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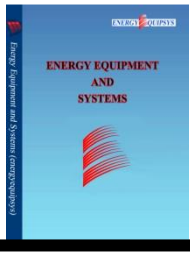


# Energy input-output analysis under different farm sizes of forage maize cultivation in the Varamin region

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**ABSTRACT**

*Energy analysis in agriculture plays a significant role in developing the human perspective towards agricultural ecosystems, which enhances the quality of decision-making and planning in agricultural management and development. In this study, according to data obtained from the agricultural centers of the Varamin region, the different levels of forage maize cultivation were classified into three levels, less than one hectare (A1), between one to three hectares (A2), and more than three hectares (A3). By calculating the amount of input and output energy, energy evaluation indices, such as energy use efficiency, energy productivity, and net energy, were determined and compared at the different levels of utilization. According to the results, an increase in the cultivation levels, the human labor, machinery, diesel fuel, oil and nitrogen fertilizer (N) energies decreased, but the water for irrigation, phosphate ($P_2O_5$) fertilizer, potassium ($K_2O$) fertilizer, pesticides, herbicides, and seed energies increased. On the other hand, the maximum amount of energy consumed at each level was calculated for nitrogen fertilizer inputs and diesel fuel, respectively, and the lowest ones were calculated for pesticides and potassium fertilizer, respectively. According to the results, the energy use efficiency in the different levels of utilization for A1, A2, and A3 levels was 11.02, 21.97, and 22.94, and the energy productivity for these levels was 1.37, 6.87, and 11.47 kg $MJ^{-1}$, respectively. Finally, net energy was calculated as 349175.43, 458157.76, and 478208.72 MJ $ha^{-1}$, respectively.*

**Keywords:** Energy Productivity, Energy Use Efficiency, Net Energy, Farm Size.

## 1. Introduction

Maize (*Zea mays* L.) is a major silage plant because it is a high-yielding crop and high-energy forage, requiring less labor and equipment compared with other forage crops. Approximately 65% of the world's total maize production is used for animal feed, 15% as human food and 20% for industrial purposes [1]. Maize is the most important crop that is widely cultivated in Iran with 1,650,000 tons in a cropping area of 225,000 ha. Of the corn-producing countries in 2018, the United States occupies 20.08 % of the world's crop with 28,041 hectares, ranking first. Then, China ranked second with 16.8% and Brazil with 8.84 % achieved the third position and Iran's share is 0.12 %. Corn production in 2017 was 599 million tons, according to statistics released by

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the FAO; the United States produced 235 million tons, accounting for 39.17 % of world production among the countries. After the United States and China, Brazil ranked third with 6.9 % and the share of Iran of the world production is 0.17% [2]. Agriculture is both the producer and consumer of energy. In agriculture, diverse sources of energy are used directly and indirectly. In this regard, the cost-effective use of energy increases production and productivity and helps the economy, profitability and competitiveness of agriculture in rural areas [3, 4]. Conventional farming systems that rely heavily on energy consumption in the form of various entities are technologically, economically, socially, and environmentally vulnerable. So in all ecosystems of ecological farming systems reduction of system, dependence on inputs and energy consumption and increase of energy efficiency are essential goals [5]. The enhancement of energy efficiency not only improves competitiveness through reduced costs, it also leads to a reduction in the energy-associated environmental pollution associated, contributing to sustainable development. The input-output energy analysis (IOEA) is usually carried out to assess the efficiency and environmental impact of manufacturing systems [6]. Recently, many researchers have studied the amount of energy consumption for different agricultural productions [4, 7, 8, 9]. It is worth noting that many studies have investigated the impact of farm size on energy efficiency used in agricultural production. Yilmaz et al. [10] in Turkey calculated the amount of direct and indirect energy used to produce cotton and examined the effect of farm size on the amount of energy consumed. They calculated the energy use efficiency and energy productivity, 0.47 and 0.06 kg $MJ^{-1}$, respectively. Based on the results, larger farms were more successful in terms of energy use efficiency and economic performance. Mousavi–Avval et al. [3] measured the input-output energy to grow canola on farms of different sizes to examine the efficiency of energy consumption. The results showed that the total energy input for the production of canola rose from 15817.24 MJ $ha^{-1}$, on small farms (less than 2 hectares) to 20663.13 MJ $ha^{-1}$ on large farms (over 4 hectares). The highest yield was 2286.36 kg $ha^{-1}$ on medium-sized farms (2 to 4 hectares). Medium-sized farms had also the highest energy efficiency (75.3). In addition, the energy efficiency for small and large farms was respectively 3.35 and 3.07. Pishgar-Komleh et al. [11] examined the economic analysis and energy consumption of Maize silage under three cultivated areas. Results indicated that the most energy input was related to the machinery and chemical fertilizers which accounted for 42% and 28% of the total energy input respectively. Total energy consumption was 68.928 MJ $ha^{-1}$ and the output was 148.380 MJ $ha^{-1}$. As indicated by the results, the lowest energy consumption was on the farms which covered more than 10 hectares. Energy, efficiency, specific energy, and net energy were 2.27, 0.28 kg $MJ^{-1}$, 3.76 MJ $kg^{-1}$ and 79,452 MJ $ha^{-1}$ respectively. Esengun et al. [12] have investigated the energy use efficiency and economic analysis in different farm sizes of the dry apricot production. Based on the results, by increasing the farm size, both the total input and output energy in apricot production decreased; however, the energy use efficiency and energy productivity increased. Cetin and Vardar [13] examined the energy consumption of tomato fields under three levels, namely small, medium and large. They concluded that large farms are more successful in terms of energy efficiency and economic performance. Given the importance of the subject, the main objective of this study is energy use analysis in different sizes of forage maize cultivation in the Varamin region.

## 2. Materials and methods

### 2.1. Geographic location of the place

The study was conducted in summer 2018 in Varamin city, Javad Abad district (35 19′N, 39 51′E) and at an elevation of 1000 m above the mean sea level. Its climate is predominantly desert and semi-desert and the average annual rainfall of the region is 175 mm that mainly occurs in the late autumn and early spring.

### 2.2. Data collection

Based on the information obtained from agricultural centers in the region, different levels of maize cultivation were classified into three levels: less than one hectare (A1), between one to three hectares (A2), and more than three hectares (A3). To collect the information concerning the types of the common activities in the forage maize agriculture, a technical and specialized questionnaire was prepared in the form of 150 questions on all stages of tillage, planting, protection and harvesting. Then at least 50 farmers were selected randomly and the information related to maize production was extracted in the form of questionnaires by them [11]. Table 1 shows the information related to the kind of inputs, output and their energy equivalent.

Equation 1 was used to calculate the amount of consumed oil and Eqs. 2 and 3 were used to calculate the index values mentioned [17].

$$Q_p = \frac{14.098 \times P_r}{1000} \quad (1)$$

where: $Q_p$ = used oil (lit $h^{-1}$), $P_r$ = tractor power (kW).

$$P = \frac{\gamma Q H}{75\,\eta} \quad (2)$$

$$K = Qab \quad (3)$$

where: P = pump power (hp), γ= the specific gravity of water (N $m^{-3}$), Q= pump discharge ($m^3$ $s^{-1}$), H= suction height (m), ŋ = pump efficiency (60 %), K= the amount of irrigation water ($m^3$), a= the number of irrigation intervals, and b= the duration of irrigation (h).

The amount of energy consumed in each group is calculated by multiplying the input and the equivalent of energy in each unit. Taking the energy input-output into consideration, the energy efficiency, energy productivity and net energy were calculated [18] as

$$\text{Energy use efficiency} = \frac{\text{Energy Output (MJ ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \quad (4)$$

$$\text{Energy prodyctivity} = \frac{\text{Yield of forage maize (kg ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \quad (5)$$

$$\text{Net energy} = \text{Energy Output (MJ ha}^{-1}) - \text{Energy Input (MJ ha}^{-1}). \quad (6)$$

Then data were analyzed using a randomized complete block design. The means were compared by Duncan's multiple range tests using the SPSS16 software 16 version.

## 3. Results and discussion

The results of the comparison of the average amount of consumed and produced energy at the different levels of operation are shown in Table 2.

**Table 1.** The energy equivalent of inputs and outputs in maize production (MJ/unit$^{-1}$)

| Particulars | Unit | Energy equivalent (MJ/unit$^{-1}$) | Refs. |
|---|---|---|---|
| Human labor | H | 1.96 | [11] |
| Machinery | H | 62.70 | [14] |
| Diesel fuel | L | 56.31 | [14] |
| Oil | L | 38.41 | [14] |
| Chemical fertilizers | kg | - | - |
| (a) Nitrogen (N) | kg | 66.14 | [14] |
| (b) Phosphate ($P_2O_5$) | kg | 12.44 | [14] |
| (c) Potassium ($K_2O$) | kg | 11.15 | [14] |
| Pesticide | L | 101.2 | [14] |
| Herbicide | L | 238 | [14] |
| Water for Irrigation | $m^3$ | 1.02 | [14] |
| Seeds | kg | 15.70 | [15] |
| Dry matter of forage maize | kg | 8.00 | [16] |

**Table 2.** Energy input-output analysis in maize production at the different levels of operation (MJ)

| Input-output energy (MJ) | A1 | A2 | A3 |
|---|---|---|---|
| Human labor | 779.10[a] | 457.85[b] | 330.75[c] |
| Machinery | 2194.50[a] | 777.48[b] | 627[c] |
| Diesel fuel | 6222.95[a] | 3676.14[b] | 3309.76[c] |
| Oil | 530.34[a] | 412.15[b] | 320.128[c] |
| Water for Irrigation | 3659.25[a] | 2927.40[b] | 2985.94[b] |
| Nitrogen (N) | 16700.35[a] | 10999.87[b] | 10647.75[c] |
| Phosphate ($P_2O_5$) | 2332.5[a] | 970.32[c] | 1943.75[b] |
| Potassium ($K_2O$) | 975.625[a] | 446[b] | 408.12[c] |
| Pesticide | 37.95[a] | 30.03[b] | 34.155[ab] |
| Herbicide | 803.25[a] | 642.60[c] | 722.92[b] |
| Seeds | 588.75[a] | 502.40[b] | 461[c] |
| Yield (dry matter of forage maize) | 384000[c] | 480000[b] | 500000[a] |

In each row, different letters indicate a significant difference between means at $P \leq 0.05$

### 3.1. Analysis of input energy components

#### 3.1.1. Human Labor energy

On average, the number of work hours for labor for the first level (A1) was calculated 318, 584 for the second level (A2) and 675 hours for the third level (A3). Considering the equivalent energy coefficient of 1.96 MJ $h^{-1}$, the amount of the desired energy was calculated as 779.10, 457.85, and 330.75 MJ, respectively.

#### 3.1.2. Mechanical energy

On average, the number of work hours for the tractors and equipment was 28 hours for the first level (A1), 31 hours for the second level (A2) and 40 hours for the third level (A3). Considering the equivalent energy coefficient of 62.7 MJ $h^{-1}$, the desired amount of energy was 2194.50, 777.48, and 627 MJ, respectively.

#### 3.1.3. Diesel fuel energy

On average, the amount of fuel consumed at the first level (A1) was 88.41, 163.21 for the second level (A2), and 235.11 liters for the third level (A3), investigating the energy equivalent coefficient of 56.31 MJ for each liter of fuel. The amount of the desired energy was calculated as 6222.95, 3676.14, and 3309.76 MJ, respectively.

#### 3.1.4. Oil energy consumption

The tractor power used in the research was 75 hp (56 kW). By replacing the number 56 in Equation 1, the amount of oil consumed was 0.789 lit $h^{-1}$. Since the number of work hours for tractors and equipment was 28, 31, and 40 hours for the first, second, and third-level, respectively, the amount of the oil consumed in the first, second, and third-level was 11.046, 26.826, and 33.338 liters, respectively. Based on the results, the equivalent energy coefficient was 38.41 MJ for each liter of oil, and the desired amount of energy was 530.34, 412.15, and 320.128 MJ, respectively.

#### 3.1.5. Water for irrigation energy

Based on the measurements, the average water flow rate was 15.94 $lits^{-1}$ or 57.4 $m^3$ $h^{-1}$. Considering the number of hours and irrigation intervals of 5 hours and 10 rounds, respectively, the amount of water consumed was 2870 $m^3$. Considering the equivalent energy coefficient of 1.02 MJ $m^{-3}$, the average amount of this energy was 3656.25, 2927.40, and 2985.94 MJ for the first, second, and third-level, respectively.

#### 3.1.6. Nitrogen fertilizer energy

On average, the amount of fertilizer consumed at the first, second, and third-level was 202, 412, and 650 kg, respectively. Considering the equivalent energy coefficient of 66.14 MJ $kg^{-1}$, the desired energy value was calculated 16700.35, 10999.87, and 10647.75 MJ, respectively.

3.1.7. Phosphate fertilizer energy

The average amount of fertilizer consumed at the first, second, and third-level was 150, 195, and 625 kg, respectively. Considering the energy equivalence coefficient of 12.44 MJ $kg^{-1}$, the amount of energy consumed was 2332.5, 970.32, and 1943.75 MJ, respectively.

3.1.8. Potassium fertilizer energy

The average amount of fertilizer consumed 70, 100, and 150 kg for the first, second, and third-level, respectively. Considering the equivalent energy coefficient of 11.15 MJ $kg^{-1}$, the desired energy value was determined 975.625, 446, and 408.125 MJ, respectively.

3.1.9. Pesticide energy

On average, the amount of pesticide consumed at the first, second, and third-level was 0.3, 0.75, and 1.35 kg, respectively. Considering the equivalent energy coefficient of 101.2 MJ $kg^{-1}$ for the pesticide, the calculated energy was 37.95, 30.03, and 34.15 MJ, respectively.

3.1.10. Herbicides energy

The average amount of the herbicide consumed was 2.7, 6.75, 12.15 kg for the first, second, and third-level, respectively. Considering the equivalent energy coefficient as 238 MJ $kg^{-1}$ for the herbicide, the values of the desired energy were 803.25, 642.60, and 722.92 MJ, respectively.

3.1.11. Seeds energy

The average amount of seed consumed at the first, second, and third-level was 30, 80, and 120 kg, respectively. Considering the equivalent energy coefficient of 15.7 MJ $kg^{-1}$, the desired amount of the energy was obtained as 588.75, 502.4, and 461 MJ, respectively.

3.1.12. Yield (dry matter of forage maize)

Based on the results, the forage produced was 48, 150, and 250 tones for the first, second, and third-level, respectively. Considering the equivalent energy coefficient of 8 MJ $kg^{-1}$, the amount of energy required was calculated as 384000, 480000, and 500000 MJ, respectively.

As shown in Table 3, the percentage of labor energy consumed decreased by an increasing cultivation area. The most important reason is that it is possible to perform mechanized operations by increasing the area under cultivation. In other words, increasing the area under cultivation increased the mechanization coefficient, leading to a decrease in the labor force. Furthermore, Esengun et al. [12] achieved the same results. On the other hand, the expansion of the fields under cultivation has led to an increase in the consumption of mechanical energy, the most important reason of which are the time wasted during making a turn at the corners of small fields, time-consuming processes of preparing, adjusting and connecting the equipment; it means that on small farms low efficiency of agricultural equipment decreases the capacity, making it impossible to use compound equipment. Esengun et al. [12] indicated that small levels of utilization are a limiting factor for developing agricultural mechanization leading to greater energy consumption. In other words, non-compliance of the equipment with the cultivated areas increases energy consumption. Based on the results in Table 3, an increase in the area under cultivation decreased the rate of fuel energy, which is related to the decrease in mechanical energy consumed at large crop areas. Beheshti Tabar et al. [19] stated that compound equipment and reduced movement of small equipment contribute to a reduction in fuel consumption. On the other hand, fuel consumption decreases as the cultivation level increases, which is mainly related to the reduction in mechanical energy consumed at large scales. The reason for the low amount of oil energy consumed on surfaces (A1) than on surfaces (A2) is the lack of use of combines in some of these farms. Thus, this reduction seems reasonable.

As shown in Table 3, the amount of energy consumed for water irrigation increased by increasing operating levels. It is obvious that the energy needed for irrigation is a major part.

New irrigation methods can reduce both energy consumption and the water needed for the plant [9]. It is worth noting that irrigation schemes cannot be implemented on small farms.

Based

**Table 3.** Percentage of total energy input at the different levels of operation (%)

| **Input-output energy** | **A1** | **A2** | **A3** |
|---|---|---|---|
| Human labor | $2.23^{a}$ | $2.09^{b}$ | $1.51^{c}$ |
| Machinery | $6.31^{a}$ | $3.55^{b}$ | $2.87^{c}$ |
| Diesel fuel | $17.86^{a}$ | $16.83^{b}$ | $15.18^{c}$ |
| Oil | $1.52^{ab}$ | $1.88^{a}$ | $1.46^{b}$ |
| Water for Irrigation | $10.50^{b}$ | $13.40^{a}$ | $13.70^{a}$ |
| Nitrogen (N) | $47.95^{b}$ | $48.86^{ab}$ | $49.01^{a}$ |
| Phosphate ($P_2O_5$) | $6.44^{b}$ | $6.60^{b}$ | $8.91^{a}$ |
| Potassium ($K_2O$) | $1.94^{b}$ | $2.04^{b}$ | $2.18^{a}$ |
| Pesticide | $0.11^{b}$ | $0.14^{ab}$ | $0.16^{a}$ |
| Herbicide | $2.30^{c}$ | $2.94^{b}$ | $3.31^{a}$ |
| Seeds | $1.70^{b}$ | $2.27^{a}$ | $2.21^{a}$ |

In each row, different letters indicate a significant difference between means at $P \leq 0.05$

on the results in Table 3, among the inputs used in the production process, the energy share of nitrogen fertilizers was higher than the other inputs. The levels of (A1), (A2), and (A3) were 47.95 %, 49.01 %, and 48.86 %, respectively. It should be noted that the share of the above input decreases as the area under cultivation increases. The reason is that the fertilizer distribution with the seed was made possible by the machine by increasing the area under cultivation, which results in preventing its over-consumption [20]. The results were similar to Phipps et al. [20] reached similar conclusions.

Amanlou et al. [21] stated that the most energy consumption in the production of the Silage maize in Zanjan is first related to the chemical fertilizers and then to the diesel fuel. Shahan et al. [22] indicated that increasing the consuming fertilizer and irrigation rate while increasing the wheat yield led to a decrease in energy efficiency. In addition, proper use of these inputs can reduce energy consumption by about 20-50 % and increase energy efficiency. On the other hand, unlike the nitrogen fertilizer, the percentage of phosphate and potassium fertilizers increased by increasing utilization levels since these fertilizers are manually distributed in large quantities and sometimes more than needed in the region farms. Therefore, they are not uniformly distributed. It is noteworthy that the rate of application of pesticides and herbicides increased by increasing the under cultivation levels, which is related to the lack of biodiversity in the time dimension (due to lack of crop rotation and fallow), the lack of biodiversity in spatial dimension (due to the lack of application of the types of mixed cropping systems), as well as the lack of biological control of pests, diseases and weeds in the area. Therefore, the high diversity of weeds and outbreaks of pests and diseases in the region led to a multi-stage chemical struggle [22]. As shown in Table 3, the amount of seed energy consumed increased by increasing the level of utilization. The levels of A1, A2, and A3 were calculated as 1.70, 2.27, and 2.21, respectively. It is worth noting that, because of the mechanization of planting operations, the optimum seed was consumed at the A2 and A3 levels.

### 3.2. Results of energy indicators survey

#### 3.2.1. Energy use efficiency

Based on the results in Table 4, the energy use efficiency indexes for A1, A2, and A3 levels were calculated at 11.02, 21.97, and 22.94, respectively. At the A3 level, much of the operation was mechanized, and the energy consumption of inputs such as nitrogen fertilizer, fuel, and water irrigation decreased significantly compared to the other levels, which is a fundamental reason for increasing energy efficiency at the A3 level.

Higher energy efficiency leads to a more desirable system. However, high performance does not always mean high system performance because they may be small in the

**Table 4.** Indicators of energy in maize production systems

| Energy indicators | A1 | A2 | A3 |
|---|---|---|---|
| Energy use efficiency (dimensionless) | 11.02[b] | 21.97[a] | 22.94[a] |
| Energy productivity (kg $MJ^{-1}$) | 1.37[c] | 6.87[b] | 11.47[a] |
| Net energy (MJ $ha^{-1}$) | 349175.43[c] | 458157.76[b] | 478208.72[a] |

In each row, different letters indicate a significant difference between means at $P \leq 0.05$

system, although the performance and input energy are both small and their ratio is high.

In general, the energy efficiency of the system can be improved by reducing the input energy consumption by observing the pattern of energy consumption and replacing the low energy inputs instead of the energy-efficient ones. Further, it can be developed by keeping the input energy balanced, and increasing the performance, and thereby increasing the output energy generated by the production system [20]. As a rule, if we are only limited to the input energy to the system, we cannot avoid the consequences of a reduction in output. Therefore, fundamental changes should be made to the ecosystem of the existing farming systems in order to increase the efficiency of energy consumption. In other words, they should be replaced by the industrial energies with the biological and or designing the new ecosystems. It seems that more complicated strategies are needed for managing agricultural ecosystems at the beginning of the 21st century although increasing the production potential in the plants through breeding play a significant role in increasing the energy efficiency in agricultural production in the mid-20th century. Obviously, the energy efficiency for the different crops depends on the changes and the ecological structure of agricultural systems. Ghiyasi et al. [23] investigated the impact of production systems area on energy efficiency and reported that high energy efficiency and optimal energy efficiency are achieved in larger farms. Beheshti Tabar et al. [19] reported that mechanized land preparation and irrigation methods increased water transfer efficiency, proper distribution of chemical fertilizers, and reduction of the workforce, increasing the energy efficiency index. Shahan et al. [22] showed that there is a direct but there is negative correlation between the amount of fertilizer and energy efficiency in agricultural systems. This means that increased consumption of fertilizers reduces energy efficiency. Irregular use of chemical fertilizers has caused environmental challenges in the wheat production ecosystem in Kangavar.

### 3.2.2. Energy productivity

Based on the results in Table 4, the above index values for A1, A2, and A3 levels were calculated 1.37, 6.87, and 11.47 kg $MJ^{-1}$, respectively.

### 3.2.3. Net energy

As shown in Table 4, the above index values for A1, A2, and A3 levels were 349175.43, 458157.76, and 478208.72 MJ $ha^{-1}$, respectively. The energy use efficiency and net energy indices increased with an increasing area under cultivation. Accordingly, the development has increased due to the following reasons. The increase in the productivity of plowing and reduction in the movement on the field significantly reduced fuel consumption. Electrifying agricultural well engine increases the efficiency of transmission and the distribution of agricultural irrigation water [24]. Using the energy more efficiently by optimizing the consumption of the inputs used in the system (the proper distribution of the seed and fertilizer by different rows, as well as the appropriate distribution of the pesticides using tractor back pesticides). Reducing crop waste during harvesting. Implementing the combined machinery which can perform several tasks simultaneously.

## 4. Conclusion

Based on the results, the energy use efficiency in the different levels of utilization for A1, A2, and A3 levels was 11.02, 21.97 and 22.94, the energy productivity for these levels was 1.37, 6.87, and 11.47 kg $MJ^{-1}$, and net energy was calculated as 349175.43, 458157.76, and 478208.72 MJ $ha^{-1}$, respectively. In order to optimize different cultivation systems and maintain sustainability in Varamin, the following tips should be considered: 1 Preventing fragmentation of agricultural lands to transform traditional agricultural practices into commercial, developed methods. 2. According to the studies, an area covering at least 5 hectares should be dedicated to this crop. 3. Renewable energy sources should be replaced by renewable energy sources. 4. Chemical fertilizers should be limited and replaced by organic and biological fertilizers due to high energy consumption in the production process, as well as environmental hazards. 5. The use of efficient irrigation systems in order to save power and prevent water loss. 6. Multi-purpose use of agricultural equipment to conserve fuel and reduce the wear of machinery.

## References

[1] Lorzadeh SH., Mahdavidamghani A., Enayatgholizadeh MR., Yousefi M., Energy Input-Output Analysis for Maize Production Systems in Shooshtar, Iran, Advances in Environmental Biology (2011) 5(11): 3641-3644.

[2] Anonymous., FAOSTAT, Statistical databases and data sets of the Food and Agriculture Organization of the United Nations. (2017) http://faostat.fao.org/default.aspx

[3] Mousavi-Avval SH., Rafiee Sh., Jafari A., Mohammadi A., Energy Efficiency and Cost Analysis of Canola Production in Different Farm Sizes, International Journal of Energy and Environment (2011) 2(5): 845-852.

[4] Cunha JPB., Campos AT., Martins FGL., Paula VR., Volpato CES., Silva FC., Energy Demand of Different Soil Managements in Corn Crop, Bioscience Journal (2015) 31(3): 808-817.

[5] Hatirli SA., Ozkan B., Fert K., An Econometric Analysis of Energy Input/Output in Turkish Agricultural, Renewable and Sustainable Energy Reviews (2005) 9(6): 608-623.

[6] Hedayatipour A., Younesi-Alamouti M., The Effect of Tillage Methods on Energy Consumption and Grain Yield of Irrigated Wheat in Arak Province, Agricultural Mechanization and Systems Research (2018) 19(71): 17-28. (In Farsi).

[7] Ferro ND., Zanin G., Borin M., Crop Yield and Energy Use in Organic and Conventional Farming: A Case Study in North-East Italy, European Journal of Agronomy (2017) 86: 37-47.

[8] Martins FGL., Barbosa JA., Carvalho RCS., Veloso AV., Marin DB., Energetic Analysis of Corn Production for Silage Grown in Different Spacing, Energia na Agricultura (2015) 30(4): 418-428.

[9] Ferreira TA., Ferreira SC., Barbosa TA., Volpato CES., Ferreira RC., Silva MJ., Barbosa LM., Energy Balance of Irrigated Maize Silage, Ciência Rural (2018) 48(5): 1-7.

[10] Yilmaz I., Akcaoz H., Ozkan B., An Analysis of Energy Use and Input Costs for Cotton Production in Turkey, Renewable Energy (2005) 30: 45-55.

[11] Pishgar-Komleh SH., Keyhani AR., Rafiee Sh., Sefeedpari P., Energy Use and Economic Analysis of Corn Silage Production Under Three Cultivated Area Levels in Tehran Province of Iran, Energy (2011) 36: 3335-3341.

[12] Esengun K., Gunduz O., Erdal G., Input-Output Energy Analysis in Dry Apricot Production of Turkey, Energy Conversion and Management (2007) 48(2): 592-598.

[13] Çetin B., Vardar A., An Economic Analysis of Energy Requirements and Input Costs for Tomato Production in Turkey, Renewable Energy (2008) 33(3): 428-433.

[14] Banaeian N., Zangeneh M., Study on Energy Efficiency in Corn Production of Iran, Energy (2011) 36 (8): 5394-5402.

[15] Canakci M., Topakci M., Akinci I., Ozmerzi A., Energy Use Pattern of Some Field Crops and Vegetable Production: Case Study for Antalya Region, Turkey, Energy Conversion and Management (2005) 46: 655–666.

[16] Robinson PH., Estimating the Energy Value of Corn Silage and Other Forages, Science (2001) 45: 1519-20.

[17] Mandal KG., Saha KP., Ghosh PK., Hatli KM., Bandyopadhyay KK., Bioenergy and Economic Analysis of Soybean-Based Crop Production Systems in Central India, Biomass Bioenergy (2002) 23(5): 337-345.

[18] Demircan V., Ekinci K., Keener HM., Akbolat D., Ekinci C., Energy and Economic Analysis of Sweet Cherry Production in Turkey: A Case Study From Isparta Province, Energy Conversion and Management (2006) 47: 1761-1769.

[19] Bheshti Tabar I., Keihani A., Rafiee S., Energy Balance in Iran Agronomy (1996-2006), Renewable and Sustainable Energy Reviews (2010) 14: 849-855.

[20] Phipps RH., Pain BF., Mulvany PM., A Comparison of the Energy Output/Input Relationship for Forage Maize and Grass leys on the Dairy Farm, Agriculture and Environment (1976) 3:15-20.

[21] Amanlou A., Ghasemi Mobtaker H., Keyhani A., Afsahi A., Mohammadi A., Investigation of Energy Consumption of Maize Production-Case Study: Zanjan Province. In: The 6th National Conference on Agricultural Machinery Engineering and Mechanization, Iran (2010) September.15-16.

[22] Shahan S., Jafari A., Moibili H., Rafiee S., Karimi M., Energy Use and Economical Analysis of Wheat Production in Iran: A Case Study From Ardabil Province, Journal of Agricultural Technology (2008) 4(1): 77-88.

[23] Ghiyasi M., Pouryousef M., Tajbakhsh M., Hasanzadeh Ghurtappeh M., Salehzadeh H., The evaluation of Energy Balance of Wheat Under Rained Farming in West Azerbaijan, Research Journal of Biological Science (2008) 12: 1408-1410.

[24] Mobtaker HG., Keyhani A., Mohammadi A., Rafiee S., Akram A., Sensitivity Analysis of Energy Input for Barley Production in Hamedan Province of Iran, Agriculture Ecosystem Environment (2010) 137: 367-372.