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Modeling output energy based on fossil fuels and electricity energy consumption on dairy farms of Iran: Application of adaptive neural-fuzzy inference system technique

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ABSTRACT

This research examined an adaptive neural-fuzzy inference system to model output energy on the basis of energies of fossil fuels and electricity inputs. Energy use especially non-renewable forms are widely considered in livestock farming management in recent years. Data were collected randomly from 50 dairy farms in Tehran province of Iran in 2011. A review of the published literature indicated that the adaptive neural-fuzzy inference system (ANFIS) has rarely been used or tested to model agricultural energy demand. ANFIS model based on energy consumption was developed for dairy farm units in Tehran province, Iran. In this research, fossil fuels and electrical energy required and energy output produced were treated as inputs and output of ANFIS model, respectively. The computational results demonstrated that ANFIS model is generally comparable with linear regression analysis approach and is promising in modeling fossil fuels and electricity energy consumption. The comparison of the coefficient of determination (R^2) (0.79 and 0.11), the root mean square error (RMSE) (0.11 and 0.22) and the mean absolute percentage error (MAPE) (0.007 and 0.014) demonstrated the above mentioned result for both proposed methods, respectively. The accurate model performance is beneficial to predict energy usage as the first step toward energy management and it would be constructive in developing future energy related researches and planning strategies.

1. Introduction

Energy can be exploited from different input resources such as human labor, animal, fossil-based fuels, electricity and machinery to perform various operations in dairy production. Implementing more automatic equipment and performing mechanized operations has caused the crisis of environmental deterioration. Meanwhile, non-renewable energy sources like fossil-based fuels and electricity are exploited more frequently; namely, many production systems are not sustainable. Moreover, since energy resources are limited and depleting, the outlook of energy consumption needs optimizing decisions. So that, improving energy use management level is upgrading for combating rising energy costs, depletion of natural resources and environmental deterioration (Dovi et al., 2009). The share of agriculture in these resources usage is going to rise further in the face of the rising population of the communities and in the view of the consequent demand for increased yield and the necessity to provide sufficient food for the population growth. Therefore, fossil-based fuel energy resources should be conserved and managed, and careful forecasts of fossil fuel consumption analyses are needed. As a matter of fact, by increasing use of fossil-based fuel energy sources, the related significant global problems will probably increase (Ermis et al., 2007). This scenario of high-energy need necessitates increased emphasis on energy efficiency and conservation (Chauhan et al., 2006). So far, insufficient knowledge is available about the energy efficiency of production technologies, their share in total energy consumption and how yield is influenced by energy inputs flow in a production process in livestock keeping farms (Kraatz et al., 2006).

Today dairy farming and dairy farm milk collection posts are huge energy consumers, because of several operating equipment such as milking machines, water heaters, milk coolers, vacuum pumps and lighting appliances (Rodrigues et al., 2011). In Iran, considering to high energy costs in comparison with low yield and farmers' income, amount of energy expenditure is befit of attention. As a matter of fact, non-renewable energy resources

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(such as fossil-based fuels) are extensively utilized in electricity generation process in Iran whereas renewable resources have stayed useless, unfortunately. Regarding the above mentioned reason and the electricity mix of Iran (as the following formula: natural gas: 72.24%, oil: 19.50%, hidric: 8.19%, other renewable sources (wind and sun): 0.07%), electricity is considered as non-renewable energy resource.

The province of Tehran plays an important role in the national production of milk representing approximately 30% of total output. On the other hand, within Iran, Tehran province accounts for over 13% of the total number of dairy farms. The milk yield for the first 3 months of the year 2010 was announced as 265,501 tons from 1897 dairy farming units in Tehran province (Anonymous, 2010b). It was also reported that the average milk yield per cow in 2010 (with average cows weight of 635 kg) was about 27 kg day^{-1}.

Traditionally, regression analysis has been known as the most popular modeling technique in predicting energy consumption by researchers (Al-Ghandoor et al., 2008a,b,c; Flores et al., 2004; Al-Garni et al., 1994). Recently, with the rapid development of data modeling techniques, alternative approaches such as neural networks and neuro-fuzzy methods have become of particular importance since they are easier to operate in different areas (Sanzogni and Kerr, 2001; Onqsakal and Chayakulkheere, 2005; Mrinal and Chitralekha, 2006; Craninx et al., 2008). However, they have been rarely explored in energy analysis and prediction applications (Al-Ghandoor and Samhouri, 2009; Ekici and Aksoy, 2011). The advantages of applying these approaches are generally the same i.e. a tool for energy management and planning strategies as the first step for massive cases such as a region or country energy management programs. As a whole, governments and private sectors handling energy auditing programs are interested in such predicting and modeling researches to make their plans achieved. As the organizations and policy makers are improved by applying such tools, farmers would not be deprived of benefits. Farming operations in the light of better and safer conditions would help a farmer to achieve the goals for producing better quality products. In such a system, the whole members are benefited from their practices and eventually, a cleaner life would expect them.

However, there are relatively less published materials in the literature in relation to modeling of energy based on energy sources such as fossil-based fuels and electricity (as the main non-renewable energy sources) in dairy farming. Hence, we just cited previous researches in other fields. Pan and Yang (2006) analyzed livestock farm odor using a neuro-fuzzy approach. They came to the conclusion that adaptive neural-fuzzy inference system (ANFIS) is effective in comparison to neural networks. The paper by Ermis et al. (2007) focused on the analysis of world primary energy including fossil fuels such as coal, oil and natural gas through artificial neural networks (ANNs). The ANNs was observed to be a suitable method for forecasting energy consumption data. Two techniques, for modeling electricity consumption of the Jordanian industrial sector, including multivariate linear regression and neuro-fuzzy models were presented in the study done by Al-Ghandoor and Samhouri (2009). Based on the square root of average squared error of data it was concluded that the neuro-fuzzy model performs slightly better for prediction of electricity consumption than the multivariate linear regression model. Qaddoum et al. (2011) explored the dynamics of neural networks in forecasting crop (tomato) yield using environmental variables. Recently, in Iran, Naderloo et al. (2012) applied ANFIS to predict the grain yield of irrigated wheat on the basis of different energy inputs in Iran. In their study, a multi layered ANFIS approach showed that the applying ANFIS with multiple layers could predict the grain yield with good accuracy. Similar studies were carried out by Khoshnevisan et al. (2014a,b) in Iran.

In present study, the application of soft computing method for data analysis called adaptive neuro-fuzzy inference system (ANFIS) to model the output energy of milk production process in Iran was demonstrated. Moreover, various statistical indices (R^2, RMSE and MAPE) were calculated to compare the results with regression analysis for validation.

2. Material and methods

2.1. Data collection and assumptions

The research material included 50 dairy farms in Tehran province of Iran (the capital of Iran). Tehran province is located within 35°34′ and 35°50′ north latitude and 51°02′ and 51°36′ east longitude (Anonymous, 2010a). Tehran province with 4443 industrial dairy and beef cattle farms plays an important role in producing milk and meat for the population of Iran. The milk yield for the first 3 months of 2010 was announced as 265,501 tons yielded from 1897 dairy farm units (Anonymous, 2010b). This survey was made in 2011 by interviewing the dairy farm managers using a face-to-face questionnaire method. Data culled from questionnaires were of the amount of consumed inputs (fossil based fuels and electricity) in milk production; Moreover, milk yield and cow manure amounts were among questions along with other useful information such as the area of farms and number of cattles. The sample size was determined by using the random sampling method (Cochran, 1977).

Some assumptions were essential due to have a much more precise computation such as the period which energy consumption was estimated for. Lactation period of a cow was 305 days and cows were kept dry about 60 days. Therefore, input consumptions assigned to a production year were considered. More specific information about the target farms and cows are given in Table 1.

2.2. Data preparation

Input energy sources for this analysis in the studied region were electricity and fossil fuels including diesel, gasoline, kerosene and natural gas. The amount of each input use (on the basis of unit (L, m^3 or kW h)) was multiplied with its corresponding energy coefficient (on the basis of MJ unit^{-1}) (Table 2) to calculate the energy use per cow. These coefficients were adapted from several literature sources that best fit Iran's conditions.

The fuels energy was computed based on the whole fuel use in various operations including feed preparation, feeding, heating of farm buildings, labor houses and management facilities, transportation, etc. Then, energy input of fuels could be computed as following (Eq. (1)):

$$E_p = Q_i \times E_i \quad (1)$$

where E_p denotes the energy amount of fuel (MJ cow^{-1}), Q_i is fuel use (unit cow^{-1}) and E_i denotes the fuel energy coefficient (MJ unit^{-1}). A similar approach was used to estimate electricity

Table 1
Characteristics of the dairy farms and cows of the studied area.

Breed of cows	Holstein
Average no. of cows per farms (head)	129
Lactation period (days)	305
Drying period (days)	60
Average milk yield (kg day^{-1} cow^{-1})	26.5
No. of lactations (times per day)	3
Average feed intake of lactating cow (kg day^{-1} cow^{-1}) (DM[a])	19
Average feed intake of dry cow (kg day^{-1} cow^{-1}) (DM)	35

[a] Dry matter.