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Prophesying egg production based on energy consumption using multi-layered adaptive neural fuzzy inference system approach

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ABSTRACT

Adaptive neural fuzzy inference system (ANFIS) is an intelligent neuro-fuzzy technique used for modeling and control of uncertain systems. In this paper, we proposed an ANFIS based modeling approach (called MLANFIS) where the number of data pairs employed for training was adjusted by application of clustering method. By employing this method, the number of data required for learning step and thereby its complexity were significantly reduced. The results obtained were compared with those obtained by using artificial neural networks (ANNs). Inputs to the first group were feed supply, fuel and machinery and the ones to second cluster were pullet, electricity and labor energies. Finally, the outputs of aforementioned networks were considered as inputs to ANFIS 3 network and predicted values of egg yield were derived. The coefficient of determination (R^2), root mean square error (RMSE) and mean absolute percentage error (MAPE) parameters of ANFIS 3 network were calculated as 0.92, 448.126, 0.014, respectively showing that ANFIS compared with ANNs with statistical parameters as 0.81, 751.96 and 0.019 respectively, can properly predict the egg yield of poultry farms. As a recommendation for future studies, ANFIS models with multi-layered structures can be developed to find the optimum number of layers.

1. Introduction

Energy and feed are main components of the production costs which are of interest in most animal production management systems. In order to control the production costs and the use of natural resources, perceiving parameters that affect the energy use is vital (Rivera-Torres et al., 2010).

The production of egg is increasingly driven by a shift in diet and food consumption patterns. Over the last decade, production of egg in Asia – where the bulk of the world population increase has taken place – has been growing (by almost 5 percent per annum) (depicted in Fig. 1). Moreover, in many developing countries, where the need to increase protein consumption is greatest, the productive sector has not participated in the "livestock revolution" (Anonymous, 2010). According to data obtained in 2010, Islamic Republic of Iran has had about 563669.9 tonnes of egg production during 1990–2010 (Anonymous, 2010). Thus the layer chicken industry is considered as an important livestock sector in Iran.

The intensive poultry production requires substantial amounts of energy to expend which should be used in an efficient manner. Some of the major energy inputs are feedstuffs, machinery and fuels which in some cases consume great quantities of energy related to their production process. Furthermore, based on the sustainability aim of each process, sustainable agriculture has been focused in livestock products as well (Heitschmidt et al., 1996). We can define sustainability as a conserving management strategy of resources use directed in a way that present and future generations would attain them steadily (Anonymous, 1991).

In recent years, the growing population and increased energy demands have forced governments and policy makers to take energy use and its efficiency into account which is an indicator of potential long term sustainability (Atilgan and Koknaroglu, 2006). Energy use pattern and the contribution of each energy input in total yield vary from agricultural system to system. Attending the relationship between inputs and yield using various mathematical functions is of great importance (Hatirli et al., 2006). These classic models with less complexity are based on exact definition of mathematical model equations. Perceiving and analysing systems with relatively high level of complexity (uncertainty) can be conducted by modern initiative methods such as artificial intelligence and neural network. Training the network is the advantage of these approaches; hence, uncertainty would decrease

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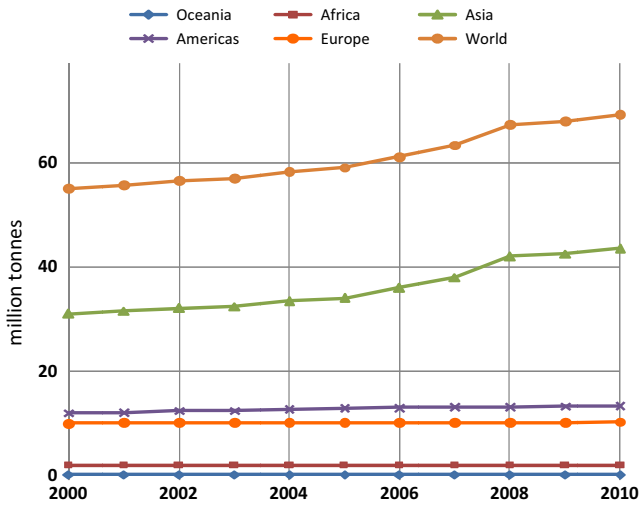

Fig. 1. Egg production diagram over 10 years (2000–2010) (Anonymous, 2013).

and therewith the effective analysis capability of system increases. This approach and its various forms are becoming popular due to their popularity for being efficient and less time-consuming. Recently, fuzzy logic has overcome the deficiency of previous concepts. Therefore, for problems which are not well defined and for which it is difficult, or even impossible to find a solution, fuzzy logic has been suitable (Singh and Singh, 2010; Serge, 2001). This useful computing framework based on the concepts of fuzzy set theory, fuzzy if–then rules and fuzzy reasoning is called fuzzy inference system (FIS). Adaptive neural fuzzy inference system (ANFIS) is a FIS implemented in the framework of an adaptive fuzzy neural network.

The advent of ANFIS provides a set of powerful tools for solving real world problems, with uncertain and nonlinear environments. This approach represents a useful neural network approach for the solution of function approximation problems. Data driven procedures for the synthesis of ANFIS networks are typically based on clustering a training set of numerical samples of the unknown function to be approximated. Researchers have reported the ability of modern approaches against classic models in various studies such as study done by Moreno (2009). The monthly ideal generation of an agent with a hydraulic plant within the Colombian power market was forecasted. ANIFS was used and compared against a multiple linear regression (MLR) model. The obtained results showed a considerable decrease of the mean percentage error overcoming the MLR model. Al-Ghandoor and Samhouri (2009) modeled electricity consumption of the Jordanian industrial sector using multivariate linear regression and neuro-fuzzy models. ANFIS technique was applied to yield modeling by Arkhipov et al. (2008). Qaddoum et al. (2011) explored the dynamics of neural networks in forecasting crop yield using environmental variables. In a study conducted by Pan and Yang (2006), livestock farm odour was analysed using a neuro-fuzzy approach. They came to the conclusion that ANFIS is effective in comparison to neural networks. A comparison between ANFIS method and traditional statistical techniques for exploring complex root distribution patterns under field conditions was done by Krueger et al. (2011). Their results showed that the fuzzy method offers a viable alternative to more traditional statistical techniques. Moreover, Fahimifard et al. (2009) applied ANFIS to predict the poultry retail price. Some other non-linear models such as artificial neural networks, the adaptive neuro-fuzzy inference system and a non-linear regression technique have been applied in similar studies (Ekici and Aksoy, 2011; Mellit and Kalogirou, 2011; Talebizadeh and Moridnejad, 2011; Nefeslioglu et al., 2008; Yagiz et al., 2009; Dagdelenler et al., 2011). In recent studies, a multi-layered ANFIS was employed to predict yield of agricultural crops with good accuracy in contrast to conventional models (Naderloo et al., 2012; Khoshnevisan et al., 2014a, 2014b). In a study, ANNs was performed to model energy output in egg-hen farms of Iran by Sefeedpari et al. (2012a). The same authors have studied similar farms from the energy efficiency point of view. Technical efficient farmers were selected using fuzzy data envelopment analysis approach (Sefeedpari et al., 2012b). Based on the literature review, we are sure that application of ANFIS in production systems is of interest to readers including policy makers and energy consultants. However, there are previous works that use ANNs and single- layered ANFIS and Multi-layered ANFIS to model other agricultural production processes (especially agricultural crops) but we believe the application of our proposed method for livestock production systems is a state of the art approach.

In this study we generated a combined (multi-layered) ANFIS model instead of a single layered one, to predict and model yield levels for egg production industry (poultry farming) in Iran. In view of this, the main objectives of the present paper are as follows:

1. To evaluate energy use pattern (energy cost of each kilogram of egg) based on the real data of the existing situation.
2. To present a combined ANFIS approach for predicting yield level of egg production.
3. To compare the results with those by ANNs model and analyse the obtained results using some statistical parameters.

In order to reach these aims, software programs such as Microsoft Excel 2013 was employed. The computational code of both ANNs and ANFIS was written in MATLAB v.7.1 (R2012a).

2. Material and methods

2.1. Data collection and case study region selection

Data were collected from 40 poultry for egg production farms in Alborz province of Iran, located in northwest of Tehran, within 35° 31′ and 36° 12′ north latitude and 50° 11′ and 51° 29′ east longitude with total area of 5800 km^2, by using a face to face questionnaire method in 2011–2012 production year. The province of Alborz has four municipalities including Karaj, Savojbolagh, Eshtehard, Nazarabad and Mahdasht (Fig. 2). Thus, inquiries were sought on inputs used for production of egg as well as output values. This province is situated 1300 m above sea levels. The annual average of temperature and rainfall is about 16 °C and 200 mm, respectively.

Sample farms were randomly selected from the study area by using a stratified random sampling technique. The sample size was calculated using the Cochran method (Eq. (1)) (Cochran, 1977).

$$n = \frac{Nt^2S^2}{Nd^2 + t^2S^2} \quad (1)$$

where n is the required sample size, N is the number of units in target population, S is the standard deviation, t is the reliability coefficient at 95% confidence limit (1.96), and d is the acceptable error. The permissible error in the sample size was defined to be 5% for 95% confidence. The specific information about the characteristics of the target poultry farm systems are given in Table 1.

For energy use pattern estimation, first, all inputs and outputs, were identified and quantified and later transformed into energy units. Inputs used in the selected farms were machinery, diesel fuel, electricity, human labor, pullet and feed; while the products were egg and manure. The energy equivalents of the inputs and