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# The modeling of effective factors on Qaenat saffron yield using GFA and ANFIS

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## Abstract

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Saffron is one of main strategic crops in Iran that have exclusive position in non-oil export products of the country. There is special weather condition in Qaenat state for saffron production and so saffron allocated high proportion of agricultural products in this region. In current research, the modelling of affecting factors on saffron yield using Genetic function approximation and adaptive neuro-fuzzy inference system in Qaenat state was done.

The statistical samples were taken using coincidence sampling among 120 saffron growers' in Qaenat state at 2017. Results are shown that cultivation area, related education, total sale, product price, labor cost, irrigation and harvest cost are most effective factors on saffron yield. Price elasticity coefficient was higher in comparison with other factors that show growers reaction to price was higher than others. Labor cost elasticity coefficient was higher among saffron production inputs that means increase in labor cost have more portion in increasing of yield compared than other inputs. Results of comparison between genetic function approximation and adaptive neuro-fuzzy inference system showed that genetic function approximation was predicted in lower error compared than adaptive neuro-fuzzy inference system.

*Keywords:* ANFIS; GFA; modeling; saffron; yield

## Introduction

Agriculture is the most important economic sector in many developed and developing countries. Also, many developing countries for industrialization made a lot of changes in the processing of agricultural products so that some economists believe that industrial revolution has grown and developed in the context of agricultural sector and thus agriculture can be considered as a motive for economic growth, food security, non-oil exports and sustainable exploitation of the environment (Asadi, 2016; Mashayekhan et al., 2014; Mohtashemi et al., 2016; Higgins, 2017).

Iran is located in the arid and semi-arid region of the world and water as the most limiting factor, determines the priority of cultivation. But for a long time ago, intelligent Iranian farmers specially in Ghaenat region have become familiar with the important principle of productivity and therefore try to saffron cultivation which does not require much water (Saeidirad & Mokhtarian, 2009; Beigi, 2011; Keshavarz et al., 2005) and it has caused that the south Khorasan province now has the second rank of saffron production in terms to area and production amount and so that more than 10000 hectares of land in the province allocated to cultivate of this main medicinal plant (Anonymous, 2017). In southern Khorasan province, due to the specific climate conditions especially in the city of Qaenat, such as desert area, land poverty due to lack of nutrients and water, this product has contributed greatly in the agricultural sector and society income (Hatami et al., 2014; Saeidirad & Mokhtarian 2009).

There are special characteristics for saffron cultivation such as low water requirement, need to water during non-critical irrigation period of other crops, growth in both sand and loan soils, no need to heavy and modern agricultural machines, low field soil preparation, be perennial crop, high price in the world and very high absorption potential of rural labors during valuable stigma harvest (Kafi et al., 2002; Asadi, 2016; Kiani et al., 2018). Because of highest quality of Iranian saffron, there is great advantage among agricultural products regards to export in the world. The high quality of Iranian saffron is cause by different factors like soil, relative humidity, temperature and sum of sunny hours and therefore saffron have exclusive position in non-oil export products (Ghodrati, 2011; Abrishami, 2004).

Ghodrati (2011) has estimated the demand function of Iran's saffron export to selected countries using panel data (for the period 2001–2008 years) and it was concluded that the demand function to the income of the importing countries is high elasticity, and the elasticity coefficient was estimated to be 44/11. Relative prices have no significant effect on demand and the elasticity coefficient of the real exchange rate in export demand function was 293.4.

Joukar (2011) showed that the value of exports was higher than exports, in order to analyze the structure of the global market for saffron and Iran's market power using the Herfindahl-Hirschman and Lerner indexes. But in total, the global market structure for non-competitive saffron market was evaluated and also found indirectly that the focus amount on global market of saffron tends to decrease. Jasemi et al. (2011) the process of changes in cultivation area and the yield of saffron (1984 to 2009) in three cities including Birjand, Qaenat and Sarayan in the form of time series were analyzed and state of the future of saffron production in the country is expected with the continuation of the series of time for 2011–2012 year.

Iran is the biggest saffron producer and exporter in the world with 95% saffron world production. The highest quality of saffron is produced in Qaenat region that cultivation area is 4492 hectares and 30% of relevant province production (Agricultural Statistical Book, 2017). There is no comprehensive researches on saffron in this region and only done few researches with low variables. Therefore, because of high importance of saffron in Qaenat, the aim of this study was to evaluate of effective factors on saffron yield using genetic function approximation and adaptive neuro-fuzzy inference system.

## Materials and Methods

In this research, in order to yield modeling, we used Genetic Function Approximation (GFA) algorithm and adaptive neuro-fuzzy inference system (ANFIS).

***Adaptive neuro-fuzzy inference system (ANFIS)***

Fuzzy method is based on linguistic variables. This is an intelligent calculation method to solve many different issues about mathematics, science, economic, and engineering. Despite the positive points of this method, a major problem is that there is no systematic approach to system design phase. The neural networks offer learning capability through training data. Thus, according to the capabilities of each method, combining them can provide the kind of networks that have all of these advantages. In fact, the idea is to use neural networks to create a network that changes the parameters of fuzzy system, which ultimately have best fitness with training data. Neuro-Fuzzy system is used by learning artificial neural network to determine the input and output variables. ANFIS, developed by Jang (1993), is a kind of Neuro-Fuzzy system. Structure of ANFIS includes different nodes that have relationships with one another. Output of this network depends on regulated parameters (Morgan, 1993; Jang, 1993; Jang & Sun, 1993).

Learning the rules of the network determines how these parameters can minimize the error. A Fuzzy Inference System is a framework based on fuzzy theory and fuzzy IF-THEN rules. The structure of a fuzzy inference system consists of three main components-rules, database, and a reasoning mechanism (Sugeno, 1985; Gallo et al., 1999). A fuzzy rule consists of fuzzy IF-THEN rules. Database and membership functions are used in fuzzy rules. The reasoning mechanisms process the input variables.

***Adaptive fuzzy neural network structure***

Figure 1 shows the structure of fuzzy neural network (Tanaka, 1998). This network has five layers.

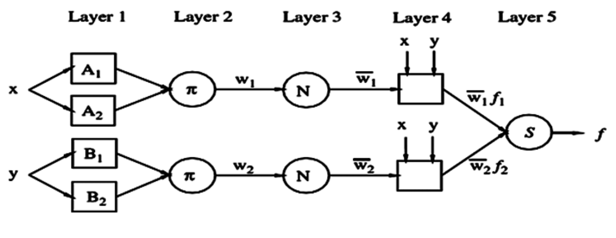



**Fig. 1. Structure of fuzzy neural network ANFIS**

For this, input and output nodes show input and predicted values respectively. In order to simplify the figure, a network with two inputs and one output is considered. Thus, the simulation of the first order can be based on a set of fuzzy IF-THEN rules as follows. Moreover, database of fuzzy rules is similar to the following rules:

Rule *i*: If *x* is *Ai and y is Bi THEN*

$f_i = p_i x + q_i y + r_i \qquad i=1, 2, ..., n \qquad (1)$

where $n$ is the number of rules and $p_i$, $q_i$ and $r_i$ are the parameters determined during the training process. In general, the structure of fuzzy neural network has five layers. Each layer has different nodes, and each node is a fixed adaptive layer. Different layers with different nodes are described briefly in the following section:

*First layer:* This layer describes the membership of each input in different fuzzy sets. At first stage of the learning process, the membership function (μ) of each of the linguistic labels $A_i$ and $B_i$ are calculated as follow:

$$O_{1,i} = \mu_{A_{i(x)}}, \qquad i = 1,2$$
$$O_{1,i} = \mu_{B_{i-2(y)}}, \qquad i = 3,4$$

For instance, if the Gaussian membership function is employed, $\mu_{Ai\,(x)}$ is given by:

$$\mu_{Ai\,(x)} = \frac{1}{1 + \left[(\frac{x - c_i}{a_i})^2\right]^{b_i}},$$

where $a_i$, $b_i$ and $c_I$ are the premise parameters of the membership function.

*Second layer:* In this layer, operators determine the extent to which this rule is true for inputs. The layer from operator 'and' used to calculate the degree of participation of each rule.

$$O_{2,i} = w_i = \mu_{A_{i(x)}} \mu_{B_{i(y)}}, \qquad i = 1,2$$

*Third layer:* The third layer implements a normalization function and the outputs of this layer can be represented as follows:

$$O_{3,i} = \bar{w}_i = \frac{w_i}{w_1 + w_2} \qquad i = 1,2$$

*Fourth layer:* In this layer, contribution of each rule is calculated for calculating output of the model. Where $w_i$ is neuron output of the previous layer and $r_i$, $q_i$, and $p_i$ are linear adaptive parameters.

$$O_{4,i} = \bar{w}_i f_i = w_i(p_i x + q_i y + r_i) \qquad i = 1,2$$

*Fifth layer:* This layer is called the output layer. In fact, the previous output neurons of this layer are summed together.

$$O_{5,i} = \sum_i \bar{w}_i f_i = \frac{\sum_i w_i f_i}{w_1 + w_2}$$

***Genetic Function Approximation (GFA) algorithm***

GFA algorithm describes the basic problem of approximating the function (Rogers & Hopfinger, 1994). Many factors affect the response variable and primary input for the correlation with best response. This algorithm works with a range of strings called population, which is developed for the purpose of searching. Three operators also run appropriately selection, crossover, and mutation. New members are given scores according to the estimator criterion. In the GFA, criteria scoring obtained fitted regression models. The selection probabilities should add each new member to the population again. This method continues for a specified number of generations until the point of convergence. GFA algorithm can be used to produce a generation with respect to the evolution charts according to the achieved time. This graph shows the number of events for each variable about the population, which has evolved for each generation. GFA algorithm converges when no progress in population occurs. At this time, the model is significant which that model is best for all models of population (Samuel et al., 2015; Khajeh & Modarress, 2010).

***Estimators of modelling with GFA***

*1-LOF Friedman:* For each equation, it is calculated according to the following:

$$SSE/\left(1 - \frac{(c + df)}{n}\right)^2$$

*SSE*: the sum of squared errors, *c*: Number of main functions (except for the constant factor), *d*: parameter adjustment, *f*: the main features and principal functions, and *n*: total input data. 2 – $R^2$ is a fraction of the total variation obtained by genetic function approximation and whatever is closer to one when the obtained approximation model is the best model. $R^2$ is equal to *SSR/SST* where *SSR*: sum of squares regression error and *SST*: total sum of squares. 3 – Adjusted R-square is reduced with regard to size of model and is equal to:

$$1 - \frac{\frac{SSE}{(n-p)}}{\frac{SST}{(n-1)}},$$

where SSE is the sum of squares of errors, n is the number of data points from which the model is estimated, and p is the number of parameters in a regression model (Samuel et al., 2015).

As a result, predictive models of ANFIS and GFA are measured by various performance indicators. There is no general consensus on the best criterion for assessing the performance of prediction model. In this study, in order to evaluate fuzzy neural network and genetic function approximation is used from $R^2$ and root mean square error (RMSE) estimators, where $y_i^{exp}$, $y_i^{calc}$ and $\overline{y}$ are predicted, computed values and observations average, respectively and $n$ is the number of observations.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i^{exp} - y_i^{calc})^2}{\sum_{i=1}^{n}(y_i^{exp} - \overline{y}^{calc})^2}$$

Statistical society includes 120 Qaenat saffron growers and sampling was taken using simple randomly sampling method in 2017. Variables in modeling of genetic function approximation method are shown in Table 1.

According to the data of Table 1, using genetic algorithm function approximation and MS modeling software, modeling for effective factors on saffron yield was performed to determine which of the 44 independent variables affect the yield of saffron in Qaenat region. Specifications for the genetic algorithm function approximation are showed in Table 2. Then, followed by an adaptive neuro-fuzzy inference system modeling was performed using MATLAB software.

## Results and Discussions

The characteristics of Genetic Function Approximation (GFA) algorithm for affecting factors on saffron yield in Qaenat are shown in Table 2. Using GFA algorithm, the modeling for effecting factors on saffron yield in order to be determined which variables among 44 independent variables will affect on the saffron yield optimally.

According to the data of Table 4, elasticities for the effective factors on the yield of Qaenat saffron has been calculated that the elasticity of the cultivated area is 14.29 and shows that, under the condition of the constant of other conditions, for one percentage increase in the area of cultivation, the yield value increased by 0.142%. The elasticity of related education is 0.046, which indicates that the yield of Qaenat saffron for increasing saffron-related education will increase the yield by 0.446%, that is, increasing education and awareness of saffron will increase yield. The elasticity coefficient of total sales implies that with a one percent increase in total sales, the yield of saffron will increase by

**Table 1. Used variables for saffron yield modelling using GFA**

| Variable | Symbol |
|---|---|
| Age | x1 |
| Marriage | x2 |
| Individual number | x3 |
| Education | x4 |
| Experience | x5 |
| Yield (g) | x6 |
| Cultivation Area ($m^2$) | x7 |
| Machinery | x8 |
| Property type | x9 |
| Contribute in extension programs | x10 |
| Related Education | x11 |
| Main job | x12 |
| Manure | x13 |
| Corm sowing Suitable time | x14 |
| Plow suitable time | x15 |
| Cultivation technical Principles | x16 |
| Soil analysis | x17 |
| Diversify activities | x18 |
| Activity division | x19 |
| Use other experience | x20 |
| Field integration | x21 |
| Solve problem | x22 |
| Mechanized harvest | x23 |
| Total sale (g) | x24 |
| Price | x25 |
| Be perennial of corm | x26 |
| Corm cost | x27 |
| Labor cost | x28 |
| Manure cost | x29 |
| Irrigation cost | x30 |
| Harvest cost | x31 |
| One stage sale | x32 |
| Sale time | x33 |
| Experts advise | x34 |
| New technology | x35 |
| Price variation | x36 |
| Water quality | x37 |
| Younger corm | x38 |
| Irrigation season importance | x39 |
| Local knowledge for weather prediction | x40 |
| Money save | x41 |
| weather prediction | x42 |
| Access to information | x43 |
| Saffron growers insurance | x44 |
| Grower risk | x45 |

**Table 2. The used characteristics of GFA algorithm**

| Variable | Value |
|---|---|
| Population | 50 |
| Generation number | 500 |
| Mutation Possibility | 0.01 |

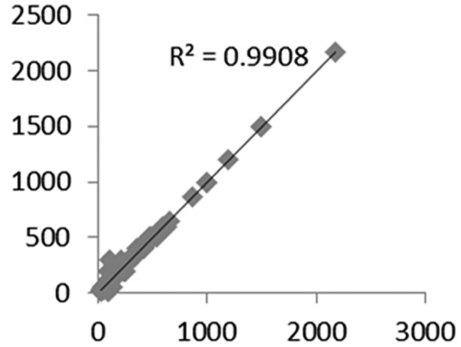
0.295 %. In other words, if the total sales increase, the yield of saffron will increase too. The elasticity coefficient of the price is 0.325, which shows that the response of the saffron growers to the price rise leads to increase in yield, and the elasticity of the price is greater than the other elasticity coefficients, which indicates that the reaction of producers is higher than the price. Since price is one of the factors affecting the production process of saffron, it has been found that the role of the price is more effective than other technical and economic variables, and saffron producers are more sensitive to price and it have more impact on yield than other variables (Dadras Moghaddam et al., 2018).

The elasticity coefficient of labor cost indicates that with a percentage increase in labor cost, the yield increases by about 0.166 %. The coefficient of irrigation is 0.077, which shows that a one percent increase in water input increases the yield by about 0.077 %. The cost-elasticity coefficient of harvesting suggests that with a percent increase in harvest cost, the yield is reduced by 0.191 %. Among the agricultural inputs (cultivation area, labor cost and water), the elasticity coefficient of labor cost factor is larger than other agricultural inputs, that means increasing the labor cost will increase the saffron yield more than other inputs.

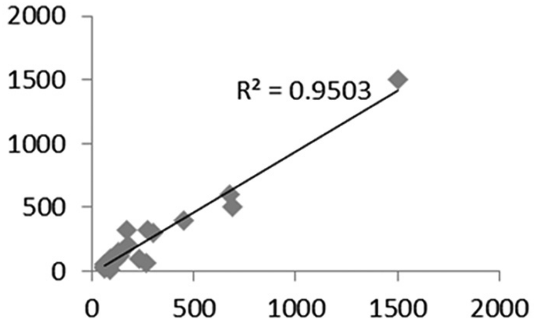
After determination of the number of rules, as well as type and primary parameters of the membership functions for each input, the fuzzy-neural network was designed and subjected in the training phase. The hybrid algorithm was used for teaching and the number of replicates was 200. Totally, 0.75 and 0.25 data were used for training process and network test, respectively. Figure 2 shows correlation between observed values with predicted values according to the adaptive neural network and therefore correlation coefficient between actual and estimated observation of effective factors on saffron yield for test and training data is 0.99 and 0.95, respectively (Table 3).

**Table 4. Elasticity of variables affecting saffron yield**

| Variable | Yield Elasticity |
|---|---|
| cultivation area | 0.142 |
| Related education | 0.046 |
| Total sale | 0.295 |
| price | 0.325 |
| Labor cost | 0.166 |
| Irrigation | 0.077 |
| Harvest cost | 0.191 |




*A*




*B*

**Fig. 2. Distribution of observed and predicted values using the ANFIS method:**
***A* – Test data for saffron yield;**
***B* – Training data for saffron yield**

**Table 3. Statistical results obtained from yield regression of saffron yields in Qaenat**

| Y = 0.011*x7 + 812.315* x11 + 0.445* x24 + 0.006* x25 + 0.0001* x28 + 0.0001* x30 – 0.0001* x31 | |
|---|---|
| Critical SOR F-value (95%) = 2.10 | Friedman LOF = 11000 |
| Repetitive data= 0 | $R^2$ = 0.80 |
| Experimental calculation error = 0 | $R^2$ = 0.79 |
| Fitted points = 112 | Cross validated $R^2$= 0.70 |
| Minimum non-significant error LOF (0.95) = 147.23 | F = 65.77 |

**Table 5. Results comparison between Adaptive neuro-fuzzy inference system (ANFIS) and genetic function approximation (GFA) Algorithm**

| Model method | ANFIS | | | | GFA | |
|---|---|---|---|---|---|---|
| | Training | | Test | | | |
| Saffron yield | RMSE | $R^2$ | RMSE | $R^2$ | RMSE | $R^2$ |
| | 586 | 0.99 | 2445 | 0.95 | 12456 | 0.80 |

In Table 5, the results of ANFIS and GFA were compared and ANFIS can predict less error than GFA about effective factors on saffron yields. However, adding fuzzy to the artificial neural network improves the model in the learning and reduces the estimation error. The R2 efficiency coefficient in the adaptive fuzzy neural network for test and teaching data was 0.99 and 0.95, respectively, which is better than the genetic function approximation algorithm. Also, the RSME efficiency coefficient for test and training data in the ANFIS was lower than the GFA method.

## Conclusions

Effective factors on the saffron yield in Qaenat (among 44 economic and technical variables) were determined using the Genetic Function Approximation (GFA) algorithm, which indicated that the cultivation area, related education, total sales, price, labor cost, irrigation and harvest costs are effective on the yield of saffron in Qaenat. Also, elasticities were calculated for the affecting factors on the yield of Qaenat saffron. The price elasticity coefficient was larger than other coefficients, which shows that response of the saffron growers to the rise in prices leads to an increase in the production of saffron, and the sensitivity of the producers to the price is higher than other factors.

Agricultural inputs including the cultivation area, labor cost and water that are effective on the yield of saffron, which elasticity coefficient of labor has greater than other inputs, that is, increased labor cost has had a greater contribution to increasing yields than other inputs. Also, the results of the adaptive fuzzy neural network (ANFIS) and the genetic function approximation (GFA) algorithm were compared and the results indicate that an ANFIS predicts the factors affecting the yield of saffron producers in the Qaenat with a lower error than the GFA algorithm.

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