Analysis of Energy Consumption Pattern in Iran

(Case study: Wheat, Barley, Corn and Rice)

Rose Hashemi[1] Reza Moghaddasi[1*] Amir Mohammadinejad[1] Mehdi Kazemnejad[2]

1. Department of Agricultural Economics, Extension and Education, Science and Research Branch, Islamic Azad University, Tehran, Iran.
2. Ministry of Agriculture, Tehran, Iran.

*Corresponding Author: r.moghaddasi@srbiau.ac.ir

Abstract

In recent years, efforts to make better use of energy resources have come to the attention of governments. In this study, consumption trends and energy efficiency indicators and econometric analysis of energy consumption in grain production were evaluated. The data used in the research are related to the period of 1998-2018 which was prepared from Ministry of Agriculture and the Statistics Center of Iran. In this study, four cereal important crops, including wheat, barley, corn and rice. After determining the amount of consumption of each input in the production of 1 ha of product, each input turn into its energy equivalence. the energy of all inputs except chemical pesticides has increased during the mentioned period. Chemical fertilizer showed a decreasing trend during the period 1996-2001, but again has an increasing trend during the period 2006-2018. The trend of energy ratio (output to input) in the production of major grain products during the study period had an increasing trend. on average 84% of changes in product yield were justified by the variables in the model. Also, the Durbin-Watson test value is 1.99, which indicates that there is no problem of autocorrelation of the disturbance components in the pattern. Grain yield will increase with increasing consumption of this type of energy.

Key words: Energy modeling, Energy ratio, Econometric analysis, Input.

Introduction

Energy is one of the most important inputs for development and one of the main factors of production. In agriculture, energy is an important production input and therefore the timely, reliable and cheap supply of required energy, has particular importance in increasing the production of agriculture products and increasing the country's non-oil exports. Energy consumption in the agriculture is increasing due to the response to the growing population demand, the limited supply of arable land and the existence of high living standards. The constant demand for food increases the heavy use of chemical fertilizers, pesticides, machinery and natural resources, which create problems for human health and the environment. While efficient energy consumption in the agriculture reduces environmental problems, it prevents the waste of environmental resources and promotes a sustainable agricultural system as an economic production system (FAO, 2013). Total energy consumption in Iran's agricultural sector in 2018 amounted to 45 million barrels of crude oil equivalent, which shows a growth of 4% compared to 2017. The diversity of work done worldwide is so great that studies show that the following articles and reports provide valuable information on how to analyze the energy of this sector and contribute to the richness of the methodology as well as useful data. The reports provided by Yang et al. (2009) in connection with the development strategies of agricultural machinery in the field of improving agriculture and horticulture and the energy consumption dimensions of machinery has opened a new horizon in this field. Khosruzzaman et al. (2010) examined the intensity of energy consumption and energy efficiency in the agriculture of Bangladesh, which of course have analyzed both direct energy (commercial energy) and indirect energy (human, animal and fertilizer capacity). Uzunoz et al (2008) stated that the total energy required for sunflower production in Turkey was 18,931 mj ha^{-1}, with the largest share of chemical fertilizer inputs (51.3%) and fossil fuels (28.5%). Kallivrousis et al (2002) stated that the total energy required for the production of sunflower in Greece was 10490 mj ha^{-1}, with chemical fertilizers having the largest share and the energy efficiency and net energy calculated at 4.5 and 36870 mj ha^{-1}, respectively. Hatirli et al. (2006) investigated the relationship between input energy and crop yield in greenhouse tomato production. This study evaluates the patterns of energy use and the relationship between input energy and yield for tomato production in Antalya, Turkey. The results showed that fuel was 34.35%, chemical fertilizers were 27.59%, electricity was 16.01%, toxins were 10.19% and manpower was 8.64%. Yilmaz et al. (2004) showed that cotton production generally consumed 49.73 gj ha^{-1} of energy, of which 31.1% was related to the consumption of diesel and the rest was related to the use of chemical fertilizers and machinery. In the field of using data envelopment analysis to study the efficiency of production units, many studies have been done. Skevas et al (2012) stated that the dynamic effects of pesticide using and production, uncertainty play an important role in farmers' production decisions. In this research, the pattern of energy consumption in important cereal products in Iran is discussed. In this study, the input and output energy were calculated. Output energy is the output energy of important cereal crops (wheat, barley, rice and corn) and input energy is machine energy, fuel, labor, fertilizer, chemical pesticides, irrigation and electricity.

Research Methods

The data used in the research are related to the period of 1998-2018 which was prepared from Ministry of Agriculture and the Statistics Center of Iran. In this study, four cereal important crops, including wheat, barley, corn and rice, which in total covers about 70% of the total area of Iran's arable land, were considered. Important inputs in the production of the studied products included manpower, direct energy (electricity, fossil fuels), fertilizers (chemical and animal), seeds, pesticides and water. To calculate the input energy, the energy equivalent of labor, electricity, diesel fuel, seeds, water and fertilizer and chemical toxins and in order to calculate the output energy, the average yield of each product per year according to their energy equivalent was considered. The energy equivalent used in the products was taken according to ASAE standard. The energy equivalents of inputs and outputs are shown in table 1.

Table 1. Energy equivalent of inputs and outputs

Input	Unit	Energy equivalent	Input	Unit	Energy equivalent
Manpower	hours	1.96	Insecticide	kg	58
Diesel fuel	litre	47.3	Fungicides	kg	115
Irrigation water	m^3	1.02	Herbicides	kg	295
Nitrogen fertilizer	kg	60.1	Seed	kg	25
Phosphate fertilizer	kg	17.4	**Output**		
Potassium fertilizer	kg	13.7	Cereals	kg	14.7
Organic Fertilizer	kg	0.3			

Kitani, 1999

To calculate seed energy, multiply the average seed consumption per hectare of crop by the energy equivalent to each kg of seed, and the input energy per kg of seed consumption was obtained. To measure manpower energy, the data firstly were converted from units per day per hectare to units per hour per hectare (equivalent to 8 working hours per day). Then, according to the value of each hour of manpower work, which is an average of 1.96 mj h^{-1} based on available resources, the amount of manpower energy in each product was obtained Animal power was eliminated due to its small share in the total input energy. The mechanization degree of various operations, including tillage, planting, holding and harvesting for various crops in the studied years, was extracted from the production cost statistics of the Ministry of Agriculture.

Regarding the amount of electricity, due to the lack of data on the amount of electricity required to crops produceing, the input energy due to the consumption of electricity was calculated from the following equation (Singh, 2000):

$$\mathrm{DE} = \frac{\gamma g H Q}{\varepsilon_q}$$

DE: Direct energy (gj ha^{-1})

γ: Water intensity (1000 kg m^{-3})

g: Gravity (9.8 m s^{-2})

H: Average of water pumping depth (According to the report of the ministry of energy, was considered 80 meters)

Q: pure water requiring of plant (m^3 ha^{-1}). To obtain this parameter, Cropwat program was used. For this purpose, for each product in each year, by entering the amount of evapotranspiration and rainfall of the whole country in the mentioned program, the amount of pure water requirement was calculated. After calculating the energy related to the effective inputs in the total input energy of the studied products, the indicators of energy efficiency, energy efficiency and net energy for the products in each year were calculated using the following equations:

$$\text{Energy efficiency} = \frac{\text{Output energy (gj ha}^{-1}\text{)}}{\text{input energy (gj ha}^{-1}\text{)}}$$

$$\text{Energy efficiency} = \frac{\text{Output amount (kg ha}^{-1}\text{)}}{\text{input energy (mj ha}^{-1}\text{)}}$$

Pure energy=output energy-input energy

In order to investigate the relationship between energy input consumption and yield of selected crops (wheat, barley, corn and rice), the Cobb-Douglas production function was used (Ghasemi Mobtaker et al., 2010; Hatirli et al., 2006). The linear form of this function is as follows:

$$\ln Y_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 T + e$$

In this equation, the yield of the studied products is a function of the man power (x1), fuel (x2), fertilizer (x3), pesticides (x4), water irrigation (x5), seed (x6) energies and T (as a variable that shows the changes in technology over time). Also, the effect of direct energies (DE) and indirect (IDE), renewable energies (RE) and non-renewable (NRE) on the production of the mentioned products was analyzed. Direct energies include fuel, manpower, irrigation water, and indirect energies include seeds, fertilizers, and chemical pesticides. Also, renewable energies include irrigation water, manpower, and seeds, and non-renewable energies include fuels, fertilizers, and chemical toxins. For this purpose, the Cobb Douglas function was used as follows:

$$\ln Y_i = a_0 + \beta_1 \ln DE_t + \beta_2 \ln IDE_t + \beta_3 T + e$$

$$\ln Y_i = a_0 + \gamma_1 \ln RE_t + \gamma_2 \ln NRE_t + \gamma_3 T + e$$

Ordinary least squares method and SHAZAM 10 software were used to estimate the econometric equations.

Results and discussion

Input and output energy analyzes are performed on a hectare basis. Accordingly, after examining the trend of energy inputs in the production of crops in the study period, energy indicators of these crops are expressed and then econometric analysis of energy consumption in the production of crops is presented.

Investigating the energy trend of inputs in grain production

The average of the total energy of inputs in the production of the studied crops during the years 1996-1997 is shown in table 2. According to the results of table 1, the energy of all inputs except chemical pesticides has increased during the mentioned period. Chemical fertilizer showed a decreasing trend during the period 1996-2001, but again has an increasing trend during the period 2006-2018. Chemical fertilizer has the largest share of total input energy so that its growth rate during the period 2001-2018 was 28.3%. The effect of chemical fertilizer on yield increasing per unit area has been one of the most important reasons for increasing the total input energy consumption during the period of studing. The average chemical fertilizer energy of the studied crops during the mentioned period was 17.32 gj ha^{-1}, which is very high compared to the average chemical fertilizer energy in agriculture of Iran with an average of 9.8 gj ha^{-1} (Beheshti Tabar et al., 2010). This indicates the high consumption of chemical fertilizers, especially nitrogen in the production of Iranian cereals. After chemical fertilizer, fuel energy has the largest share of total input energy, so that the average energy of this input in the period under review in all crops, is estimated at 8.63gjha^{-1}. It should be noted that the main fuel consumption in wheat and barley products is related to driving forces (types of tractors) and self-propelled machines (combine, etc.) and in the production of rice and corn is related to pumping water for irrigation. Rice cultivation in various parts of Iran, especially in the north of the country is flooded and requires high water consumption and therefore requires high energy to pump water to produce this product, which leads to increased fuel consumption. Since the corn plant is cultivated in most parts of the country, especially Khuzestan (with the highest area under corn cultivation in the country) in summer, it needs a lot of irrigation water and fuel and therefore leads to high fuel consumption in the production of these products.

Investigating the trend of energy indicators in cereals

The trend of energy ratio (output to input) in the production of major grain products during the study period had an increasing trend. So that the average growth of the total energy ratio in the mentioned products during the period under study was 1.87% (table 3). In general, the average energy ratio in the production of these products during the period under review is equal to 1.87 (table 3). Beheshti Tabar et al. (2010) in the study of energy consumption trends in iran's agricultural crops during the period 1990-2006 showed that the trend of energy efficiency in Iran's agricultural sector has increased during the period. On the other hand, Alam et al. (2005) in a study of energy flow in agriculture in Bangladesh, during the period 1980 - 2000 showed that energy efficiency, ie the ratio of input to energy data in the mentioned period, decreased by 28%, indicating input energy faster has increased than output energy and consequently energy efficiency has decreased. In general, it can be said that the results of this study have shown that the increase in energy efficiency indicates a greater growth trend of output energy (due to higher performance growth per unit area) than the growth of input energy.

The trend of changes in energy efficiency and net energy indices in the production of the studied products in 1996-2018 is shown in table4. The average energy efficiency was 0.134

kg mj^{-1}, which means that for each mj, the yield increases by 0.134 kg. Energy efficiency has increased from 0.114 to 0.162 kg mj^{-1} during the period under review. Also, net energy during the mentioned period has shown an increasing trend so that the average growth of net energy in each year in the period under review, has grown 32.27%. A study of 104 agricultural products in Turkey during the years 1975-2000 showed that the indicators of energy efficiency and net energy decreased over time, indicating the fact that the pattern of energy consumption in Turkish agriculture is inefficient and can lead to environmental issues (Hatirli et al., 2005).

The results of this study show better consumption of production resources in the agricultural sector of Iran in the production of the studied products over time. Comparison of energy ratios in the agricultural sector of Iran and other countries such as Turkey shows that the energy ratio in Iran is low, which is mainly due to the low efficiency of chemical fertilizer and irrigation water inputs. The average of direct, indirect, renewable and non-renewable energy inputs during the period under study is shown in table 5. Non-renewable energy with approximately 75% had the largest share in crop production during the years 1996-2018, which shows the dependence of Iranian agriculture in the production of crops to non-renewable energy. Renewable energies with an approximate amount of 29% had the lowest share in crop production during 1996-2018.

The regression results of the effect of energies of different inputs on the average yield of products are shown in Table 5. The value of R was equal to 0.84, which shows that on average 84% of changes in product yield were justified by the variables in the model. Also, the Durbin-Watson test value is 1.99, which indicates that there is no problem of autocorrelation of the disturbance components in the pattern.

The variable coefficient of energy consumption of chemical pesticides and seeds, was statistically significant at the level of 5% . It shows that increasing the consumption of this type of energy increases the yield of cereal crops. The regression coefficients of pesticides and seed energies for cereals in the period under study are equal to 1.157 and 0.095, respectively. This means that firstly, the consumption of seeds and pesticides in the production of crops increases their yield, and secondly, if the consumption of pesticides and seeds in the production of crops increases by one percent, the production of grains by 157 / 1 and 0.095% will increase. Also, the time variable, which indicates technological changes during the period under review, is significant at the level of 1% and shows its impact on the yield of the under review products. Onakitan et al (2010) and Hatirli et al (2005) also reported a significant effect of chemical pesticides on crop yield in energy econometric analysis of the Turkish agricultural sector.

Table 6 shows the effect of direct and indirect energies as well as renewable and non-renewable energies on the average grain yield. The regression coefficient of indirect energy and non-renewable energy has become significant at the level of 5%, which shows that grain yield will increase with increasing consumption of this type of energy. Hatirli et al (2006) showed that an increase in the consumption of non-renewable energy increases the production of 104 agricultural products in Turkey.

Conclusion

The results of this study show that the energy efficiency of the country's cereals has increased over time, and it is important to note that this increase in efficiency has been accompanied by an increase in input energy such as fertilizers and chemical pesticides, indicating the growing dependence of ecosystems on Resources are non-renewable. Energy efficiency in the production of important cereal products in Iran has been lower than other countries, which can be attributed to low fuel prices, subsidies for chemical fertilizers and the low role of promoting and educating agriculture in teaching the proper use of available resources. Cited. Hence, there is a need to shift the ecosystem of agricultural systems towards sustainable agriculture to make optimal use of production resources and reduce energy inputs (especially high-consumption inputs such as chemical fertilizers and fuels).

References

Alam, M.S., Alam, M.R. & Islam, K, K. (2005). Energy flow in agriculture: Bangladesh. American Journal of Environmental Science 3: 213-220.

Beheshti Tabar, I., Keyhani, A., & Rafiee, S. (2010). Energy balance in Iran's agronomy (1990–2006). Renewable and Sustainable Energy Reviews 14:849– 55.

Food and Agriculture Organization. (2013). Biodiversity: Agricultural biodiversity in FAO. Retrieved January 12, 2005, from http://www.fao.org/biodiversity.

Ghasemi Mobtaker, H, G,. Keyhani, A., Mohammadi, A., Rafiee S., & Akram, A., (2010). Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. Agriculture Ecosystem Environ. 137: 367-372.

Hatirli S.A, Ozkan B., & Fert, C. (2006). Energy inputs and crop yield relationship in greenhouse tomato production. Renewable Energy. 31:427-438. - Kitani, O. (1999). CIGR handbook of agricultural engineering. Energy & biomass engineering. ASAE Publication.

Hatirli, S.A., Ozkan, B., & Fert, C. (2005). An econometric analysis of energy input–output in Turkish agriculture. Renewable and Sustainable Energy Reviews 9: 608–623.

Kallivrousis, L., Natsis, A. and Papadakis, G., 2002. RD -Rural development the energy balance of sunflower production for biodiesel in Greece. Biosystem Engineering. 18, 347 -354 .

Khosruzzaman S., Asgar M.A., Karim N. and Akbar S., (2010) Energy intensity and productivity in relation to agriculture– Bangladesh perspective, Journal of Agricultural Technology, Vol. 6(4): 615-63.

Kitani, O. 1999. "CIGR handbook of agricultural engineering, vol. 5, Energy and biomass engineering", ASAE Publications, St Joseph, MI.

machinery based on energy –saving in china, September .

Singh G, Singh S and Singh J, 2004. Optimization of energy inputs for wheat crop in Punjab. Energy Conversation and Management 45: 453–465.

Skevas T, Alfonos L, Spiro S. (2012). Measuring technical efficiency in the presence of pesticide spillovers and production uncertainty: The case of Dutch arable farms, European Journal of Operational Research 223 550–559.

Unakitan, G., Hurma, H., & Yilmaz, F. (2010). An analysis of energy use efficiency of canola production in Turkey. Journal of Energy 35: 3623-3627.

Uzunoz, M., Akcay, Y. and Esengun, K ., 2008. Energy input -output analysis of sunflower seed oil in Turkey. Energy Sources. 3, 215 - 223 .

Yang, Z., Chen, G., Duan, J., Peng , J., Wang, J.,(2009) Development strategy of agricultural

Yilmaz I, Akcaoz H and Ozkan B, 2005. An analysis of energy use and input costs for cotton production in Turkey. Renewable Energy, 30: 145-155.

Table 2. Average energy of inputs and outputs (Gj ha^{-1}) of the studied products in the period 1998-2018

Input	1998	2003	2008	2013	2018	Total average
Man power	0.81	0.72	0.94	0.92	0.95	0.86
Diesel fuel	8.23	8.35	8.78	8.88	8.95	8.63
Irrigation water	4.22	4.31	4.74	4.80	4.95	4.63
Fertilizer	18.14	14.34	17.78	17.95	18.40	17.32
Pesticides	0.98	0.60	0.64	0.69	0.71	0.72
Seed	3.31	3.91	4.90	4.95	4.97	4.39
Output (yield)	6.02	66.74	70.02	70.23	73.44	68.09

Table 3. The average of total energy indicators in the production of the studied crops during the years 1998-2018.

Input	1998	2003	2008	2013	2018	Total average
Input energy (Gj ha^{-1})	35.72	32.22	37.58	38.92	39.28	36.74
Output energy (Gj ha^{-1})	60.02	66.74	70.18	72.28	75.08	68.86
Energy ratio	1.68	2.07	1.86	1.85	1.91	1.87
Energy efficiency (kg mj^{-1})	0.114	0.14	0.130	0.129	0.162	0.134
Pure energy (Gj)	24.3	34.51	33.24	32.60	36.71	32.27

Table 4. Different types of energy in the production of crops under study (average of the whole period).

Types of energy	Mean (Gj ha-1)	(%)
Direct energy [a]	14.20	39.40
Indirect energy [b]	20.95	60.60
Renewable energy [c]	9.35	28.70
Non-renewable energy [d]	28.15	75.10

[a] fuel, manpower, irrigation water, [b] seeds, chemical fertilizers and pesticides, [c] irrigation water, manpower and seeds, [d] fuel, chemical fertilizers and pesticides.

Table 5. Results of estimating the effect of energy inputs on grain yield

Variable	coefficient	t test
	$\ln Y_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln + X_6 + \alpha_7 T + e$	
Constant coefficient	2.834	0.238
Year	0.065	2.33**
Manpower	1.256	0.948
Fuel	-0.066	-0.20
Fertilizer	-0.028	0.450
Pesticides	1.157	1.58*
Irrigation water	0.000069	0.534
Seed	0.095	0.460
Durbin-Watson test	1.99	
R^2	0.84	

** and * significance at the level of 1 and 5%, respectively

Table 6. Results of estimating the effect of direct, indirect, renewable and non-renewable energies on grain yield.

Variable	coefficient	t test
		$\ln Y_i = a_0 + \beta_1 \ln DE_t + \beta_2 \ln IDE_t + \beta_3 T + e$
Constant coefficient	0.644	0.375
Year	0.039	2.185**
Direct energy	0.04	0.385
Indirect energy	0.045	1.48*
Durbin-Watson test	1.89	
R^2	0.82	
		$\ln Y_i = a_0 + \gamma_1 \ln RE_t + \gamma_2 \ln NRE_t + \gamma_3 T + e$
Seed	0.457	0.415
Durbin-Watson test	0.044	2.044**
Renewable energy	0.006	1.335*
Non-renewable energy	0.052	0.045
Durbin-Watson test	1.88	
R^2	0.84	

** and * significance at the level of 1 and 5%, respectively