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Article

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Research paper

Agricultural energy demand modeling in Iran: Approaching to a more sustainable situation

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ABSTRACT

Energy has been heavily subsidized in Iranian economy for decades. Due to low oil prices, and, thus, budget limit, fossil fuel prices are under gradual liberalization. This will result in higher cost of production in all fuel consuming activities including agriculture. So it seems that farmers will plan to substitute fossil fuels by non-fossil alternatives. This study aims at modeling and prediction of energy demand (as a key factor of production) in Iranian agriculture. Box–Jenkins methodology is applied to model agricultural consumption of four major sources of energy including: gasoline, kerosene, gasoil and electricity for the period spanning from 1988 to 2014. Also same data are predicted for 2015–2026 in order to check model adequacy and provide information regarding status of energy demand in Iranian agriculture in the future. Main results indicate a downward trend in consumption of four energy types except electricity which is predicted to go up. This implies that, as far as energy consumption is concerned, Iranian agriculture is approaching to a more sustainable situation. Rearrangement of fuel price support policy from nonrenewable to renewable sources and provision of more governmental support for switching to lower-carbon and environment-friendly energy sources is recommended.

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1. Introduction

Energy demand forecasting is crucial for energy planning, formulating strategies and recommending energy policies (Bhattacharyya and Timilsina, 2009). Considering the fact that world population is increasing and predicted to reach 8.5 billion by 2030 (United Nations, 2015), energy demand will also be increasing. As the world becomes more dependent on technology and economies getting more developed, the energy consumption and thus dependency on energy will continue to rise. In conventional terms, demanding more energy implies a more tight dependence on fossil fuels like natural gas and oil which are, however, left with limited reserves and release greenhouse gases which are harmful to the environment and the global climate change. All these reasons force countries to adopt new sustainable energy policies, and to find alternative ways to balance the energy demand in most efficient, cheapest and strategic way (Oguz, 2013).

The agriculture sector has at its core the production process for foodstuff (e.g., grains, fruits and vegetables, meat, fish, poultry, and milk), and non-food vegetable products of economic value (e.g., tobacco, jute, hemp). However, the sector also comprises or has close links with processes that take place before and after

this core production process, such as fertilizer production, post-harvest processing, and transport of foodstuff. Defined broadly, the agriculture sector has as its primary goal the delivery of food on the table for the population or for export. Thus, any measure that will reduce the fossil energy consumption while delivering the food service is in principle a potential candidate for analysis as a way of greenhouse gas (GHG) mitigation option (Sathaye and Meyers, 1995).

Agricultural activities require energy as an important input to production. Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, and for lighting on the farm, and indirectly in the fertilizers and chemicals produced off the farm. Modern agriculture needs modern energy — the two are closely linked. For many developing countries, agriculture is the dominant sector in developing the economy. Increasing productivity and the modernization of agricultural production systems are the primary drivers of global poverty reduction and energy plays a key role in achieving this. Energy input to modern and sustainable agricultural production and processing systems is a key factor in moving beyond subsistence farming towards food security, added value in rural areas and expansion into new agricultural markets. In many cases, renewable energy technologies and hybrid systems can provide energy services that neatly support the production process, e.g., by providing irrigation (pumps) or post harvest treatment (cooling) or processing (drying,

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milling, pressing). The requirements of mechanical energy in the agricultural production process are also of critical importance and include human and animal labor as well as fuels for mechanization, pumping and other activities, and indirectly the production of fertilizers and agrochemicals. However, in many cases energy consumption in agriculture tends to be inefficient because of price subsidies (Swarnkar and Singh, 2013).

Fossil fuel subsidies – public financial support for fossil fuels – come in many forms and through many methods. These subsidies can be facilitated and applied through numerous policy processes and tools, and subsidies vary in their form across different countries. Environmental degradation, air pollution and health costs stemming from extracting and burning fossil fuels are not carried by the industry but paid by society. Therefore, these ‘external costs’ are also considered as fossil fuel subsidies. It is believed that all forms of fossil fuel subsidies are inefficient, harmful to the environment and blocking the transition to clean energy systems (Ozturk et al., 2010). As a result many countries including Iran have developed a roadmap to gradually phase out fossil fuel subsidies in the next decades.

Agriculture is central to Iranian economy accounting for about 10% of gross domestic product, 20% of employment and more than 20% of non-oil exports (CBI¹, 2015). Iranian government has been committed to support farmers by providing cheap inputs for decades. In spite of liberalization in market for some inputs (like pesticide), energy continued to be supplied with subsidized prices until recent years. Based on World Bank data global gasoline price has increased from 0.54 to 1.13 USD per liter (109%) during the period 1998–2017, while same data for Iranian economy was 0.08 and 0.36 (350% increase). As a result average energy consumption in Iranian agriculture is three times more than world level. Official data shows that gasoil has greatest share in total fossil fuels consumed in agriculture (94%), while electricity consumption has experienced an average annual growth rate of 45% during 1988–2014 (MOE², 2016).

Considering all the above points, main contribution of the current study can be defined as the modeling of demand for four major Iranian agricultural energy sources, and prediction of future consumption trend which clearly depicts the outcome of energy subsidy reduction policy followed by the government.

2. Literature review

Previous studies on energy consumption can be separated in two groups. First, those studies devoted to energy-growth association at national and sector levels. For example causality and cointegration relationship between energy consumption and economic growth is reported by some researchers (Mucuk and Sugoza, 2011; Senturk and Sataf, 2015; Ozturk et al., 2010; Sharma, 2010; Stern, 2010). Mehra (2007) found strong unidirectional causality from economic growth to energy consumption in a group of oil exporting countries. Kayhan et al. (2010) analyzed dynamic causal relationship between electricity consumption and economic growth in the Romanian economy during 2001–2010. Their results support causality relationship from electricity consumption to economic growth. Second, works trying at modeling and forecasting energy price and consumption (Fu and Nguyen, 2003; Meng et al., 2011; Chang et al., 2011; González-Romera et al., 2008). Camara et al. (2016) examined the forecasting performance of SARIMA and ANN methods in the context of U.S. residential energy consumption. They conclude that the neural network model has slight superiority over SARIMA. Jankovic (2017) provided forecasts for energy consumption in Serbia using ARIMA methodology for period of 2016 to

2027. Main results revealed that, in the following years, an increase can be expected in demand for oils.

In the context of Iranian economy some economy-wide works are done. For instance, Fallahi and Montazeri (2010) by using 35 years time series data showed that energy use had a negative effect on economic growth which is against theoretical expectation. But little is conducted on energy consumption modeling especially at sector level. Assessing the current situation and forecasting the future energy demand are essential for developing sustainable energy policies that support the increasing energy demand. In this context, low oil prices and public budget limit, necessitate liberalization of fossil fuel prices which definitely imposes higher cost to farmers. In order to reduce this burden, renewable energy resources seem to be the best alternatives. So the main objective of this paper is provision of economic model and reliable insight on energy (different types) consumption in agriculture. In sum, the main recognized gap in the relevant literature goes to the lack of any work dealing with modeling and prediction of different energy sources’ consumption in Iranian agriculture.

The rest of the paper is organized as follows. Section 3 briefly presents methodology applied. Section 4 discusses main results obtained from the estimated model and finally Section 5 concludes.

3. Materials and methods

3.1. Background

Forecasting demand is both a science and an art. Econometric methods of forecasting, in the context of energy demand forecasting, can be described as the science and art of specification, estimation, testing and evaluation of models of economic processes that drive the demand for fuels (Meetamehra, 2009). Energy demand forecasting is a challenging task not only in developing countries where required data and proper models are lacking, but also in industrialized countries in which these limitations are somewhat less serious.

Since the first oil crisis in the early 1970’s, bulk of research has been done in order to understand the nature of energy demand in both developed and developing economies. This has led to important methodological developments, and as a result a wide variety of models became available for analyzing and prediction of energy demand (Bhattacharyya and Timilsina, 2009). In a broad classification main methods include: trend analysis, end-use method, econometric approach, time series and hybrid models. Trend analysis is a non-causal method that does not explain how the values of the variable being predicted are determined. Its main disadvantage lies in the fact that it ignores possible interaction of relevant factors. Thus it could be considered only as a way of providing preliminary estimate of the predicted value of the variable. Application of end-use method in agriculture requires detail data on each of the end-uses (tractors, pumps, etc.) which is usually unavailable in developing countries. By using econometric approach one combines economic theory with statistical methods to specify an equation (or system of equations) for forecasting energy demand. This requires a consistent dataset over a reasonably long period. Moreover, researcher should assume a specific rate of change for explanatory variables during forecasting process which might seem incorrect.

Time series methods are in fact a subset of econometric models where behavior of a variable is explained only by its own lagged values. Simplicity and no need to collect data on multiple variables are among the main advantages of this method. Finally, hybrid approaches have recently been chosen by many researchers due to their more forecasting accuracy. Considering all the pros and cons of aforementioned methods in one hand and available data for Iranian agricultural fuel consumption on the other hand, time series methods are utilized in this study. More description of the applied method is provided in the next section.

¹ Central Bank of the Islamic Republic of Iran.

² Ministry of Energy.

3.2. The Box–Jenkins methodology

The BJ methodology, commonly known as ARIMA³ model, is, in theory, the most general class of univariate time series models for forecasting a variable. In literature, selecting a true model for ARIMA is considered as an art implying that a group of ARIMAs should be estimated in order to find the best model describing underlying behavior of a variable. ARIMA forecasts future values by looking only at the past pattern of the time series without using other independent variables. It is widely recognized as the most appropriate forecasting technique in many areas and is used extensively for time series modeling in practice (Oguz, 2013). The Box–Jenkins methodology of ARIMA models has some advantages over other time series methods. It provides more information from any other time series methods while using a minimum number of parameters. It also allows for flexibility in the process of choosing the correct forecasting mode. It includes a process that allows us to examine a large variety of models in our search for the correct one. On the other hand, the only problem with ARIMA is the modeling which is difficult mathematically and requires a deep knowledge of the method. Therefore, it is not easy to build an ARIMA model without training in statistical analysis and a good knowledge of the methodology. A general ARIMA model is represented as “ARIMA (p, d, q)”, where:

- p is the order of autoregressive part,
- d is the number of nonseasonal differences needed for stationarity, and
- q is the order of moving average part.

Partial autocorrelation function (PACF) and autocorrelation function (ACF) are commonly used to determine proper values of p and q , respectively. Mathematically a time series (y) can be specified as an ARIMA (p, d, q) as follows:

$$\hat{y}_t = \mu + \phi_1 y_{t-1} + \dots + \phi_p y_{t-p} - \theta_1 e_{t-1} - \dots - \theta_q e_{t-q} \quad (1)$$

here, “ ϕ ’s” and “ θ ’s” are autoregressive and moving average parameters, respectively.

The Box–Jenkins methodology for modeling time series consists of five different steps, namely, differencing (to make sure that series entering into the forecasting process is stationary), identification (to determine proper value for p and q), estimation (to provide numeric value for model parameters), diagnostic checking (to decide on model adequacy) and forecasting (to get future values of the series) (Asteriou and Hall, 2011).

Accuracy of forecasts provided by estimated model is evaluated by following criteria:

$$RMSE^4 = \sqrt{\frac{1}{T} \sum_{t=1}^T (y_{obs} - y_{pred})^2} \quad (2)$$

$$MAPE^5 = \frac{1}{T} \sum_{t=1}^T \frac{|y_{obs} - y_{pred}|}{y_{obs}} \times 100$$

where T is the number of observations (years), Z_{obs} and Z_{pred} are observed and predicted values of the variable, respectively. The lower are RMSE and MAPE the more accurate is the estimated model. Moreover, adequacy of the estimated models is investigated by detail examination of residuals. The Ljung–Box statistic could be calculated to decide on the significance of residuals at different lags. Also, three widely used statistical and econometric tests including Jarque–Bera (for normality), Breusch–Godfrey (for

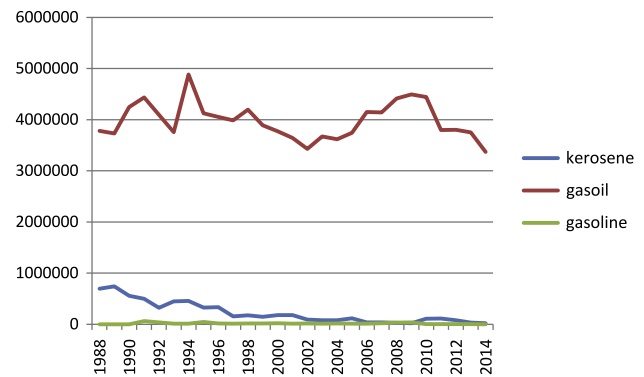


Fig. 1. Changes in three agricultural fossil fuel consumptions (thousand liters).

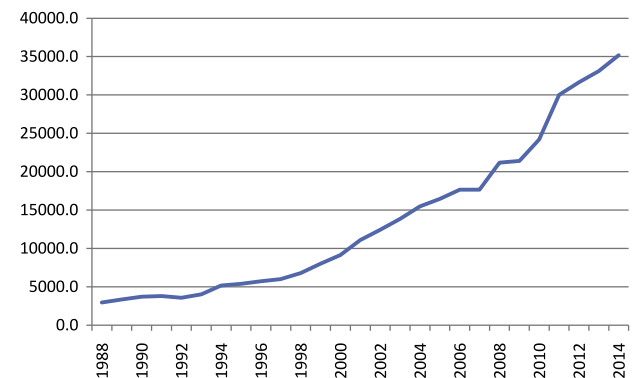


Fig. 2. Changes in agricultural electricity consumptions (million kWh).

serial correlation) and ARCH (for heteroscedasticity) are separately applied for all estimated models.

3.3. Data

In this study consumption of four major sources of energy in Iranian agriculture are separately modeled over the period 1988 to 2014. Then, relevant future values are predicted for the next decade. Annual data on agricultural consumption of four major sources of energy including: kerosene, gasoil, gasoline and electricity for the period 1988–2014 is gathered from CBI and MOE official documents. Description of the data is provided in the next section.

4. Results and discussion

Figs. 1 and 2 show evolution of the data. As is clear all three fossil fuels have followed decreasing trend though, due to negligible share in total fossil fuel consumption, the line for gasoline is not clear. The reverse situation is found for electricity implying more reliance of farmers on electricity as a new source of their energy needs.

Also some statistical features of the variables are presented in Table 1. All three fossil fuels consumption followed a slight declining trend, though the major item, gasoil, shows an insignificant change. On the other hand, electricity use in agricultural activities has risen, implying relative success of government in substituting nonrenewable fuels by renewable and clean alternatives.

As the first stage of BJ methodology, stationarity of variables are checked. Table 2 has more.

Both applied tests reject the null hypothesis of stationarity in favor of the existence of one unit root. Thus the order of integration for all variables is determined at one. Next section documents the results of estimated ARIMA models for all energy sources.

³ Autoregressive Integrated Moving Average.

⁴ Root Mean Squared Error.

⁵ Mean Absolute Percentage Error.

Table 1
Descriptive statistics (1988–2014).

Variable statistic	Kerosene (million liter)	Gasoil	Gasoline	Electricity (million kWh)
Mean	224.6	3978.1	16.4	13 669.9
Standard deviation	212.3	355.7	15.4	10163.1
Maximum	740.3	4882.3	62.9	35187.9
Minimum	190.1	337.1	119.1	2947.0
Growth rate (%)	−12.9	−0.4	−14.2	10.0
Share in total fossil fuel consumption (%)	5.1	94.5	0.4	–

Table 2
Stationarity tests results.

Test variable	ADF		Philips-Perron		Result
	Level	First difference	Level	First difference	
Kerosene	−0.35	−7.56***	−2.07	−7.76***	I (1)
Gasoil	−2.89	−6.42***	−2.87	−6.55***	I (1)
Gasoline	−1.14	−5.80***	−2.60	−9.35***	I (1)
Electricity	−0.66	−4.59***	−0.18	−7.04***	I (1)

Note:

*** Denotes significance at one percent level.

Table 3
ARIMA (4,1,2) estimates for kerosene consumption.

Variable	Coefficient	Std. Error	t-statistic
Constant	−15 900.8	10 662.2	−1.49
AR(2)	−0.62	0.20	−3.06***
AR(4)	−0.41	0.15	−2.59**
MA(2)	0.99	0.07	12.75***
$R^2 = 0.72$	RMSE = 37858.8		MAPE = 129.3

Note:

** Denote significance at 5% level.

*** Denote significance at 1% level.

Table 5
ARIMA (0,1,4) estimates for gasoline consumption.

Variable	Coefficient	Std. Error	t-statistic
Constant	−591.70	274.82	−2.15**
MA(1)	−0.35	0.06	−5.39***
MA(2)	−1.03	0.10	−10.02***
MA(3)	−0.42	0.07	−6.00***
MA(4)	0.91	0.05	17.85***
$R^2 = 0.74$	RMSE = 5779.6		MAPE = 242.5

Note:

** Denote significance at 5% level.

*** Denote significance at 1% level.

4.1. Estimated model for kerosene consumption

As the first choice of p and q in Eq. (1) one should refer to PACF and ACF of kerosene consumption data in first difference mode. Those lags representing a sudden cut-off could be a good starting candidates. Here, lags of 1, 2, 4, and 6 for p , and 1, 2, 3, 5, and 6 for q were considered. By estimation of the first model (1,1,1) and looking at its residuals, more technically significance of Ljung–Box statistic, the adequacy of estimated model was rejected. So in the second round the next model (1,1,2) was estimated, and again found to be unsuitable. After running different models and examining their adequacy, ARIMA (4,1,2) is chosen as the best fit to kerosene consumption data with minimized RMSE and MAPE. As Table 3 shows all slope coefficients are significant and the estimated model has acceptable goodness of fit. Furthermore adequacy of the model was confirmed by three diagnostic checking tests reported in Table 4.

Fig. 3 depicts predicted kerosene consumption trend for the period 2015–2026. The red lines boundary is 95% confidence interval. Obviously, on average, kerosene use is expected to stop in Iranian agriculture meaning a shift in energy sources.

4.2. Estimated model for gasoline consumption

Based on model adequacy criteria, ARIMA (0,1,4) is selected as the best model explaining gasoline consumption variations

(Table 5). All five parameters are highly significant and R -squared shows an acceptable explanatory power of the model. Based on data provided in Table 6 no sign of rejection of classic regression analysis assumptions is seen implying adequacy of the estimated model.

Fig. 4 illustrates the gasoline consumption projection for the period 2015–2026. Similar to results stated for kerosene, we anticipate a declining trend and stoppage of gasoline use in next decade. This can be treated as another sign of movement to environment-friendly agriculture in the future.

4.3. Estimated model for gasoil consumption

Tables 7 and 8 portray the optimum ARIMA model describing gasoil consumption data and its adequacy. The order of both AR and MA parts is three. Model has passed all criteria deciding on satisfactoriness. Moreover, based on Fig. 5, dependence of agriculture on gasoil, as major fossil fuel utilized, is predicted to decline (by 13.6%) in upcoming years.

4.4. Estimated model for electricity consumption

MOJA has tried to promote non-fossil fuels application in Iranian agriculture since mid 1990s by providing incentives like subsidized price. So it is very important from policy making point of

Table 4
Model adequacy tests results for kerosene consumption.

Test	Jarque–Bera(normality)	BG-LM(serialcorrelation)	ARCH(heteroscedasticity)
Statistic	0.58(0.75)	1.48(0.26)	0.46(0.51)

Note: Figures in parentheses are p -values.

Table 6

Model adequacy tests results for gasoline consumption.

Test	Jarque–Bera(normality)	BG-LM(serialcorrelation)	ARCH(heteroscedasticity)
Statistic	2.81(0.25)	1.42(0.25)	0.33(0.57)

Note: Figures in parentheses are *p*-values.**Table 7**

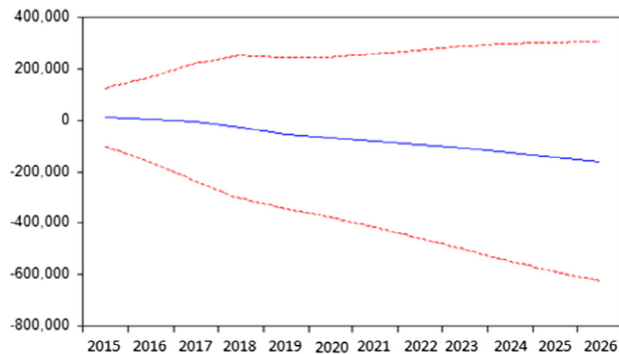
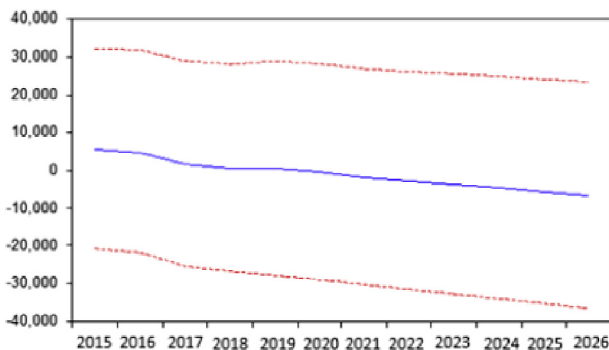
ARIMA (3,1,3) estimates for gasoil consumption.

Variable	Coefficient	Std. Error	<i>t</i> -statistic
Constant	−57597	43768.6	−1.31
AR(3)	0.47	0.12	3.62**
MA(3)	−0.92	0.02	−32.86***
$R^2 = 0.76$	RMSE = 4525.1		MAPE = 179

Note:

** Denote significance at 5% level.

*** Denote significance at 1% level.

**Fig. 3.** Kerosene consumption forecasts (2015–2026). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)**Fig. 4.** Gasoline consumption forecasts (2015–2026).

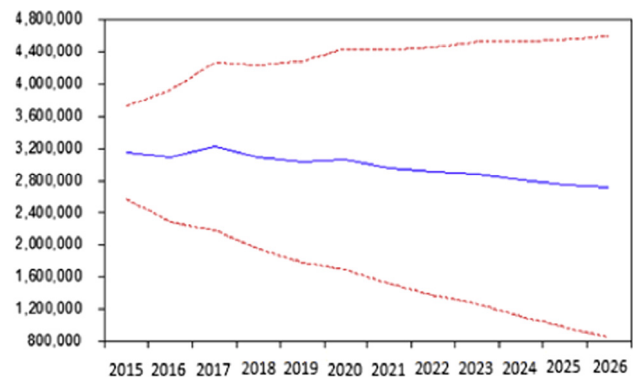
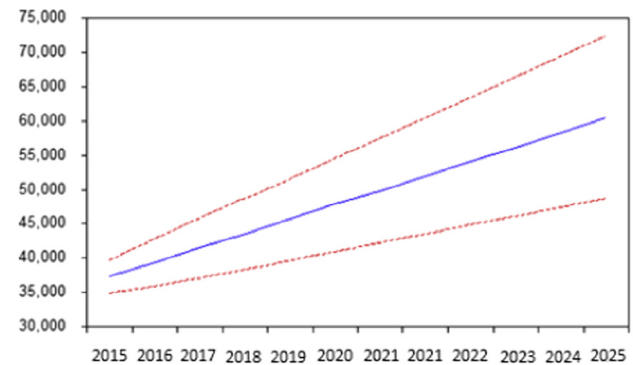
view to know how effective would be such policy in the future. As Tables 9 and 10 show an ARIMA (1,1,1) meeting all decision criteria, is estimated to give accurate forecasts on electricity consumption.

Forecasts obtained from the estimated model suggest an almost 65.7% increase in agricultural electricity consumption for next decade. It clearly points out to gradual substitution of electricity for other three fossil fuels (see Fig. 6).

Table 8

Model adequacy tests results for gasoil consumption.

Test	Jarque–Bera(normality)	BG-LM(serialcorrelation)	ARCH(heteroscedasticity)
Statistic	1.02(0.60)	0.54(0.47)	0.15(0.71)

Note: Figures in parentheses are *p*-values.**Fig. 5.** Gasoil consumption forecasts (2015–2026).**Fig. 6.** Electricity consumption forecasts (2015–2026).**Table 9**

ARIMA (1,1,1) estimates for electricity consumption.

Variable	Coefficient	Std. Error	<i>t</i> -statistic
Constant	2162.9	548.1	3.94**
AR(1)	0.88	0.08	10.77***
MA(1)	−0.99	0.10	−9.61***
$R^2 = 0.81$	RMSE = 622.67		MAPE = 1.74

Note:

** Denote significance at 5% level.

*** Denote significance at 1% level.

In order to check the superiority of the estimated ARIMAs, forecasts from artificial neural network (ANN) models are produced. Table 11 compares the accuracy of forecasts from two competing methods. It is clear that for all energy sources, forecasts from ARIMAs have lower value of RMSE and MAPE compared to those from ANNs validating the superiority of estimated ARIMAs.

Table 10
Model adequacy tests results for electricity consumption.

Test	Jarque–Bera(normality)	BG-LM(serialcorrelation)	ARCH(heteroscedasticity)
Statistic	0.94(0.72)	1.05(0.32)	0.09(0.77)

Note: Figures in parentheses are *p*-values.

Table 11
Forecasts' accuracy comparison.

	Kerosene		Gasoline		Gasoil		Electricity	
	RMSE	MAPE	RMSE	MAPE	RMSE	MAPE	RMSE	MAPE
ARIMA	37 858.8	129.3	5779.6	242.5	4525.1	179.0	622.7	1.7
ANN	38 001.1	131.7	5829.5	253.9	4612.6	196.2	689.4	1.9

5. Conclusion

Given the fast growing population's food needs, the world's finite supply of fossil fuels and the adverse environmental impacts of using this nonrenewable resource, the existing relationship between agriculture and energy must be dramatically altered. Despite the challenges posed by the energy-intensive nature of agriculture, the careful utilization of resources and judicious application of technology has the capacity to significantly improve the long-term sustainability of food production.

Forecasting demand is both a science and an art. Econometric approaches of forecasting, in the context of energy demand modeling, can be characterized as 'the science and art of specification, estimation, testing and evaluation of models of economic processes' that drive the demand for fuels. Agriculture plays a critical role in Iranian economy in terms of production, employment, non-oil export and food security. Providing cheap fossil fuels for decades resulted in overuse of these energy sources and, of course, more pressure on environment. This has forced MOJA to revise its supportive policies with the aim of promoting application of renewable energy. Investing on the renewable energy sources can also be a way to support economic growth, and to reduce unemployment. So the Iranian government adopted targets and strategies for 2025 in order to increase the share of renewable energy sources in energy demand and to reduce the carbon emissions.

This study thus attempted to forecast the sectoral energy demand of Iranian agriculture for different energy sources as an elaboration to the existing non-source or integrated estimations. Agricultural energy consumption in Iran for four major items is modeled using BJ approach as a widespread technique. Annual data on use of kerosene, gasoline, gasoil and, electricity for the period spanning from 1998 to 2014 is employed for model estimation. Data for 2015 and 2016 is used to check prediction power of the model and finally projection is made for next decade.

Main findings reveal the upward trend in electricity demand as is projected to rise from 35 188 million kWh in 2014 to 58 764 million kWh in 2026 (almost 65.7% increase). Besides, this paper anticipates termination for kerosene and gasoline use and a 13.6% fall for gasoil consumption in forthcoming years. In sum, present study predicts that, as far as energy consumption is concerned, Iranian agriculture will move to a more sustainable situation during next decade. This definitely contributes to mitigation of environmental problems since agriculture captures nearly 20 million hectares of the country area. It could be regarded as a great achievement for government following fossil energy subsidy reduction policy.

Available policy options for more utilization of non-fossil fuels mostly include preferential loan programs and financial incentives, thought opportunities for efficient use of non-fossil energy resources tend to be rather site-specific so policy responses require some kind of outreach. Also, because of the large number of individual agricultural enterprises spread over a wide area, greater management resources are needed to implement and monitor policies.

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