Journal of Applied Research in Water and Wastewater 13 (2020) 48-56

Journal of
Applied Research in Water and Wastewater
Journal homepage: www.arww.razi.ac.ir

Original paper

An approach to reduce water consumption by optimizing and determining of crop cultivation pattern using meta-heuristic algorithms: A case study on Moghan plain

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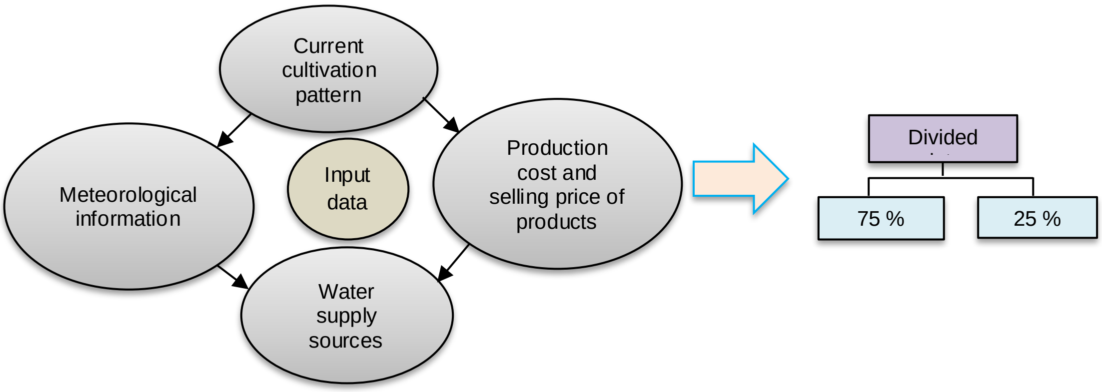
GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 5 March 2020
Reviewed 15 April 2020
Received in revised form 20 May 2020
Accepted 21 May 2020

Keywords:
Cultivation pattern
Election algorithm
Gray wolf optimizer algorithm
Economic net

ABSTRACT

Optimizing the crop cultivation pattern, in order to reduce water consumption, in arid and semi-arid regions such as Iran, due to water scarcity and food intake, is an essential solution for food intakes needs. Optimizing the crop cultivation pattern, in order to reduce water consumption, in arid and semi-arid regions such as Iran, due to water scarcity and food intake, is an essential solution for food intakes needs. In this study, new methods based on the election algorithms (EA) and gray wolf optimizer (GWO) algorithms were used to determine the optimal cultivation pattern in Moghan plain during the statistical years of 2007-2016. The objective function in the agricultural sector was based on each product and its yield, net from each product and the cultivar. Then, maximization of the objective function was performed using GWO and EA algorithm. The results of using GWO algorithm in determining the optimal crop pattern in Moghan plain showed that using economic policies such as changing the cultivar pattern, we can obtain a better result compared to EA algorithm in the agricultural sector. In general, the results of GWO algorithm showed that in the Moghan plain with 0.9, 140 billion rials, that is, about 42 % will have economic growth. In sum, the results showed that GWO algorithm with high values of statistical criteria (R^2=0.96, RMSE=0.022 and NSE=0.75) has a higher efficiency in optimizing the crop cultivation pattern of Moghan plain, which can be applied to the correct planning for other cultivation areas to be employed.

1. Introduction

The limitation of water and soil resources due to the geographical and climatic location of the country on the one hand and the high share of water consumption in the agricultural sector on the other hand, the need to optimize the pattern of cultivation in order to optimize water use and maximum exploitation of cultivated land in the country is inevitable (Shabani et al. 2008). Cultivation pattern is one of the important elements in water resources management, which is based on the optimal use of water resources (Esmaeili et al. 2015). The cultivation pattern is the establishment of a sustainable economic system based on macro policies of the country, indigenous knowledge

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of farmers and the optimal utilization of regional potentials by observing the principles of eco-physiological production of agricultural products in keeping with the environment. Determining the pattern of cultivation for an agricultural area is associated with a great deal of ignorance. The variety of arable crops, the percentage of crops, the amount of water required, employment, the profitability of each product, as well as the amount of available water resources, are the factors that determine the proper culture pattern. In line with the objectives of the fourth development plan based on an increase in the production of agricultural products, the proper design of the cultivation pattern is necessary in order to achieve the highest production and increase income. The design of the pattern of cultivation should be carried out in such a way as to ensure, in addition to the optimum use of existing capacities, to provide part of the regional and national needs (Saliyani. 1996). The optimization of the cultivation pattern has always been one of the most important strategies for the progress of water resource managers in order to improve the utilization of water resources (Nazari Far et al. 2012). There are various ways to optimize the culture pattern. Some of these methods rely on math modeling and linear programming (lp), nonlinear (nlp) and dynamic (DP) programming techniques (Detox et al. 2016; Ghaherman et al. 2002; Joupie et al. 2011). Given that definitive methods are stopped as soon as they reach the first optimal local point, they are unable to move from this point and move to a better optimum point (Shabani et al. 2008). Therefore, in recent years, in order to solve this problem, many researchers have turned to modern methods, including fuzzy logic, artificial neural networks, and evolutionary algorithms. Evolutionary algorithms, as optimization methods, are inspired by nature and operate on a random basis based on a variety of methods (Borhani and Farahmand. 2011). The use of new methods to optimize the pattern of cultivation in recent decades has attracted many researchers. Several studies are reported in the field of optimization of the cultivated area by some researchers (Gorgani and the Kohansal. (2014); Mirzaei et al. 2015; Raju and Kumar. 2004; Shabani et al. (2008); Siheki et al. 2014; Talebi Verlachi et al. 2012). Singh et al., (2001) used a linear programming model to optimize the pattern of cultivation with the goal of maximizing net income in a region of Pakistan. In this model, the amount of land and minimum wheat and rice cultivation for farmers' nutritional needs were considered as model constraints. Nakhaee et al. (2015) reported that the criteria for profit and water consumption are more important than other factors in determining the ranking of products and the type of cultivation. Siasar and Honar (2017), concluded that the using Genetic algorithm (GA) is an effective economic product for the first cultivation of wheat and the second cultivation of the crop was watermelon, and other products have a lower proportion in optimizing water use. Asadi and Keramatzade (2017) optimized cropping pattern with the aim of maximizing profit using linear programming method in Gorgan city. The results showed that applying optimum cultivar with a decrease of 14 % of the cultivated area would increase the program's efficiency by 52 % compared to existing patterns. Mirzaie et al., (2017) using genetic algorithm to determine the optimal cultivar pattern in irrigation and drainage network of Golestan dam and concluded that the current cultivation pattern of the region is not optimal. Zheng et al., (2010) emphasized on the important role of regional agricultural planning in agricultural water management, using linear fuzzy linear programming to determine the optimal cultivar pattern. Alabdulkader et al., (2012) using math planning to optimized the cultivation pattern in Saudi Arabia. The results showed that optimum cultivating pattern yielded about $ 2 billion over 22 years. Khanjari et al., (2014), used genetic algorithm for optimizing water allocation and determining the optimal cultivation pattern of agricultural area covered by Doroodzan dam located in Fars province. Barikhani et al., (2012) attempt to use a linear programming model to optimize the Qazvin plain crop pattern. The results show that the benefits of maximizing social benefits outweigh the benefits of market profits. Mohsenzadeh (2012) determined the optimal cultivar pattern in Golestan province using Lingo software and genetic algorithm and stated that the current culture pattern was not optimal and if the pattern was applied. The proposed crop, net income increases dramatically.

Investigating studies observed that the scope of application of new optimization algorithms in optimizing the cultivar pattern of Moghan plain as one of the important plains in northwestern Iran, was very limited or studies have not been performed. Given that all new meta-heuristic methods are inspired by nature and each strategy is different in reaching the optimal answer, so, the purpose of this research was to determine the optimal cultivating pattern of agricultural area in Moghan plain under Aras dam in Ardebil province using the gray wolf optimizer (GWO) and election algorithms (EA) with the aim of maximizing net profit and achieving the highest profit from cultivating part of Moghan plain fields to adapt these algorithms with a smaller number of parameters and their speed in optimizing compared to other optimization methods.

2. Materials and methods

2.1. Case study

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. This plain is divided into two parts by the borderline of Iran and the Republic of Azerbaijan. The part, which is called Moghan plain, is estimated to be 300-350 thousand hectares where the project of developing the exploitation of Aras river water resources has been implemented at a level of 90 thousand hectares. The Moghan plain is located on the right bank of the Aras River, which is limited to the Aras river and Dasht-e-Mil in the Republic of Azerbaijan from the north, and along the borderline to the Republic of Azerbaijan from the east, to the city of Germi and Meshghin Shahr from the south, and the slopes of Sabalan and is limited to the city of Ahar from the west. The location of the study site is shown in Fig. 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 volume, and the average annual water allocation. The demand for water allocation from the Aras dam comes from drinking sector, downstream lands of agriculture, industrial sector, and 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 amount 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, 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 (Fig. 2).

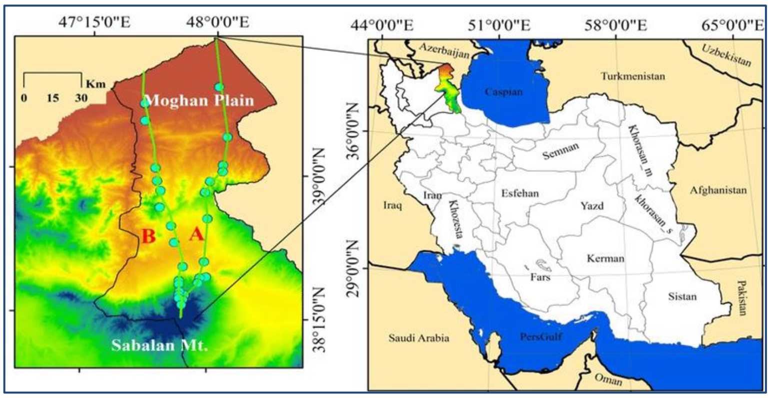

Fig. 1. The geographical location of the Moghan plain.

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Of the total 1202.69 million cubic meters of the input water to the network,100.24 million cubic meters (equivalent to 8 %) is wasted on the main channel and the remaining 1102.24 million cubic meters (92 %) is distributed in the network of which 868.18 million cubic meters (72.2 % of the total input water) and 234.28 million cubic meters (19.5 % of the input water to the network) are distributed among the agricultural sector and gardens and non-agricultural sector, respectively.

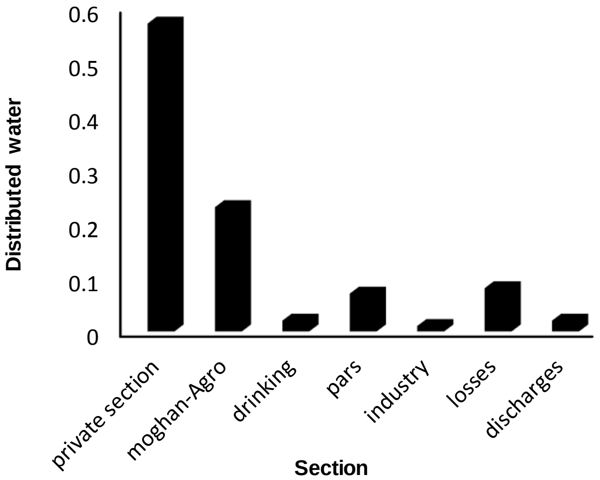

Fig. 2. The contribution of different consumption sections in the Moghan network (%).

Figs. 3 and 4 depict the acreage and stock comparisons of aquaculture in the past five years, respectively, which was increased year by year by the continuous follow-ups of the realization of the company's income arising from the price of water and have the upward trend.

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 (Daniel and Larose. 2004).

$$\begin{cases} Y_i = \frac{X_{oi}}{X_{omax}}, & X_{oi} \geq 0 \\ Y_i = \frac{X_{oi}}{|X_{omin}|}, & X_{oi} < 0 \end{cases} \tag{1}$$

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

2.2. 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 Eqs. 2 to 4.

$$\text{Maximaze: TB-TCE-TCS} \tag{2}$$

$$TB = \sum_{J=1}^{4} \sum_{C=1}^{8} (Y*A)*P_c \tag{3}$$

$$Y_c = Y\,max_c \left(1 - \sum_{t=1}^{n} ky_{ct} \left(1 - \frac{ET_c}{ETmax_c}\right)_t\right) \tag{4}$$

where, TB, TCS, TCE, Ycj, C, Acj, j, T_{maxc}, c, ky_{ct} and Et_{max} are the net profit of the network, the shortage of expenditures on allocating to the drinking and industrial sectors, the shortage of expenditures on allocating to the environmental sector, the total weight of the produced crop *c* in area *j* as per unit area below C, total cultivated area of the crop *c* in area *j*, unit price of the productive weight of the crop *c*, maximum production of the crop *c* without water stress, sensitivity coefficient of the crop *c* in month *t* and actual evaporation of the crop c in month *t* without water stress, respectively. The index c represents the type of the crop, j is the cropping area and t is the time index (month).

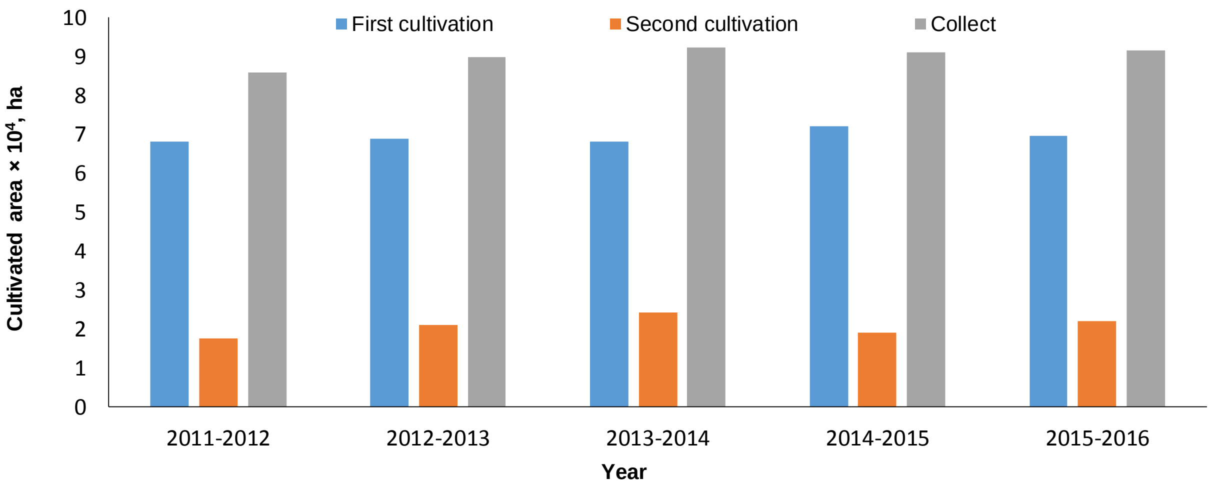

Fig. 3. The network cultivation diagram in the last five years.

2.3. Limitations and constraints

In the initial state, the storage of the dam is considered to be intact and then the harvesting is reduced. Drinking water and services are fully provided. The amount of water should be more than what is needed for products in each area. The total cultivation area should not exceed the total area and should always be considered constant. At the end of the year, the storage capacity of the dam should not be less than its initial volume. The following Eqs. represent the mathematical form of the above constraints and limitations:

$$W\,dem_{jt} \leq W\,av_{jt} \tag{5}$$

$$W\,dem_{jt} \equiv \sum_{c=1}^{8} W\,dem_{jt} \tag{6}$$

$$W\,av_{jt} = SW_{jt} + GW_{jt} \tag{7}$$

$$GW_{jt} \leq PGW_{jt} \tag{8}$$

$$SW_{jt} = RDR_{jt} + BW_{jt} + Var_{jt} \tag{9}$$

$$BW_{jt} \leq PBW_{jt} \tag{10}$$

In these Eqs., $W\,dem_{jt}$ represents the water allocated to the area j at month t, $W\,av_{jt}$ denotes the water available in the area *j* at month *t*, $W\,dem_{jt}$ displays the water allocated to the crop *c* in the area *j* at month *t*, and GW_{jt} shows the groundwater used in the area *j* at month t. After defining the constraints, the appropriate options must be chosen for different parts of the neural network model. However, the correct choice of these options will have a direct impact on the performance and speed of this model. In this study, various options were, also, tested to achieve the best solution for each part of the neural network model based on their high capabilities. In some cases, the best option was chosen for each case using the sensitivity analysis.

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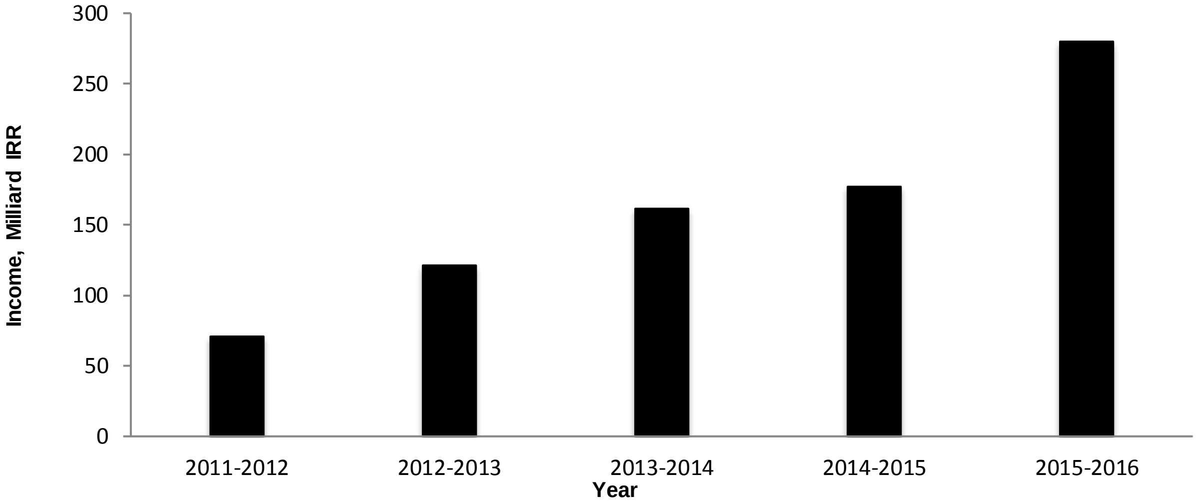

Fig. 4. Collected comparative diagram of the price of water in the last five years.

2.4. Statistical criteria

In order to compare the results of GWO and EA algorithms with each other and observation values as well as their evaluation, it is necessary to have criteria that can judge the function of the models in the whole data set compared to the experimental results. In the present study, root mean squared error (RMSE), mean absolute error (MAE) and Nash–Sutcliffe criteria (NSE) were used for this purpose. These parameters are used to analyze models output data. This statistics are calculated using following Eqs. (Ghorbani et al. 2017).

$$\mathrm{RMSE} = \frac{\sqrt{\Sigma(Q_o - Q_M)}}{N} \quad (11)$$

$$\mathrm{MAE} = \frac{\Sigma|Q_o - Q_M|}{N} \quad (12)$$

$$\mathrm{NSE} = \left[1 - \frac{\Sigma(Q_o - Q_M)}{\Sigma(Q_o - Q_M)}\right] \quad (13)$$

where, Q_o is observation data, Q_M is predicted data and N is Number of data. Also, in this research, RMSE, MAE and NSE were 0.03, 0.41 and 0.74, respectively, which are in a great range of satisfaction.

2.5. The used algorithms

In different stages of this study, in order to optimize and determine crop cultivation pattern, GWO and EA algorithms were used.

2.5.1. Gray wolf optimizer algorithm (GWO)

Gray wolf algorithm (GWO) is a nature-inspired meta-heuristic algorithm based on the hierarchical structure and wolf's social behavior during hunting. The GWO algorithm is population-based and has a simple process in configuration and can easily be generalized to large-scale issues (Mirjalili. 2014; Mirjalili et al. 2014). The hierarchical structure and social behavior of gray wolves are as follows. Gray wolves are at the top of the food chain and have a social life. The average number of wolves per herd is between 5 and 12. There are 4 main categories in each herd.

Group leader wolves are called alpha, which can be male or female. These wolves are dominant in flock and manage things like resting or hunting, but in addition to the dominant behavior of alpha wolves, a democratic structure is also seen in the group.

Beta wolves help alpha wolves in their decision-making process and are also prone to being selected instead.

Delta wolves are lower than beta wolves and include old wolves, hunters, and wolves that care for babies.

Omega wolves have the lowest rank in the pyramid of hierarchy and the least right compared to the rest of the group. They eat after all and do not participate in the decision-making process (Mech. 1999; Mirjalili et al. 2014). In Fig. 5, the hierarchical structure of wolves groups is shown.

- The hunting process of gray wolves

According to Muro et al. the main stages of gray wolves hunting include three main phases (Escobedo et al. 2011; Muro. 2011).

A) Seeing, tracing and tracking (tracking and approaching) hunting

B) Approaching, surrounding (encircling) hunting and misleading until it moves (Pursing and encircling).

C) Attacking hunting

Optimization is done using the alpha, delta and beta wolves. An alpha wolf is assumed as the main leader of the algorithm, and one beta and one delta wolf also participate, and the rest of the wolves are considered as their followers. In Fig. 6, these steps are shown.

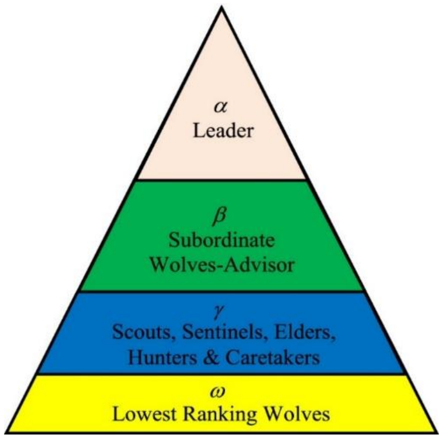

Fig. 5. Hierarchy of grey wolf (dominance decreases from top down) (Mirjalili et al. 2014).

2.5.2. Election algorithm (EA)

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, the 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. In addition to be more clear, a path through the EA's components is shown as a flowchart in Fig. 7. (Emami and Derakhshan. 2015).

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Fig. 6. Hunting behavior of grey wolves (Mirjalili et al. 2014).

- Selecting the variable representation and eligibility function

The EA begins its work by defining the optimization variables, the eligibility function, and the eligibility. The EA in each iteration works with a set of solutions collectively known as the population. Usually, in the absence of any knowledge of the problem domain, this population is generated randomly. Each individual of the population is called a person and indicates a potential solution to the problem. In an N_{var}-dimensional (N_{var} variables) problem, each person is formed an array of variable values to be optimized. If the person has N var-variables given by $x_1, x_2, . . . , x_{Nvar}$ then the person is written as an $1 \times N_{var}$ element row vector such as follow:

$$\text{Person}=[X_1,X_2,..., X_{Nvar}] \tag{14}$$

Each variable in this array can be interpreted as a sociopolitical characteristic of a person such as language, culture, religion, nationality, economical policy and other opinions. The variable values in the person can be represented by all kinds of characters such as numbers, alphabets and any other form of data representation symbols. In the EA, each person must be assigned an eligibility value, which is related to the objective function of the problem. An eligibility function is used to assess the ability and qualifications of persons. In the optimization problems, the main goal is to find a solution having the minimum cost. Thus, in the EA, the persons who have smaller cost then larger eligibility values are assigned to them. The eligibility of an individual is found by evaluating. The eligibility function *f* at the variables $x_1, x_2, . . . , x_{Nvar}$ considering the related objective function. Therefore, we have:

$$\text{Eligibility} = f(\text{person}) = f(X_1,X_2,\ldots, X_{Nvar}) \tag{15}$$

To begin the EA, we define an initial population of NPop persons. The initial population is an NPop × Nvar matrix filled with randomly generated persons. Each row in the matrix is representative of a person and is being an 1 × Nvar array of variable values. Then the worth of each one is evaluated by the eligibility function. So at this point, the persons are passed to the eligibility function to assess their capability. After forming the initial population, we divide the entire persons into some political parties in the solution space. To fulfill this aim, the *Nc* persons randomly are selected to be candidates and the remaining *Nv* persons will form the initial supporters (or voters) of these candidates. The candidate rate, Cr, is the fraction of NPop that selected as the initial candidates. Thus, the number of persons that are selected as initial candidates is given by the Eq. below.

$$N_c=[C_r \times NP_{op}] \tag{16}$$

2.5.3. Advertisement

- Positive advertisement

The aim of positive advertisement is to introduce a candidate through focusing on his/her abilities or stance on issues. During positive advertisement, candidates begin to expose their plans and ideas to voters and try to influence the decisions made by voters. Candidates attempt to create a lasting impression with the voters.

- Negative advertisement

Candidates through negative advertisement try to attract the supporters of other parties toward themselves. Negative campaigning leads to an increase in the popularity of popular parties and conversely a decrease in the popularity of unpopular parties (Fig. 8). In the implementations of this algorithm, contrast advertisement is used among different negative campaigning techniques. To do this, candidates travel to the different areas of solution space (between other parties) and they try to attract those voters toward themselves using negotiation.

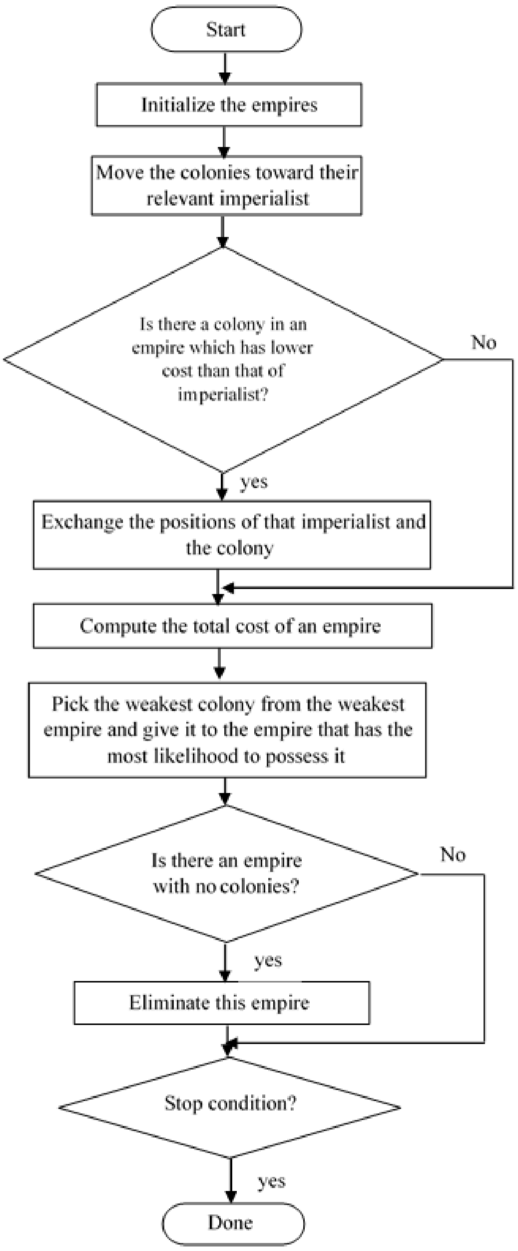

Fig. 7. Flowchart of the election algorithm (Emami and Derakhshan 2015).

- Coalition

Similar to the process of candidates coalition in a real election, sometimes two or more than two candidates in the solution space become more closer together. In that case, they can join and create a new party. Therefore, some candidates leave the campaign and join to another candidate who is called “leader”. The candidate who leaves the election arena is called “follower”. The follower candidates collate to the leader one and encourage their supporters to follow the leader. All of the supporters of the follower candidates become the supporters of the leader one. Different criteria can be defined to model the coalition mechanism and to specify a candidate to be either a leader or a follower. In our implementation, among the candidates that wish to collate together, a candidate is picked at random to be the leader candidate and the remaining is considered as the followers (Fig. 9).

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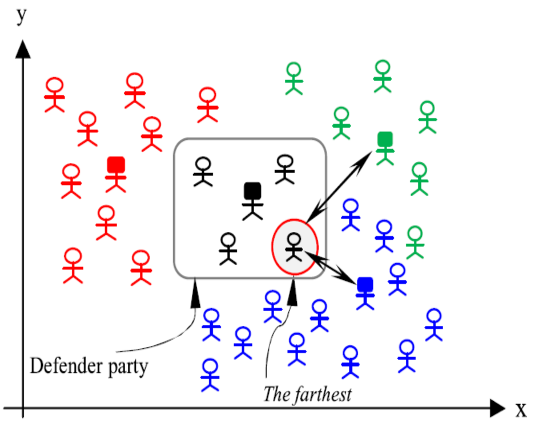

Fig. 8. Negative advertisement among candidates (Emami and Derakhshan. 2015).

2.6. Problem statement

In the present study consisted of 9-year monthly statistics for the period of 2007-2016 to determine the optimal cultivar pattern of Moghan plain. The numeric code was written in MATLAB software. For this purpose, 75 % of the available data was used to train the model, and 25 % of the data was used to validate the model. Verification was used to determine the optimal cultivar pattern, using a number of 2000 replications that had a good performance and less error for the model. For the verification of the results of the modeling, assuming that all the coefficients and parameters were fixed, the results of the models were compared with that of the current crop area. Until a termination condition is not satisfied three operators – positive advertisement, negative advertisement and coalition–are applied to update the population EA and GWO algorithms parameters, presented in Table 1.

Table 1. Parameters used in GWO and EA algorithms.

GWO		EA	
Parameter	**Value**	**Parameter**	**Value**
The number of wolves	12	The number of initial population	100
Low range	30	N_c	0.7
High range	-30	Coalition rate	0.2
Maximum replication	300	Selection rate	0.3

3. Results and discussion

The results of comparing the values calculated with the observed values in Table 2 are presented.

Table 2. Comparison of calculated values with observed values of cultivated area.

Crop name	Crop area	Optimal area (EA)	Optimal area (GWO)
Wheat	33496	31600	34800
Barely	2723.6	2940	2670
Maize	1200	1528	1325
Corn (Zea of mays)	1891.5	1450	1912
Corn	2576	2710	2420
Cotton	2001.2	1840	2000

According to Table 3, the results from the implementation of the GWO algorithm are desirable, which indicates the high efficiency and precision of this algorithm. Based on obtained results, the mean values obtained from the criteria parameters of the EA and GWO algorithm were 0.73, 0.027, 0.93, 0.75, 0.023 and 0.96, respectively, which are in the most ideal limit, and a particular trend in errors indicating an accumulation of error in the models, it is not considered. According to Fig. 12, it is determined that the total area under cultivation is optimal for products equal to 69533.24 hectares, and the cotton product is lower due to low economic efficiency compared to other products. Wheat has also been considered as a high-yielding crop due to its high economic benefits and the cultivated area has been created due to its high economic profitability. Therefore, it is recommended that the economic profitability model in this region should tend to shift from crops to high-yielding and economic products.

Table 3. Proposed crop pattern and maximum net profit predicted GWO algorithm in first cultivation.

Crop name	Optimal area (GWO)	Maximum net profit (Rial)
Wheat	35600	1744400000
Barely	2910	1425000000
Maize	1320	646000000
Corn (Zea of mays)	1980	970000000
Corn	2760	1352000000
Cotton	2200	1355000000

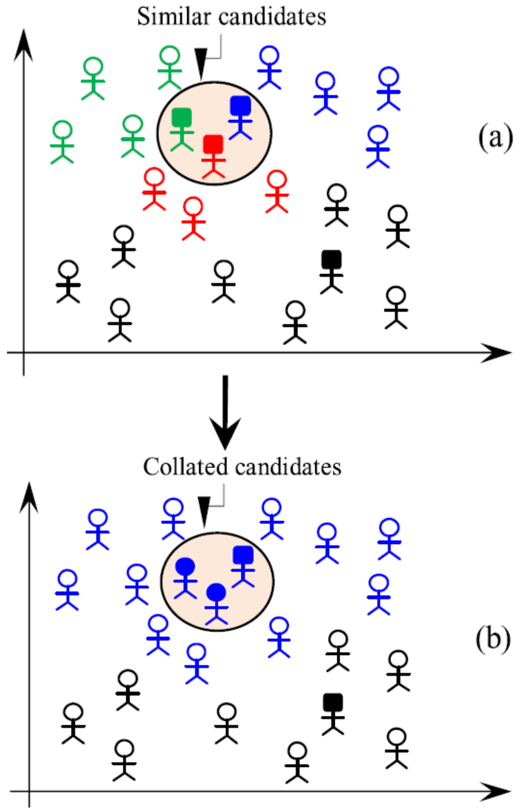

Fig. 9. Coalition between parties in the search space (Emami and Derakhshan. 2015).

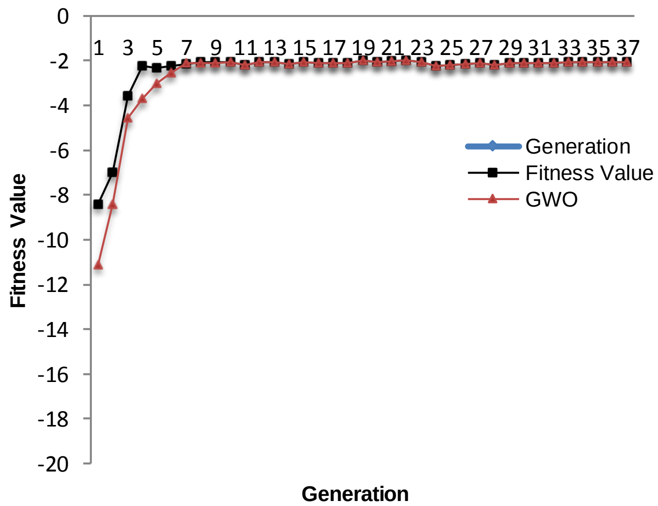

Fig. 10. The convergence diagram.

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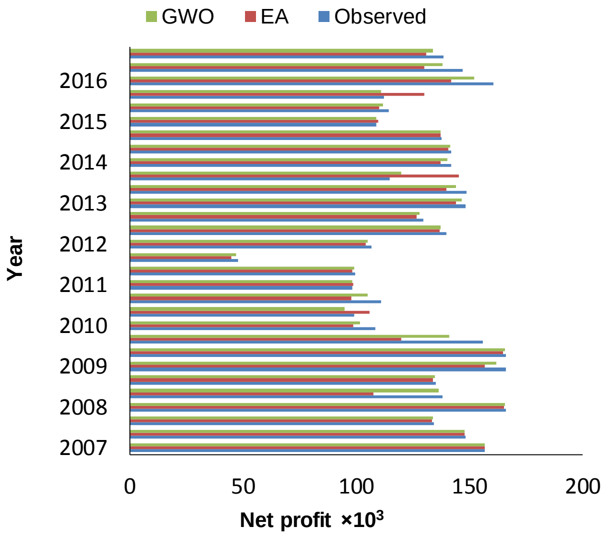

Fig. 11. Net Profit for each year applying a coefficient of 0.6, 0.75 and 0.9 for algorithm.

Tables 3 and 4 show the predict crop cultivation pattern by the GWO algorithm for the first and second crops, respectively.

According to the results presented in the above table, ea model uses the maximum potential of arable area and in the first crop, the most crop area was allocated to the wheat crop and the second crop was allocated to Soybean crop.

Also, the maximum profit in first cultivation, which has a greater cultivation area than the second crop, was 1.4 billion Rials. In Figs. 13 and 14, the ratio of net profit to the cultivated area in the proposed culture pattern (optimal) was compared with the election algorithm (EA) and the current culture pattern in the first and second crops.

Table 4. Proposed crop pattern and maximum net profit predicted GWO algorithm in second cultivation**.**

Crop name	Optimal area (GWO)	Maximum net profit, Rial
Clover	150	57000000
Maize	1100	410000000
Corn (Zea of mays)	6800	290000000
Soybean	15000	5800000000

According to the Figs., the optimum culture pattern in the first crop has an average of 7000000 rials per hectare, which is estimated to be 630000 rials per hectare in the current cultivation pattern. In the proposed cultivation pattern, the per capita income per hectare was increased by 42 % compared to the current pattern of the region. In the second crop, each hectare of land yielded an average of 580000 profits, the average value of which in the optimal cultivation is equal to 460000.

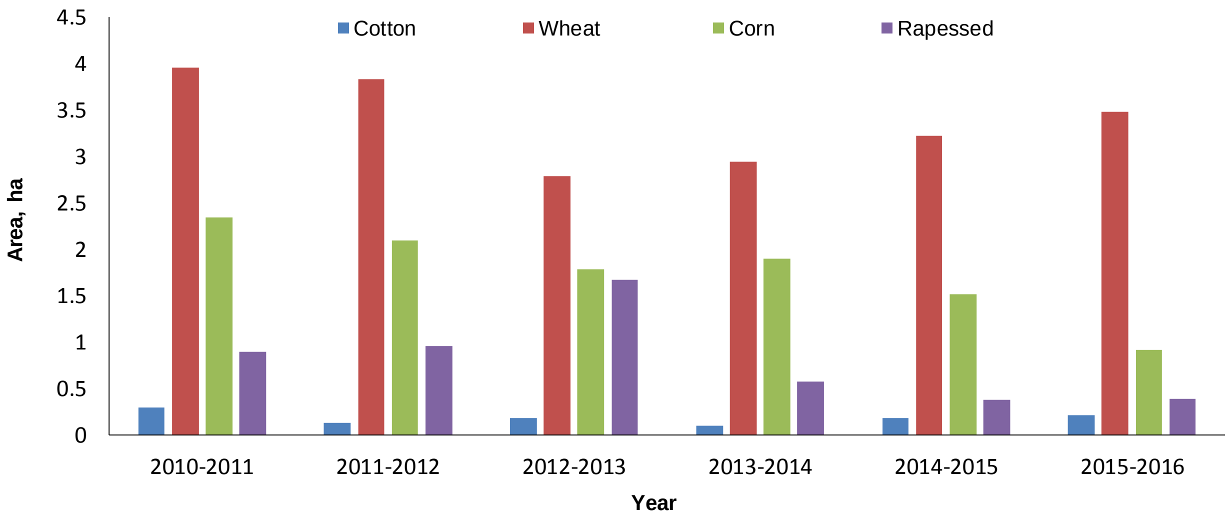

Fig. 12. Total optimal cropping area at the beginning of each month based on the predicted values of GWO algorithm**.**

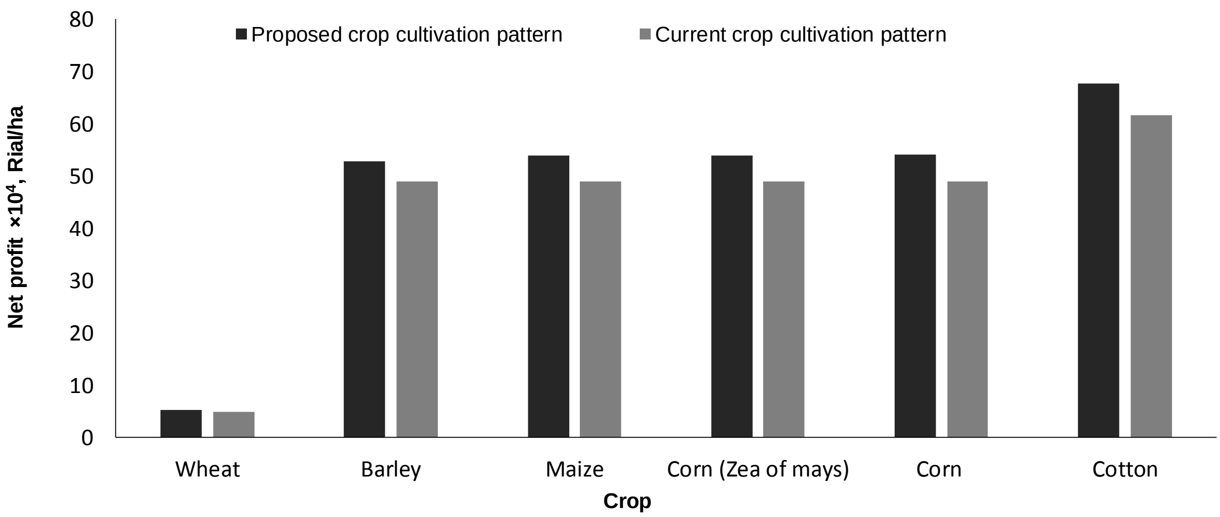

Fig. 13. Comparisons the ratio of net profit to the cultivated area in the current cultivation and proposed cultivation (first cultivation)**.**

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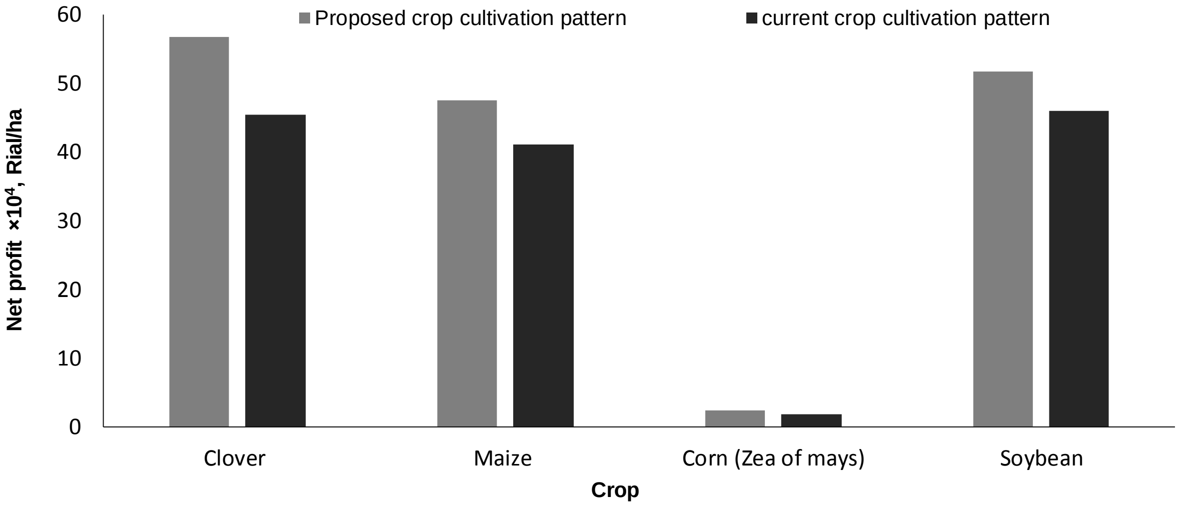

Fig. 14. Comparisons the ratio of net profit to the cultivated area in the current cultivation and proposed cultivation (Second cultivation).

4. Conclusions

The results showed that the current cultivation pattern in the Moghan Plain is somewhat optimal and does not use all potential in the region. In the area of Moghan Plain, compared with the central and desert parts of Iran, wheat crop is considered as a high-yielding crop as a high-yielding crop area and as a result, an optimal cropping pattern derived from the GWO algorithm in this area with a 42 % will be. The high correlation coefficient (R^2) obtained from the GWO algorithm indicates the high accuracy of the GWO algorithm in optimizing crop cultivation pattern compared with other evolutionary algorithms such as EA. The results showed that in determining the optimal crop cultivation pattern, GWO algorithm works with optimum allocation of 140 billion rials in agricultural sector which equals 42 % of the economic growth in the agricultural sector, and has high speed and accuracy in finding the optimal solution. It was also concluded that by increasing the area under cultivation of wheat, its income will increase and economic growth will be achieved for the Moghan plain area. Results showed that the optimum culture pattern in the first crop has an average of 7000000 rials per hectare, which is estimated to be 630000 rials per hectare in the current cultivation pattern. Based on the results, wheat crops were introduced as the most profitable cultivation area.

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