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Optimal Economic of Water Allocation Using EA and ICA Evolutionary Algorithms

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ABSTRACT: In arid and semi-arid regions, like Iran, water is one of the main factors limiting economic development. In the present study, a new high-performance method was used for optimal water allocation in the agricultural sector from 2007 to 2016 years. Election Algorithm is an iterative population-based algorithm, which works with a set of solutions known as population. The results of this method were compared with the results of the Imperialist Competitive Algorithm (ICA). The objective function was determined for each product in the agricultural sector as well as product performance, each product benefits and cultivated area of the demand function, then maximization of the objective function and optimal water resources allocation were performed using EA and ICA algorithms. The results of the application of the EA and ICA algorithms to the optimal water allocation problem showed that in this section, higher benefits could be obtained through economic policies as well as changing the cultivation pattern. Generally, in the case of Moghan plain can be expressed by applying a coefficient of 0.9, 135 Billion Rials, that is, about 40% of the optimal water resources allocation benefits improving between the agriculture sectors compared to the current situation.

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1. INTRODUCTION

Water is a vital resource for any biological and human phenomenon. in arid and semi-arid regions such as Iran, agriculture is dependent on irrigation. Therefore, water resource scarcity is one of the most important factors that can affect the development of the country, so, new methods of water allocation needed. Water allocation is the amount of water that is specified by the Ministry of Energy for various uses in each of the study and catchment areas, in terms of the previous consumers and communicated to companies [1].

Water allocation should be economically viable in ideal conditions. Therefore, there is a need for an appropriate water allocation system in which water is considered as an economic and social commodity [2].

The research has shown that time series models, optimization algorithms, artificial neural networks and other modern and new methods have the highest efficiency in water resources allocating and optimizing. The study finding of researchers using new methods such as GAPSO, PSO, multi-objective bargaining, fuzzy programming and other modern methods with the aim of maximizing economic benefit, show that, with optimal water resources allocation between different sectors (agriculture, industry and services) can increase benefit in the central of Iran by up to 56% [3-5].

According to the research, the agricultural sector has the largest share of water resources consumption. Therefore, in this paper, the nonlinear purpose function, based on the amount of water consumed in the agricultural sector, was formed as the most important user of water resources. Also, in this section, limitations and constraints were considered. Given that the objective function and other constraints followed the nonlinear process, therefore, in solving this problem, the Election algorithm (EA) was used to improve the economic situation by maximizing net profit for water optimal and water resource allocation. Also, the results were compared with the Imperialist Competitive Algorithm (ICA).

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2. MATERIAL AND METHODS

2.1. Case Study

Moghan plain is a plain northwestern Iran and the southern part of the Republic Azerbaijan. Moghan is a large plain located in the north of Ardebil province and the west of the Caspian Sea between the longitudes of 47.5° and 48° E. and the latitudes of 39.20° and 39.42° N. The highest density of irrigation canals is in the section of the Moghan plain which lies in the Republic Azerbaijan (Figure 1). The most common crops in this region are wheat, barley, maize (three types), and cotton. The present study used the data pertaining to the period of 2007-2016 including those on the annual input flow into the Aras dam reservoir, the average annual flow of the dam, the average monthly storage, the average annual water

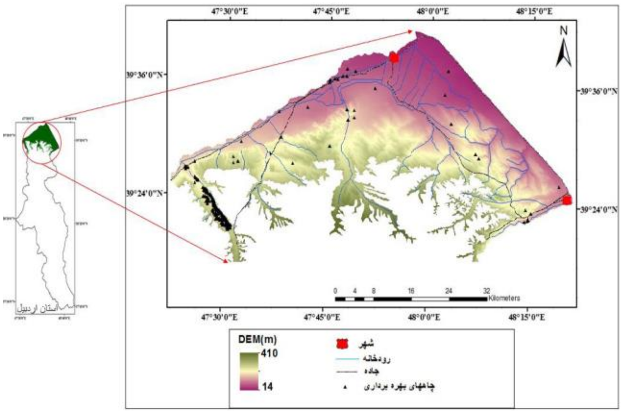

Figure 1. The geographical location of the Moghan plain

volume, and the average annual water allocation. The demand for water allocation from the Aras dam comes from the drinking sector, downstream lands of agriculture, industrial sector, and the environmental sector. As previously mentioned and according to the data available, the highest amount of water is allocated to agricultural sector (mainly consumed for irrigation of the downstream regions), Since the number of water requirements was not, consequently, changed in the industrial, drinking and environmental sectors, the water was allocated to the Aras Dam in the agricultural sector. All data on evaporation and transpiration, the water requirement of cultivated plants as well as conventional farming practices of the region were derived from the Irrigation and Drainage Exploitation Company of the Moghan plain.

2.2. EA Algorithm

EA begins its search and optimization process with a population of solutions. Each individual in the population is called a person and can be either a candidate or a voter. Forming a number of parties in the solution space, people can participate in their preferred party. Then these parties begin their advertising campaign. Advertising campaign forms the basis of this algorithm and causes the persons to converge to the global optimum of solution space. During advertisements, popular candidates attract more voters using various techniques. Therefore, the unpopular ones lose their supporters and might resign from the election arena. Advertisement causes the persons to converge to the global optimum of solution space. On election days, voters cast their votes and the candidate that attains the most votes would be announced as the winner [6].

2.3. ICA Algorithm

Pseudocode for the proposed algorithm is as follows [7]:

1) Select some random points on the function and initialize the empires.

2) Move the colonies toward their relevant imperialist (Assimilating).

3) If there is a colony in an empire which has a lower cost than that of imperialist, exchange the positions of that colony and the imperialist.

4) Compute the total cost of all empires (Related to the power of both imperialist and its colonies).

5) Pick the weakest colony (colonies) from the weakest empire and give it (them) to the empire that has the most likely to possess it (Imperialistic competition).

6) Eliminate the powerless empires.

7) If there is just one empire, stop, if not go to 2.

The input of data in raw form reduces the speed and accuracy of the model, so the inputs and outputs must be standardized between 0 and 1; hence the data are normalized as Eq. (1):

$$\begin{cases} Y_i = \dfrac{X_{oi}}{X_{omax}}\,, & X_{oi} \ge 0 \\ Y_i = \dfrac{X_{oi}}{\left|X_{omin}\right|}\,, & X_{oi} < 0 \end{cases} \tag{3}$$

In which, Y_i, X_{Oi}, Xo_{min} and Xo_{max} are standardized, observation values, minimum observational and the maximum observational values, respectively.

2.4. The objective function

Since after the beginning of the growing season, the cultivating area and agricultural costs remain constant, the objective function is determined to maximize the gross revenue from sales of crops as well as minimizing the losses caused by shortages in the allocation of drinking costs, industries, etc. Therefore, the objective functions are equations (2) to (4):

$$\text{Maximize: } TB - TCE - TCS \tag{4}$$

$$TB = \sum_{J=1}^{4}\sum_{C=1}^{8}\left(Y^{*}A\right)^{*}P_c \tag{5}$$

$$Y_c = Y\,max_c\left(1 - \sum_{t=1}^{n} ky_{ct}\left(1 - \frac{ET_c}{ETmax_c}\right)_t\right. \tag{6}$$

3. RESULTS AND DISCUSSION

The study used the monthly statistics for the period of 2007-2016 investigated the ability of the EA and ICA algorithms. Also, according to the literature and the acceptable performance of optimization algorithms, the present study applied the EA and ICA algorithms. On the basis of the presented relations and proportions, the distraction data were excluded; thus, the collected data consisted of 1064 data. About 70% and 10% of the data were used to train the models and validate the models, respectively.

In Figure 2, the cultivation area is presented in 5 crop years.

In Figure 3, the results of EA and ICA algorithms implementation and observation values were compared for the water allocated during the growing season of the Moghan plain. It was observed that the results of EA algorithm implementation are very close to the measured amount of water allocation. Therefore, there was high convergence, proficiency and efficiency in this method in water resources

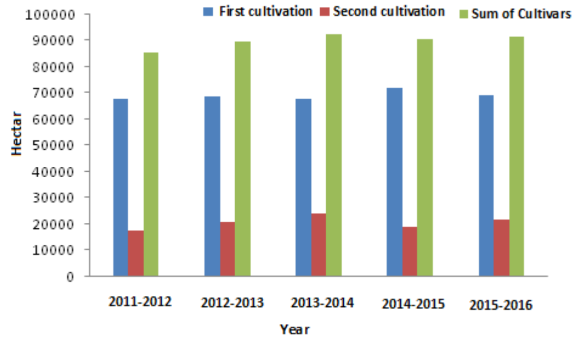

Figure 2. Cultivation area diagram in the last 5 years

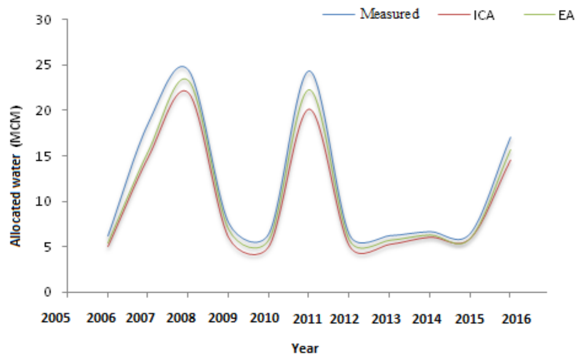

Figure 3. Comparison of Measured allocated water, EA and ICA implementation

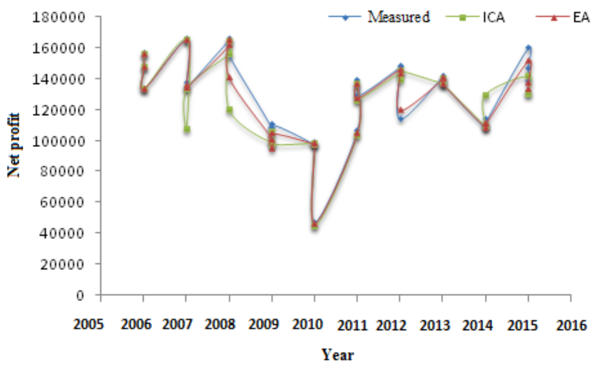

Figure 4. The net profit in each year by applying coefficients of 0.6, 0.75 and 0.9

systems.

In Figure 4, net profit is shown in each year by applying coefficients of 0.6, 0.75 and 0.9. As shown in Figure 4, the profit experienced a bullish and growing trend during 2008-2010, but then a downside trend. Applying the coefficient of 0.9, compared to the two coefficients of 0.75 and 0.6, includes greater profit from the sale of products. In these years, the lowest amount of profit belongs to 2011, which can be attributed to the optimum acreage area and the regional water allocation. The highest amount of income, therefore, belongs to the years 1997, 2008 and 2009 indicating the regional agricultural growth.

By examining Figure 5, it was determined that the total

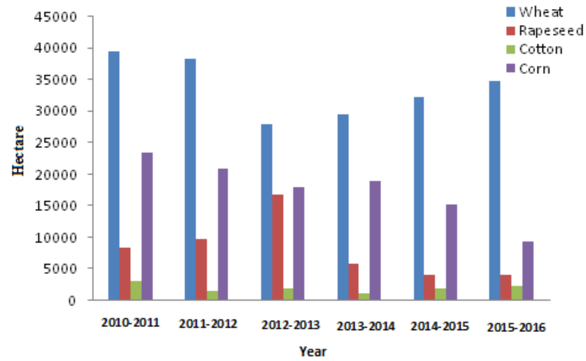

Figure 5. Total optimal acreage at the beginning of each month per hectare, based on estimated values

optimal cultivating area of the products is equal to 69533.24 hectares. Given the results, it was concluded that cotton has a less cultivating area due to its low economic efficiency than other products. Wheat has, therefore, been considered as a high-yielding product due to its high economic profits. In sum, therefore, it is necessary that, in this region, the economic profitability model should tend towards crop production obtaining high-income and economic products.

4. CONCLUSIONS

In this study, two new methods of EA and ICA algorithms, with 3000 cycles, were used irrigation and drainage network the Moghan plain to allocate the optimal water resources using an economic approach. The results of the implementation and application of the proposed methods were determined using the actual values of the comparison and efficiency of the applied methods. The results revealed that the proposed model (EA algorithm) performs well in predicting the water resources values. It has a high speed and accuracy in finding the optimal solution. The neural network allocations were generated $ 135 billion (40%) in the agricultural sector. It was also concluded that by increasing the number of wheat fields, the income will increase and the economic growth will, finally, be achieved for the Moghan plain.

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