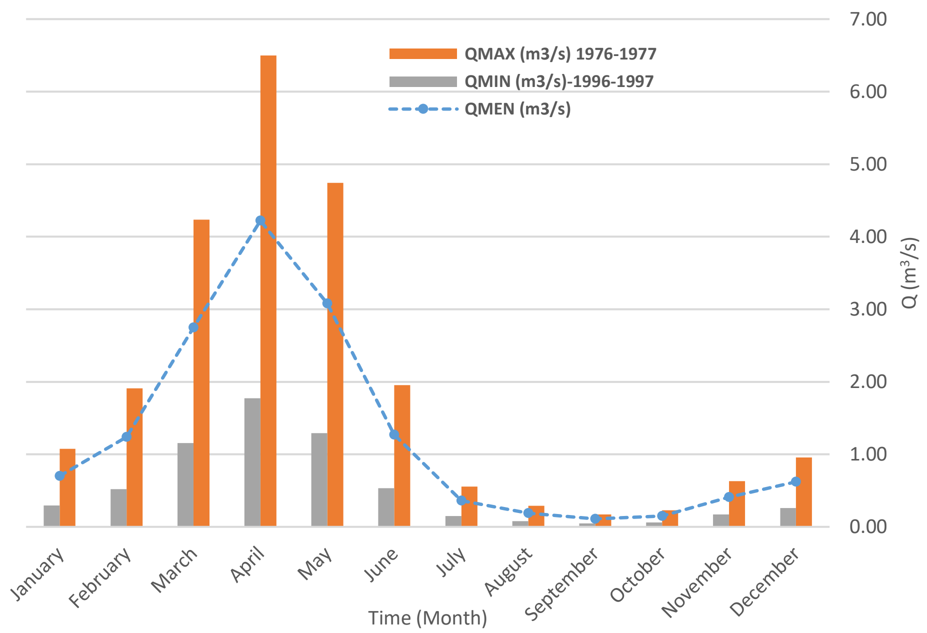


Figure 3. Inflow rate of Eyvashan earth dam (1990-2020)

A trapezoidal channel with a length of about 324 meters has been used to guide the river flow of the diversion inlet structure. The level of the catchment floor at the minimum operating level is equal to 1817 (masl) meters above sea level, which is connected to the Calvert inlet floor at 1809 (masl). The maximum discharge capacity of the deviation system is 20 m3/s. The amount of monthly inflow water to the dam reservoir from 2014 to 2020 is shown in Figure 4.

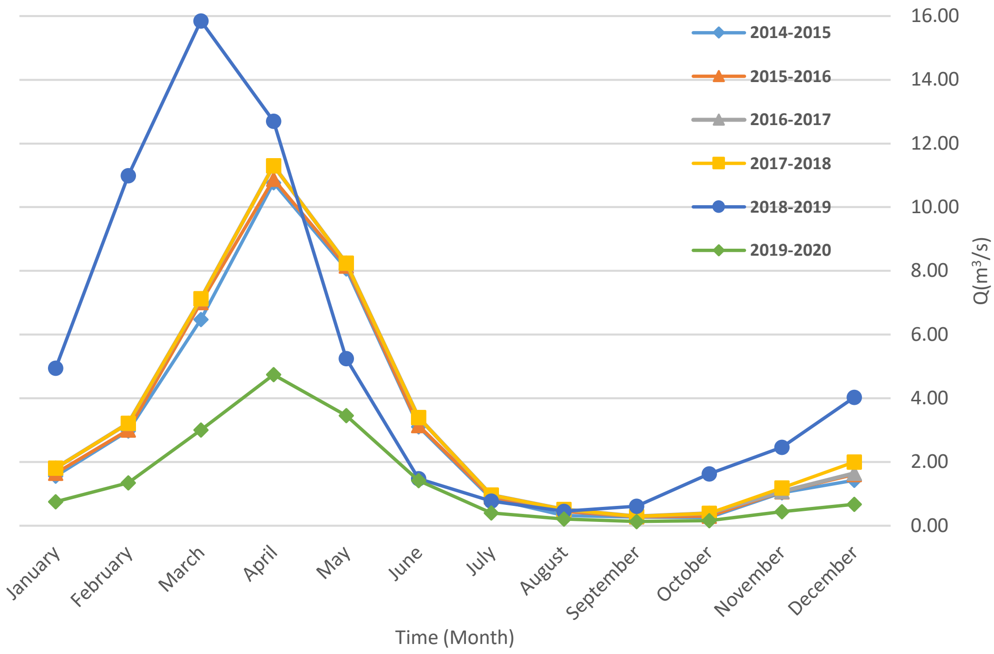


Figure 4. Volume of monthly inflow of Eyvashan earth dam in the statistical period 2014 to 2020

The highest volume of inputs to the reservoir of Eyvashan earthdam in 2018-2019 has occurred due to wet periods and floods.

2.4. AGRICULTURAL WATER NEEDS OF LANDS DOWNSTREAM OF EYVASHAN EARTH DAM

The main purpose of constructing the Eyvashan earth dam was to provide safe agricultural water for rainfed and susceptible lands in the amount of about 5300 hectares. The water requirement of the lands downstream of Eyvashan earth dam includes the lands of Eyvashan and Chaghalvandi plain, which according to the crops and crop area (wheat, barley, alfalfa, etc.), the average water requirement of Eyvashan plain is 23.42 (MCM) for Chaghalvandi plain. 17.61 (MCM). It should be noted that the amount of evaporation, infiltration and unauthorized extraction losses in the water transfer route from the dam to the network has also been taken into account. Therefore, the gross agricultural water requirement of the lands downstream of Eyvashan earth dam, according to the type of cultivation, has been met at a total of 41.03 (MCM) per year (Table 3).

Table 3. Monthly distribution of water needs of agricultural lands of Eyvashan and Chaghalvandi plains

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annually
Water requirement of agricultural farms (MCM)-Eyvashan	0	0	0	0	1.77	6.81	5.08	4.42	2.73	2.61	0.00	0.00	23.42
Water requirement of agricultural farms (MCM)-Chaghalvandi	0	0	0	0	2.27	3.49	3.25	3.52	3.01	2.03	0.40	0.00	17.61

2.5. EVAPORATION

Evaporation values from the free surface of the water at the site of Eyvashan Reservoir Dam based on meteorological studies have been estimated to be 1306.2 mm per year. The monthly distribution of evaporation from the free surface of the water is shown in Table 5. The highest evaporation at the dam site was observed in July and the lowest in December. About 60% of evaporation is related to the 4 months of June, July, August, and November. According to the results, the rate of evaporation at the normal level of 1864 (masl) will be equal to 2.9 (MCM) per year. Table 4.

Table 4. Evaporation rate from the free surface water at Eyvashan earth dam

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annually
Evaporation from the free surface water (mm)	36.8	50.2	69.4	98.8	142.5	188.6	205.8	190.9	150.8	90.5	48.7	33.2	1306.2
Evaporation from the free surface water (MCM)	0.08	0.11	0.15	0.22	0.32	0.42	0.46	0.42	0.33	0.20	0.11	0.07	2.9
Percent (%)	2.82	3.84	5.31	7.56	10.91	14.44	15.76	14.61	11.54	6.93	3.73	2.54	100

2.6. ENVIRONMENTAL NEEDS

The construction of a dam on the river will change the flow of water downstream, resulting in major environmental problems. Considering the ecological needs of various aquatic species of the river and also the need to provide a minimum flow after achieving the initial goals, estimating this amount is necessary to maintain the aquatic environment and generally protect the aquatic ecosystem downstream of the dam. In the present study, the modified Tennant hydrological method has been used to calculate the minimum environmental flow of the Herod River. According to the river discharge, February to July is considered a wet period, and August to January is considered a drought period. Therefore, the annual environmental requirement of the river downstream of Eyvashan Dam is equal to 0.58 million cubic meters per year (Table 5) .

Table 5. Minimum environmental requirements of Horod River on a monthly scale (MCM)

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annually
Q (MCM)	0.29	0.87	0.87	0.87	0.87	0.87	0.87	0.29	0.29	0.29	0.29	0.29	0.58

2.7. ANNUAL BEHAVIOR OF EYVASHAN EARTH DAM STORAGE RESERVOIR SYSTEM

Surface water storage systems are required to balance the Demand and Inflow to the reservoir during water scarcity during the critical period in the recorded flow data. For this reason, the design of surface water reservoirs is often done by one of the techniques called General Critical Period Methods. The critical period is the interval when a storage reservoir reaches a full state from the empty state without any full-filling or overflow occurring at this distance. As a result, the critical period represents a series of very low flows among the recorded flow data. In general, if the shortage between the inlet flow and the water requested by the project coincides with this period, then the use of water stored in the reservoir to meet this shortage is necessary. Figure 5 shows the critical period of the Eyvashan earth dam.

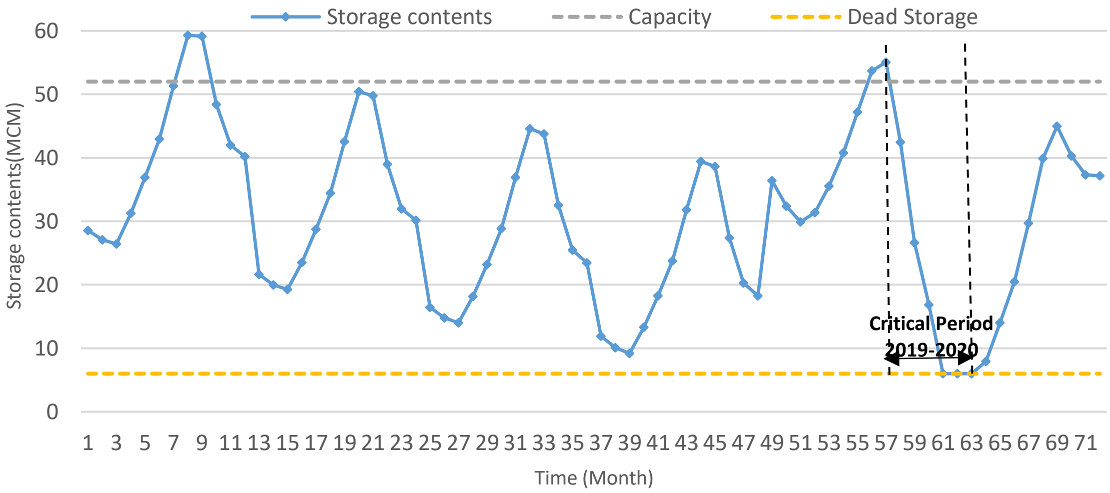


Figure 5. Critical period of Eyvashan earth dam (2014-2020)

Figure 5 shows the general trend of the water storage reservoir of Eyvashan dam, which has reached the lowest amount of reserve in 2019-2020.

2.8. PSO ALGORITHM

James Kennedy, a social psychologist, and Russell C. Eberhart [18], an electrical engineer, are the main proponents of the PSO algorithm. They initially intended to use social models and existing social relations to create a type of computational intelligence that did not require special individual abilities. Their first simulation was performed in 1995, which led them to simulate the behavior of birds to find grain. The PSO algorithm is one of the evolutionary algorithms inspired by real-world models. Or they are an issue, and they form a crowd. These particles move in the problem space and try to find the optimal solution in the search space based on their individual experiences and collective experiences. This method is not much affected by the dimensions and non-linearity of the problem and has good results in static, noise, and constantly changing environments. These features, in addition to the simplicity of implementation, no need for objective function continuity, and the ability to adapt to a dynamic environment, make this algorithm used in many different fields. In this algorithm, the velocity and new location of each particle based on the position of the best particle in the group and the best location experienced by the particle itself are obtained based on the following formulas.

$$V(t+1) = W \times V(t) + C_1 \times R_1 \times [Pbest_i - X(t)] + C_2 \times R_2 \times [Gbest_i - X(t)] \quad (1)$$

$$X(t+1) = X(t) + V(t+1) \quad (2)$$

In these relationships, V(t) and V(t + 1) are particle velocities in t and t + 1 iterations, R1 and R2, respectively. Between zero and two, Pbesti is the best position experienced by all particles, and X(t) and X(t + 1) are the previous and current positions of the particle, respectively. W is the coefficient of inertia defined by Equation (3).

$$W = (W_{max} - W_{min}) \times \left(\frac{Iter_{max}}{Iter_{min}}\right) + W_{min} \quad (3)$$

Wmax and Wmin are the maximum inertia coefficient and the minimum inertia coefficient, respectively, which are considered 0.9 and 0.2 in this study. Iter is the number of iterations and Itermax is the maximum number of iterations. The flowchart of PSO is shown in Fig6.

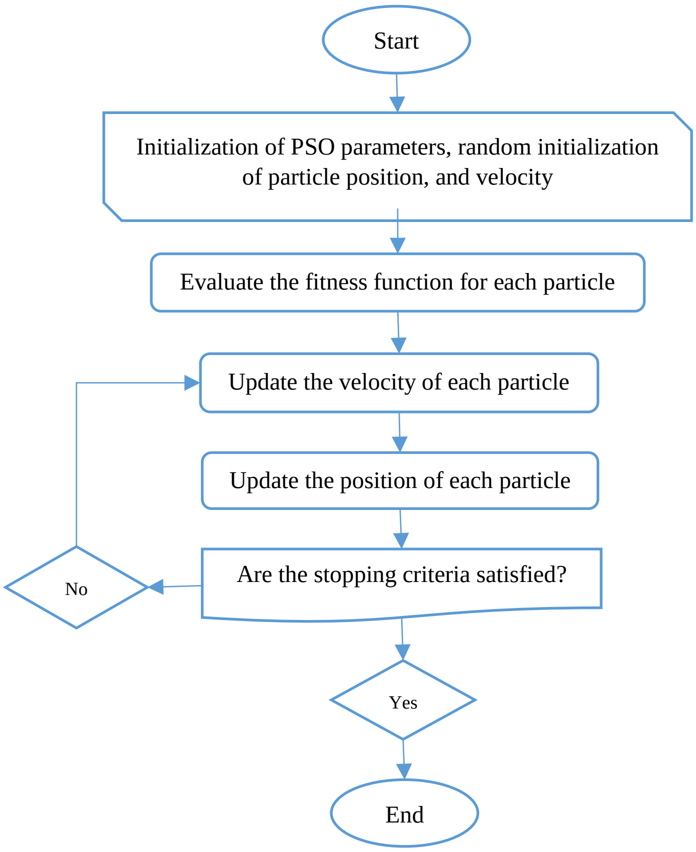


Figure 6. Basic PSO Algorithm Flowchart

2.9. MATHEMATICAL MODEL OF EYVASHAN DAM RESERVOIR OPERATION

The output value and volume of the reservoir are decision and state variables, respectively. The purpose of optimization is to minimize the severity of agricultural shortages during the operation period. Objective model of the optimization model to evaluate the resilience of the Eyvashan dam reservoir to supply agricultural water to the project lands, the reservoir operation simulation model has been used. When operating the dam reservoir, encounter various problems such as flood control, water supply downstream, electricity generation, and environmental objectives; the relationship between these objectives is not linear and therefore the use of resource systems. Water has many complexities and problems in decision-making. This model is based on the water balance of the reservoir with a nonlinear objective function according to Equation 4.

$$Minimum(f) = \sum_{t=1}^{t} \left(\frac{R(t)-D(t)}{D_{\max}}\right)^2 \qquad t=1,2,3,\ldots 72 \tag{4}$$

In all stages of optimizing the operation of the reservoir, a mass balance must be established between the input and output values and the storage volume of the reservoir. The continuity relationship used in this study is Equation 5. Due to the small amount of leakage water volume from the dam reservoir relative to the reservoir volume, the continuity relationship is considered from this parameter, and it is assumed that the minimum environmental requirement of the river (DE (t)) is fully met (100%). Input information to the model includes river flow volume, evaporation rate, and required volumes monthly.

$$S(t+1) = S(t) + Q(t) + PP(t) + EV(t) - Spill(t) - Re(t) - De(t) \tag{5}$$

The rate of evaporation from the reservoir's surface and the amount of precipitation at the reservoir's surface to calculate the amount of reservoir storage per month is based on Equation 6.

$$\begin{gathered} \{PP(t) = P(t) \times A(t)\} \\ \{EV(t) = E(t) \times A(t)\} \end{gathered} \tag{6}$$

Equation 7 also shows the limitations of the decision variable.

$$\begin{gathered} S_{\min} \le S(t) \le S_{\max} \\ 0 \le R(t) \le D(t) \end{gathered} \tag{7}$$

The constraints on the overflow volume are in Equation 8:

$$Spill(t) = \begin{Bmatrix} S(t+1) - S_{\max} \ldots\ldots\, if \ldots\ldots S(t+1) \succ S_{\max} \\ 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\, if \ldots\ldots S(t+1) \prec S_{\max} \end{Bmatrix} \tag{8}$$

Penalty function related to reservoir volume (9):

$$Penalty_{1i} = \begin{Bmatrix} \sum_{t=1}^{t} \left(\frac{s_{i,t} - s_{\min i}}{s_{\min i}}\right)^2 \ldots\ldots if \ldots\ldots s_{i,t} \prec s_{\min i} \\ \sum_{t=1}^{t} \left(\frac{s_{i,t} - s_{\max i}}{s_{\max i}}\right)^2 \ldots\ldots if \ldots\ldots s_{i,t} \succ s_{\max i} \\ 0 \ldots\ldots if \ldots\ldots s_{i,t} \ge s_{\min i} \ldots\ldots and \ldots\ldots s_{i,t} \le s_{\max i} \end{Bmatrix} \tag{9}$$

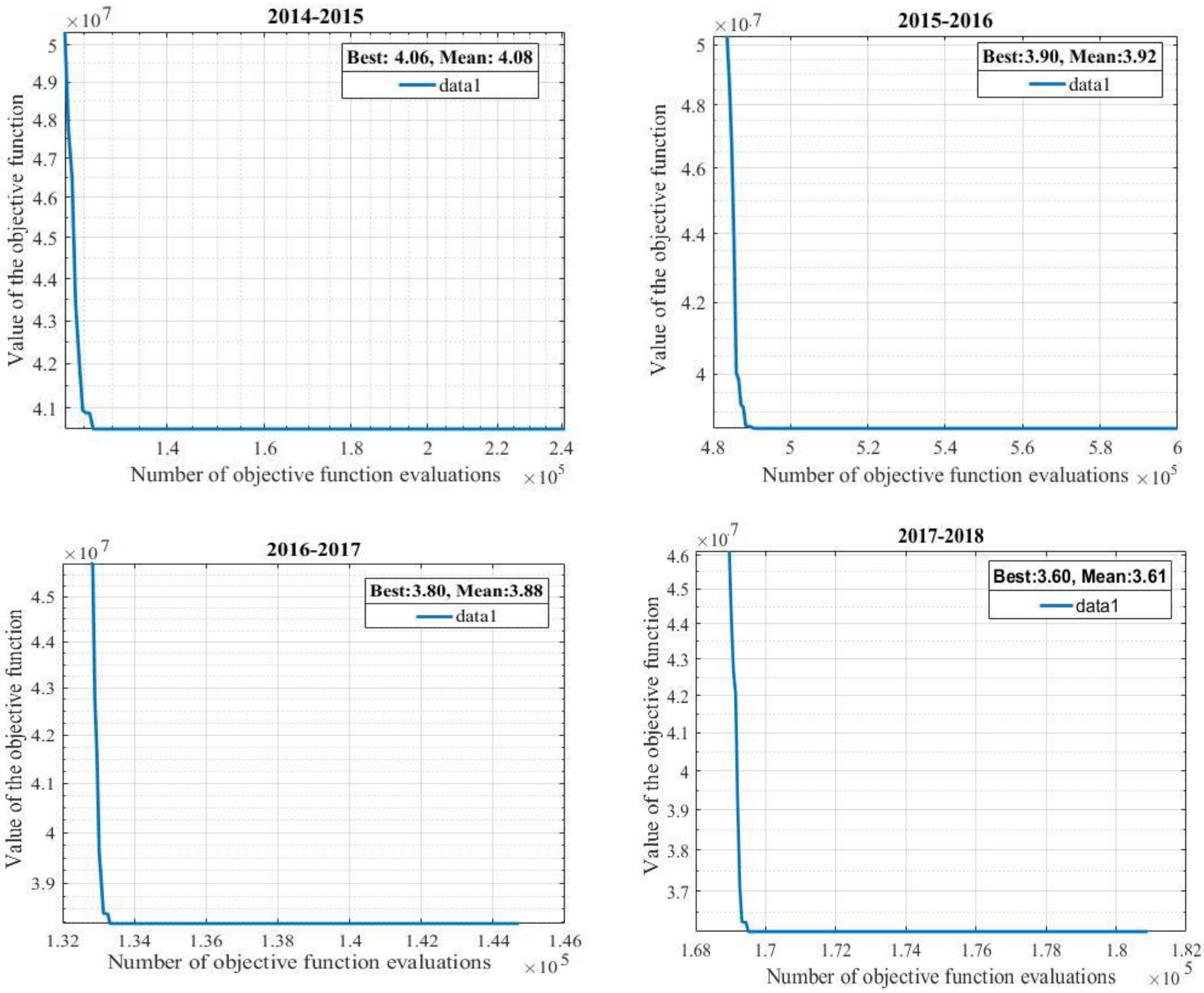
Release penalty function (10):

$$Penalty_{2i} = \begin{Bmatrix} \sum_{t=1}^{t} \left(\frac{Re_{i,t} - De_{\min i}}{De_{\min i}}\right)^2 \ldots\ldots if \ldots\ldots Re_{i,t} \prec De_{\min i} \\ \sum_{t=1}^{t} \left(\frac{Re_{i,t} - De_{\max i}}{De_{\max i}}\right)^2 \ldots\ldots if \ldots\ldots Re_{i,t} \succ De_{\max i} \\ 0 \ldots\ldots if \ldots\ldots Re_{i,t} \ge De_{\min i} \ldots\ldots and \ldots\ldots Re_{i,t} \le De_{\max i} \end{Bmatrix} \tag{10}$$

In this relationship, f the objective function, $Re(t)$ the amount of water released monthly, $De(t)$ the amount of agricultural demand per month, D_{max} maximum monthly agricultural demand during the period of operation, S_{min} minimum reservoir volume, S_{max} maximum Reservoir volume, $S(t+1)$ The amount of volume of water stored in the reservoir in the period $(t+1)$, $S(t)$ The amount of volume of water stored in the reservoir in the period (t), $Q(t)$ The volume of inflow to the reservoir In the month (t), $PP(t)$ rainfall volume directly on the lake surface per month (t), $EV(t)$ volume of water evaporated from the lake surface per month (t), $Spill(t)$ volume of water overflow in Moon (t), $De_{min\,i,t}$ and $De_{max\,i,t}$, respectively minimum and maximum river environmental requirements per month (t), $A(t)$ Reservoir level that of relation (1) is obtained. Equation 5 is executed by the PSO algorithm in MATLAB programming software to determine the model that results in the least value of the objective function. After extracting these parameters by the PSO algorithm, the release rate from the reservoir is determined separately for different months of each wet, normal, and dry year.

3. RESULTS AND DISCUSSION

In this study, a multi-objective optimization model with a one-year planning horizon and monthly periods have been extracted to optimally exploit the Eyvashan Dam with the objective function of maximizing agricultural water allocation. For optimal operation of Eyvashan dam reservoir, assuming that the relationship between decision variables is linear, the PSO algorithm was implemented based on the governing relationships. The number of repetitions and the number of particles used in the dam have been used according to the results of trial and error and analysis of these results. As the number of particles increases, the results of the objective function improve. The criterion for deciding the number of iterations is to stabilize the value of the objective function. Objective variations with the number of objective function evaluations in the best execution of the particle collection algorithm are shown in Figures 7 and 8.



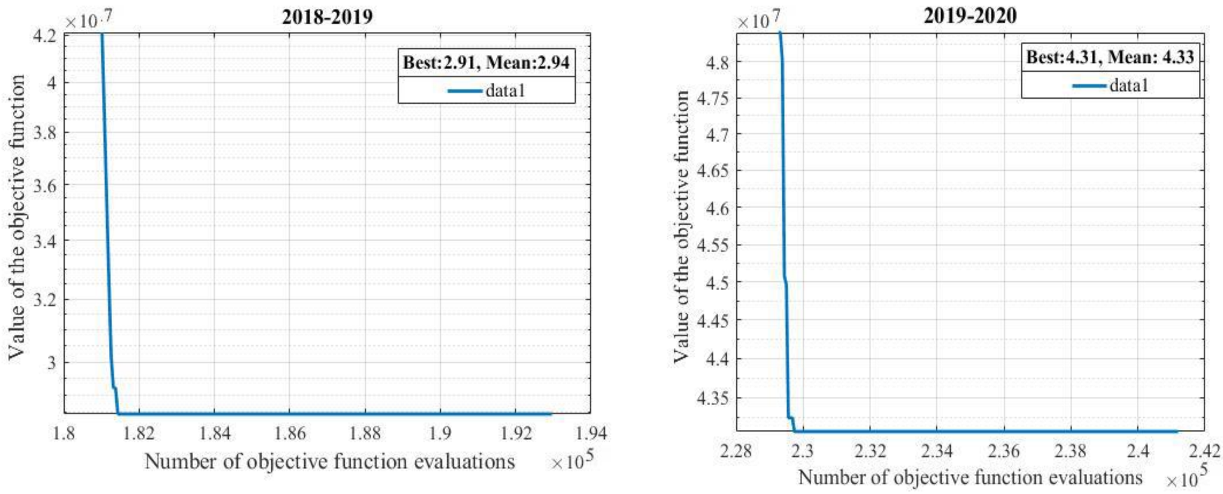


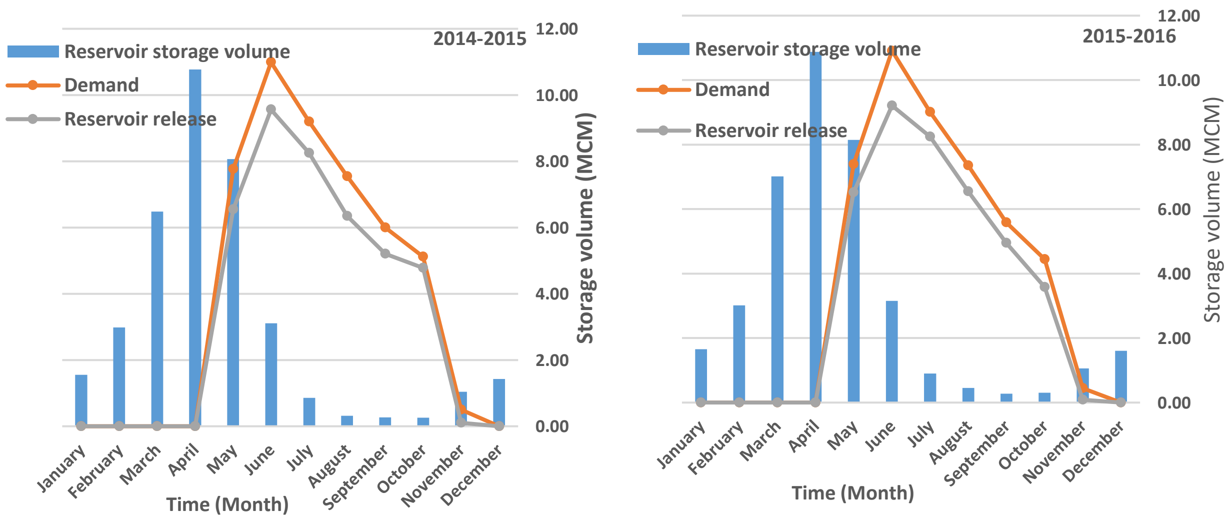
Figure 7. Changes in the objective function with the number of evaluations of the objective function in the best implementation of the PSO algorithm (2014-2020)

As can be seen from Figure 7, the mean line curve of the convergence trend of the objective function during the execution of the program was able to approach its optimal value. So, the optimal value of the objective function was not to change the convergence curve due to increasing the number of iterations. The high convexity of the convergence curves indicates the higher efficiency of the algorithm and the higher speed of finding the optimal answers and also shows that the defined constraints were appropriate for the problem. At the end of the graph, the changes of the objective function are very small and mean that the optimal answer is achieved, and there is no need to repeat more. In this way, the objective function is optimized for Eyvashan Dam after 200 repetitions. Also, the value of the objective function for 15 times of program execution in 200 times of repetition is shown in Table 6.

Table 6. Output results from particle swarm optimization model (PSO)

Year	Min	Max	Standard deviation	Number of particles	Number of repetitions
2014-2015	40.60	41.01	1445.6	300	200
2015-2016	39.01	39.50	856.7	300	200
2016-2017	36.05	36.43	875.7	300	200
2017-2018	38.09	39.19	542.5	300	200
2018-2019	43.07	43.53	760.2	300	200
2019-2020	29.21	29.66	261.2	300	200

As shown in Table 6, the best answer obtained from 10 times of program execution for different years of operation of the dam reservoir is shown. Figure 8 shows the release volume, reservoir inlet flow, and downstream reservoir requirements.



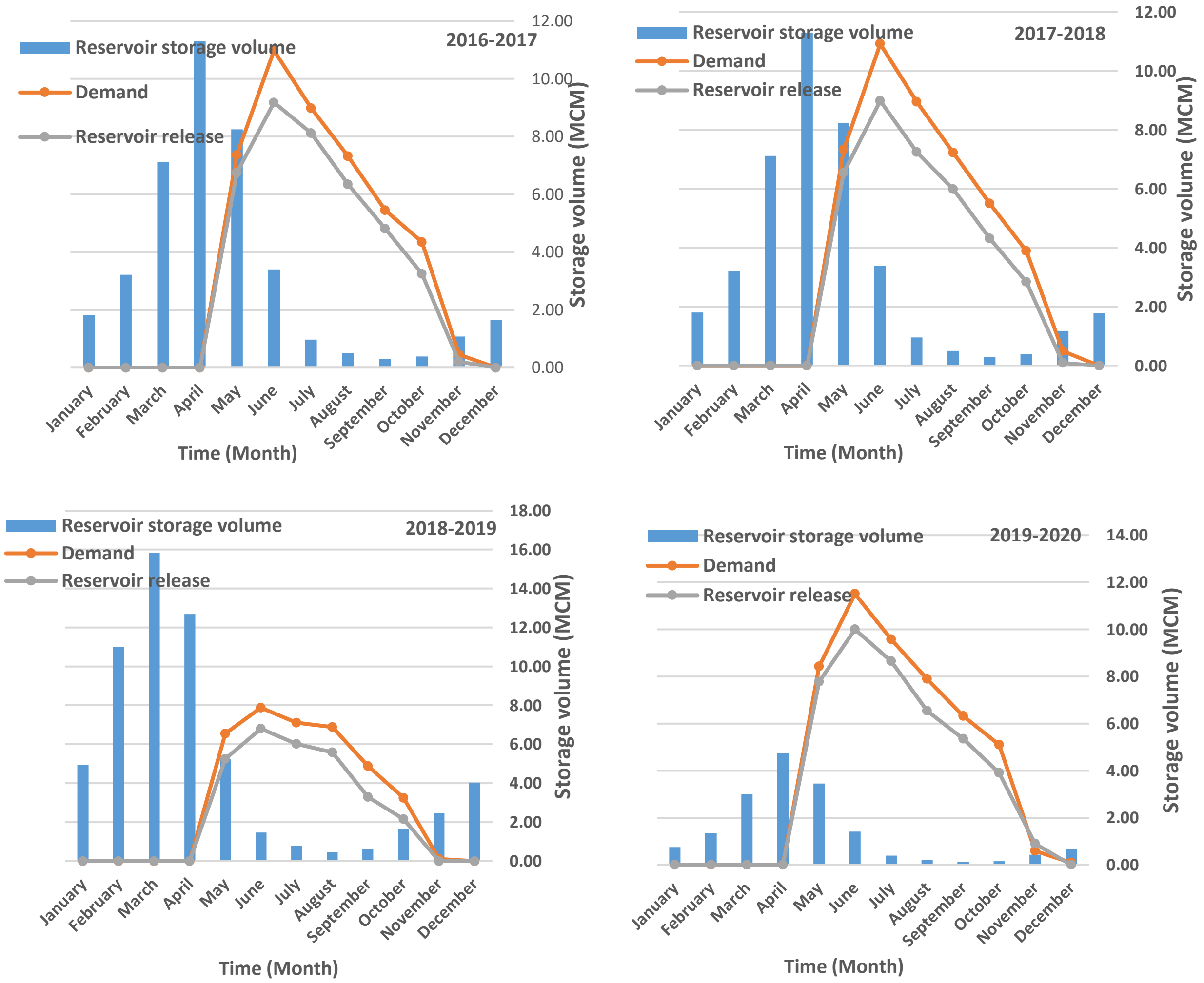


Figure 8. Reservoir release, reservoir storage volume, and downstream needs(demand) for each period (2020-2014)

To optimize the reservoir and water supply for agriculture and downstream environment, planning in the PSO algorithm has been done in such a way that the total monthly needs of agriculture and environment are met. Figure 9.

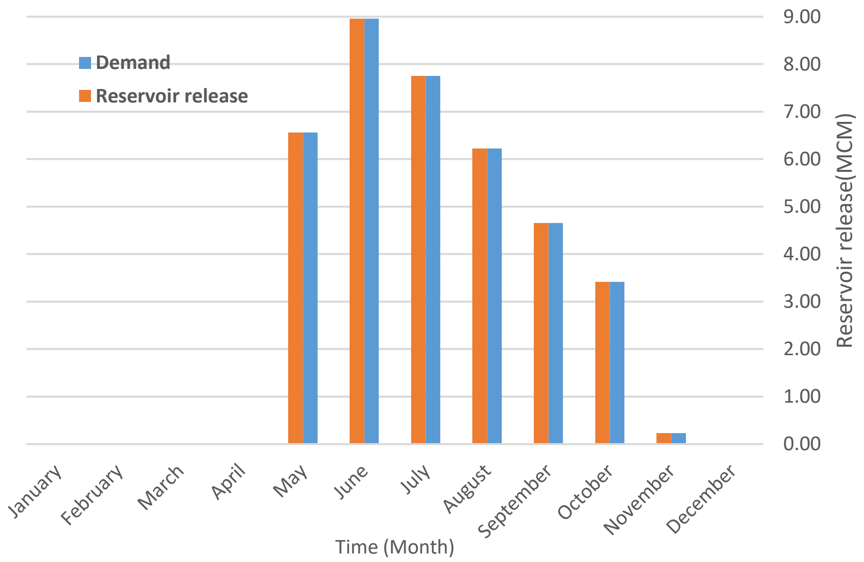


Figure 9. The optimal volume of monthly agricultural and environmental needs

According to Figure 9, the maximum downstream agricultural demand in June is 8.96 (MCM), and the lowest is in January, February, March, and April, which do not require water in these seasons. The results show that 37.80 (MCM) water storage per year is needed to meet the downstream water needs. Of course, changing the cultivation pattern and new irrigation and agriculture methods can significantly reduce this amount.

4. CONCLUSION

In this research, a particle swarm algorithm has been used for optimal utilization of the Eyvashan dam reservoir for downstream agricultural needs. For this purpose, first, the necessary initial information, including discharge data and the rate of evaporation from the free surface of the water at the dam site, was collected, and water needs in the study area including drinking, agricultural, environmental and industrial needs were determined. This information was used as input data for modeling. Accordingly, the best solution (minimum value) for the objective function for 6 water cycles was obtained. Considering the amount of annual inflow and also proper storage in rainy months, it can be said that the reservoir of Eyvashan Dam easily meets the downstream water needs. It should be noted that the useful volume of Eyvashan Dam with a dead volume fraction is about 50 million cubic meters, so in wet and wet years, the reservoir can be full, and in dry years this reserve can be used. Also, one of the advantages of this algorithm is the high speed of convergence of this algorithm in achieving optimal answers. In general, the PSO algorithm, according to the demand for water required by the downstream, is released from the reservoir, and by providing 100% of the monthly needs, it has been able to effectively supply the water required by the downstream for the entire desired period. In fact, according to the PSO model, about 7.9% can be saved in each operation period in releasing water for downstream agricultural needs in the months of high water demand. Using other optimization methods such as genetic algorithms and ants and comparing their results with each other can be a good suggestion for future research.

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CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

5. REFRENCES

[1] Shourian, M. Mousavi. G. Optimal planning of water resources allocation at the catchment level with the objectives of inter-basin water transfer. Second Conference on Water Resources Management, Isfahan University of Technology. 2006.

[2] Ye X, Chen B, Jing L, Zhang B, Liu Y. Multi-agent hybrid particle swarm optimization (MAHPSO) for wastewater treatment network planning. Journal of environmental management. 2019 Mar 15;234:525-36. [View at Google Scholar]; [View at Publisher]

[3] Li J, Lu W, Wang H, Fan Y, Chang Z. Groundwater contamination source identification based on a hybrid particle swarm optimization-extreme learning machine. Journal of Hydrology. 2020 May 1;584:124657. [View at Google Scholar]; [View at Publisher]

[4] Cyriac R, Rastogi AK. An overview of the applications of particle swarm in water resources optimization. InProceedings of Seventh International Conference on Bio-Inspired Computing: Theories and Applications (BIC-TA 2012) 2013 (pp. 41-52). Springer, India. [View at Google Scholar]; [View at Publisher]

[5] Joodavi A, Izady A, Maroof MT, Majidi M, Rossetto R. Deriving optimal operational policies for off-stream man-made reservoir considering conjunctive use of surface-and groundwater at the Bar dam reservoir (Iran). Journal of Hydrology: Regional Studies. 2020 Oct 1;31:100725. [View at Google Scholar]; [View at Publisher]

[6] Taghizadeh S, Khani S, Rajaee T. Hybrid SWMM and particle swarm optimization model for urban runoff water quality control by using green infrastructures (LID-BMPs). Urban Forestry & Urban Greening. 2021 May 1;60:127032. [View at Google Scholar]; [View at Publisher]

[7] Yousefi M, Banihabib ME, Soltani J, Roozbahani A. Multi-objective particle swarm optimization model for conjunctive use of treated wastewater and groundwater. Agricultural water management. 2018 Sep 30;208:224-31. [View at Google Scholar]; [View at Publisher]

[8] Taghizadeh S. Khani S, and Rajaee T. Hybrid SWMM and particle swarm optimization model for urban runoff water quality control by using green infrastructures (LID-BMPs). Urban Forestry & Urban Greening. May 2021, Volume 60, 127032. [View at Google Scholar]; [View at Publisher]

[9] Xiang Y, Fu SY, Zhu K, Yuan H, Fang ZY. Seepage safety monitoring model for an earth rock dam under influence of high-impact typhoons based on particle swarm optimization algorithm. Water science and Engineering. 2017 Jan 1;10(1):70-7. [View at Google Scholar]; [View at Publisher]

[10] Zhang J, Wu Z, Cheng CT, Zhang SQ. Improved particle swarm optimization algorithm for multi-reservoir system operation. Water Science and Engineering. 2011 Mar 1;4(1):61-74. [View at Google Scholar]; [View at Publisher]

[11] Paliwal VA, Ghare AD, Mirajkar AB. Single-Reservoir operation optimization using Jaya Algorithm for Jayakwadi-1 dam, India. InProceedings of the E-proceedings of the IAHR World Congress, Kuala Lumpur, Malaysia 2017 Aug 13 (pp. 13-18). [View at Google Scholar]; [View at Publisher]

[12] Kong, A.L., Liang, S., Li, C.L., Liang, Z.F., Chen, Y., Optimizing microgrid operation based on improved PSO. J. Hohai Univ. (Nat. Sci.) 45(6), 550e555 2017. (in Chinese). https://doi.org/10.3876/j.issn.1000-1980.2017.06.012. [View at Google Scholar]; [View at Publisher]

[13] Yang L, Su H, Wen Z. Improved PLS and PSO methods-based back analysis for elastic modulus of dam. Advances in Engineering Software. 2019 May 1;131:205-16. [View at Google Scholar]; [View at Publisher]

[14] Fallah-Mehdipour E, Haddad OB, Mariño MA. MOPSO algorithm and its application in multipurpose multireservoir operations. Journal of Hydroinformatics. 2011 Oct;13(4):794-811. [View at Google Scholar]; [View at Publisher]

[15] Rezaei F, Safavi HR, Mirchi A, Madani K. f-MOPSO: An alternative multi-objective PSO algorithm for conjunctive water use management. Journal of Hydro-environment Research. 2017 Mar 1;14:1-8. [View at Google Scholar]; [View at Publisher]

[16] Mirzaie N, Banihabib ME, Randhir TO. Fuzzy particle swarm optimization for conjunctive use of groundwater and reclaimed wastewater under uncertainty. Agricultural Water Management. 2021 Oct 1;256:107116. [View at Google Scholar]; [View at Publisher]

[17] Bilal. Deepti Rani. Millie Pant.S. K. Jain, 2020, Dynamic programming integrated particle swarm optimization algorithm for reservoir operation, 123International Journal of SystemAssurance Engineering and management, 10.1007/s13198-020-0097.

[18] Eberhart R, Kennedy J. A new optimizer using particle swarm theory. InMHS'95. Proceedings of the Sixth International Symposium on Micro Machine and Human Science 1995 Oct 4 (pp. 39-43). Ieee. [View at Google Scholar]; [View at Publisher]